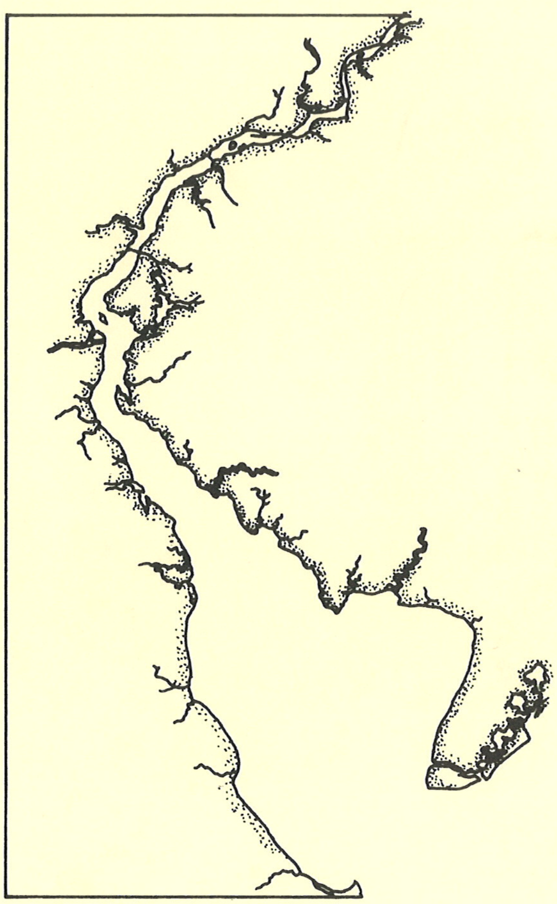
NOAA Estuary-of-the-Month
Seminar Series No. 2

Delaware Bay: Issues, Resources, Status and Management

December 1986



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA Estuarine Programs Office

Delaware Bay: Issues, Resources, Status and Management

Edited by David M. Goodrich

Proceedings of a Seminar
Held March 1, 1985
Washington, D.C.

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Administrator

NOAA Estuarine Programs Office
Virginia K. Tippie, Director

DELAWARE BAY:
ISSUES, RESOURCES, STATUS AND MANAGEMENT

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EDITOR'S PREFACE

The following is the proceeding of a seminar on Delaware Bay held on March 1, 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 in our Nation's estuaries. To this end, the seminar first presented an overview of the Bay by senior scientific investigators, followed by an examination of management issues by leaders of planning and regulatory agencies involved in the Bay.

We would like to acknowledge the assistance of Dr. Jonathan Sharp of the University of Delaware, who had principal responsibility for assembling the speakers and whose long involvement with the Bay and its people was invaluable. The seminar series was primarily organized by Dr. John B. Pearce, Director of EPO, and Dr. James P. Thomas, with the assistance of other members of the EPO staff. Seminar transcription was done by Margaret Powell and word processing by Janet Davis.

David M. Goodrich
NOAA Estuarine Programs Office
Washington, D.C.

INTRODUCTION

Robert B. Abel
New Jersey Marine Sciences Consortium

The story that you will be listening to today is the story of an estuary to which is contributed the waste of from one of about every twenty human beings in the United States. It's the story, in part, of an attempt to penetrate the estuarine technology by institutions in three states--the University of Delaware in Delaware, Lehigh in Pennsylvania, and Princeton, Rutgers and Stevens in New Jersey. The last four are members of the New Jersey Marine Sciences Consortium.

In New Jersey, as many of you know, we tend to approach marine and coastal problems in a consortial manner, which is to say that we recruit teams from our 28 member institutions *ad hoc*, according to the nature of the job. This is, admittedly, an unconventional management technique. It works. We form the team according to the task at hand. In the case of the Delaware program, we discovered an absolutely marvelous management technique. It is called Jonathan Sharp, and I want to commend it very highly to you. In fact, it's one of the two reasons that I'm here today--simply to identify the nature of the machine and the brain which ran it and hopefully will continue to run it.

The other purpose goes back about 15 years when I was invited from Washington to visit New Jersey to discuss with a group of state agency, industrial and academic representatives how to initiate a major ocean program in any given state. I offered the usual littany about local initiative and adherence to procedures and such. Unfortunately, old big mouth couldn't resist the opportunity to make a gratuitous observation at the end that while other states use their Congressional delegations, New Jersey's appeared to be the least active.

Upon my return to the National Science Foundation, there was a note on my desk, "The Director wants to see you and he's most unhappy." Apparently, in the time it took to return from Trenton to Washington, a gentleman named Clifford Case, who at the time was third ranking on the Senate Appropriations Committee, had sent a message over to the National Science Foundation demanding to know who this person Abel was that was criticizing the Congress of the United States. The only reason I'm still alive was that statistically, at the time, New Jersey was the only coastal state without representation on any of the relevant House or Senate Oversight or Appropriations Committees. Now, as you know, quite the reverse is true. The New Jersey Congressional delegation is extremely active and very highly supportive of the kinds of efforts for which we're gathered today.

Clearly, Congressman Bill Hughes has been extremely supportive and active on the Merchant Marine and Fisheries Committee; that's why we wanted him here today. The inevitable conflict of geography, unfortunately, prevented his coming in person. In his place, Representative Hughes asked his Congressional staff executive, Richard Schwabacker, to represent him. This is most fortuitous, because over the last decade there have not been any Congressional staff executives more active in support of our programs than Rich. Accordingly, with great pleasure, I yield the podium to him.

OPENING REMARKS

Richard Schwabacker
Legislative Counsel to
Congressman William J. Hughes

I'm pleased to be here this morning to wander into the muddy waters of the Delaware Bay. You have a distinguished group of speakers, so I'm going to try to be short, if possible, and just focus on the estuarine issues from the Congressional point of view.

Over the past decade the American people and Congress have become increasingly aware of the importance of estuaries and estuarine resources. In order to protect the quality of the environment, Congress has enacted a number of important statutes which directly or indirectly affect estuarine resources. These include The Coastal Zone Management Act, The Clean Water Act, The National Environmental Policy Act, The Marine Protection Research and Sanctuary Act, and the Sea Grant Program among others.

Congress is also paying increasing attention to wetlands. Scientists have long recognized that wetlands are among the most productive ecosystems in the world. Two-thirds of the commercially important fish and shellfish species harvested along the Atlantic and Gulf Coast are dependent upon the nation's east and Gulf Coast wetlands for habitat and food production. In the 99th Congress, legislation has been introduced which will provide federal assistance for state wetland acquisition, preservation, and enhancement projects.

Despite the broad array of federal and state statutes, however, we are still novices in managing complex environmental problems such as those which are occurring in the nation's large estuarine areas. We are just beginning to address these problems in a comprehensive and systematic fashion.

For many people the Delaware Bay constitutes an enigma. Despite its rich history and productive fisheries, the Delaware has not captured the public's attention the way the Chesapeake has. The Bay is most often viewed as an important transportation corridor for vessels traveling to and from one of the region's largest port facilities.

At the same time the Delaware has the dubious distinction of serving as a sink area for over seven million people who live in the Bay's drainage area. There's little doubt that the Bay's once bountiful fishery resources have declined over the past century. Menhaden, along with sturgeon, have virtually disappeared from the Delaware Bay. American shad and white perch are still found, but are far fewer than at the end of the nineteenth century. The Bay no longer supports a commercial striped bass fishery. Commercial fishing continues, however. Weakfish constitute the most important edible species in the Bay. Bluefish, shad and white perch also continue to be fished commercially.

Despite the decline in water quality and the fishery decline that we've seen over the past century, the Delaware Bay is now off the endangered list as a result of aggressive pollution control efforts by the Delaware River Basin Commission. Many experts now believe that the Delaware is successfully coping with the stresses that the highly urbanized and industrial mid-Atlantic region places on it. The Bay, however, will continue to experience demands from all sides as land development and flood control measures eat away at the region's wetlands and as society continues to use coastal and estuarine waters for waste disposal purposes.

These challenges also provide new opportunities, however. Clean fill material from dredging operations can be used to create new wetlands to serve as habitat for the Bay's fishery and wildlife resources. New waste management techniques and pollution control strategies will result in further improvement in the Bay's water quality.

Increased public concern and attention to the Bay will translate into better decisionmaking and water quality improvements. Congress now recognizes the need to protect the nation's estuarine systems and has begun to look more closely at the need to assure the preservation of these unique resources.

EPA and NOAA have also begun to focus on broader estuarine issues. At the same time, however, NOAA has recommended a 40% cutback in its Ocean and Great Lakes Assessment Program and a 50% cut in grants for estuarine sanctuary programs.

In addition, Sea Grant, Coastal Zone Management and a number of important fishery programs, which support coastal and estuarine work, are on the chopping block. From a national perspective, it's important that we move away from the pork barrel approach of addressing problems in the nation's estuarine areas and focus our attention on broader water quality issues.

Congressional staff in both the House and the Senate have begun to look at legislative approaches to assure that the nation's estuarine resources are not forgotten as new state and federal budget priorities are established. A legislative proposal recently developed by the staff of the Merchant Marine and Fisheries Committee would require the continued monitoring of the nation's ocean and coastal waters while providing a framework for developing and coordinating estuarine management programs.

Clearly, we need to move ahead with a long-term program aimed at protecting and managing our nation's estuarine resources. At the same time, we need to assure better coordination among federal and state authorities involved in coastal and estuarine issues.

Perhaps the most difficult part of the task involves educating both the public and policymakers who are charged with protecting the public interests. Meetings such as this one play a key role in that educational process. I hope all of you will continue to take an interest in the Delaware Bay and work for the protection and wise use of our coastal and estuarine resources.

HUMAN COLONIZATION AND DEVELOPMENT

Jonathan H. Sharp
University of Delaware

What I'll try to do in this presentation is follow the same approach that was used in studying the Delaware Bay. In recent years, the effort has largely been at several academic institutions. A lot of the support that we have had has been through the NOAA Sea Grant Office. We have also had some private bi-state support from the Delaware River and Bay Authority. A lot of what we've done has been coordinated on hot air and hopes for the future. We have not had a major effort on the Delaware Bay of the magnitude, for instance, of the EPA Chesapeake Bay Program.

Part of our success or ability to get anywhere with this has been made possible through the low-key encouragement and cooperation of the Delaware Department of Natural Resources and Environmental Control, the New Jersey Department of Environmental Protection, the Delaware River Basin Commission and a number of local installations of federal laboratories.

However, we have begun a major effort in the Delaware Bay without the sort of doom-and-gloom approach or clean-up-the-Bay approach that has been prevalent on the Chesapeake Bay and San Francisco Bay in previous efforts. We have had a low-key local accommodation, not a local push. There is a need, I think, for greater public and political awareness of resources like the Delaware Bay, and we're hoping we can get at that.

The underlying question in our efforts on the Delaware Bay is: "How does this system work as a large estuarine system?" The research that's gone on has been relatively fundamental and somewhat generic in its transferability from one estuary to another. However, the application of the information that we've been trying to develop on the Delaware for management, regulation, and development, is, and I think must be, somewhat local and specific. There are many general principles and general processes of estuaries that one can learn from studying the Delaware. These have translation then to other estuaries.

However, I think that application of basic knowledge about an estuary is not something that can be done monolithically on a generic basis. Application requires a great deal of local and specific knowledge.

The Delaware estuary is exemplary. It's exemplary in that it yields more knowledge perhaps than any other estuary due to some of its strange geometric proportions and some of its hydrography. It's exemplary also in that a mechanism exists in the Delaware for more ready translation to management, development, and regulatory activities than in many other estuaries. We will try to bring these out in the panel discussion.

For today's seminar the speakers are from various academic institutions in the area, from some of the state agencies, and from the Delaware River Basin Commission. I would like to start with the first presentation as a brief historical picture of the Delaware.

The Delaware River Basin (Figure 1) is a fairly large area going into New York State, much of eastern Pennsylvania, much of the western side of New Jersey and almost all of Delaware Bay proper. Therefore, many of the important things that happen in the Delaware Bay have strong influence from this large upstream drainage basin. The drainage basin of the Delaware is about 13,000 square miles. It houses about 7.1 million people, two-thirds of whom are in the general Philadelphia-southern New Jersey region.

The Delaware estuary was probably used by prehistoric man as early as 8,000 years before the present. It was used for transportation and for some harvesting of fisheries resources.

The Delaware was discovered for western civilization by Henry Hudson, who sailed into the mouth of the Delaware Bay in 1609. He had originally been hired for the exorbitant fee of $320 by the Dutch government to find the Northwest Passage. Having run into foul weather and the foul tempers of his crew in the Arctic, he sailed south to the Virginia colony that he knew of through his friend John Smith. He then tried going up the coast to see if he could find an inland passage. He found the Delaware Bay to be too shallow and too rough and decided that this was indeed not a strait to the Northwest Passage but a river. He abandoned it and went north to discover the North River, which was later named for him. Figure 2 is an early map drawn by the river pilot, Joshua Fisher. It shows the shoals and also the locations of many of the early settlements.

The Delaware was later explored by other Dutch, Swedish and British people. In 1623, Fort Nassau was settled in the area that is now Gloucester City, New Jersey. This was settled by the Dutch and became the first colony in the area, but not a permanent one.

In 1631 a colony was settled at the present location of Lewes, Delaware, and this entire area was named by the Dutch as Zwaanendael, Valley of the Swans. In 1638 the first permanent colony was made on the Christina River, the colony and river named for the infant princess of Sweden. It was a Swedish colony led by the disgruntled Dutchman Peter Minuet. It was, as were many of the early colonizations of this country, mainly

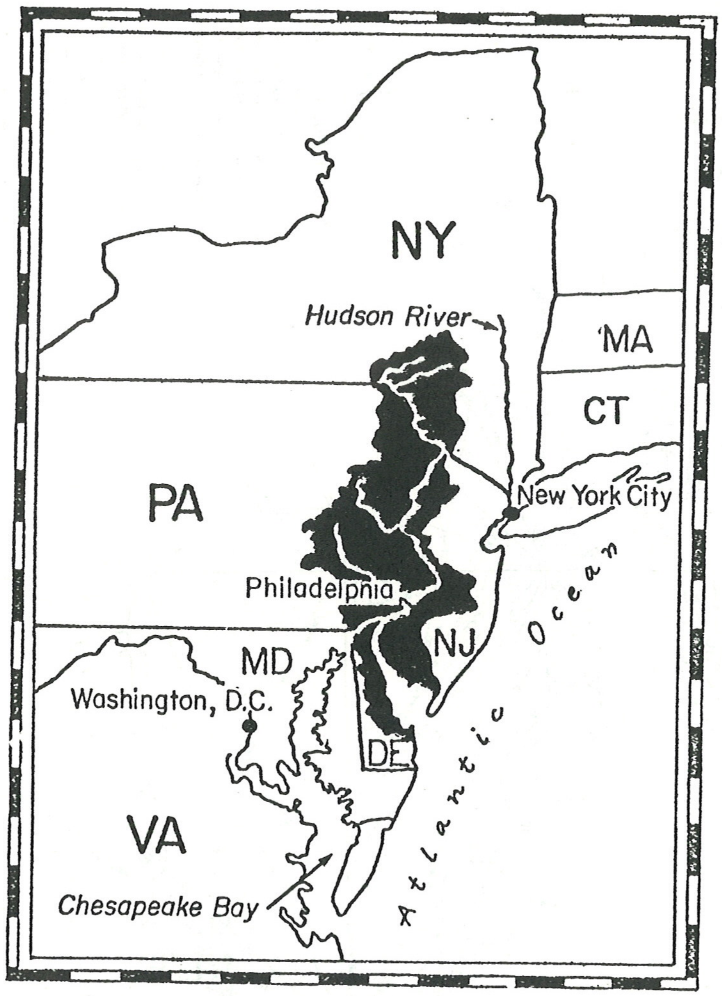


Figure 1. The Drainage Basin of the Delaware River and Bay.

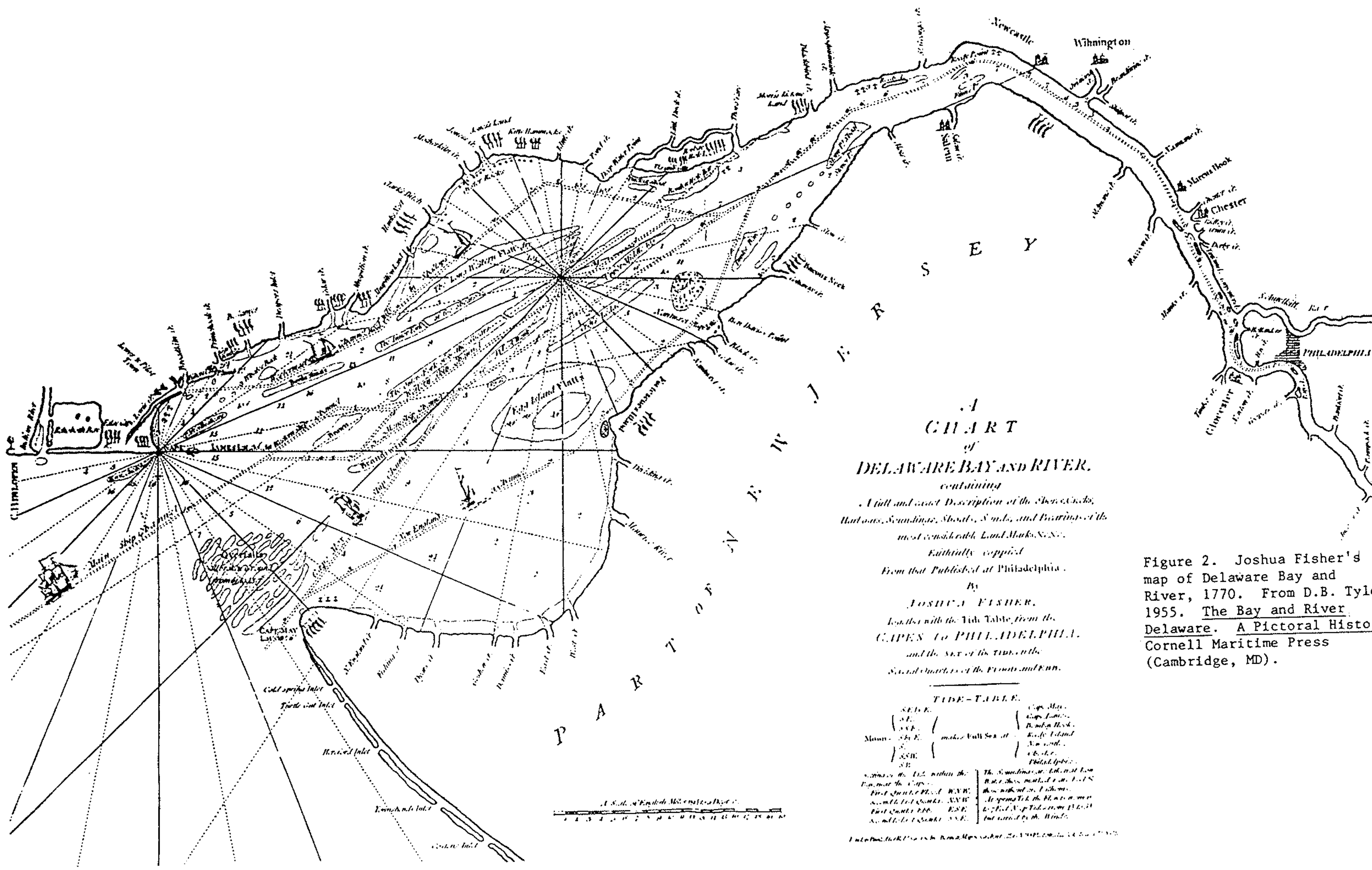


Figure 2. Joshua Fisher's map of Delaware Bay and River, 1770. From D.B. Tyler, 1955. The Bay and River Delaware. A Pictoral History. Cornell Maritime Press (Cambridge, MD).

accommodated by a number of misfits and criminals from Europe who were brought over to start a new colony. It's an interesting historic note that some of the Finnish in this group, having lived in the northern country with large forests, built a local structure that became the frontier log cabin in this country. So the first log cabin in this country was built at Fort Christina, the present site of Wilmington, Delaware. In the 1630's through 1650's there was a tremendous exploration and attempt at colonization by the Swedish and Dutch, with a minor war going on between Sweden and Holland for control of this area.

Shortly after Hudson, a British sailor by the name of Samuel Argall sailed into the Delaware Bay around 1610, claiming the entire area for Britain. He named the bay after the governor of the Virginia colony, Lord De La Warre, and therefore the name Delaware was given to the Bay.

The British were not that active in the early claims of the territory, but became so by the end of the 1600s. The Quakers claimed much of southern New Jersey, and William Penn was given a grant of a large area of land between 40 and 42 degrees north and stretching 5 degrees to the west from the river, the present area of the State of Pennsylvania. The three lower counties of the Pennsylvania colony (present-day state of Delaware) were claimed by the Duke of York. But in 1682 he turned these over to William Penn as well. So the entire area around Delaware Bay was claimed by the British primarily under the protectorate of William Penn.

Lord Baltimore also claimed much of present-day Delaware, and there were constant attempts to overtake the Duke of York's claims. However, the present-day development of the area is an outgrowth of the efforts of William Penn and his followers.

The Delaware very quickly became a major shipping area and a lot of produce was shipped on the Bay. The small streams coming into the Delaware became very good areas to set up mills. Here flour was ground, and it became a major export. There was a small steel mill built early on north of Philadelphia. A lot of early shipping on the Delaware was done in vessels called Durham boats. They were boats with very shallow draft, two to three feet, and up to 60 foot lengths, that were poled up and down the river carrying cargo.

In Penn's time and earlier, there were abundant shad and sturgeon and "many huge oysters as large as six inches." When Delaware was first settled, "the river yielded inexhaustible plenty." Among other fish, "herring swarmed in incredible numbers."

So the Bay was used very early on for both fishery resources and for major shipping. One of the Delaware's first major products was lumber that was forested in the northeastern Pennsylvania and New York areas and rafted down the river. There was a tremendous rafting of lumber down the river in early days.

In the late 17th and early 18th century river trade and transportation flourished, but not without its dangers. There was constant fear of predation by pirates in the area. Edward Teach (Blackbeard) was notorious on the Delaware Bay.

During the Revolutionary War era the lower Delaware Bay played a significant role in many naval battles between the revolutionaries and the British. Philadelphia was the seat of the revolutionary government. Greenwich, New Jersey, had an earlier and larger tea burning than the famous Boston Tea Party. The upper Delaware was crucial in a number of battles and is remembered today for the famous Washington crossing of the Delaware.

Colonial Philadelphia fronted on the Delaware River with the Schuylkill River on the other side. The Schuylkill was named earlier by the Dutch as a hidden river. I found a note of a major shad war in the 1730's on the Schuylkill River. People in the area of Valley Forge tried to block off the river with dams to capture all the shad, and the people upstream caused quite a ruckus over that. So for at least 250 years, there has been a demonstrated need for some form of fisheries management.

There was a tremendous amount of shipping, and the Delaware rapidly became the major port of this country. The principal ports were Philadelphia and Wilmington, Delaware, with trade going to Europe and to the Orient. Canals opened shortly to expand the transportation coverage.

In 1803 the Chesapeake and Delaware (C&D) Canal, running between the Chesapeake and Delaware Bays, was started; it was opened in 1829. The canal originally had three locks, one at Delaware City on the Delaware side of the Bay, one at St. George's, and another at Chesapeake City on the Chesapeake side. The locks had a maximum length of a hundred feet and had a depth of seven feet. So these were able to take some of the largest barges of the day.

In 1927 the C&D Canal was enlarged and deepened as a sea level canal. It was further expanded in later decades with the last enlargement occurring in the mid-1970s. This is a major transportation corridor between the Chesapeake and Delaware Bays, and as we're beginning to learn more, perhaps also a major ecological transportation corridor between the two Bays.

Two other canals were also opened in the 1830's. One was between the Delaware around Bordentown, New Jersey, and the Raritan Bay, carrying traffic between the Delaware Bay and the Raritan Bay. Further north, there was also a canal between the Delaware River and Hudson River. These canals permitted major traffic between the Delaware and other bodies of water. The Delaware-Hudson Canal was a significant route for the transport of coal from eastern Pennsylvania into the New York area in the early nineteenth century. It was apparently active until 1898 when it was closed. Both this waterway and the Delaware-Raritan Canal are totally closed today to barge traffic.

Cobbles were picked up in the upper part of the Delaware River, brought down by canal boat, and used to pave the cobblestone streets of Philadelphia. Log rafting, which was one of the early activities coming down the Delaware, ceased in the 1890's.

The Delaware was a somewhat dangerous body of water to navigate, and an effort was made in 1828 to build a breakwater at the mouth of the Delaware Bay off Lewes. This was replaced by a larger one in 1897. Now the mouth of the Delaware Bay is a calm harbor of refuge.

Pea Patch Island, on the upper Delaware just north of the mouth of the C&D Canal, was supposedly started by a ship with a cargo of peas that ran across a shoal. The peas sprouted and gave the name of the island. Fort Delaware was built there during the Civil War, and it served as a major prison camp for Confederate war prisoners.

The heavy shad and sturgeon fishing on the Delaware have both declined. I have seen a picture of a 500 pound sturgeon taken from the Delaware in 1953, with the note that they were rare to find at that time. They are considerably rarer today, although a few are still taken.

There was much passenger traffic on the Delaware for a number of centuries. Philadelphia had traffic upstream to the small towns further north. There was also traffic between Philadelphia and Newcastle, Philadelphia and Baltimore, and Philadelphia and New York. Thus passengers, as well as cargo, were a major commodity transported along the Delaware.

The heavy cargo traffic of the early days for lumber and flour yielded more and more to manufactured goods and eventually to oil. Large schooners used as oil tankers as early as 1912 led, in the present day, to some of the largest oil tankers in the world's oceans coming into the Delaware.

The Delaware today is the third largest port in gross tonnage in the United States, serving as the entry point for much of the traffic going to Baltimore, Philadelphia, Newcastle, Marcus Hook (Pennsylvania), Delaware City, and Paulsboro (New Jersey).

The Delaware Estuary has an interesting claim: it is one of three major river systems in the country with large nuclear power plants on its shores. The other two are the Tennessee Valley and the Susquehanna River Valley. There is a major installation on the Delaware at Artificial Island with two 1,000 megawatt reactors operating and a third one going up.

In contrast, the Delaware is one of only a handful of rivers in the Scenic Rivers and Riverways National Registry. On a olume basis, the Delaware receives some of the heaviest sewage effluent inputs of any major estuary in the United States. Yet, also -- and despite thoughts otherwise as the Chesapeake Bay's dirty little sister -- the Delaware also serves as a very valuable fishery and recreational resource.

What we would like to do today is to look a little bit at this successful multi-use resource. We'd like to look at it in terms of some of the characteristics of the Delaware today, and also discuss some of the pressing needs for further research to properly use the resource. During this morning's session, we will talk about the ecology of the Bay, and in the afternoon we'll get more into the use of the Bay.

QUESTION: Just a comment. I think the Delaware-Raritan Canal is still viable.

DR. SHARP: Oh, really? I've seen pictures of it grown over.

QUESTION: No mules or barges, but you can canoe out there.

MR. HANSLER: The Delaware-Raritan Canal is still viable. It's used as a major source of water for Middlesex County bringing an authorized draw of 100 mgd from the Delaware.

QUESTION: There was also a considerable whaling industry in the Delaware Bay during the late 1600's to early 1700's.

DR. SHARP: I believe that's correct. In fact, the colony established in 1631 in Lewes at the mouth of the Bay was initially a whaling colony. There was also one established in Cape May for whaling purposes. Apparently a large number of whales were taken right in the mouth of the Bay.

QUESTION: What point in time was it perceived that there was a water quality problem in the Bay? Where do your earliest efforts date from?

DR. SHARP: I believe around the turn of the present century, there was concern of pollution in the Delaware River. I think that Jerry Hansler of the Delaware River Basin Commission may be able to address this more this afternoon.

MR. HANSLER: What I'll say is that we've had a good handle on what's been going on for the last 17 years, 19 years, since we've had a commission. I'm not sure about a repository of turn-of-the century data.

DR. SHARP: I don't think there was good data back that far, but there are some recorded observations. Actually, I've seen statements as early as the Revolutionary War era that speaks of the "stinking Delaware" in the Philadelphia area. I think there were major concerns around the turn of the present century, with a large decline in the shad landings attributed to pollution. y the second World War President Roosevelt made comments that there was fear that the water pollution in Delaware River was hampering the war effort. There was a very strong perception of this by the World War II era.

DR. PEARCE: There's a series of documents that come from our predecessor organization, the old Fisheries Service, authored by Professor Goode. They are available in most of the larger libraries. They mentioned some of the aspects of the deterioration of water quality in the Delaware and Newark Bay, at the time of the Civil War or slightly after. I would comment that you look at those documents. They provide an early historical basis for environmental change suggesting that it's nothing new, and that there was concern at that time.

GEOLOGICAL HISTORY AND SETTING

Robert B. Biggs
University of Delaware

The material I'm going to talk about is not principally my own work, but the accumulation of 20 or 25 years of work of geologists at the university. I want to present a brief geologic history talk and a bit about suspended sediment; sediment geochemistry will be covered by other speakers later.

The Delaware is a coastal plain estuary (Figure 1). Over the course of the last 20 years, scientists at the Department of Geology have developed one of the most well-documented sea level rise curves available for any coastal area in the world. This sea level rise curve for Delaware Bay extends back about 8,000 years before the present when sea level was at minus 20 meters, and the coastline was 40 or 45 kilometers offshore from its present location. This curve (Figure 2a) is developed by some 75 or 85 basal peat determinations.

The Bay itself is the drowned river remnant of the Delaware River at the lower stands in sea level. This sea level rise, in fact, is continuing. Figure 2b shows the tide record from 1923 on the left to 1975 on the right-hand side at the mouth of the Delaware Bay. This graphic depicts mean high water with variations and data gaps. There is a general trend from left to right of a rise in sea level on the order of 25 centimeters per century.

Figure 3 shows a distribution map of the bottom sediments in Delaware Bay. The darkest areas represent the largest, coarsest material, and the lightest areas represent fine-grained materials. The Delaware bottom sediments are in contrast to its neighbor estuary, the Chesapeake. In the Chesapeake the finest grained sediments are located in the central part of the Bay. The coarsest-grained sediments are located in shallow water where they're winnowed by wave activity. The Delaware is the exact reverse. The coarsest sediments occur in the deepest areas of Delaware Bay. The finest grained sediments, mostly muds, occur in the shallowest areas. This is because the Delaware has a much more vigorous tidal regime than does the Chesapeake, and tidal stirring and tidal activity in the Delaware is responsible for these coarse grained deposits in the central part of the Bay.

In Figure 4, I've depicted a cross-section of the Delaware Bay, about halfway through it, just to show you both the geologic history and the bathymetry in the Delaware system. The Delaware side is on the left and the New Jersey side is on the right. The old Pleistocene (pre-8,000 year-old) channel of the Delaware River has been flooded up to sea level. Major

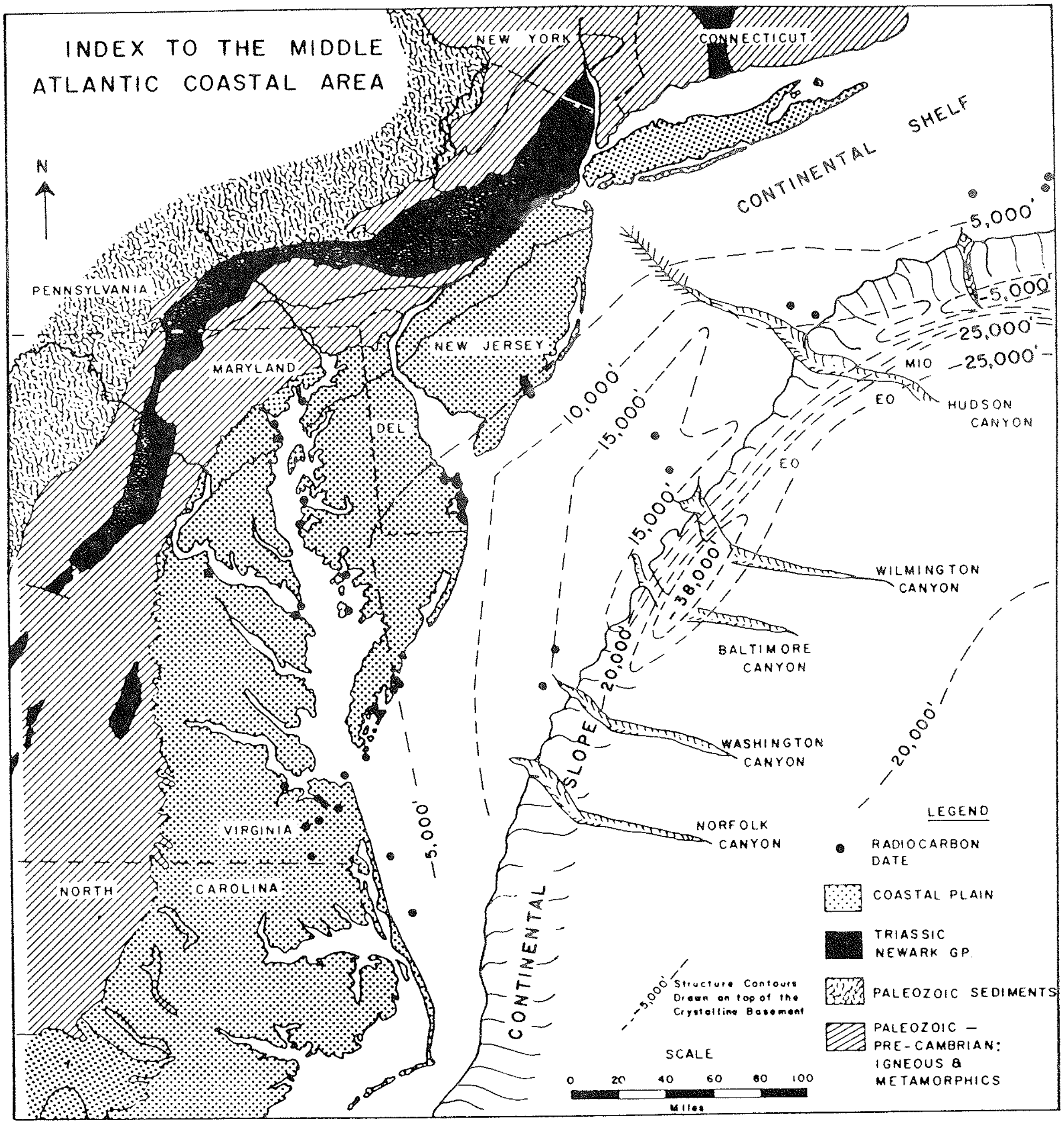


Figure 1. Geologic setting of Mid-Atlantic estuaries.

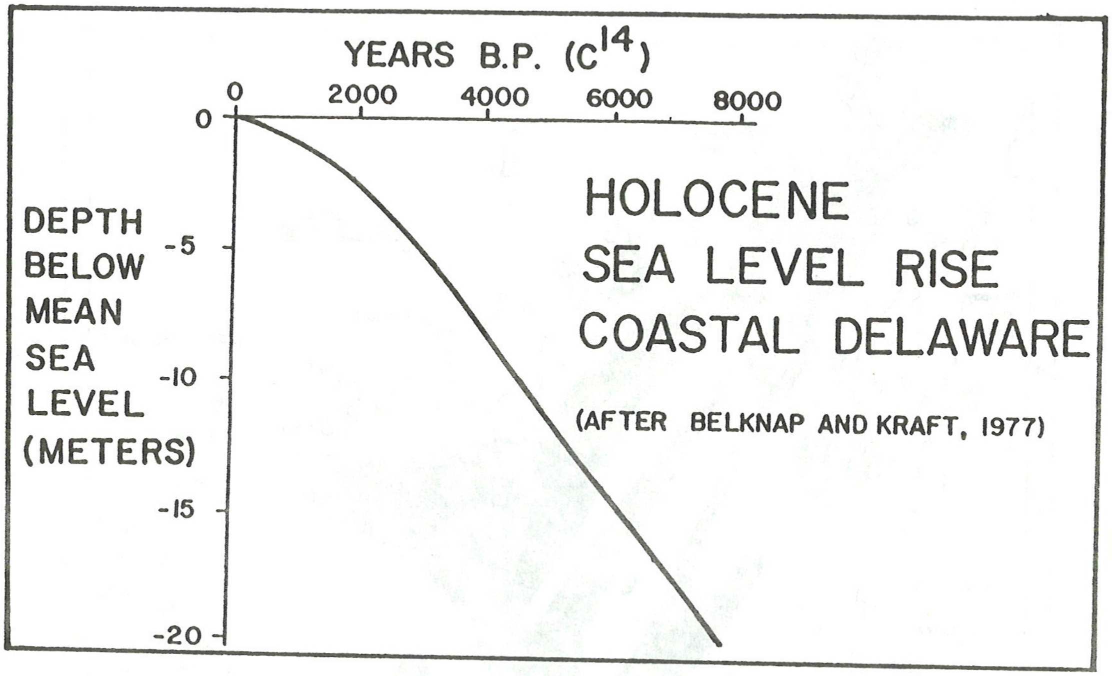
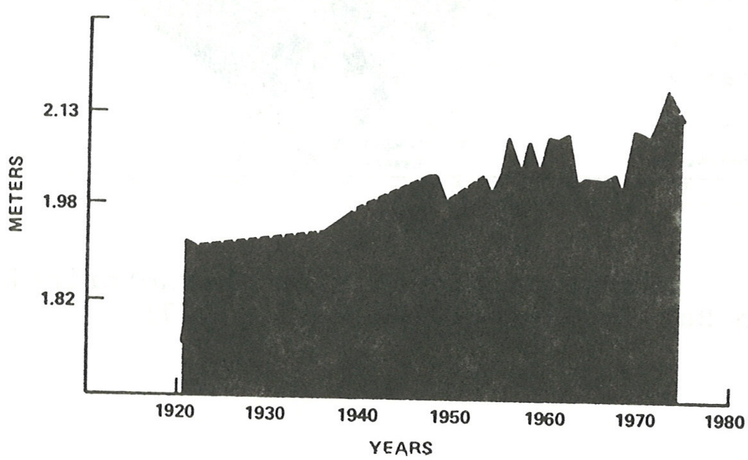


Figure 2. Sea level history on Delmarva

a) Holocene sea level rise from radiocarbon age of peats (after Belknap and Kraft, 1977).



b) Tide gauge records from Lewes, Delaware (Demarest, 1978).

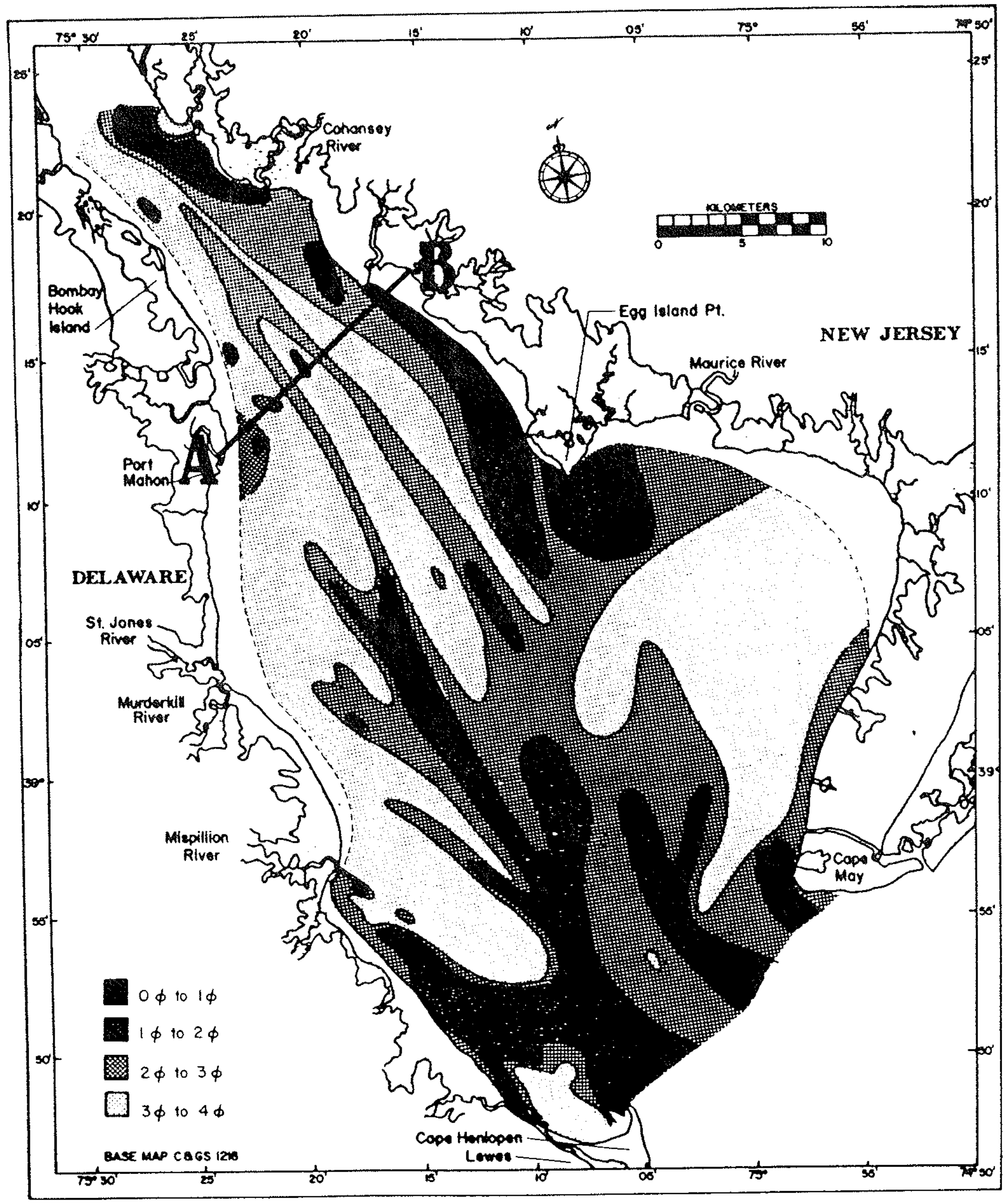


Figure 3. Surface sediment size characteristics for Delaware Bay (modified from Weil, 1977).

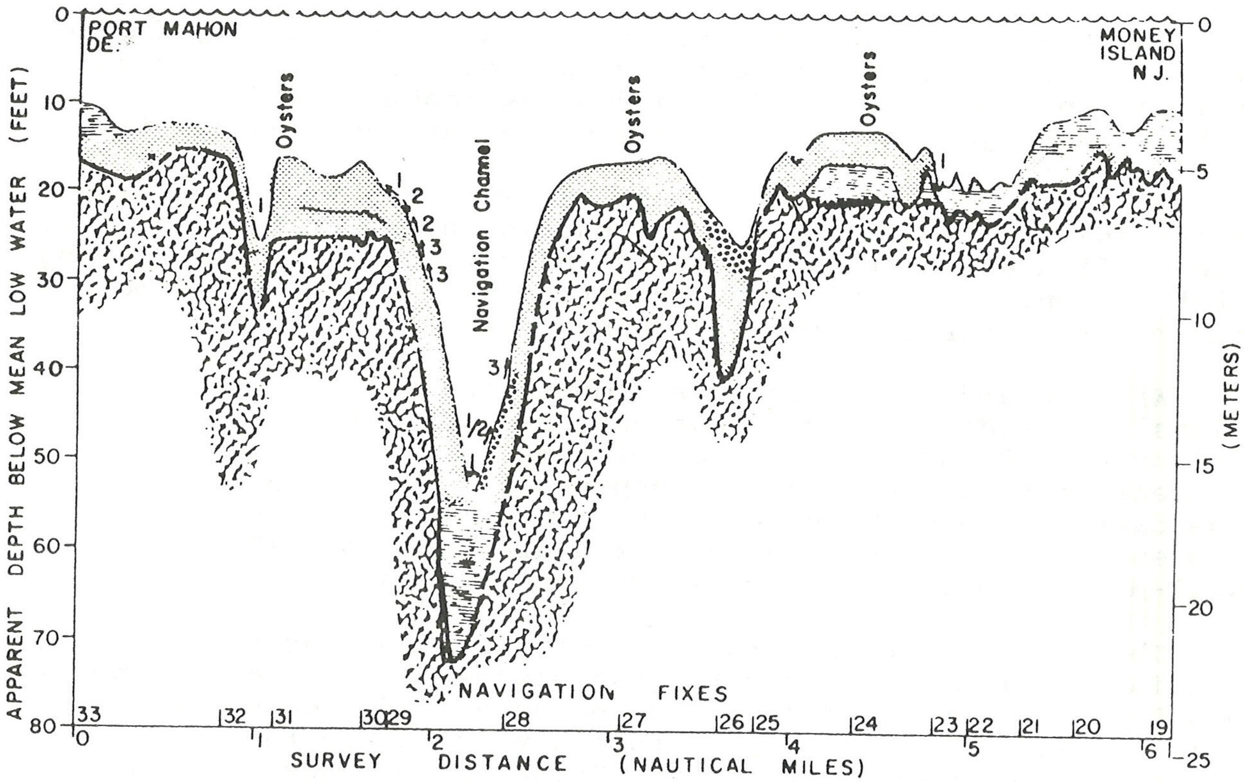


Figure 31 Interpreted Section, Port Mahon to Money Island

Lithology Key:

Sand
Silt
Clay
Peat
material under S1 reflector

Figure 4. Shallow seismic section of Delaware Bay. Section location presented on Figure 3. (Moose, 1973).

concentrations of oysters are limited to topographic highs. These topographic highs often are composed principally of oyster shells with depth, that is, the oysters have created their own topography.

The bottom of Delaware Bay, at the present time, is active, in the sense that it's relatively mobile. Sands waves extend halfway up the estuary. The sand waves range from Ø.3-1.Ø meters in height and are actively moving at the present time.

Old bathymetric charts of the Delaware Bay have been used to determine stability of the major shoals which exist in the Bay. The configuration of these shoals changes with time, indicating that not only are sand waves operating in the Bay, but some of the major features in the Bay change also.

With regard to suspended sediment, the Delaware has a classic turbidity maximum that one sees in partially-mixed estuaries. Figure 5 is a plot of time, salinity, and concentration of material in suspension. The concentrations in the darkest areas are greater than 3Ø milligrams per liter. The concentrations in the clearest area are less than 1Ø. The well-developed turbidity maximum changes location with time.

The Delaware appears to have not just one, but two, turbidity maxima. One occurs just upstream from the Chesapeake and Delaware Canal entrance and one occurs just downstream from this point. The Canal may in some way influence the distribution of turbidity in the Delaware, perhaps through exchange between the Chesapeake and Delaware Bays.

LANDSAT imagery has been used to measure suspended sediment distribution and to see if one can identify different water masses in Delaware Bay. One such image is presented in Figure 6a. High concentrations of suspended sediment are generally restricted to areas around the margin of the Bay. Eigenvector analysis of the distribution of color from LANDSAT imagery shows that, at times of high suspended sediment discharge, there really are three water masses in Delaware Bay which are persistent over short time frames like weeks. Figure 6b illustrates the same analysis but at low discharge, with the clear water penetrating further up the system. The open waters of the Delaware are surrounded by salt marsh systems. On a short-term basis, say weeks, the marsh and nearshore waters are closely coupled. But this nearshore water doesn't seem to exchange very much on short time cycles like weeks with the deeper clearer waters of the Bay.

Approximately 8Ø% of the shoreline of the Delaware consists of salt marsh. Isolated Pleistocene headlands are reflected by sandy beaches. The marshes are sites of active deposition as they have kept pace with the documented rise in sea level. The

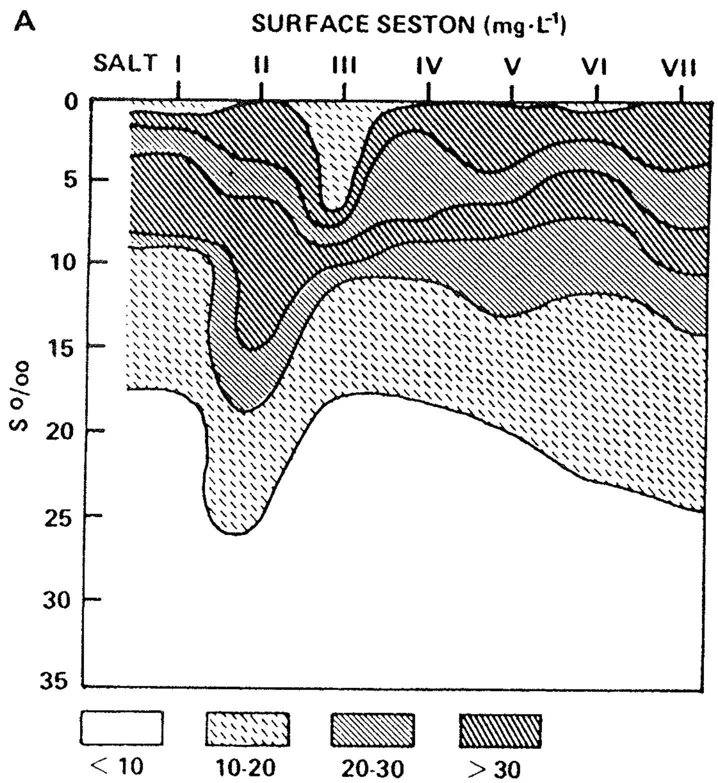


Figure 5. Concentration of total material in suspension along the salinity gradient in Delaware Bay. Salt I - Oct. 1980, Salt VIII - July 1981. (Biggs et al, 1983).

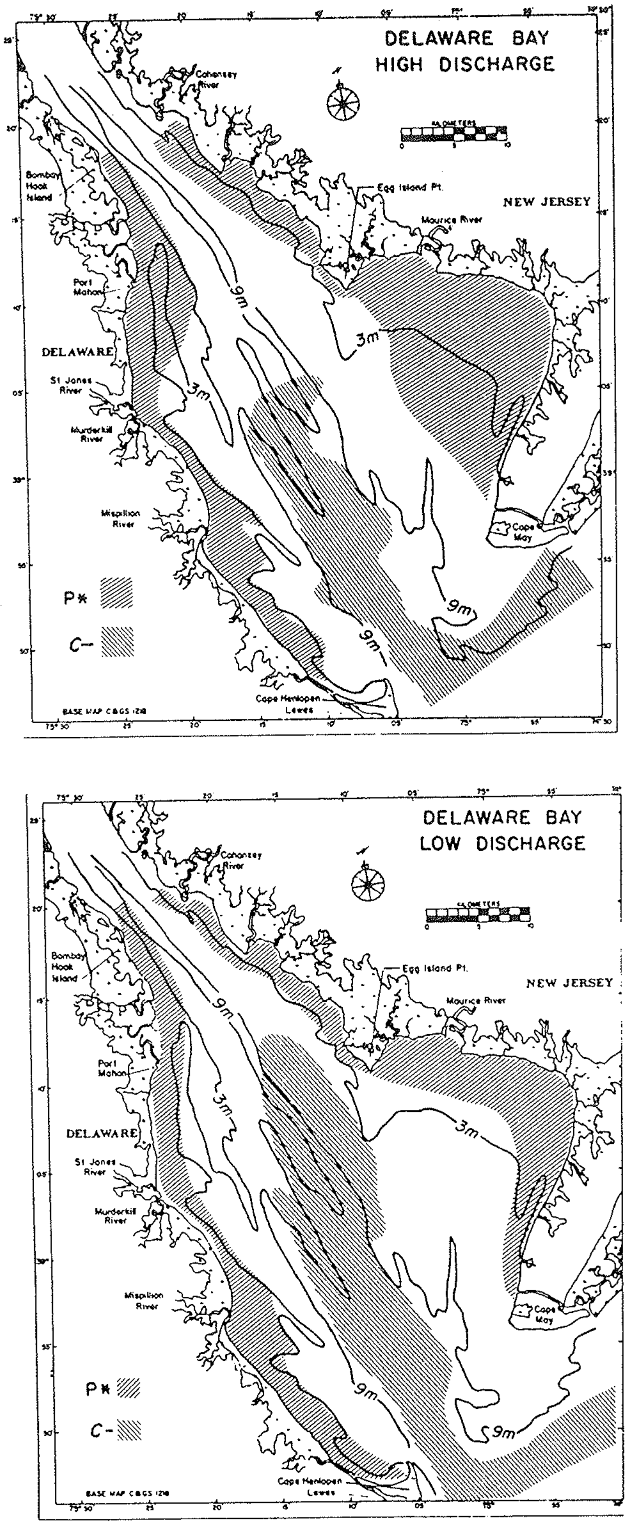


Figure 6. Eigenvector analysis of LANDSAT scenes to determine statistically different water masses in Delaware Bay. P* is a platform water mass, C- is a channel water mass (Stumpf, 1984)

a) High freshwater discharge.
b) Low freshwater discharge.

process of sedimentation occurring in the salt marshes is also reflected by the distribution of trace metals. The apparent influence of anthropogenic zinc concentration is illustrated in Figure 7. Similar patterns are evident for copper, lead, and cadmium.

I would submit a speculative hypothesis that deserves serious consideration and testing. I've suggested that the bottom of Delaware Bay in general is unstable. I've suggested that suspended sediment concentration is relatively high. I submit the following hypothesis:

Through the recent rise in sea level, which may have accelerated erosion, and/or through pollution by man and/or overfishing of benthic resources in the Delaware Bay, the bottom of Delaware Bay has become unstable, and this is due at least in part to man's activities.

That's a hypothesis that has no support at the present time because we don't have enough data and we haven't examined it carefully. But I submit to you that the relatively high concentrations of suspended sediments that one sees in Delaware Bay at the present time and the unstable bottom in general is in fact a function of man's activity and is not the pristine condition in which Delaware Bay was found. Thank you. Any questions?

QUESTION: The cross-section that you showed from New Jersey to Delaware looked like it had three deep channels. Are the side channels remnants of the previous water course?

DR. BIGGS: No. The side channels seem to be tidal. They seem to be related to the present, or the very recent, hydrography. That is, only the central deep channels' bottoms are modern, in the sense that they represent materials which have been deposited over the last several thousand years. So the side channels appear to be tidal scour channels. But just use that in a very generic sense.

QUESTION: Have you seen sand wave activities in any southeastern or Gulf Coast estuaries comparable to what you see in the Delaware Bay?

DR. BIGGS: Sure. Let's start with New England. You can look at the Parker River Estuary, and you can go down to inlets and the inlet areas around the Gulf Coast. So clearly there are places where such things occur. It's merely a hypothesis that I've asserted, not theory. I have no supporting evidence at the present time. But the idea that I have is that it's very much like when we went to the prairies and plowed the buffalo grass and destablized what was an otherwise stable situation. You can do that in any number of ways.

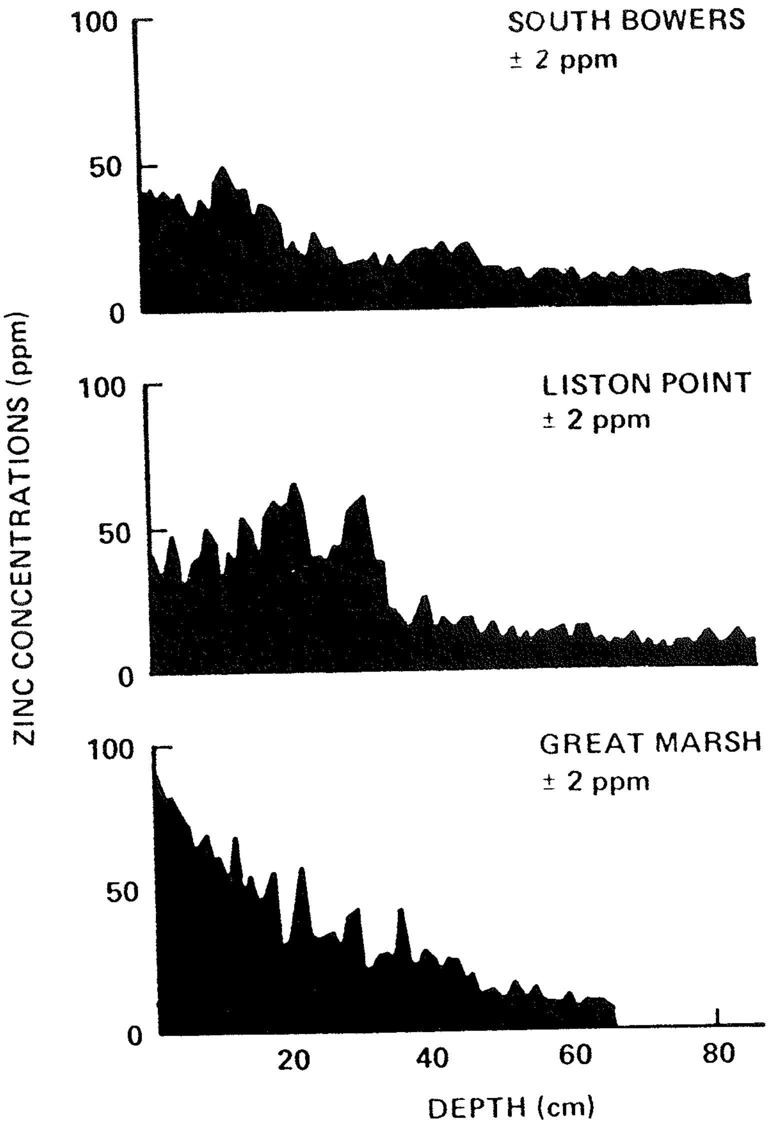


Figure 7. Concentration of zinc as a function of depth in three Delaware Bay salt marsh cores. Liston Pt. is near Bombay Hook Island, South Bowers is near the Murder Kill River mouth, and Great Marsh is near Lewes, all in Delaware. See Figure 6 for core locations (DeAngelis, 1982).

Man's activity in the watersheds can add suspended sediment, which can smother benthic organisms and destablize the bottom, for example. A rise in sea level, which we're experiencing at the present time, causes a more rapid erosion of the salt marshes, and adds lots of suspended sediment to the system.

The taking of millions of pounds of oysters at the turn of the century, including their shells, and using them for fill and lime in agriculture, certainly could contribute. So the hypothesis--strictly a hypothesis--is that you're starting to open up these patches on the bottom which are unstable due to all of these kinds of effects. Pollution and predators are also possible contributors. I'm not saying that it's all man's activity, but some combination of these effects. We open up these patches of unstable bottom which start to migrate around and can smother other areas of bottom, which have been biologically stable.

QUESTION: Does your hypothesis suggest that the amount of submerged aquatic vegetation is greater or was greater in the past?

DR. BIGGS: That's a very interesting question. First of all, there is no submerged aquatic vegetation at the present time in Delaware Bay, perhaps because of the turbidity; I would assume so.

I tried to look at the anecdotal natural history literature of folks who went around and wrote <u>National Geographic</u> articles about cruising on the Delaware and Chesapeake to find any evidence that there ever was any submerged aquatic vegetation, and I found no evidence to suggest that there was or wasn't. I've not been able to find any literature that says "We had these great beds of eelgrass and the fish were swimming through them". I've seen no evidence of that, even anecdotal.

We've not looked in the cores in the marshes, for example, for seeds, SAV seeds, or any direct indication that they may be present. That is clearly one thrust that one could take to test this hypothesis that I've put forward.

QUESTION: Do any of the states have programs to prevent erosion and runoff and the attendant turbidity against the rivers and the Bay from man-made activities? Do you think there should ever be a program by man to prevent the bayside erosion of the wetlands, which may be even a greater factor so far as the turbidity input?

DR. BIGGS: Well, there could be. Should there be? I'm not in a position to evaluate that at the present. Let me offer the following hypothesis, though, not as a substitute, but as an ancillary hypothesis.

Primary productivity in Delaware Bay is controlled by turbidity. That is, primary production in Delaware Bay is light-limited. If we decrease the suspended sediments in Delaware Bay at the present time, given the nutrient loads that we have at the present time, we may experience dramatically increased productivity. One would have to be very careful. This would only be an element in a much larger program.

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PHYSICAL OCEANOGRAPHY

George L. Mellor
Princeton University

I'll introduce myself a little bit more than does the program. I am on the faculty of the Princeton University, but I am also in cahoots with NOAA's Geophysical Fluid Dynamics Laboratory. So you'll find out along the way that I have an interest in numerical models of estuaries. Now I know very little about biochemistry, and I suspect that most of the audience does know a great deal about that subject. But I think most of you also realize that you really need to know something about transports in an estuary. You need to know, as my wife would say, where the "trites" and "trates" go to and from whence they come. So with that, I'll proceed with some discussion of the physics of Delaware estuary.

I should also say that we just finished working on a numerical model of New York Harbor. I have a lot to say about New York Harbor, whereas we're only halfway through our study of Delaware Bay. Having said that, I'll now move on to attempt to give you an idea of the physical characteristics from an oceanographic point of view of the Delaware estuary and then at the end say something about our modeling studies.

Figure 1 is a map of the Delaware juxtaposed with Chesapeake Bay and more importantly, juxtaposed with the whole shelf. The real system includes not only the estuary itself, but the continental shelf going all the way up to the Gulf of Maine.

The Delaware is a partially mixed estuary in the sense that salt gets quite a ways into the estuary. The other extreme would be the Amazon where the whole river and most of the mouth of the Amazon is fresh water. All the mixing processes take place on the shelf in the Amazon.

From the salinity point of view, the estuary is driven by fresh water runoff. Figure 2 is a plot showing runoff at Trenton from January 1978 to January 1984. That's about half the total fresh water runoff into the system. About 20% comes from the Schuylkill, another 30-40% comes from the small rivers and non-point source runoff. So this is the fresh water runoff, which meets the salinity from the open ocean and creates a salinity distribution.

In Figure 3 we see extreme salinity distributions, a flood period in March 1936. The fresh water came all the way down to well inside the Bay whereas in November of the drought year of 1930 there was salt all the way up to Philadelphia.

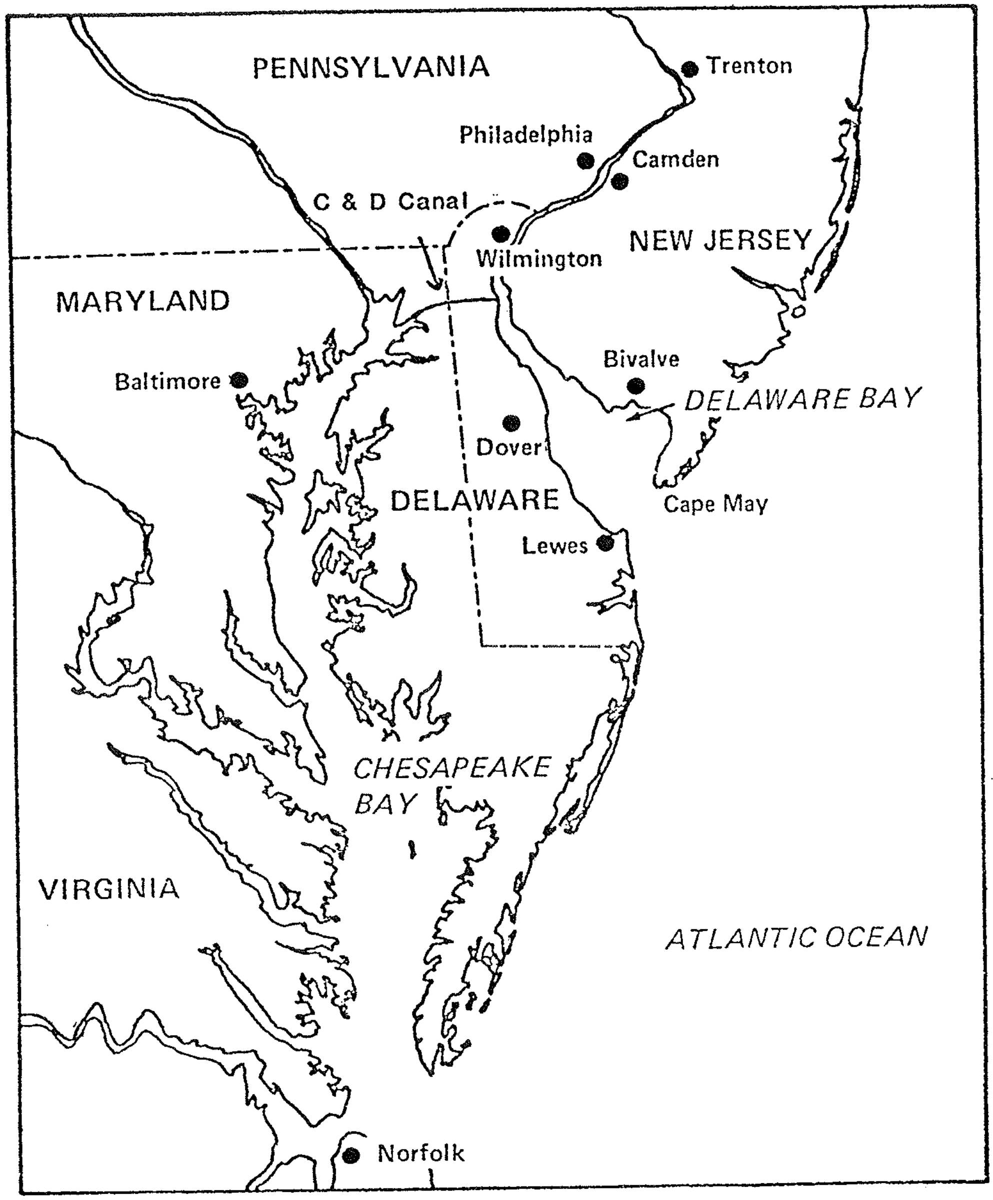

Figure 1. Delaware Bay, Chesapeake Bay and the connecting Continental Shelf.

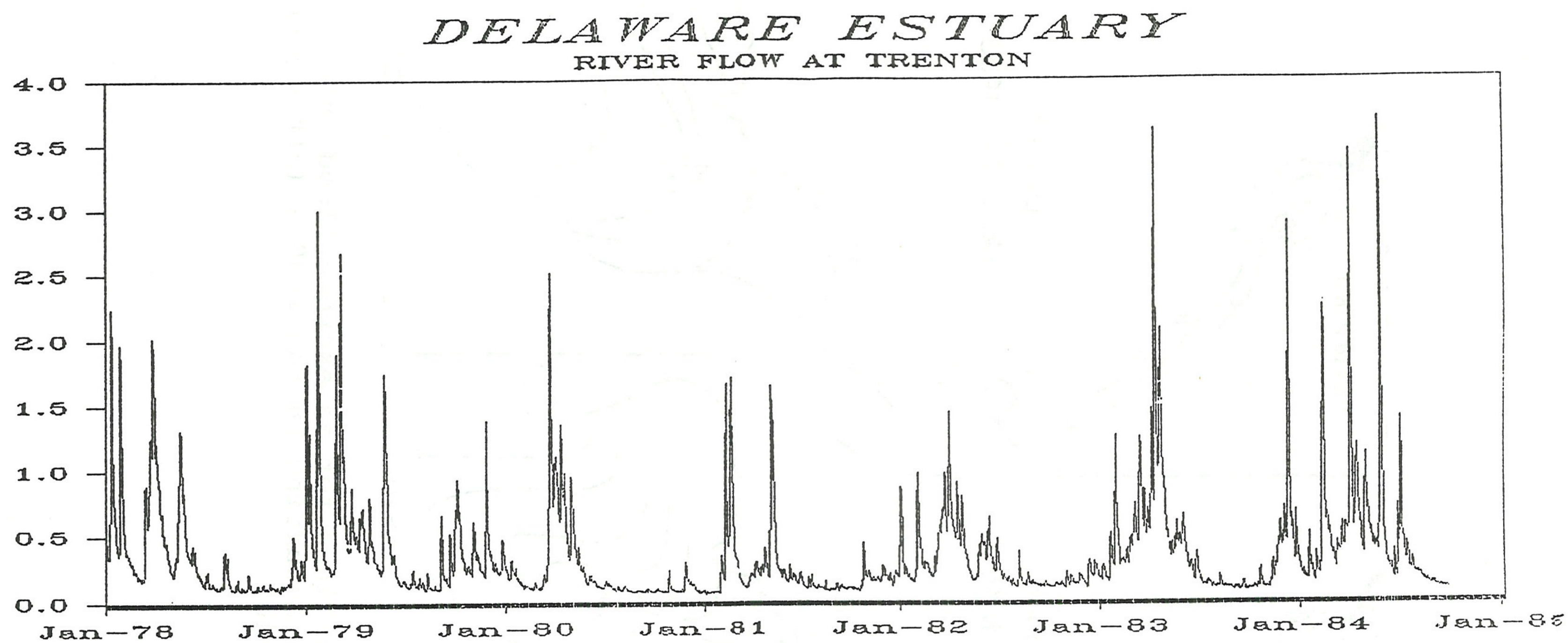

Figure 2. Fresh water runoff at Trenton. (after Sharp et al., 1986)

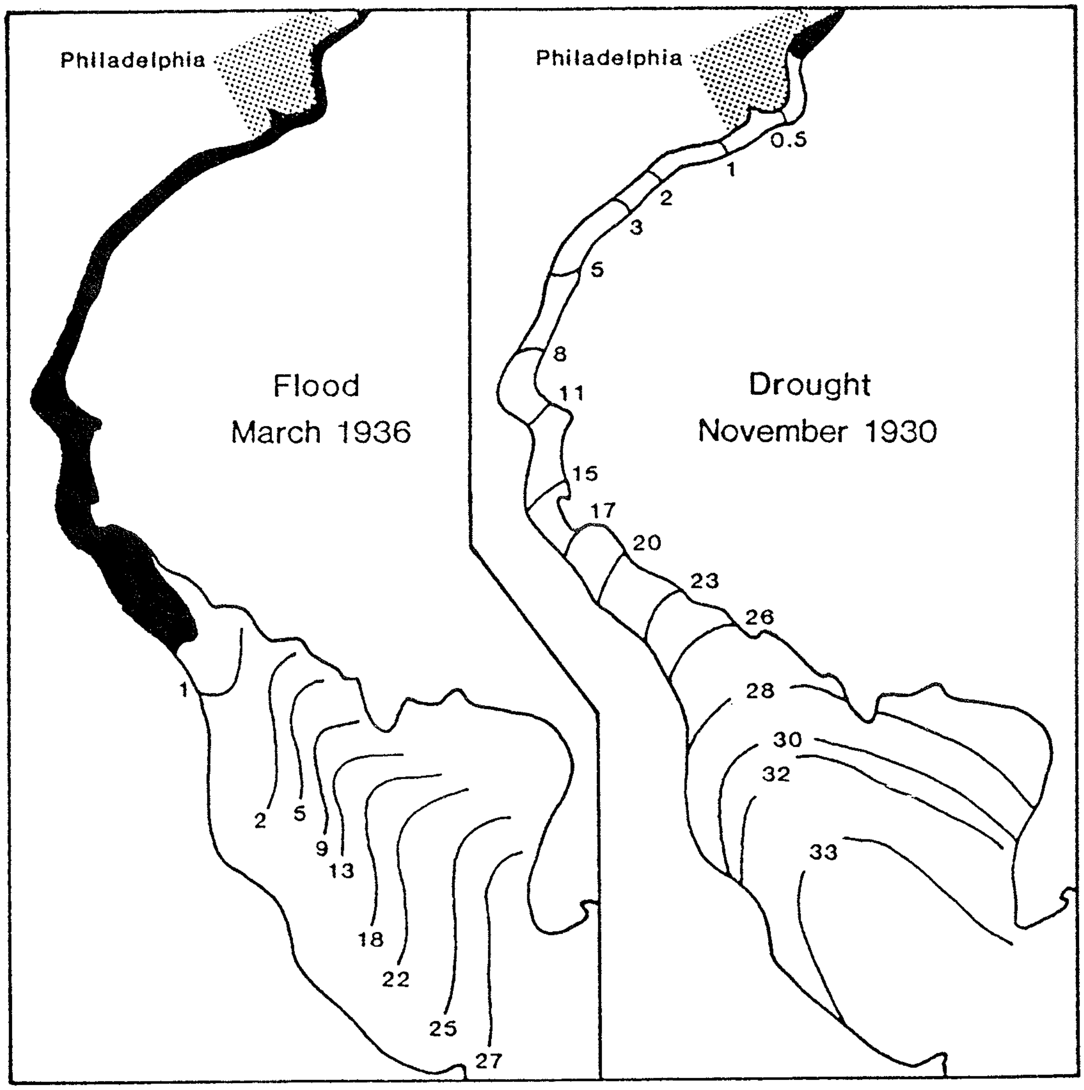

Figure 3. Isohalines for an extreme flood and an extreme drought occurring in the 1930's (after Manson and Pietsch, 1940)

Figure 4 is a detailed salinity distribution obtained by Jon Sharp and his people at Delaware; it shows 29 ppt in the Bay, decreasing to zero in the northern portions. This can be compared with typical oceanic values of 36 ppt off the shelf break.

Figure 5 shows some of Hal Haskins' data. Here we see a transect across Brandywine Shoals just in from the mouth of the estuary. This is a period where there's low flow in the fall of 1952. We see essentially a non-stratified distribution from top to bottom. We contrast that with high fresh water runoff in the spring of 1952, where there is a variation in the deepest water from 3Ø to 32 ppt. That's a very strong stratifiction as go estuaries. Indeed, that will influence the physics of the flow quite a bit. This shows the fresher water running off from the surface. And you see bottom water representing a flow from the sea into the bottom of the estuary. That's the classical estuarine circulation.

Figure 6, a more detailed slide again from the University of Delaware, shows vertical salinity stratification of only 1 ppt at ebb tide. But that turns out, if you look into the physics of the matter, to be significantly stratified. Also one sees a left to right or a Delaware to New Jersey variation of salinity. We have much fresher water coming into the southern part of the mouth of the Bay. That can be attributed to the earth's rotation.

Figure 7 needs some explanation. The ordinate is depth at one station in the mouth of the Bay, and the abscissa is time. This encompasses about two tidal periods or 25 hours. So there is a rich variability in time as well as in space. Mainly, it's dominated by the tidal signal, the M2 tide, and this would be modified by other elements, which I'll mention very shortly.

I'll like to say a bit about our modeling studies. We now have a model of Delaware Bay on super computers at the Geophysical Fluid Dynamics Laboratory. It's a three-dimensional model with salt in it, all the currents and so on; it's driven by tides and winds. We're about halfway through our work on Delaware Bay, having just finished New York Harbor.

Figure 8 gives an idea of what we're talking about. We represent position in the Delaware by discrete points. We have a fairly high resolution. The more resolution, the better you're going to model the estuary and the more expensive it's going to be to do so. As time goes on, the expense goes down and the resolution goes up. This is happening fairly quickly in the computational field.

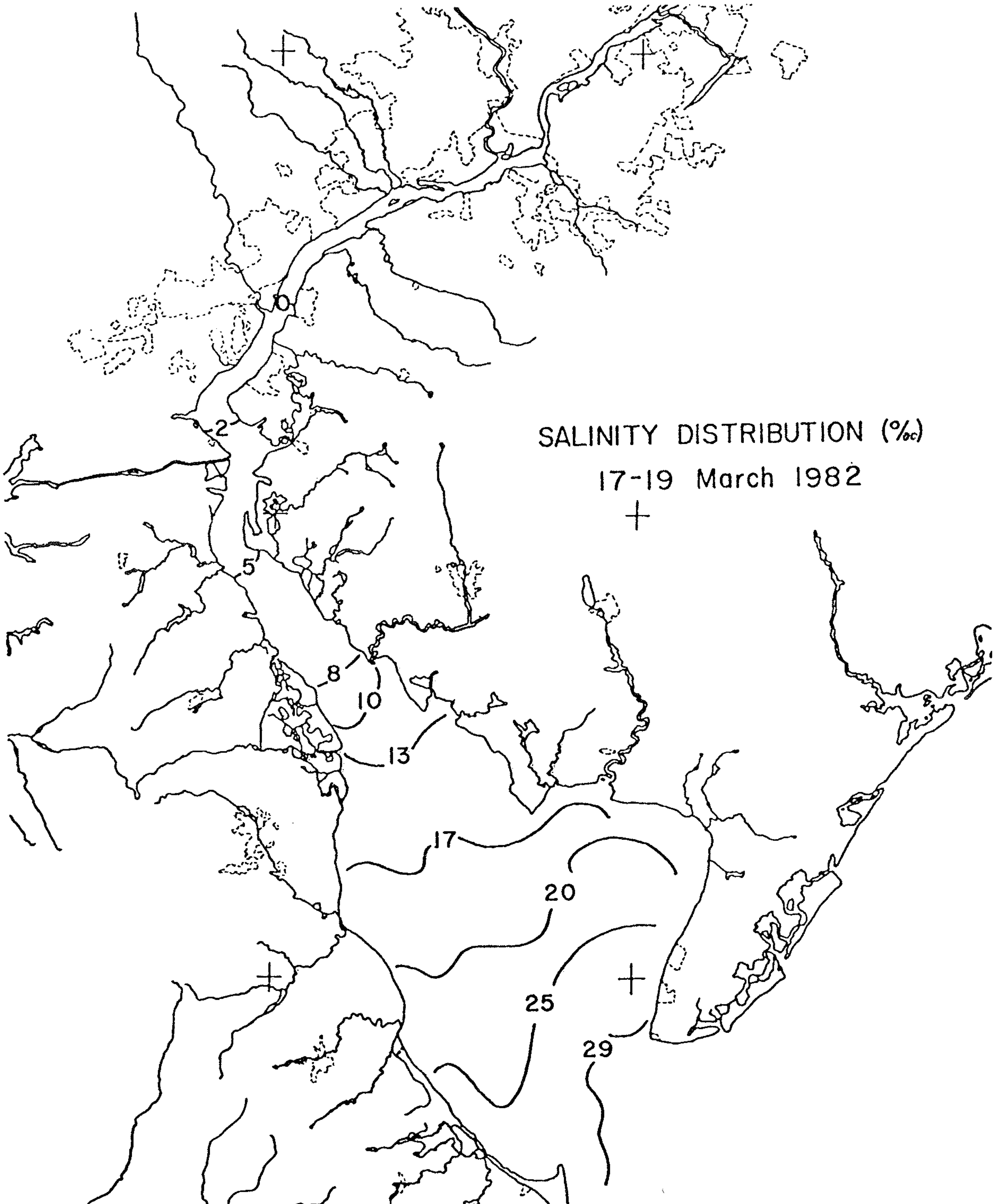

Figure 4. March 1982 surface salinity data. After Sharp, unpublished

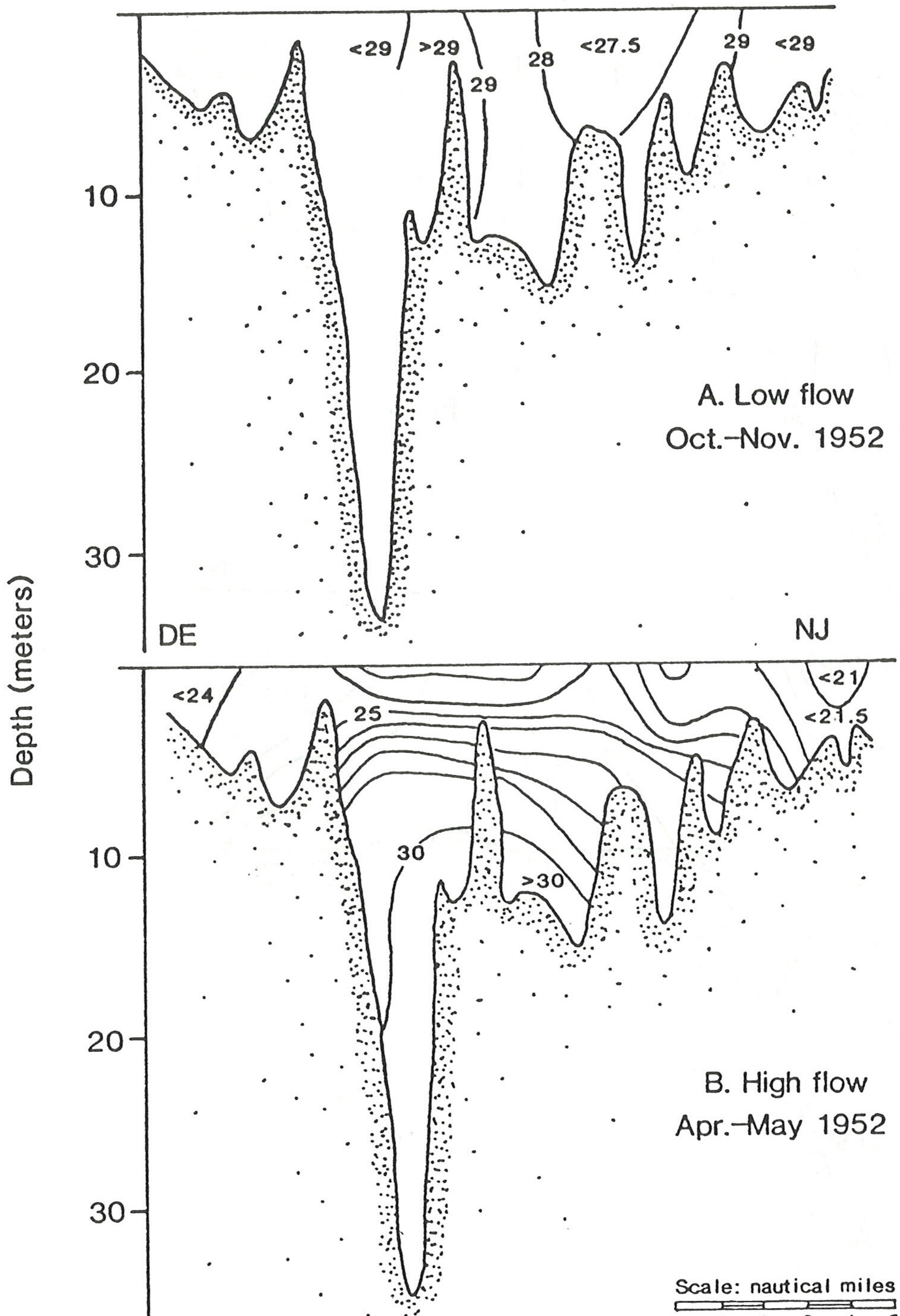

Figure 5. Cross-section of Delaware Bay looking upstream through Brandywine Shoal, from composite of sampling at low water. Isopleths of salinity are shown. Data from Haskins, unpublished.

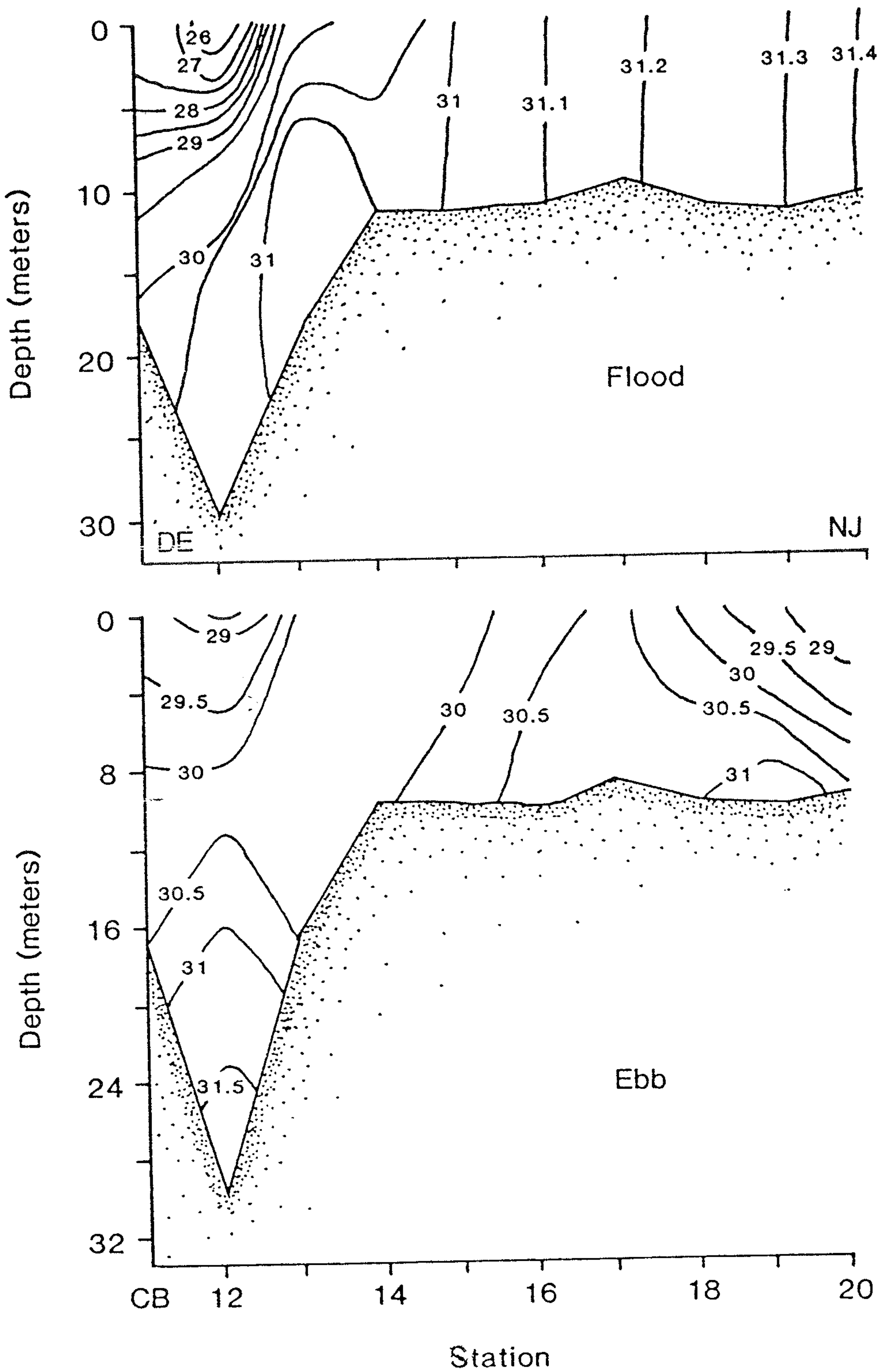

Figure 6. Cross-section at mouth of the Delaware Bay during high flow conditions (May 1982), showing salinity contours.

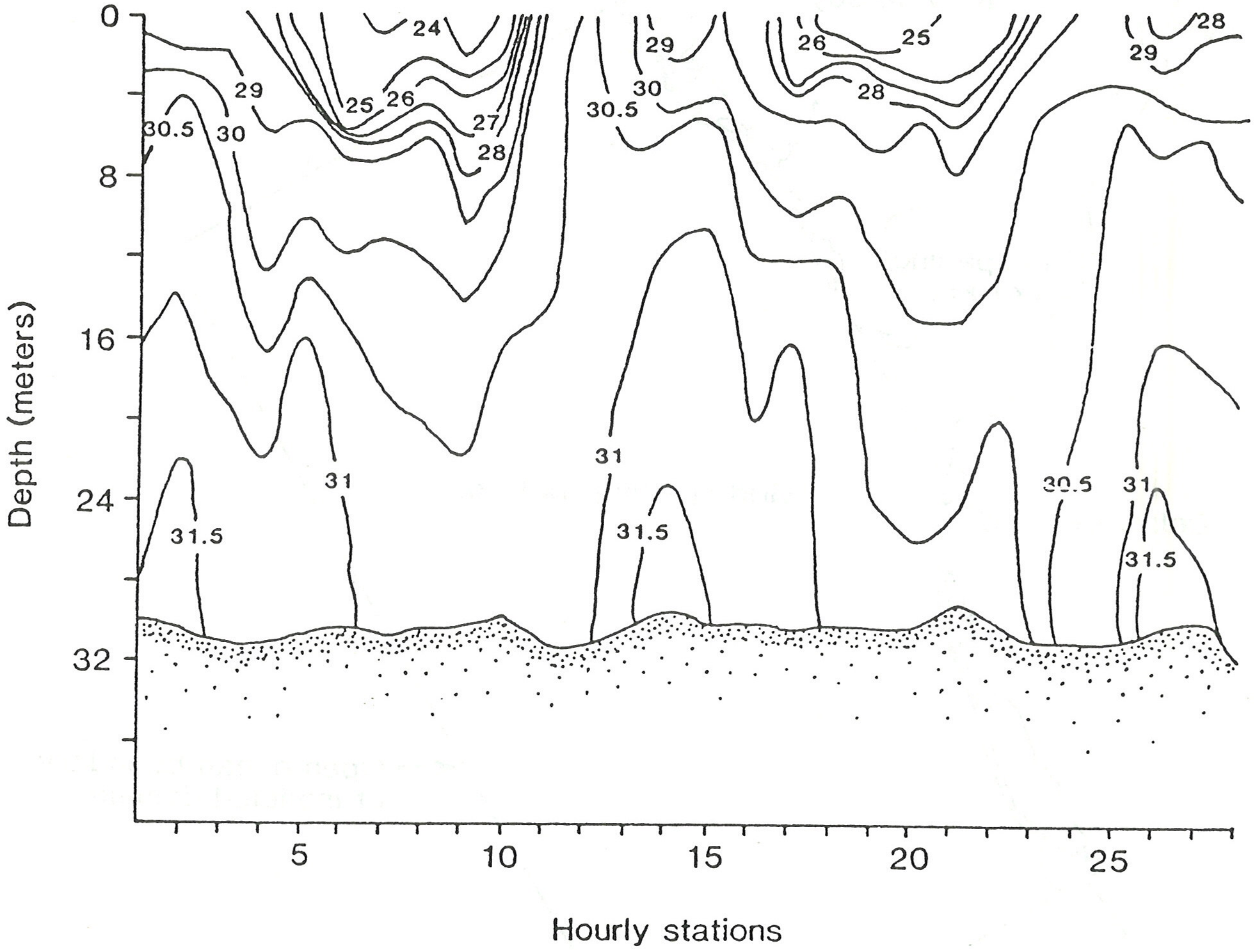

Figure 7. Salinity variations at the bay mouth over two tidal cycles during high flow conditions.

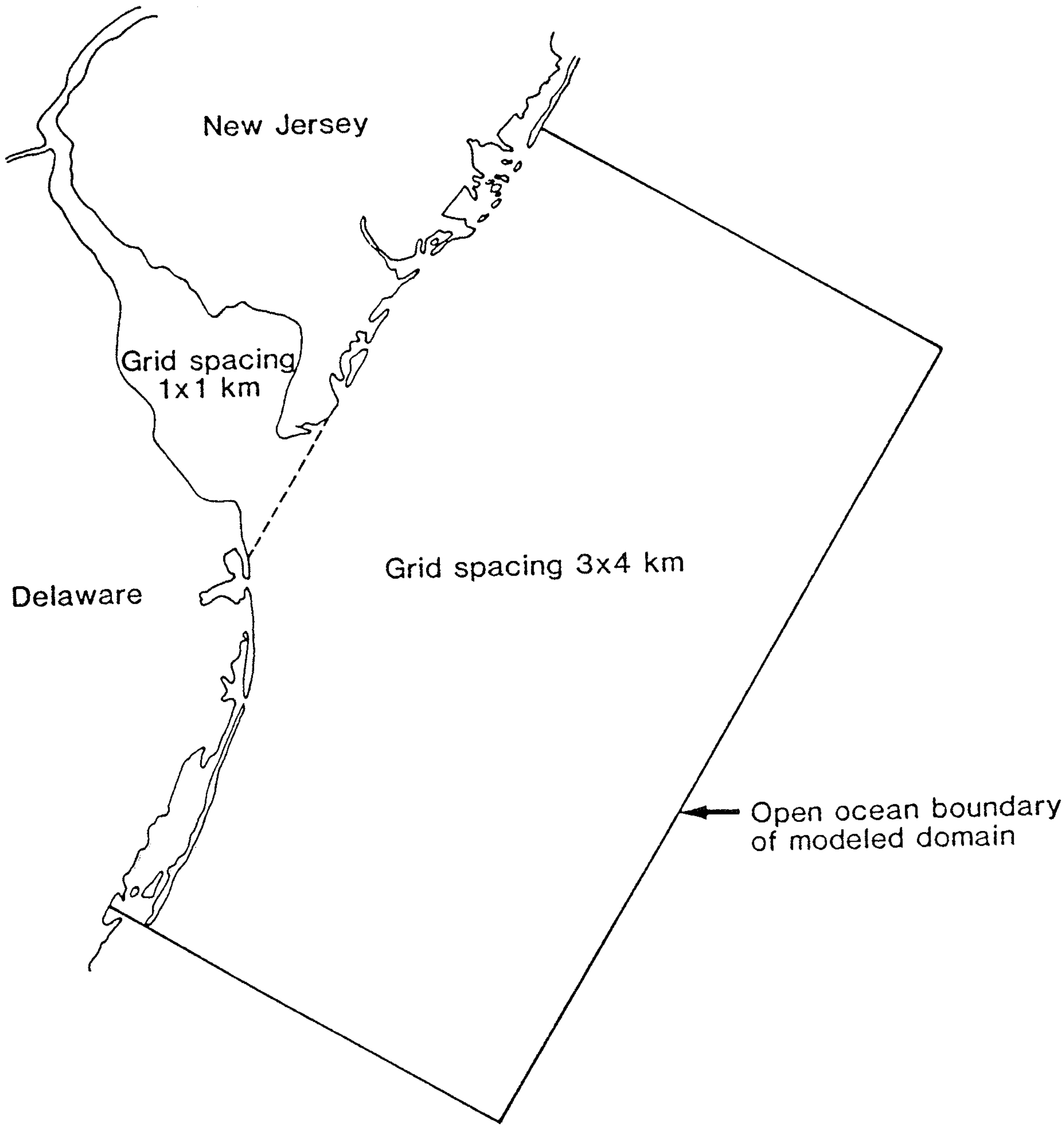

Figure 8. Delaware Bay and Continental Shelf model domain.

In the Delaware proper our model has a resolution of one by one kilometer. At the same time we have a rather rough resolution on the shelf. This model will represent the exchanges between the shelf and the Bay proper. This is the first time we've connected up an estuary with the shelf water from which it derives salt and presumably other good things from the relatively unimpacted open sea.

I'm now going to talk about the components of the flow in the estuary. We in the physical oceanographic world break up the current response in terms of so-called barotropic and baroclinic responses. The barotropic response is the vertically averaged part that changes in horizontal space and in time. In an estuary the biggest contribution to the dynamics of the Bay are the barotropic currents and tidal elevations. The tidal range at the mouth of the Bay is about a meter, and at Trenton it's about 2.1 meters. Along with that one can expect tidal currents, depending on where you are in the Bay, from zero to about one meter per second.

There is some suppositions that, from an ecological point of view, one wants to take an average of the tidal currents. So if you average elevation and currents, one finds that you get about a Ø.3 meter change from the mouth of the Bay up to Trenton just from the non-linear terms in equations of motion. Also you get residual currents of about 5 centimeters per second.

In Figure 9 we have computer drawn currents for Delaware Bay on the left. Again, this is the barotropic response. On the right are data from NOS tidal current charts; there are 12 of these charts representing every hour. I'm not going to bore you with all those twelve plots. But this is perhaps a more interesting one where you see strong flooding currents at the mouth and through the lower Bay. At the same time, the upper Bay and the river are ebbing. The model does a fairly good job of showing those details.

If you want to examine the so-called tidal residual, which is the average of the currents throughout the tidal cycle, we can examine Figure 1Ø. Maybe this will have some value from an ecological or a sediment-transport point of view, but that remains to be seen.

The other component that drives the system are winds over the shelf. More and more we're coming to the realization that as far as transporting material up and down the estuary, the winds create important long-term processes. You can have sustained currents into an estuary. Perhaps even the smaller currents, which last for a longer time, can affect greater exchanges.

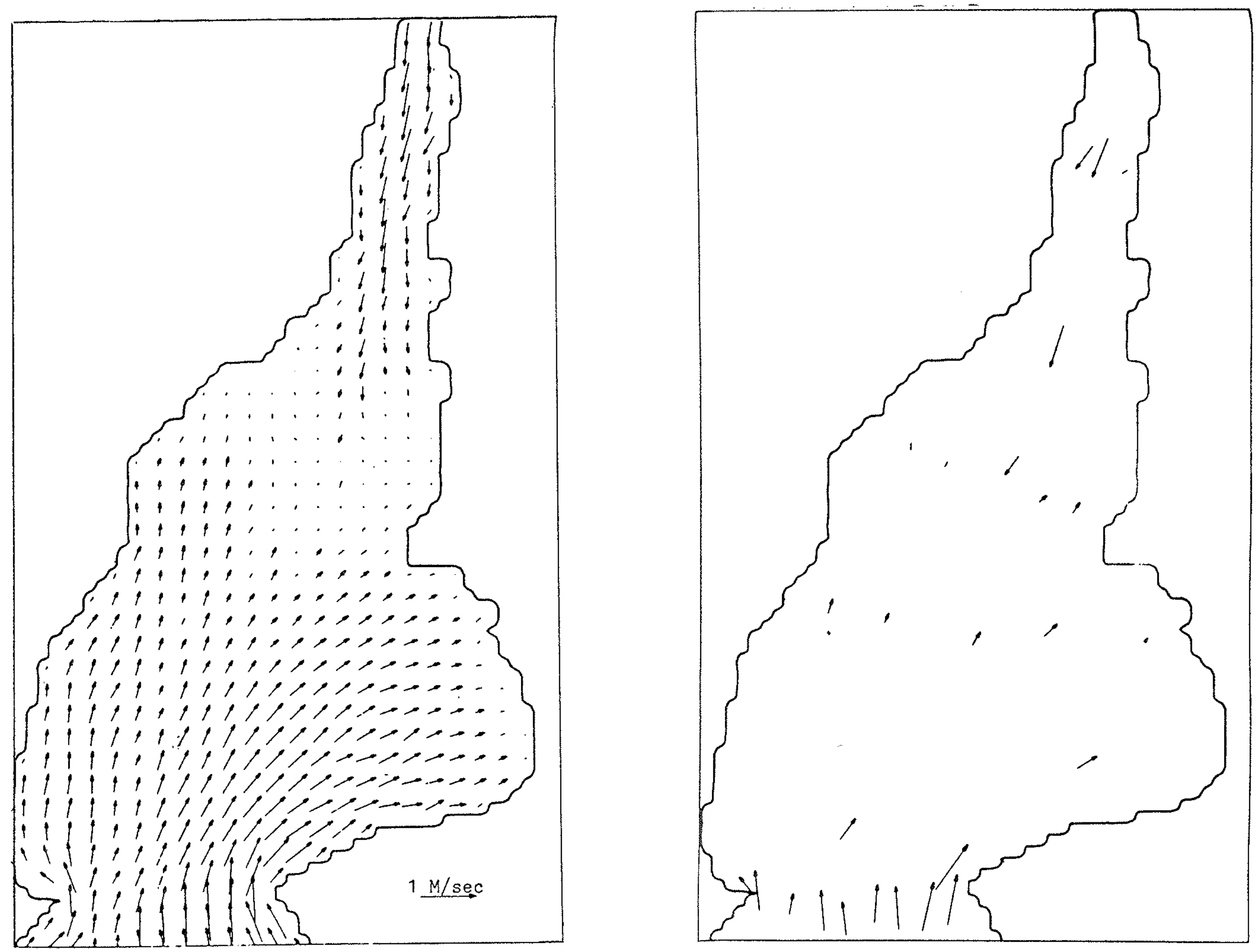

Figure 9. Model (left side) and NOS (right side) tidal currents at maximum flood plus 2 hours at Delaware Bay entrance.

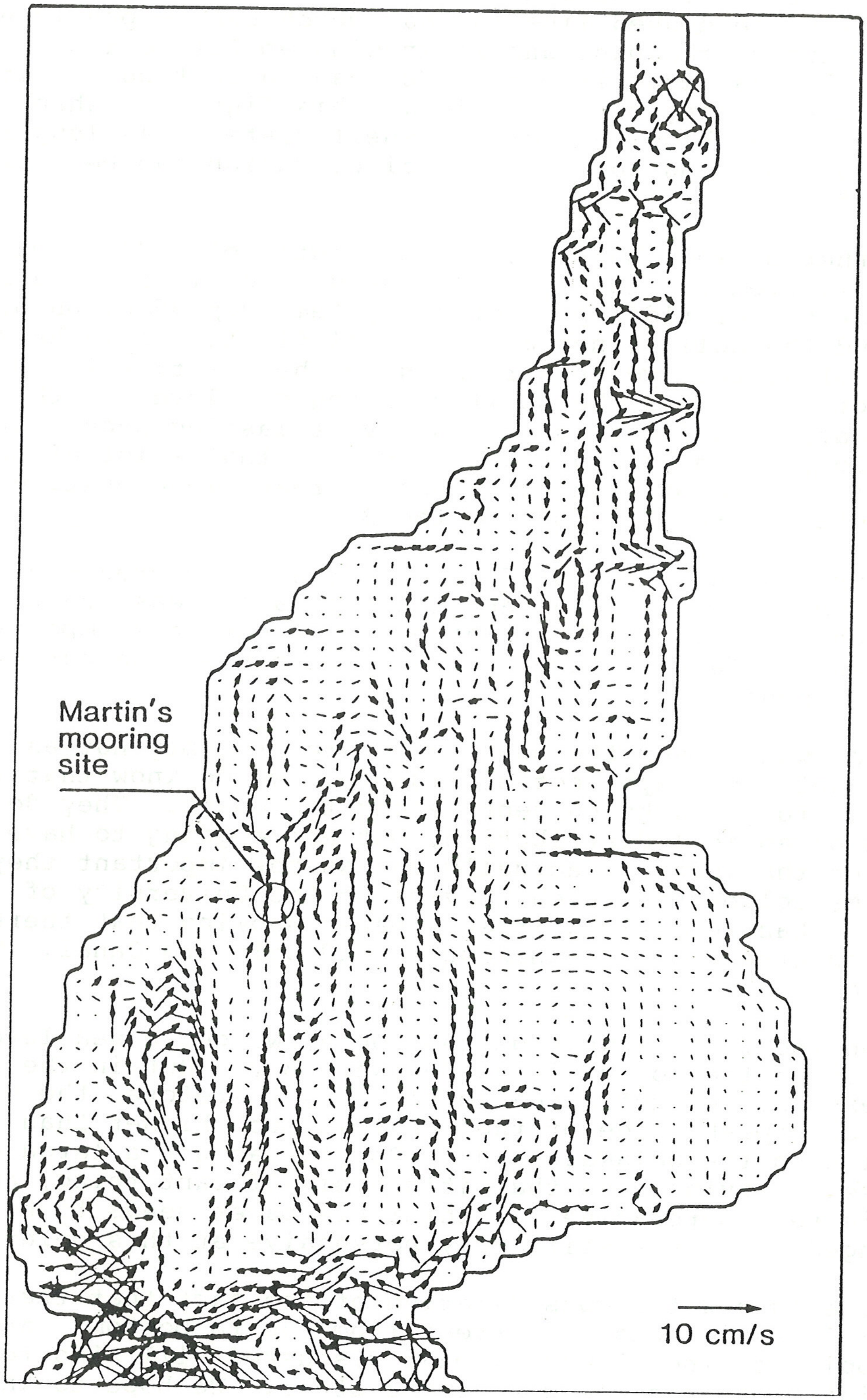

Figure 10. Computed tidal residual currents in Delaware Bay.

Figure 11 shows a tide record at Lewes, Delaware, at the beginning of July. The actual tide gauge record is the solid line, while the dashed line is that which can be predicted from measurements of the past and in knowing amplitude and phase of each of 37 tidal constituents. You can in fact do a fairly good job of representing the real tide. This figure is when there's hardly any wind blowing over the shelf system. As long as the wind is not blowing too hard, tidal elevation can be well predicted.

Another period, however, in the winter of 1977 shows quite a bit of difference. In Figure 12 the dashed lines are again what comes out of the tidal prediction system, dependent on history only, and the solid lines are the real tides. So we have here effects of winter cyclones running up the coast; this is the effect of winds over the shelf changing sea level at the mouth of the Bay. The figure shows one event lasting about three days. So you can bet your bottom dollar that a lot of transport occurred because of that sustained decrease in elevation here. That would be transport out of the Bay.

Figure 13 shows the difference between the predictable astronomical tidal forcing and that actually measured by a tide gauge for a year. So these large wind events are important, and that's why in fact we have a model of the shelf in our Delaware numerical model.

Local winds over the Bay itself are probably not as significant, but maybe not negligible. We do know that they give rise to jet-like currents along the coast. They do have a known geographical distribution, but we're going to have to depend on the model to actually assess how important they are. One of my colleagues, Rich Garvine at the University of Delaware, has recently written a paper showing that there is indeed an effect of the Chesapeake and Delaware Canal. The scenario is this:

When the wind blows from the south, we get a sea level reduction at the mouth of the Delaware Bay. But in the upper Chesapeake Bay we get a sea level rise; therefore, the elevation at the Chesapeake side of the Canal is much higher than the elevation on the Delaware side. So you can get a large current response. Garvine says that it's a significant thing, and his paper is very persuasive. I think his paper needs to be challenged, but it's still very persuasive at this point.

There is now the consideration of the fact that there are baroclinic variations in current from top to bottom. And every barotropic forcing element I have discussed will also force the baroclinic response one way or the other. We hope to know more about the baroclinic response when we finish our modeling study. But of course, from a residual point of view one knows

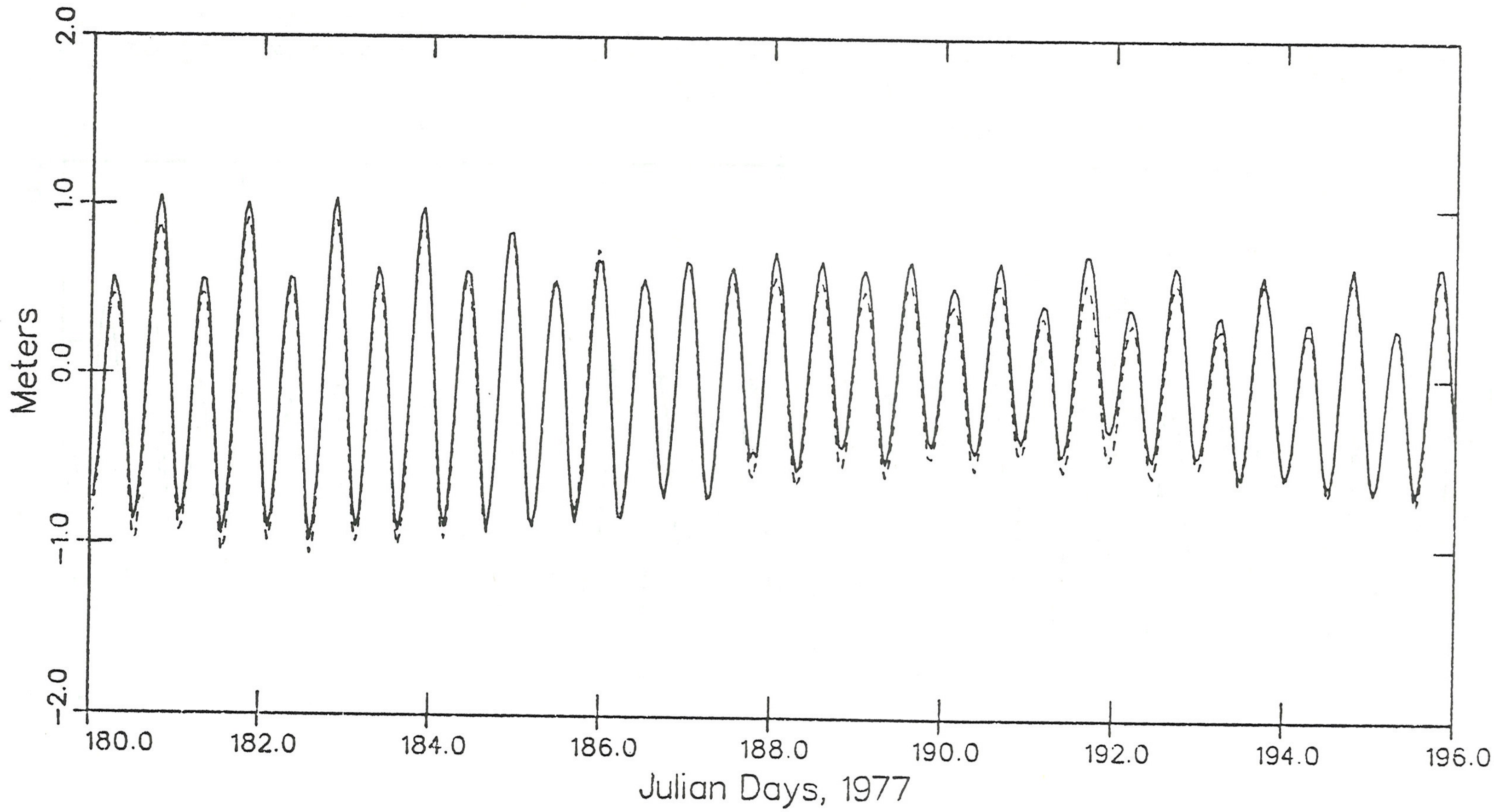

Figure 11. Measured (solid curve) and predicted (dashed curve) tidal elevation at Cape May during the summer.

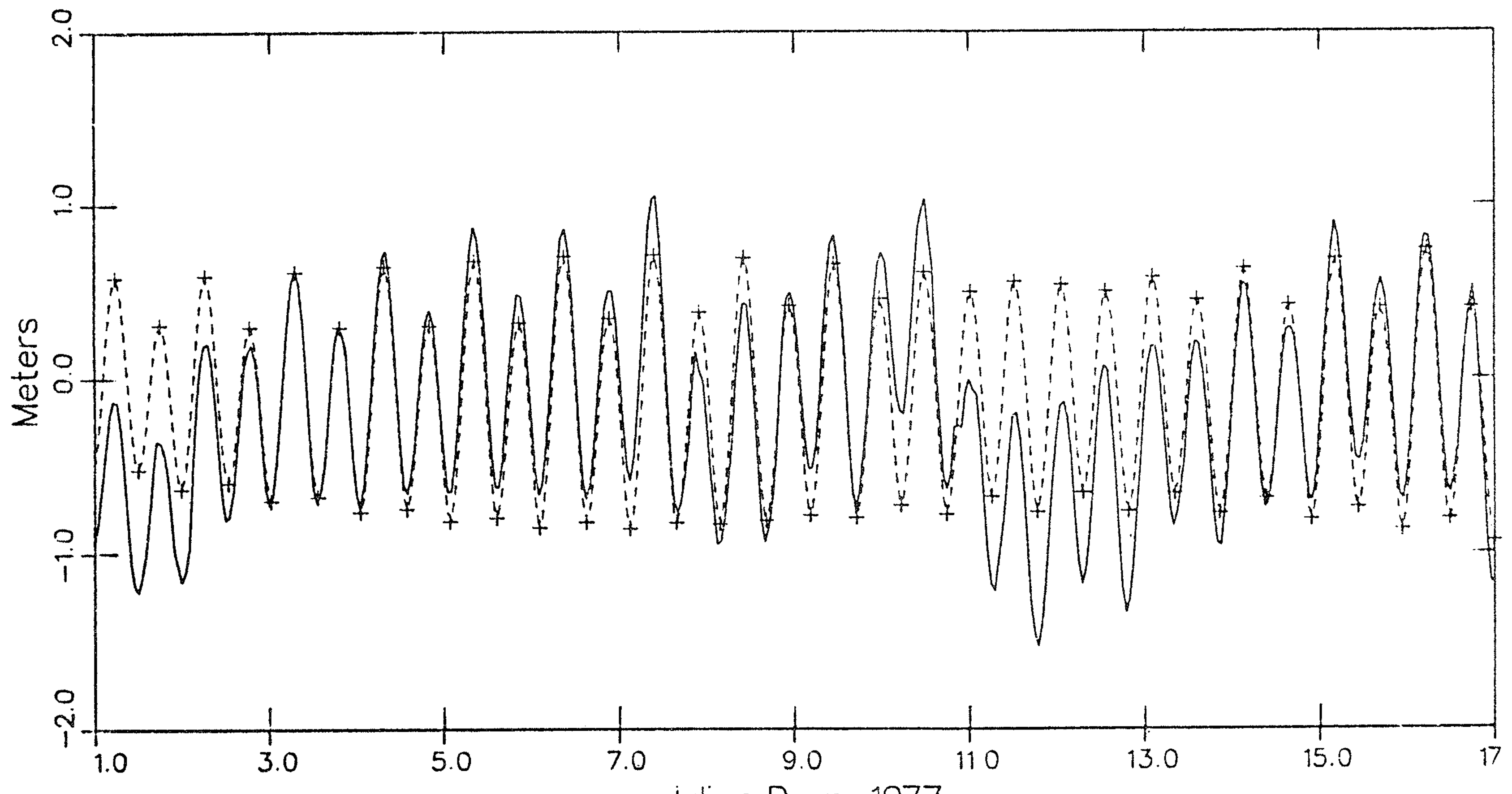

Figure 12. Measured (solid curve) and predicted (dashed curve) tidal elevation at Cape May during the winter.

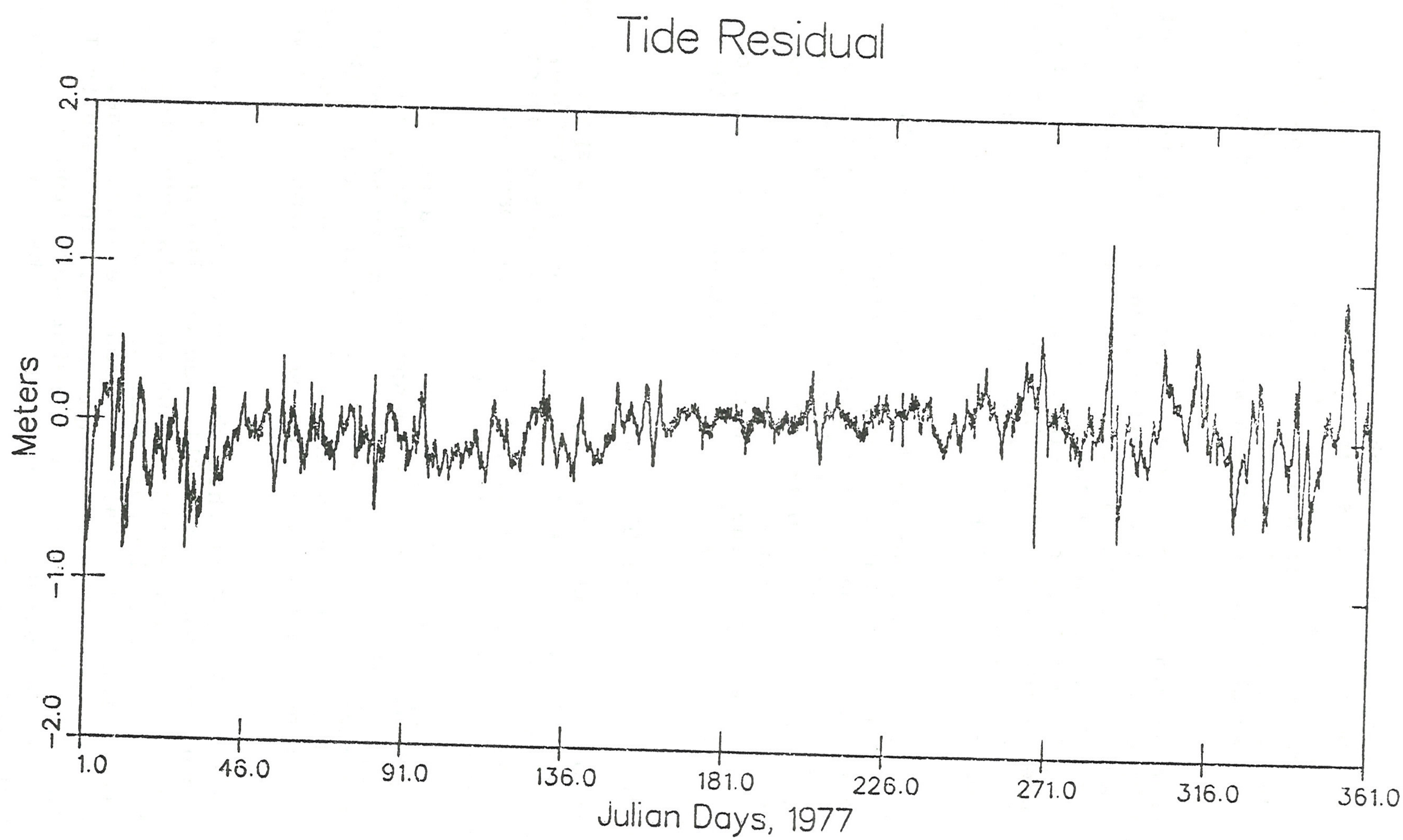

Figure 13. Tidal residual (measured minus predicted tidal elevation) at Cape May.

that there's flow coming out on the surface of the estuary and flow into the bottom of the estuary from the sea. At the surface, rough numbers are about 10 centimeters per second whereas, at the bottom, flows of about 1 centimeter per second are up-estuary. These bottom currents bring with them the salt from the sea, which then gets mixed with the fresher surface water.

Professor Garvine has also done a very interesting job of estimating by deployment of drifters--7,000 drifters--currents at the surface. As seen in Figure 14, the surface current does tend to go to the shore of Delaware. That means there must be a bottom return flow to the other side. The drifters released on the shelf are in agreement with other current meter measurements on the shelf, namely a southward flow from 5 to 10 centimeters per second on the shelf all the way from here to, say, Woods Hole.

In Figure 15 you see bottom drifters going into the estuary. The guess is that you have a range of influence of maybe 40-50 kilometers out on the shelf wherein the system itself gobbles everything up and funnels it into the mouth of the estuary. It gets mixed with the fresh water coming on top, and that forms the estuarine system. I understand that this study was motivated by an investigation into the ecology of the blue crab larvae. The only thing I know about them is that they're delicious.

DR. SHARP: After they grow up.

DR. MELLOR: After they grow up. And there is speculation, of course, that these larvae go out in the surface waters, grow and become juveniles. They then drop to the bottom, where they're entrained in the bottom water and come back into the estuary to become edible creatures eventually.

The other aspect is that, because there is a shelf connecting the Delaware with the Chesapeake, in the case of at least this one species of animal there is an exchange between the two embayments. The blue crab larvae that spawn in this region may end up in the Chesapeake and visa versa. I suppose a very small percentage actually come back to become real live crabs.

Well, that's the end of this short discourse. We have, again, a numerical model that will spew out hundreds of thousands of numbers for salinity and currents everywhere in the Bay. I should say that the work that we're doing at Princeton is partly sponsored by the National Ocean Service. They have now gone operational using our simple model. The results I showed with little arrows from a computer were from a vertically-averaged barotropic model only. We now have running a three-dimensional model.

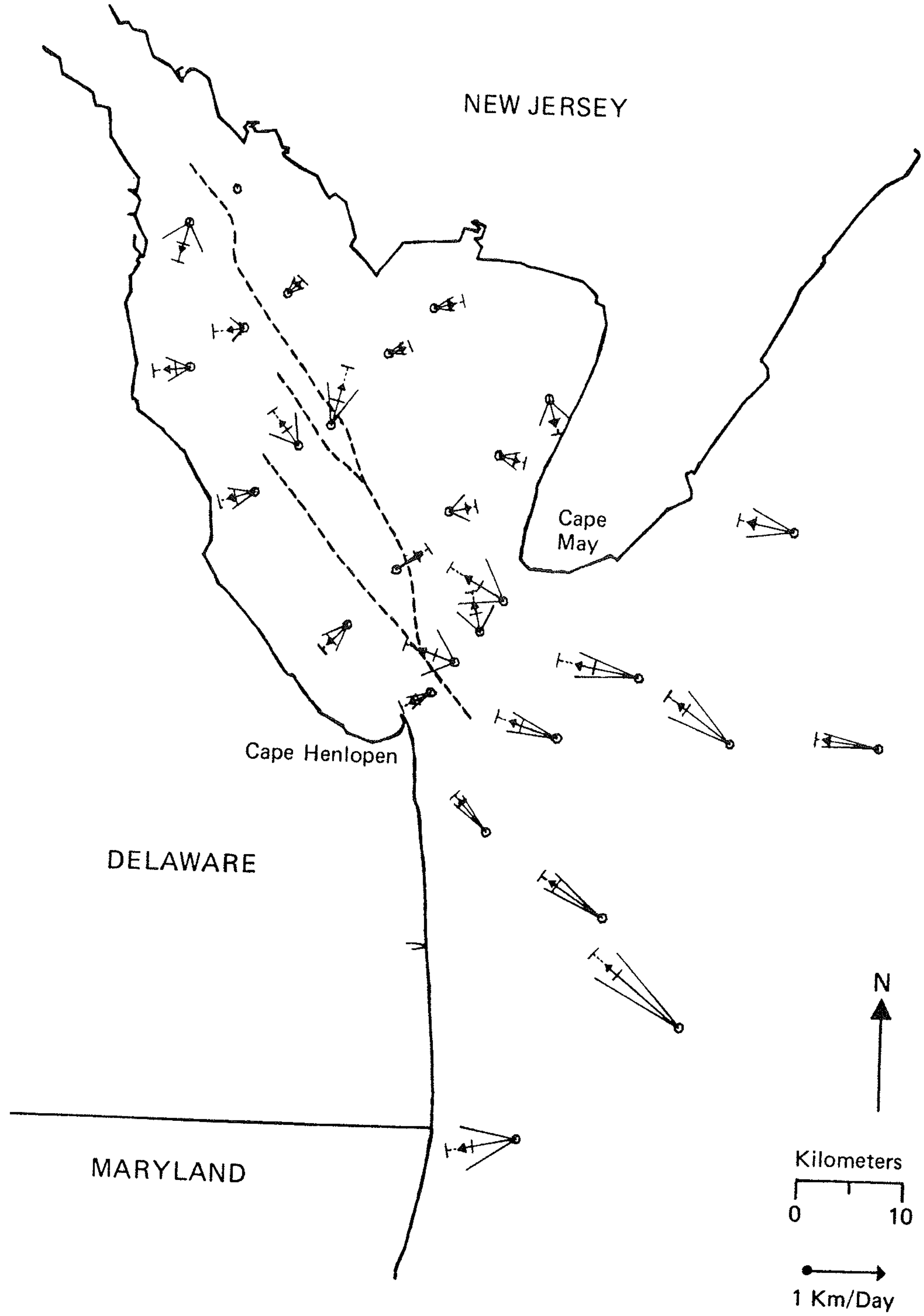

Figure 14. Vector mean currents and associated 95% confidence interval deduced from surface drifters (after Pape and Garvine, 1982).

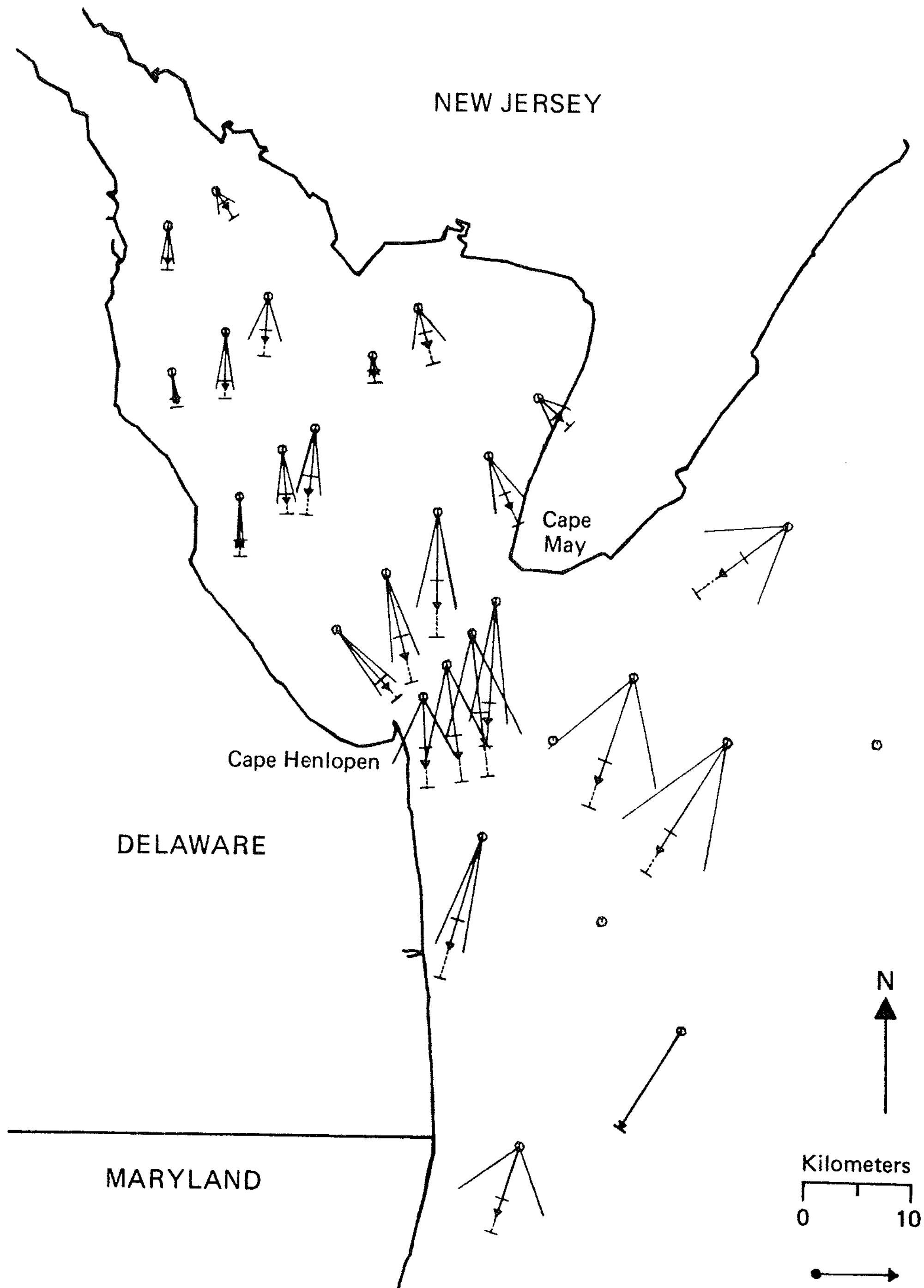

Figure 15. Vector mean currents and associated 95% confidence interval deduced for bottom drifters (after Pape and Garvine, 1982).

But the model that is now in the hands of the National Ocean Service is an operational tool. You can dial up a number here in Washington and if you have an IBM-PC and the proper software, you can find out an estimate of what's going to happen in the Delaware anywhere from now to 36 hours from now. The 90 or so pilots that navigate ships into the Delaware estuary here are able to obtain tidal elevations which are influenced by winds and wind forecasts. And they can now obtain what are our best estimates of the currents. So this is an estuarine forecasting system that is now on line just as we have numerical output from the National Weather Service to give you tomorrow's weather. [Editor's note: As of this writing, the NOS Delaware Bay model is in a standby status and is not running in a real-time configuration.]

The last thing I want to mention is that along with this emphasis on modeling on the part of NOS and NOAA is an observational study now in progress. There are lots of current meters deployed, some using fairly sophisticated new instrumentation along with tidal, salinity, and hydrographic stations. These measurements are being taken not only in the Bay, but on the adjacent shelf. This is a mound of data which I'm going to be coping with for some years to come. The bottom line is that, in two years or so, we're going to know a great deal about the currents and the transports in this particular estuary. Therefore, it is a fertile ground to go on from there and to use our model not only for navigational purposes, but for ecological studies in the future.

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CHEMICAL OCEANOGRAPHY

Jonathan H. Sharp
University of Delaware

I'd like to talk a little bit now about the chemistry of the Delaware Bay. We have had a fairly intensive study going on for the last four or five years in which we have tried to use the full geographic extent of the estuary for our sampling. We have tried to orient the study toward processes. It has not been a pollutant study, but more of an attempt to understand the chemical behavior and the chemical characteristics over time and space.

Figure 1 shows some geographic and salinity axis information. We have done some limited sampling all the way up to Trenton at the head of tide, so we have covered the full extent of the estuarine tidal influence. Just south of Philadelphia is really the extent of the measurable salt influence. From this point on down to the mouth of the Bay is the salinity gradient.

The full length of the system all the way up to Trenton, is about 120 nautical miles. The Philadelphia region is about 60 or 70 nautical miles from the mouth. The lower Bay where the estuary widens is about 30 nautical miles.

An important and interesting fact, as Professor Mellor pointed out, is that over 50% of the fresh water flow of the estuary is from the Delaware itself. The Schuylkill River comes in above the salt line with another 10%. So at the head of the salinity gradient we have in excess of 60% of the total flow of the estuary. None of the smaller rivers (Christina, Salem, Smyrna, Cohansey) put in more than about 1% of the total flow. Close to 40% of the total flow of the river is small point or non-point source diffuse input.

We can look at this in a modeling sense with the major input north of the salinity gradient. By this point, most of the chemicals in which we're interested are at their maximum from agricultural and municipal inputs. So, most of them are at their maximum at zero salinity. If we look at a salinity gradient, most of the river flow and most of the chemical input is at the zero-salt end. From there, concentrations decrease in essentially a downhill trend. This provides an incredibly valuable tool for trying to understand chemical behavior.

One of the big concerns in pollution and water quality is dissolved oxygen, and the Delaware has a very significant sag of dissolved oxygen in its municipal region. Figure 2 shows dissolved oxygen plotted against distance up the estuary from the Bay mouth; the dissolved oxygen values are in milligrams per

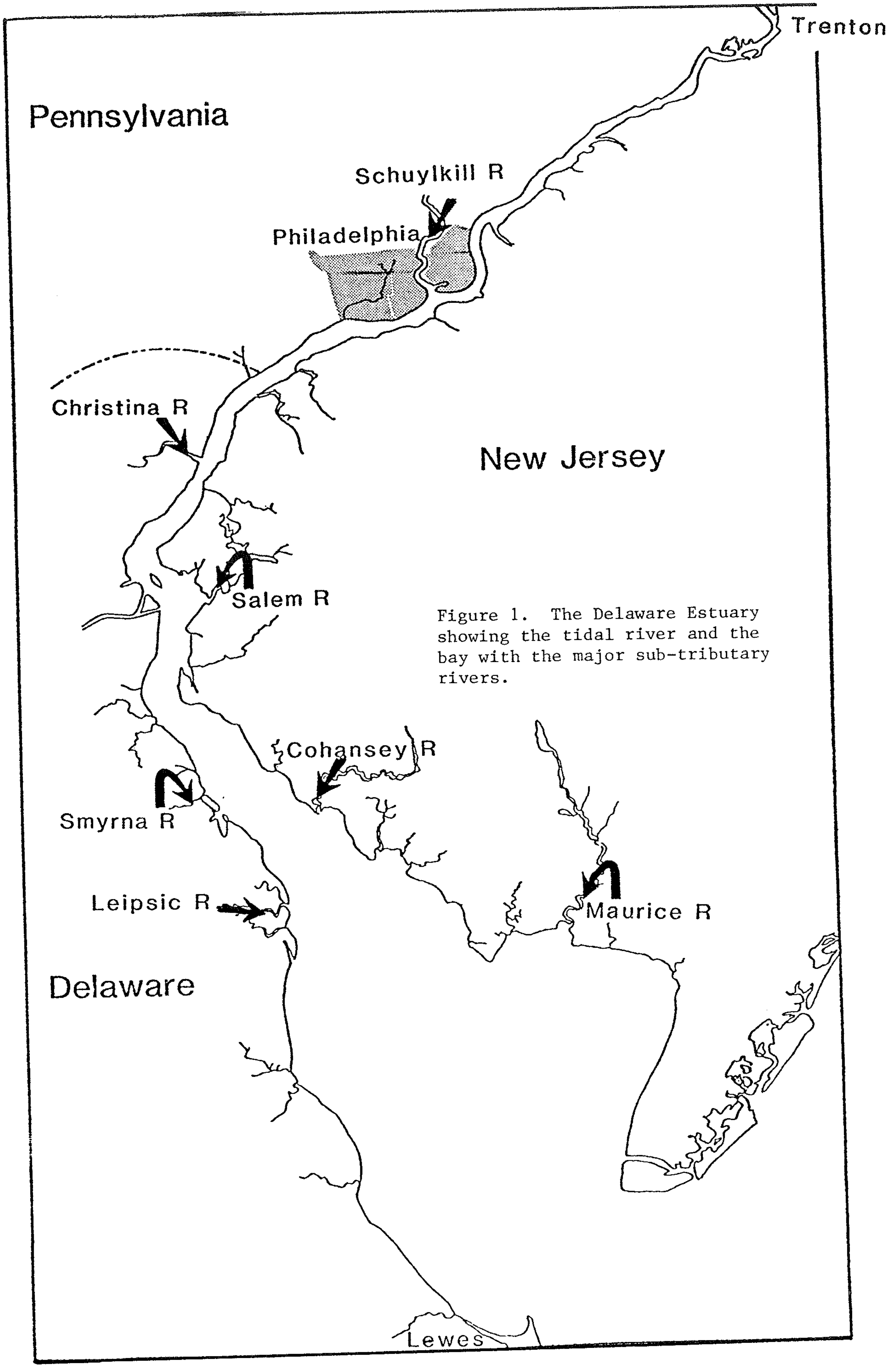


Figure 1. The Delaware Estuary showing the tidal river and the bay with the major sub-tributary rivers.

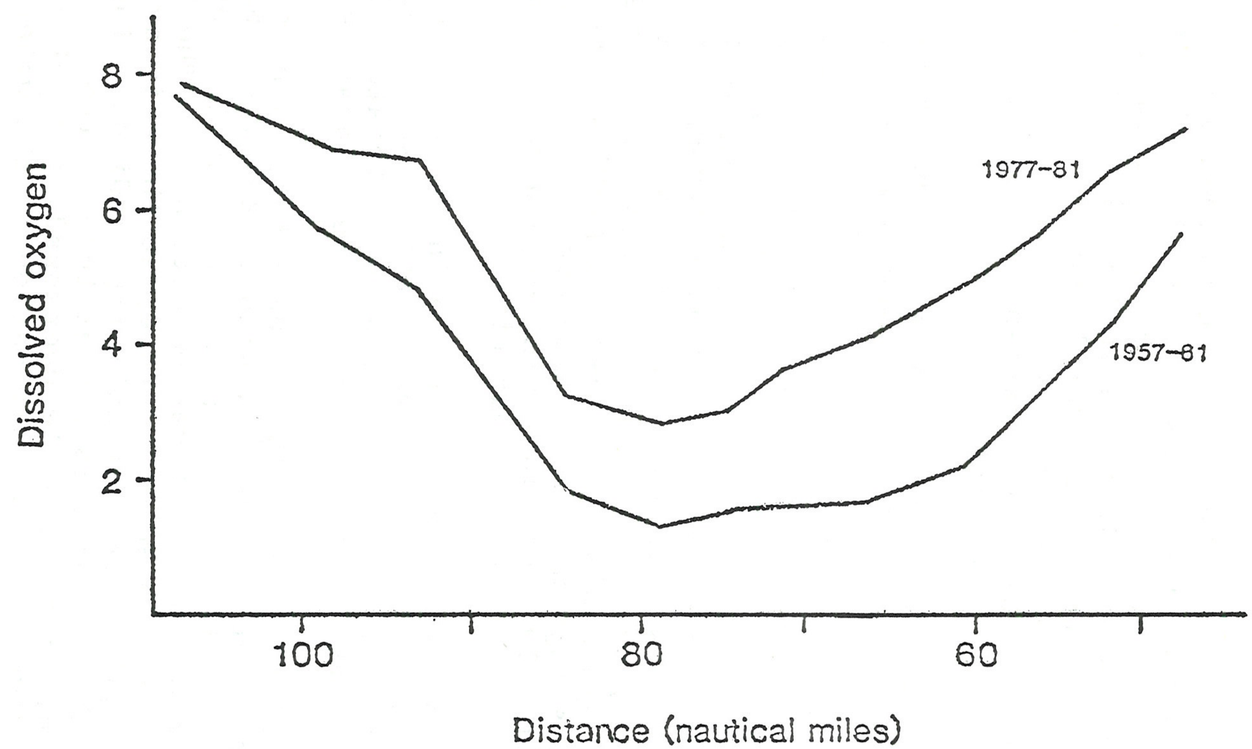


Figure 2. Comparison of mean dissolved oxygen values (milligrams/liter) for 1957-61 and 1977-81 from sampling in the period of June through October. From DRBA Report.

liter. The data are from the Delaware River Basin Commission. A distinct oxygen sag is seen from about 50 to 120 nautical miles. It runs from the head of the Bay itself up the river toward Trenton. Near Trenton, one can see fairly high, close to saturation oxygen content, as would be expected from mixing with the atmosphere. The water in the lower Bay, again, has oxygen content fairly close to what one would expect from atmospheric mixing. Between these points there is a very large biochemical oxygen demand from the municipal region.

A very significant point here is seen in the comparison of averaged summer data (for the period of June through October) of the 1957 through 1961 period compared to the 1977 through 1981 period. There is a dramatic increase in the dissolved oxygen content of the water in the last several decades. Thus, there has been a significant increase in water quality in the Delaware, as measured by dissolved oxygen. It can be well documented as the figure indicates.

An oceanographic concept that we have been using to look at this type of phenomenon is what we call apparent oxygen utilization (AOU). Figure 3 plots AOU against salinity for the entire Delaware estuary. AOU is the difference between the dissolved oxygen that one would predict from purely physical mixing of the atmosphere and the water and the dissolved oxygen that is measured. The zero line means that the water is saturated with oxygen, as one would get from atmospheric mixing. Negative values indicate that more oxygen is in the water than predicted, and this is due to biological oxygen production by photosynthesis of microscopic plants. Positive values indicate less oxygen than is predicted. This is due to oxygen demand, primarily bacteria taking oxygen out of the water as they digest organic or reduced material.

There is a pronounced oxygen decrease in the upper reaches, the upper 0-5 ppt salinity. The lower portion, which has higher salinity, is either near saturation or super-saturated with oxygen. This covers the vast majority of the Delaware Bay.

The pH, the acidity-alkalinity of the water, changes from fresh water to sea water as Figure 4 shows. Sea water has a pH of about 8. A fresh water river can be more alkaline (have higher pH) than the ocean, or it can be more acid. The Delaware is a river that has a more acidic nature, so there is an increase in the pH going down the salinity gradient. The pH in the upper part of the Delaware is higher than in the Philadelphia region, which is quite depressed, indicating that there is probably significant acidification of the water from municipal inputs.

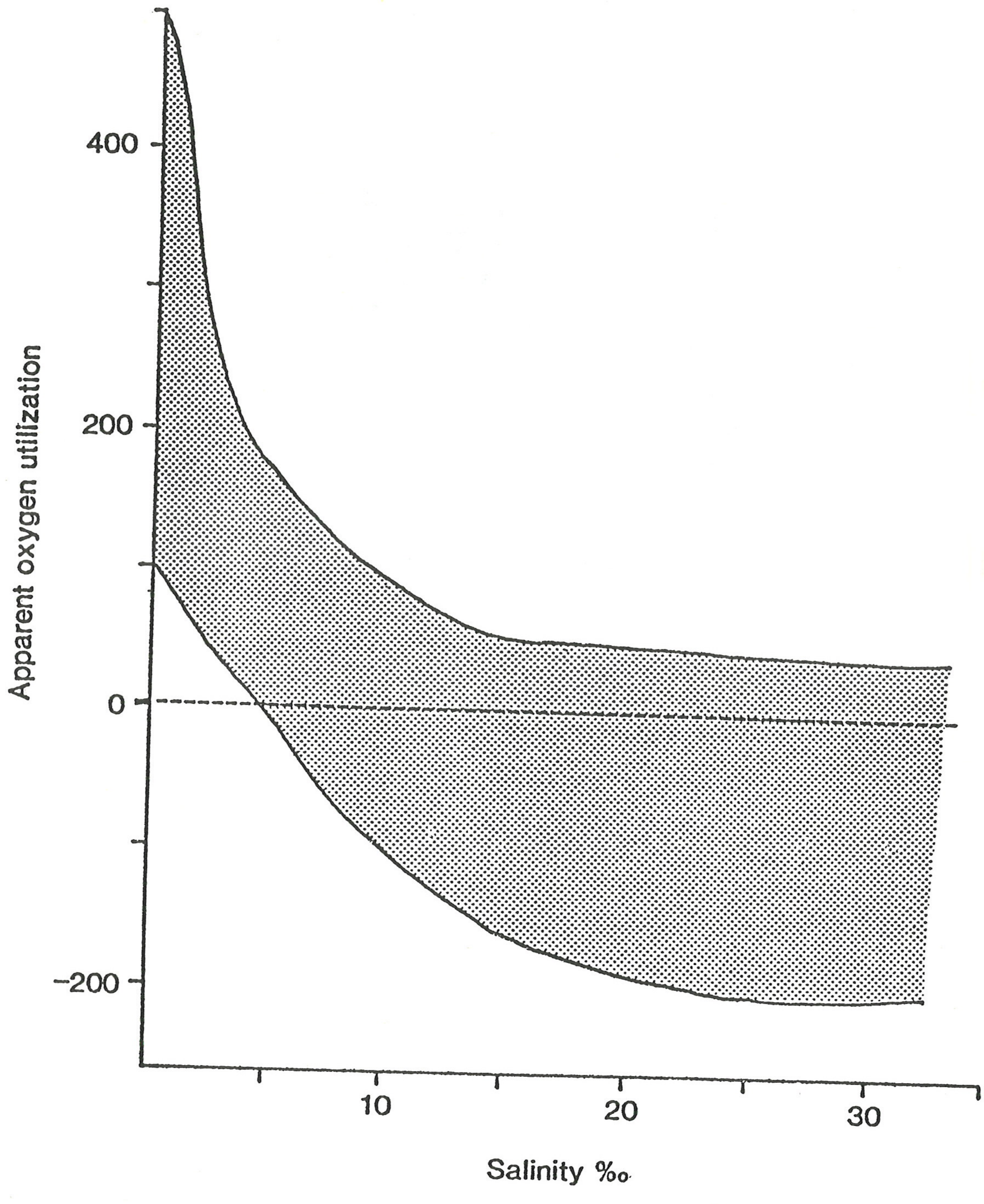


Figure 3. Apparent oxygen utilization (microgram-atoms oxygen per liter) vs. salinity for surface central channel samples from the Delaware Estuary from 1978-83. From DRBA Report.

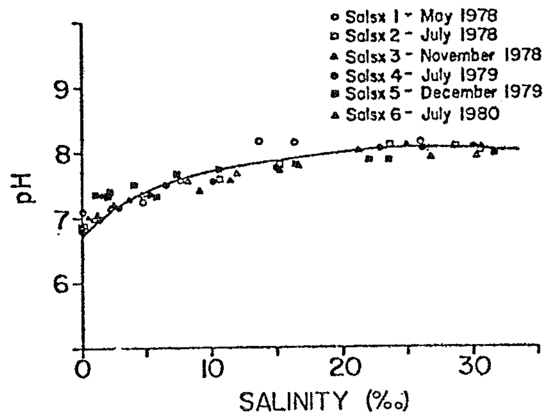


Fig. Composite plot of pH vs. salinity.

Figure 4. Plot of pH versus salinity for the Delaware Estuary. From Sharp et al., 1982.

A concept that is valuable to us is alkalinity of the water. This is basically the total salt balance of the water. Figure 5 is the alkalinity for about a five-year period from all seasons plotted against salinity. The important point is that it is a linear relationship. This means that we can rely on an oceanic concept that was first postulated in the early 1800s and absolutely confirmed with the Challenger expedition in the 1870s. That is that the major constituents in sea water are in constant proportions. If you can extrapolate into an estuary with this, you could say that if you dilute sea water in half, then you should have half as much magnesium, half as much potassium, half as much calcium as you have in ocean water.

So if this concept holds, if there is linearity in an estuary, one can say that from the oceanic end all the way up to almost the head of the salinity gradient, the water can be viewed as being dilute sea water. Then 99% of the composition of the water is specified. Thus we know the major constituents of the water; and the only thing that will vary beyond that, and the area where we've put our major emphasis, is the minor constituents. The Delaware estuary can be modeled and understood in the physical-chemical sense as dilute sea water almost all the way to the head of the salinity gradient.

Going back to this picture of the Bay with Figure 6, point one is at the head of the salinity gradient. Point two is where the estuary widens and becomes a major Bay. One can look at the span between the two as a portion of the salinity gradient. Point one is almost predictably at 0 parts per thousand salinity today. At point two, the salinity can vary from 0 to 15 ppt.

Figure 7 has a distance axis in nautical miles going up to Trenton. There is a major input in the Delaware from sewage effluent materials as well as from land runoff of agricultural input. A significant factor in this is nitrogen.

There is a tremedous nitrogen input into the Delaware, and we can see a very large peak of ammonium in the Philadelphia area. Ammonium drops off followed by a peak of nitrite and then a peak of nitrate.

I point this out partially because this fits classical oceanographic concepts. With depth in the ocean, one can see pretty much the same type of picture. Ammonium is produced as a reduced form coming from organisms, in this case, the organisms being humans with sewage. It is oxidized naturally due to laws of thermodynamics to nitrite and then to nitrate. The same thing happens on a distance axis in the Delaware that happens with a depth axis in the ocean. We're trying to use some classical oceanographic concepts to understand the chemistry of the Delaware, and they do work.

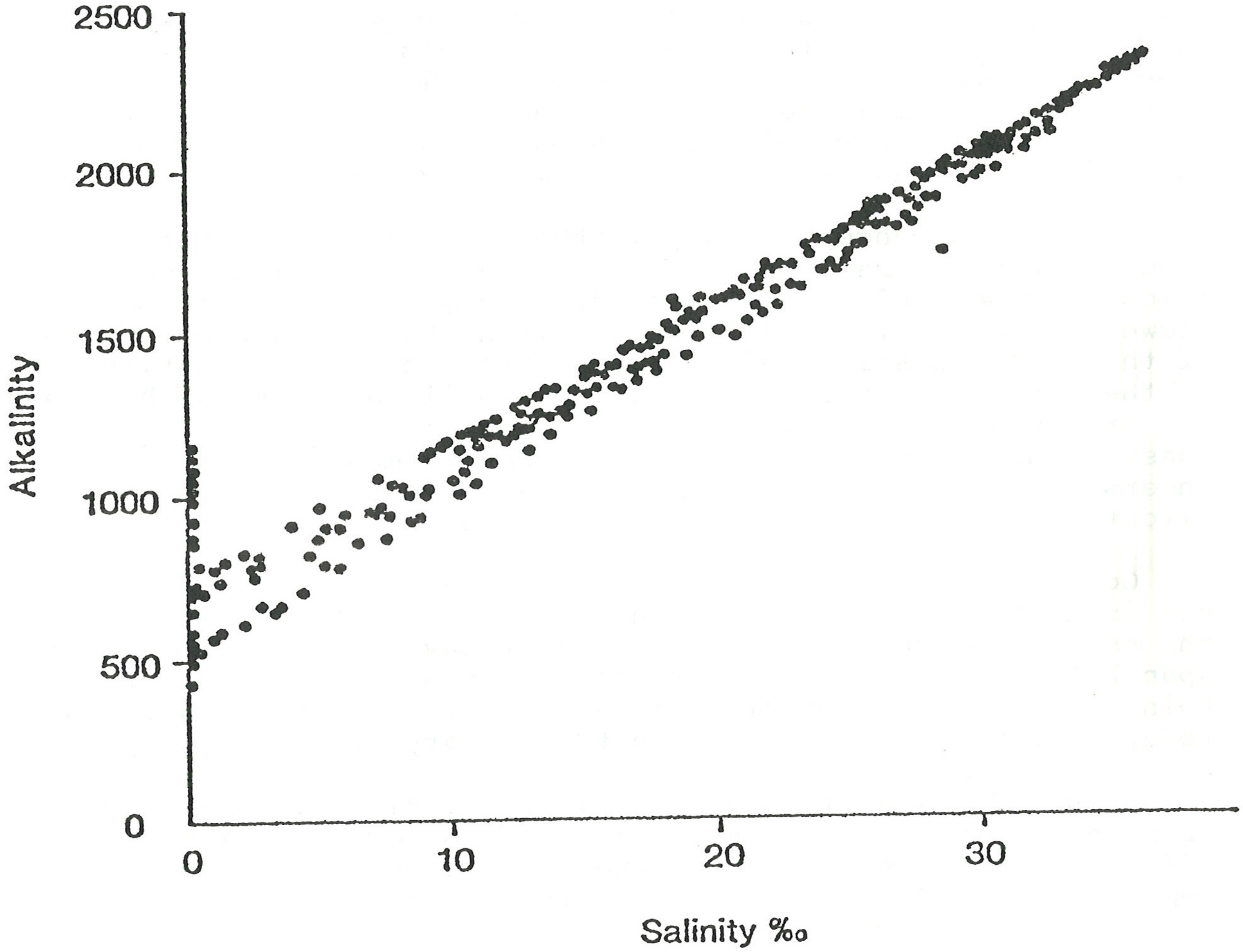


Figure 5. Alkalinity (microequivalents per kilogram) versus salinity for all samples from 1978-83 for the Delaware Estuary. From DRBA Report.

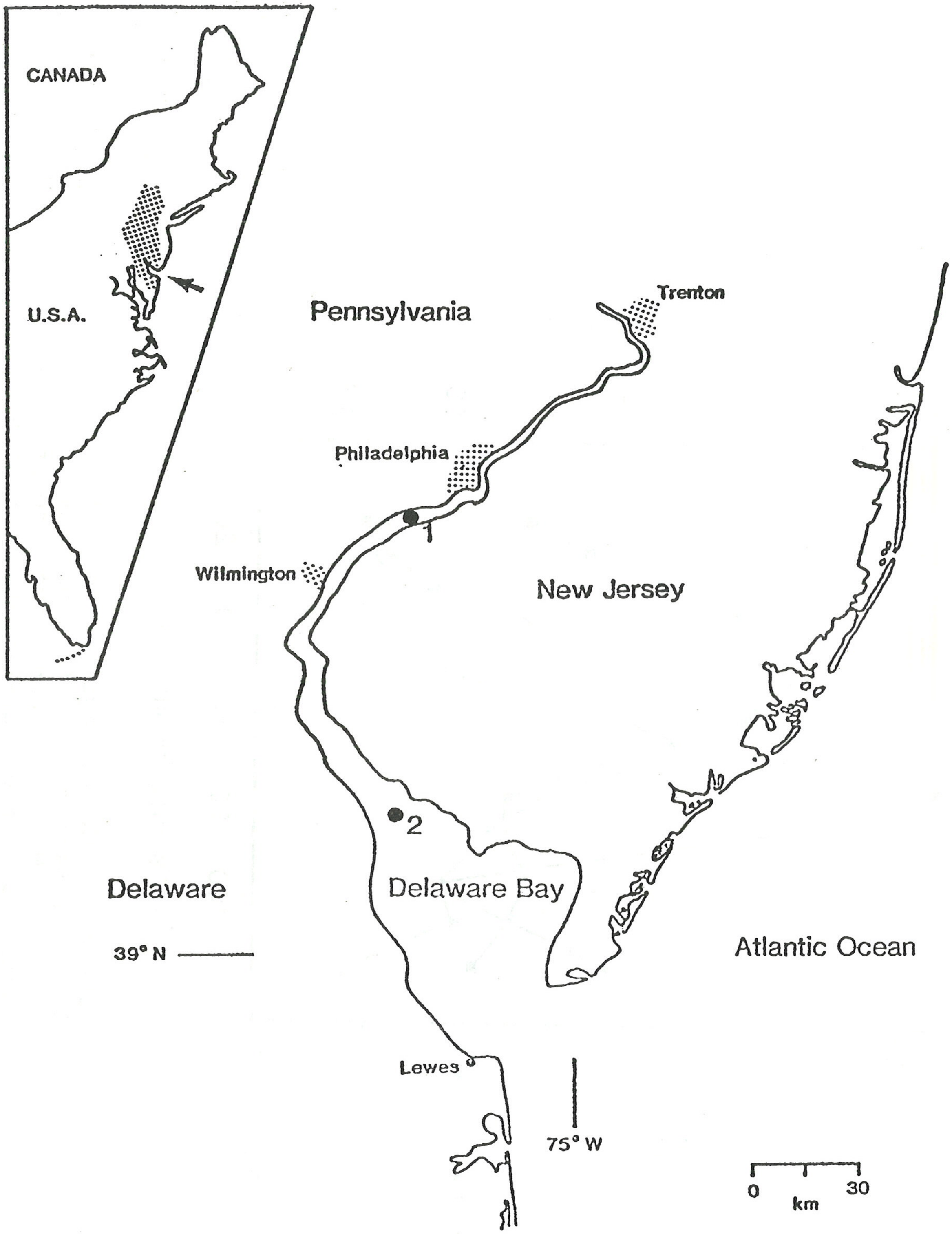


Figure 6. The Delaware Estuary, insert indicates location and shows the drainage basin (stippled area). The estuary extends from Trenton to the bay mouth, the saline portion runs from point 1 to mouth, and the Delaware Bay runs from point 2 to mouth. From DRBA Report.

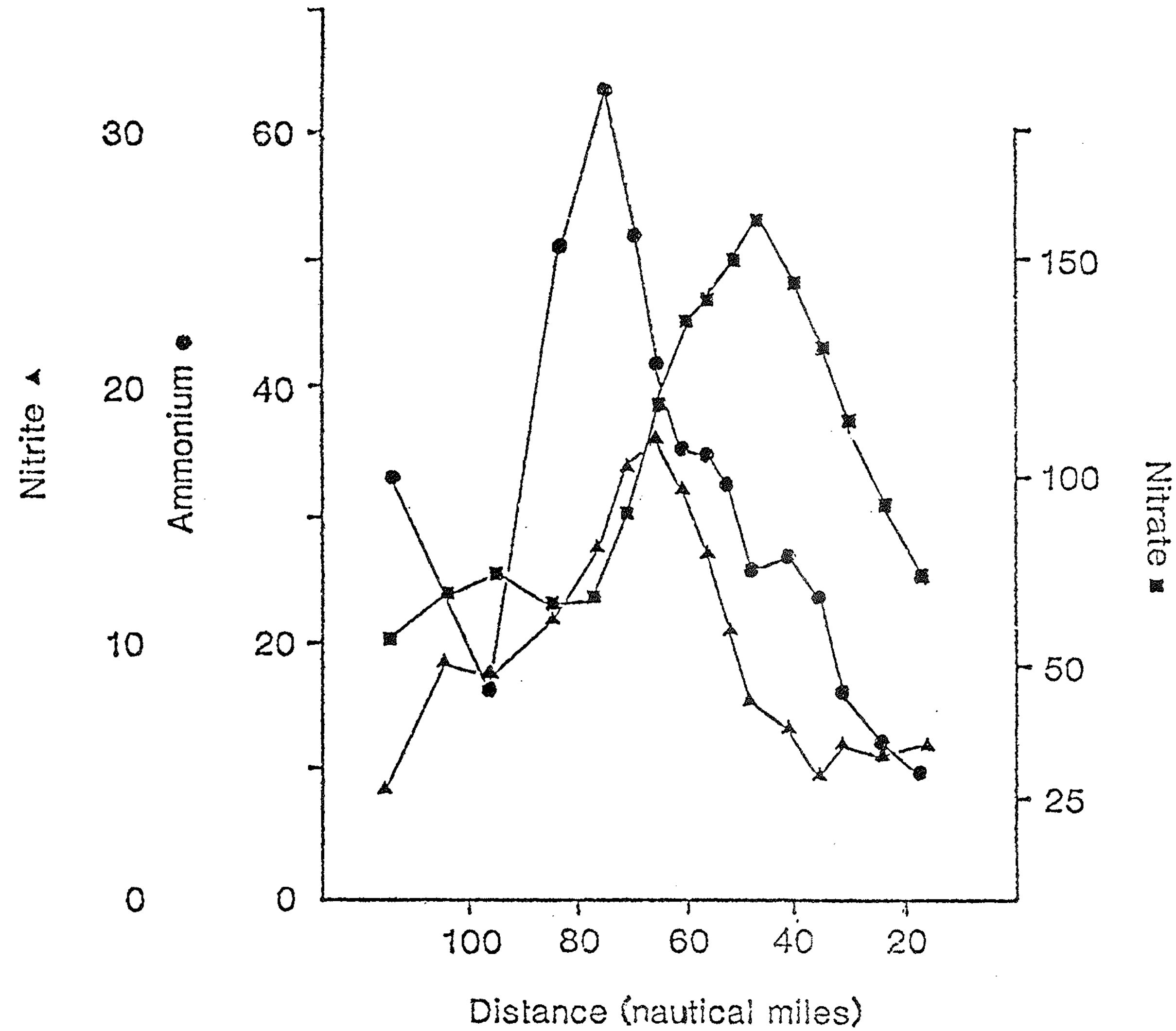


Figure 7. The nitrogen cycle in the Delaware Estuary. Nitrite, ammonium, and nitrate (uM) vs. distance from the Bay mouth. Data are averaged August values for 1967-80 from the Delaware River Basin Commission. From DRBA Report.

I published a paper a few years ago for which one of the reviewers was very critical and said, "You can't really talk about chemistry in the Delaware because it's a polluted estuary." The point I'm trying to make is that it makes no difference whether you call it polluted or not. A lot of the basic chemical processes, the basic chemical principles, hold. Which means we can use a century's worth of good background information on ocean chemistry to understand this system better.

A concept that has been developed primarily in Europe and is being used increasingly in this country is that of property-salinity plots (Figure 8). With this, one can take salinity as an axis. If we look at something that's more concentrated in fresh water, as are most of the chemicals we're interested in, we find that they decrease with distance going from zero to full salinity. For the Delaware we have Ø ppt salinity right around Chester, Pennsylvania, and 3Ø-31 ppt at the mouth of the Bay between Cape May and Cape Henlopen.

A property that is just diluted and does not react chemically would show a conservative pattern, a straight line plotted against salinity. A property that shows a downward curvature implies a net removal. This could be from either a geochemical precipitation type of behavior (flocculation) or a biological uptake. There is a net loss of this constituent as compared to conservative mixing. If there's an upward curvature, then it indicates a net input.

A net input could take place by an effluent coming in or another sub-tributary coming in. Also net inputs can be due to geochemical behavior, things dissolving off sediments either suspended or on the bottom. The latter source is probably most important in the Delaware. It's a very valuable concept for trying to understand behavior of chemicals in the estuary.

Figure 9 shows an averaged picture for phosphate, which is an important fertilizer from sewage and agricultural runoff. Also nitrate is shown, again an imporant component from the sewage and agriculture. Both of them also come from land runoff. Both are naturally in estuaries and ocean waters, but are much enhanced in the Delaware.

The nitrate in a pristine estuary, such as the Zaire River in Africa, is usually found at the zero salinity end of the estuary on the order of 1Ø micromolar. In the Delaware, it is about 15Ø micromolar. Thus it is very much enhanced. In fact, looking at this type of plot of nitrate against salinity, we find, with a few exceptions of very heavily polluted European estuaries, that no other estuary in the world has as high a nitrate concentration as the Delaware. Certainly there is no other major estuary in this country with as high a nitrate concentration.

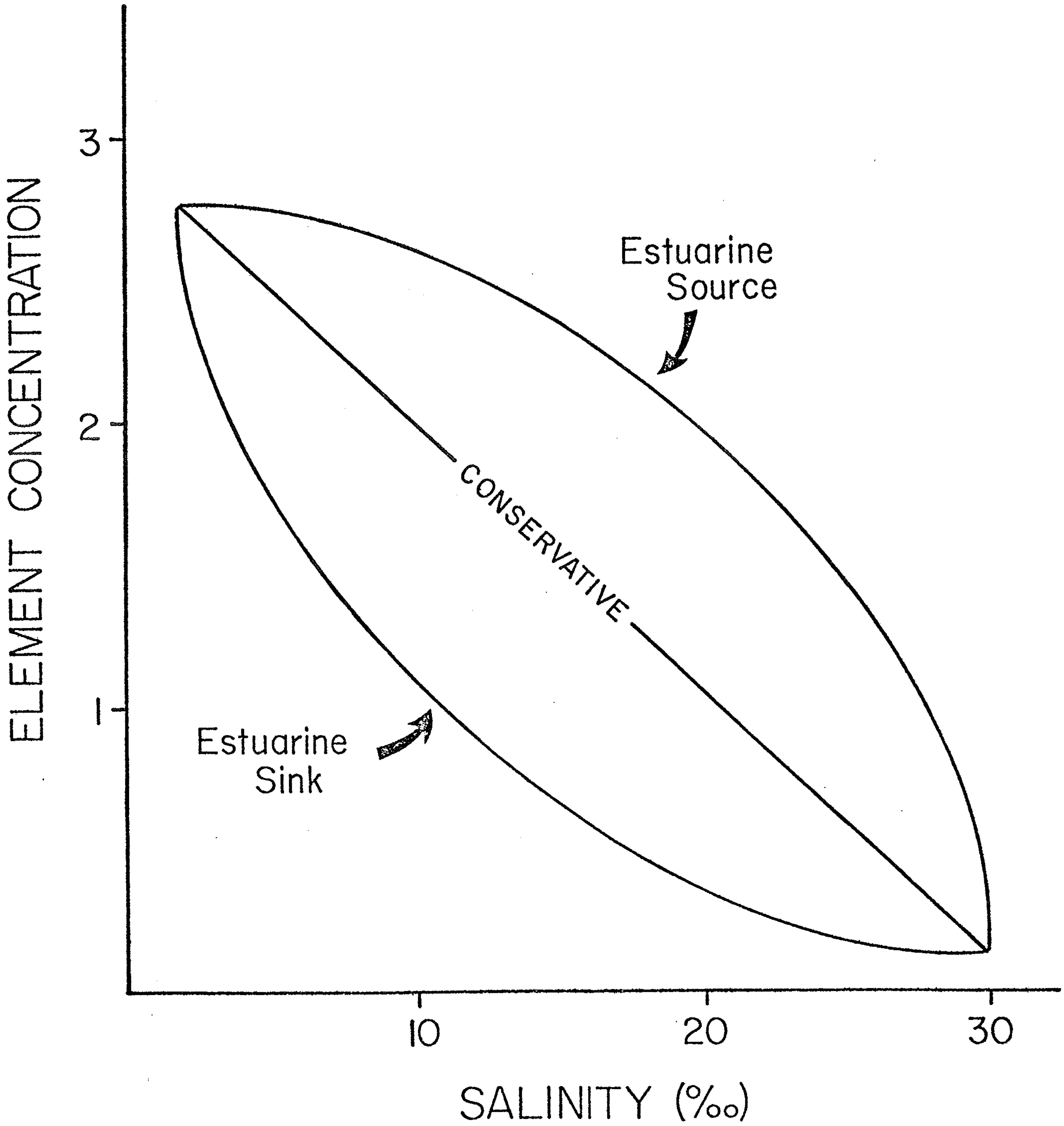


Figure 8. A property-salinity plot showing deviations from linearity as estuarine sources and sinks.

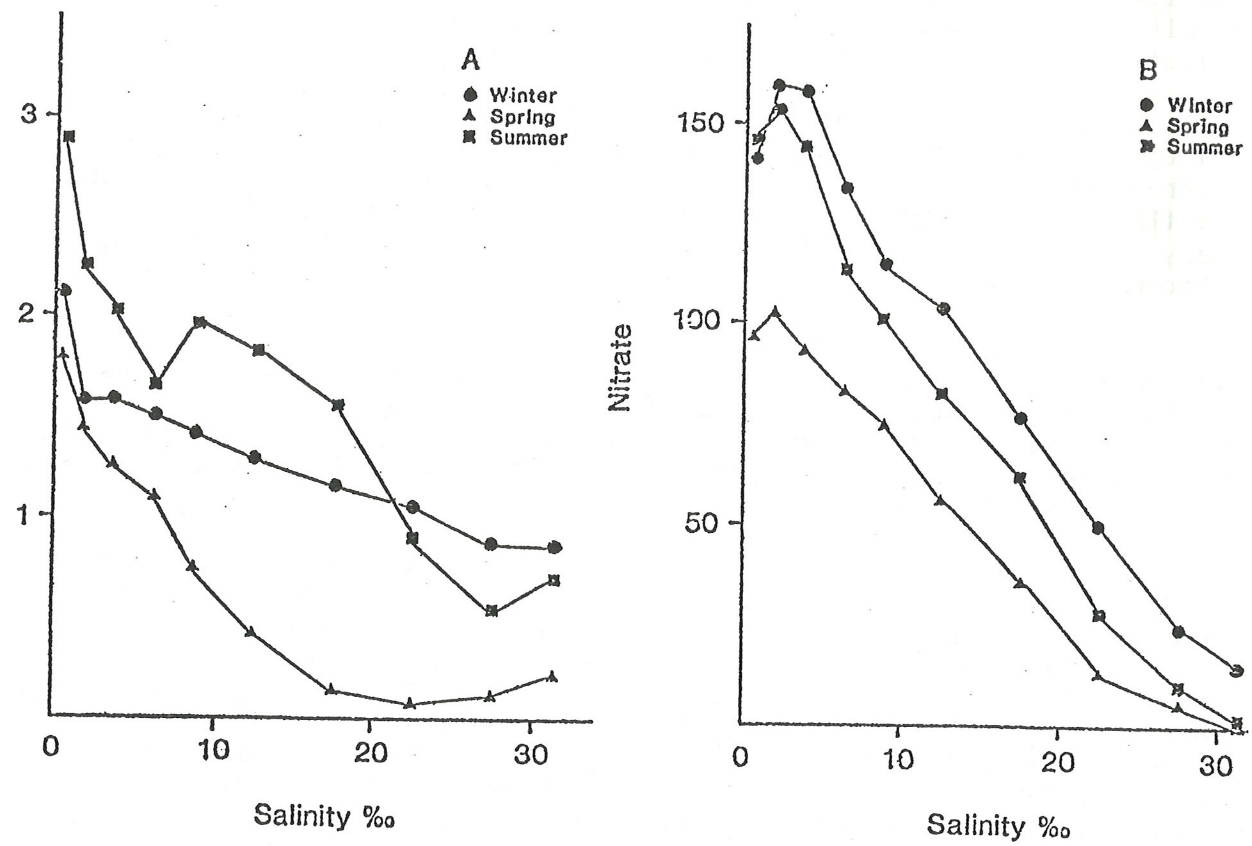


Figure 9. Phosphate and nitrate versus salinity in the Delaware Estuary. Averaged values from 1978-1983. From DRBA Report.

It's interesting that during most of the year nitrate seems to behave relatively conservatively with salinity. This is significant in that it indicates there is no major nitrogen loss going down the salinity gradient. The major way a loss would take place is through utilization.

If in the upper estuary, where the nitrogen is so high, massive algal blooms were to occur, we'd expect a rather rapid dropoff. We do not see this. This very, very high nitrogen content is not stimulating massive algal blooms in the upper estuary.

Phosphorus is also elevated, and phosphorus shows a relatively constant composition through much of the estuarine gradient, 0-15 ppt. This is a fairly well-documented thing called the "phosphorus buffer", seen in many estuaries of the world where phosphate will precipitate out, come back into solution, and maintain a fairly constant composition.

If one were to put a straight line on this figure, there is an upward curvature indicating phosphorus input from sources within the estuary, suspended sediments and bottom sediments. In the spring there is a fairly large phosphorus fallout due to very high flow and high biological activity with the spring bloom.

Figure 10 shows similar seasonal pictures for ammonium-nitrogen and silicate. In the winter, ammonium is very high. In the summer it is much lower. A very high nitrification conversion of ammonium to nitrate takes place in the summer. Hence, comparatively little ammonium exists in the estuary in the summer.

Silicate also shows a large seasonal variation which is due partially to biological uptake, but also to geochemical activity. Both of these nutrients as well as phosphate, show major increases in the summer in the lower estuary due to remineralization. It turns out somewhat odd, really, that even though there is very high nutrient input in the Delaware from sewage, the primary productivity of the lower estuary seems to be supported and driven by remineralization in the lower estuary, not transport from the upper estuary.

A question that I've had in some of my research is "What is the fate of this tremedously high nutrient input into the Delaware?" It would appear possible that much of this is being swept out and enhancing the productivity of the coastal ocean. It is not causing local algal blooms where it's coming in. It is in fact being dispersed.

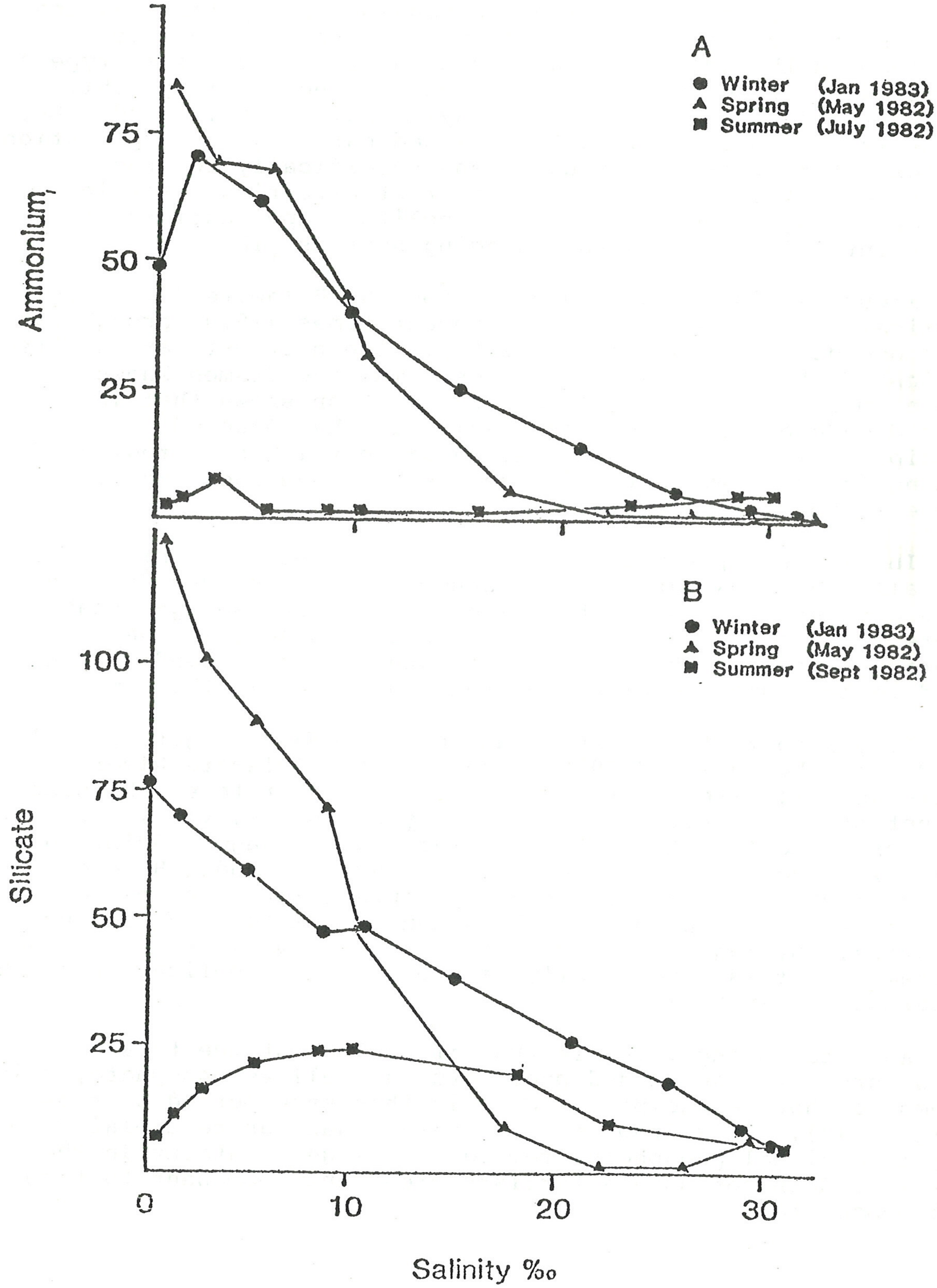


Figure 10. Ammonium and silicate versus salinity in the Delaware Estuary. Typical plots. From DRBA Report.

This has tremendous significance because one of the concerns in the Chesapeake Bay today is that the increased nutrient input through land runoff and sewage is causing eutrophication, and there's talk about cutting back nutrient inputs. We see no evidence in the Delaware today to suggest that the same type of strategy would be one that should be used here. I say this somewhat cautiously. We're not saying pollution is good. But I think we must evaluate, as I mentioned earlier, the application of the information individually and specifically for the different estuarine systems. Different estuaries react in different ways. We cannot make monolithic applications of fundamental information for managing systems like this.

Figure 11 is based upon data from the Delaware River Basin Commission. It compares fairly recent times (1979 through 1981) to a decade ago (1967 through 1969). The nutrients are plotted against distance in nautical miles. The two frames shows ammonium and nitrate nitrogen. Examination shows that in the last decade or so, the ammonium-nitrogen has dropped precipitously. There's less ammonium in this upper region coming in from sewage than there was a decade ago. However, there's much more nitrate.

In Figure 12, these are added as together total nitrogen. Overall, there is very little change in the last decade. What this indicates is that with the more efficient sewage treatment there's a greater oxidation of the nitrogen so that the thermodynamically stable form, nitrate, is more abundant than it used to be. But the amount of total nitrogen is the same.

If you go to the Almanac and look at census figures, you'll find that the 1970 and 1980 census for the Delaware River drainage basin are pretty much the same. Therefore, the same amount of sewage nitrogen is probably coming in, yet it's in a more oxidized form today than it was a decade ago. Being in a more oxidized state, it causes less oxygen demand. However, there is the potential secondary pollutant impact of being fertilizer for algal blooms which don't seem to occur in the Delaware. My major point with this is that we must understand a system like this specifically before any wise application of the information can be made.

An interesting thing is that if we look at the total phosphorus, the suspended phosphorus as well as phosphate, this seems to show a precipitous drop in that same period of time (Figure 12). This drop is far greater than can be explained by any intentional phosphorus removal. Sewage treatment in the Delaware does not have a tertiary treatment component to take out phosphate.

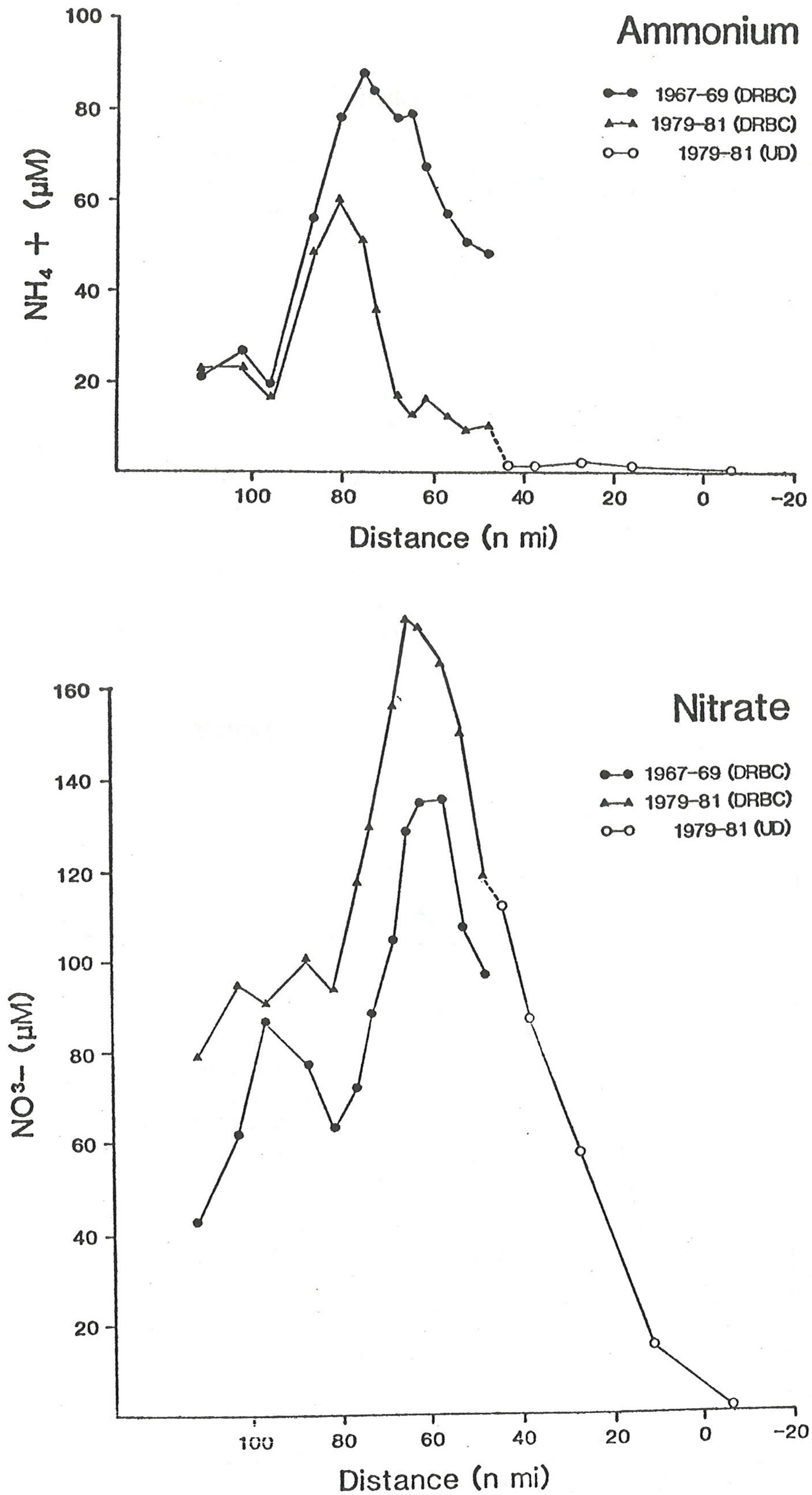


Figure 11. Ammonium and nitrate versus salinity for the Delaware Estuary in summer. From Sharp, unpublished data.

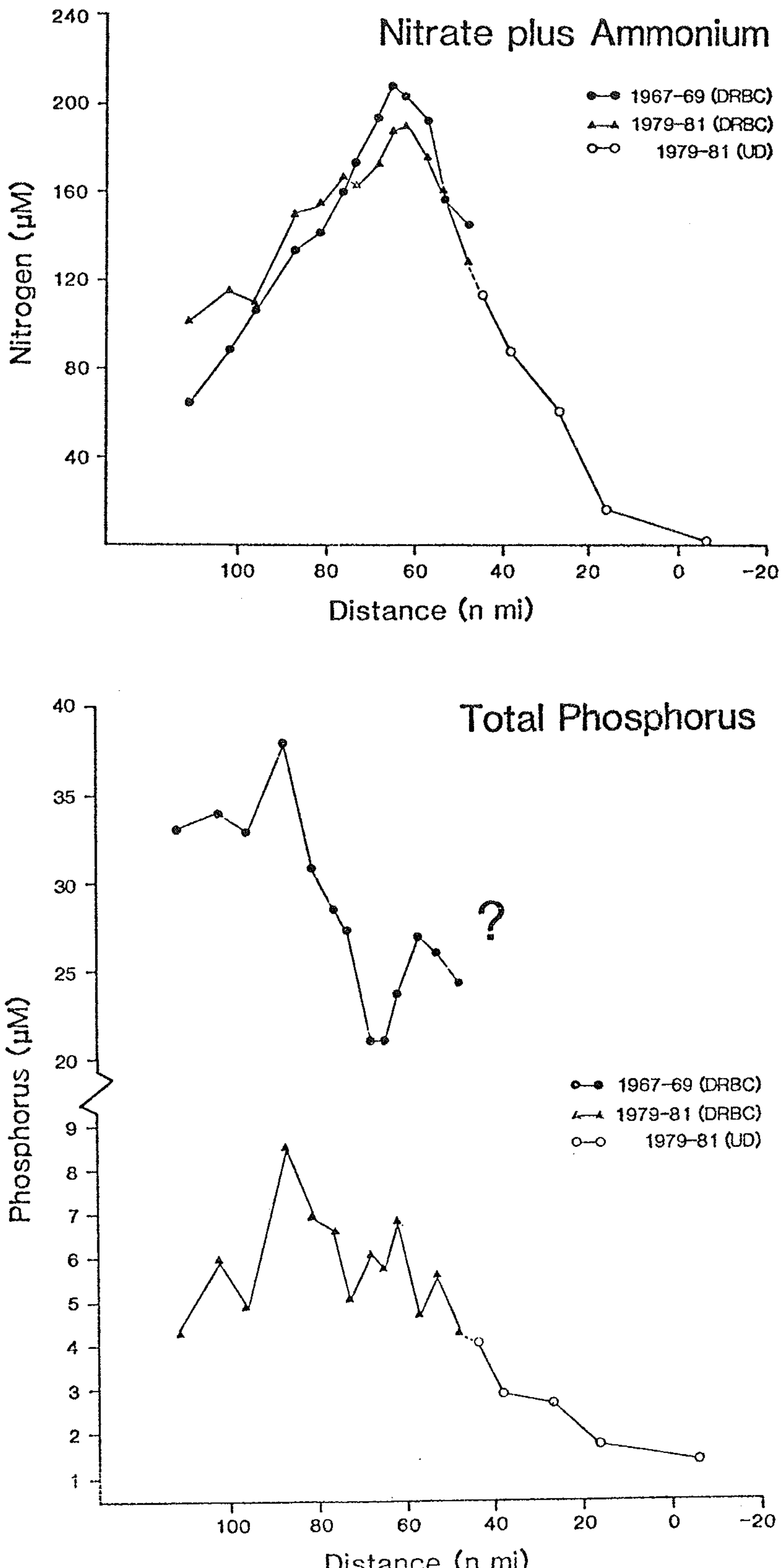


Figure 12. Nitrate plus ammonium and total phosphorus versus salinity for the Delaware Estuary. From Sharp, unpublished data.

The phosphate drop may be inadvertently due to greater efficiency of sewage treatment causing some precipitation or due to decreased phosphorus in detergents, the national attempt to cut down detergent phosphorus. Or it might be due to changes in dredging practices which may have altered the resuspension of material. Probably it is due to a combination of these factors. However, it's a somewhat surprising result and one again I would like to find better confirmation for.

One of the other concerns with estuaries is trace metal pollution. Figure 13 is from some work by Bob Biggs and one of his former students. It covers an area in the Delaware where the river opens out into the Bay and uses a method of factor analysis to illustrate enrichment of metals in the bottom sediments.

In frame A, riverine types of metals, iron, lithium, potassium and aluminum are shown enriched at the edges of the marsh and the upper portion of the estuary. In frame B, marine-origin metals, magnesium, strontium, calcium, and sodium are shown enriched in the lower part of the estuary toward the mouth. This indicates the marine influence of these metals in the sediments. Frame C shows metals of more pollutant interest, such as chromium, copper, lead and mercury. They have higher concentrations upriver from industrial and municipal sources and, curiously, in the outflow region of the Cohansey River. This is indicative of anthropogenic influx.

There certainly is evidence in the Delaware of enhancement of metals due to anthropogenic activity. Bob Biggs and Tom Church, from the University of Delaware, are now trying to look into historical records to see changes in sediment-metal concentrations to better understand the historical picture.

Many of the metals dissolved in the water behave rather conservatively. Figure 14 consists of nickel and copper plotted against salinity for the Delaware. This is from an individual transect going down the Bay. It shows relatively conservative behavior with little reactivity. Other metals show pronounced non-conservative behavior. Iron and manganese, as two extremes, show a rapid dropoff in the upper portion of the estuary and then fairly constant levels going downstream. This has caused my colleague Tom Church to try to group the metals into two groups.

Metals such as manganese and iron show the majority of the metal loading (majority of the total metal) is in the particulate phase (Figure 15). This is a plot of total and dissolved metals against salinity averaged for a large number of different samplings. The dissolved iron is very slight. Almost all the iron is in particulate phase. The manganese is similar; almost all of this metal is in the particulate phase.

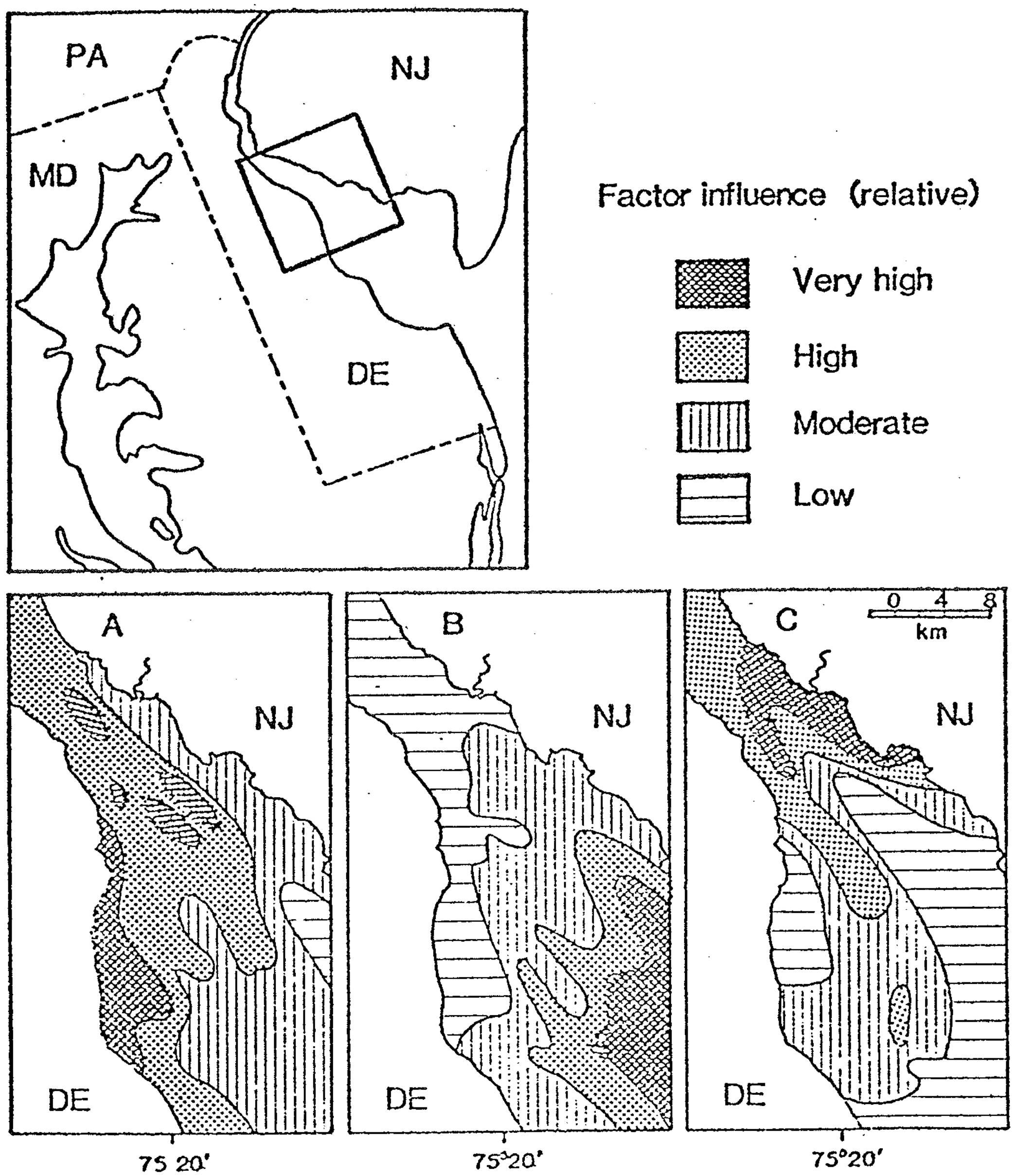


Figure 13. Distribution of trace metals in Delaware Bay sediments attributed to factors of (a) riverine sources (iron, magnesium, lithium, potassium, and aluminum), (b) marine sources (magnesium, strontium, calcium, and sodium), and (c) pollution sources (chromium, copper, lead, and mercury) sources. From DRBA Report.

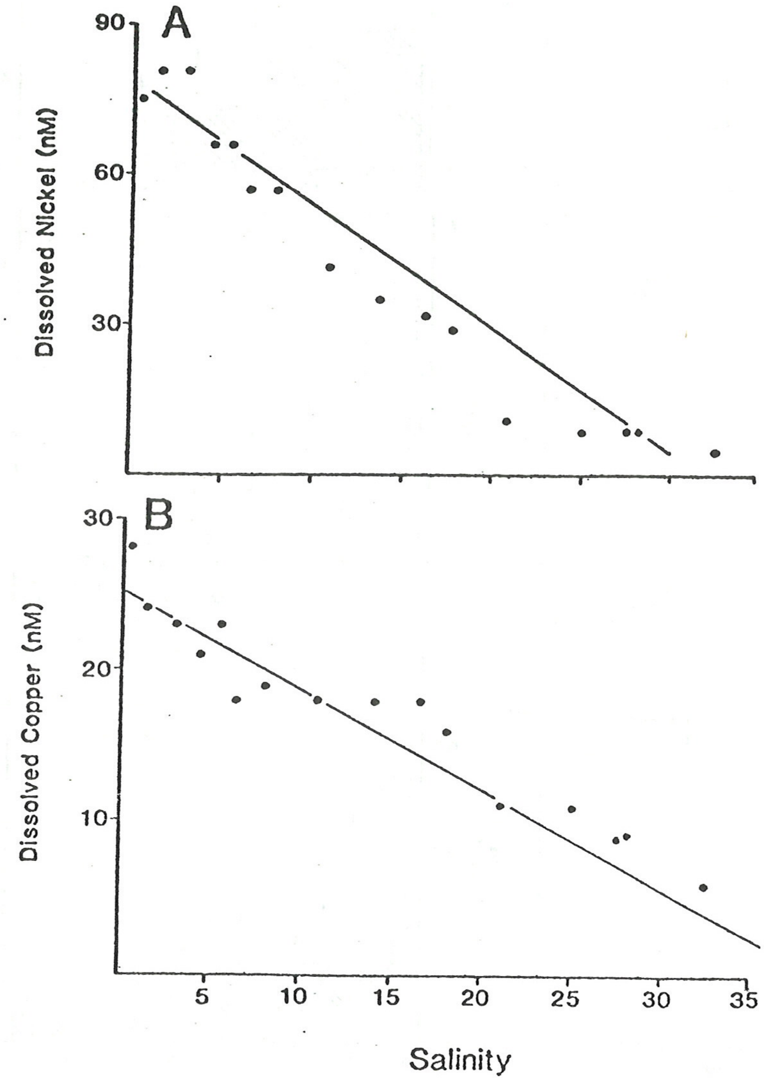


Figure 14. Conservative metals plots from the Delaware Estuary (A) Dissolved nickel concentration and (B) dissolved copper concentration versus salinity for the Delaware Estuary in May 1981. From Sharp et. al., 1984.

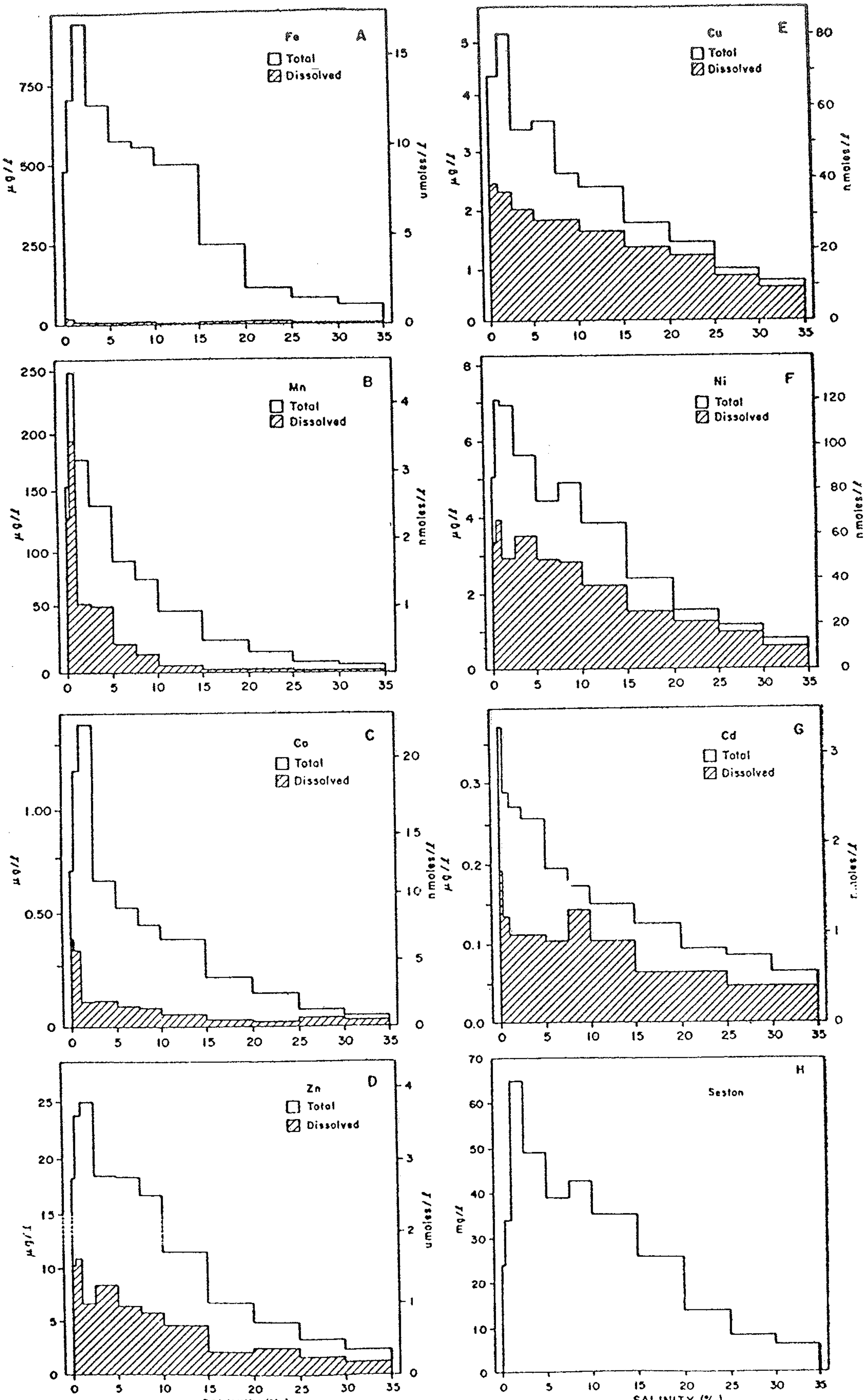


Figure 15. Dissolved and particulate metals versus salinity from the Delaware Estuary. From Church et al., 1984.

This is contrasted to what we consider to be the more conservative metals, those that don't show geochemical behavior to that extent. For example, copper and nickel show a very significant portion as dissolved. In the lower estuary the vast majority of the metal is in the dissolved phase rather than the particulate phase. This leads to a type of picture (Figure 16) showing Ø to 35 ppt salinity versus percent of the metal in the particulate and in the dissolved phases. Again, we have the extremes, such as iron and manganese, where almost all the metal in the water is suspended sediments, contrasted to nickel and copper where almost all of it is in the dissolved phase.

This once more leads to caution on monolithic types of approaches. If one is concerned with metal pollution, one must understand the behavior of metals. Metals don't all behave the same way. One must understand some of the individual behaviors to get at the types of problems we want to look at.

Next, let's turn to organic material. Figure 17 is a plot of the total dissolved organic carbon and two fractions versus salinity (again, averaged from multiple seasons). One observation from this plot is that the organic matter is not that high compared to many estuaries. Many natural (peaty) estuaries have dissolved organic carbon contents considerably higher than this very municipal estuary. The other point is that, in general, the behavior is relatively conservative. The total organic carbon pool shows a relatively conservative behavior against salinity. If this organic carbon were a trememdous slug that caused oxygen demand, we'd expect a more rapid dropoff than we see.

So the organic content of the waters in the upper region are themselves not a major oxygen sink in terms of food for bacteria and causing a decrease in the oxygen. In fact, somewhat curiously, we find that the bacterial populations and activities are highest in the lower part of the estuary, not up in the municipal region. This was quite surprising to us.

If we look at components of this, the humic acid (a typical land origin runoff material) drops very precipitously. This is due to geochemical behavior. Other organic components, such as amino acids, are highest in the lower estuary and are being put in through primary producers (the phytoplankton). This is apparently why the bacterial populations are higher in the lower estuary.

In spite of the fact that this is a "polluted, very industrialized, municipal" estuary, much of the oceanography does not show this. Much of the typical biogeochemical processes show a much more natural type of situation.

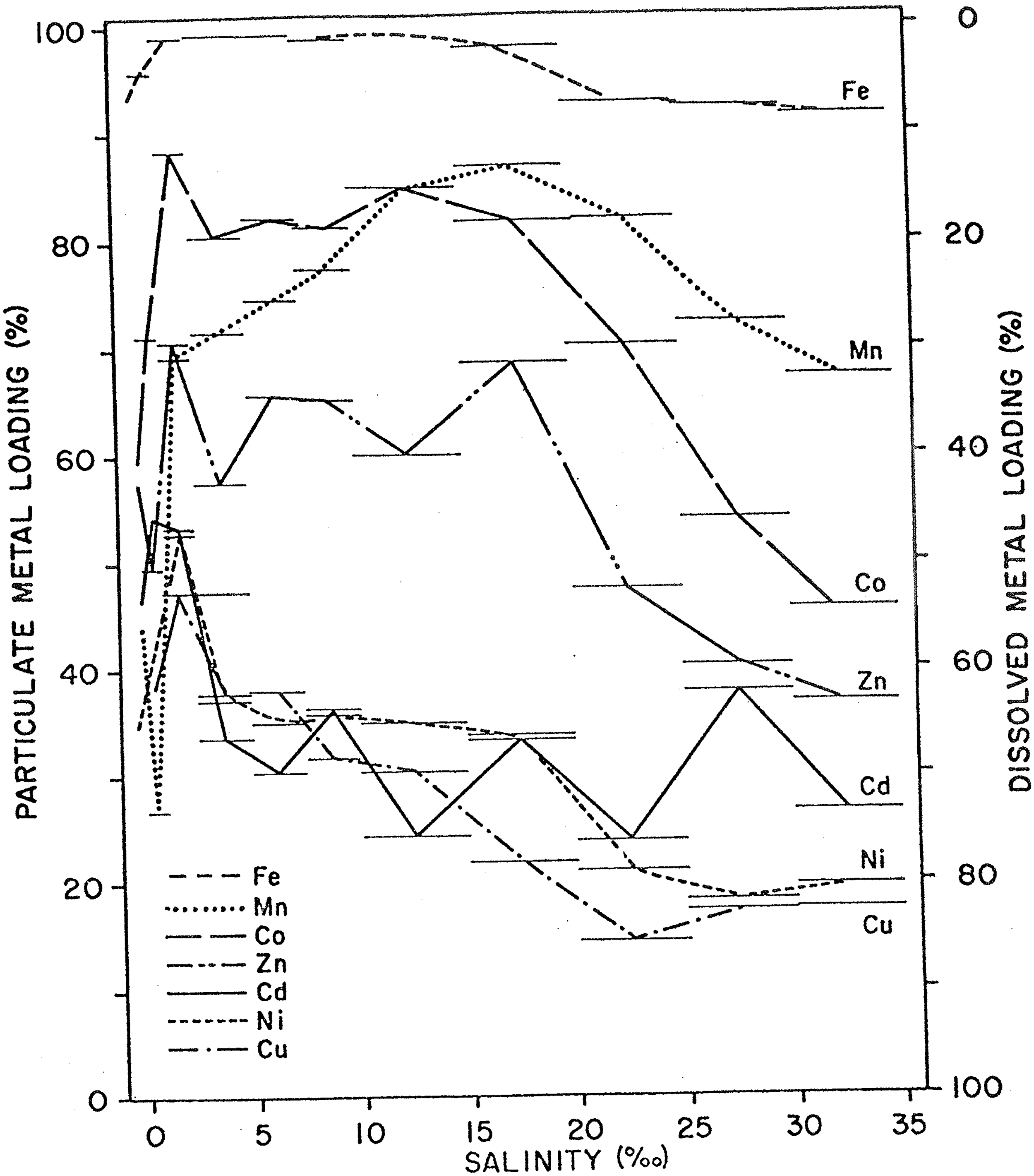


Figure 16. Composite metals partitioning plot. From Church et al., 1984.

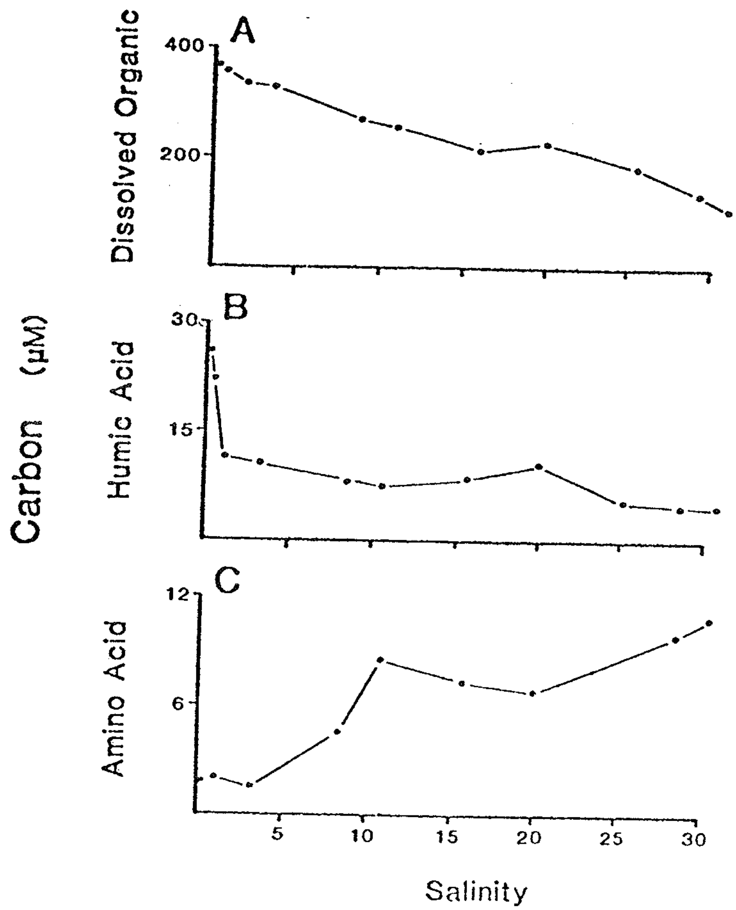


Figure 17. Total dissolved organic carbon, humic acids and amino acids versus salinity (micromolar carbon) from the Delaware Estuary in March 1982. From Sharp et. al., 1984

We do not know much about specific organic compounds and have not looked much at particular organics. There was some work in the past that showed fairly high concentrations of petroleum hydrocarbons in the sediments near the refineries in the upper estuary. Some sampling done on the sediments under the anchorage area (where lightering of oil goes on) does not show much increase over adjacent areas. There doesn't appear to be a major increase in petroleum hydrocarbons in the lower Bay from the lightering activity.

Looking at some specific chlorinated organics, such as PCBs, a few measures that have been made in the Delaware do show high values. I think it's definitely necessary for us to look further at chlorinated organics, especially organics that can be produced by chlorination of the water. There is major chlorination of waters of the Delaware through sewage treatment and through chlorination to prevent fouling in cooling use. We know very little about what this does, and it's a major red flag that we must investigate further.

Another valuable tool that gives us some interesting information is property-property plots, plotting one property against another. Figure 18 is dissolved iron versus salinity showing a rapid dropoff and phosphate also showing a fairly rapid dropoff in the upper portion of the salinity regime. This must be handled carefully by season. In late winter, with a relatively high flow and low biological activity, we can see a picture like this which indicates these are both showing some fallout by floculation and precipitation.

If we plot the phosphate against the iron, we find a fairly good linear relationship. This allows us to use some sort of standard geochemical considerations and stoichiometry. Stoichiometry is a fancy chemical term for balancing equations.

A stoichiometric comparision shows that if iron and phosphorus are in equal molar concentrations, such as occurs in the mineral strengite, there would be a one-to-one relationship between the two. In Fe_2PO_4 (the mineral vivianite) there would be a 1:1.5 relationship. The plot of iron versus phosphorus shows a ratio of 1:5 for the iron to phosphorus. This does not indicate formation of a standard, well-known mineral. Instead semi-independent processes may be taking place together.

While this may not on the surface appear to be much, it may provide a great deal of information for understanding global ocean chemistry. If we can use the very high chemical signals we get in an estuary to look at the chemicals' behavior, we can understand something about their behavior on a global scale. So it's a valuable tool.

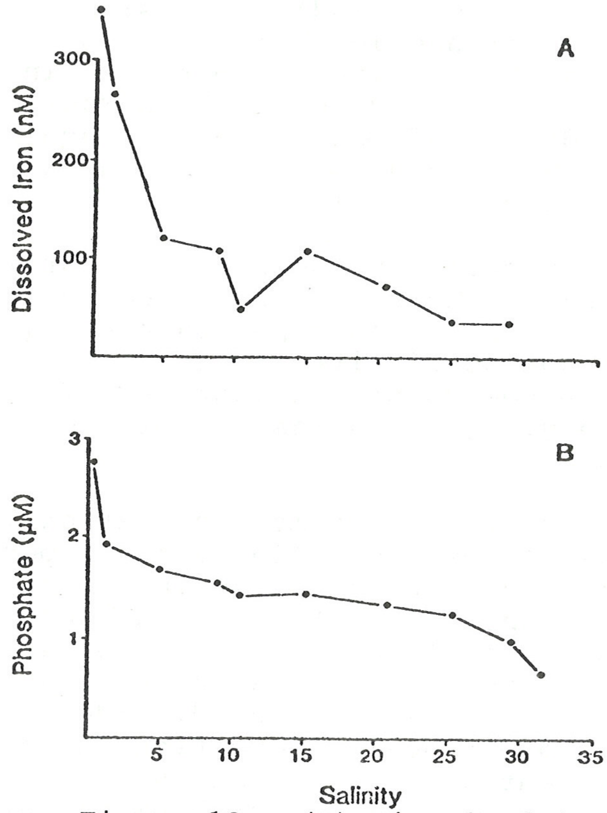
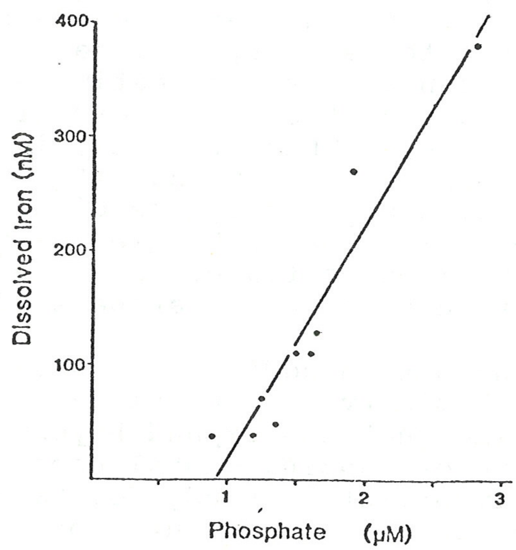


Figure 18. (A) Dissolved iron concentration and (B) phosphate concentration versus salinity in the Delaware Estuary in January 1982.



Dissolved iron concentration versus phosphate concentration in the Delaware Estuary in January 1982. The mole to mole slope of the line is 0.21 (R^2 = 0.91). From Sharp et. al., 1984

Figure 19 is of phosphorus versus cadmium in the late spring (at the end of the algal bloom period). The slope of the curve is about 4×10^{-4} This is strange in that it seems to be the same thing that one finds in particulate material in the open ocean and coastal waters. There seems to be a magic relationship between cadmium and phosphate in biochemical use. This type of approach can be used to help us understand the biological response and use of metal.

A tool we're just beginning to use now is natural carbon and nitrogen isotope chemistry. We can look at the enrichment of the non-radioactive heavy carbon isotope (carbon-13) and the non-radioactive heavy isotope of nitrogen (nitrogen-15) in relationship to the more common stable isotopes of carbon-12 and nitrogen-14, respectively. Such ratios can become very interesting tracer tools.

Figure 20 is a plot of the enrichment of carbon-13 versus salinity and of nitrogen-15 versus salinity for a period in April 1984. These curves give us a lot of information about mixing between river and estuary, between marsh and estuary, and between estuary and the coastal ocean waters. We are currently expanding our use of isotopes. This has an applicability in the present-day concern over increased carbon dioxide in the atmosphere. There is a great deal of question whether or not the ocean is a major potential sink to take up the increased CO_2. This is a dissimilar but related problem to the question of what is the net exchange between the land and the sea of organic material. It is the type of question that we can begin to get at with isotope tracers.

An age-old question has been that of the exchange between the marsh and the estuary. We have gone along for decades saying that marshes are valuable nursery grounds because they feed organic material into the estuary. It has never been well documented. There have been some recent estimates using carbon-13, which suggested that there was very little exchange between marshes and estuaries. These results, in Georgia, led to a response by developers saying, "Good, let's pave over all the marshes in the country because they are of no value." We do not know today what the real exchange between marshes and estuaries is. Hopefully, isotope tracers are the type of tool that will help us get at this in an estuarine study.

I have tried to point out in addition to some of the general characteristics of the chemistry of the Delaware estuary some of the tools that we're using that can expand beyond just estuarine chemistry to assist in understanding global ocean chemistry. So estuaries are not only important to study for background in managing them, but they are also important laboratories to help us understand the chemistry of the earth.

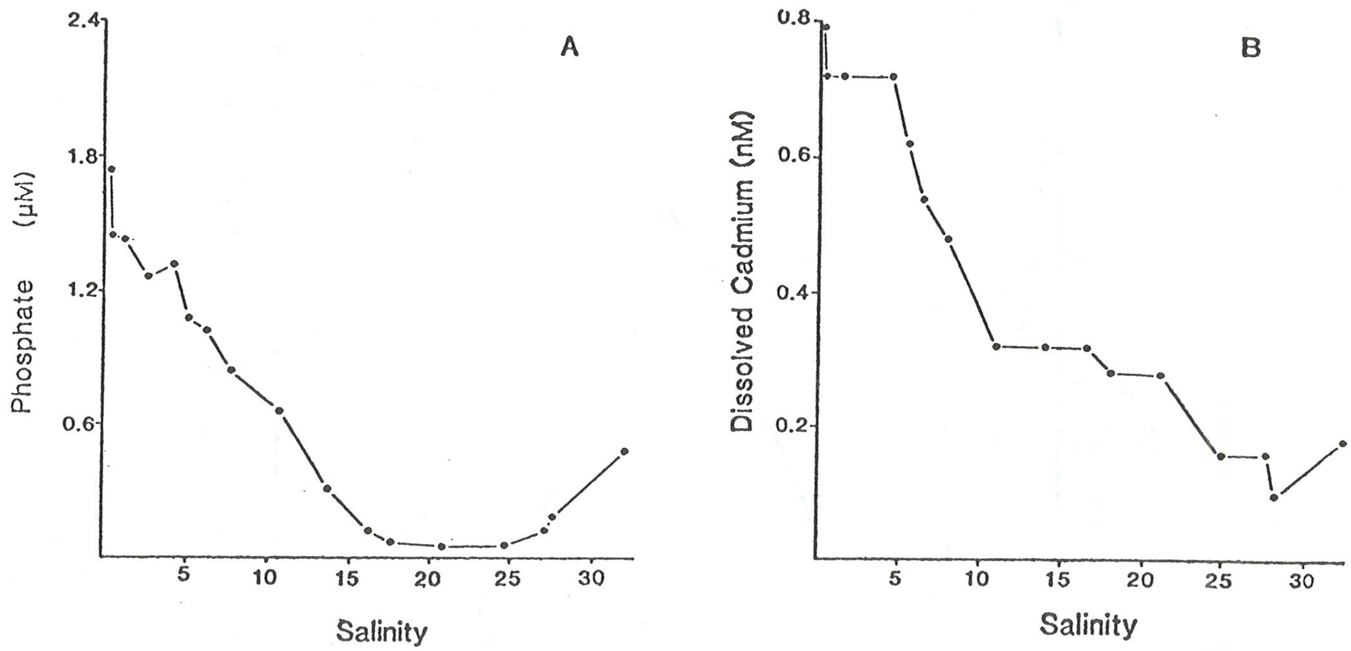
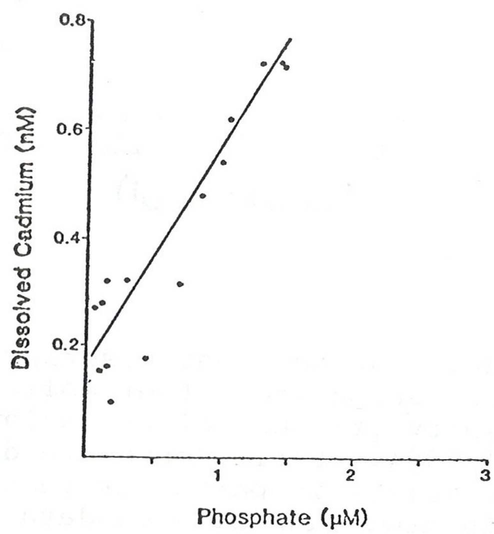


Figure 19. (A) Dissolved phosphate concentration and (B) dissolved cadmium concentration versus salinity in the Delaware Estuary in May 1981.



Dissolved cadmium concentration versus phosphate concentration in the Delaware Estuary in May 1981. The mole to mole slope of the line is 3.9×10^{-4} ($R^2 = 0.88$). From Sharp et. al., 1984

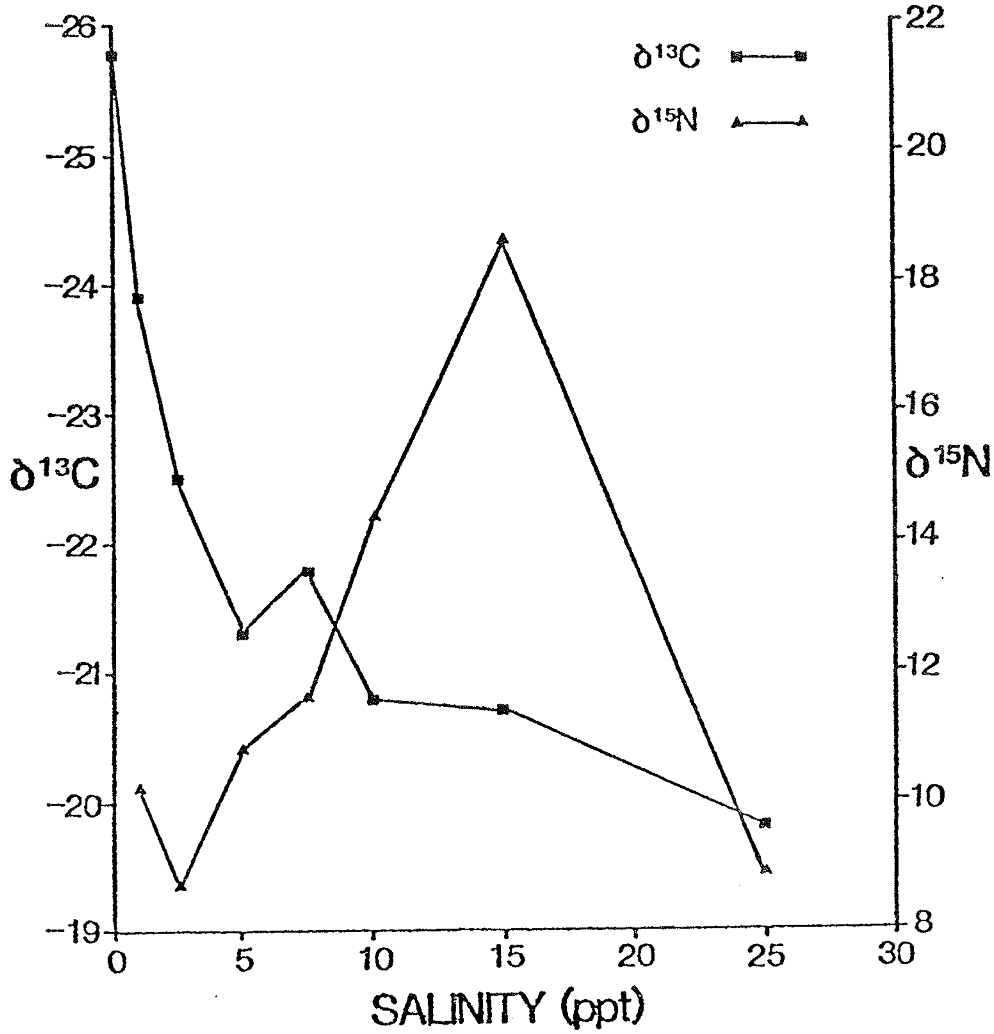


Figure 20. Natural heavy isotope enrichment values for suspended matter collected along the salinity gradient of the Delaware Estuary in April 1984. Enrichments are deviations from standard values in parts per thousand. From L.A. Cifuentes, unpublished data.

QUESTION: Did you look at aluminum concentrations at all?

DR. SHARP: We have done some aluminum. This element is a natural input chemical from erosion of rocks. Aluminum is one of the major constituents of the earth, so aluminum in an estuary is primarily an indication of erosional input. It does not show much anthropogenic signal.

Aluminum is very important in fresh waters because of its mobilization due to acidification. It is not a pollutant input of metal but is a pollutant release of the metal from the natural pool. There's a tremendous amount of aluminum there.

QUESTION: Do you have any data on cadmium and mercury in the Delaware?

DR. SHARP: The data on cadmium shows some elevation. It does not show very high values and thus is not an indication of tremendous pollution. The mercury work has not been extensive, but what has been done, again, is somewhat surprising. Even in municipal regions, the levels of mercury in the sediments are not as high as one might expect from a grossly polluted situation. So far the metals do show, certainly, enhancement and anthropogenic inputs. However, they do not show values as high as some other municipal estuaries.

QUESTION: Can you provide any insights on why there might be no microbial activity in lower salinities?

DR. SHARP: It seemed to be linked directly with primary productivity and not to the sewage effluent input. Why that is, is another question, one that is more complex. Right now our main linkage to the bacterial activity is to primary productivity, not to municipal input.

QUESTION: Do you ever get seasonally low enough ammonium values toward the mouth of the Bay where there are phytoplankton blooms so that there is measurable nitrate uptake?

DR. SHARP: The late spring-early summer period is the only time that there was significant nitrate uptake. The average annual nitrogen source for the phytoplankton has been estimated as 82% from ammonium. Only in this late spring period where there is exhaustion of ammonium do we see significant nitrate uptake. That's late April through May.

QUESTION: In assessing phosphate against salinity, can you account for the minimum that you've shown at about 27 ppt?

DR. SHARP: I think the best explanation of it is that our station at the mouth of the Bay is probably not representative and is not really an oceanic end member. I've seen several recent satellite photographs that are quite exciting which have indications of upwelling right at the mouth of the Bay due to the coastal circulation.

So we may be seeing an indication there of a poor choice of an end member station that shows enhancement from bottom shelf waters.

QUESTION: A major concern in Chesapeake Bay is the development of anoxia in deep portions of the Bay. I noticed in your presentation that you showed no vertical distribution of oxygen.

DR. SHARP: The majority of the year, as George Mellor's picture showed, the Delaware Bay is fairly homogeneous from top to bottom. This is true from about June through February. When we have measured chemical parameters in deep samples, we have found little difference between top and bottom. With the high spring runoff there is strong stratification through March, April and into early May. By June, this breaks up and the waters become well mixed. The oxygen demand in the somewhat stagnant bottom waters of the Chesapeake have no counterpart in the Delaware.

The summer homogeneity is a somewhat unique hydrographic feature of the Delaware. As compared to the Chesapeake, it is a different feature which demands different interpretation, understanding and application for management. These two systems do not behave in similar manners in terms of the gross physics in that stratified, isolated bottom waters of the Chesapeake just don't occur in the Delaware.

QUESTION: Are you saying that generally they're not mixed or that they are literally mixed down to the very bottom?

DR. SHARP: As far as we can see, to the bottom. We have limitations--the point is that as far as we can easily measure and sample, the waters are well mixed through most of the year. When we get into the microlayer right at the bottom there are very different characteristics. This is something that requires a very different sampling strategy. But these waters are not isolated. They are subject to strong tidal motions and do mix back up into the upper waters.

In the Chesapeake Bay the strong stratification persists throughout the summer, and there's a tremendous density barrier for mixing that isolates a portion of the water column that is over half of the depth profile of the Chesapeake. In the Delaware this does not occur. We can find absolutely uniform dissolved oxygen, salinity, and nutrient concentrations from the surface down to within one to two meters above the bottom.

QUESTION: In the stratified period in the Delaware Bay, how persistent is this vertical structure? Does it break down with change of tides?

DR. SHARP: I think stratification increases and lessens with the tides, but the phenomenon persists. Yet we do not see much change in the chemistry above and below. Probably in the spring it is too cold for higher bacterial activity. Hopefully, this season we'll be getting a much better picture of that because we're trying to follow it very frequently through the spring bloom period.

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GENERAL BIOLOGY

Sidney S. Herman and Bruce R. Hargreaves
Lehigh University

I want to thank Bob Biggs and George Mellor for giving part of my talk for me when they mentioned phytoplankton, turbidity, and blue crab larvae. That's alright, it saved some time.

One of the questions which you hear asked many times is whether or not the Delaware is impoverished biologically. You respond by saying, "Impoverished compared to what?" I assume that people are talking about other estuaries. I don't think I'll answer that question; I think you can draw your own conclusions based on the information which follows.

For this presentation I'm only going to handle certain selected biological segments. Figure 1 shows the food web of Delaware Bay, which is very typical of what you might find in an estuary or a bay. The arrows show the direction in which the energy flows. What I want to show is that the food web itself is extremely complex. If we are ever really going to understand what's going on, if we really want to attain the greatest economic yield and still manage the estuary properly, then we truly have to understand what is going on at the various levels in the food chain. It is not an easy thing to do.

As I say, I'm only going to cover certain aspects. I'll talk about phytoplankton; much of this information comes from the work of Jon Pennock and others at the University of Delaware. I'm also going to talk about zooplankton; this segment is a result of studies conducted by Lehigh University staff. The information is preliminary in nature. I shall also say a few words about these strange critters, the mysids. Many of you who know me have heard me speak of the significance of this group before. I will add some information on blue crab larvae, based on data provided by Steve Sulkin and Chuck Epifanio. Finally, I will say a few words about the benthos in Delaware Bay.

The first group I want to deal with is the phytoplankton. They form the base of the food chain and there are several ways of examining them. First of all, you may examine the biomass as chlorophyll (standing crop), shown in Figure 2. As most of you know, this tells you nothing about the rate of change in the population. Nonetheless, it is a valuable tool which has its uses. Pennock and his co-authors have been able here to divide phytoplankton cycles into three different seasons: a spring season from March through May or June; a transition of summer--July through September and the winter season. This slide is a plot of chlorophyll a in ug/L versus the distance up the estuary in nautical miles. Each of these is a

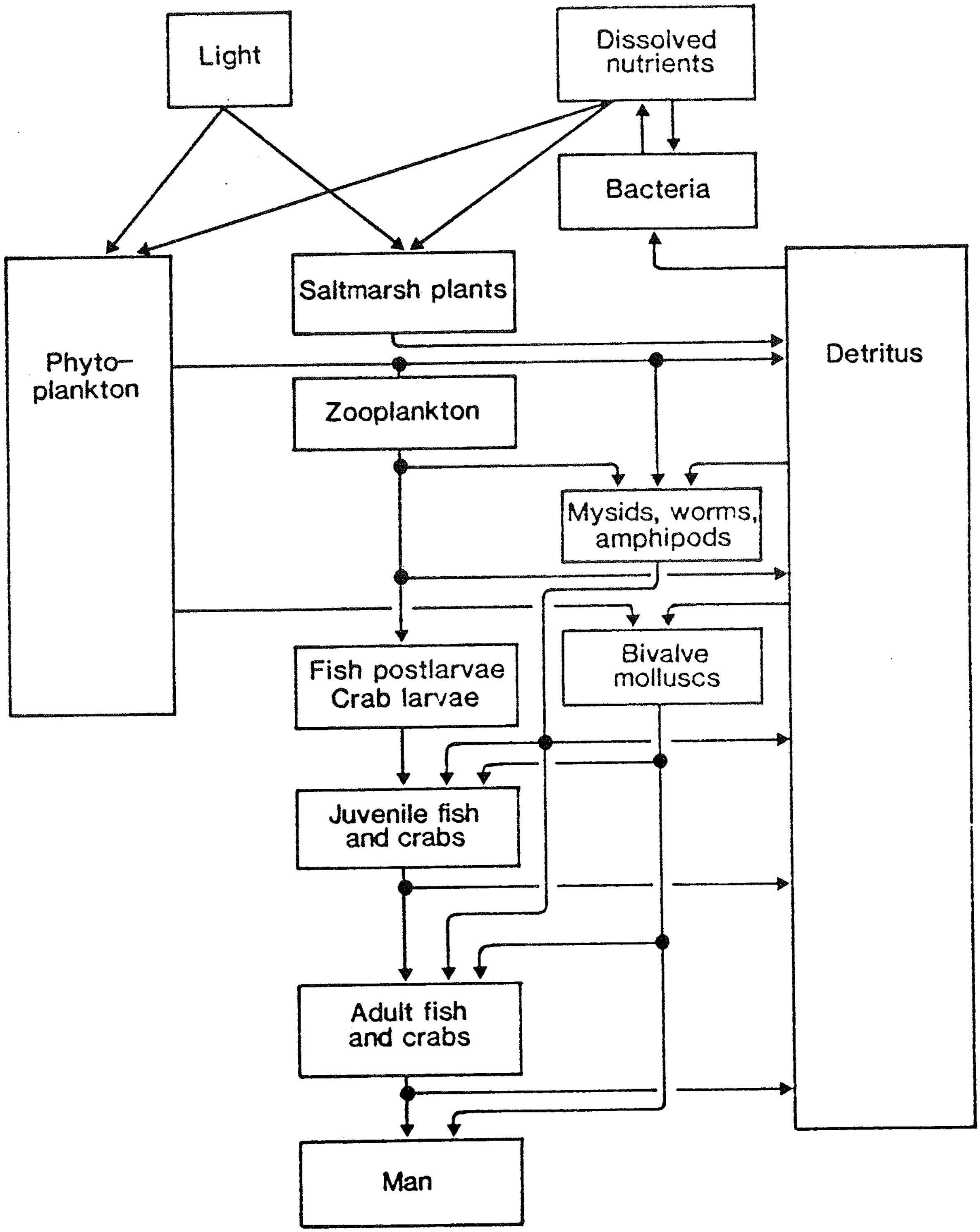

Figure 1. The Delaware Estuary food web. Arrows point from a component used by the component at the end of the arrow. (From Herman et al., Delaware Bay Report).

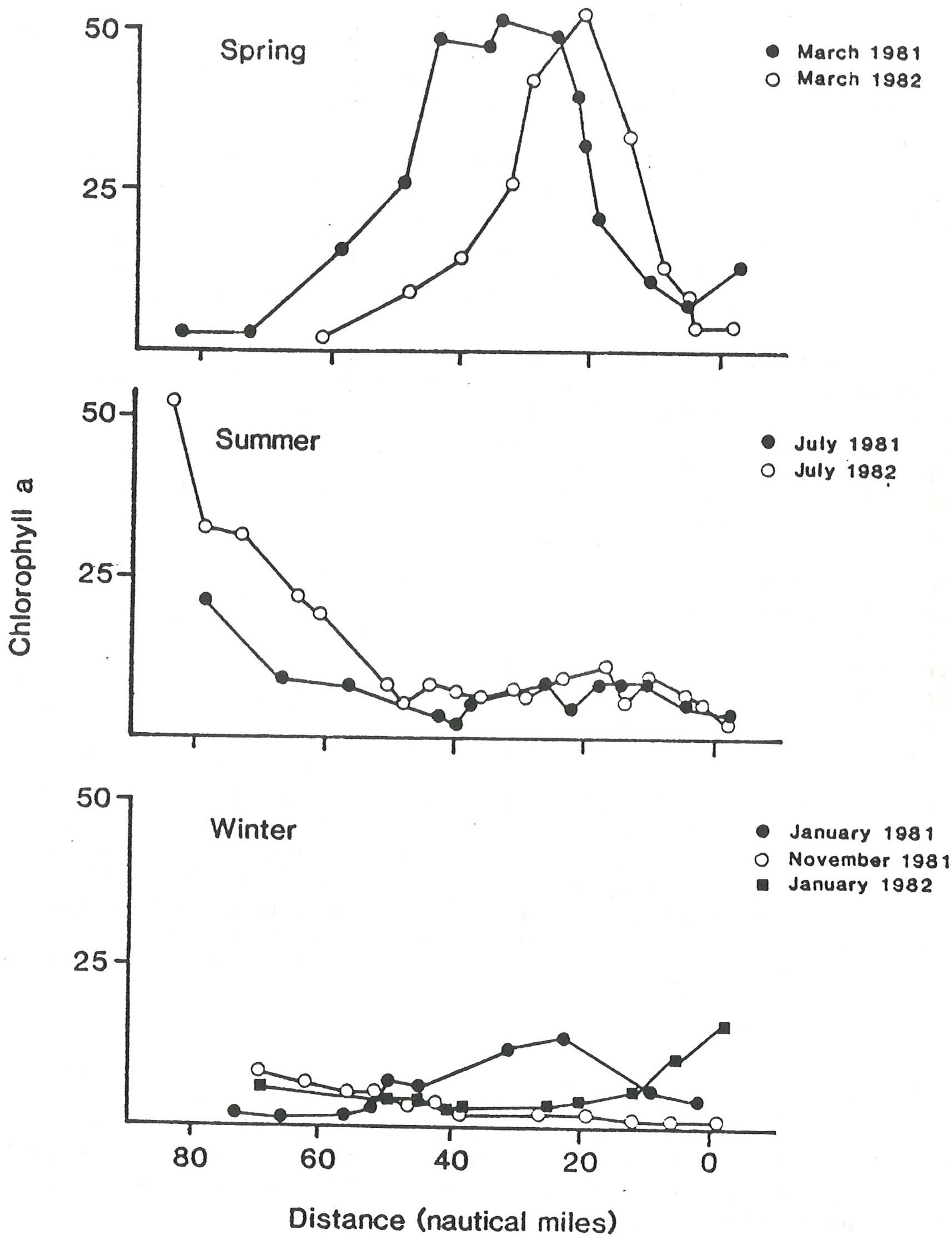

Figure 2. Chlorophyll concentrations (ug/L) vs. distance above mouth of the bay along main axis of the estuary. Data have been grouped into three seasons (From Pennock et al., Delaware Bay Report).

representation from a particular time of the year. For example, March represents the spring phytoplankton situation with regard to chlorophyll, with several different years indicated.

Basically, the data shows that the phytoplankton bloom in the springtime seems to be in the middle of the estuary. The bloom decreases quite rapidly with distance up or down estuary. In the main axis of the estuary, chlorophyll a values were quite high. While you cannot see this on the graph, even higher values occurred in some of the shallow, inshore waters.

In the summer, there is an increase in chlorophyll as we go up river and lower levels at the lower end of the estuary. Try to keep this information in mind later on, when I talk about productivity. Things are different down estuary--a peak occurs here in the summer which is not present when we talk about chlorophyll and biomass. The winter period seems to be a fairly stable situation with low levels.

One of the things we always attempt to do is to compare the Delaware to other estuaries based on chlorophyll. Table 1 is a fairly good representation. We have chlorophyll a in ug/L plotted as maximum, minimum and average for various estuaries throughout the country. While the values vary from the upper estuary to the lower estuary, the average is about 17, which is not greatly different from what we see in other estuaries.

The other way of looking at phytoplankton is to study the true productivity, i.e., rates. The panels in Figure 3 are productivity in $gC/m^2/day$ plotted against distance from the mouth of the Bay in nautical miles. We find the same three seasons which we described for chlorophyll, namely the spring season, the transition to summer and the winter season. Again, individual months represent the season. Clearly, what you see in March and again in May is the pulse which is occurring in the middle of the estuary.

As we move into the summer, there is some increase in productivity upstream (Figure 4). I mentioned when we were discussing chlorophyll that there was a marked increase in productivity downstream which did not show up with chlorophyll. This is indicated in both the July and September plots. In October, we begin to get a decrease.

I would like to say a few words about turbidity. Clearly, the maximum seston, the suspended materials, occur up river, typically around the Chesapeake and Delaware Canal. There is a definite part of the estuary where turbidity is occurring. There is a definite relationship between productivity and turbidity, and Figure 5 shows one way of depicting this relationship. It is possible to divide the estuary into eight sections or segments based on the salinity gradient, as shown.

Estuary	Chlorophyll a Min-Max	Chlorophyll a Average	Reference
Barataria Bay, LA	5 - 16	10	Day (1973)
Pamlico River, NC	10- 25	18	Kuenzler et al. (1979)
Chesapeake Bay			
upper estuary	2 - 25	14	Boynton et al. (1982)
middle estuary	1 - 13	7	
Patuxent River, MD			
upper estuary	2 - 43	23	Flemer et al. (1970)
middle estuary	5 - 33	16	
Raritan Bay, NJ	2 - 45	16	Patten (1961)
Hudson River, NY	1 - 5	3	Boynton et al. (1982)
Long Island Sound	4 - 8	6	Bowman (1977)
Narragansett Bay, RI	2 - 12	6	Furnas et al. (1976)
Delaware Bay			
upper estuary	1 - 50		
lower estuary	3 - 65	17	this study
shoals	3 - 95		

Table 1 - Concentration of chlorophyll a, in micrograms per liter, are given as minimum to maximum and average values for several United States estuaries. (From Pennock et al., Delaware Bay Report).

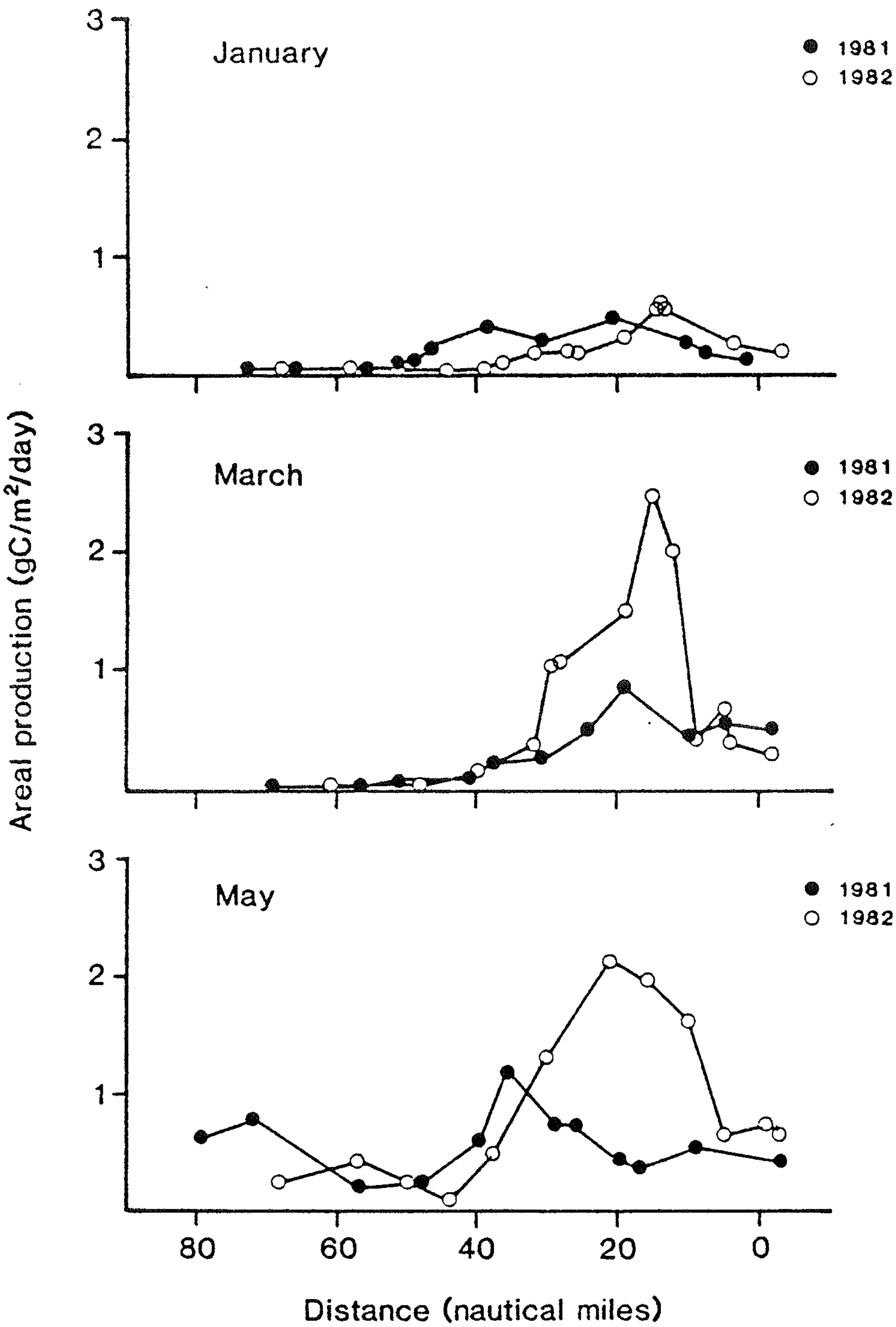

Figure 3. Phytoplankton areal production along the main axis of the estuary vs. distance from the bay mouth for January, March, and May. (From Pennock, et al., Delaware Bay Report).

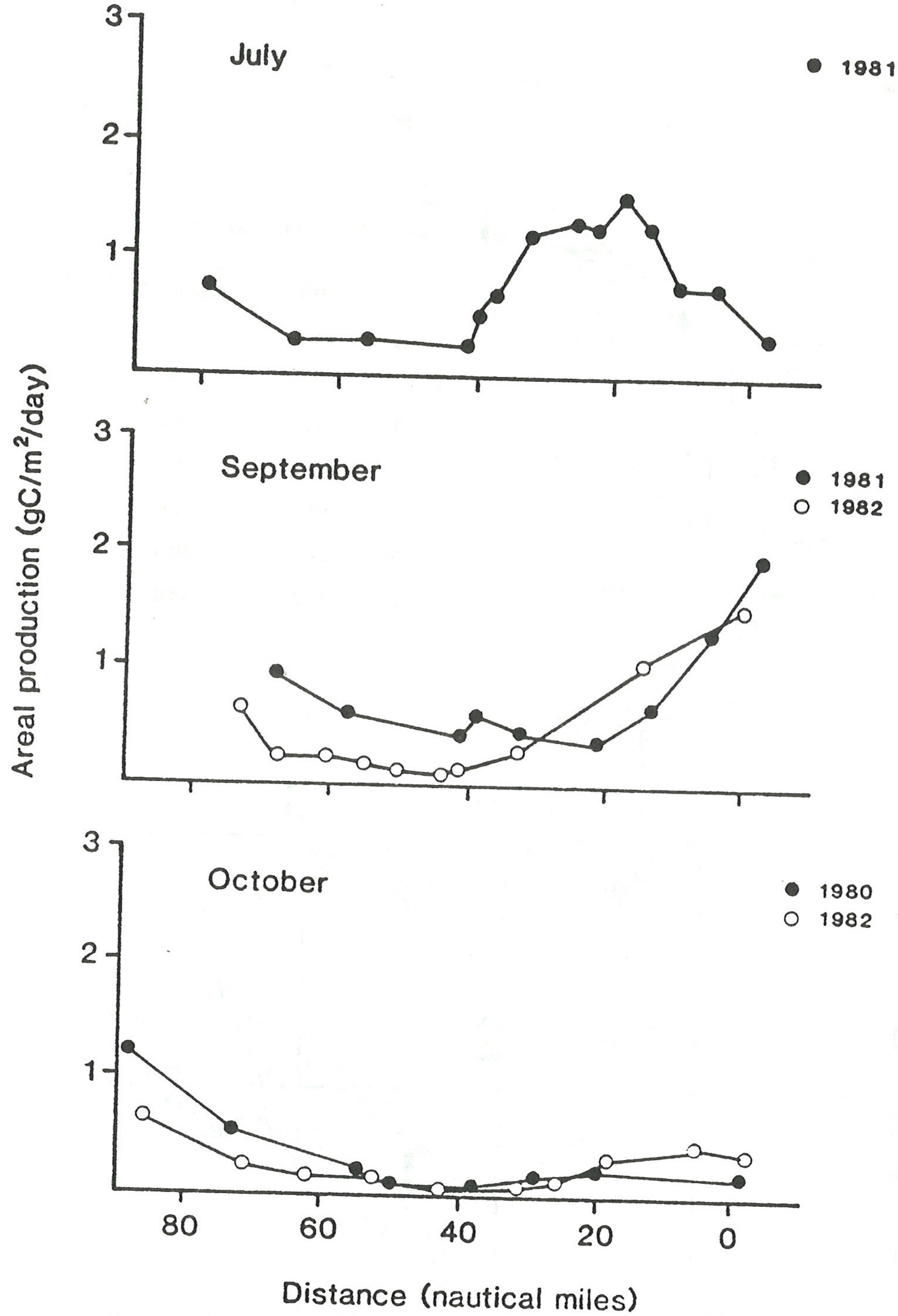

Figure 4. Phytoplankton areal production along the main axis of the estuary vs. distance from the bay mouth for July, September, and October. (From Pennock et al., Delaware Bay Report).

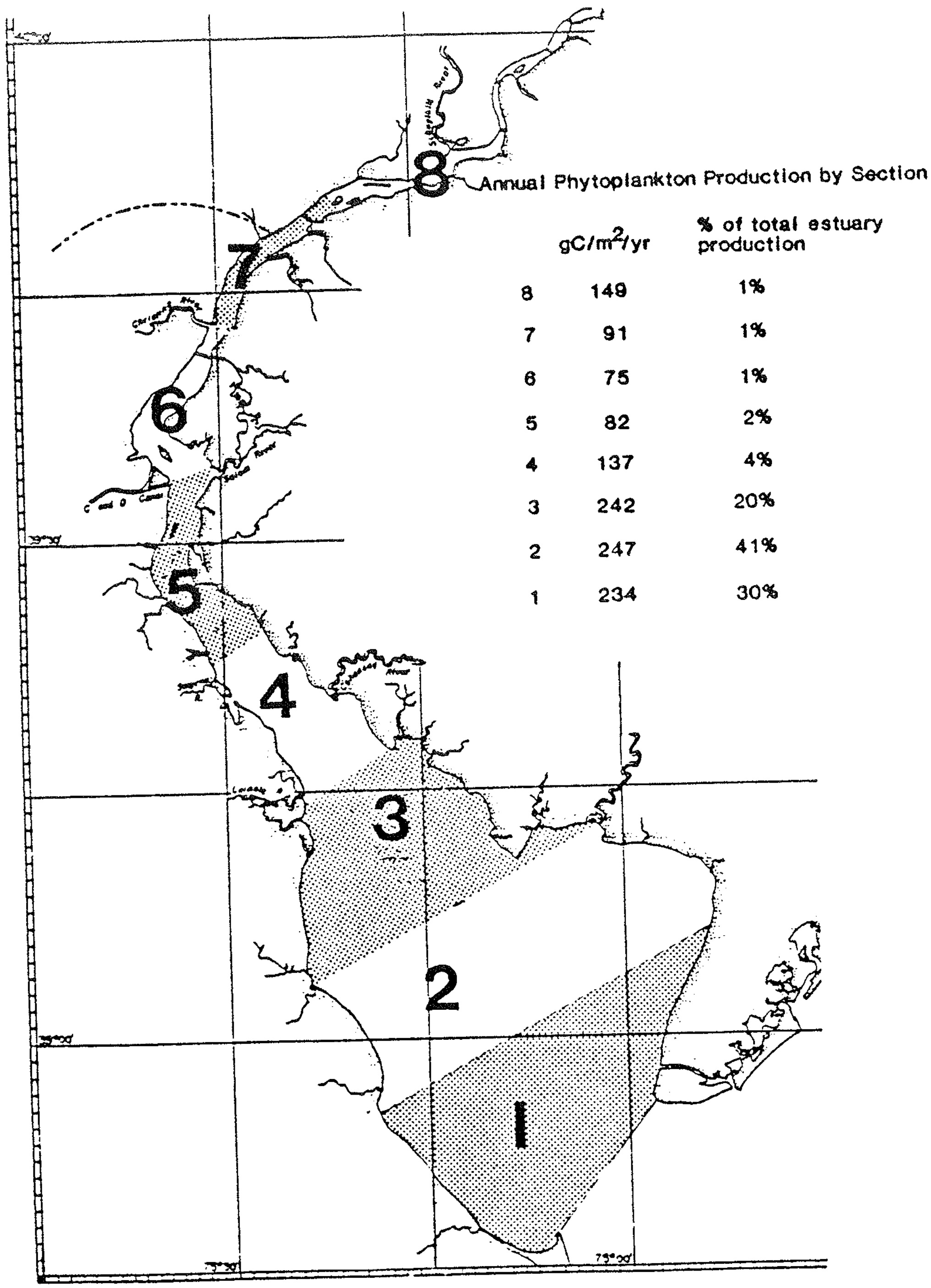

Figure 5. Average yearly areal production values for 8 sections along the salinity gradient of the estuary. (From Pennock et al., Delaware Bay Report).

Two things should be pointed out. First, about 9Ø% of the total estuarine production is occurring in the lower part of the estuary. Second, the impact of the area of maximum turbidity can be seen in segments five, six, and seven; these are the segments with the greatest amount of suspended material. I would also like to point out that there is a slight increase in productivity as you go above that point. The high productivity values down estuary coincide well with what we found with zooplankton.

Again, let's compare the Delaware estuary to others in regard to productivity (Table 2). Daily values of productivity for these estuaries are as high as 6.Ø gC/m^2/day and annual values high as 37Ø gC/m^2/year. On an annual basis, there are some higher values, but the Delaware looks good. Values for daily productivity also indicate that the Delaware estuary is hardly impoverished.

I feel an obligation to be a little more specific with the zooplankton. As I stated before, the interpretation of the data is preliminary. We established a series of nine stations which ran the length of the Bay north to south and across the Bay east to west (Figure 6). We considered it important to include as much of the salinity gradient as possible, and it was a prodigious chore trying to sample such an area on a regular basis. The stations were sampled approximately every two weeks. We made oblique tows with half-meter number ten nets (158 um). Flow meters were present in the mouths of the nets and replicate tows were made. In addition, we made simultaneous tows with a special epibenthic dredge to collect the mysids present at the bottom. Previous experience of my own had indicated that if you are really interested in sampling the epifauna swimming above the bottom, you need some type of special apparatus that will collect the animals in that area. This particular type of sled has been very effective.

So we had a series of stations (1, 2, and 3) which represented the upper part of the estuary where there are lower salinities and higher turbidities, as opposed to the remaining stations which were located in the lower estuary with higher salinities and lower turbidity.

Forgive the busy nature of Figure 7. It shows zooplankton concentration in numbers/m^3, plotted against the time of year. Notice here that "L" represents the lower Delaware stations, or everything except Stations 1, 2, and 3. We also have a plot for these upper stations (labeled "U"). We see that very typically there is a spring "pulse" down-estuary with a small decrease toward the end of the spring period. This is followed by high levels during the summer into the fall and then a reduction. Upstream we detect a cycle which seems to run aboout a month or two behind the lower Bay. Remember, this is

Estuary	Production Daily	Production Annual	Reference
Wassaw Estuary, GA	0.9-2.2	90	Turner et al. (1979)
Pamlico River, NC	0.1-3.3	200	Kuenzler et al. (1979) Davis et al. (1978)
Chesapeake Bay	0.1-3.3		Flemer (1970)
Patuxent River, MD	0.1-1.5		Flemer et al. (1970)
Raritan Bay, NJ	0.1-1.5		Patten (1961)
Hudson Estuary			
lower bay	0.1-2.2		Malone (1977)
New York Bight Apex	0.1-6.0	370	Malone (1976)
Long Island Sound		166	Ryther and Yentsch (1958)
Narragansett Bay	0.2-3.2	220	Furnas et al. (1976) Smayda (1973)
San Francisco Bay			
lower bay	0.1-0.5		Cloern (1979)
upper bay	0.1-0.9		Peterson (1979)
Delaware Estuary			
upper estuary	0.1-1.3		
lower estuary	0.1-3.0	228	Pennock et al. (this study)

Table 2 - A comparison of phytoplankton production in several United States estuaries is shown with production in units of grams of carbon produced per square meter of estuary surface on a daily and annual basis. (From Pennock et al., Delaware Bay Report).

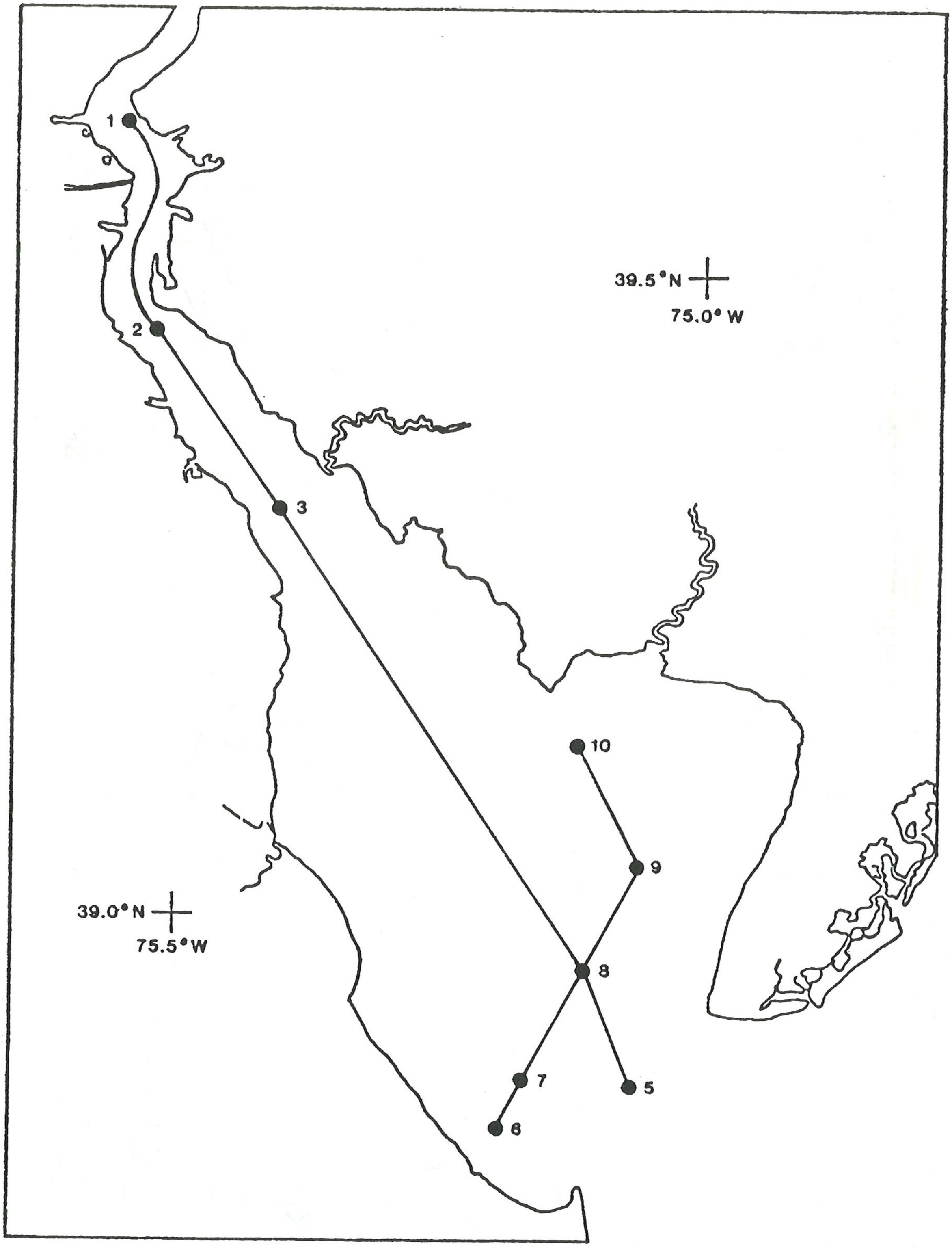

Figure 6. The Delaware Estuary showing locations of zooplankton sampling stations. (From Herman et al., Delaware Bay Report).

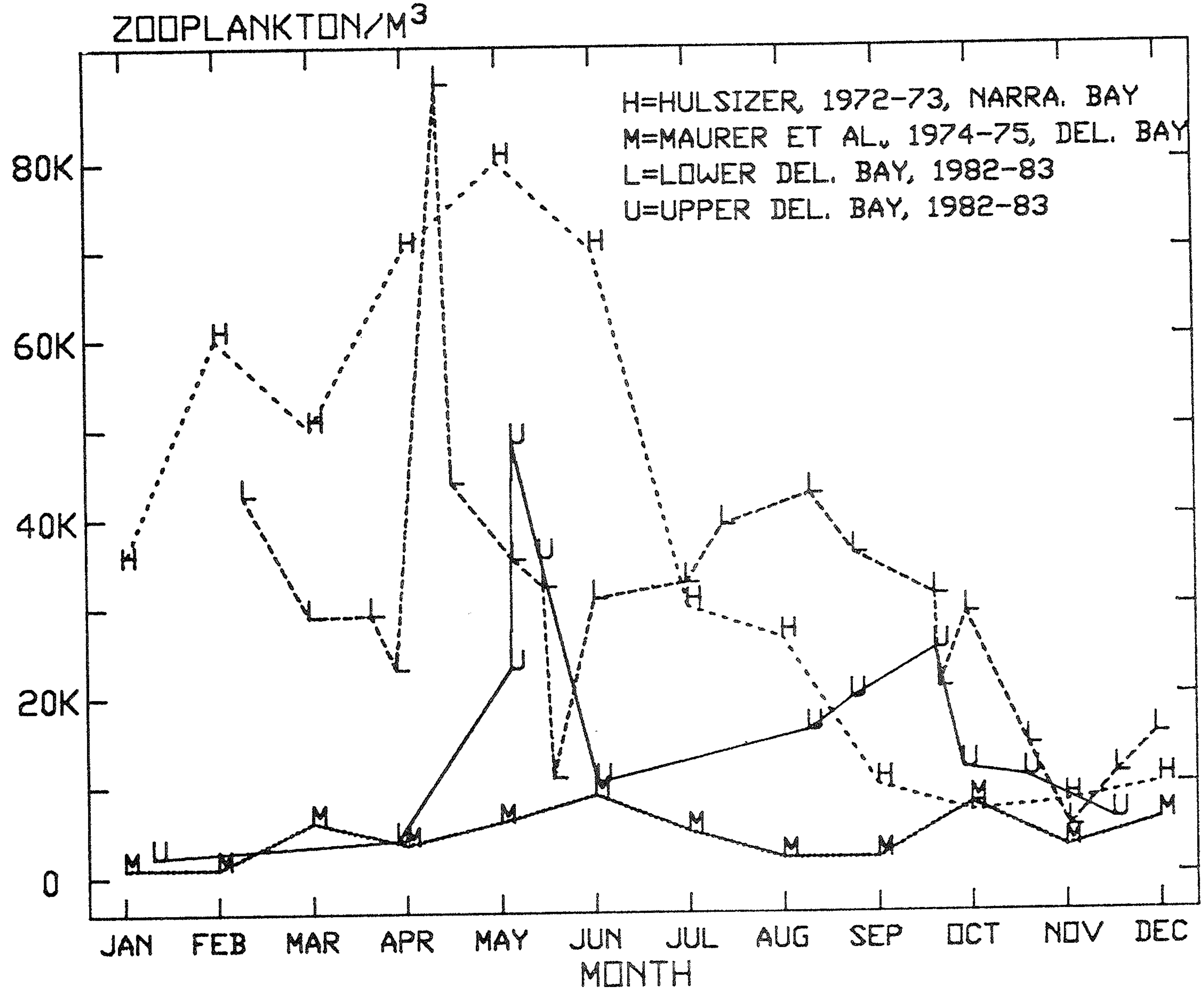

Figure 7. Zooplankton concentration in Narragansett and Delaware Bay.

only data from one year's collection; we certainly need more information here.

What else is plotted on this graph? The Delaware is an area where we have had very few zooplankton studies. Maurer et al. in a paper in 1978 (based on tows made in 1974 and 1975) reported on the lower part of the estuary. Note the very low values recorded. There can be a number of different reasons for the lower values: use of different mesh size, difference in frequency of sampling, difference in time of sampling, etc. Until our study, this low value on zooplankton concentration was the one which had to be used. As you can see, it is considerably different from our values.

I've also plotted data from Narragansett Bay, Rhode Island based on a study by Hulsizer (1976). Narragansett Bay is supposed to be a "fairly rich" area. When one compares the two areas, they are not too different.

I have attempted in Figure 8 to show how the zooplankton concentration in Delaware Bay fits in with other studies. This is a plot which was prepared by Scott Nixon and others in their report to the EPA in 1983 on comparisons between various estuaries. At the time of their study, our information was not available. I have simply added it to the plot. The table compares the zooplankton concentrations and net mesh size for different studies. Notice the solid circles which represent those studies conducted with a net mesh size of 100-200 um. Also note that the Delaware estuary values (labeled L, X, and U) fit in very well with similar mesh size studies.

I'd like to take the opportunity to talk about mysids for a few minutes. We do consider the mysids to be an integral part of the food web. We feel that they may contribute much more significantly than has been appreciated in the past. They are present in huge numbers on the bottom. Their role in the food web is not well understood at all. When we started our studies in the Delaware, we knew that we would have difficulty in comparing our information to other investigations because there have been so few studies on the distribution and quantitative nature of the group.

Well, what have we found? Figure 9 is a plot of the annual cycle of the mysids in numbers per square meter. The information is for the lower part of the estuary only, and I should mention here that mysids penetrate all the way up to the fresh water mark. There is a pulse in the spring with a second peak occurring in the late summer. We believe that these peaks are simply representations of reproduction. There are two or three generations of mysids produced each year. We don't understand yet what or how migrations contribute to this. We don't know the reason(s) for the low levels in midsummer. Are

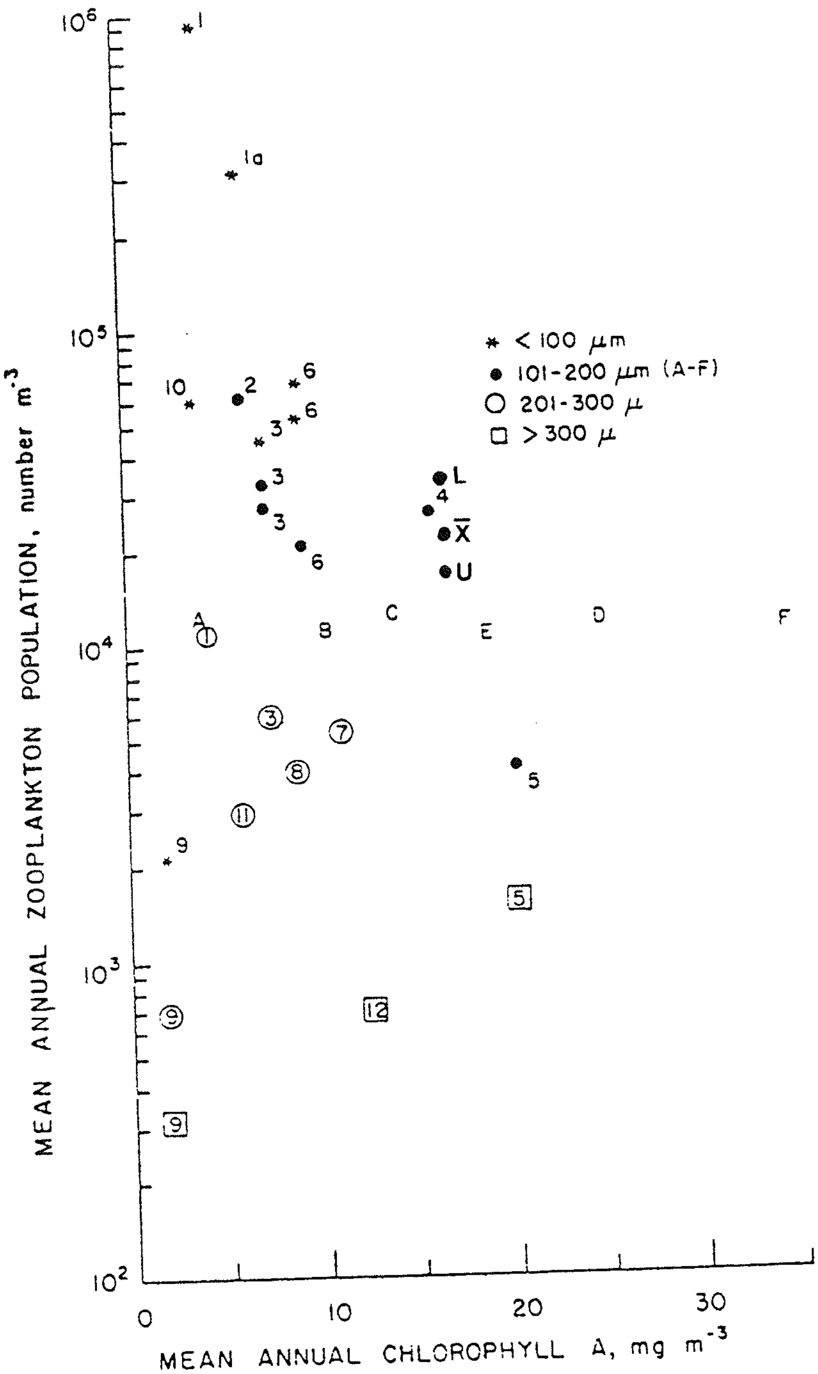

Figure 8. Mean annual zooplankton abundance and the mean annual standing crop of pelagic chlorophyll a in several U.S. estuaries. 1 = Chesapeake Bay, 2 = Long Island Sound, 3 = Narragansett Bay, 4 = Pamlico Estuary, 5 = Patuxent Estuary, 6 = Potomac Estuary, 7 = Raritan Bay, 8 = Lower Delaware Bay, 9 = Kaneohe Bay, 10 = South San Francisco Bay, 11 = Mobile Bay, 12 = Barataria Bay, A-G = MERL microcosms. (From Nixon, EPA Report on Chesapeake Bay, 1983).

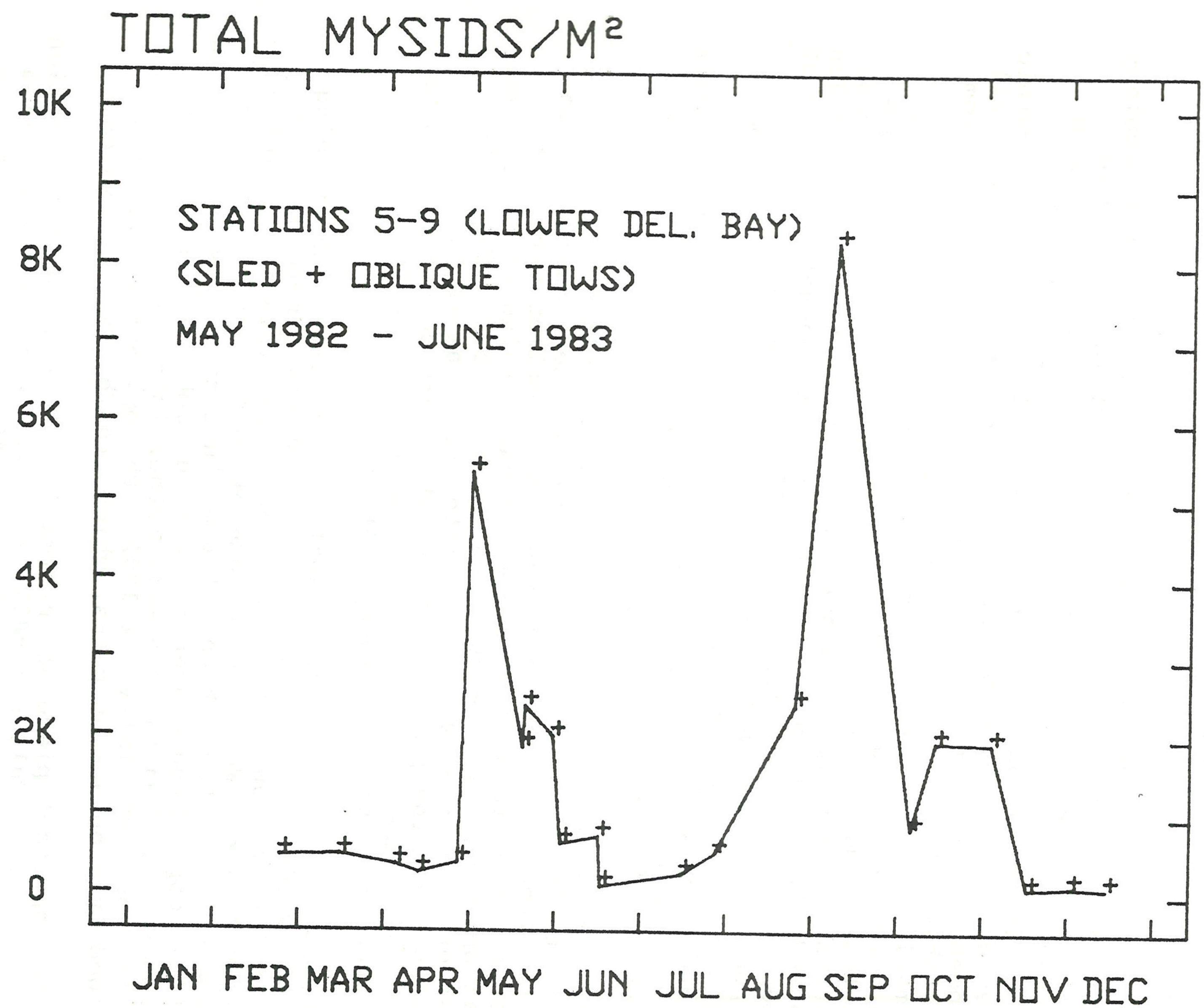

Figure 9. Annual cycle - total mysids /m^2.

these low levels related to predation? Weakfish represent one of the most important commercial commodities in the Delaware. Juvenile weakfish gorge themselves on mysids. Early in their life history they feed on copepods, then they turn to mysids as a source of food. There are many questions to be resolved regarding these relationships.

This a good place to say something about the benthic ecology of the Bay. We do not have a great deal of information on distribution of benthic species. The studies that have been published indicate that the Delaware is improvished. Dr. Haskins, in the Delaware report of 1983, states that the benthic studies which have been reported on in the Delaware estuary all have been completed in those areas of the Bay where the bottom is unstable. Bob Biggs mentioned this in his talk. So, the information that we have may be unreliable. The few studies which have been conducted in areas where the bottom is stable point towards the Delaware as being as productive as many other estuaries, and perhaps even more so. I understand from both Jon Sharp and Jim Thomas that Dr. Bill Amos has conducted a study of the benthos of the Delaware in the 1950's. The data has not been published, but is available from Dr. Amos. It would be very interesting to have another study of the benthos of the area and compare the results to those of Dr. Amos. Indeed, this would be a rare opportunity to examine the changes which may have occurred in the 30-year period.

As far as blue crabs are concerned, I can't hope to do justice to the work of Chuck Epifanio and Steve Sulkin. I do wish to elaborate slightly on what George Mellor said. The number of blue crabs in Delaware Bay has nothing to do with the actual spawning which takes place in the area. Rather, the number of blue crabs which come into the Delaware Bay are dependent upon the physical cycles which are occurring outside of the Bay. The wind and the current activity determine the blue crab crop for the Delaware estuary.

Figure 10 compares phytoplankton production with standing crop of mysids and zooplankton. I think this represents the type of information that we need, and again this is preliminary and speculative. We borrowed some of the maximum values for chlorophyll from Pennock and plotted this over a two year period opposite zooplankton concentrations in numbers/m^2 and mysids in numbers/m^2. You can see some rather interesting correlations, especially for 1982. Phytoplankton peaks are followed by zooplankton peaks, which are followed by mysids.

One important piece of information which I forgot to mention is the fact that Fulton (1982) has shown in his North Carolina studies that mysids are capable of feeding on zooplankton to a point where they can control the qualitative makeup of the population. Specifically, he showed that *Acartia tonsa*, which

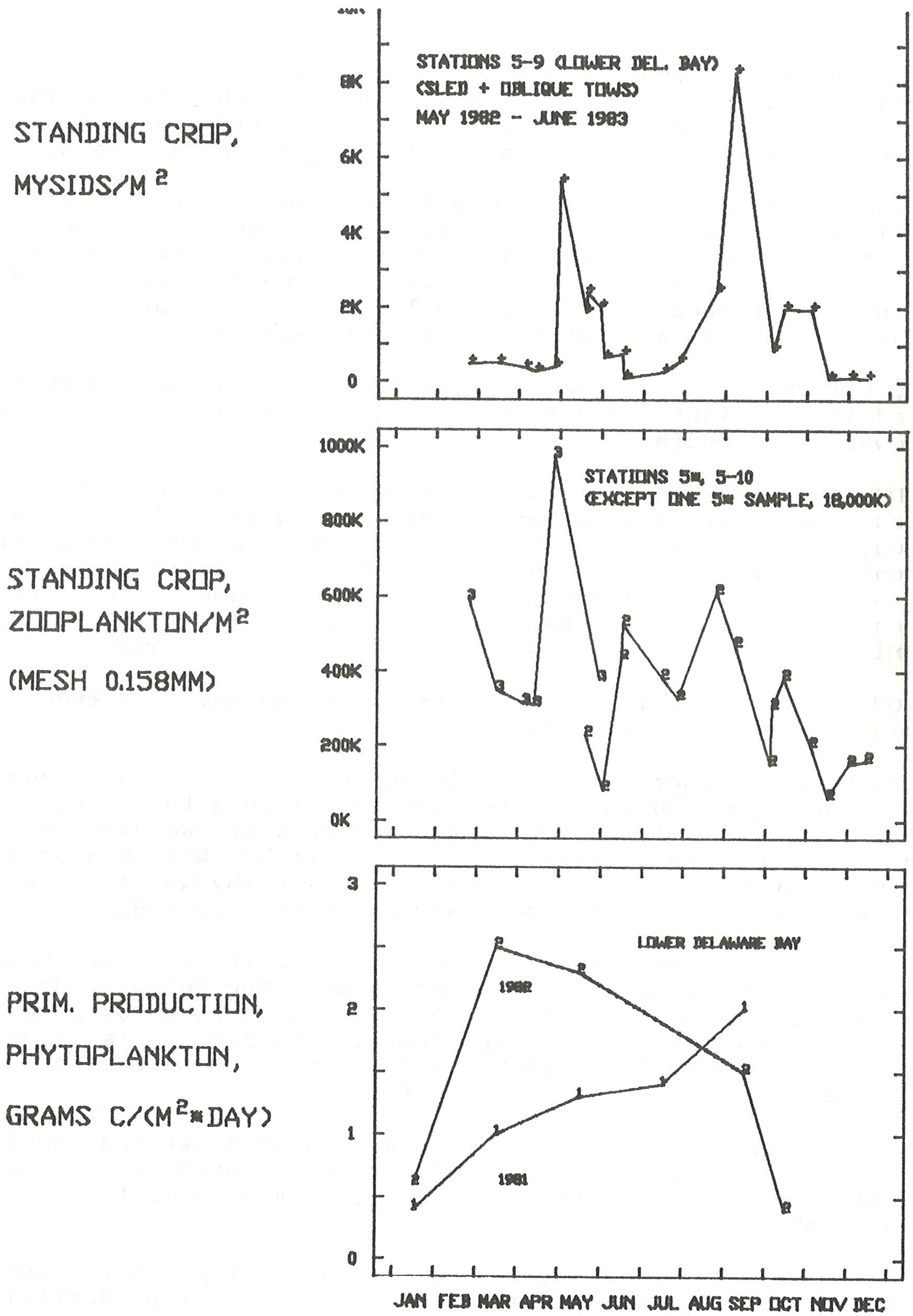

Figure 10. Comparison of some phytoplankton production values with standing crop of mysids and zooplankton.

is the dominant copepod along the East Coast of the United States, is the organism that was controlled. When the mysids were present and feeding on the plankton, Acartia was absent. As soon as the mysids disappeared, Acartia showed up again.

The point is that there seems to be a very significant relationship between phytoplankton, zooplankton, mysids and young fish. These are the things that we must understand in order to properly assess the food web. We need to understand the interrelationships if we're really going to be able to manage the estuary and obtain the proper rewards.

QUESTION: If you'd measured productivity farther north past Philadelphia, might you not have found figures almost as great as towards the mouth?

DR. SHARP: The little bit that we have done does not suggest that. It is somewhat higher than in the Philadelphia region, but it is not terribly higher. We have not done a very thorough survey there. I think there is some earlier work done for the Philadelphia Academy that might shed some light there. But on an areal basis certainly the productivity, even the upper riverine portion, would be slight compared to the lower Bay.

QUESTION: What is the composition of the phytoplankton population below Philadelphia?

DR.HERMAN: There are a couple of things I know, although I can't answer your question specifically. I know there are areas in the lower part of the Bay in the summer where we have the high values of productivity, and it is attributable to a smaller form which has not much chlorophyll. That's why we have the peak in productivity. I don't know about the upper Bay.

DR. SHARP: Many estuaries, for instance the Potomac, have very high proportions of blue-green algae. The Delaware does not. I don't know why, but the upper Delaware does not have the tremedous numbers of blue-greens there. The ammonia is largely controlled bacterially we think, and a lot of it has to do with the temperature effect of nitrification.

DR. HERMAN: Yes, I should have mentioned something about ammonia. Both ammonia and nitrate are very abundant, but the phytoplankton seem to take up the nitrogen mostly in the form of ammonia (about 82%).

QUESTION: Is there any feeling at all whether in the upper reaches of the Bay that there are other sources of productivity besides the phytoplankton, like the periphyton?

DR. SHARP: One point on that is that everything we've measured is for phytoplankton. We're taking whole water samples. The waters are quite muddy in the upper reaches and relatively deep, so there's probably not much that would be attached on the bottom or sides that would contribute much to the productivity.

QUESTION: By "up there," what do you mean?

DR. SHARP: Through the Philadelphia region up to Trenton. When you get up closer to Trenton the waters are a little bit clearer, but still it's a relatively deep river for the width, and there's really not a great deal of opportunity for anything to grow on the side. There's not much light.

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REAL-TIME CIRCULATION MODELING OF DELAWARE BAY

Bruce B. Parker
NOAA National Ocean Service

The Delaware estuary has a special place in NOS's priorities, and in our hearts as well, for two reasons. First, the 1-1/2 year NOS Circulation Survey of the Delaware River and Bay is the last traditional circulation survey that we will do in-house with NOAA vessels. Even though it's the last such survey, it's going out with a big bang because we were able to bring in some new technology that we'd never used prior to this survey, including high frequency radar to look synoptically at the circulation over the entire lower Bay. A remote acoustic Doppler current measurement system, and real-time water level and meteorological instrumentation.

But the big reason that we're so interested in Delaware Bay is that it is the first area where we have put into operation a real-time numerical circulation model. By that I mean a model that is actually running around the clock using water level, meteorological, and other data coming in from the Delaware Bay itself over phone lines and being fed into the model. The model is updated with real-time data hourly and also run in a 36-hour forecast mode twice daily.

The Delaware Bay is the first place that this has been done, and it represents the beginning of a redirection of our entire circulation program. The redirection has two main points. One is that NOS will now rely more on numerical models than it has in the past to provide some of its products and services. Secondly, and perhaps more important in some ways, we are no longer going to concentrate just on the traditional tidal products, that is, the tide tables, the tidal current tables and the tidal current charts. We are going to attempt to provide forecasts of the total picture, including the effects of wind and river discharge.

As Dr. Mellor mentioned earlier in his talk, the wind over the continental shelf, river runoff, and other meteorological effects can greatly affect the water level and the currents inside the Bay. There are an increasing number of users in the marine community who want water level and current information to such accuracy that it requires that we give them the total picture and not just tidal predictions.

Dr. Mellor mentioned a little bit about what we've been doing in the Delaware estuary. We are using his model as part of this prototype real-time system. Such a system requires the integration of measurement, telecommunication and data processing technologies, as well as data base management, forecasting, and advanced numerical modeling techniques.

As you heard Dr. Sharp say this morning, the Delaware estuary is the third largest port in the United States. It is the needs of the pilots and the shipping industry using this port that have motivated this particular project. When you have a 40 foot draft tanker and you're trying to bring it into a channel that is 40 feet deep, every inch counts both from safety and monetary standpoints. If you can save time waiting outside the Bay and bring the ship in sooner because you know exactly what the water level is, or if you can load an outbound ship a foot deeper, you're greatly increasing the efficiency of your operation and saving a lot of money. So the major impetus for this project has been the pilots and marine navigation.

What needs to be remembered is the need for going beyond just the tidal products, the need to be able to provide to the user exactly what the water level is and what it should be up to a day-and-a-half into the future. That's being made possible now because of the advances in technology in the telecommunications, modeling and short-term forecasting.

It has always been relatively simple to predict the tide because of the astronomical periodicities inherent in tidal motions. With harmonic constants derived from a long enough time series, you could predict tide years into the future. But the rest of what's happening is so tied to the weather that you couldn't do much better than you could do predicting the weather.

But now with the capability of putting real-time instruments in the field and extrapolating forward in time from this recent real-time information, we're able to at least try to provide this type of information. The Delaware project is the beginning of this.

QUESTION: What is the expected accuracy of the current and water level predictions for, 6, 12, or 36 hours in advance?

DR. PARKER: Accuracies will, of course, get worse as you get further ahead in time. At this point, I don't think anyone would make any promises. I think one of the areas where we need the most effort is on the short-term forecasting part of the operation. Even when you have a good model and it's running in real time and being kept up to date, you still have to worry about how to accurately forecast the open boundary conditions so the model can be run into the future. We are presently using outputs from NWS's Local Fine Mesh weather model when making these forecasts. But this doesn't solve the problem of how to forecast the open boundary conditions. We are considering statistical techniques based on looking at a lot of historical data and then using that to project ahead. We are also considering connecting the Delaware model to a shelf model.

By the way, our version of Dr. Mellor's model is the two-dimensional version, and we don't have the shelf included right now. But it is possible to connect the model to the shelf, make the problem a little bit more removed and get a better handle on what the wind is doing on the shelf. Statistical correlation techniques could then be used to forecast in this region. But it's a difficult part of the problem. I could say what we hope to do, but we don't know how soon we'll be able to do it, or how well.

At the very least the model is always kept up to date, i.e., in real time. So even if you went to the extreme, which is what we're doing right now, of predicting the tidal portion in the traditional way and using some kind of very simple scheme to extrapolate ahead the non-tidal portion, you're still doing a lot better than you could do with just tidal prediction.

QUESTION: Could research users gain access to the data?

DR. PARKER: The Delaware circulation survey data set isn't completely processed yet, but it should be available within six months to a year. [Editor's note: Processing has now been completed on the Delaware survey data and it is currently available to users. In addition, water level data at Philadelphia, PA and Lewes, DE can be accessed in real-time with an NOS software package called TIDES-ABC.]

INTRODUCTION AND STATEMENT BY SENATOR ROTH

Ferris Webster
University of Delaware

You heard this morning that the issues and problems relating to Delaware Bay heavily involve two states, New Jersey and Delaware. You heard a little bit about New Jersey this morning. I'd like to assure you that the Delawareans are not lagging behind the New Jersey people in trying to understand the Delaware Bay and to make effective use of it.

You're probably all wondering, as we were, about Congressional views on new initiatives regarding Delaware Bay in this period of extreme budget stringency. Jon Sharp, on your behalf, invited Senator Roth, the senior Senator from the State of Delaware, to address us this afternoon. The bad news is that Senator Roth wasn't able to come this afternoon. The good news is that he did send a statement. Even better news is that it isn't very long and has interesting information.

Part of the reason for this effective statement may be due to an individual in the back of the room, Nick Brown, a legislative assistant to Senator Roth who specializes in environmental issues. I'm honored to have a chance to read this statement on behalf of Senator Roth.

"It gives me a great deal of pleasure to welcome our presenters to Washington and to say hello to the interested folks who have come today to learn more about the Delaware estuary. My staff and I have worked very closely with Carolyn Thoroughgood and Jon Sharp in recent years and have admired and encouraged the work which they and their colleagues have been doing at the University of Delaware's College of Marine Studies.

I'm also impressed by the cooperative effort which institutions in Delaware, New Jersey, and Pennsylvania have made to the ongoing estuary study. It is important that we in Delaware be reminded that the Bay is not our own. We greatly appreciate the contribution that our neighbors are making toward understanding and protecting our shared resources.

Very recently, I spoke to the Wilmington Kiwanis Club and outlined my views on the 1986 budget. The rest of my message is, as you might guess, that there has to be a sacrifice across the board, as it is imperative that we gain control of federal spending. There are very few areas in my mind where cuts should not be made. But one of these is the field of research and development.

For this country to remain competitive with the rest of the world, we must continue and even expand R&D. Cutting back is penny wise and pound foolish. I have long been interested in our state university's work in marine studies and have worked tenaciously, for example, to ensure that Sea Grant is funded each year and that awards are made promptly to the participating institutions.

But of all of this work, one of the most important projects in my mind is the Delaware estuary study. Our Delaware Bay has not gotten the media attention that others have. Maybe the problem is that it's not within an hour of Washington. Maybe it's because it appears to be in relatively good health. Regardless, it is a most valuable resource. It is a recreational Bay, but also a working Bay. It has provided substantial service as a fishery, in assimilating waste, and in supporting vital shipping.

We have exploited and, at times, abused it, undoubtedly not for the last time. But it is because of these demands that I believe that we must know a great deal more about it.

In recent years, at least two-and-a-half million dollars in private money has been spent to develop information for an assessment of the state of the Delaware estuary. The end product will hopefully help us to better manage this resource.

I, for one, am committed to seeing that task carried out. I commend the project participants for their good work, and I urge the National Oceanic and Atmospheric Administration officials to join in supporting this important work."

New Jersey Shore: Use and Value

Alex W. Wypyszinski
New Jersey Sea Grant Program

New Jersey's Delaware Bay shore is one of the State's best kept secrets. The State is very often referred to as the most densely populated in the nation, and that's true. It is also very often described as paved over and polluted. In some areas that's also true.

But none of this is true in those areas of Salem, Cumberland and Cape May Counties that border on Delaware Bay and are, for the most part, quiet rural areas with very small populations. These areas also illustrate the paradox of New Jersey.

New Jersey's number one industry is the petrochemical industry. The Dupont Chemical Chambers Works is located next to the eastern side of the Delaware Memorial Bridge. More heavy industry can be found just to the south at the Salem Generating Station where two nuclear power plants operate using the cooling waters of the Delaware Bay. However, the number two industry of the State is tourism; and that's the most important segment of the economy in Cape May County -- the southernmost of the three counties that border on the Bay.

The point to be made is that this heavily trafficked Bay, bordered by refineries and heavy industry, also sustains large wildlife populations, a significant fishing industry, and attracts hundreds of thousands of tourists.

There are 40 miles of River and Bay shoreline in Salem County. At Hope Creek the River officially becomes Delaware Bay. Despite the presence of the previously mentioned Chambers Works and the Public Service Electric and Gas nuclear plant, agriculture is the primary economic activity in Salem County. About 40 million dollars of soy beans and corn are grown there, most destined for markets further to the south. Until very recently soy beans were trucked to market, but officials at the newly created Port of Salem in Pennsville have demonstrated that farm products can be barged through the Chesapeake and Delaware Canal at significant savings to the farmers. They also plan to develop a fertilizer plant, an ethanol plant and fish processing facilities at the Port.

Although there is no commerical fishing port in Salem County, major fisheries include oysters, crabs, shad, eels and menhaden. Sport and commerical boats operate from landings along the ten major creeks that drain the area.

There are 24,500 acres of tidal marshes in Salem County. Although economics is one subject area which needs more investigation, it has been reported that muskrat trapping contributes almost as much to the area's economy as the oyster industry. Salem County, New Jersey, claims to be the Muskrat Capital of the World. At the annual Muskrat Festival one can feast on muskrat at the firehouse in Salem.

Located further south is Cumberland County, with 39 miles of Bay and over 43,000 acres of tidal marshes. The Morris River is the county's major tributary to the Bay and is the focus of the state's oyster industry.

Some sand mining takes place off the Morris River, but the towns of Cedarville, Dividing Creek, Ft. Norris and Bivalve have historically been the center of the shellfishing and boat building industries in Delaware Bay. There are ten oyster shucking plants and three seed clam processing plants along the Cumberland County coast. The oyster industry employs about 700 people and contributes in excess of ten million dollars to the state's economy. Although oystering is the major fishing activity, there are about 20 Cumberland County marinas which provide services to boaters and to commercial fishing vessels which concentrate on the stocks of weakfish, bluefish, shad, eel and crabs.

Even so, agriculture is the major economic activity here as well. There are about 120,000 acres under cultivation, producing half of the state's fresh market and processed vegetables. Agriculture in Cumberland County is worth about 50 million dollars to the state's economy.

The Bay meets the Atlantic Ocean in Cape May County, which has about eighteen miles of Bay coastline and only about nine acres of salt marsh along the Bay. Tourism is the major economic activity, and tour buses now bring people to the town on Cape May year' round. The area has been a tourist mecca since early in the 19th Century. The Victorian architecture is particularly notable. Commercial fishing is the second largest industry. Most surprisingly, Cape May has been subjected to an increasing amount of development pressure, very often aimed at sensitive ecosystems in wetlands areas.

All along the New Jersey side of the Bay numerous bird species use the coastline for nesting and feeding areas. They include bald eagles, herons, egrets, glossy ibis and other wading birds. One remarkable natural phenomenon occurs annually during the full moons of May and June, when birds migrating to the north from Chile and Argentina meet the millions of horseshore crabs which use the shores of Delaware Bay as a major spawning area. The birds eat crab eggs to fuel their journey further north.

The Salem Generating Plant recently required about seven acres of wetlands for a road expansion. The New Jersey Department of Environmental Protection manages a vigorous wetlands protection program which normally would require the electric company to replace the wetlands destroyed. In a novel mitigation agreement, PSE & G provided funds with which DEP purchased beach areas or easement rights to protect the horseshoe crab spawning grounds from development and to preserve the natural cycle which has been taking place for thousands of years.

The most obvious way to describe "use and value" is in terms of dollars and human activity. But, New Jersey's Delaware Bay coast is one of the state's best kept secrets in terms of the value of its wildlife, aesthetics, history and culture as well.

FISHERIES MANAGEMENT

Roy W. Miller
Delaware Department of Natural
Resources and Environmental Control

Perhaps some of you are not too familiar with exactly what we mean by "fisheries management". George Rounsefell, the eminent fisheries scientist, defines "fisheries management" as manipulating the factors that affect fish populations so as to produce the largest available surplus for harvest.

So, what are some of the tools we have for fisheries management? One of the tools we have are laws and regulations to restrict fisheries. Both Delaware and New Jersey have laws designed for this specific purpose. A second tool used in fisheries management would include the general topic of habitat protection and enhancement. Another type of fisheries management is artificial propagation and stocking. I will discuss each of these tools in turn but I will spend more time on the first one - that is, laws and regulations. What is the purpose of fishery laws and regulations?

Basically, they are to conserve the resource. However, as it turns out, what you're actually doing is hampering one form of fishing to benefit another form of fishing.

What are some of the general types of measures employed in fisheries management through laws and regulations? I'll give you a few examples, and then I'll go into them in more depth later with some local examples:

1) Maximum and minimum size limits;

2) Creel or harvest limits - the number of fish that may be taken by a given angler or person in a given day;

3) Catch quotas - ceilings put on commercial catches primarily;

4) Seasonal restrictions on fishing -when you can and can't fish in an area;

5) Restrictions on the gear - what type of gear you can use (trawls, gill nets, etc.);

6) Limited entry - numbers of fishermen allowed to enter a fishery, and whether it is

unrestricted or restricted;

7) Permits and fees - a form of limited entry sometimes if the fee is high enough; and

8) Area closures - certain areas might be closed to a certain type of fishing.

A brief history of fisheries management in the Delaware estuary will help orient us a little bit through time. In one of the slides shown today, William Penn drew a 12 mile radius from the New Castle County courthouse, and since that radius encompasses the New Jersey shoreline to the low tide line, it has presented some problems down through the years.

In 1878, the State of New Jersey filed an injunction against Delaware because Delaware was restricting the commercial fisheries--that is, preventing New Jersey residents from fishing in the Delware River. Conflicts of this type finally led to the formation of a commission in 1905 whose job was to draw up a compact between the States of New Jersey and Delaware.

They accomplished this objective and in 1907 laws were drafted and approved by both the States of Delaware and New Jersey. But by 1923 there had been a lot of amendments passed on both sides, and a new set of laws were drafted and approved.

The original compact stipulated that all laws regarding fishing had to be concurrent. However, the new set of laws approved in 1923 by Delaware were not approved in New Jersey. In 1927, the same thing occurred in that Delaware drafted a new set of laws and New Jersey did not approve them.

In 1934 an important event occurred. The boundary issue was settled from the Pennsylvania line seaward. The entire river shoreline is within Delaware's jurisdiction to the low tide line, proceeding down Bay to the tip of Artificial Island. There, Delaware's jurisdiction extends to the middle of the boating channel and proceeds south. However, above Artificial Island everything from the low tide line over is in Delaware, so that means if you're living near Penns Grove in New Jersey and you're fishing in the River, you're fishing in Delaware.

Moving down the Bay a bit, the New Jersey-Delaware line approximately follows the midddle of the Bay. Everyone is familiar with Brandywine Light if you're a fisherman in the Delaware Estuary. Brandywine Light is on the New Jersey side of the channel and is within that state's jurisdiction.

In 1977, the Delaware Attorney General's office ruled that the compact had never been properly implemented, thereby concluding that because concurrent laws were never implemented, the Compact was not in force. Suddenly we managers discovered that the Compact in fact was never properly implemented and could be ignored. With this legal requirement for concurrent laws and regulations removed, are there any formal management agreements today between Delaware and New Jersey?

Basically, each State manages their own fisheries with certain exceptions. Where there are approved interstate fishery management plans, there is some consistency, specifically with regard to certain species. A couple of notable plans familiar to most are for striped bass and summer flounder. These fishery management plans have been implemented in the states. However, there are still some discrepancies with regard to striped bass between Delaware and New Jersey, even though we share the same Bay and the same fish.

Striped Bass. Delaware now has a total moratorium on striped bass fishing similar to Maryland's moratorium. The striped bass resource is greatly depleted. Since most of our striped bass were marketed in Maryland before the moratorium, it was logical to implement a moratorium to coincide with Maryland's.

New Jersey does not have a moratorium on striped bass. Even though you are not allowed to take a striped bass in a net in New Jersey, they still may be marketed. In fact, some New Jersey striped bass are sold in Delaware.

Summer Flounder. At the moment, we have a 12 inch minimum size. Our plans are to go to 14 inches, as recommended in the Atlantic States Marine Fisheries Commission (ASMFC) flounder plan. New Jersey's present size limit on summer flounder in Delaware Bay is 12 inches and they plan to go to 13 inches next year and then to 14 inches the following year. This means that for one year at least New Jersey and Delaware will have different size limits for summer flounder in Delaware Bay.

We have had a better track record of cooperation in regard to research and surveys. For instance, we participate with New Jersey in angling surveys and surveys of juvenile crabs and juvenile finfishes.

Problem Areas

So what is the central problem? Why is there so little cooperation in management? Well, it's a common property resource. The managers themselves have been anxious to cooperate. It's when we attempted to pass management measures via the political process that special interest groups ensured that everything came unraveled. There were conflicts over time and space. For example, commercial fishing is a viable industry in the Delaware estuary, as is recreational fishing. Both activities are often conducted in the same place and are often vying for the same species.

The weakfish is an example of a problem species, with the two fishing groups competing for the same limited resource. There is good evidence that the weakfish has been declining as of late. The population, particularly of the larger 10-12 pound fish, peaked in the mid- to late 1970's and then headed on a downward cycle. Fortunately, there is some reason for encouragement in that recent recruitment indices show promise that young fish now moving up into the fishery will sustain the fishing for a number of years yet.

Industries also are competing for time and space with fisheries. For example, a recent proposal to use the anchorage off Big Stone Beach as a major coal lightering area is very controversial because of its proximity to important fishing grounds. Industry, both inshore and offshore, is competing for important fishing grounds or required fish nursery areas.

There are other problems, such as blurred jurisdictions. New Jersey has two fishery sections within the same division, a freshwater section and a marine section. I am not always sure which section has jurisdiction over a particular issue. Similar jurisdictional blurring occurs in our State in regard to pollution-related issues.

Both the States of Delaware and New Jersey have marine fisheries advisory councils. New Jersey's council has veto authority on any regulations their Department passes. The Delaware Advisory Council on Tidal Finfisheries does not have veto authority. However, they have a great deal of influence. The Pennsylvania Fish Commission, on the other hand, as is typical of the commission form of government, can approve any regulations that are written by the executive director and his staff.

Now I want to examine some of the specific laws and regulations that are in effect today, particularly as related to the management measures that I specified earlier. In 1984, all of Delaware's laws on fishing for everything except shellfish changed with the passage of much-needed comprehensive legislation. Some of the policies for the Division of Fish and Wildlife specified in this new act are: manage for optimum yield of fisheries, base the management on the best available scientific and socio-economic information and very importantly, manage the stocks as a unit throughout the range of the species.

In Delaware we recognized that with our 100 miles of coastline, we cannot be an entity unto ourselves in dealing with migratory fish, especially in regard to fish like the weakfish that range all the way from New England down to the coast of South Carolina. Another policy is to recognize the historical rights of fisheries. Economic efficiency cannot be the sole basis for managing fish stocks. Lastly, management measures should not be excessively costly nor should they duplicate other measures.

In regard to our Department's regulatory authority, most of the authority continues to rest with the Legislature. Our Division's authority chiefly consists of the ability to implement approved interstate fishery management plans. That means that once a management plan is approved by two or more states, we can implement it by regulation without going through the long, drawn out legislative process. A specific application of this regulatory authority is our participation in the Delaware River Fish and Wildlife Cooperative.

The Cooperative consists of two Federal agencies--the National Marine Fisheries Service and the U.S. Fish and Wildlife Service--the Delaware River Basin Commission, and the States of Pennsylvania, New Jersey, New York and Delaware. We meet periodically to oversee the preparation of fisheries management plans. Thus far, we have implemented a plan for management of American shad in the Delaware Basin. As you have heard in our talks today, the shad population in the Delaware is expanding. Estimates of the spawning populations over the last couple of years have been up around the half million mark, which is five to ten times what they were twenty years ago.

We also participate, as do the other Basin states, in the Atlantic States Marine Fisheries Commission along with all the other east coast states. Some of the plans produced through this interstate process include striped bass, summer flounder, shad and river herring, and weakfish.

Another management group we participate in is the Mid-Atlantic Regional Fishery Management Council. The Council's jurisdiction lies outside three miles from the State coastlines, as opposed to the plans written by ASMFC which pertain chiefly to inshore waters. Since striped bass don't recognize the three-mile limit, the Mid-Atlantic Council has prepared a plan to regulate fishing for this species so that it can be managed throughout its entire range.

Examples of Rules and Regulations

What are some examples of rules and regulations used for fishery management purposes or fishery conservation purposes in the Delaware Estuary?

1) Permits and fees. In Delaware, commercial fishermen are required to purchasea $15Ø license. It's $1,5ØØ for non-residents.

2) Size limits. I already mentioned that we have a 12-inch size limit for flounder. Usually, the purpose of size limits in marine fisheries is to increase the yield per recruit or to allow a greater proportion of the fish to spawn before being harvested.

3) Limited entry. Our Legislature decided to put a ceiling on the number of gill net permits we may issue in a year. Our gill net fishery by and large consists of about 1ØØ two-man operations. Landings might range from 1.2 to 1.5 million pounds a year. In comparison to some states this is a very small fishery and there are no big landing ports or major processing facilities. Still, the Legislatiure decided to restrict the amount of gear that could be used in this fishery to avoid conflicts between recreational interests and commercial interests over weakfish stocks. Another one of the gear restrictions the Legislature imposed is a 1ØØØ-yard net limit to be in effect April 1 through May 1Ø. No commercial fisherman can fish over 1ØØØ yards of gill net per day. Again, this measure was felt to be necessary to minimize conflicts between gill netters and recreational fishermen. There also are seasonal restrictions on netting in Delaware. For instance, no

anchored gill nets may be set after May 10. Since most recreational boating takes place after May 10, this helps minimize the likelihood of recreational boaters running through gill nets.

4) Area closure. All of the Delaware Bay, both on the New Jersey side and our side, is closed to trawling and has been since the mid-1960's. Trawls are very efficient gear. With today's technology, trawls are fully capable of taking vast schools of fish in one swoop. One could say we've opted for a more primitive form of fishing so that we can spread the harvest out among a greater number of users. The Pennsylvania Fish Commission on the other hand, allows no commercial fishing in the Delaware River, only recreational fishing.

Under the general topic of habitat protection and enhancement, the importance of wetlands as habitat and nursery areas for fisheries are well recognized. Our job as regulators is to maintain or enhance our present resource. In some cases, our role has to slow the rate of destruction as much as possible. Almost 10% of the Delaware coastal marshes have been lost in the last 30 or 40 years in spite of the best efforts of resource regulators. It is our responsibility to require the preparation of environmental impact statements on any application potentially impacting coastal resources.

It is also our responsibility to review permits for discharges. Since a discharge permit can be looked upon as a license to pollute, our role again is to minimize the potential threat to the environment. We have not always been successful in the Delaware system, but as you heard today, our record is improving and we have reason to be optimistic about the future of the Delaware estuary.

With some environmental issues, we become involved after the fact, as in oil spill assessment. Fish and wildlife agencies usually are required to pass judgement on any environmental impact statement and that is when we make our wishes known beforehand.

Enhancement

This is an interesting area that I haven't had the opportunity to participate in a great deal, at least not in the marine environment. One especially interesting approach is in the creation of wetlands. In Delaware thus far, the projects have been of a small, pilot nature.

Another management activity that could be considered under the topic of enchancement is the use of a radial ditcher in the open marsh water management form of mosquito control. The radial ditcher eliminates the need for a lot of spraying of costly and potentially environmentally damaging pesticides for control of mosquitos. Open marsh water management is commonly practiced in the New Jersey, Maryland and Delaware. It's a science unto itself, and something that could be discussed at great length. The basic idea is to allow the fish to move onto the marshes to eat the mosquito larvae, thus avoiding the use of chemicals.

Another method of enhancement is the planting of wetland plants in disturbed areas or areas filled with spoil materials. The reintroduction of wetland plants and creation of marshlands is a practice that is gaining wide acceptance.

Another enhancement tool that we're just beginning to look into in Delaware Bay is artificial reef construction. What do artificial reefs do? Well, we know they concentrate fishes by providing new habitat where it didn't exist before. If you have a smooth uninterrupted bottom, you're not going to find many sea bass or tautog because these are structure-oriented fish. If you wish to have a fishery for these types of fish, you must provide them with the required habitat. Artificial reefs are one possibility.

The National Marine Fisheries Service (NMFS) has suggested that we use artificial reefs as mitigation for destruction of subaqueous land. For example, the Army Corps of Engineers plans to fill 200 acres of subaqueous land at the mouth of Wilmington Harbor. The NMFS would like us to mitigate the loss of those 200 acres of wetland by building an artificial reef in Delaware Bay. Will the same species be found in Delaware Bay as at the mouth of Wilmington Harbor? The obvious answer is no. Clearly mitigation of this sort cannot be considered as mitigation "in-kind". But it is one tool available to managers.

Another enhancement technique, is artificial propagation and stocking. It's been used relatively little in marine waters in this area in the last 100 years, at least in regard to finfish. There is a lot of potential in the Delaware for restoration of the exterminated stocks of striped bass. There are indications that striped bass once were plentiful in the Delaware River back in the 1800's. For the most part they disappeared with the advent of the industrial revolution and its resultant gross pollution of the lower Delaware River. There is a small remnant population, perhaps even a small remnant spawning stock. There is some hope of restoration of this population because of a gradual improvement in water quality in the lower Delaware River. The stocking of fingerling striped bass is one tool that could be used to accelerate this restoration.

Another artificial propagation and stocking tool would be the transfer of seed oysters. This process involves moving the young oysters from the nursery areas up the Bay to the saltier, faster growing areas further down the Bay .

To sum up, what is the future of management in the Delaware estuary? I look for additional conflicts over time and space for limited resources. Not necessarily armed conflicts, like the Chesapeake Bay oyster wars, but conflicts nonetheless. What is the key to dealing with these conflicts? I feel it is interstate management. We cannot manage migratory fishes alone. It must be in conjunction with other states and other interested agencies.

If the states cannot provide the required management, federal intervention may become necessary to force the states to manage their fishery resources. A very recent example is the so-called Studds Bill legislation, HR-5492, requiring the states to implement the 1981 striped bass plan as amended or face federal intervention in the form of having a moratorium declared on their striped bass fisheries. This heavy-handed approach may become necessary with other species. The precedent has already been set. All this management will go for naught, however, if we compromise on environmental standards. Clearly, as regulators, we need to pursue management while continuing to be vigilant in protecting the resources we have inherited.

DR. SHARP: We now come to the last scheduled speaker and one who has been given a lot of blame throughout the earlier presentations that "Jerry will give us this and Jerry will give us that." He not only has the hard problem of being the last speaker but the one that everyone keeps deferring to.

I would like to point out, and would like to discuss this further in the panel discussion, that we are indeed very fortunate in the Delaware River Basin to have an effective multi-state agency like the Delaware River Basin Commission. It has tremendous authority and I think, as we will see, a very good success in the past of trying to handle potentially large conflicts between four states that share this basin.

I would like to now introduce Mr. Gerald Hansler, the Director of the Delaware River Basin Commission, to talk a little bit about the Delaware River Basin Commission's interests and concerns.

DELAWARE RIVER BASIN COMMISSION INTERESTS

Gerald Hansler
Delaware River Basin Commission

I'd like to refer to the Delaware River and Bay as "my river," but based on the number of people here, I think a lot of people feel that way. It was fun to be asked to attend this meeting to enhance the coffers of research institutions dealing with the Delaware Bay. We are not a research agency. The Delaware River Basin Commission was formed in 1961 by compact as authorized by the Constitution. The four states--New York, New Jersey, Pennsylvania, Delaware--passed identical legislation. This was probably the first time in the country where Congress didn't merely ratify a compact between states, but joined in the compact, with the United States as a full voting party. In the good old days, that was great because we had access to the Federal Treasury. Now things are a bit tighter.

The members of the Commission are the governors of each of the four states and a person appointed by the President. Historically, that's been the Secretary of the Interior. It need not be. Each of the members appoint an alternate member, usually one of the leaders in an environmental agency within their state.

The compact which created the Commission has tons of power and authority, but it remains latent until unleashed by a simple three-out-of-five vote of the members. This compact did not set water quality standards. It did not set effluent standards. It did not set creel limits. It did not say how we could allocate the withdrawal of water from the surface or ground or what we could do in the wetlands.

What it said is that this forum that was created, DRBC, could do that. The DBRC is not Jerry Hansler and his staff. It's five governments, and they are the ones that vote. I'd like to take credit for the cleanup of the Delaware estuary. I cannot. That was laid down in the late 1960's. A water quality mathematical model of the upper Delaware estuary was made, one of the first in the country.

Decisions were made to clean the estuary up. It was dirty. For four months of the year dissolved oxygen during the critical summer months, was zero. There was a statement made, and it wasn't a joke, that when pilots flew across the Delaware River approaching the Philadelphia Airport they would become nauseated. It's not that way any more.

The minimum dissolved oxygen averaged daily is up above about three parts per million now. The shad are coming back. They're finding more striped bass and even some spawners in the estuary between Trenton and Philadelphia.

In general, from a hazardous waste-toxic materials standpoint, we've got an estuary cleaner than a lot of others. We've been conducting fish sampling from Cape May-Lewes all the way up to Hancock, New York. How do we do this when we don't have a laboratory? We contract with state agencies and, on certain projects, with universities to obtain this information.

We look at PCB's, for instance, in shellfish and in fish all the way up to Hancock, New York. The highest concentration of PCB found in any shellfish analyzed, I think, was 48 parts per trillion. The EPA standard was 5,000 parts per trillion; now it's down to 2,000. By comparison, in the lower end of Long Island Sound they had shellfish samples with concentrations up to 9,000 parts per trillion.

So, contrary to some of the doomsdayers, I don't think the Bay and the River are getting dirtier. It's getting cleaner. That's being proven not just by measured water quality, but by the return of some important species.

The Commission does many things upstream which affect the estuary and Bay. As I said before, about 7.5 million people live in the Delaware Basin. About 22 million people use the waters of the Delaware. Close to 60% of all of New York City's water supply comes from the Delaware River. That's the 800 million gallons a day they're allowed to take out of the basin. They give us quid pro quo for that, though. They've got to release waters from their reservoirs to maintain a minimum flow at Port Jervis, the tri-state boundary between Pennsylvania, New York and New Jersey.

A funny thing happened, though, on the way to the forum, one might say. When the Supreme Court apportioned the waters of the Delaware in 1954, seven years before the formation of the Commission, they did it based upon the then-current hydrologic records. The drought of record was in the mid-1930's.

In the 1960's, a much more severe drought occurred. There was not enough water to go around. New York City got a bit hoggish. Things became tense. I think by the time they finally ironed out who was on first and who was on second, it took about four years and the drought was over.

The Commission saw this, and because a major keystone to our Comprehensive Plan for water supply--i.e., the Tocks Island Project--was shelved in 1975, they looked towards reassessing the Comprehensive Plan which drives the operation of the basin. The Comprehensive Plan also consists of everything that was in place the day the compact took effect in 1961.

If you were a city and took water out, if you were a waste discharger and discharged something when doing business, if you were a farmer, you had certain rights. The Comprehensive Plan consists of projects and programs to be developed in the future. The Comprehensive Plan consists of rules, regulations, standards and policies. These have the effect of law. They have the effect of law anywhere in the basin without regard to political boundary.

So, in the mid-1970's the Commission had to go back and reassess this Comprehensive Plan because one of the keystone projects probably would not be built in our lifetime, or at least in the foreseeable future. We looked at this because the compact allowed it. We also looked at the Supreme Court decree.

If the Justices in their wisdom had not made the right answers because they couldn't foresee a more severe drought in the future, the compact provided for a mechanism to reduce diversions out of the basin during drought warning and drought emergency. New York City would be cut from 800 down to 520 million gallons a day. That's not a goal, that's absolute. The valves are turned.

The New Jersey out-of-basin diversion, similarly, would be reduced from 100 million gallons a day down to 65. Right now we're in the lower half of a drought warning. New York City can take only 560 million gallons a day.

In addition, the diversions to the basin were lowered. This was to conserve water. Water conservation has to be practiced. We had a mini-drought in 1980-1981. The four governors, the mayors of New York and Philadelphia, and Federal representatives had a commission meeting on five days' notice and unanimously passed six pieces of water conservation legislation. That had the effect of law immediately, and it was implemented.

Another element in our Comprehensive Plan was the inclusion of additional storage to get us through dry periods, storage for both water supply and flow augementation in the river. About 50% of the recharge of an important aquifer in south Burlington-Camden-Gloucester County called the Potomac-Raritan-Magothy system is recharged from the Delaware River. If this recharge is salty, there can be permanent sodium chloride degradation of an important aquifer.

The final element of the Plan, the additional storage, is to modify projects where dams already existed. The Corps of Engineers has a large dam called F.E. Walter for flood control in the Poconos, and a fairly good sized but smaller dam in the Poconos called Prompton. There are also two other dams, a small industrial dam owned by Ingersol-Rand in the Merrill Creek area of New Jersey and the Cannonsville Project, the largest watershed being dammed up by New York City on the Delaware system. All of these would be modified to include additional water supply storage.

Before the Commission can approve any water project, public notice and hearing are required. Nobody can drill and operate a well anywhere in the basin that yields 100,000 gallons a day or more without DRBC approval. They can't take surface water in the same amount without approval. No one can discharge waste into the basin of 50,000 gallons a day or more without DRBC approval. Our yardsticks are the effluent and water quality standards that we have in our Comprehensive Plan.

The Merrill Creek Project is an example of how we look at what goes on downstream. We examined recharge of an aquifer in the Philadelphia-Camden area. We also looked at what goes on down in the shellfish beds. We had to take action in approving this project, to be built by a consortium of electric utilities.

There's a lot of water evaporated through cooling and much more is evaporated if you use cooling towers. We wanted them to make up low stream flows for the amount of evaporative losses. Before we could approve this project, we had to go ahead with a scoping study and invite comments from interested parties. We had to prepare an environmental impact statement. In that impact statement we had to indicate how the water would be pumped to Merrill Creek because it was a pump-storage project and how it would be released.

We received comments from the oyster interests and Dr. Hal Haskin. They didn't like the idea of taking water from April through June, which is an important time in the shellfish maturation process. We went back to use our computer models and found that we could draw from the river and release, so that in fact during dry years there would be more water released during this critical period than was drawn from the river. Or, to put it another way, there would be more fresh water flowing down over the shellfish beds than would have flowed down without the project.

Another interesting project was the so-called pump at Point Pleasant. I was sued twice on that project for the decisions I'd made. I thought I made them under the law and based upon the facts. DRBC won the first one at the Appellate Court. The next one went all the way to the U.S. Supreme Court. We won. I still think we have the facts and the law on our side.

One of the major issues on the Point Pleasant Project was one of fisheries, and it dealt with the Bay. It dealt with the American shad. There was testimony presented under oath to the effect that you're going to bludgeon and entrap and impinge and entrain the shad larvae on your intake screens. So we asked

U.S. Fish and Wildlife and the fisheries agencies for the best technology. They said to use Johnson-Wells screens. And they said, "But you're still going to kill some."

We found that you might bludgeon four or five larvae to death per day. And this brings up a point alluded to by Roy Miller, and that's harvest management. Roy, how many eggs are in a female shad approximately?

MR. MILLER: A couple of million.

MR. HANSLER: Originally I'm from the State of Washington. I saw what happened to the salmon industry when the commercial fishermen wanted 90% of the catch and the sport fishermen wanted 90% of the catch and the Indians wanted a 90% of the catch. They wanted, really, three times the amount they should have taken in a fair, sharing fashion.

We spent a lot of money in cleaning up the Delaware estuary. A lot of money is continuing to be spent on the waste treatment systems. I don't think it makes much sense to open up the upper river for spawning of an invaluable species if the fish management agencies aren't going to take the bull by the horns and better control the commercial and sport catch.

I've heard people brag, "I got 18 shad today and 12 of them are female, and boy, is the price up." These are rod and reel sport fishermen. I hope that we don't come to the point that fisheries people did with salmon in the Northwest, because what we do upstream is important to the commercial and sport fishing in the Bay. I hope we don't ruin it.

Pennsylvania, to their credit, has gone to a creel limit for shad, six per person. New Jersey has none. New York has none. I don't think Delaware has any. I would hope that, as Roy Miller has said, that by using the good offices of the National Marine Fisheries Service, the Fish and Wildlife Service, the four states' fishing agencies and DRBC, we can come to agreement within the basin, so that someone does not have to go the Congressional route and have something ordered from above.

Another example of impact on the estuary is in how we direct the cleanup of pollution. We remove chemical contaminants. We remove organic contaminants that cause the depletion of dissolved oxygen. We go to industry and say there can only be tenths of pounds or pounds per day of chlorinated or halogenated hydrocarbons, which are very toxic to marine fisheries.

At the same time we direct cities like Philadelphia, Wilmington and Trenton to add chlorine to their treatment plant effluent. One plant in Philadelphia adds three tons of chlorine a day to their effluent. Disinfection, they call it. One of the harshest things you can do to an aquatic or an aquatic/marine environment, I think, is to require the addition of these chloramines. Free chlorine evaporates in a hurry, but halogenated hydrocarbons are pretty tough.

There have been some papers written regarding the impact of this on the Chesapeake Bay. They can't blame it entirely on chlorinated effluents. But they believe there is a direct relationship between excessive chlorination and the diminution of fish and shellfish activity in particular areas of the Chesapeake.

The Commission is working now towards a two or three year study to determine the effects of this disinfection. Hopefully, we can go to seasonal disinfection or maybe remove it altogether. I came up through the health protection chain and believe that we should chlorinate where it's necessary to protect public health. I think it's environmental masochism to do so if protecting public health is not necessary.

We set wetland policy, upland and marine. Nowhere in the basin can there be a 25 acre wetland developed without approval by DRBC, even though it might have been reviewed and approved by the State of New Jersey or Delaware or a federal agency such as the Corps of Engineers or EPA. The policy pertains to wetlands high in the hills. This has been on the books for about five years. We've used it six or seven times. It's been beneficial in every respect. The development continued, but they did it by mitigating or actually improving the conditions over what existed originally.

We have flood plain regulations that also relate not just to the upland, but to tidal areas. We're a small outfit, probably 25 professionals. That's the way it should be. If you added up the professionals working in water regulation--two EPA regions, four state agencies, Corps of Engineers, U.S. Fish and Wildlife, Coast Guard, on and on--it'd probably number over 3,000 in the basin. The framers of this compact said that this Commission should be for overview and policy setting and should make its decisions without regard to political boundary. This has worked quite well.

What haven't we done? We haven't put in a good monitoring system, nor have the states basin-wide, for hazardous priority pollutants--some 134 of them. We had a beginning by looking at what wound up in the highest levels of the marine-aquatic chain--i.e., fish and shellfish.

We haven't plugged other gaps in monitoring. We have no acid rain program. We haven't developed local flood warning systems, although we're authorized to do that by the compact. We haven't because there's only so much you can do in a year, and the people that dictate what we do are the four states and the Federal Government. Our process for what we do in a year occurs this way:

First, we lay out things that the compact indicates we shall do. The Commissioners or the governors then lay out priority things they think we should do. We put them on a blackboard. They might number 40. Then they tell us what money we get each year. I've got to go to four state legislatures and Congress for a budget for a staff of 40 people. That's called quintuple jeopardy. Anyway, we know what we'd like to do. What we do depends upon the resources we get each year.

The compact also says that we can work outside of the basin if we're invited to do so by one of the members. And this actually happened in Delaware where Governor DuPont said, "Why don't you work out the flood plain mapping for the entire state of Delaware since you're doing it inside the basin?" So we did that.

QUESTION: Are we better off or worse off to face a drought situation now?

MR. HANSLER: Much better off. During drought of the 1960's, the low flow at Trenton was 1,100 cfs. If we had a recurrence of this drought, we could guarantee a minimum flow of 2,500 cfs for a four year period.

PANEL DISCUSSION

DR. SHARP: What we will do now is ask the speakers to come up and talk a little bit about what we see as needs for future research, etc. for the basin, for the Delaware estuary.

LYNN EDGERTON: I've been listening all day, and no one has mentioned the Coastal Zone Act of Delaware, which I think is one of the more interesting pieces of coastal protection legislation that has been passed in many years. It's my understanding that it was passed in 1971 as a result of considerable debate among Delawareans with respect to what they wanted their Bay to look like. The primary goal of Delawareans with respect to the Delaware Bay was to preserve it for recreation and tourism.

In so doing, the Delaware legislators prohibited certain kinds of heavy industrial uses in the coastal zone of Delaware and prohibited new uses. I would be interested in your comments, any of you who would like to comment, on what impact this Act might have had in helping to preserve the oyster population, the recreational fishing, the commercial fishing and other uses of the Bay, because that was the purpose of its passage.

Of course, one of the difficult things is once something is already polluted, you say, "Oh, we can see why it's polluted." But when you have something that's still clean, people tend to think, "Well, it was always that way." Whereas in reality it may be the result of Governor Russell Peterson's commission and a lot of Delaware Legislators who studied what Delawareans wanted to do with the Bay in 1971.

So I wanted to open the floor for any comments by any of you with respect to that very important legislation, which in fact preceded the Federal Coastal Zone Management Act of 1972.

MR. MANUS: I believe there's been three or four challenges to it, but the integrity of the Delaware Coastal Zone Act remains. I might add that New Jersey also has a Coastal Zone Management Program that's built around three laws: The Wetlands Protection Act, The Coastal Area Facilities Review Act, and The Waterfront Development Act. The three of them combined do what The Delaware Coastal Zone Management Act does, and then there is the federal legislation on top of that. So whenever development does take place, it will take place in light of those pieces of legislation.

MR. HANSLER: Insofar as the New Jersey Coastal Zone Management Plan for the estuary portion of the Delaware, the Delaware River Basin Commission was subcontracted to do a portion of that based upon what we already had in our Comprehensive Plan and what was protected. There was not a redundant planning process. The Commission wove in something that existed and used that as a background.

I have written the Department of Environmental Protection Commissioner in the State of New Jersey regarding the proposed coal reloading operation in the lower Delaware Bay. That does concern some people. That concerns the DRBC staff. He's holding in abeyance any response to that because it is, I guess, going up to the Supreme Court in the State of Delaware.

That issue, again, is a challenge of a coastal zone management plan. We're not averse to development. In fact, our Comprehensive Plan says that we shall approve any projects that do not conflict with our Comprehensive Plan. But I think the Commission has put in the necessary wetland, water quality, and related land use regulations and standards that give us a good yardstick in our Comprehensive Plan for any proposed development in Delaware Bay.

DR. HASKIN: I think the Coastal Zone Management Plan was a key step in the preservation of the shores of the Bay. It came along at just the right time. As I recall, there was a strong move at that time for an oil refinery to be set up on the Delaware side.

Partly I think, because of the legislation, some of our people were encouraged to move the atomic reactor, which was scheduled to go in on the north side of the Cohansey River in Greenwich, at least ten miles farther up the Bay. We were able to work with that because of the legislation. So we were very glad to have that step as an example of what could be done.

MR. MILLER: That tract of land that I believe was referred to was 2,000 acres owned by Shell Oil. Most of that will become--some of it already is--a wildlife refuge. You might say that the refineries and heavy industry are now confined to north of the Chesapeake and Delaware Canal. If the Shell Oil tract had been developed, that would have opened up the coastal zone to other industrial development, which was largely prevented by the passage of the Coastal Zone Management Act. So it has been with us for 14 years. Perhaps that's why we overlooked mentioning it specifically today. It's accepted as a given.

DR. SHARP: Let me, with that, make a comment. I think you've heard a number of people today make a statement that perhaps some people here didn't appreciate as fully as those of us working on the Delaware. That is that the Delaware is not hopelessly polluted. It appears that most of the lower Bay has never had much pollution impact. A lot of the upper reaches of the estuary, the municipal regions, have had a tremendous improvement in water quality in recent years.

I think this leads to an interesting situation--I tried to make a list of Bay uses (Exhibit 1). The Delaware Bay has diverse uses today. There are a number of different purposes that for the most part do not conflict with each other. Let's not say they're totally non-conflicting, but they are uses that can seem to be accommodated in a somewhat compatible fashion. We may have tremendous potential conflict with some future uses and these uses are, as you can see, quite diverse. But I think it's interesting to note that the present uses today have at least some level of compatibility.

DR. HASKIN: I made a big pitch that the Bay was in fine shape and that I thought it had been unfairly treated in the past by claims that we have a grossly polluted estuary here. I tried to point out that we had a important industry which depended on pretty high quality water. But I have to weasel just a little bit to tell you that in looking at ways to increase the production of oysters on our oysters beds, you have to make the best use of those seeds that come from those uppermost seed beds.

There was a time during seed shortage back in the 1950's and early 1960's when our industry was almost totally dependent on taking seed from the Arnold and Cohansey region of the Bay to bring down into the planting grounds. Now we find that some of those uppermost seed beds are holding some very old oysters that are not growing very much.

In our present demand for larger seed to come down for shorter periods of time below that southwest line, we're getting quite concerned about the growth rate. With the production of a lot of chlorinated substances, perhaps by our power plant a few miles above that, and not knowing precisely what's coming down that river, we are very anxious to get some good chemistry going in that part of the Bay.

Tell us whether we really do have a problem so we can pinpoint it and perhaps do something about it. We had a new chemist come on board November 1 and is beginning to get to work in that area. What we would like to see out of this is more effort and more support for effort in that area.

QUESTION: You mentioned, Hal, that things like chlorine can be released on different schedules. Is that correct?

DR. HASKIN: Yes.

QUESTION: So, in other words, this is something that could be optimized to minimize the harmful effects?

DR. HASKIN: There are other ways of keeping the fouling out of the tubing at a power plant than chlorination.

EXHIBIT 1

PRESENT USES

Water disposal

Transportation

Cargo transfer

Bulk cargo transshipment

Cooling water

Mineral extraction

Commercial fishing

Sport fishing

Fish propagation

Swimming and boating

Waterfowl preserves

Potable water

DR. SHARP: An interesting point here. Jerry Hansler mentioned the subject of the chlorination of the sewage water. There's also a lot of chlorination of cooling water. The permissible withdrawal of once-through cooling by Delaware River Basin Commission standards is such that if all the permissible withdrawals were taken, it would almost be double the low river flow at Trenton. So you could make a somewhat simple-minded back-of-the-envelope calculation that says the entire water of the Delaware estuary could go through a power plant for cooling in the transit down the estuary. Not all of this water is chlorinated, and not all of it is used all the time.

MR. HANSLER: As a matter of fact, the Commission has been trying for two years to revise its year-round disinfection policy to go to seasonal disinfection or disinfection only when necessary for public health protection. It's not a secret that the State of New Jersey DEP does not like that idea; they want to disinfect year-round.

But it takes a three-out-of-five vote of the members of the Commission to revise a policy or make a new policy. What we're trying to do is get additional technical information through research and study to support the right decision. Not necessarily our decision or their decision, but the right decision.

Insofar as adding chlorine, if you've got 3,000 cubic feet per second, which is low flow in the summer at Trenton, that's 2,000 mgd. Another 1,000 mgd at the Schuylkill River and the other sources in the upper estuary brings the total to 3,000 mgd. There's over 1,000 mgd of treated municipal effluent alone that go into the estuary.

This means we're sanitizing one third of the flow. If you add the industries and the power plants onto that, it gets to be a pretty scary thing. At the same time we're trying to control halogenated hydrocarbon effluents from industries down to the tenths of pounds and pounds per day, we're adding tons of it from municipalities. For what purpose?

QUESTION: You've been discussing seasonal chlorination and effects on oysters. Does the panel have any feelings on dechlorination with sulfur compounds, sulfur dioxide?

MR. HANSLER: I do. It's awfully expensive to chlorinate and dechlorinate when you're talking about flows of, we'll say, a billion gallons per day. What we want to look at is protecting the shellfish beds from a bacteriological and pathogenic standpoint. But the discharges are far up the estuary, and our 17 years of historical data lead us to believe that even when there wasn't adequate treatment and chlorination, they still harvested the oysters down in the planting beds. There might have been problems in the seed bed, but it was like depuration. They were moved from Arnold's Bed.

With the advent of secondary treatment at Wilmington where there is about 90% removal in the summer, and the southwest plant at Philadelphia that gets over 90% removal of organic matter, the bacteria levels in the discharge drop way down without chlorination. When you look at the completion of Philadelphia's southeast plant, its northeast plant and the Camden plant, all of which are under construction--and the two Philly plants should be completed by the end of this year--the estuary is going to clean up tremendously.

When you do that, why treat the remaining 10%, the tough part of biodegradeable organics, with chlorine?

QUESTION: That may be fine for municipal plants, but power plants still have a problem.

MR. HANSLER: With power plants that's a different treatment technology and they treat for different things. They're not trying to kill bacteria; they're trying to kill organic matter or plant matter that foul their tubes.

Another fallacy for year-round chlorination or even seasonal chlorination in the Delaware estuary has to do with combined sewer overflows. Every time you get a half-inch of rain, the sewers discharge a combination of storm water flow from the streets and sanitary sewage. It doesn't take a scientist to tell what's out there in the river from those combined sewer overflows. And, practically, you're never going to solve that problem.

In the city of Philadelphia, there's really no other place to put it. They can screen it and get the lumps out. They can hit it with chlorine. But I think most scientists in this room realize you don't get a complete pathogenic or bacteriological kill by chlorinating raw or even primary treated sewage.

I know we looked for help whenever we proposed a new or revised standard. We held a public hearing on a proposed standard to not require year-round chlorination, and there wasn't one person from the fisheries agency that testified. We need people from the scientific community, not just bureaucrats like ourselves or from state pollution control agencies, to put the facts on the table.

DR. SHARP: One other comment on dechlorination. Dechlorination will remove the total residual chlorine, but this disappears very rapidly on its own. Dechlorination probably would have little or no impact on some of the halogenated organics that are formed, which may be the real problem. So it's very unlikely that dechlorination can really solve the problem. We have tried some monitoring of total residual chlorine right in the effluent of sewage treatment plants, and you can't see anything within several hundred yards outside the plant. So the total residual chlorine that we get rid of by dechlorination is not really the problem.

QUESTION: I assumed that the industrial chemical wastes would have been rather considerable. You mentioned just PCB's and petroleum hydrocarbons. Did you say anything about the industrial wastes, considering that the DuPont Chemical Company has a long history in the Delaware area?

DR. SHARP: In our research efforts we have not looked specifically at some of the compounds there. The industrial effluents are very heavily regulated and I think Jerry can probably speak to that.

MR. HANSLER: I was with EPA Region II before coming to DRBC, and there was an attempt nationally to get a handle on all waste discharges, especially industrial waste discharge. Through the 1899 Refuse Act, we initiated a permit program with the Corps of Engineers where we did all the technical work and they actually issued the permit. That was overtaken by the passage of The Clean Water Act in 1972, where the approach was that there would be national effluent standards, and a permit would be based on those or a higher level of removal necessary to meet a water quality standard.

During the first couple of years of that program, we still had to get permits out. We had a great system. We had guidance. We had technical documents. We'd go through technical documents and look at the impact on the stream, and then at the specific discharge case-by-case.

This was done with DuPont's Chambers Works Plant. We put out a proposed permit. We gave an opportunity for public hearing. Probably the only entity that would have asked for a public hearing was DuPont, because the permit was pretty stringent. They didn't.

We issued the permit. They didn't contest it through a formal adversary hearing or go to court. They spent probably close to 120 million dollars on waste treatment at Chambers Works. If we'd taken a lower level of treatment, it would have been 60 million or even a lower level, maybe 40 million.

When the final EPA effluent standards came out for that type chemical plant, they were much less stringent than what we had been able to obtain with DuPont. DuPont was a good corporate environmental firm.

On the Delaware estuary all of the municipal waste treatment requirements are driven by DRBC standards, not EPA, because ours are more stringent. About one-third of the industrial standards are driven by DRBC, and about two-thirds by EPA requirements. The compact says, "A state or federal agency can have a more stringent standard in the Basin, but not less stringent than DRBC." So it's a pretty good system.

QUESTION: So you're saying that it's been pretty well cleaned up as far as industrial wastes are concerned?

MR. HANSLER: The industries have cleaned up much faster than the municipalities. The municipalities waited in line for 75% money and to form regional systems and to sue each other because they didn't want to form regional systems. It's been like pulling teeth.

For example, when the Philadelphia southwest plant went on line, the minimum dissolved oxygen in the estuary increased by 20%. And when these next three plants go on line--southeast, northeast and Camden--you're going to see another marked incremental increase. Not a mere blip at a time.

QUESTION: The sediments were cleaned up also? There were no residuals left in the sediment?

MR. HANSLER: Well, we don't monitor that; that's one of the gaps in our monitoring. But we do monitor what the Corps digs up, and they have to maintain a channel. Their dredge is working constantly all year long. The sediments are analyzed for toxics before they can deposit them on land areas. Often those land deposition areas might drain into a wetland or could contaminate a groundwater aquifer. The deposits have been fairly clean. They're not an adverse health impact or ecological doomsday impact at this point in time. They're not like the PCB's in the Hudson.

QUESTION: If the Bay is relatively clean and relatively healthy now, are there pressure points that you recognize in the future? Are there places where you see possible degradation happening if certain uses grow?

DR. SHARP: I think one preliminary thing to say is that the Delaware estuary is certainly not pristine. The Delaware estuary is cleaner than it once was, and we're trying to convince people that it's not hopelessly polluted.

There are certain problems with the estuary. A thing that has bothered me for a long time is that there is a great hue and cry right now on the Chesapeake Bay where the water quality is deteriorating and the fisheries are declining. Many of the same species of fish that are being documented as declining in the Chesapeake are declining in the Delaware on the exact parallel track. If you look at a century-long landing record, you see a beautiful parallel nature to decline in landings of shad, a decline in the harvest of oysters and a decline in a number of species of fisheries.

It's clear that the water quality explanation of the problem in the Chesapeake is not either totally correct for the Chesapeake nor totally translatable to the Delaware. It's clear that a number of species that are desirable to be harvested in the Delaware can probably be enhanced with proper management. It's clear that a lot of the decline in fisheries all over the east coast of the United States is due to habitat destruction and overfishing as much or more so than to "pollution."

So I think a lot of problems in the Delaware are not necessarily just related to water quality. They demand a better understanding of a system like this to better manage it. Certainly one of the clearest things is that we do need a much more rational approach for fisheries management and fisheries enhancement.

MR. HANSLER: I think there are some areas we've got to focus on. Hal mentioned the massive chlorination at the power plants. I mentioned the chlorination at municipal plants. I think we've got to get ahead of the game and look at non-point-source impact.

We've done some studies on the Delaware estuary. Zone I of the Delaware is from Trenton all the way up to New York State. Zone II is from Trenton down to about Bristol. The amount of organic matter measured by five-day biochemical oxygen demand going into the Zone II today from treated municipal-industrial sources is 34,000 pounds per day dry weather flow. At the same time that organic demand from non-point-source is 170,000 pounds per day.

Clearly, our target has to be non-point-source. Also, we have to look at the toxic material, the nonbiodegradables in non-point-source runoff. In our fish flesh sampling we found one contaminant that was pervasive everywhere in the estuary from the LeHigh down. It was chlordane.

Now, chlordane hasn't been used for about the past 10 years. But 10 or 12 years ago what turf builders put in their lawn material for fertilizer and weed control was chlordane. That stuff doesn't biodegrade. You're always going to have it flush off your lawn. Fellows who work for me say they still have patches on their lawn where nothing can grow, and that's probably where the spreader ran too long. It's the chlordane.

The pest exterminators still use chlordane, in going around the foundations of your houses for termite control. So there are still some important man-made chemical constituents that we've got to look at.

MR. MILLER: There are two areas that I wanted to point out that requires future vigilance. Although the pollution block has been considerably reduced in time and space and area, we're still reporting zero DO at times during the summer in the Philadelphia area. That's driving the recovery of our anadromous fish stocks. That is, the fish that spend the bulk of their lives in the ocean and go up in the fresh water to spawn.

Until the pollution block is cleaned up further, until we get three or four parts per million as an instantaneous minimum, we're going to continue to have depressed anadromous fish stocks, even though they're recovering over what they have in the past.

Another thing I wanted to bring up is very recently I sat in on a permit review for a firm that wants to haul toxic wastes from the Philadelphia area and incinerate it off the Delaware shoreline 120 miles off their shore. Our Delaware Congressional delegation came out the other day very strongly opposed to this proposal for a lot of reasons. One reason that scares me is that in their pilot program they are proposing to haul PCB's and DDT. We're talking about a million-and-a-half-gallon boat. What if there's an accident? A spill? A line rupture? What if there's heavy weather and they have to jettison their cargo on the way out? What if they burn it too soon?

There are so many "what if's" it scares me to death. Material like this being hauled in bulk day-to-day would be a disaster of the first consequence if it were to be released into the environment. It could shut our river down for commercial fishing just like the Hudson and the James.

MR. HANSLER: I'd like to comment on the DO matter. You in the audience might have heard two different stories on minimum DO in the estuary now. Roy said at times that it gets to zero during summer. It does, instantaneously. I said the minimum daily average is between 2.6 and 3.0 ppm. That's true because of the diurnal range of dissolved oxygen. Noon is the high point, when there is high photosynthesis. Probably 3:00 or 4:00 in the morning is the low point.

Regarding DO, The Clean Water Act says, "4.0 ppm DO instantaneous," which is the so-called fishable, swimmable standard, with the caveat "where achievable." If we implemented 100% organic removal of municipal-industrial wastes in the Delaware estuary we could not reach 4.0 ppm instantaneous because of the non-point-source load.

DR. SHARP: Let me point out one thing. I tried to stress earlier that the Delaware has incredibly high nutrient enrichment. We don't see eutrophication problems. Another twist to that same thing is that perhaps this very high nutrient enrichment is being used in a beneficial fashion to feed the fisheries, maybe not only of the Bay, but of the coastal water as well. It's a type of thing we're going to have to understand because we are at the stage in technological development where we ought to be able to translate from a system like this to other estuaries and start really engineering estuarine systems.

I'd like to put up a couple of points here. I tried to take notes throughout the presentation today of some of the research needs. The previous exhibit I showed was the present usage and I stated that the conflicts in the present uses are not great. Future uses could have much greater potential for conflict. So, really, one of the points here is use conflicts and resolution. Even before that, we need a better survey of the present uses.

It was very interesting--in trying to get this ready for today, I went to the Governor's office and said, "We would like someone to come and talk to this panel in Washington about the value of the Delaware estuary to the State of Delaware." After about a month of thinking it over the fellow I talked to in the Governor's office got back to me and said, "Well, we don't think anybody knows."

I think the reality of the case is that the Delaware Bay has been neglected in many ways because not many people really thought about the multiple value of the Bay as it is used today. We have had several recent cases where proposed future uses have created tremendous potential conflicts.

I think there are a lot of very important points on future use that do create conflicts. The main things I've listed here under these research needs (Exhibit 2) come mostly from the technical presentations this morning on research needs to better understand the system for future use and for continued present use.

There are sometimes problems in information on economic value of Bay uses. Andy Manus, in trying to get information on the economic value, went to the Barcroft Company in Lewes, Delaware (magnesium extraction). A friend of mine who works there called me and said, "We're not going to tell these people what they want to know because we're afraid they're going to try to slap a tax on us. If we have a value using the Bay, they might try to tax us."

EXHIBIT 2

RESEARCH NEEDS

Effect of rising sea level.

Effect and cause of bottom instability.

Effect of local winds, sea level rise, Chesapeake and Delaware Canal on circulation.

Refinement of applied Princeton model.

Quantities and effects of chlorinated organics.

Clearer picture of benthos.

Food chain dynamics.

Better estimates and enhancement of fisheries.

Good survey of estuary use and value.

Use conflicts and resolutions.

Better fisheries management cooperation.

Enhancement of fisheries and wetlands.

Monitoring program for entire estuary.

So I think there is a reluctance on the part of some users to have a value put on their use because of the fear that this is going to be taxed.

MR. HANSLER: On your point of conflict resolution--and Roy Miller brought it up--about moving a million-and-a-half gallons of mixed PCB's and dioxin or DDT down the channel and burning it 106 miles out, what the Coast Guard allows in the deep water lightering operations is important. It's one thing for coal and another thing for soy beans.

There was a project proposed in the estuary by Dow Chemical. They wanted to take nine different old seaports they had on the east coast that were falling apart where they loaded on toxic chemicals and build one good fixed station someplace. So they selected the Delaware estuary between Philadelphia and Trenton.

Anybody can apply to us for any project, and they did. We felt that there were major environmental consequences and we would have to prepare an environmental impact statement. We prepared draft and final environmental impact statements. We held a public hearing on the proposed docket decision. Three of the five Commissioners to the DRBC wouldn't vote on it. So Dow Chemical took their ships someplace else. I don't know if they're down in Norfolk or up in Boston, but they're not in the Delaware. But they had a fair shot, and we used our regulations in our Comprehensive Plan as a yardstick.

Probably the key factor was the last use you had on your other slide, Jon, potable water supply. Why risk an ocean-dumping vessel filled with pesticides running into the Taconey-Elmira Bridge pier or the Bristol Bridge pier and rupturing? These locations are upstream form the Toursdale intake, which serves about three million people.

We made a risk analysis. In looking at use and conflicts they all look at risk analysis. I think that is going to be an important thing for the future.

QUESTION: I wonder if someone would comment on the loss of wetlands around the Delaware Bay? Have you got any statistics as to rate of loss?

MR. MILLER: Well, the number I quoted was 9% loss between 1937 and 1971, since the Coastal Zone Act, on the Delaware side. That's of the tidal wetlands, coastal wetlands.

MR. HANSLER: There was some wetland loss to provide for Corps of Engineers dredge spoil. Again, it's competing uses. Everybody wants navigation and they want economy in the area, so they have to put dredge spoil somewhere.

The latest project that we reviewed was to put a new pier in Camden. There was dredging that had to be done. There would be disposal in two areas of a wetland. It actually improved the area tremendously, but the requirements there was one-for-one; for two acres they tore up, they had to make two other acres somewhere else in the same area. I would imagine the new area was probably better than the Camden waterfront.

On that note, the contractor did not follow the plan and he ruined two acres that he shouldn't have ruined. So the applicant had to go out and find two additional acres, plus DRBC fined the applicant $6,500 for violating our permit. There is enforcement.

There's been a debate at Trenton when Interstate 295 is completed as to whether to put it on stilts or on fill. I'm sure if they put it on fill, there will be a requirement of one-for-one marsh creation. If they put it on stilts, they really won't be using any of it.

QUESTION: Has there been any studies on just the changes in the status of wetlands that might not be attributable to direct human activities, such as change in sea levels?

DR. SHARP: I don't think that's been looked at. There have been some recent concerns. In fact, one of the first points I've got up here is what the effects of rise in sea level would be on the wetlands. There is a considerable potential effect.

One of the approaches we've tried to take on our effort here is to try to look at how this estuary works on a large scale system with the idea that we can hopefully begin to provide the type of information for future questions rather than, as is so often the case in environmental matters, answers for questions from yesterday.

DR. HASKIN: May I have one comment on this rise in sea level question? I'm puzzled by the implication here that the rise in sea level would have a destructive impact on the wetlands. My concept here, based on studies of Redfield in Barnstable Harbor is that the wetlands are landbuilding marshes. Without that we'd have the sea back in the woods somewhere.

DR. BIGGS: First of all, with regard to your comment about natural loss of wetlands due to coastal erosion, we're losing about 200 acres a year to natural processes in Delaware Bay.

With regard to the other question, the sea level rise question, the following is relevant: The marshes in Delaware Bay are 75-80% inorganic water. They are not a peat sort of marsh like one might think of in Barnstable Harbor in New England, which might be 90% organic matter. These are more like 20 or 30% organic matter.

Therefore, inorganic sedimentation is the principal process by which the marshes accrete vertically. The question is, what is the absolute rate of vertical increase that can be achieved given the suspended sediment concentration we have at the present time?

If the maximum amount of inorganic sediment that can be put on the marsh is the equivalent of 1.0 centimeter per year rise in sea level, and in fact sea level rise is 1.4 centimeters per year, then in fact the marsh would be drowned. So the marsh will not grow in response to any rise in sea level. It'll only grow in response to a rise in sea level with which it can keep pace.

At the present time Delaware salt marshes are building as fast as sea level is rising. The question is, is the rate of sea level rise going to remain as it is at the present time? I don't know the answer to that. Can the marshes keep pace with an increased rise in sea level? I don't know the answer to that either.

MR. HANSLER: If they're building at a rate equal to sea level rise, why are you losing 200 acres a year?

DR. BIGGS: I suspect that the principal source of the sediment that's causing the rise of the marsh is in fact the erosion of the base of the marsh. The marsh face is retreating. The material that's eroding is cycling through the tidal channels back up on to the surface of the marsh in back. That's helping it to keep up with the rise in sea level.

That's in part why I couldn't answer the question about bulkheading the face of the marsh. If you bulkhead the face of the marsh and all that mud on the face is now closed off to the marsh, I don't know that the marsh would keep pace with the rise in sea level. I have no idea.

DR. HASKIN: Bob, isn't that a small fraction, though, of the circulating sediment in Delaware Bay? With every northwest wind that blows, you're stirring up that fine sediment that you were talking about in the sloughs down the river of the Bay. Isn't there much, much more than you could account for than just in the face of the marsh?

DR. BIGGS: Yes. The amount of material that's eroded from the face of the marsh we've estimated is about 20% of the total material that's applied to the estuary. It may be the 20% that helps the marsh keep pace with the sea level rise. I can't answer that question.

QUESTION: Isn't it true also that as the marshes grow, as the sea level rise, particularly if it rises rapidly, the marshes will tend to grow inland?

DR. BIGGS: Yes.

QUESTION: And we draw a line on the map and say, "This is marsh on that side, and this is dry land on that side." We maintain that line, and the marsh is being lost from the other end. Essentially we're limiting the growth of the marsh with sea level rise.

QUESTION: This question is always very interesting to the National Marine Fisheries Service. We've always been faced with an apparent anomaly. In the Gulf of Mexico where we've had losses in wetlands, developers always pointed out that the shrimp catch is actually increasing each year. One of our researchers down there has an interesting theory that as you increase the amount of interface between water and the marsh area, you actually do increase primary productivity, and secondary productivity, up to a point. Once you've passed that point and the interface decreases, it like a checkerboard. You can only increase interface so much, then you pass the point of no return, and your secondary productivity quickly drops.

In a number of areas we haven't reached that point yet. So we're losing marshes and we're actually accelerating secondary productivity.

DR. SHARP: Let me make a last point. I tried to stress that the Delaware estuary was exemplary in that it gave us some real advantages for study that probably make it possible to learn things from this that we can apply to other estuaries. I also alluded to the point that it had some real advantages of an exemplary nature for management. I would just like to stress these.

One very important one is that the line between Delaware and New Jersey and the Bay runs up and down the Bay. If you contrast this to the Chesapeake Bay where there is a line between Maryland and Virginia running at right angles to the axis of the Bay, we have the full ecological range of the Bay shared by the two states. So in many ways Delaware and New Jersey share the Bay equally, at least in terms of not one state having the spawning population and the other one adult population of oysters and crabs.

Upstream, Pennsylvania and New Jersey also share the river somewhat equally in that both states are dumping into and pulling out of the river. You don't have one state like Pennsylvania pouring things into the Susquehanna and not being concerned with what happens on the other end of it, as occurs in the Chesapeake Bay. There is a natural, forced geographic compatibility between the three states, or the major ones, on the estuary.

The third point here is that we have a successful function in the Delaware River Basin Commission that really takes the interest of four states and tries to balance these decisions on use of the estuary. I think if you look at other estuaries that this is exemplary.

I remember talking to a friend at San Francisco State University when I was visiting there recently and commenting that in many ways they have a much simpler thing in the San Francisco Bay estuary because it's all within one state. I quickly learned that the conflicts between county and state and municipal agencies in California were far more severe than those between the four states in our estuary. So I think that the DRBC is a rare management tool in trying to get compatibility.

This estuary is easier to understand, I think, than most. This is why I think it's exemplary for study. I think we've started--it certainly is far from completed and far from giving us all the answers--a relatively effective, large-scale cooperative research effort. We're trying to put together efforts from various institutions trying to work closely with the government agencies in the area.

I think in many ways the Delaware, hopefully, can have some national lessons for other estuaries. So with that advertisement, I will close.