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This report contains papers presented at a seminar on Long Island Sound held on May 10, 1985 with the objective to bring to the public attention the important research and management issues in the Sound. The 10 papers address the natural, biological, chemical, geological, and physical processes that characterize Long Island Sound; the status of the Sound's living marine resources; the effects of humankind on the Sound environment and living resources; and management problems.

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Seminar Series No. 3

Long Island Sound: Issues, Resources, Status and Management Seminar Proceedings

January 1987

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

Long Island Sound: Issues, Resources, Status and Management

Proceedings of a Seminar
Held May 10, 1985
Washington, D.C.

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Under Secretary for Oceans and Atmosphere

NOAA Estuarine Programs Office
Virginia K. Tippie, Director

LONG ISLAND SOUND

Environmental Status and Management of Living Resources

an
ESTUARY-OF-THE-MONTH
SEMINAR

presented
at the
U.S. Department of Commerce
14th & Constitution Avenue
Main Auditorium
Washington, DC

May 10, 1985

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by
THE NOAA ESTUARINE PROGRAMS OFFICE
and
THE U.S. ENVIRONMENTAL PROTECTION AGENCY

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Washington, DC

January 15, 1986

PREFACE

These proceedings are from a seminar on the status and management of living resources in Long Island Sound. The seminar, sponsored jointly by the National Oceanic and Atmospheric Administration's (NOAA) Estuarine Programs Office and the U.S. Environmental Protection Agency's (EPA) Office of Marine and Estuarine Protection, was held in the main auditorium of the U.S. Department of Commerce on May 10, 1985.

The Estuarine Programs Office is a relatively new entity within NOAA. It was established in October 1984 and received formal approval in early 1985. The mission of this office is to coordinate studies that involve the Nation's estuaries, emphasizing interaction between NOAA, other Federal agencies, State agencies, and the academic community. This coordination has led to extensive planning activities for some of the Nation's estuaries, including Chesapeake Bay, Buzzards Bay, Narragansett Bay, Puget Sound, and Long Island Sound.

The seminar was coordinated by Dr. J.R. Schubel, director of the Marine Sciences Research Center at the State University of New York at Stony Brook. Dr. Schubel developed a program that included ten speakers who addressed the natural, biological, chemical, geological, and physical processes that characterize Long Island Sound, the status of the Sound's living marine resources, and the effects of humankind on the Long Island Sound environment and living resources.

The speakers also addressed the kinds of information needed for effective management of the Sound and which of those pieces of information are currently missing. They discussed how the missing pieces of information can be generated and how they can be converted into forms useful to managers in conserving those parts of the Sound that are healthy and in rehabilitating those parts of it that are not so healthy.

The seminar served as an early forum for the discussion of environmental management issues between scientists and managers from the Long Island Sound region. Many of the ideas were later incorporated into the work plans for the Long Island Sound Estuary Project, which includes both EPA and NOAA as members of the Management Committee.

CONTENTS

LONG ISLAND SOUND IN TIME AND SPACE: AN OVERVIEW

J.R. Schubel
Marine Sciences Research Center
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I am going to try to set the stage for the rest of the day. I want to talk to you in very general terms about Long Island Sound for those of you who aren't familiar with it, and remind you about some of its important characteristic features. I am going to describe for you how Long Island Sound was formed, how it developed, and look a little bit at what the future might hold for Long Island Sound.

I assume that most of you know enough about Long Island Sound that you can find it. It is to the north of Chesapeake Bay and Delaware Bay and to the south of Narragansett Bay. Long Island Sound is at the north end of the Atlantic coastal plain, which is shown in Figure 1. It actually lies along the fall line, which is the boundary between the hard crystalline rocks of the piedmont and the soft sedimentary rocks that make up the coastal plain (Figure 2).

Long Island Sound is about 204 km (110 miles) long. It averages about 28 km (15 miles) in width, has a maximum width of about 39 km (22 miles), and at its western end near New York City it narrows to about 0.9 km (0.5 miles).

The eastern extremity is marked by the boundary near Block Island. The eastern end is delineated by a series of islands that sit atop a submerged ridge. The western boundary is somewhat less clear. Some people put the western boundary of Long Island Sound at the Triborough Bridge, but most oceanographers and marine scientists would put the western boundary at Hell Gate.

Hell Gate is a submerged ridge where the Harlem River intersects the East River. It was given the name Hell Gate by Adrian Block because of the strong currents and the turbulence in that part of the river, which made it very difficult for the small ships in the early days to navigate this stretch of water. Long Island Sound has strong tidal currents, particularly at its two ends. This led to the early name for Long Island Sound--the Devil's Belt.

Long Island Sound is a sound and also an estuary, so it fits into the Estuary-of-the-Month series.

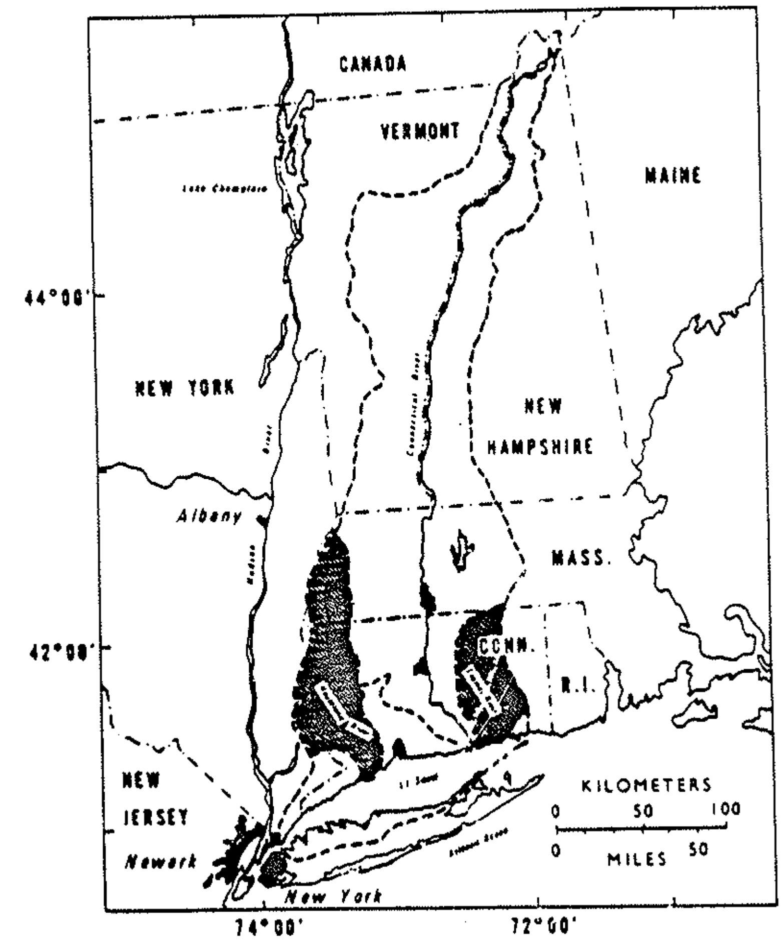

Figure 1. The Long Island Sound Region showing the drainage basin of the Sound.

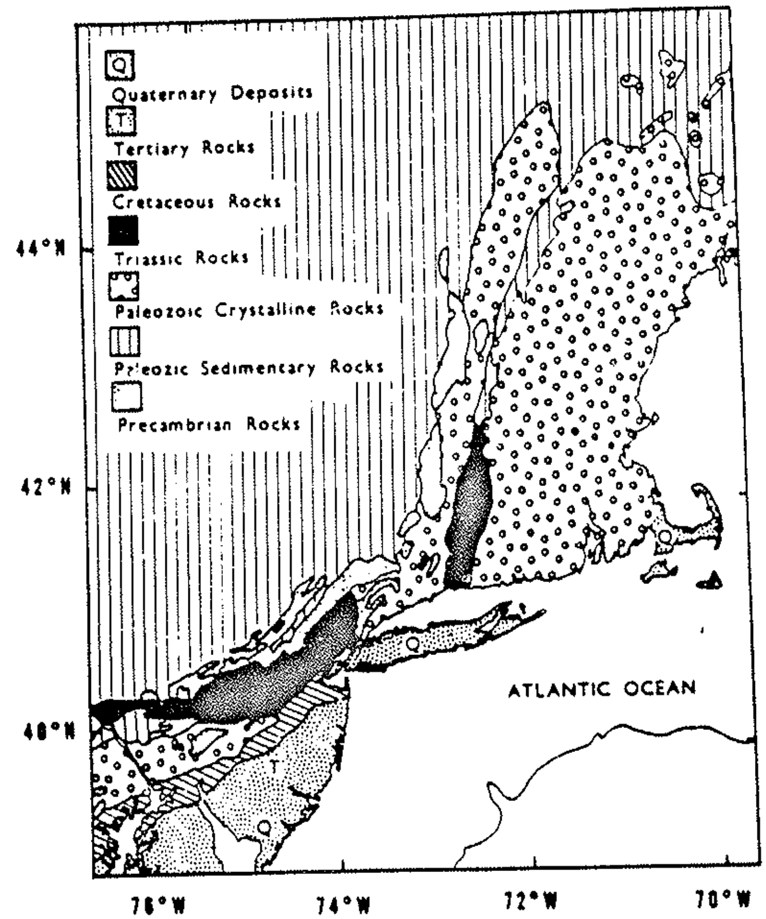

Figure 2. Geologic map of the northeastern United States. Note that Long Island lies along the boundary between the relatively old rocks exposed in New England and the younger rocks of Long Island and New Jersey (from Koppelman et al. 1976).

That describes Long Island Sound today, but if we had a satellite photograph of this area 20 thousand years ago, we would have seen a very different picture of Long Island and Long Island Sound. About 20 thousand years ago was the maximum advance of the most recent glacial episode, and Long Island Sound was covered with glacial ice. There wasn't any Long Island Sound as recently as 20 thousand years ago.

The glacier ended near the southern margin of Long Island and extended unbroken all the way back up through Connecticut, New England, Canada to the Arctic. It averaged about a mile in thickness. The ice sheet on Long Island might have been a couple of hundred feet thick. The water that went to make up the glaciers had come from the ocean. Twenty thousand years ago sea level was somewhere around 125 m (425 ft) lower than it is today. At that time, the entire continental shelf off this region was high and dry and exposed to the atmosphere.

Glacial ice covered all of Long Island Sound extending to near the southern shore of Long Island. The continental shelf, as I said, was high and dry. It was covered with climax vegetation, with conifers and hardwoods; and with freshwater meadows and marshes. The Hudson River flowed all the way across the shelf and discharged into the ocean beyond the edge of the continental shelf. The Connecticut River also flowed all the way across the shelf to discharge into the ocean off the edge of the continental shelf.

And that was only 20 thousand years ago; not very long ago on a geological time scale. At that time ancient elephants, bison, musk oxen, and horses roamed over the Atlantic continental shelf. I remember when I was a graduate student at Harvard I took a course in anthropology, and the professor claimed that you could take a Neanderthal man, dress him up and put him on the New York subway, and nobody would even notice him. I don't believe, though, that you could take one of these animals and walk him around Central Park without having somebody notice.

About 15 thousand years ago, the climate began to warm up and the glaciers began to melt and retreat. The melt water was returned to the ocean, and the sea began to rise. Figure 3 shows changes in sea level, and I really want you to pay attention to the lefthand side of the curve.

You can see that 15 to 20 thousand years ago sea level was about 125 m lower than today, and you can see that at that time it began to rise rapidly. By about 15 thousand years ago the sea had actually climbed out of its oceanic basin and had begun to march across the continental shelf. That march continues to this day. You probably know that geologists call these attacks of the sea on the land "transgressions" as though to suggest that the has a responsibility to remain within its own oceanic basin. In fact, for most of the last million years or so the ocean has

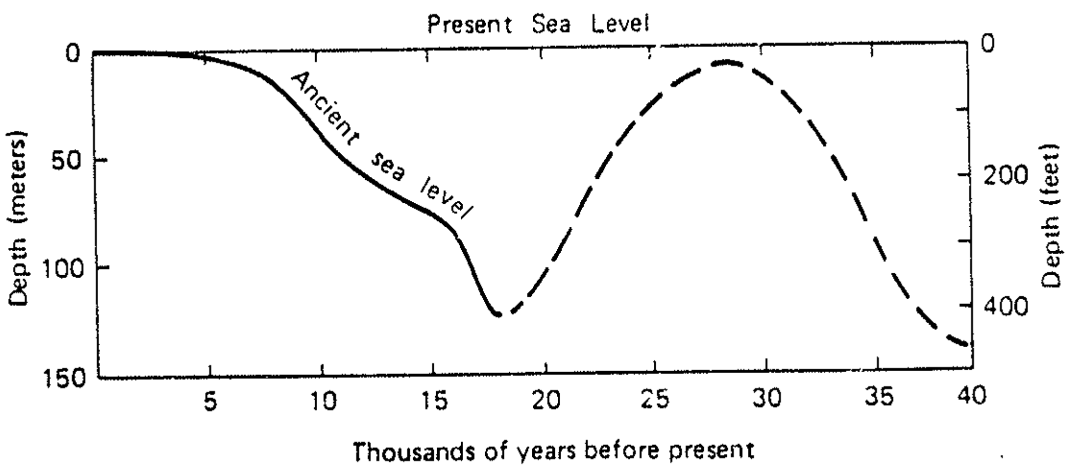

Figure 3. Changes in sea level caused by growth and melting of continental glaciers during the most recent glacial stage. (After J.R. Curray, 1965. Late Quaternary history, continental shelves of the United States. In H.E. Wright and D.G. Frey (Eds.), The Quaternary of the United States, pp. 723-735. Princeton University Press, Princeton, N.J.)

resided peacefully within its basin and has encroached up onto the continents only relatively infrequently.

The continental shelf off New York, in fact, off of this entire area, is very flat. It has a slope off of New York of something like 3 minutes of arc. That means that it changes in elevation about 1 in every 1000 units in the horizontal. Let's look again at the sea level curve (Figure 3). When the sea began to rise, it rose very rapidly. It rose at a rate of about 5 m (16.40 ft) per century for a few centuries. Then for most of the time from about 15 thousand years ago up until about 5 thousand years ago it rose at a rate of about 1 m (3.28 ft) per century.

That means then that for every meter (3.28 ft) the sea was rising vertically, it was advancing horizontally 1000 m (3280 ft). That is equivalent to a shore erosion rate of about 10 m (33 ft) per year. Talk about "our beaches are moving." If you have lived on the shelf at that time, they really were moving. During that period, waterfront property obviously would not have been a very good investment.

By about 13 thousand years ago the glacier had retreated to the south shore of Connecticut. Long Island Sound was free of glacial ice. We still did not have an estuary, however, because 13 thousand years ago sea level was still 80 m (262 ft) or so below its present position. At that time we did have a glacial lake in part of Long Island Sound, as you can see in Figure 4.

By about 8 thousand years ago, the sea had risen high enough that it began to spill into the eastern end of Long Island Sound, and that is when the present Long Island Sound estuary began to be formed. The encroaching sea converted this environment, with its quiescent glacial lake, into a dynamic estuary with strong tidal currents.

About 3 thousand years ago the rate of rise in sea level slowed appreciably. It still continues to rise, but much more slowly than it had in the past. The local rate of sea level rise for the Long Island Sound area is something like 3 mm/year (1 ft per century). That still is not a trivial rate of sea level rise.

The origin and development of Long Island Sound and the birth and development of its ancestral sounds have been controlled by sea level changes. These changes have been driven by climatic changes that have led to advances and retreats in continental glaciers. We have the trough now filled by Long Island Sound. Over the last several million years it has been alternately drowned by the sea and drained when sea level has fallen. And if you look back over the past several million years, we probably have had a Long Island Sound estuary about once in every 100 thousand years, and each has lasted perhaps 10 to 15 thousand years.

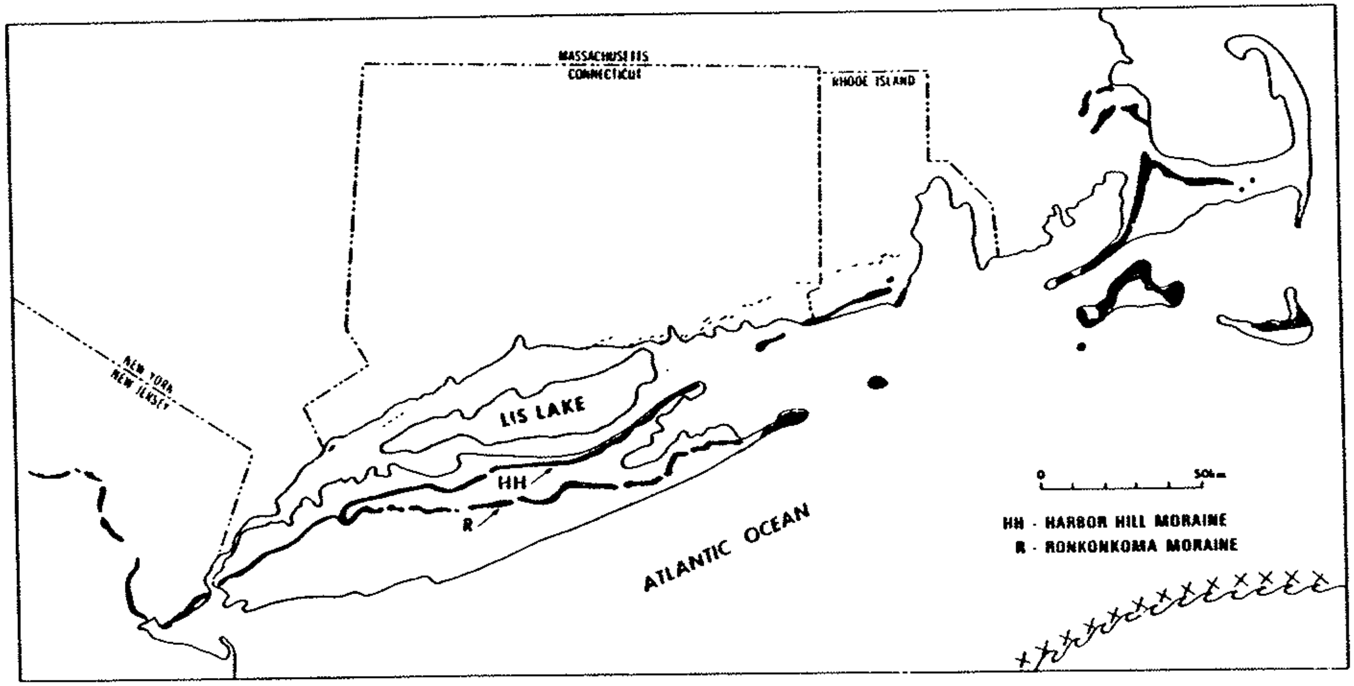

Figure 4. Map showing Long Island Sound glacial lake and glacial moraines in the region.

So the present Long Island Sound estuary is a relatively infrequent occurrence. And the present estuary we see is very young. It's only 8 thousand years old, or less. If sea level remains nearly constant, Long Island Sound will still have a long lifetime. The reason is that the sediment input into the Sound is very small. The sedimentation rate in Long Island Sound is actually only about one-third of the local rate of rise of sea level. Long Island Sound, in other words, is still growing because the rise of sea level is more rapid than the sedimentation rate.

If sea level were to fall, obviously the lifetime of Long Island Sound as an estuary would decrease; it would be shortened. If sea level were to rise, the lifetime of the estuary would be extended. It's not clear to everybody what is going to happen to sea level in the future. In a recent book by Schneider and Londer (1984) they state, "Left to her own devices nature will continue to nudge the earth towards the next ice age." The trouble is we may not have left nature to her own devices. You are all familiar with the greenhouse effect, so I'm not going to dwell on it.

The predictions that come from the National Academy of Sciences and that seem to be accepted by most people indicate that sea level may rise by as much as 70 cm over the next century, with about 40 cm (16 in) of that resulting from the melting of ice and the addition of water to the ocean, and 30 cm (12 in) from expansion of the upper ocean because of heating. That may or may not happen.

The modern Long Island Sound estuary, as I mentioned, fills a trough. The age of the estuary is about 8 thousand years. The trough is much older than that. To the best of our knowledge, the trough is about 50 million years old. That makes it much older in terms of an estuarine trough than places like the Chesapeake Bay, for example.

The trough was carved by a river, or rivers, that followed either from the east to the west or from the west to the east. There is not general agreement on which way those rivers flowed, except that they flowed along the long axis of Long Island Sound. A ridge left by those ancient rivers is actually the foundation of Long Island. If there were no cover by the later glacial deposits, that ridge would have produced an island that would only be about 16 to 20 km long. That's how long Long Island would be if it had not been for the glacial cover. Any of you who have ever been stuck on the Long Island Expressway may wish that the glaciers had never come and the island was only 16 to 20 km long.

The basin--the Long Island Sound trough--is actually divided up into three basins (Figure 5). I want to run through these very quickly for you so that when the other speakers refer to

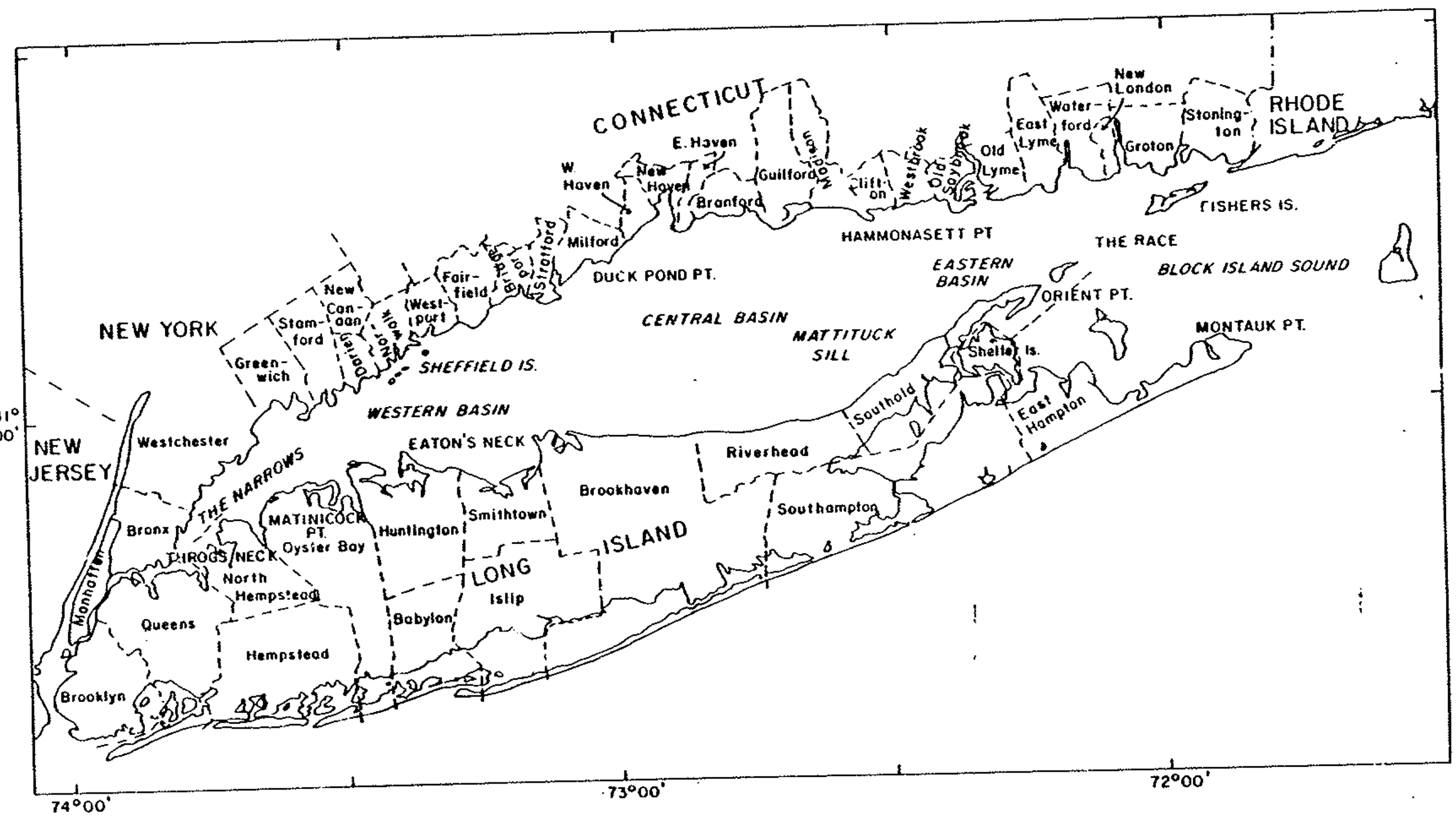

Figure 5. Map of the Long Island Sound region showing the location of the three basins in Long Island Sound and geographic names.

geographic names you will have a better idea of what they are talking about.

If we start in the west and move to the east, the East River links Long Island Sound to New York Harbor. The East River is actually a tidal strait. I'm sure you know that this was a recent court decision. The question was, is the East River a river or is it a tidal strait? And the ruling was that the East River is a tidal strait. That decision came from the Supreme Court, not Judge Wapner, so I think we probably have to pay attention to it. It also means that because the East River is a strait, Long Island Sound is a bay and the states then have jurisdiction over it.

Hell Gate, as I mentioned, was named by Adrian Block because of the sill there that creates a great deal of turbulence within the East River. Hell Gate is the western boundary of Long Island Sound as far as the oceanographic situation is concerned.

The westernmost section of the Sound, which is called the Narrows (Figure 5), extends from Hell Gate to a shoals called the Hempstead Sill, which runs roughly from Matinicock Point on Long Island across the Sound to the New York-Connecticut boundary. This section of the Sound has depths generally in the vicinity of 11.5 to 12 m (38 to 40 ft).

The western basin--remember we're moving from west to east--extends from Hempstead Shoals to Stratford Shoals. It is deeper and wider than the Narrows, and the bottom of the western basin is quite irregular. In the middle there is a north-south shoal that extends from Eatons Neck on Long Island across to the Connecticut shore. The shores of this part of Long Island Sound are quite deeply embayed; as a result, there are a lot of small harbors and ports both on the Long Island side and on the Connecticut side.

The central basin, the widest part of Long Island Sound, also is the place where we have the largest and most important port on the Sound, New Haven Harbor. Along that stretch of the Long Island coast we can see that the coastline is very straight, and there are very few embayments or indentations. The coastline is marked by quite high bluffs that extend in places to more than 100 feet above the beaches. Along the Connecticut coast of the central basin, there are fewer harbors than either farther to the east or farther to the west.

The boundary between the central and eastern basins is a line that extends roughly from Duck Point on Long Island across to the Connecticut shore. The eastern basin receives the discharge of the Sound's major river, the Connecticut. It also receives the discharge from the Thames. Most of the freshwater input to the Sound comes into the eastern basin, making this a very unusual estuary. About 80 percent of the total freshwater input to the estuary enters along its margins and very near the mouth.

If you think back to Delaware Bay or Chesapeake Bay, that is not what happens in those systems.

Let's take a quick look at the trough that contains the Sound. Figure 6 shows a cross-section from Connecticut on the right side through Long Island Sound and down through Long Island on the left. You can see that the whole region is covered by a thin glacial blanket of sand and some coarser material that was deposited about 15 to 20 thousand years ago, when sea level was much lower than it is today.

If you were to go to Long Island and drill through this blanket, you would go into Cretaceous rock, which is much older--about 100 million years old. And if you kept on drilling you would get down to Paleozoic or Pre-Cambrian rocks, which are about 600 million years old. You don't have to go very deep. On Long Island, you would have to go down about a quarter of a mile. These same rocks actually outcrop in Connecticut where they form some of the hills and even parts of the shoreline. But it's the glacial blanket that we see for the most part when we look at the present landscape.

Two of the most important features on Long Island are the two features shown by the dark bands in Figure 7. These are glacial moraines. They are long ridges of material that were originally deposited at the leading edge of the glacier. The one farther south is the Ronkonkoma Moraine; the one to the north is the Harbor Hills Moraine. If we had time, we would discuss the controversy that surrounds when and how these were formed, but we don't.

I want to say just a little about the beaches. For the most part, you have sandy shoreline on the Long Island side, and a mixture of sandy shorelines and rocky outcrops on the Connecticut side (Figure 7). The salt marshes surrounding the Sound are limited compared to some of the other estuaries you probably are familiar with. Relative to Chesapeake Bay, for example, Long Island Sound is pretty impoverished in its salt marshes.

The beaches are sandy, but if we were to drain the Sound and look at the sediments that line the floor, we would find a very different picture (Figure 8). On the eastern end of Long Island you have a great deal of sand. You have the sands along the shoreline and certainly on the beaches and fine sand on the shoals. But within the central and western basins, the bottom of Long Island Sound is floored with mud, silt, and clay.

This mud was not deposited by the glacier. Some of the mud in the central Sound was deposited in the glacial lake, although not this because this is the map of the surficial sediment. This is material that has been brought into the Sound in the last 8 thousand years. For the most part, it has been brought in by the Connecticut River. You may ask, if it's brought in by the Connecticut River, how does it get all the way into the central

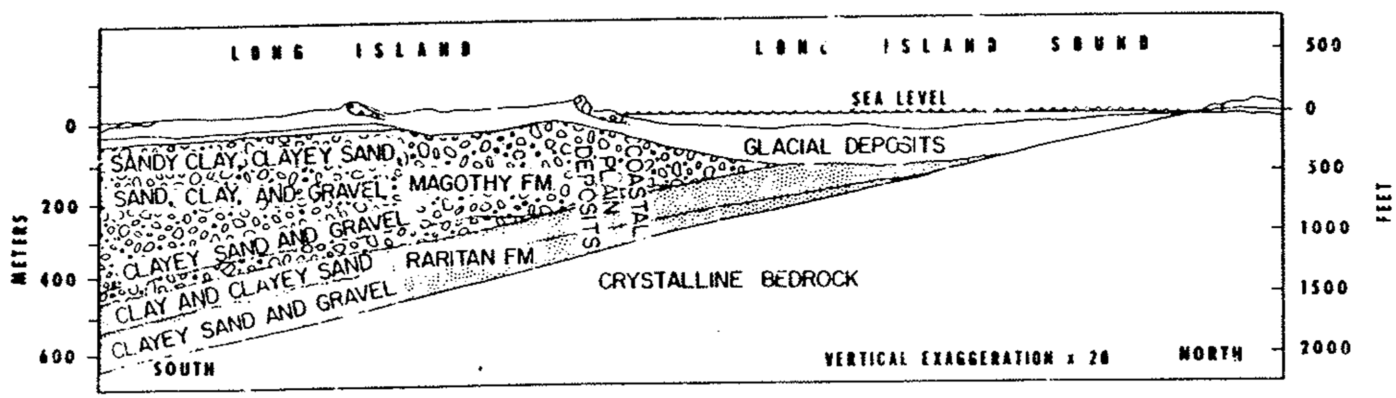

Figure 6. Geological cross section showing the buried bedrock and coast plain deposits beneath the surficial glacial deposits on Long Island. The section extends generally southward from the Connecticut River (from Koppelman et al. 1976).

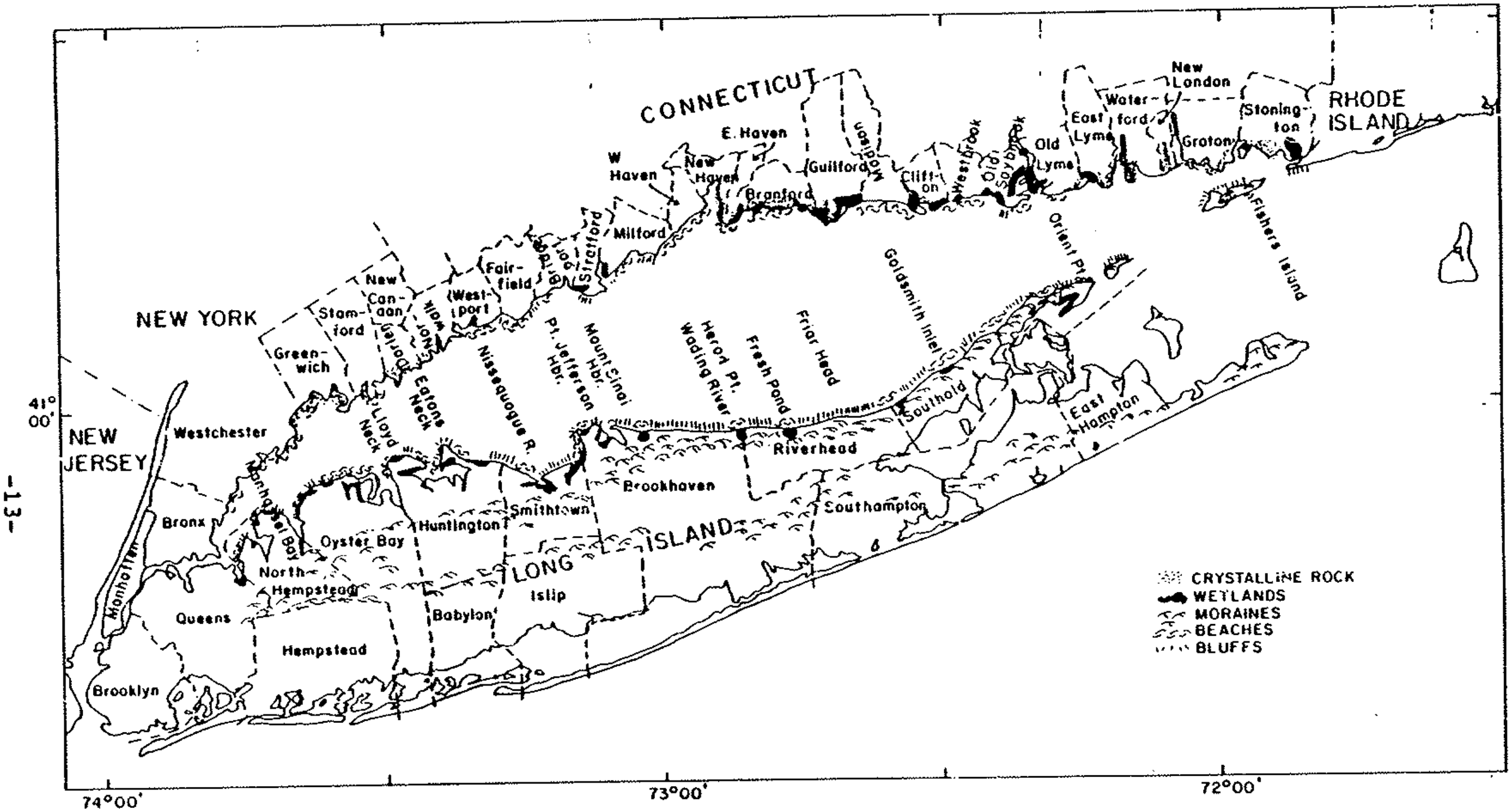

Figure 7. Major features of the Long Island Sound shoreline (from Koppelman et al., 1976).

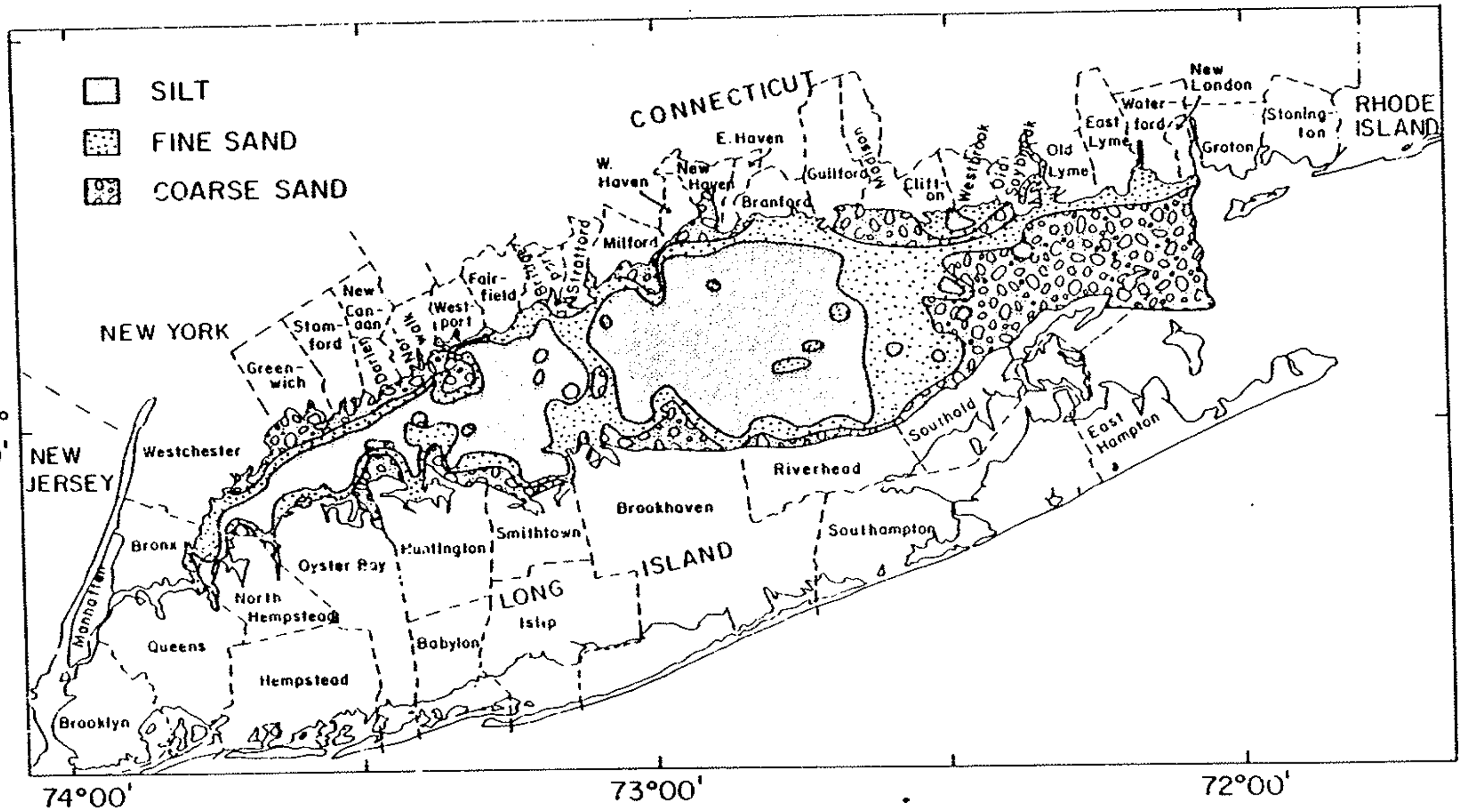

Figure 8. Map of surficial sediments in Long Island Sound (from Koppelman et al., 1976).

Sound? The answer, of course, is that it gets there by the estuarine circulation. Data from current meters that were placed about 2 m off the bottom show a net flow to the west, which causes the fine-grained material from the Connecticut River to be brought to the west and accumulate in the central basin and to some extent in the western basin.

Like most other estuaries, Long Island Sound is a very effective trap for fine-grained sediment. It traps essentially all the sediment that it receives from its rivers and it actually imports some sediment from the ocean. Most estuaries are very effective traps until they are in a fairly advanced stage of their geological evolution.

It is interesting to look at the amount of sediment put into Long Island Sound. The total amount of fine-grained sediment from all sources, except dredging operations, is estimated to be about 0.5 million metric tons. The total amount of sand that is put into Long Island Sound is about 1 million tons per year. Most of the sand comes from shore erosion on the Long Island side. So 0.5 million metric tons per year of fine-grained material, and 1 million metric tons of sand per year brings the total elastic sediment input to about 1.5 million tons per year.

I want to give you some idea how the sediment input to the Sound compares with two other estuaries: the Yangtze River and the Yellow River, both in China. The Yangtze has an annual discharge of suspended sediment of about 500 million tons per year. Remember, Long Island Sound gets 0.5 million tons of suspended sediment per year. The Yellow River discharges more than 1 billion tons of sediment every year. What that means is that the Yellow discharges as much sediment by 4:30 every morning of every day as Long Island Sound receives in an entire year. By 8:30 every morning of every day, the Yangtze accomplishes that same feat that it takes us a full year to accomplish.

If you want to put this in another context, all of the estuaries of the world were formed by the most recent rise in sea level; all of them have ages of 10 thousand years or less. Long Island Sound and the estuaries of the Yangtze and the Yellow all are roughly the same age. Over its entire 8-thousand-year history, Long Island Sound has received only as much sediment as the Yellow estuary received in the first four years of its existence. And the Sound has received an amount of sediment over its entire 8-thousand-year history that is equivalent to what the Yangtze received in the first eight years of its history as an estuary. So it shouldn't be surprising that the Yellow no longer has an estuary. The Yangtze River only has an estuary during periods of low river discharge; during periods of high flow it has no estuary. Long Island Sound is going to have an estuary for a very long time.

Let's quickly run through a few things about the human history of the area. From the time of the first Indians, which was about 12 thousand years ago in the New York region, up until the present, the human history of Long Island and coastal Connecticut indicates a continued dependency upon the marine environment.

Long Island Sound and other water bodies always were important food sources for the Indians. There is an interesting early Dutch account that says, "If oysters had legs, the Indians would starve." Agriculture also was important to the Indians, but the quality of the soil, particularly on Long Island, was so poor that agriculture was not as important as fishing to them. It has been estimated that at the time the European settlers arrived in this region there might have been somewhere between 10 to 40 thousand Indians in Connecticut and on Long Island combined; not a terribly large population. Their chief fish food was flounder, but they also ate other fish and shellfish.

The first European contact with Long Island Sound was probably by Giovanni Verrazano in 1524. The first real exploration of Long Island Sound, as far as we know, by any European was by Adrian Block. He led a Dutch expedition in 1614. Their base was on Manhattan. They went off to trade with the Indians in 1614 and when they came back their boat was in flames. The prospects of having to spend the rest of their lives in New York, I guess was too much for them. They built a vessel they named the Onrust, which is Dutch for "restless." She was a small boat, only about 40 feet or so long. Before taking her out into the ocean they thought they would test her in some inshore waters. They sailed through the East River, through Long Island Sound and up to Cape Cod, stopping long enough to name an island after Mr. Block and making a few other stops along the way.

The Dutch never really exploited the settlement in this area. In 1619 Captain Tom Dermer, who was British, sailed through Long Island Sound in the opposite direction. He entered at the east, sailed through the Sound, went through the East River and into New York Harbor. So there were at least two European ships that had gone through Long Island Sound before the Mayflower landed at Plymouth Rock in 1620.

Next, I'd like to make a few remarks about the water that fills the basin. Long Island Sound is a very unusual body of water. It's a sound, it's an estuary, and it has two connections with the ocean, one at each end. Both of these orifices work, although not equally well. To the east, the Sound mingles with the clean waters of Block Island Sound and communicates with the ocean. To the west it communicates with the ocean through the East River and the lower bay of New York Harbor.

As I mentioned, the major freshwater inputs enter along the northern margin of Long Island Sound, along the Connecticut shoreline and fairly close to its mouth--its eastern end. There is a large west-to-east gradient of environmental quality in Long Island Sound. The waters of the central, and particularly the eastern, Sound are clean and relatively unstressed. In the western part of the Sound, environmental degradation is obvious. These sharp gradients in water quality make Long Island Sound an excellent laboratory within which to study estuarine management practices. It is a laboratory that has been neglected. We have high hopes for the studies that are being planned now.

Figure 9 shows the freshwater input. Let me summarize it very quickly for you. More than 80 percent of the total freshwater input enters within 20 km (12 miles) of the mouth. Although the Connecticut River is the largest source of fresh water, accounting for approximately 72 percent of the total freshwater input, it is not the most important source of fresh water as far as the estuarine circulation in the Sound is concerned. That distinction belongs to the East River. Well, actually, it belongs to the Hudson River, some of whose discharge comes through the East River. It is that input of fresh water, which now has been mixed with and diluted with seawater, that really drives the estuarine circulation in Long Island Sound. We don't know the magnitude of the input from the East River very well. The best estimates put the long-term average at about 100 cubic m/second. That would put it somewhere between the Thames and the Housatonic in terms of its input. A value of 100 cubic m/second (3500 cfs) is not a large amount, but it is very important.

I would like to describe very quickly two quite interesting attempts that have been made to rehabilitate Long Island Sound and to solve some of its water quality problems. The first proposal was made by Gerard in 1966. His proposal was to seal off Long Island Sound at both ends with dams--the tops of the dams would serve as bridges. He was going to convert Long Island Sound into a freshwater reservoir to solve the water problems of the metropolitan New York area and of coastal Connecticut.

This kind of a practice has been done before. It has been done in Holland and in Hong Kong, and it is being done right now in South Korea. I think almost all of us agree that it is not a good idea for long island sound. It not only would be bad for the Long Island Sound estuary--there would not be any estuary--but it would create the world's largest cesspool, and that is hardly a distinction that New York and Connecticut aspire to.

The other proposal was by Bowman in 1976. Bowman's proposal was to put tidal locks across the East River and to open them on each ebb tide, that is, when the water was flowing from Long Island Sound through the East River to the Harbor, and to close them on the flood tide. If this were done, it would create a strong, pulsating, unidirectional flow of about 2500 cubic m/second of relatively clean water from central Long Island Sound, which would go through the East River into the lower bay of New York Harbor where it would mix and flow out into the New York Bight. Using some quite simple models, Bowman predicted that if this were done, the concentration of conservative contaminants in the western Sound would drop by 88 percent within a month, and that in New York Harbor the concentrations of these same contaminants

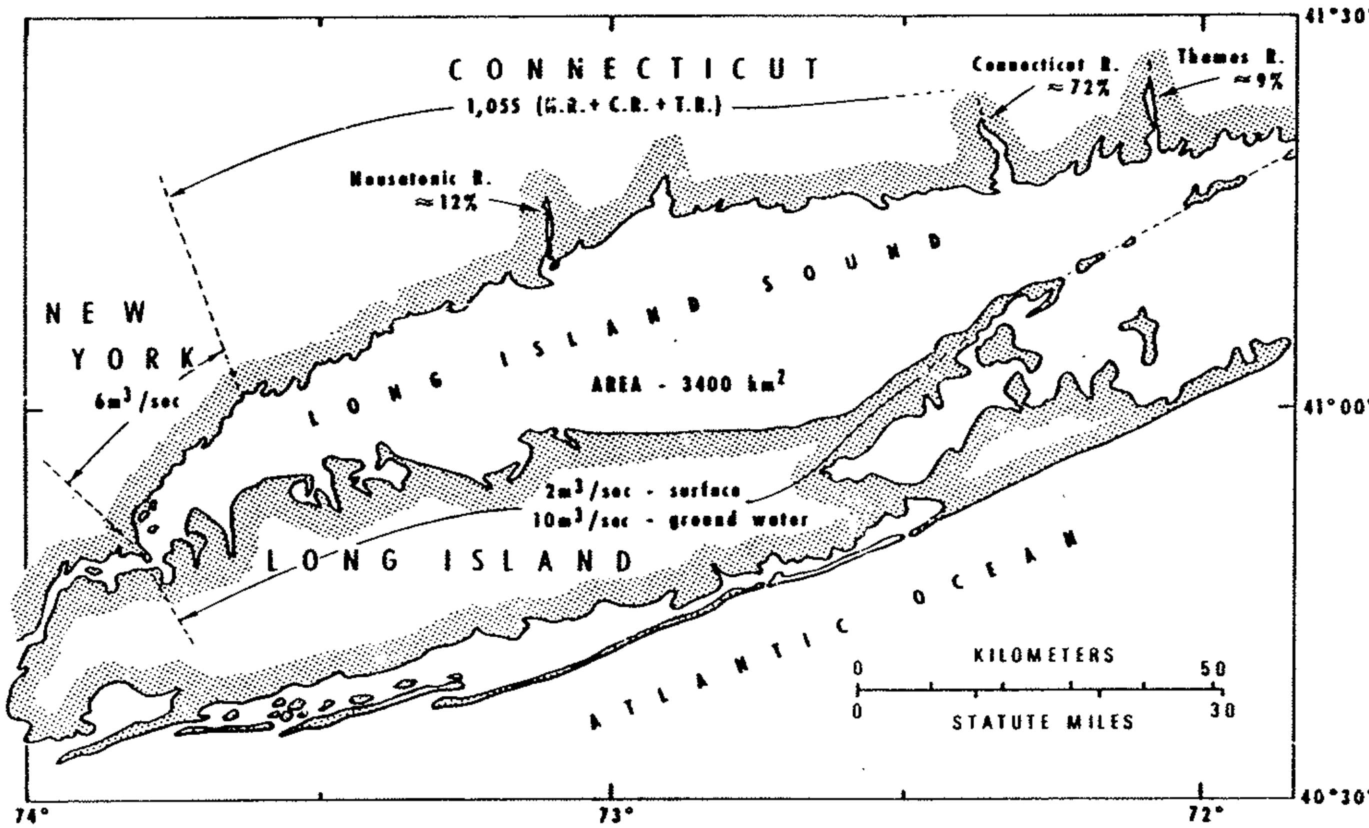

Figure 9. Freshwater discharge into Long Island Sound (from Koppelman et al. 1976).

would drop by 45 percent within one month. This particular scheme would produce dramatic improvements in the water quality both in the western Sound and in the Harbor.

Bowman's idea is not an entirely new one. Some of you might recall from Greek mythology that Hercules diverted two rivers through an Aegean stable in order to clean out the manure that had accumulated from 3000 oxen over a period of 30 years during which the stable had not been cleaned. And we're told that it worked very well. It is a practice that one might consider putting into effect in the New York subway system, perhaps during rush hour. In 1922, 50 years before Bowman, a man by the name of Reeve made a similar proposal to put tidal locks in the East River. His objective was not to clean up western Long Island Sound, but to clean up New York Harbor. As I mentioned, Bowman thought that it was likely that you would achieve both of those ends.

I think this is an idea that is worthy of some consideration. The models that Bowman used were very crude, and we now have better tools for assessing what improvements one could expect to have. There are some other serious questions that need to be considered. Obviously, if you eliminate the source of fresh water from the Hudson that I described, you would then remove the estuarine circulation, or at least reduce it, in western Long Island Sound. One has to question whether that's a good idea or not. And it is not clear what would happen to the gravitational circulation in the central Sound. But I think it is an idea that may be worth some more consideration. Certainly it's deserving of an economic analysis. It might produce more benefits, at lower cost, than some of the clean-up programs we have embarked upon.

Long after most of the estuaries of the United States and the world are gone, we are still going to have a Long Island Sound. The basin is large and the sediment inputs are puny; so the life span of Long Island Sound is going to be very large.

The quality of its life, I think, is less certain. Ernest Wynder, M.D., once remarked that "It should be the function of medicine to have people die young as late as possible." Die young as late as possible. That should probably be a function of environmental medicine, of estuarine management in particular: to do everything possible to ensure that Long Island Sound and all the other estuaries have productive life spans that match as closely as possible their geological life spans. We should do everything we can to ensure that our estuaries retain a quality of life as long as they live.

You may recall Voltaire said that the art of medicine consists of amusing the patient while nature cures the disease. The trouble is that nature is not going to cure the diseases of Long Island Sound, of Chesapeake Bay, or most of our other estuaries: at least not on time scales important to society. Many of us--

probably most of us here--are very pleased that Long Island Sound is beginning to get some attention. I think it is long overdue.

There are a number of compelling reasons to study Long Island Sound. Compared to most of the other major U.S. estuaries, it has received very little scientific attention. I would hazard a guess that there has been less money spent on research in Long Island Sound in the past century than has been spent on the Chesapeake Bay in the last decade. The difference is probably about an order of magnitude; a factor of 10.

Long Island Sound is a very important estuary to a very large number of people. About 10 percent of the total population of the entire United States--all 50 states--live within 50 miles of the Sound. According to a planning study: "Long Island Sound harbors one of the largest fleets of recreational boats in the world. In 1975 there were more than 125 thousand recreational boats that used Long Island Sound."

Recreational fishing also is terribly important. In 1975 there were about 1 million recreational fishermen and women who spent an estimated 12 million days that year pursuing their hobby. In 1975 there were an estimated 60 million swimmer days on Long Island Sound. If there were 75 beach days that year--an overestimate--that translates into 800,000 people on Long Island's beaches on an average beach day. You could have the population of the entire state of Delaware or the entire state of Alaska spend all of June, July, and all of August on Long Island Sound's beaches, and still have room for several hundred thousand people. Some of us suspect they are all here, we're not sure. That's amazing--60 million swimmer days. Half-a-million people every day for 120 days running.

There are other reasons to study Long Island Sound. In spite of the abuses of Long Island Sound and the neglect, except for the western area, the Sound is in relatively good shape, unlike many other estuaries. Because it is in relatively good shape, it is worth our attention to keep it from being degraded further. And as I mentioned, the gradients in environmental quality make the Sound particularly interesting and valuable as a natural laboratory to test strategies for estuarine management and rehabitation.

There was a celebration recently in Baltimore to honor the memory of a very important man in this region, H.L. Mencken. Mencken once said, "There is always an easy solution to every human problem. Neat, plausible, and wrong." We have the time. We still have the time to design a proper program for Long Island Sound. I hope we take that time to do it right. We have waited a long time for a Long Island Sound study.

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NUTRIENTS AND OXYGEN: TOO MUCH OF ONE AND TOO LITTLE OF THE OTHER

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I'm going to discuss nutrients and dissolved oxygen in Long Island Sound. Nutrients tend to have a stimulatory effect on the growth of phytoplankton. Phytoplankton are the microscopic algae responsible for most of the photosynthesis, or primary production, that occurs in this body of water.

If there is an adequate supply of nutrients and sunlight, and if certain other factors are optimal, you will have good growth of phytoplankton. Generally, increasing the nutrient content will increase the growth of phytoplankton until the point at which they become self-shading or light-limited.

One source of nutrients for the Sound is freshwater runoff. If we look at Long Island Sound (Figure 1), we can see that there are several different sources of fresh water. Most of the freshwater discharge, about 1000 cubic m/second, comes from Connecticut, mostly from the eastern end, the Connecticut River and the Housatonic River. Long Island itself contributes about 2 cubic m/second in surface water runoff, 10 cubic m/second in ground water, and about 6 cubic m/second in the Westchester County area of New York. So, as Dr. Schubel mentioned, the freshwater input bringing in the nutrients is relatively low on the Long Island side of the Sound.

In contrast, if we consider sewage plants, there are five relatively large ones on the East River--Tallmans Island, Hunts Point, Bowery Bay, Wards Island, and Newtown Creek (Table 1). These plants are discharging much of the sewage from the City of New York and its surrounding areas, about 725 million gallons/day. This translates to a value of around 32 cubic m/second, which is four or five times the amount entering as fresh water. Nitrogenous nutrients are the critical nutrients that stimulate the growth of phytoplankton in estuaries, and sewage contains urea, nitrite, nitrate, and ammonium (Table 2). Secondary treated sewage has a total dissolved nitrogen content of approximately 1300 microgram atoms per liter. Thus the concentration of nitrogenous nutrients in sewage is relatively high.

In contrast, fresh water has a total of perhaps 30 to 40 microgram atoms dissolved combined nitrogen compounds per liter, depending on the location of the estuary. Thus the concentration of nitrogenous nutrients is much higher in sewage than in fresh water, and the volume of sewage entering western Long Island Sound is much higher than the volume of fresh water.

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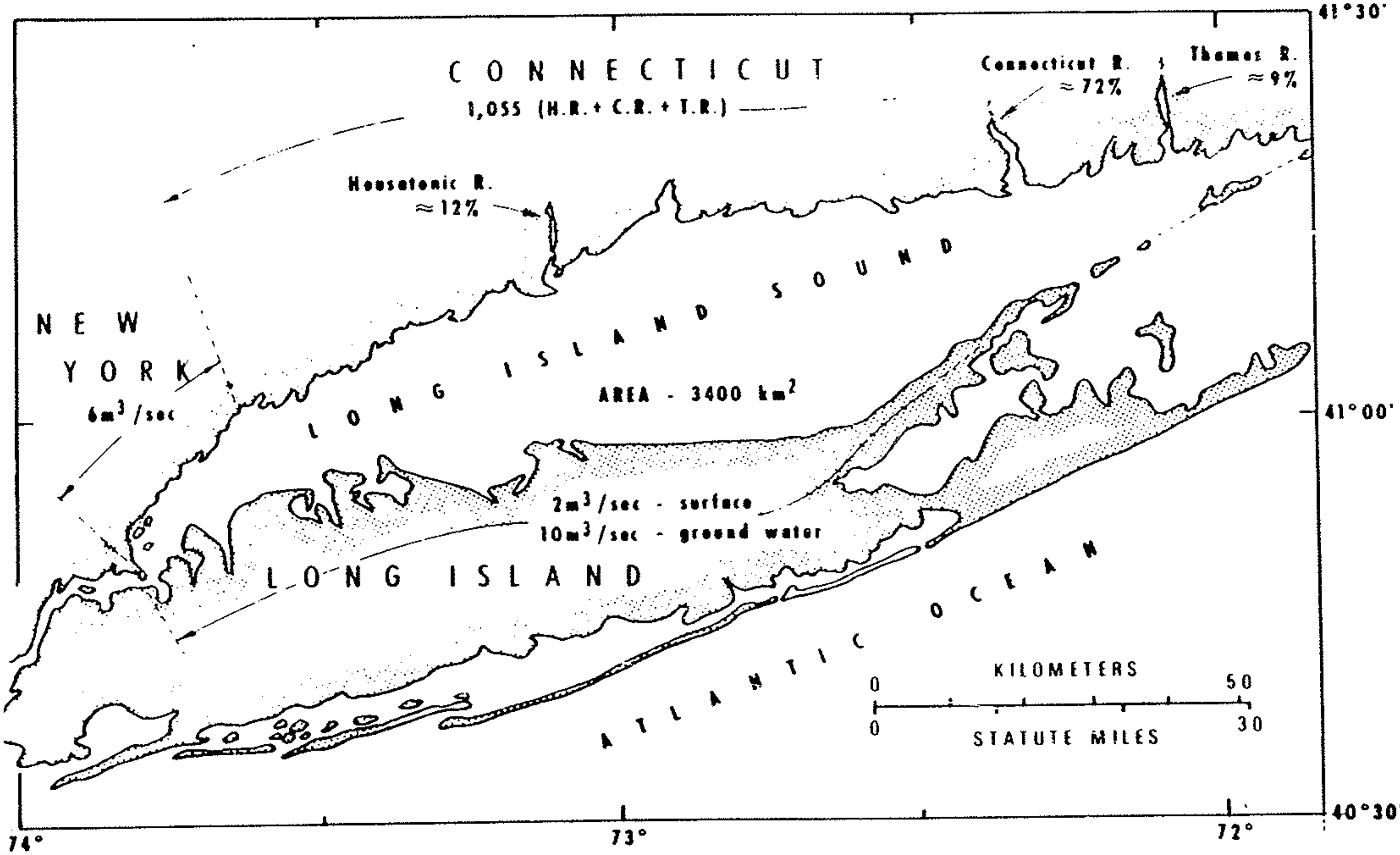

Figure 1. Freshwater discharge into Long Island Sound from streamflow and ground water (courtesy of L.E. Koppelman, P.K. Weyl, M.G. Gross, and D.S. Davies. 1976. The Urban Sea: Long Island Sound, Praeger Special Studies. New York. 223 pp.).

Table I. Nutrient species and concentration in secondary sewage discharge (courtesy of L.E. Koppelman, P.K. Weyl, M.G. Gross, and D.S. Davies. 1976. The Urban Sea: Long Island Sound, Praeger Special Studies. New York. 223 pp.).

Plant	*Discharge (in millions of gallons/day *)*	*People Served (in millions)*
Tallmans Island	59.7	0.25
Hunts Point	145.9	0.77
Bowery Bay	105.3	1.00
Wards Island	245.5	1.47
Newtown Creek	169.0	0.5
Total East River	725.4	4.0

Table 2. East River sewage treatment plants with discharge and people served in 1971. All discharge is secondary treated sewage (courtesy of L.E. Koppelman, P.K. Weyl, M.G. Gross, and D.S. Davies. 1976. The Urban Sea: Long Island Sound, Praeger Special Studies. New York. 223 pp.).

Discharge

Species	*Formula*	*Molecular Weight*	*In Secondary Sewage* ppm	*In Secondary Sewage* microgram atoms/liter
urea	NH_2CONH_3	60.06	not analyzed	
nitrite	NO_2^-	46.01	1	22
nitrate	NO_3^-	62.01	15	242
ammonium	NH_4^-	18.03	20	1109
total nitrogen	N	14.01		1373
phosphate	PO_4^{3-}	95.03	25	263
Ratio total nitrogen/phosphate				5.2

What is the result of this? Figure 2 indicates percent sewage in western Long Island Sound. The sewage plants are found on Tallmans Island, Hunts Point, and Wards Island, all located in the East River and western Long Island Sound. If you look at the percentage of sewage in the total volume of water in western Long Island Sound, you can see that in the East River as much as 1.5 percent of the total water volume is sewage that is entering from these plants. When you move farther east into the western Sound, it's diluted to about 0.5 percent of the total volume of water.

The daily nitrogen loadings from the five sewage treatment plants in the East River have shown a steady increase over the years. From about 20 tons per day in the 1950s, the nitrogen loading has risen to roughly 60 tons per day in the 1980s (Figure 3). So the population increase has been reflected by a steady increase in nitrogen loading. In addition, there are loadings from other sewage treatment plants. The darkened circles in Figure 4 represent other sources of nitrogenous nutrients coming from the introduction of sewage. Plants between the central Sound and the western Sound account for about 18 tons of nitrogen per day--roughly a quarter of the total percent. So we have about 60 to 70 tons a day from the East River plants and about 18 tons a day from the other plants, a total of 80 to 90 tons of nitrogen per day entering the Sound through sewage.

If we consider western Long Island Sound, representing about one-quarter of the entire Sound, the nitrogen loading is around 3000 millimoles per square meter per day. In contrast, nitrogen loadings in some other east coast estuaries are about 950 millimoles of nitrogen added per square meter to the estuary per year in Narragansett Bay, and about 1300 millimoles in Delaware Bay. Input to Long Island Sound is considerably higher than these other estuaries, but not as high as the lower New York Bay, which receives a phenomenal amount of sewage, almost 32,000 millimoles per square meter per day.

The high input of nitrogen to the western part of Long Island Sound is reflected in high nitrogen concentrations in that area. Twenty-five micromolar ammonia was observed in the western Sound in 1971. This is an extremely high concentration, enough to saturate the uptake systems of any phytoplankter (Figure 5). Thus, there is a superabundance of ammonia in this area.

As Dr. Schubel mentioned, the eastern Sound is more typical of coastal waters, that is, clean estuarine waters. The concentration of ammonia is only about 1 micromolar. We see the same situation reflected in the nitrate concentration, which is about 10 to 15 micromolar in the western Sound, compared to less than 5, dropping down to about 1 to 2 micromolar in the eastern Sound. So again, the eastern area is relatively pristine. A profile from Rikers Island all the way out to the Race at the eastern end of the Sound shows a gradual decrease in the concentrations of ammonium, nitrite, and nitrate, reflected by the sewage input (Figure 6).

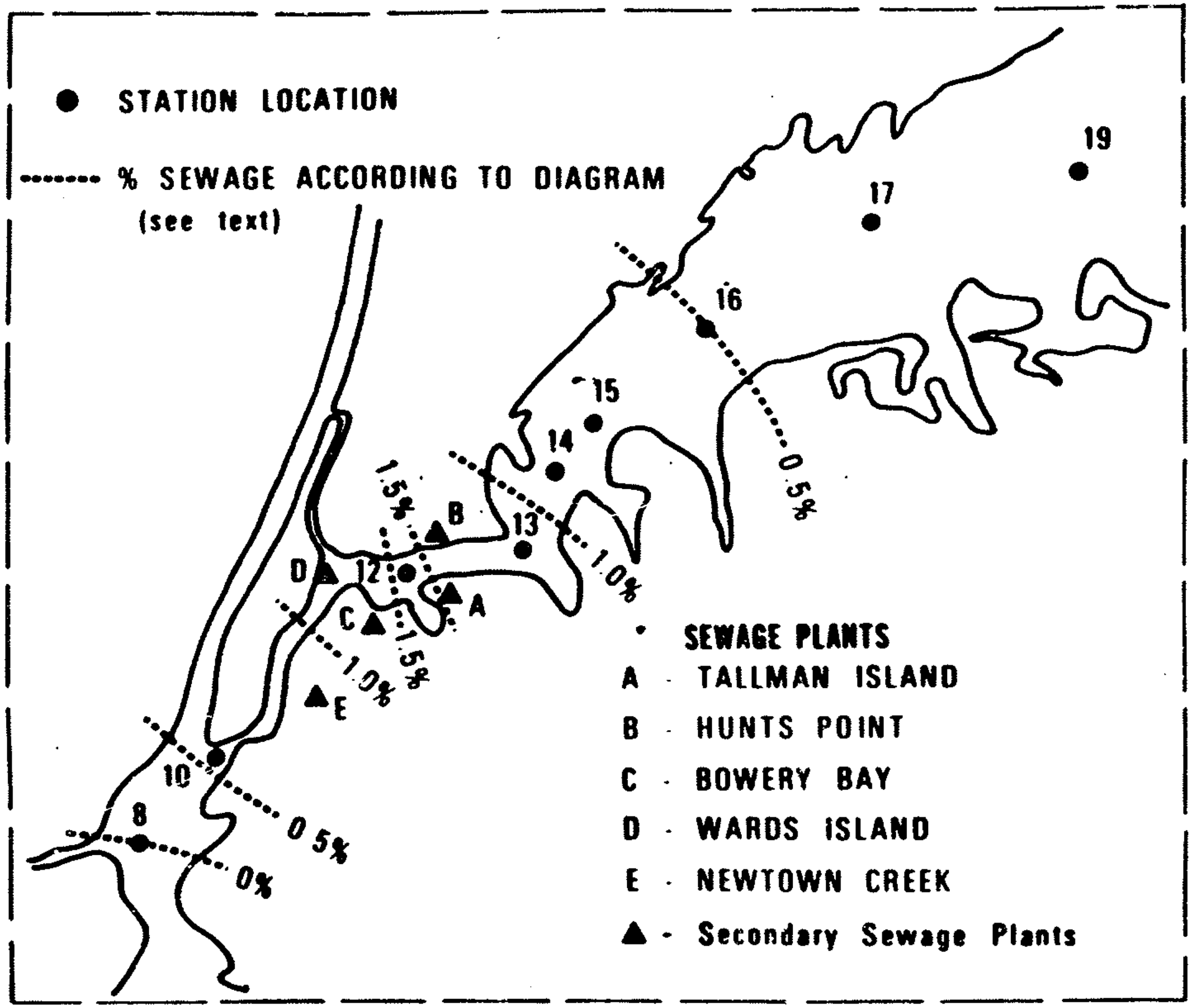

Figure 2. Location of sewage treatment plants and percent sewage in Long Island Sound (courtesy of L.E. Koppelman, P.K. Weyl, M.G. Gross, and D.S. Davies. 1976. The Urban Sea: Long Island Sound, Praeger Special Studies. New York. 223 pp.).

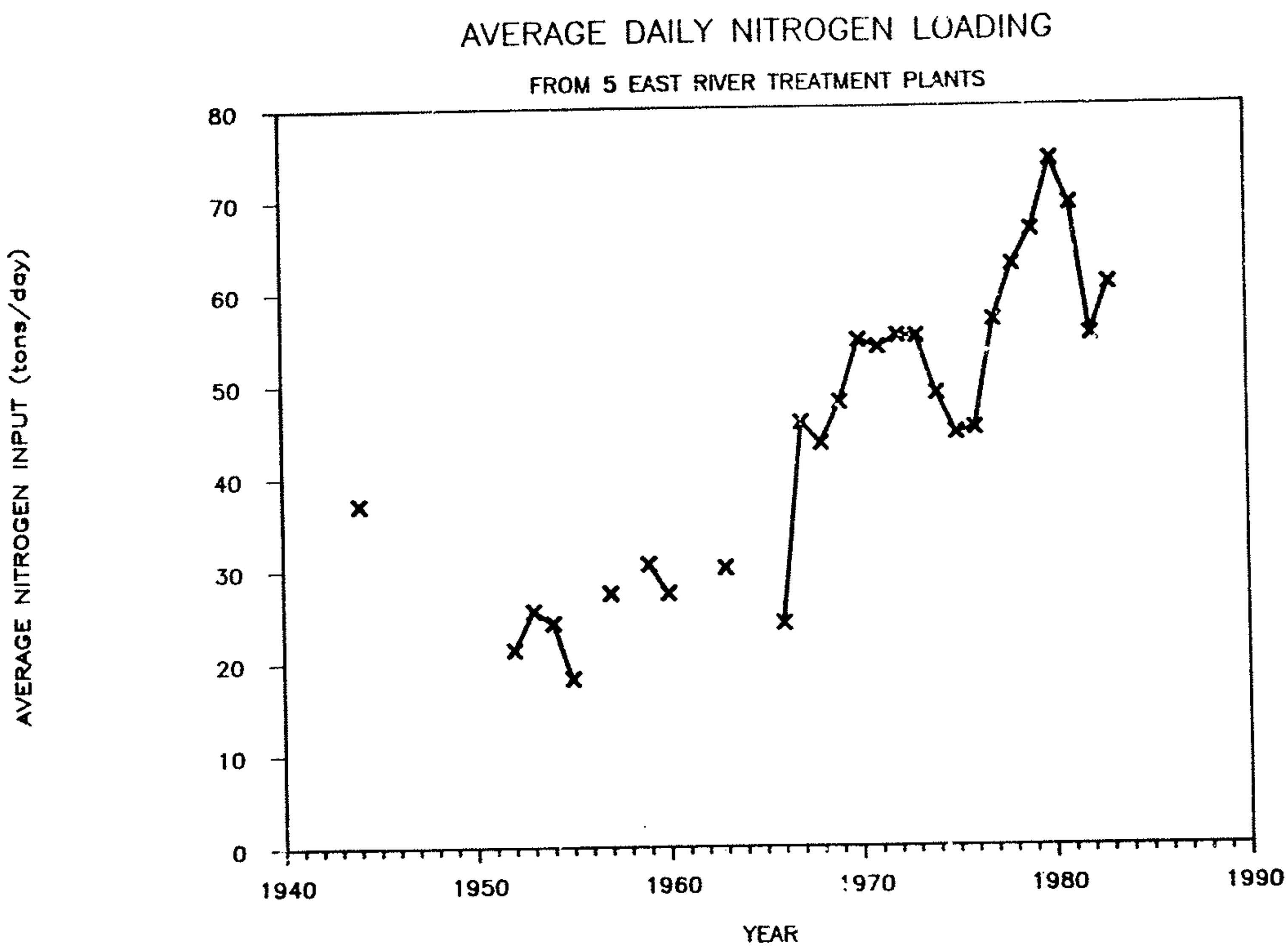

Figure 3. Average daily nitrogen loadings from five East River treatment plants from 1944 to 1983.

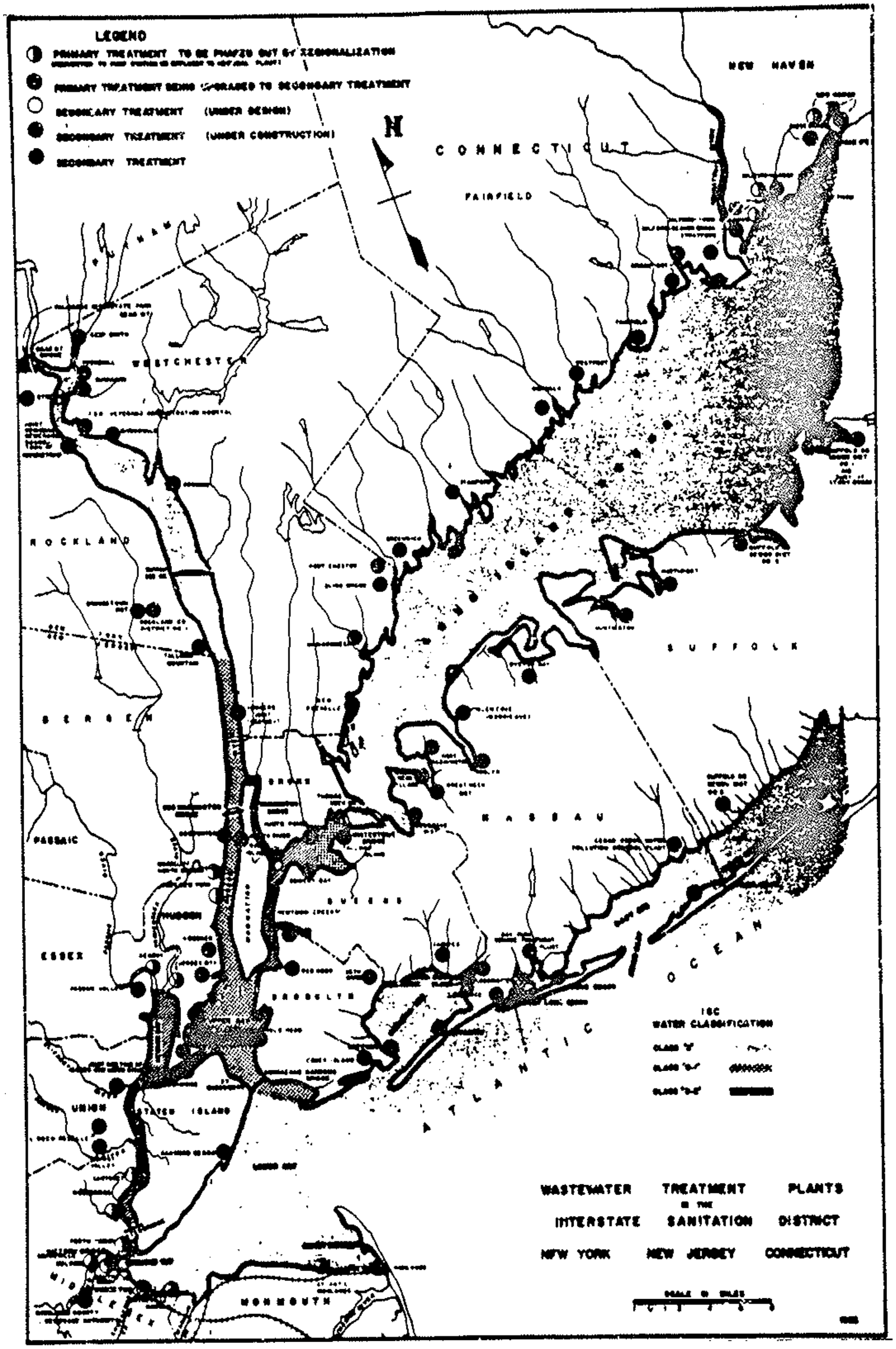

Figure 4. Location of wastewater treatment plants (shown by circles) on Long Island Sound and in the lower Hudson River area (from Interstate Sanitation Commission 1983 Annual Report. 69 pp.).

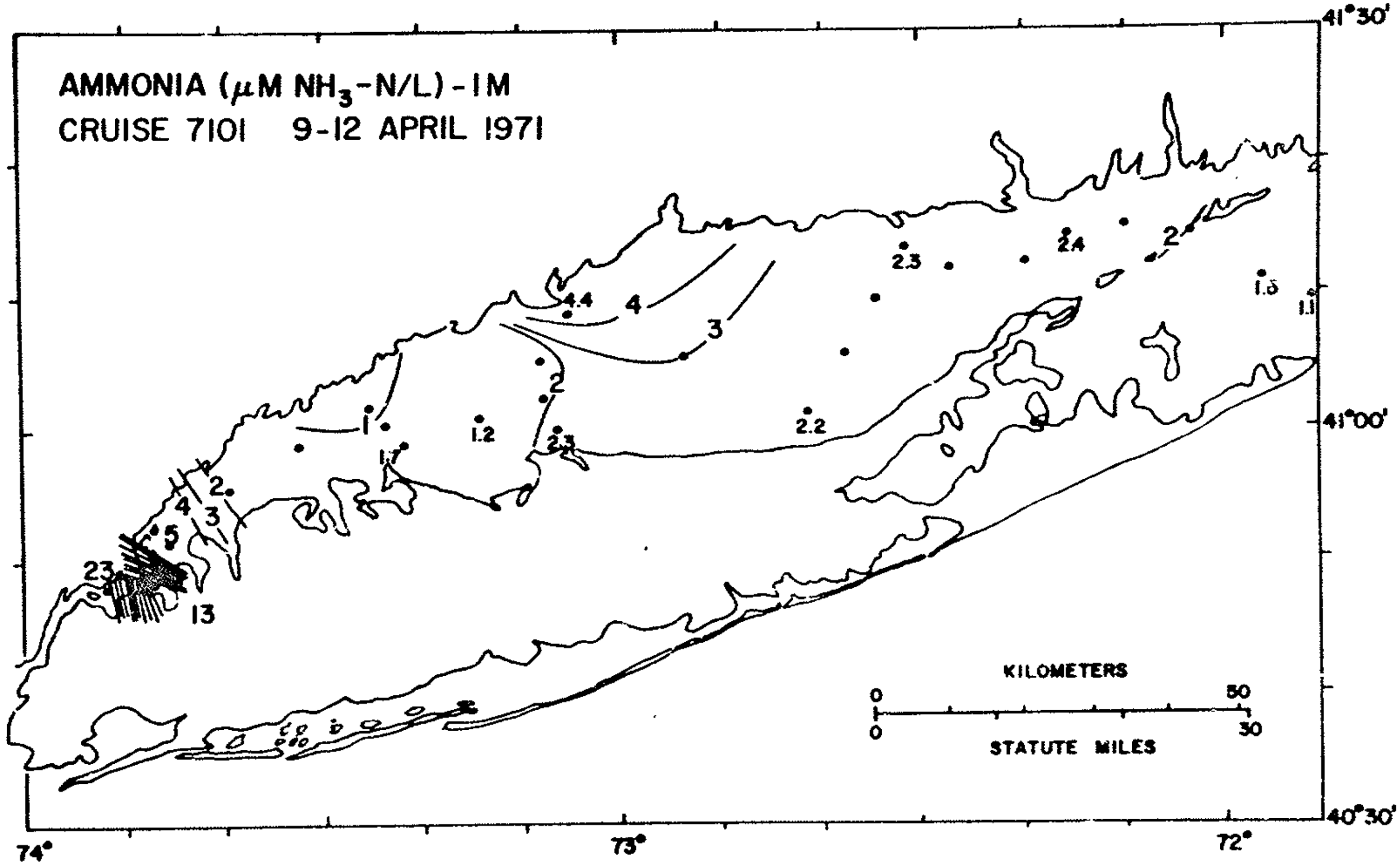

Figure 5. Ammonium concentration in surface water of Long Island Sound, 9-13 April 1971 (courtesy of C.D. Hardy. 1972. Movement and Quality of Long Island Sound Waters, 1971. Tech. Report No. 17, Marine Sciences Research Center, SUNY Stony Brook. 66 pp.).

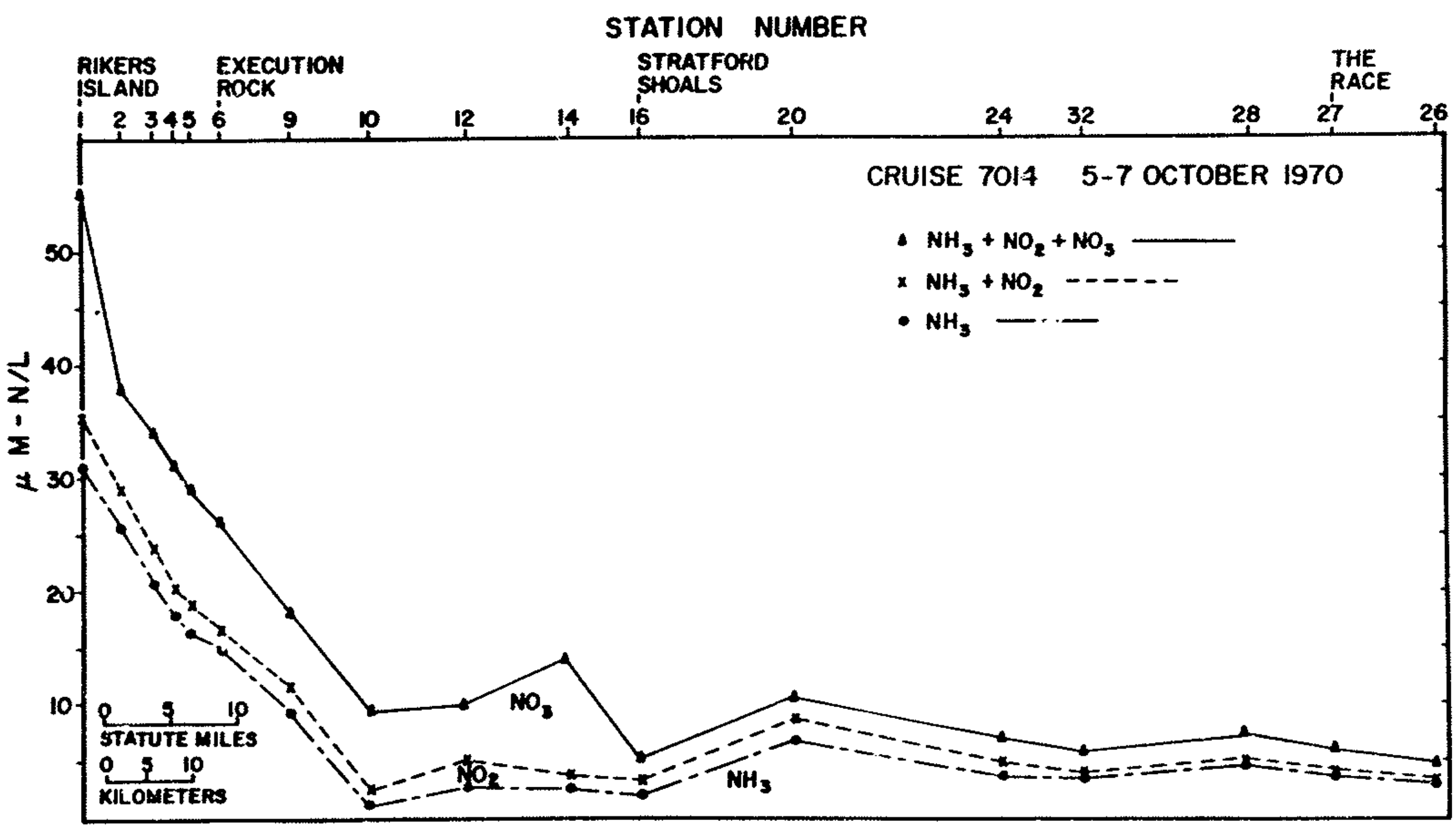

Figure 6. Concentration of nitrate, nitrite, and ammonium in surface (1 m) waters in east-west transect through Long Island Sound, 5-7 October 1970 (courtesy of C.D. Hardy. Hydrographic Data Report Long Island Sound—1970 Part II. Tech. Report No. 3, Marine Sciences Research Center, SUNY Stony Brook. 20 pp.).

What effect does that sewage input have? In Figure 7 we have sewage treatment plants adding dissolved nitrogen compounds and also adding particulates and dissolved organic carbon. During the summertime we also have thermal stratification. We have a mixed layer of water near the surface, perhaps the surface 5 or 10 m of water. Below this layer, we have a region of sharp temperature change known as the thermocline, which tends to seal off the surface waters from the bottom waters. There is a temperature gradient and a difference in the density of the water, with more dense water on the bottom and the mixed, less dense warmer water on the surface.

The dissolved nitrogen from sewage stimulates the growth of phytoplankton, which produces oxygen and tends to maintain high concentrations of oxygen in the surface waters. But the stimulated phytoplankton growth also stimulates grazing and increases the herbivore population. The herbivores produce more fecal pellets, which sink to the bottom. Carnivores also go to the bottom, and phytoplankton themselves sink. In addition, you can also have the particulate and dissolved carbon from the sewage treatment plants going to the bottom. As I discussed above, in summer the bottom of the water column is essentially sealed off from the upper layer. This increased supply of organic material increases food supply to the benthos, producing bacterial decomposition in the bottom waters and also a large benthic oxygen demand that increases bacterial respiration; thus we have enhanced oxygen consumption in bottom water.

Another factor to consider in regard to oxygen is that during the summer, seawater has a lowered ability to hold oxygen. The solubility of oxygen decreases as temperature increases (Figure 8). For example, at a temperature of 0.5°C, the solubility of oxygen in seawater is almost 9 ml/liter. In contrast, in summer the solubility decreases from almost 9 ml/liter to a little over 5 ml; so seawater can hold less oxygen in the summertime.

Note that oxygen concentrations in surface waters can exceed saturation (Figure 9). We see that in August, dissolved oxygen can be 200 percent of the saturation value. However, when you get farther into the western area of the Sound, the percent saturation decreases. It goes from 100 percent near Manhasset and New Rochelle to about 50 percent near Great Neck. Over by the Whitestone Bridge, values further decrease to 25 percent and even less. This decrease is, again, due to a substantial increase in phytoplankton production, sewage input, and bacterial and organismal respiration.

Figure 10 represents a vertical profile from the Race, the eastern end of Long Island Sound to the western Sound at Execution Rock. Values in surface waters are high: 9, 8, 5 ml/liter. But in the deeper water in the western end, values go down to 2 ml/liter. Thus there is good oxygen saturation from

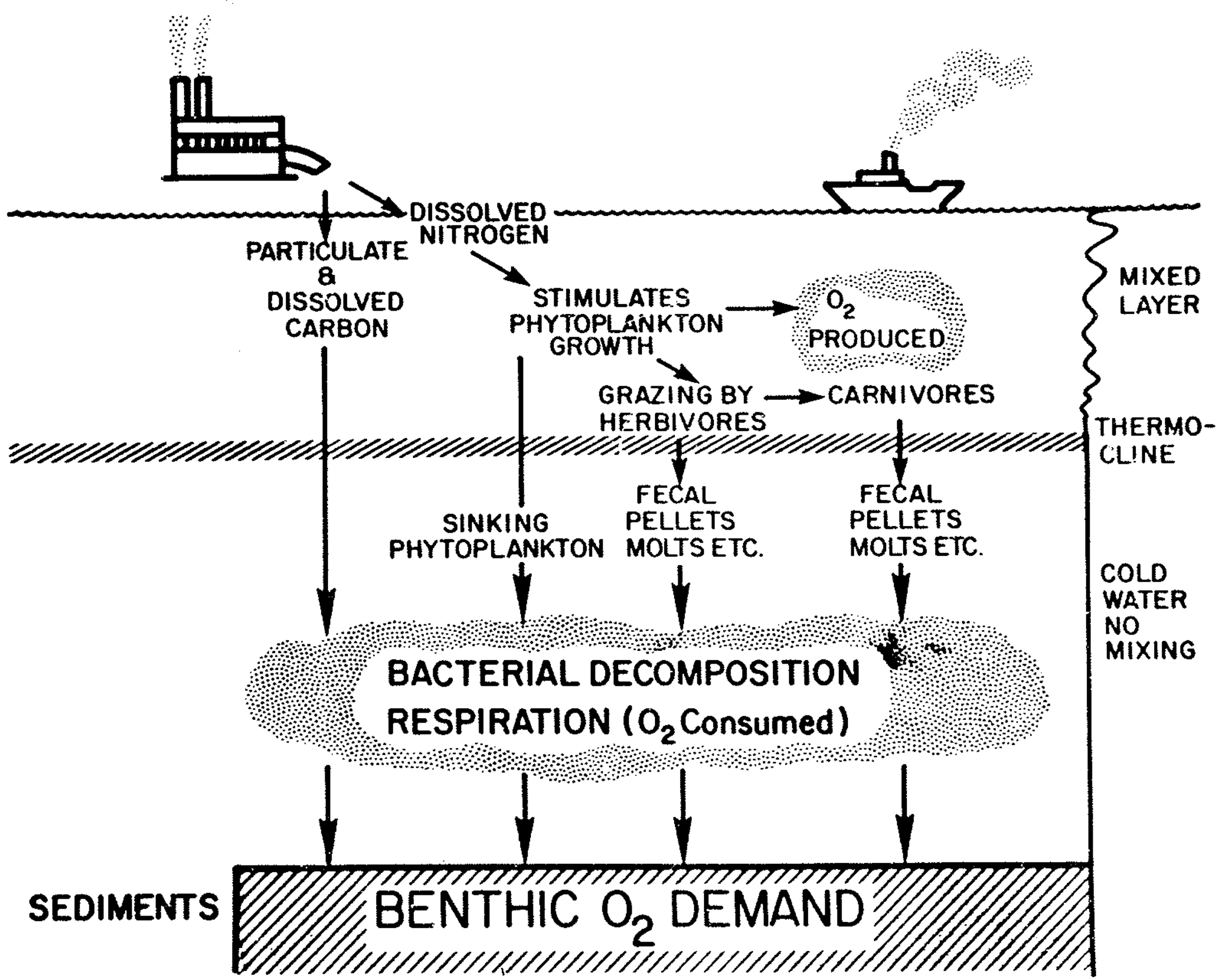

Figure 7. Factors affecting oxygen concentrations in Long Island Sound.

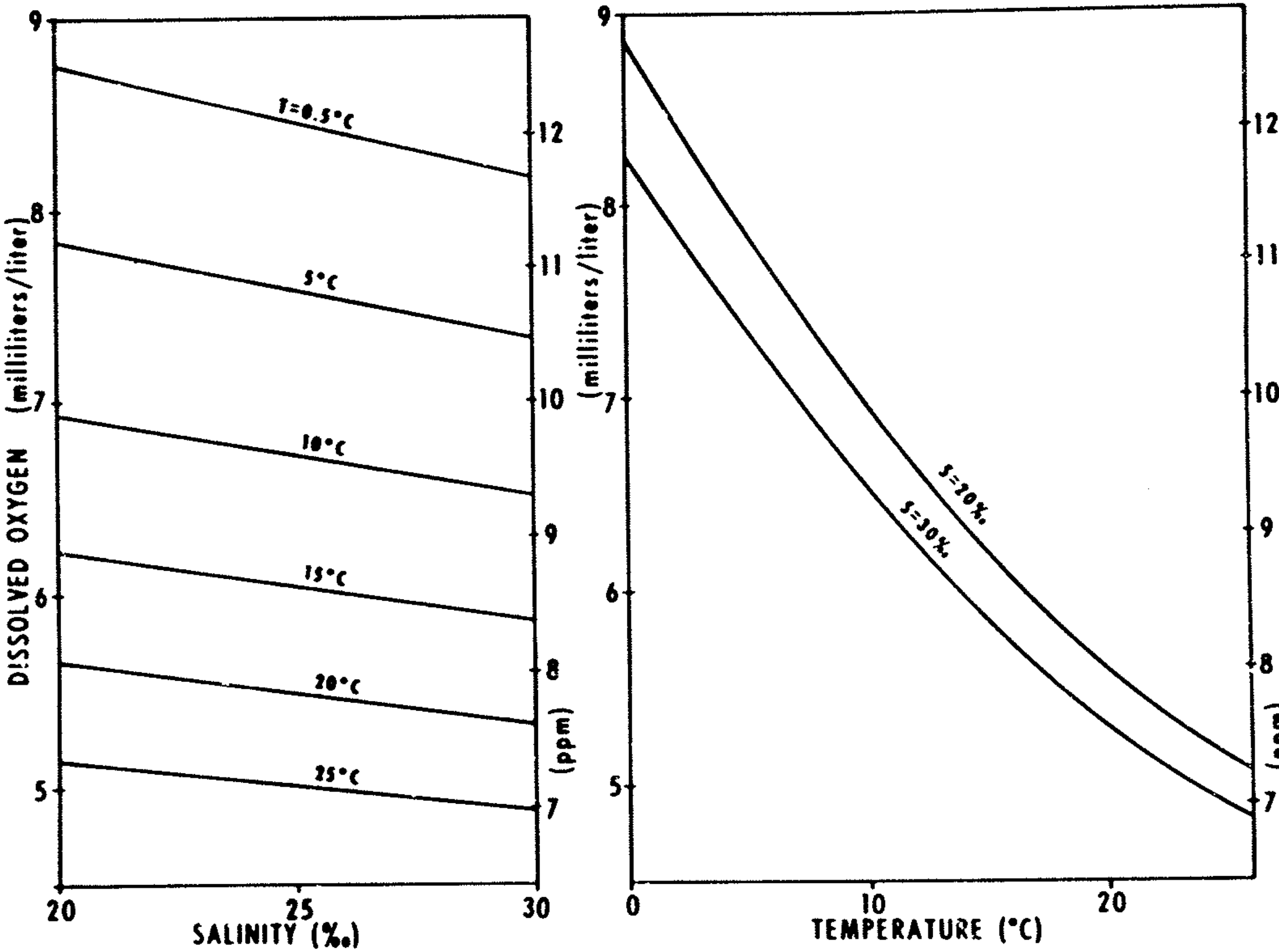

Figure 8. Solubility of atmospheric oxygen in seawater (courtesy of J.H. Carpenter. 1966. New measurements of oxygen solubility in pure and natural water. Limnol. Oceanogr. 11:261-277)

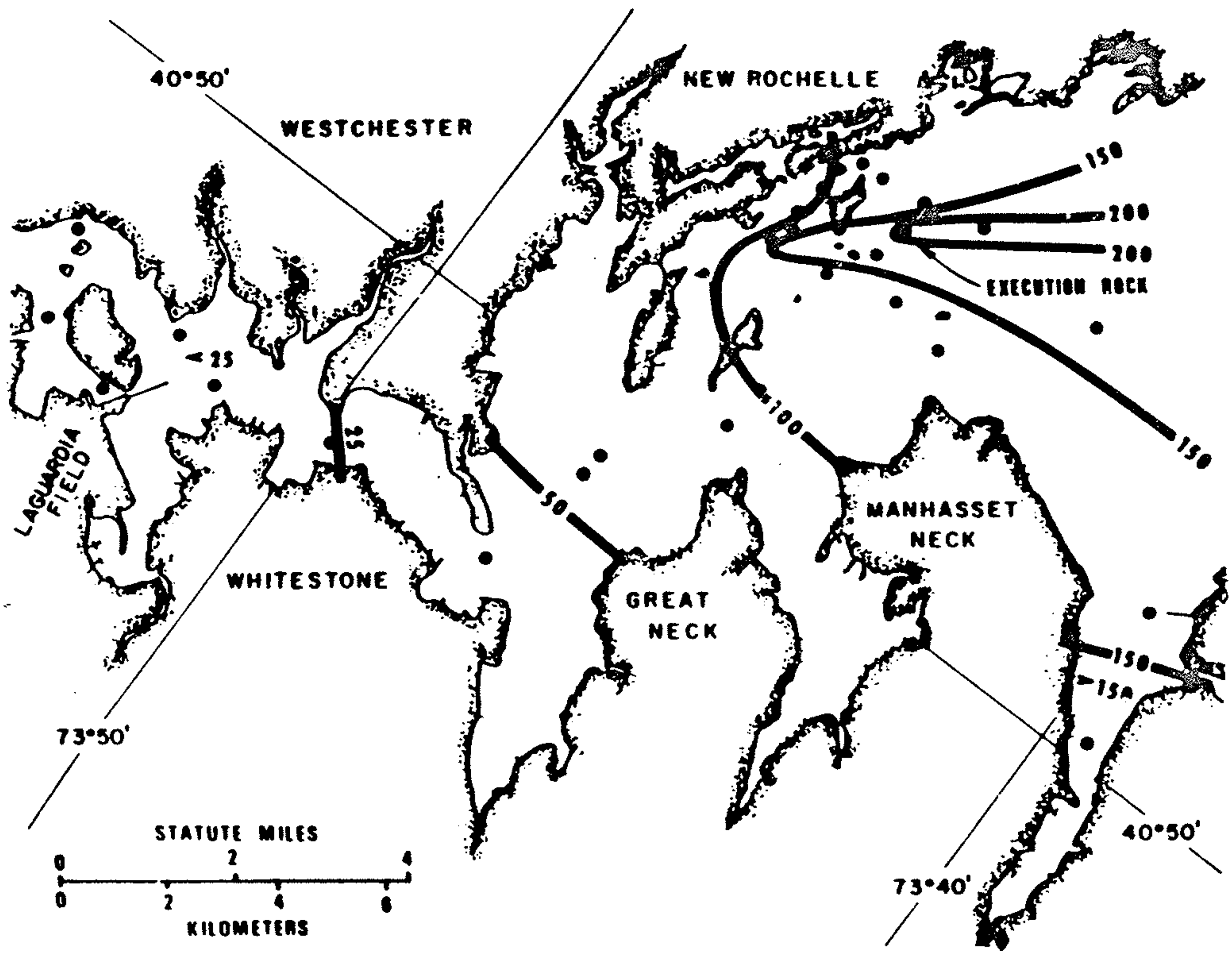

Figure 9. Surface oxygen distribution (as percent saturation), 7-8 August 1970, in western Long Island Sound (courtesy of L.E. Koppelman, P.K. Weyl, M.G. Gross, and D.S. Davies. 1976. The Urban Sea: Long Island Sound, Praeger Special Studies. New York. 223 pp.).

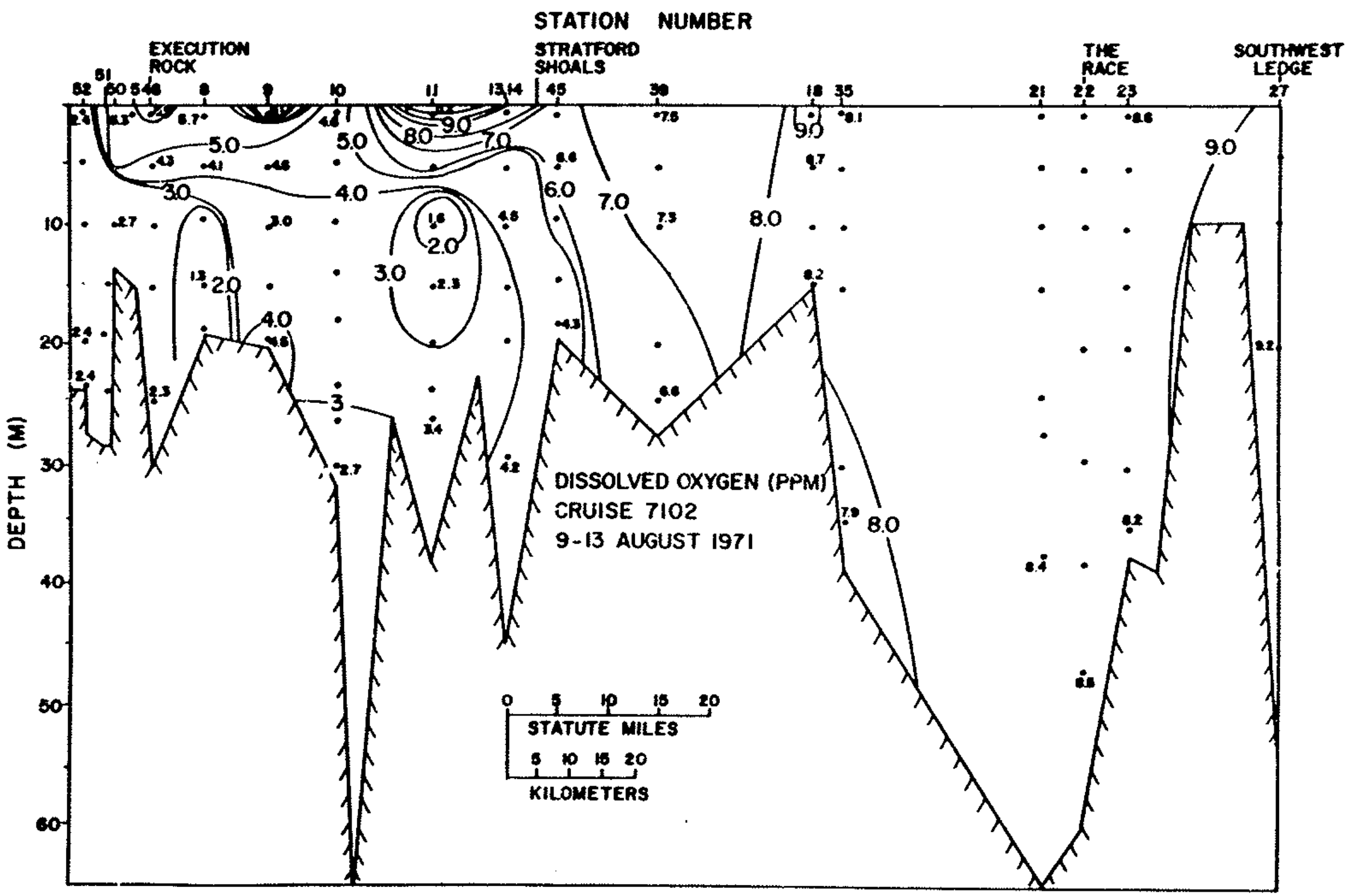

Figure 10. Dissolved oxygen distribution in east-west profile taken through central Long Island Sound, 9-13 August 1971 (courtesy of C.D. Hardy. 1972. Movement and Quality of Long Island Sound Waters, 1971. Tech. Report No. 17, Marine Sciences Research Center, SUNY Stony Brook. 66 pp.).

surface to bottom in the eastern end. As you go farther to the western end of the Sound, oxygen values decrease except in near-surface waters.

Now I would like to talk about one event that occurred in 1977 during which Weiss and Duedall (unpublished) observed the oxygen concentration in the western Sound. Temperatures in the summer of 1977 were abnormally high (Figure 11). During July the air temperature in the New York area reached 104°F and remained high for a long period of time. The oxygen concentration in deep waters of western Long Island Sound is highly dependent on the weather pattern. As I mentioned, during the summer there is less dissolved oxygen in the water because the ability of seawater to hold the oxygen decreases. In addition, prolonged periods of high temperatures combined with low winds produce high density gradients between the surface and bottom waters.

Now look at the location of Stations 3 and 4 (Figure 12), which were repeatedly sampled during this period in August. Before the first cruise the temperature was extremely high for about a week, and wind speeds were low. The wind speed averaged about 8 miles per hour at the time of the first cruise (Figure 13). After this, in late July, the wind speed picked up, reaching an average of about 14 miles an hour. At the time of the third cruise there was a decrease in temperature, and before the fourth cruise the wind speed was low again (Figure 14). Then the temperatures rose once more. At Cruises 6 and 7 there were periods of cooling.

I am going to point out the changes in the oxygen concentration as conditions changed with all these cruises (Figure 15). Again, I would like you to concentrate on Stations 3 and 4 in the central western Sound. The dashed line in Figure 15 represents the density of seawater. The solid line is oxygen content. You can see that on the first cruise after the period of high thermal heating, the water was highly stratified and very warm. Low-density water was on the surface and cooler, high-density water was on the bottom.

There was a very marked vertical change in oxygen concentration. High values in surface waters decreased to about 3 mg/liter in the bottom waters. Conditions were starting to approach anoxia until, fortunately, the wind speed picked up and the temperature dropped. By the time of the third cruise, the water was almost isothermal from surface to bottom, with a slight increase in the oxygen concentration. However, that period was followed by more heating, an increase in the stratification, though fortunately not too great, and then a decrease in oxygen content.

By the time of the sixth cruise, there was less stratification and some improvement in oxygen content, until by late in August conditions were almost isothermal from surface to bottom, accompanied by a large increase in the oxygen concentration. By late September (Figure 16) there was pronounced cooling, with

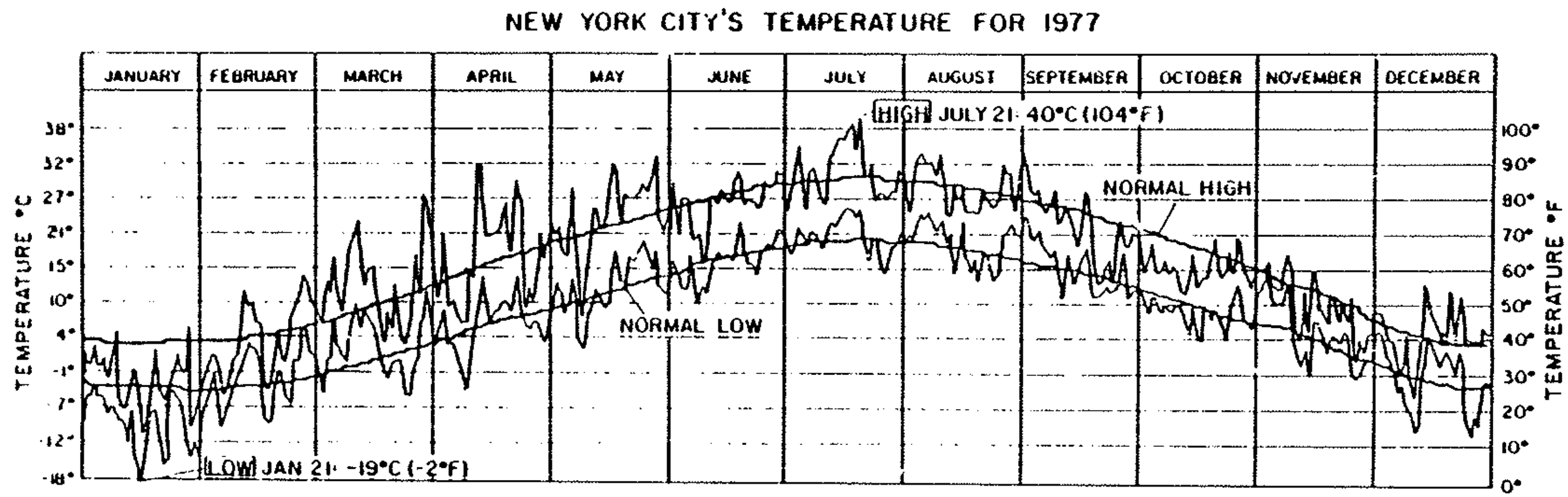

Figure 11. Temperature in New York City during 1977, showing daily high, low, and mean high and low temperatures (courtesy of E. Weiss and I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

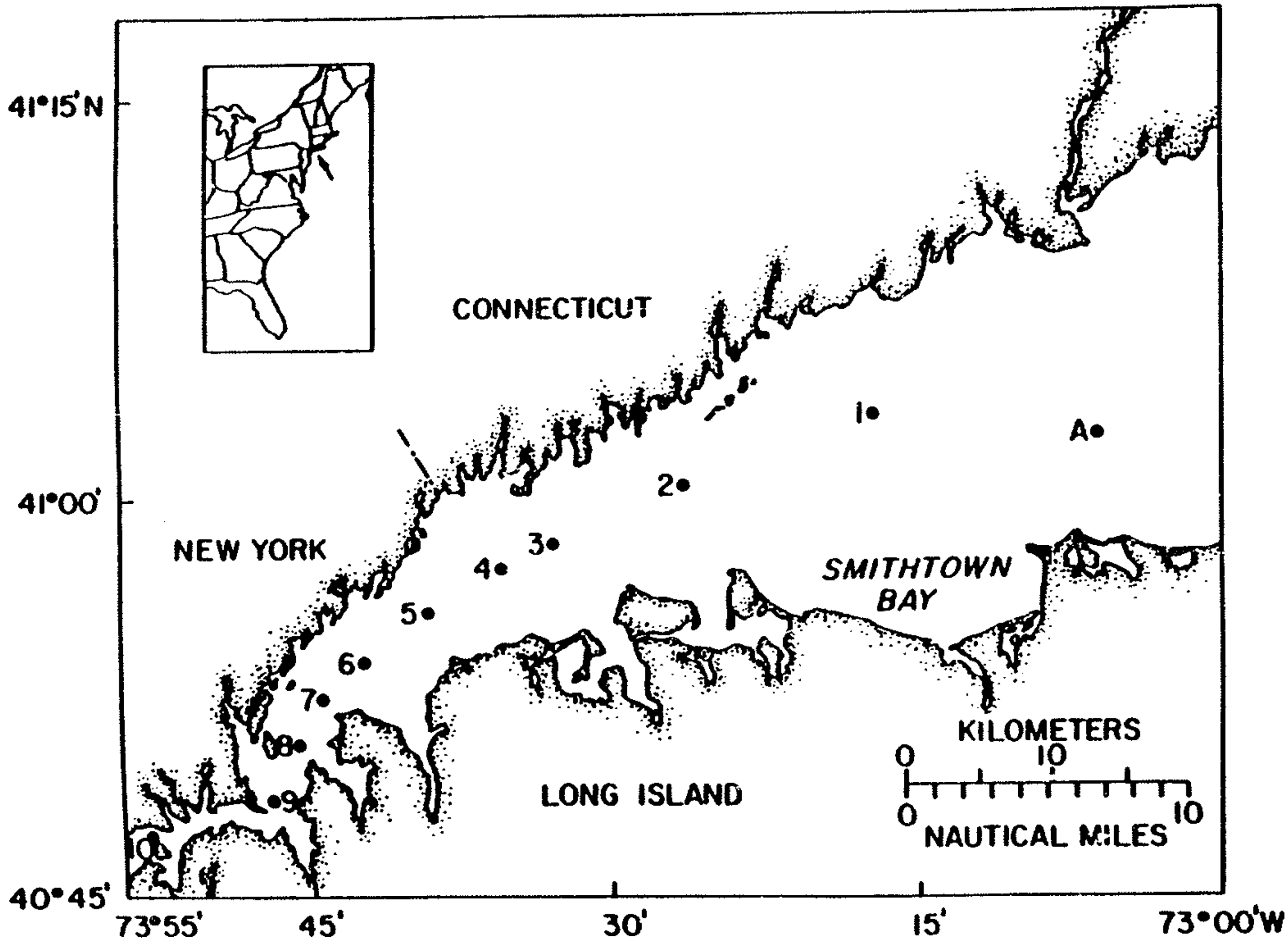

Figure 12. Sampling statistics used in 1977 for monitoring dissolved oxygen concentration in western Long Island Sound (courtesy of E. Weiss and I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

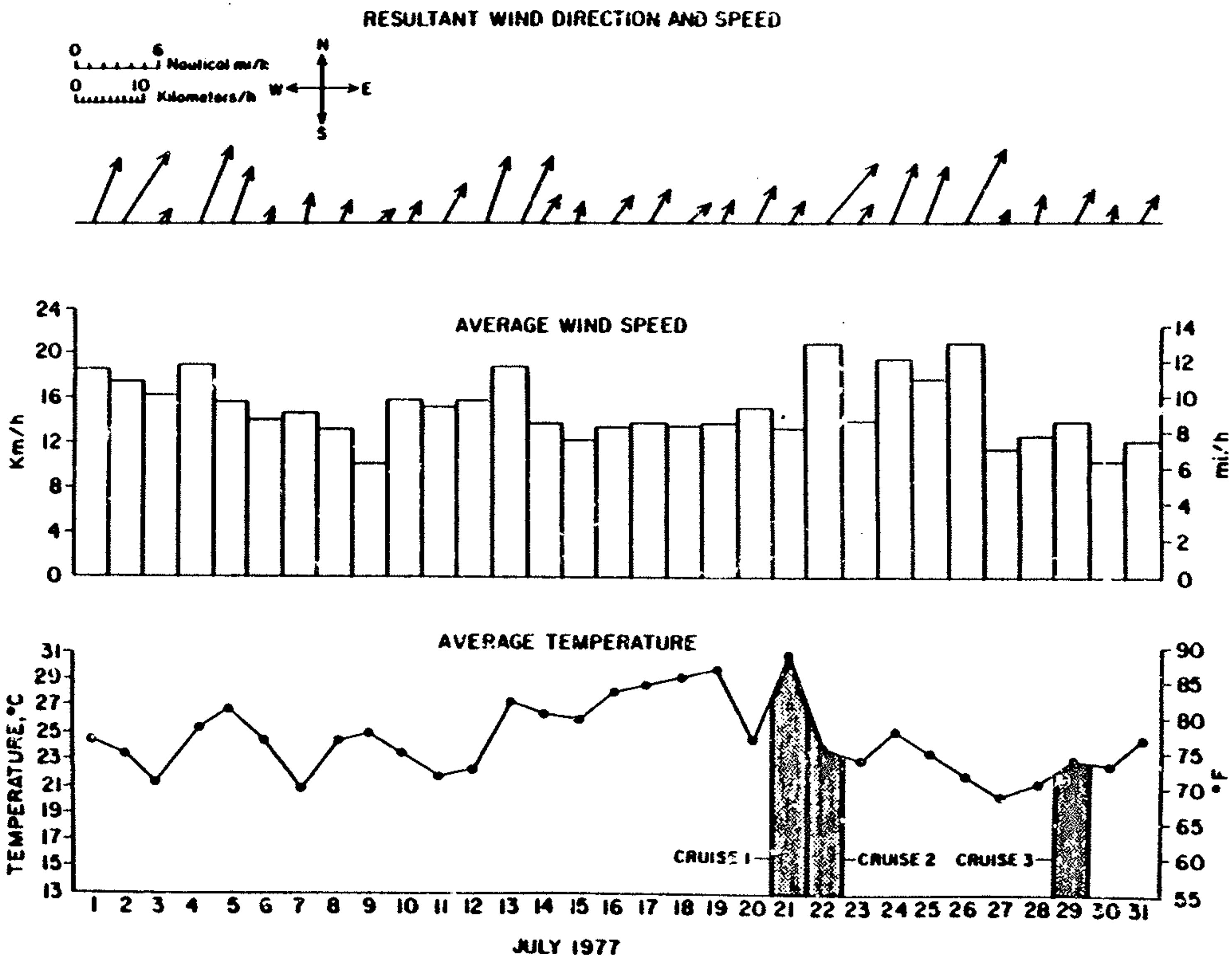

Figure 13. Average wind speed and direction and cruise dates in Long Island Sound (courtesy of E. Weiss and I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

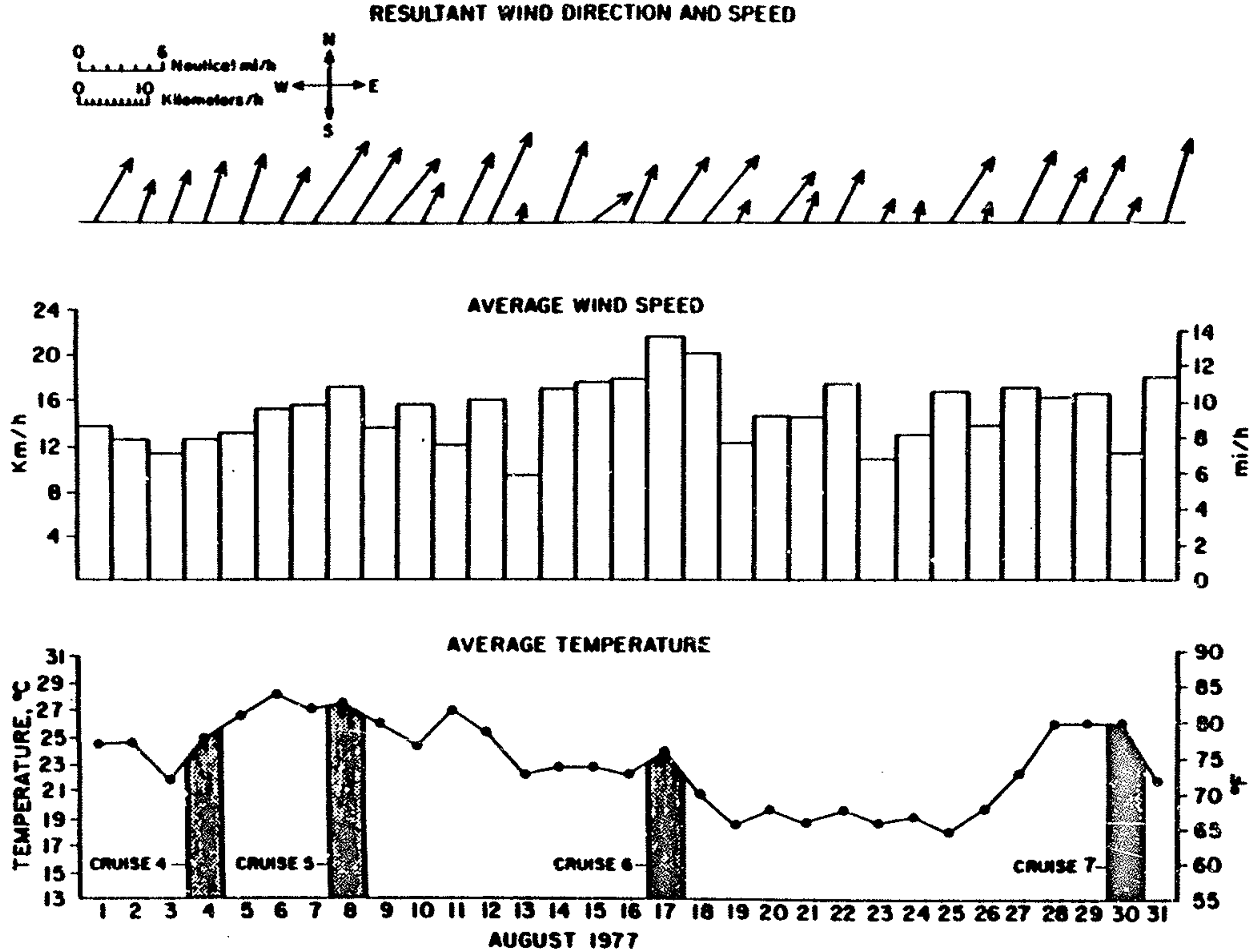

Figure 14. Average wind speed and direction and cruise dates in western Long Island Sound (courtesy of E. Weiss and I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

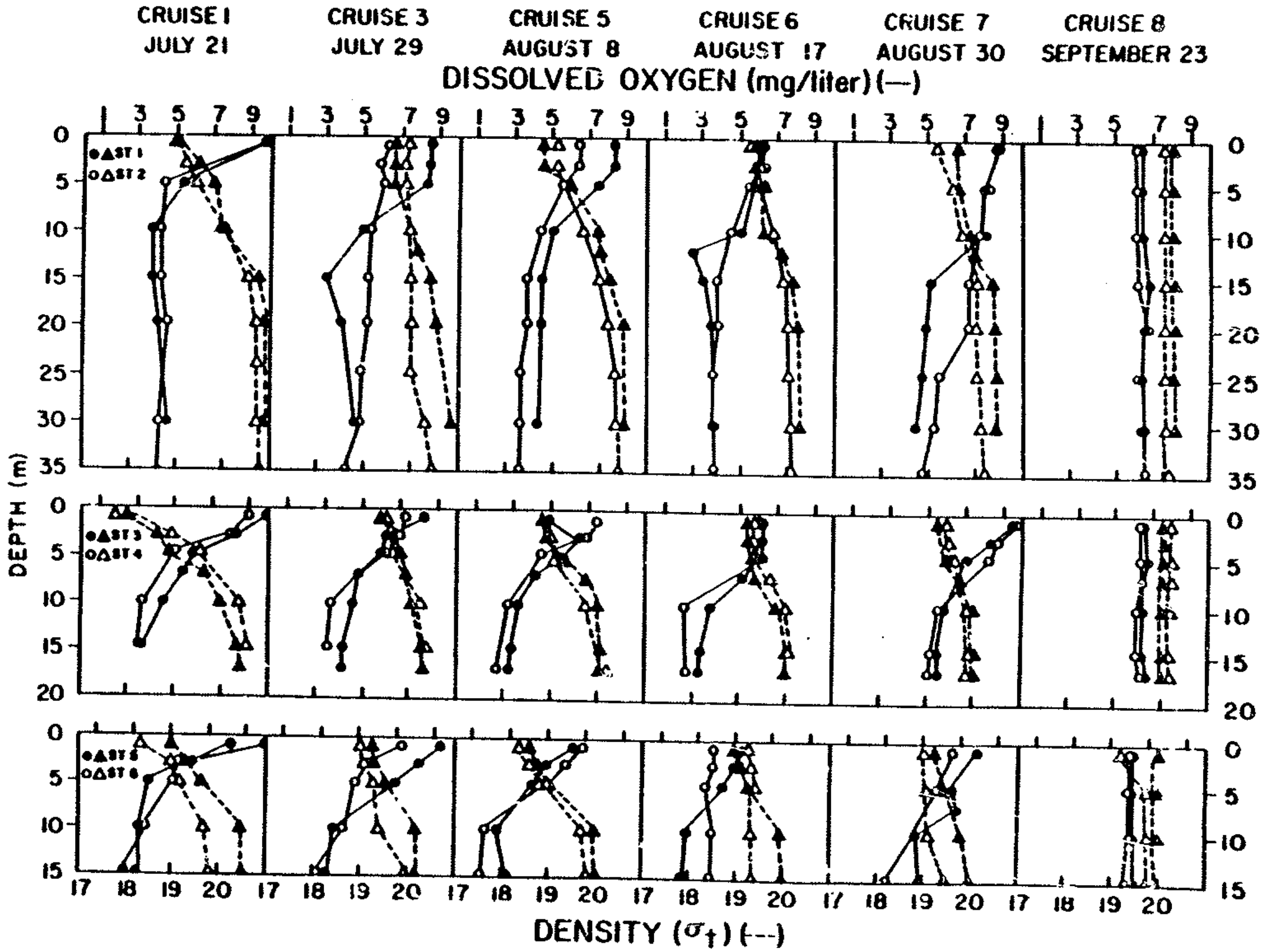

Figure 15. Vertical profile of dissolved oxygen (circles) and density as sigma t (triangles) at Stations 1-6 in western Long Island sound from 21 July to 23 September 1977 (courtesy of E. Weiss and I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

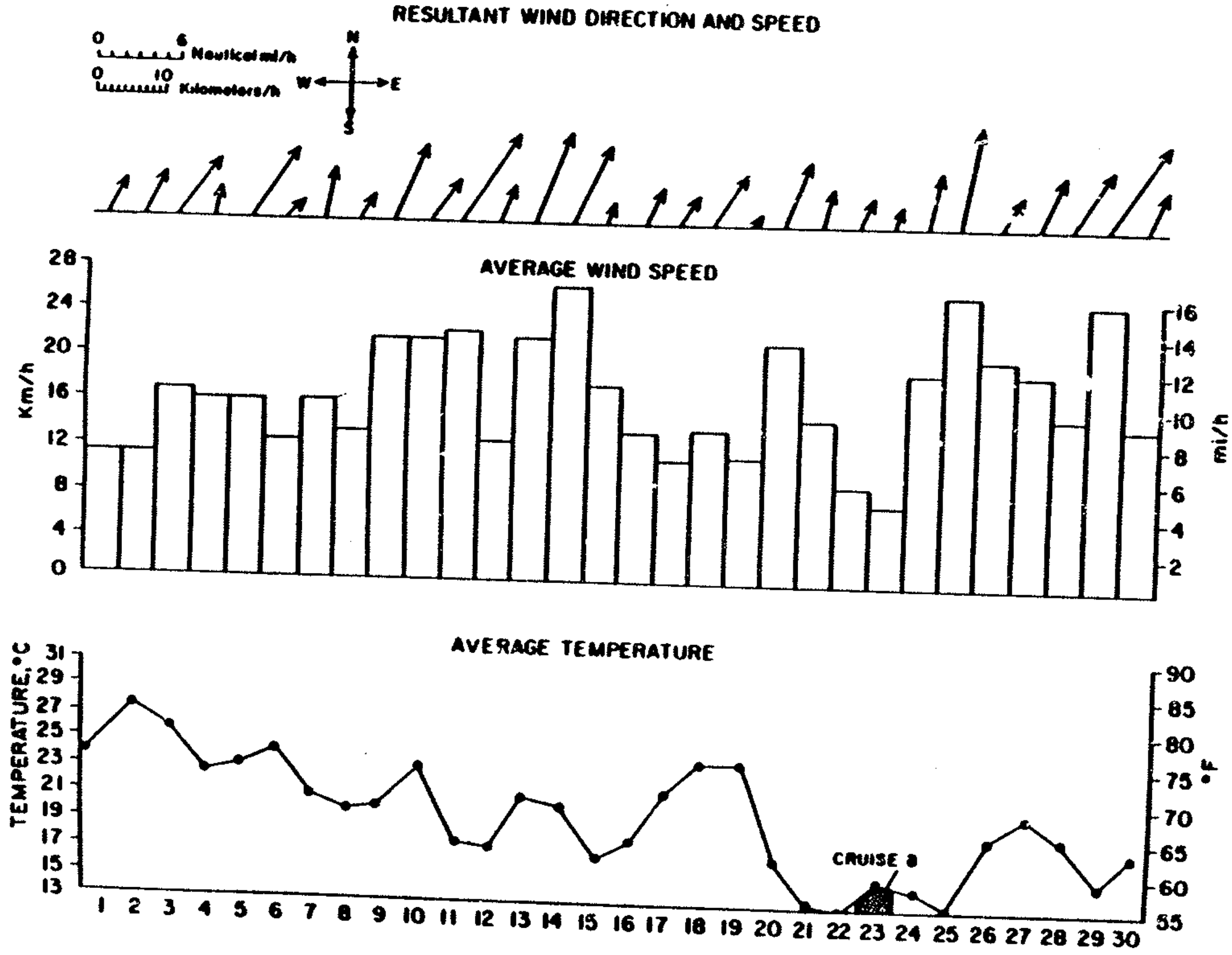

Figure 16. Average wind speed and direction in September 1977 in western Long Island Sound (courtesy of E. Weiss an I.W. Duedall (unpublished ms.). Wind and air temperature regulating dissolved oxygen concentration in an estuary. 33 pp.).

high oxygen concentrations in the surface and bottom waters, and no stratification. The density was the same, so seawater was mixing from surface to bottom.

I think this example points out how finely tuned the oxygen consumption in deep water sediments is in relation to the weather patterns. If there is a lot of stratification, a large nutrient input, and high carbon loadings, there can be an anoxic event. Such an event occurred in the coastal waters off New Jersey in 1976.

This low oxygen event, which was approximately 100 miles long by about 40 miles wide, caused the deaths of surf clams and massive die-offs of fish. This is something that we don't want to occur in western Long Island Sound. It is something that could occur, however, if the increased loading of sewage were coupled with conditions of high heating in summer. In addition, the dredge spoils being dumped into the western Sound could have an impact by cutting down the light available to phytoplankton, possibly leading to an anoxic event.

In summary, it is apparent that oxygen concentrations in the western Sound are tightly coupled to weather patterns. Nutrient concentrations, resulting from sewage input in this region, are higher and this results in high rates of primary production. This high rate of production provides oxidizable organic matter that can fuel a possible low oxygen event.

THE BENTHIC ECOSYSTEM

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I have a difficult task, as all the speakers do, because we're trying to summarize years of data and experience. In my case, some 20 years, and I hope to do it in 20 minutes or less.

Nonetheless, it's fairly easy to identify first-order problems that need attention. The first of these is the use of the Sound as a repository for dredged materials that come mainly from the harbors of Connecticut. These harbors are dredged periodically, every 6 to 10 years. On the average, about a million cubic yards of material is dredged from the harbor channels, especially from the large ports such as New London, New Haven, and Bridgeport. This sediment is barged out to disposal sites located in the open Sound in depths of 60 to 80 feet of water. The three sites in current use are located in the following areas:

- the eastern Sound off New London
- the central Sound south of New Haven
- the western Sound south of Norwalk

Because of time constraints, I am not going to say much more about the disposal problem. The New England Division of the Corps of Engineers has in place a Disposal Area Management System (DAMOS) program, and I am satisfied that this problem is well in hand. The program is funded at about a million dollars a year and monitoring of each disposal site is done seasonally. I believe it is an excellent program and environmental degradation of the seafloor could not progress very far before the DAMOS program would identify and correct such a problem in its early stages.

The second problem has to do with eutrophication. This phenomenon has received much less attention than disposal and is just as critical. The eutrophication problem in western Long Island Sound will be a recurring theme today.

Figure 1 shows the concentration of muddy sediment ($\leq$ 62 micrometers) in Long Island Sound. The organic-rich mud is largely concentrated in the central and western basins of Long Island Sound. This fine-grained sediment generally accumulates within harbors and in the open Sound at depths greater than 40 to 60 feet.

The products of sewage effluents that enter the Sound from near-shore consist of particulate organic matter, either as treated or untreated sewage, or as plankton that may bloom because of the nutrient-rich water associated with sewage effluents. In either

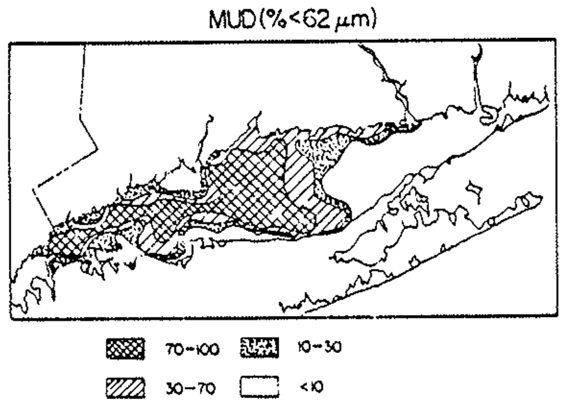

Figure 1. Distributrion of % Mud (<62 μm) in Long Island Sound (from Turekian et al., 1980).

case, this particulate organic matter (POM) also settles into the basinal areas along with natural fine-grained sediment. Many pollutants such as trace metals or organic contaminants also "ride" on these particles and become concentrated in the muddy areas. Fine-grained sediments also accumulate in low kinetic areas of harbors. This is why harbors must be periodically dredged. The accumulation of reactive organic matter in sediments leads to high sediment oxygen demands which may deplete the overlying water of its oxygen. This, in turn, may adversely affect living marine resources associated with the bottom.

The central basin off New Haven has historically been considered fairly pristine. The benthic organism-sediment relationships typical of this region are shown in Figure 2. On the left-hand side of the figure is a profile image of the bottom as seen in vertical section, showing the overlying water, sediment surface, and sediment profile down to a depth of about 16 cm. This profile structure is typical of those parts of the seafloor where organic inputs are roughly balanced with respiration. Within the bottom can be seen feeding voids or pockets that form around the head ends of infaunal organisms (mainly polychaete worms). The head-down orientation of the worms is typical. They ingest sediment and pass it up to the sediment surface in a kind of conveyor-belt mode of feeding. Besides advecting large quantities of sediment, these organisms also pump oxygenated sulfate-rich seawater into the bottom. This bioturbational activity stimulates bacterial degradation of organic matter and is important for efficient respiration of organic matter. Note the high reflectance of the sediment. Because the inventory of reactive organic matter is low, sedimentary sulfides such as hydrogen sulfide and iron sulfides are also low in concentration. In other words, below a critical loading rate of POM, these organisms keep the sediment relatively free of labile (reactive) organic matter. In excess, such labile substrates can contribute to high sediment oxygen demands. In this sense, such head-down systems serve to purge the bottom of labile organic matter. Some analogies can be drawn between this natural biological nutrient recycling system and man's tertiary sewage treatment plants. The dissolved oxygen over such a bottom type is therefore typically high, reflecting the low sediment oxygen demand of the bottom.

On the other hand, areas of the bottom that experience "supercritical" organic loading have very different organism-sediment relationships. Figure 3 shows a similar sediment profile taken in a harbor region near a sewage effluent. Here the benthos consists of small polychaete worms belonging to families known to populate enriched areas (e.g., Capitellidae or Spionidae). They live near the sediment surface and bioturbate only the near-surface sediment. Note how dark the subsurface sediment is in relation to the high concentration of labile organic matter and associated sulfides. The surficial mat of organisms is not able to burn off the input of labile organic matter as fast as it is introduced. This is an inefficient biological processing system

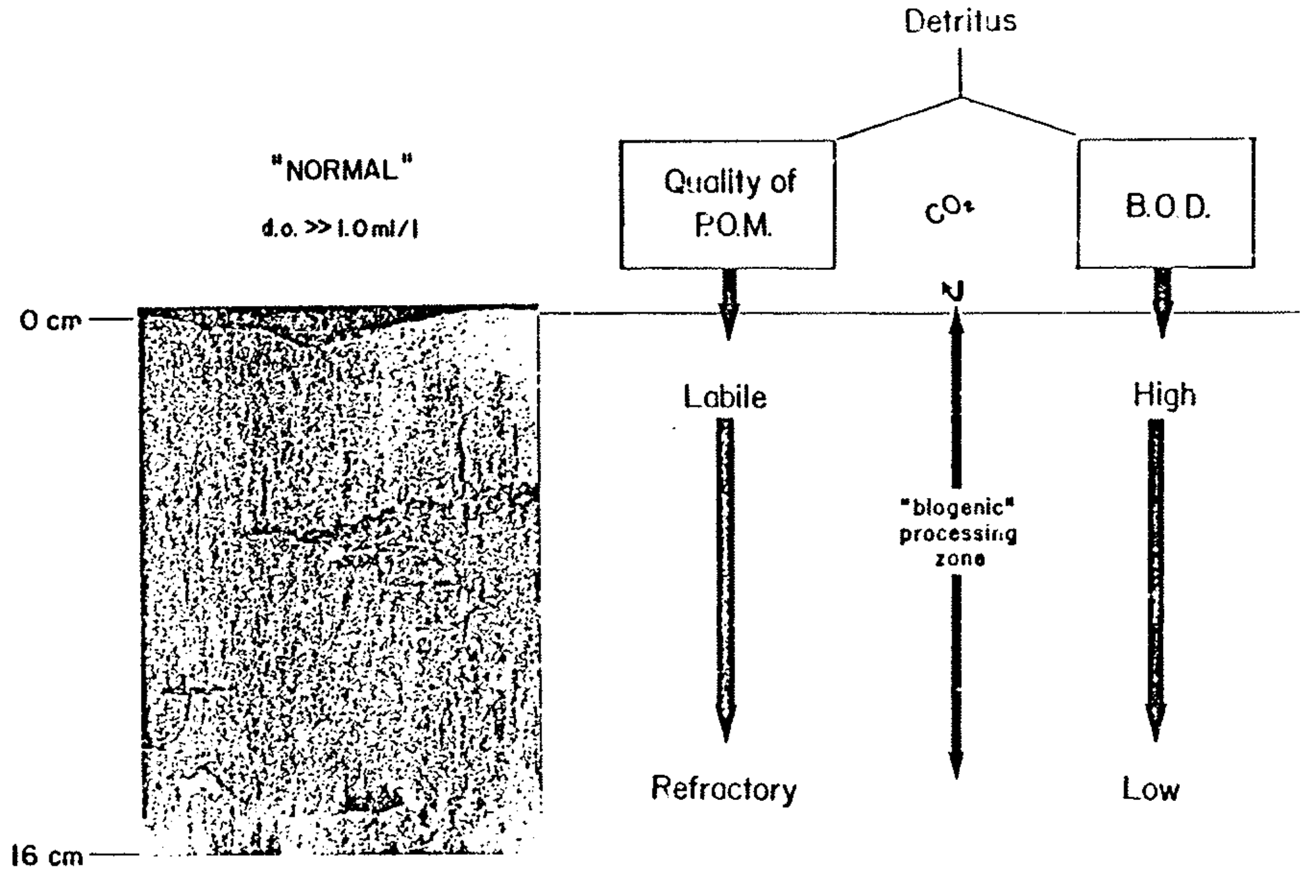

Figure 2. Organism-sediment relationships in estuarine areas not subject to organic enrichment. The biogenic processing of sedimenting particulate organic matter (POM) is efficient so that the input rate is roughly balanced with its respiration. The inventory of labile organic matter and sulfides is low. The biological oxygen demand (BOD) is correspondingly low. The overlying water is not significantly depleted in its oxygen content (from Rhoads & Germano, 1986).

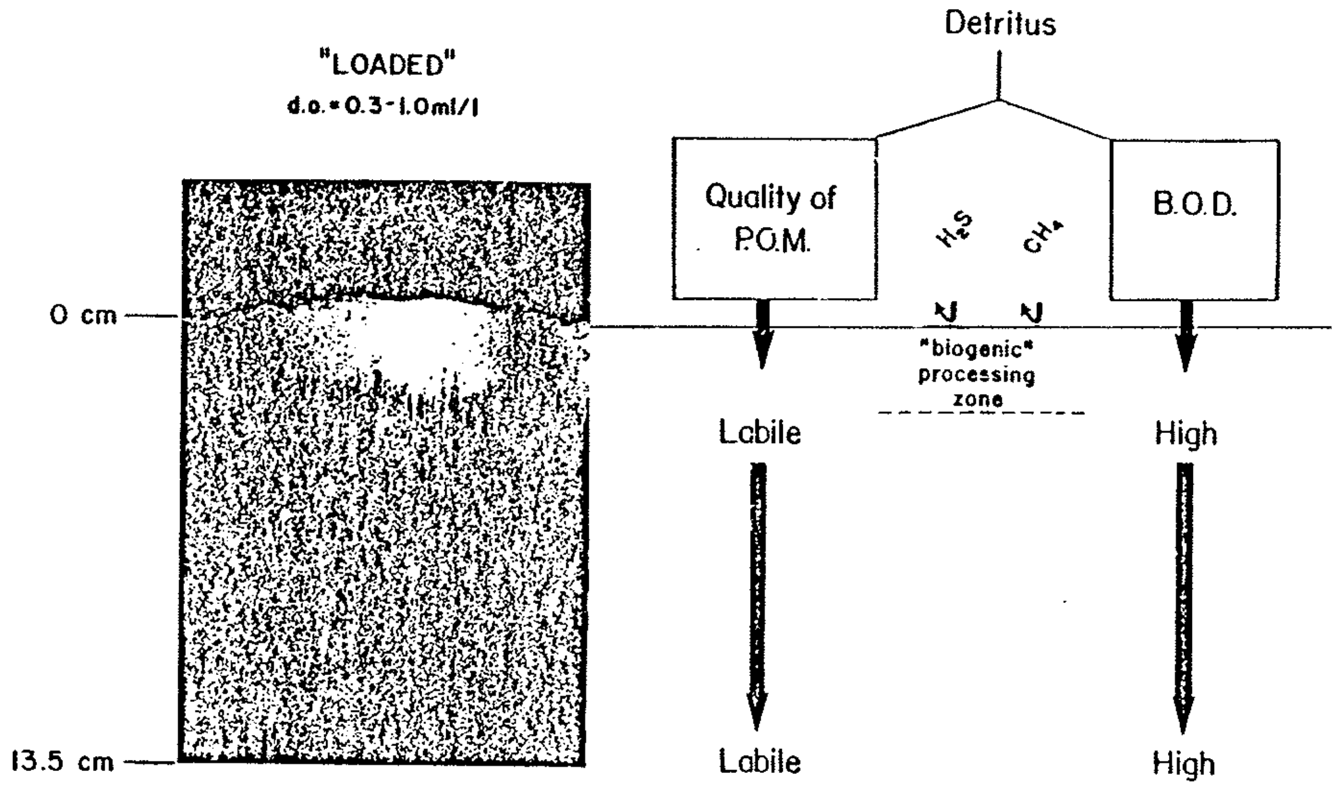

Figure 3. Organism-sediment relationships in estuarine areas subject to organic loading. The input rate of labile particulate organic matter (POM) greatly exceeds its consumption. Much of this reactive POM passes through the thin processing zone and is buried within an anoxic sediment. Hydrogen sulfide and methane gas may be released and escape into the overlying water, creating a chemical oxygen demand. This together with a high biological oxygen demand (BOD), may deplete the overlying water column of dissolved oxygen (from Rhoads & Germano, 1986).

and, in fact, the organisms themselves may serve to focus the sedimentation of POM into such areas. With the build-up of reactive organic matter in the sediment and a lack of pore water oxygen, hydrogen sulfide, ammonia, and methane gas may be generated and enter the overlying water column. These reduced compounds, along with the reactive organic matter, may deplete water in contact with the bottom of its oxygen.

The transition of a "purging" benthic system to a "storage" system can be seen in Figure 4 from the upper Chesapeake Bay. The profile shows a high reflectance sediment at depth (a formerly aerobic bottom free of sulfides) overlain by black sulfidic sediment. Arrows point to pockets of coarse material that represent the former locations of feeding areas of head-down feeders. These pockets have collapsed and are now relic structures related to the death of the head-down feeders. This purging system has been replaced by a population of enrichment species associated with the overlying sulfidic (dark reflectance) sediment. This image, and others like it, are means of mapping the historical change in organic loading of an estuarine system.

To return to Long Island Sound, what are the present distributions of purging assemblages and enrichment assemblages in the Sound, and what can these distributions tell us about the status of eutrophication? Unfortunately we do not have the answer to this question and further, we do not know what the critical loading rates of organic matter are that will change a purging system into a storage system. However, we can make some inferences about this. Figure 5 shows the distribution of sewage treatment plants (STP) in Long Island Sound. Most of these enter west of 73 degrees west longitude. As Dr. Carpenter stated earlier, the nitrogen loading within this region is very high.

We also do not know what the bottom oxygen demands are within the deeper parts of the Sound in this region, nor do we have near-bottom dissolved oxygen measurements in these areas. The Interstate Sanitation Commission has been measuring dissolved oxygen in shallower waters for many years, but those data do not address our deep-water low oxygen problem.

What are the responses of benthic organisms to near-bottom gradients in dissolved oxygen? Figure 6 is an attempt to address this question. The data do not come from estuaries but from permanently stratified low-oxygen basins like the Black Sea and continental borderland basins off southern California (Rhoads and Morse, 1971). For most benthic organisms, values of dissolved oxygen above 3 ml/liter are not limiting. This value forms the lower limit of the aerobic zone. Below 3 ml/liter, high metabolic rate species and life stages may be adversely affected, particularly fish and crustaceans. The zone between 3 ml/liter and 0.3 ml/liter is termed the dysaerobic (partially aerobic) zone in which only a few species of infauna do well. This is probably the habitat of the Sulfide Biome of Fenchel and Riedl (1970). Below concentrations of 0.1 ml/liter, metazoa do not do

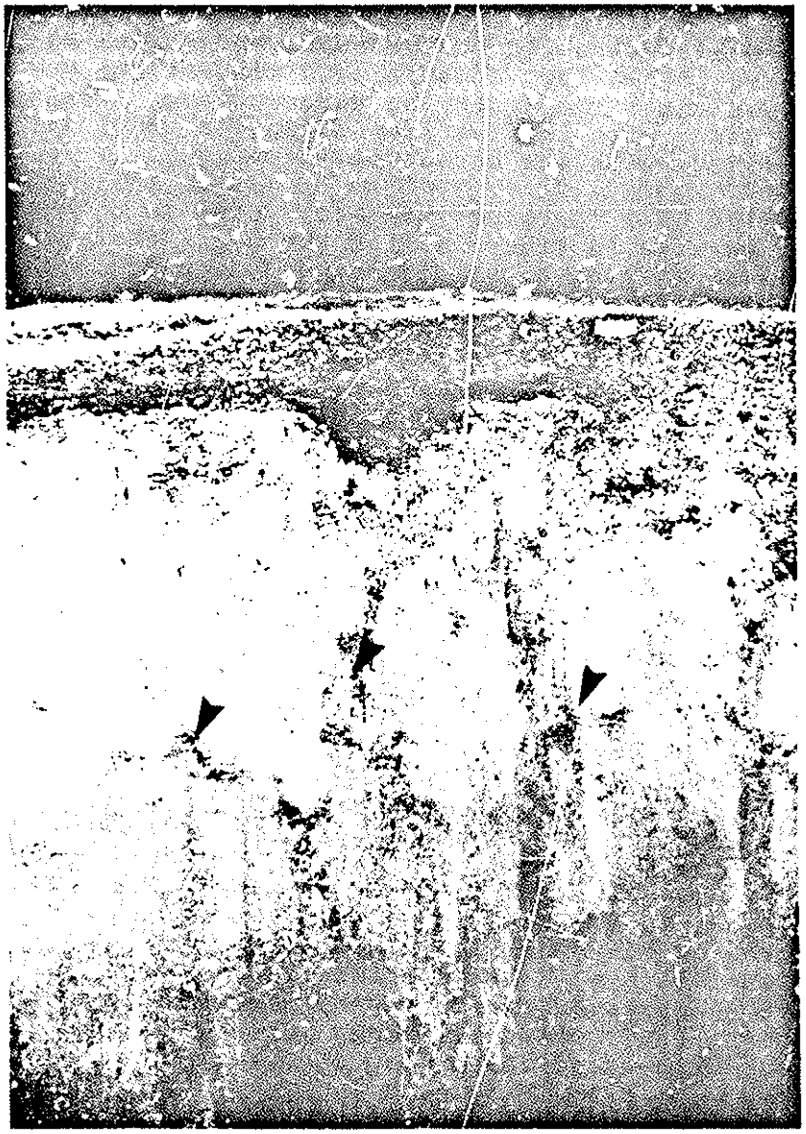

Figure 4. Historical change in bottom conditions in the upper Chesapeake Bay as manifested in sediment structure. A 1 cm thick layer of reduced pelletal sediment overlies a high reflectance sediment at depth which contains "relic" feeding pockets (arrows) produced by head-down feeders (see Fig. 2). This upward transition (at large arrow) is interpreted to represent eutrophication in the recent past (from Rhoads & Germano, 1986).

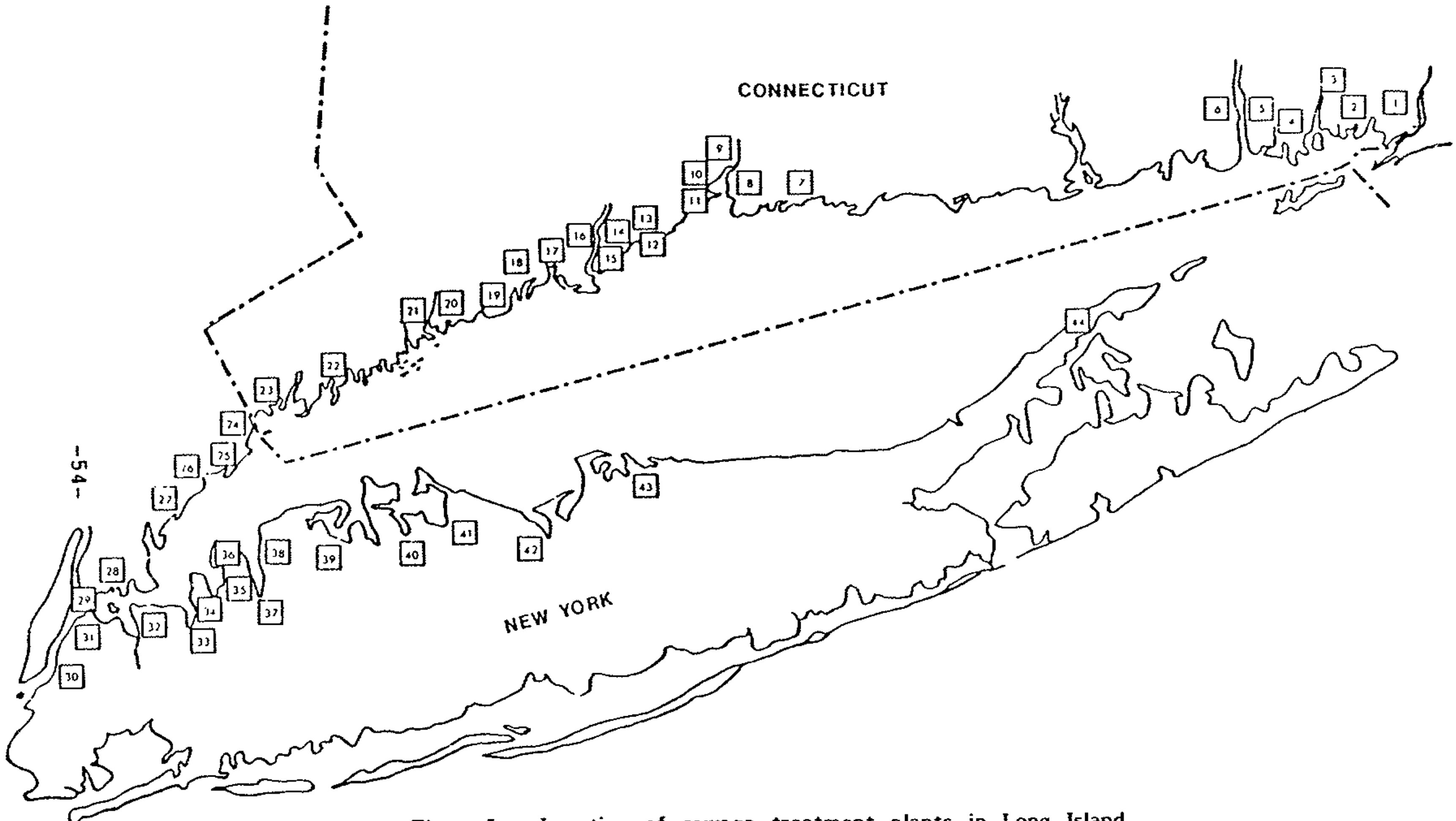

Figure 5. Location of sewage treatment plants in Long Island Sound (from Tilt, 1984).

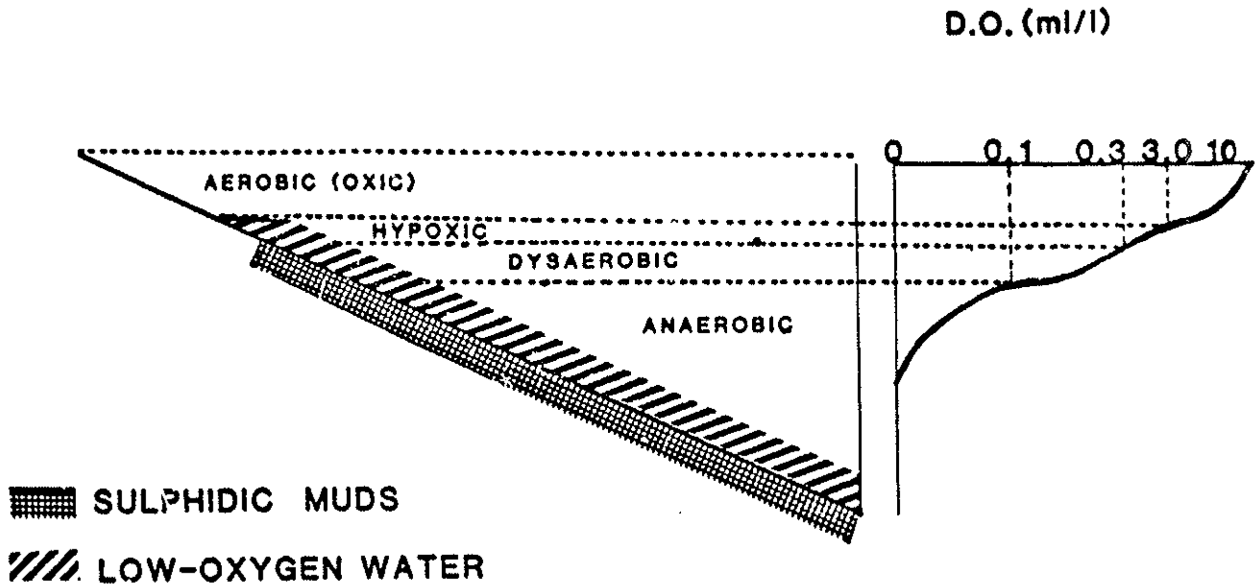

Figure 6. Bottom water dissolved oxygen facies in permanently stratified basins (modified from Rhoads & Morse, 1971).

well and only anaerobic bacteria, along with some nematodes, are found in abundance. Underlying the dysaerobic and anaerobic water one typically finds organic-rich black (i.e., sulfidic) muds that are termed sapropels. These are rich in iron monosulfides. The physical properties of these muds are distinctive and the best description that I have heard of them is that they are like a "black mayonnaise." It is unknown if the above generalizations about oxygen facies in permanently stratified basins are an appropriate description of estuarine conditions where low oxygen conditions are typically seasonal. Nevertheless, it is a model that may prove useful to test these ideas.

I want to leave you with an interesting thought about oxygen-organism relationships. Secondary benthic production can be very high in the hypoxic and dysaerobic zones, a phenomenon related to the abundance and high turnover rate of enrichment species that dominate these zones. This production (mainly polychaetes) may attract and support enhanced populations of benthic foragers such as demersal fish and crustaceans. However, as the basinal low-oxygen conditions spread up the sides of the basin, these commercially important predators may be compressed into an ever decreasing aerobic environment. The immediate perception may be one of increased catch per unit effort by fishermen. As a result, maximum commercial yields may be obtained just before there is a crash in the exploited populations. This crash may be related to enhanced fishing pressure, immigration of species from the encroaching hypoxic water, and intensified competition for space and food in the diminished aerobic habitat space. These observations are consistent with the general observation that the early to intermediate stages of eutrophication may temporarily increase the carrying capacity of a benthic system (Pearson and Rosenberg, 1978).

In summary, I would argue that the way in which we measure dissolved oxygen in estuaries is inadequate to identify problem areas in their early stages. Lowering oxygen probes to within 1 meter of the bottom is not appropriate because the early stage of increased organic loading and sediment oxygen demand can only be detected by making measurements within a few millimeters of the sediment surface. Even if these dissolved oxygen measurements are made near the sediment surface, the instantaneous measurement may not be representative of the time-integrated conditions at the site over the preceding weeks to months. Thus, instantaneous measurements of dissolved oxygen should be supplemented with studies of bottom sediments. What are the distributions of sapropels? What are the distributions of the biological storage systems (sensu Figure 3), and purging systems (sensu Figure 2)?

Is Long Island Sound oxygen stressed because of eutrophication? The answer to this must await application of the above revised monitoring protocol. From what we do know about water column nutrients and primary production in the western Sound, the probability is very high that hypoxic or dysaerobic conditions (at least) exist in the western Sound. It is imperative that these areas be mapped so that the problem can be recognized and dealt with. Let's not allow Long Island Sound to become another Chesapeake Bay before after-the-fact remedial action is applied to the problem.

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THE PELAGIC ECOSYSTEM

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It seems an impossible task to describe the pelagic ecosystem in Long Island Sound in the space of half an hour. However, I have selected some fundamental elements that I think are very much in need of public awareness and attention.

Our present perception of Long Island Sound is one of a phytoplankton-based system. This perception arises from the only existing pelagic ecosystem model available: one that was developed by Gordon Riley and his colleagues in the 1950s (Riley, 1972). The model was based mainly on data for depths greater than 10 fathoms, or 60 feet, as shown in Figure 1. In other words, it is limited to the Sound's deepwater pelagic system. Note, however, that only 50 percent of the Sound has a depth of 10 or more fathoms.

It is now time to establish long-term monitoring programs to holistically address the Sound, as Riley's group did. There have been 30 years of urbanization since the Riley data were collected. There have also been 30 years of progress in our understanding of marine ecosystems. We need to revise the Riley model with respect to the spatial and temporal characteristics of phytoplankton production. We need to determine the contributions from benthic plant production in the shallower areas. We need to quantify the couplings between shallower and deeper areas, and the couplings between the benthos and the water column. Finally, we need to collate our findings and apply them to the trophic relationships between living resources, i.e., primary producers, finfish, and shellfish.

Dr. Schubel has just spoken about geologic time scales and physical processes in Long Island Sound. Our assessments of the biological operation of the Sound system must be carried out on seasonal time scales. The rates of chemical and biochemical processes are closely linked to temperature and light regimes which change seasonally. These rates determine the ecological structure of the system.

I have diagrammed the Riley model symbolically in Figure 2. The model was based on organic carbon, all of which was assumed to be derived from phytoplankton production. The model included four categories of organisms: pelagic bacterioplankton, pelagic zooplankton, benthic filter-feeders, and benthic microbial consumers. Balancing the model over an annual cycle required that about 60 percent of the phytoplankton production be assigned to phytoplankton respiration. Sixty percent represents a rela-

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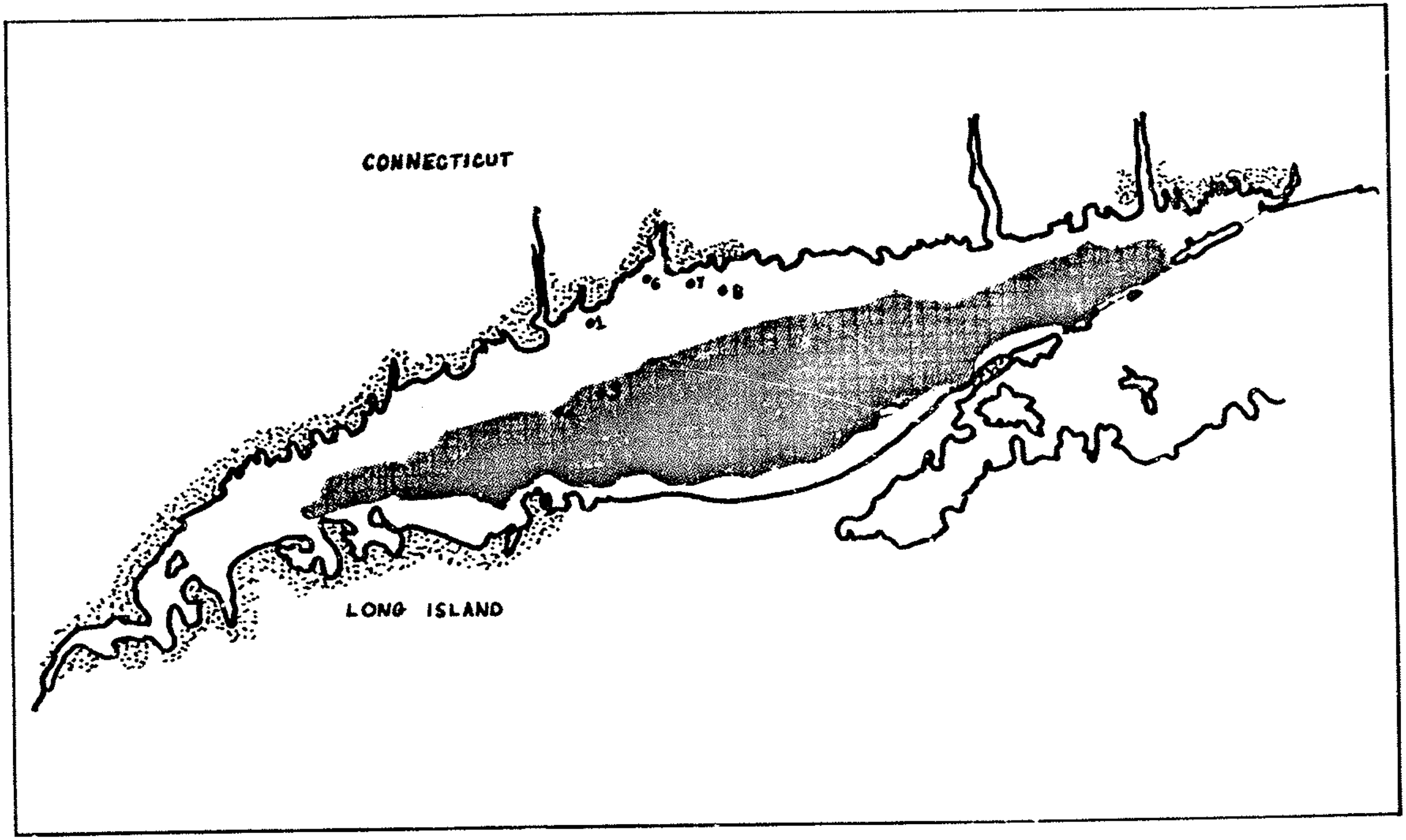

Figure 1. Long Island Sound. Areas deeper than 10 fathoms are shaded. Heavily urbanized areas discharging to the Sound are stippled. Numbers indicate "offshore" and "inshore" stations referred to by Figures 3 and 6.

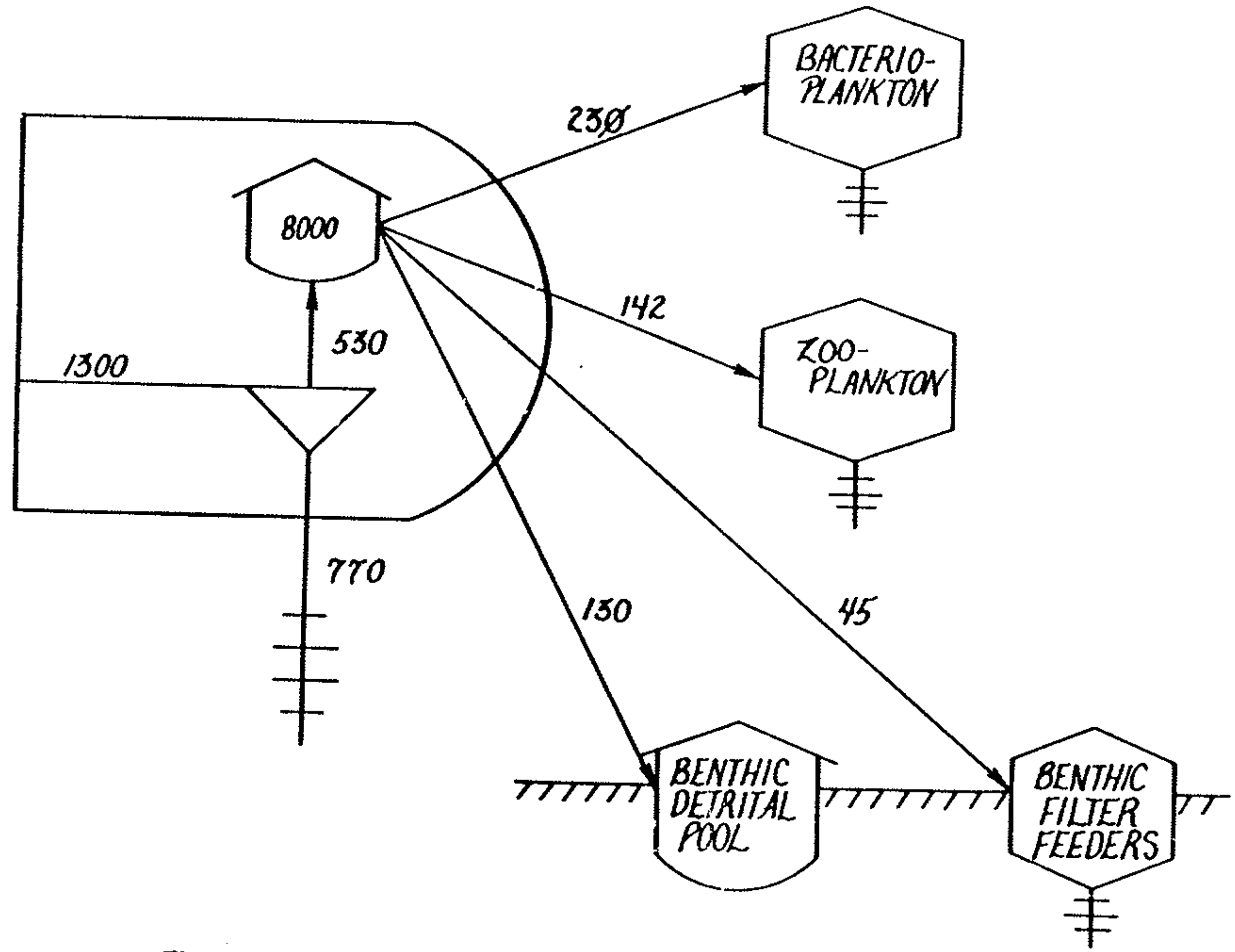

Figure 2. Schematic diagram of Long Island Sound trophic structure as presented by Riley (1972). Symbols are: ▭ = primary producer, ⬡ = consumer, ⌂ = organic storage pool, ‡ = respiration. Benthic detrital pool is assumed to supply the benthic microbial consumers referred to in text. Numbers in compartments are grams carbon per square meter. Numbers on flow vectors are grams carbon per square meter per year.

tively high respiratory requirement for phytoplankton. Riley justified the figure from the fact that Long Island Sound is very turbulent, mixing the plankton to the bottom layers away from the light and thereby increasing respiration relative to production. However, we must also recognize that this figure could be an artifact of forcing the model to balance.

Also unusual in this model were the large allocations to bacterioplankton and benthic consumers and the small allocation to zooplankton. This bypassing of zooplankton was cited by Riley as one reason for the relatively poor pelagic fishery supported by the Sound. The perception of Long Island Sound as a poor fisheries area has remained to this day, despite the substantial recreational fishery there and the firmly established role of the Sound as a nursery area.

I will reassess Riley's model with respect to the 30 ensuing years of urbanization, and with the benefits of as many subsequent years of scientific research. Figure 3 depicts a subset of Riley's data for phytoplankton production over an annual cycle for "inshore" and "offshore" stations. The inshore stations are all at water depths greater than 30 feet; they do not represent what I will later refer to as the "nearshore" environment. These data are from central and western Long Island Sound, areas that have a more distinct seasonal pattern than the eastern Sound. The seasonal features of phytoplankton abundance were classical for temperate latitudes: a bloom occurred in late winter or early spring, followed by a population crash and then another smaller bloom late in the summer. The summer bloom was less well defined and sometimes it did not occur. The spring bloom consisted mainly of diatoms, whereas the summer bloom consisted of phytoflagellates, a group of smaller algae. The switch in species was related in part to higher summer temperatures (Conover, 1956).

Another subset of Riley's data shows how nutrients controlled the phytoplankton blooms (Figure 4). Chlorophyll patterns in these data were less dramatic than in Figure 3 because they were mitigated by the less distinct seasonality in the eastern Sound. Nutrients were normally high in winter due to mixing of the water column. As solar radiation intensified and daylength increased, phytoplankton responded to high nutrients and a spring bloom developed. Rapid growth depleted the nutrient supplies, particularly nitrate. (These data constituted some of the early evidence that nitrate is the most limiting nutrient in the Sound.) The bloom ended and phytoplankton sank to the bottom. By late spring, stratification of the water column set in, keeping nutrients in the surface layer at low concentrations. Wind mixing in summer was sometimes sufficient to bring regenerated nutrients from bottom waters back to the surface, resulting in another small bloom, but nutrients were never high enough in summer to support the intensities of the winter-spring blooms. By the time the fall mixing occurred, light was declining and phytoplankton stocks remained low until the

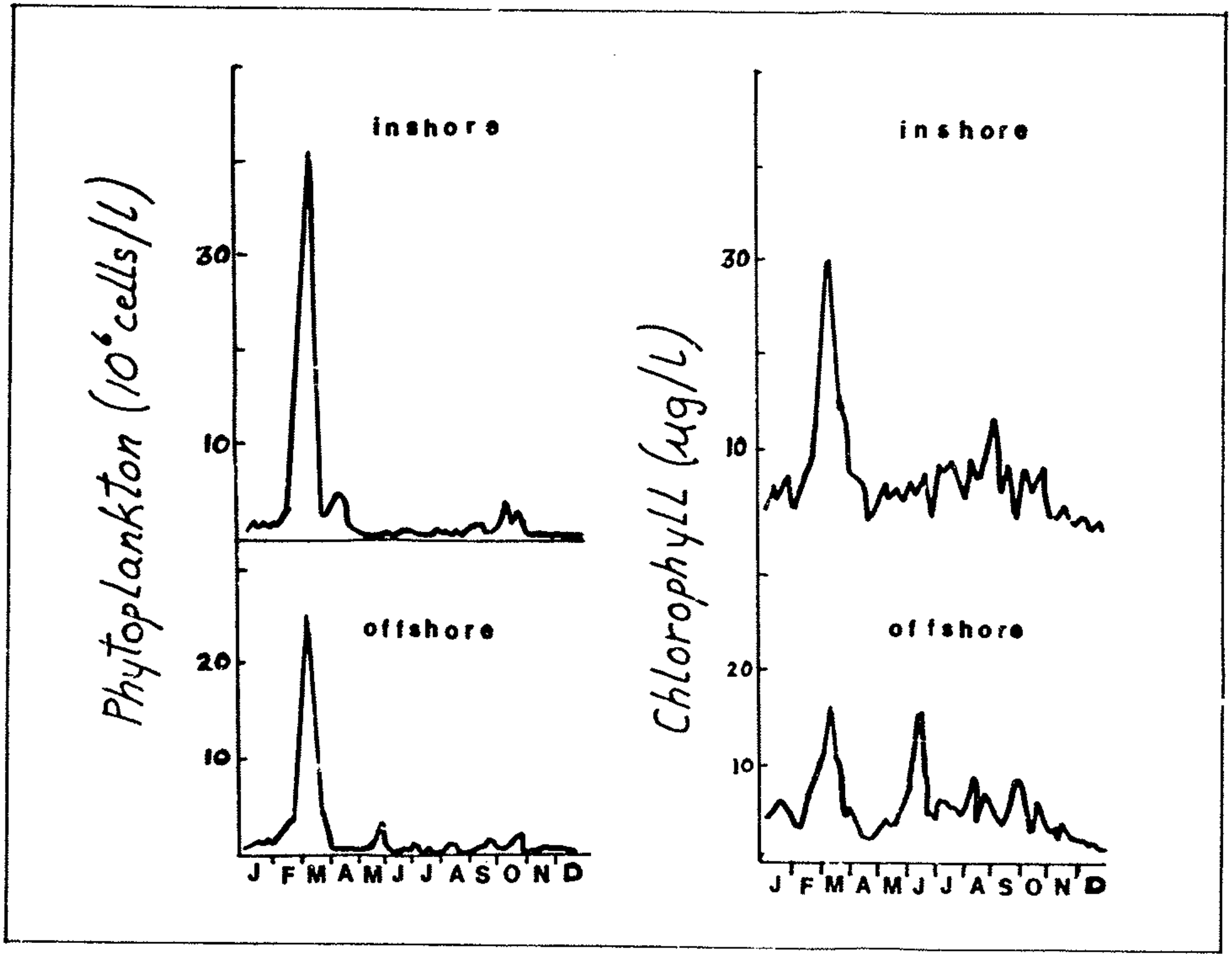

Figure 3. Seasonal cycles of phytoplankton cell densities and chlorophyll concentrations for "offshore" and "inshore" stations (see Fig. 1) in Central Long Island Sound (adapted from Conover, 1956).

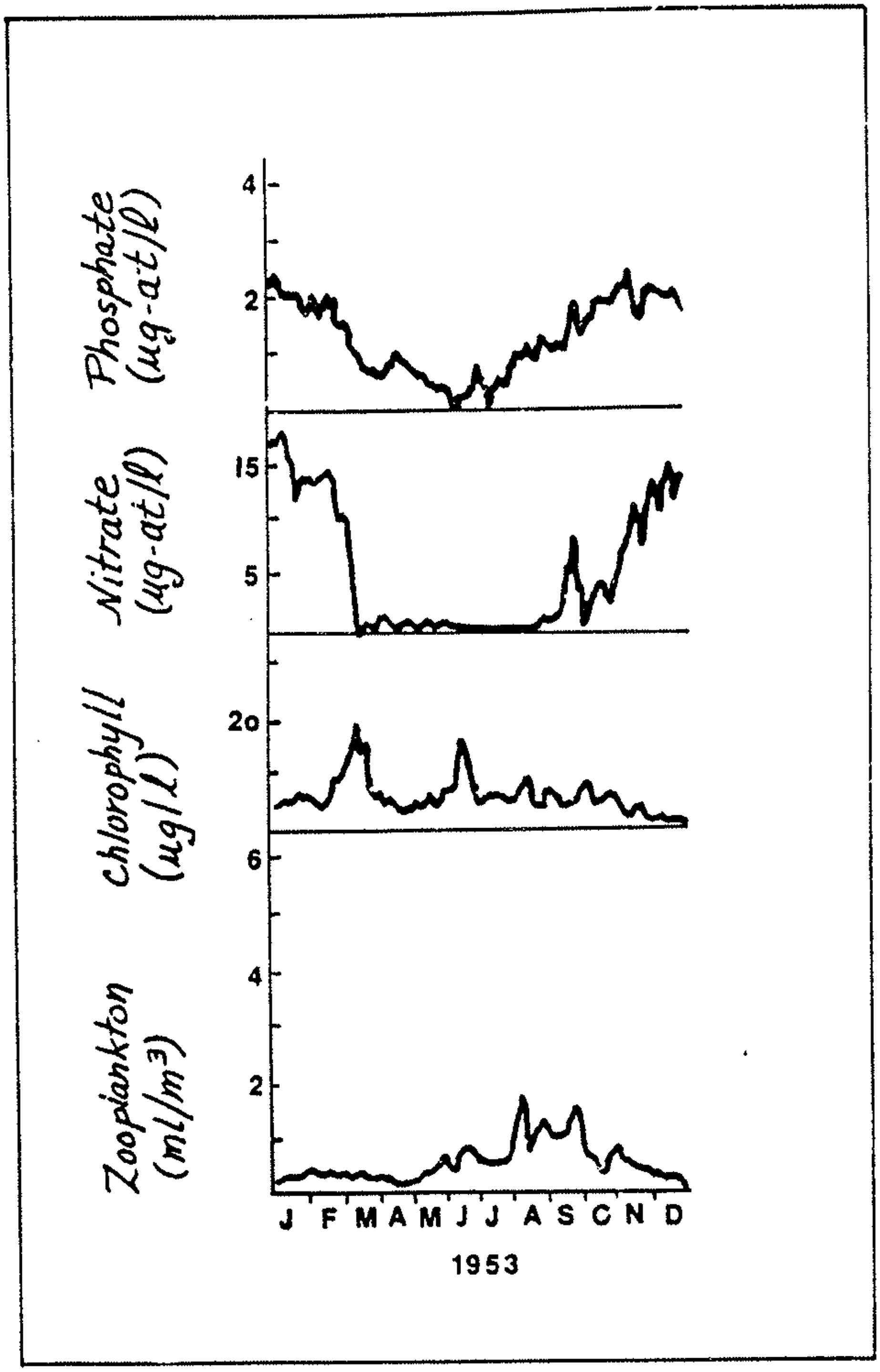

Figure 4. Seasonal cycles of nutrients, chlorophyll, and zooplankton (adapted from Riley and Conover, 1956).

following year. The important point here is that control of phytoplankton growth resides in a feedback mechanism that relies heavily on a drop in nutrient concentrations in the water column during the summer months (Riley and Conover, 1956).

In other systems, zooplankton grazing exerts a major control on phytoplankton population dynamics. In Long Island Sound, zooplankton do not grow fast enough in early spring to be considered a major controlling factor. Two-thirds of zooplankton consumption takes place in the summertime when temperatures are elevated. Although not graphed here, consumer demands by bacterioplankton and benthic consumers follow the same pattern as the zooplankton (Riley and Altschuler, 1967). Thus the bulk of consumer demand is seasonally offset from a major portion of the annual phytoplankton production, which occurs during the spring bloom.

Riley balanced the trophic budget over the annual cycle by applying surplus phytoplankton production from the spring bloom to summer consumer demands (Riley, 1956). Recent investigations have shown that decomposition rates for phytoplankton are very short. Phytoplankton detritus represents a high-quality carbon with a half-life of 10 to 12 days on the bottom (Westrich, 1983). Therefore, most of this excess of phytoplankton biomass would have decomposed by summer. We have to find other ways to balance production and consumption for this system using seasonal time scales.

There is evidence in Riley's chlorophyll data (Figure 3) that summer phytoplankton production was actually higher than he estimated. There is increasing evidence for supplementary sources of organic carbon, such as detrital material from nearshore macrophytes or urban discharges. It is highly probable that all these alternatives are operating. With respect to phytoplankton production, the summertime estimates are probably much too low because the dominant species switch from diatoms to flagellates. Flagellates show a strong temperature response. They have very high production rates per unit biomass or per unit chlorophyll compared to diatoms, and they tolerate reduced nutrient conditions better than diatoms. Moreover, many flagellates may have been missed in the Riley study because they are too small to be netted quantitatively, and they are difficult to preserve.

With respect to supplementary sources of carbon, Riley noted large amounts of detrital organic particulates in the Sound, but did not include them in his model. Even at offshore stations during heavy bloom periods, phytoplankton biomass constituted only about 10 percent of total organic particulates in the water column (Riley, 1959).

The importance of understanding phytoplankton production dynamics is this: Eutrophication has compromised the major natural controls on phytoplankton production, especially in western Long

Island Sound. By adding nutrients on a year-round basis, we are bypassing the shut-off mechanism for phytoplankton blooms, particularly during warm months. We have data that show a shift in the seasonality of blooms in the western Sound to summer months (Koppelman et al., 1976). We also have data showing that major summer blooms occur in nearshore systems (Welsh et al., 1982). Summer blooms inherently have higher production rates and higher decomposition rates because they occur at higher temperatures (Eppley, 1972; Westrich, 1983). They are dominated by flagellates rather than diatoms. Given certain combinations of conditions, which we don't fully understand, the flagellate blooms can consist of deleterious types such as redtide species.

The extension of phytoplankton blooms into the summer is a major concern because by then the water column in the western Sound is stratified, as Dr. Carpenter has just shown. Excess phytoplankton will sink to the bottom, as noted by Dr. Rhoads. Figure 5 is a photograph taken by Dr. Rhoads in March of this year in western Long Island Sound. We think that the fluff layer about 1-cm thick on the surface is largely composed of phytoplankton that have sunk to the bottom. If a similar fluff layer were deposited under summer temperature conditions, it would result in an exceedingly high oxygen demand for bottom waters. When the water column is stratified, bottom waters are capped, or isolated, from reoxygenation by the atmosphere or by photosynthesis in surface layers. Such conditions could well precipitate an anoxic event, which would be somewhat similar to the seasonal anoxias in the New York Bight and Chesapeake Bay (Officer et al., 1984).

Although Riley concentrated on deepwater areas, a hallmark of the Long Island Sound system is its deeply incised coastline along all of the Connecticut shore and the western third of Long Island (Figure 1). About 80 small estuarine systems empty into the Sound. Their cumulative area comprises less than 5 percent of the total area of the Sound, but their contribution to ecosystem dynamics far exceeds their relative size:

1. Most are shallow, inwelling systems that process detrital materials.
2. Their density of primary and secondary production is high.
3. Their major primary producer is macroalgae (seaweeds).
4. They are important shellfish bed areas and fishery nursery grounds.
5. Although individually small, their dispersed distribution makes their contributions available to the entire system.

Collectively, these estuaries increase the shoreline length by a factor of 3 over that of the Sound proper, and they thereby

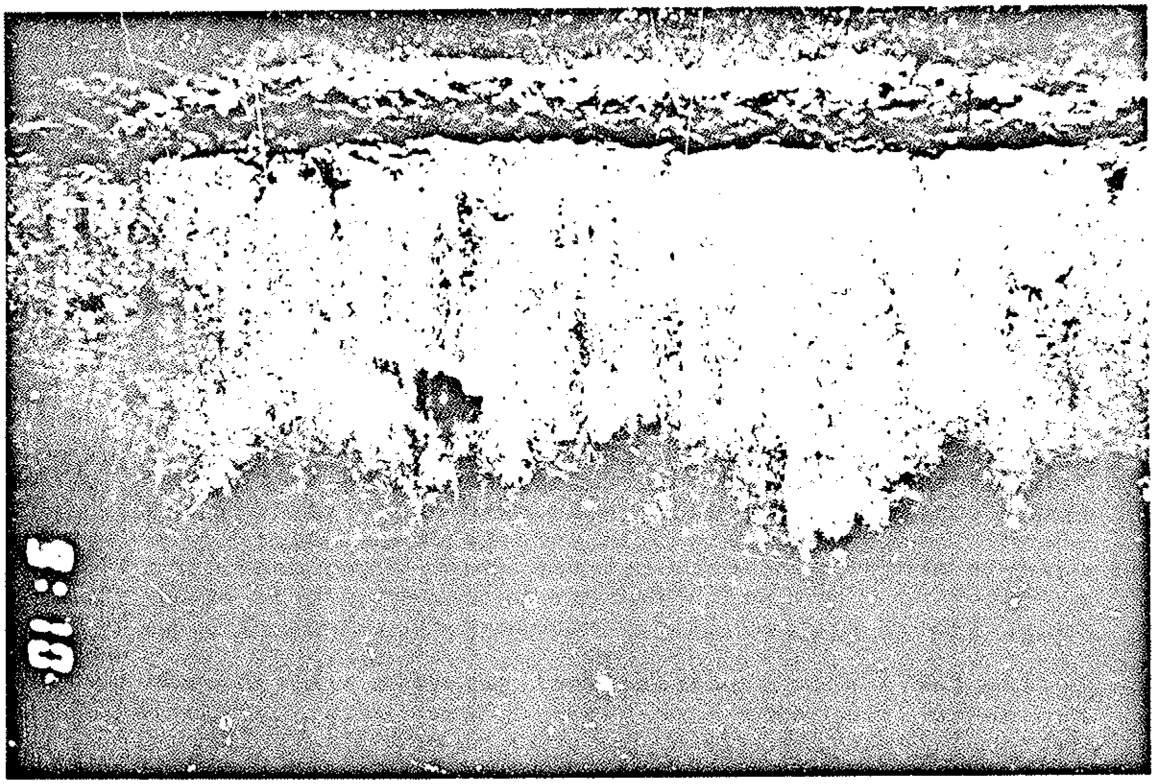

Figure 5. Benthic profile taken in western basin in March 1985, by D.C. Rhoads using a REMOTS camera. Surface "fluff" layer (arrow) is believed to be detritus originating from the spring phytoplankton bloom.

constitute a major interface between man's activities and the Long Island Sound system. For example, the distribution of sewage outfalls closely follows the distribution of small estuaries (Figure 1). Consequently, these small systems are the first to receive the impact of man's sewage and toxic substances.

It is important to realize that major aquatic plants in these systems are seaweeds (Welsh et al., 1985). This contrasts with the vascular plants that one finds in estuaries to the south, such as Chesapeake Bay. When vascular plant systems are overloaded with nutrients, the plants die (F. Short, pers. comm.). When seaweed systems are overloaded with nutrients, they grow to excess. The nutrient loading being given to Long Island Sound waters has already caused many of the small estuaries to become choked with nuisance blooms of seaweed (Welsh, 1980). We have measured as much as 3-5 kg/square m/yr in eutrophic areas during bloom periods. The growth reaches such proportions that it excludes many species of plants and animals (Johnson and Welsh, 1985).

Seaweeds also grow abundantly along the open coastal areas of the Sound. Their importance has been underrated because of a general impression that they grow only on hard substrate, which, as Dr. Schubel stated, constitutes about one-third of the Long Island Sound coastline. However, many species of red and green algae inhabit soft-bottom areas in substantial densities, as in the example above. On rocky bottoms, year-round densities typically average 400 g dry weight/square m, and some beds reach seasonal densities as high as 1417 g/square m (Welsh et al., 1985).

During their growth phases, most seaweeds are confined to nearshore areas less than about 20 feet deep, but during their detrital phase they join the pool of pelagic and benthic particulate matter that can be moved offshore to supply deepwater consumers. We don't know how much of the particulate matter offshore is derived from inshore waters. We do know that many small estuaries are inwelling systems that import large bulky plant detritus and reduce it to fine particulates and dissolved organic carbon (Welsh et al., 1982). We have no figures on the amount of these organic products or the time scales of their export.

Thus, with respect to the pelagic ecosystem in the Sound, I believe that if we were to conduct a comprehensive study, we would reach the following conclusions:

1. Existing models underestimate both production and consumption in the system.

2. Ecosystem dynamics would dictate that we include both offshore and inshore areas and the exchanges between them.

3. Benthic-pelagic interactions must be included for any trophic assessment of the system.

How does this brief outline of the pelagic structure in Long Island Sound apply to the missions of the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and other agencies concerned with the health and welfare of the Sound? Following a recurring theme of this morning's sessions, I will choose one example: the effects of nutrient loading and toxic contaminants on dissolved oxygen levels and the consequences for the Sound fishery.

As early as the 1950s, when Riley was making dissolved oxygen measurements, oxygen depletion to levels of 4-5 ppm in the water column was a recurring summer condition in the Sound (Figure 6). The significance of oxygen depletion is often overlooked. It is important to understand that oxygen depletions may be directly lethal and may also act with other stresses, such as toxic substances, to increase their lethality. It is also important to realize that control of oxygen dynamics rests with the biological community, and that cycles of oxygen depletion (hypoxia) occur naturally in biological systems. The concern here is the enhancement effect that nutrient and organic loadings may have on such natural cycles as those demonstrated by Riley's data in Figure 6. Respiration by biotic communities is analogous to a brush fire. Given sufficient fuel (organic carbon), it can burn out of control, producing extended periods of hypoxia and/or spreading hypoxia over greater areas. Again, Chesapeake Bay and the New York Bight are examples (Officer et al., 1984).

Recent data show that in the western Sound, oxygen levels can drop below 3 ppm in bottom waters in summer (Koppelman et al., 1976). Three parts per million is a convenient benchmark, because it represents an incipient lethal level for many epibenthic invertebrates. Species living offshore are less adapted to low oxygen than shallow water estuarine species. The sand shrimp, Crangon septemspinosus, is a convenient example (Figures 7, 8). It is one of the most important food items for bottom-feeding fishes such as winter flounder in Long Island Sound. Where dissolved oxygen drops below 3 ppm, Crangon dies within minutes or hours, depending on the severity of hypoxia and the temperature of the water (Welsh, 1975). There are other species that are susceptible to low dissolved oxygen. Lobsters, for instance, can tolerate hypoxia down to 1 ppm for limited periods of time only if they are not molting and if temperatures are not too high (McLeese, 1956).

In Figure 9, the diagram presented earlier by Dr. Rhoads has been annotated to include "1-prime (1')", defined as an area in which near-bottom water carries less than 3 ppm dissolved oxygen. This diagram shows how good fisheries habitat in the Sound may be further depleted, especially for bottom-dwelling species. Winter flounder is a good example of a benthic finfish that would be impacted. It utilizes sand shrimp as a primary food source and,

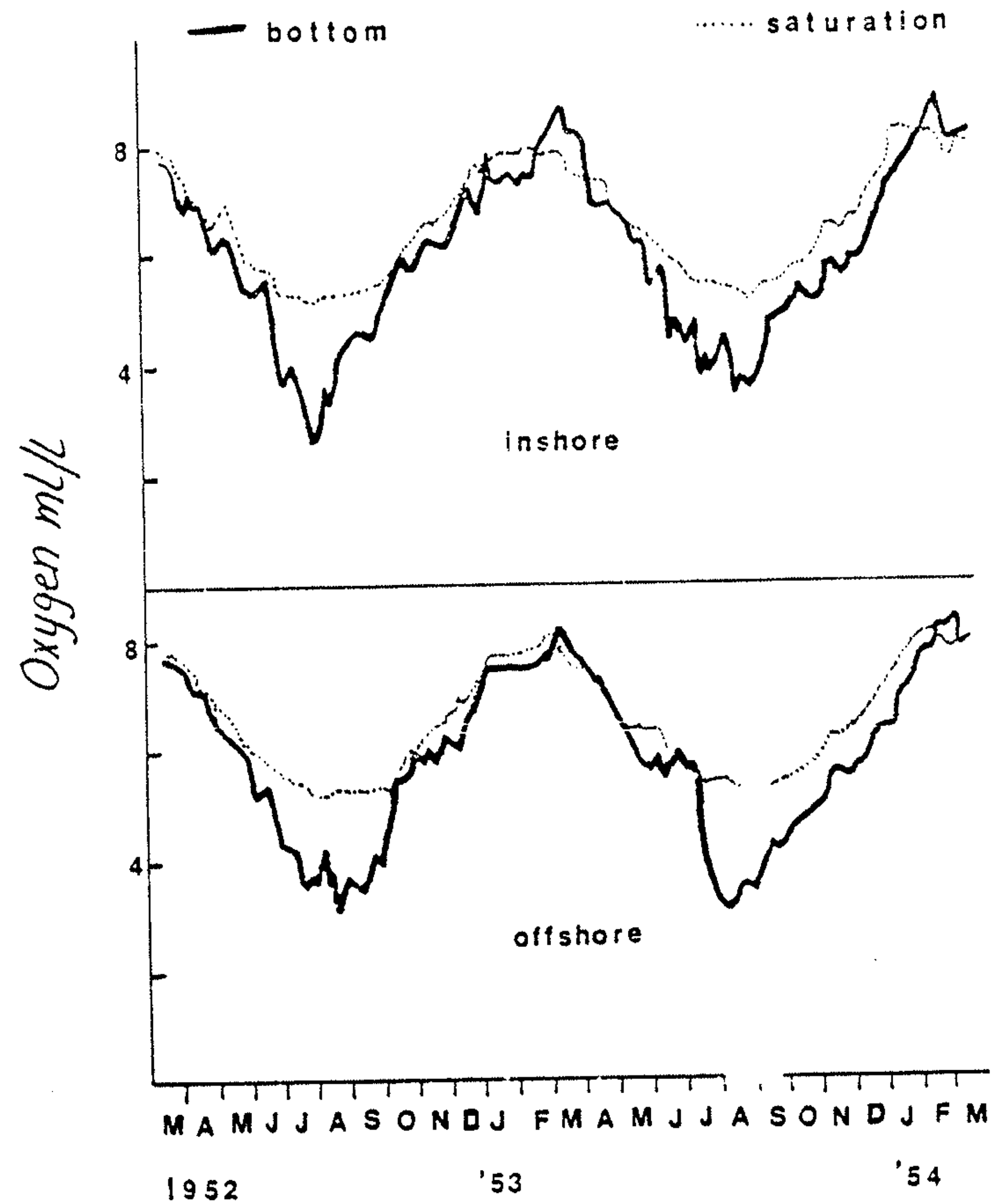

Figure 6. Seasonal oxygen depletions in Central Long Island Sound in nl/m2. For comparison with text, 1 ppm oxygen = 0.72 ml/m2 at standard temperature and pressure (adapted from Riley and Conover, 1956).

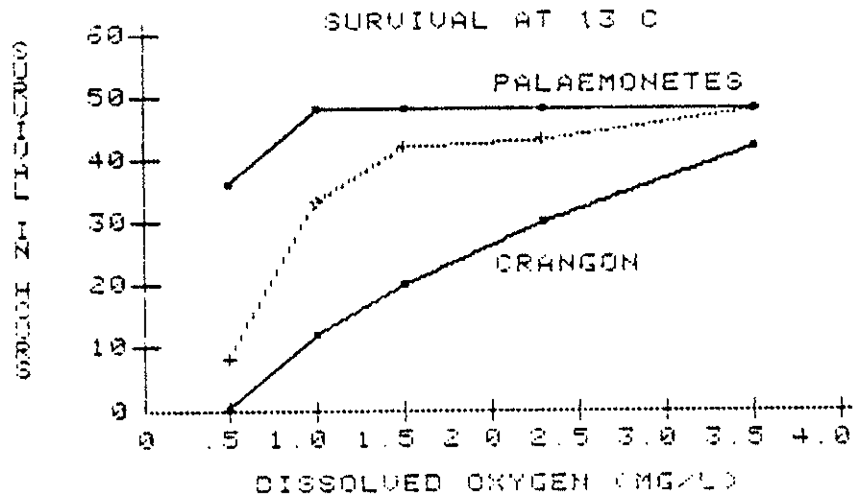

Figure 7. Susceptibility of the sand shrimp, <u>Crangon septemspinosus</u>, to hypoxic conditions compared with two species of grass shrimp, <u>Palaemonetes</u>, adapted to shallow water marshes (from Welsh, 1975).

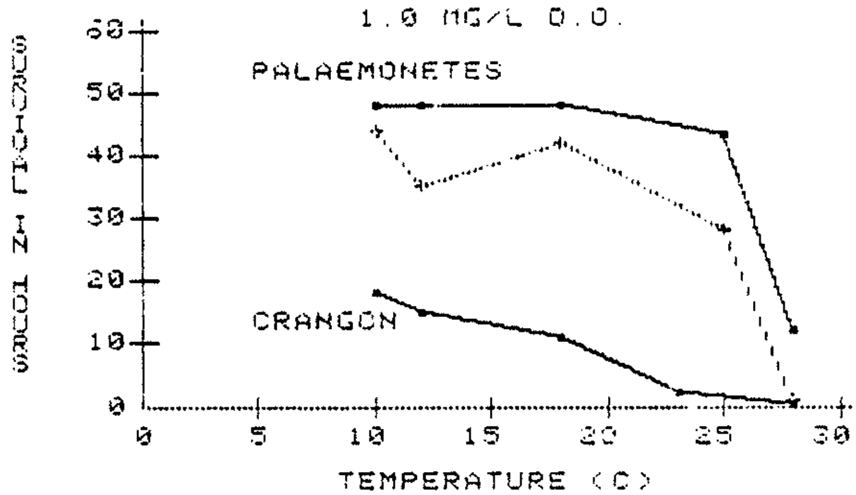

Figure 8. Effects of temperature on tolerance of hypoxia by the sand shrimp, Crangon septemspinosus, compared with the two adapted species of grass shrimp, Palaemonetes (from Welsh, 1975).

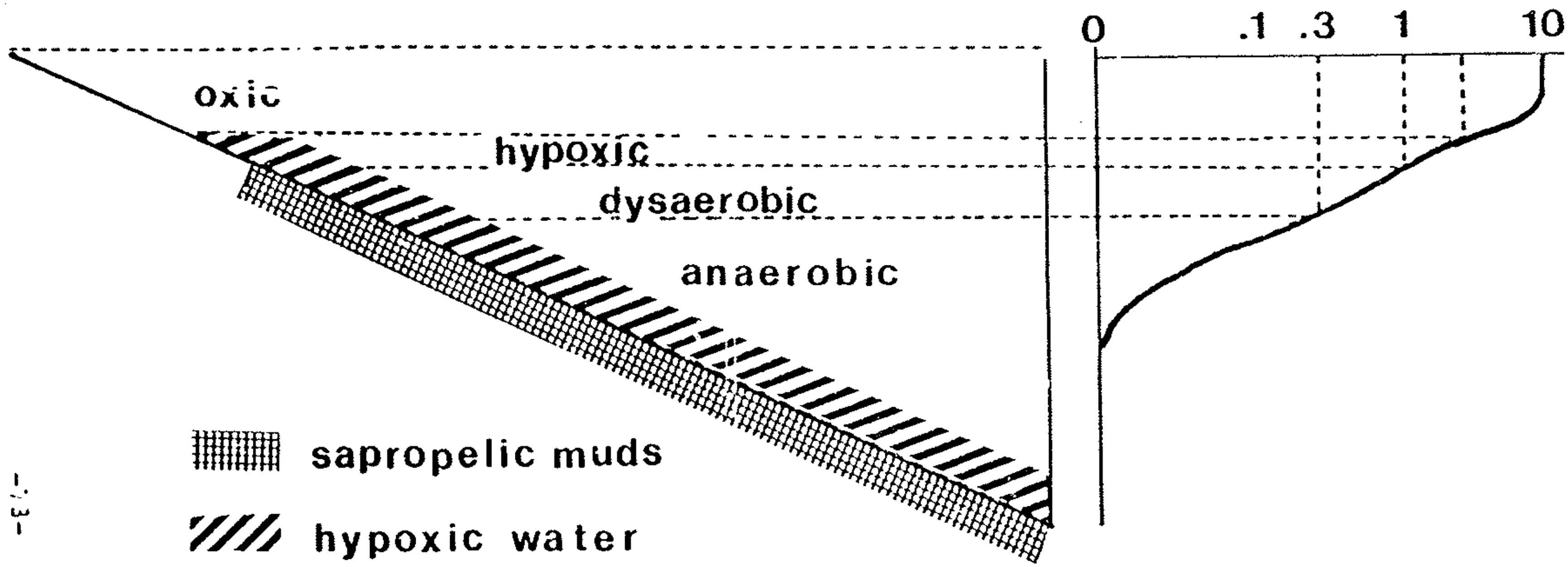

Figure 9. Schematic representation of the loss of benthic habitat with development of hypoxia less than 3 ppm (converted to ml/l for direct comparison with earlier data of Rhoads and Morse, 1971, from which figure has been adapted).

as one of the most important recreational and commercial finfish in Long Island Sound, it has great economic importance.

What will happen if we do initiate a low-oxygen event in the basins of western and central Long Island Sound? Here is one scenario that deserves careful monitoring. Sand shrimp and lobsters, being motile, will move out of areas that are becoming increasingly hypoxic. Flounders will leave, following their food supply. Any good fisherman will move his pots, nets, or lines to where they will catch something. As the migrating animals become crowded in areas peripheral to deteriorating habitats, fishermen following them will experience bigger (and easier) catches. Because fisheries statistics are compiled mainly from landings data, we must be careful that we do not perceive that fish and lobster populations are increasing, when in reality they are only being "corralled" by losses in habitat area and are in greater danger of being over-fished.

The effects described are closely linked to nutrient, toxicant, and organic loadings. Thus they represent a situation in which the separate missions of EPA, NOAA, and the state agencies truly overlap with respect to the upcoming study of Long Island Sound. Figure 10 diagrams the feedback mechanism whereby nutrients, toxicants, and organic loadings can affect the biological processes controlling oxygen regimes.

Dissolved nutrient loadings cause excessive plant production. Respiration by living plants and decomposition by detrital plants lower dissolved oxygen levels. Hypoxia may act on its own, or it may act synergistically to increase the toxicity of other contaminants. The ensuing death of biota increases organic loadings and feeds back into the oxygen demand. Once started, the feedback loop accelerates on its own. This is what happened in the New York Bight: A period of deepwater hypoxia was precipitated by a summer bloom of dinoflagellates. After the bloom was over, the hypoxia was sustained by the decomposition of sea clams (Spisula) killed off during the initial stages of hypoxia.

Once a nucleus of severe hypoxia develops, it is hard to stop. Like a biological firestorm, it can expand in area and extend its season. It would be particularly serious if the nucleus of hypoxia now seen in the deep basin of western Long Island Sound should expand into the central basin or link with hypoxic areas occurring in the estuaries. Such a sequence of events has already occurred in Chesapeake Bay, where it is believed to have been initiated by summer plankton blooms and sustained by benthic deposits of detritus (Officer et al., 1984).

Although I have been addressing a very applied situation, the phenomena are a clear demonstration of basic ecological theory. A hypothetical performance curve (Odum et al., 1979) expresses in theoretical terms some of the phenomena we've been addressing this morning (Figure 11). The upper curve in this figure

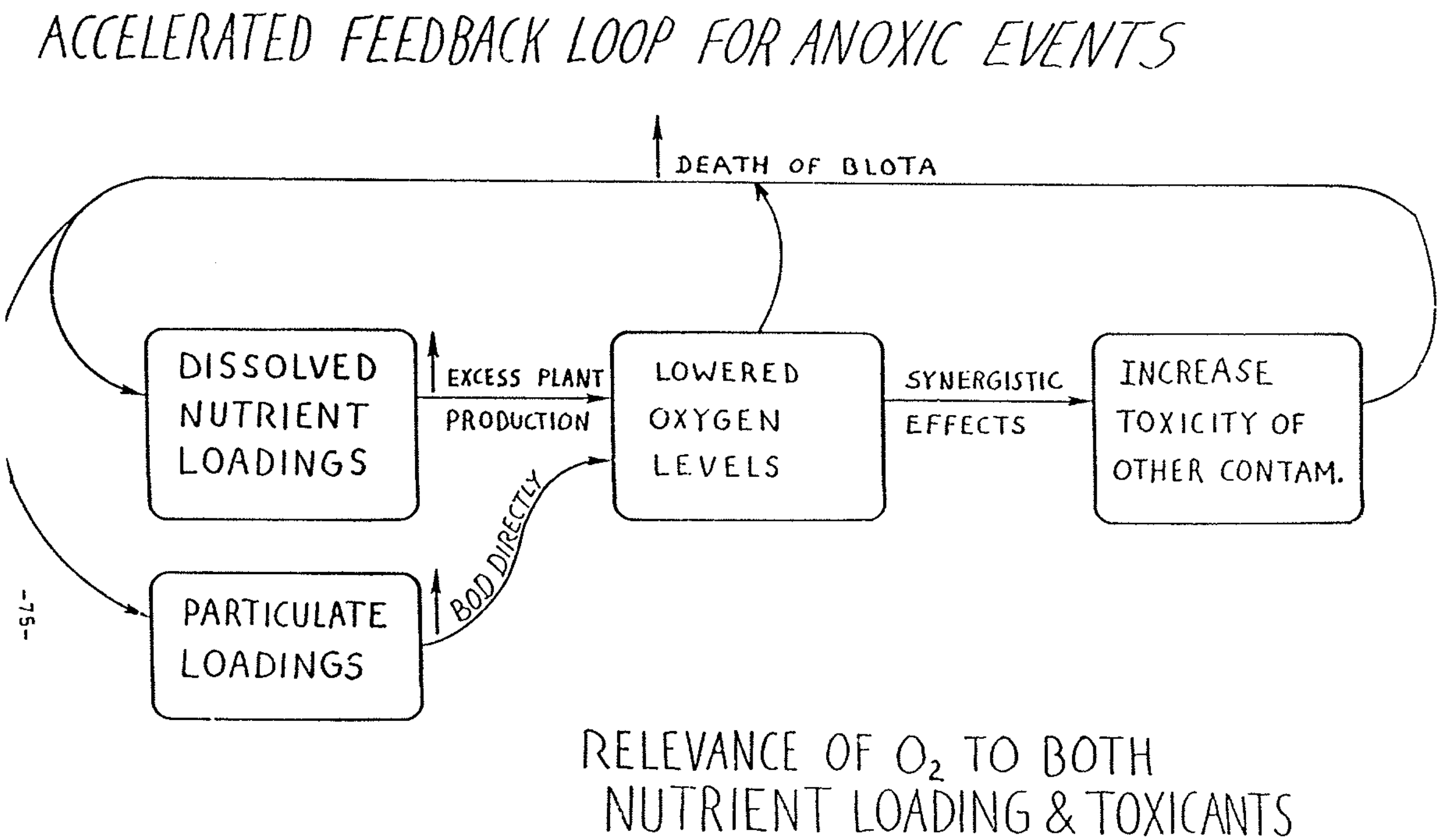

Figure 10. Accelerating feedback loop whereby an initial period of hypoxia, acting alone or synergistically with toxic contaminants, can perpetuate and expand the deterioration of benthic habitats (see text).

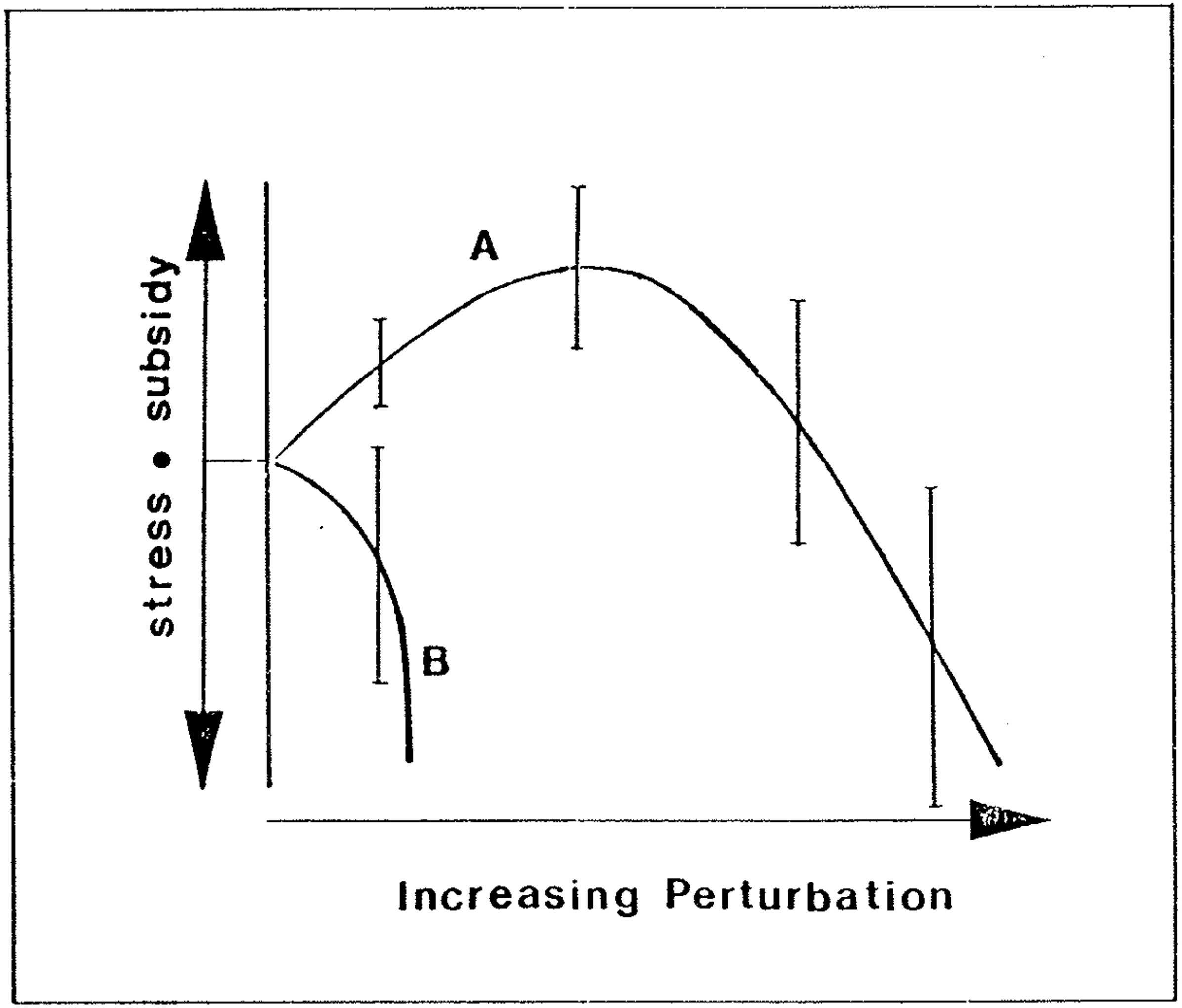

Figure 11. Hypothetical performance curve adapted from Odum et al. (1979), showing response of a system to a non-toxic perturbation such as nutrient loadings (A) versus a toxic perturbation such as contaminant loadings coupled to hypoxic conditions resulting from nutrient loadings (B).

illustrates a subsidy-stress response. Low levels of a nontoxic perturbation, in our case, nutrient additions, may initially appear to enhance some aspect of the system, in our case, primary production. As the perturbation is increased, the system becomes overloaded and highly unstable and much less predictable. This development is reflected in the increasing variability of the observed response. Production then slows; plants die off; the system dies. When the perturbation involves a toxic substance, the stress will cause an immediate decline, as in the lower curve.

In the Long Island Sound example, when nutrient loadings are acting alone, the system may follow the upper curve with a certain period of euphoria with respect to increased production. When nutrient and organic additions interfere with dissolved oxygen regimes, and when toxic contaminants are present, one may expect immediate and rapid decline of the system, as depicted by the lower curve.

In summary, low oxygen conditions constitute one of the most serious generic problems existing in Long Island Sound today. Oxygen regimes are closely linked to production dynamics and nutrient and contaminant loadings. The problem constitutes an important area of overlap between the concerns of EPA, NOAA, and the state agencies.

The only existing holistic studies of the Sound are those undertaken by Riley and his associates in the 1950s. These studies were confined to deepwater areas of the Sound. Thirty years of urbanization have occurred since the data were collected, as well as 30 years of advance in ecological research.

A new study of Long Island Sound productivity patterns is in order. Such a study will probably indicate that the existing models grossly underestimate both production and consumption. Any interpretation of ecosystem dynamics for the Sound must include a holistic understanding of production dynamics, of exchanges between nearshore and offshore areas, and of interactions between the benthos and the water column.

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LONG ISLAND SOUND FISHERIES: PAST, PRESENT, AND FUTURE

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The fisheries of Long Island Sound have a much shorter history than Long Island Sound itself. In fact, the written history goes back just about 100 years. The changes in that time have been very great. In the early days, oysters were the principal harvest. In the 1890s, for example, over 14 million pounds of meats were landed in Connecticut. There is no record of the amount of oysters landed from the Long Island waters of New York, but we do know that in the 1880s and 1890s about one-quarter of the oysters produced in New York came from Long Island Sound. One-quarter of the approximately 13 million pounds of meats produced in New York in 1898 is a little over 3 million pounds. So the total amount of oysters landed from Long Island Sound in 1898 was probably well over 17 million pounds.

Going a little farther, we have some figures from 1908. Total landings from Long Island Sound, leaving out alewives and menhaden because they are not caught in any quantity by sport fishermen, in Connecticut were 37.3 million pounds worth about 2.9 million dollars. From New York about 12.4 million pounds worth 1.1 million dollars were landed, for a total from Long Island Sound of about 49.7 million pounds, worth about 4 million dollars. Oysters from Long Island Sound were as follows: Connecticut, 9.8 million pounds worth 1.2 million dollars; New York, 2.4 million pounds worth about 400 thousand dollars, for a total of about 12.3 million pounds worth about 2.8 million dollars. Thus, in 1908 about 26 percent of all Long Island Sound commercial landings and about 43 percent of the value were oysters. There were some recreational fisheries in those early days, of course, but it obviously must have been a very small portion of the total Long Island Sound catch.

Today it is clear that the situation is quite different. In fact it is quite clear that recreational fishing now dominates in the Sound. In 1979, the latest year for which figures are available for the commercial and the recreational catch in Connecticut, the total weight of food fishes landed in Connecticut by commercial fishermen was about 4 million pounds. This is food finfishes only, not menhaden and some other species used primarily for meal and oil. The total weight landed by recreational fishermen was over 10 million pounds, about 2.5 times as much. The total weight of shellfish landed in Connecticut was about 2.4 million pounds, and the recreational catch was about 204 thousand pounds, roughly 10 percent of the commercial catch.

In the same year, the total weight of food finfishes landed in New York from Long Island Sound by commercial fishermen was about 1.3 million pounds. The total weight of shellfish was about 1.1 million pounds. There have not been any recent surveys of the recreational catch in New York from Long Island waters of the Sound, but if the recreational catch were proportional to the total catch in Connecticut, it would be about 3.3 million pounds. However, if the recreational catch in the New York part of Long Island Sound is prorated according to the recreational catch of each species in Connecticut, it becomes about 9 million pounds.

Thus, the total recreational catch in the Sound in 1979 was somewhere between 13 million and 19 million pounds, which is considerably larger than the figure of about 9 million pounds for food fishes and shellfish landed by commercial fishermen, perhaps twice as large. So it is obvious that recreational fisheries are much larger now than they were 100 years ago.

The principal species taken by commercial fishermen in Long Island Sound in 1979 were oysters (1.5 million pounds), scup (1.4 million pounds), American lobster (1.1 million), winter flounder (0.8 million), hard clam (0.4 million), weakfish (0.3 million), bluefish (0.26 million), and sea scallop (0.2 million). The principal species taken by recreational fishermen were bluefish (8.8 million pounds), scup (2.3 million), tautog (2 million), striped bass (1.8 million), Atlantic mackerel (1.4 million), winter flounder (0.9 million), weakfish (0.4 million), and sea robins (0.2 million).

How does this compare with a larger estuary such as Chesapeake Bay? In 1979 the total of food finfishes caught in the Chesapeake was about 32.5 million pounds, leaving out menhaden and other industrial species. The total shellfish catch was about 90 million pounds. I do not know what the recreational catch was, but I doubt that it equaled the catch of food finfishes by commercial fishermen. Perhaps it was half as much, which would place it at about 16 or 17 million pounds. Thus, it may have been about equal to the recreational catch of Long Island Sound. But that is purely speculation. Richards (1962) found that the saltwater sport catch in Virginia ranged from about 8 percent to about 27 percent of the commercial catch of the four most important species. This covered the period from 1955 to 1960. Thus, 50 percent of the total catch of food finfishes does not seem unreasonable for 1979.

At any rate, the total catch by both groups of fishermen in Long Island Sound is considerable. In 1983 the total value of the commercial catch was over 19 million dollars (in 1983 dollars). The recreational catch, valued conservatively on the same basis as the commercial catch, was about 25 million, for a total value of at least 44 million dollars. At retail value it might be three times as much, or about 130 million dollars. Even valued at standard dollars (1967 = 100) the value comes to about 15 million dollars landed at dockside and 45 million retail. So it is an important fishery by any standard. Certainly, from the recreational point of view, Long Island Sound is probably the most important estuary of its size anywhere along the Atlantic coast.

The future is uncertain, because parts of Long Island Sound are seriously polluted, and the fisheries generally have been overharvested. This is such an important area of the coast in human population, however, that it is unthinkable that it should be left to chance. Properly rehabilitated, Long Island Sound could become one of the most important area for fisheries anywhere along the coasts of the United States.

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GENERAL DISCUSSION

DR. SCHUBEL: We now have some time for questions.

QUESTION: What happened to The Clean Water Act concept that was supposed to get these sewage effluents down to a much lower standard?

DR. SCHUBEL: Lee, would you like to comment on that?

DR. KOPPELMAN: The basic problem is one of enforcement. Enforcement is related to the question of dollar input. After we completed the 208 Study on Long Island, we discovered that the major input that prevented us from cleaning up our embayments on the New York side of the Sound was the contribution from the sewer plants from the City of New York. Historically the City of New York has ignored all requirements, all standards. They have a dual sanitary and storm water system, so every time there is a rain event, they just open up the gates and the raw sewage comes in with the storm water and goes on to contaminate the entire New York Bight, the Hudson River, the East River Strait. It comes out through the Hell Gate and louses up western Long Island Sound. So here it's not even a question of identifying the point sources. It's a question of coming up with the money and the enforcement upgrade.

Many of the sewer facilities on Long Island are currently being upgraded. What they're doing in Connecticut I'll leave to the Connecticut experts. But the second part of this source of contamination is non-point sources, for which we have no accomplishments.

Just to clean up closed areas on Great South Bay on southern Long Island, we estimated over 100 million dollars in engineering mitigation costs to control general surface runoff. So although we know what the solutions are, the question is where support for implementation is going to come from.

QUESTION: I'm not sure who to address this to. Are you finding any problems with the oyster production since the introduction of antifouling paints on recreational vessels?

DR. MCHUGH: I think the principal problem with oyster production is the fact that the seed beds on the Connecticut side are pretty well destroyed.

DR. SCHUBEL: Jack?

DR. PEARCE: I'm not going to comment on the matter of paints, although there is a significant literature and a number of reports that one can refer to. There are people in Great Britain who are doing a lot of work with various antifouling materials.

The previous question is an extremely important one, and the response from Dr. Koppelman is in part an answer to the question; that is, the usual cop-out, there is no money. Perhaps a more important factor is that there are no real criteria. In the area of public health, if you get counts of coliform bacteria over a particular level, the state, the county or whatever will take action and it will often be enforced by Federal action. If you get a particular count of bacteria, you can close a swimming area, you can close a shellfish bed, you can say that the potable water is not safe for drinking.

In most areas that marine scientists tend to deal with there are very few existing criteria. The American Fisheries Society some years ago worked with EPA to put together the so-called Red Book, which had criteria for toxic metals and so on. As far as I know, none of that work was ever used by any legislative or regulatory body. Based on talking with people in EPA and people abroad and people in other countries, I really believe that until we use the kind of information presented here today to give our legislative bodies something to work on, very little will happen. I think marine scientists, just as public health officials did over a century ago, are going to have to develop certain criteria that say something has to be done about a particular habitat, whether it's through the non-point source runoff, point-source runoff, or whatever. But if we don't have something to manage against, we can't manage.

QUESTION: In response to the discussion about whether there are standards or criteria for nutrients and effluents and why action isn't being taken, there are requirements for sewage treatment plant effluents. So I think most sewage treatment plants in the States of New York and Connecticut are close to or at the requirements of the permits. However, traditionally those permit requirements have dealt with what are called our conventional pollutants, which include biological oxygen demand and suspended solids. Often the permits don't have specific requirements for limitations for nutrients--of nitrates, nitrites, phosphates--because the technology for sewage treatment plants is focused on decreasing the biological oxygen demand rather than on nutrient removal.

So this is an evolving regulatory framework. In each location of Long Island Sound, the studies could demonstrate the need for permits that do set nutrient limitations that would be beyond the more traditional biological oxygen demand.

QUESTION: I was wondering what type of recovery time you are talking about in terms of regeneration of these very important biological communities.

DR. RHOADS: This is unknown in the case of low oxygen conditions. That's why I'm here hoping to impart some interest in the agencies that address the first source problem. It is known in the context of recovery of disposed materials, which are reasonably pristine. The time is on the order of the mean lifespan of those head-down feeders. But I think it must be much longer in good hypoxic conditions. That's assuming that the low oxygen condition can be driven up above 1 or 3 ml/liter.

DR. D'ELIA: I have a question for both Barbara and Ed; it deals with the old issue of deriving data on phosphate concentrations. They showed data rather typical of phosphate concentrations for a lake or for offshore, coastal waters with a summer minimum. But in estuarine systems, such as the Chesapeake, we are now showing a summer maximum in phosphate concentrations. I was wondering if western Long Island Sound is changing from what it looked like in 1956 to more of what we are now seeing as a typical pattern of phosphate maxima in the Chesapeake, for example.

DR. CARPENTER: There's very little information on phosphate concentrations in western Long Island Sound. In general, it's interesting that whereas a lot of people thought this was a well-studied estuary because Gordon Riley was one of the first to work on it in the 1950s, there really isn't very much information on this body of water.

DR. WELSH: I could supplement that by saying that we're having anoxic events in many of our smaller estuaries along the borders of the Sound. Typically, phosphate is very much in excess all summer long, and the nitrate goes down.

DR. CONNOR: Is the Sound nutrient-limited or light-limited?

DR. CARPENTER: At least during the summertime, it probably is light-limited. Nutrient concentrations are extremely high. But again, there has been no comprehensive study since Gordon Riley carried out his work in the early 1950s. I think it's time for a comprehensive study of production, primary production, nutrient cycling, and carbon cycling in the Sound. I had to scratch very hard to get good oxygen data, which really do not exist, nor do data on nutrient cycling and photosynthesis. The information on photosynthesis consists of a few of Gordon Riley's stations near New Haven. Those were done using the oxygen light-dark bottle technique, which is an extremely primitive technique.

So on the whole we don't know very much at all about the Sound. We know much, much more about Narragansett Bay, Delaware Bay, and Chesapeake Bay.

QUESTION: I found it interesting that throughout these presentations there was almost a bleak picture being painted, until the last presentation when we got down to the real uses of the Sound that are of real importance to humankind. There, it seems, Long Island Sound carries its own weight compared to Chesapeake Bay.

Is there no work at all on the effects of some of these anthropogenic activities on the fisheries and other uses of the

Sound? Or is it really true that we are years away from understanding that, and this has all been an academic exercise?

DR. SCHUBEL: Jack, would you like to respond to that?

DR. PEARCE: It's only been in the last few months that the Federal Government, working with the states and various local governments, are talking about having bay-wide or sound-wide assessment programs to determine in an objective and scientific manner what the levels of fish stocks might be. And there is an effort in Chesapeake Bay at this time to set up a program involving the various states, the District of Columbia, and, to some extent, the National Marine Fisheries Service to do this. Quite obviously you cannot, again, manage fish stocks effectively if you don't have a real understanding of the stocks and the interactions between the stocks and the habitats.

DR. SCHUBEL: We may hear more about his topic this afternoon from Eric Smith from Connecticut and Gordon Colvin from New York. I think we'll have one more question and then we'll stop there.

QUESTION: For the past 25 years I've been working in various fisheries laboratories and the National Marine Fisheries. I've never been on a cruise, but there were constantly NOAA vessels and other vessels going on cruises. Didn't they do anything in Long Island Sound?

DR. PEARCE: We made a number of cruises into Long Island Sound. We were looking at standing stocks of benthic organisms from a descriptive and semiquantitative point of view. We were measuring contaminant levels in sediments, that sort of thing. And some of this information has been published, and some of it has been compared with information from other groups.

In the sense of doing large-scale stock assessments, I'm not aware that the Northeast Fisheries Center, which has jurisdiction over these areas, has ever mustered major cruises. Maybe Carl Sindermann can add an editorial comment. Do you recall major stock assessment cruises in the Sound or other estuarine waters, Carl?

DR. SINDERMANN: Most of our long-term cruises have been offshore. Only infrequently did we get into Long Island Sound or Block Island Sound, and then only for particular pertinent short-term interests.

MODELING FOR MANAGEMENT

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Rather than directly address the question of what types of water quality and hydrodynamic models might be required for the development of a management strategy for the Sound, I intend to focus on a brief description of what I consider the most important physical transport processes operative within Long Island Sound. Presumably the effects of these transport processes would have to be considered in designing modeling efforts.

Before describing the circulation and hydrographic properties in the Sound, it is important to mention that, unlike other east coast estuaries such as Chesapeake Bay or even Delaware Bay, Long Island Sound does not have a database consisting of either hydrographic cruise data taken at fixed stations on a regular basis or current velocity data from moored current meters. Therefore, we are working with a rather limited quantity of hydrographic and current velocity data in making the description.

As discussed this morning, the Sound is a semi-enclosed body of water approximately 150 km long and 30 km wide at its widest point. The mean depth is approximately 20 m but the depth can exceed 60 m in the channels. The bathymetry of the basin is very rugged, the Sound tends to be separated into three basins by two sills.

At its eastern end the Sound communicates with the Atlantic Ocean through Block Island Sound. Salinity in the eastern Sound remains high and is nearly oceanic at depth. At its western end the Sound communicates with the Upper Bay of New York Harbor through the East River tidal strait. The Upper Bay of the Harbor remains at reduced salinity because it is in reality part of the Hudson River estuarine system. The exchange between the Sound and the Upper Bay through the East River maintains the western Sound at reduced salinity. This large-scale, east-west salinity gradient tends to support a two-layer, density-driven estuarine circulation pattern within the Sound.

In addition to the estuarine circulation associated with the salinity distribution, the Sound exhibits a large tidal range and very strong tidal currents. The interaction of these strong tidal currents with the bathymetry of the basin is responsible for the production of strong residual currents distinct from those associated with density-driven estuarine circulation. The strong tidal currents are also responsible for mixing the water column in certain areas of the Sound.

There are, therefore, four basic points I want to discuss:

- Exchange through the East River.
- Density-driven or estuarine circulation in the Sound.
- Residual currents induced by the interaction of the tidal currents with the bathymetry.
- Implications for designing modeling efforts.

We have mentioned that unlike a typical estuary, the Sound has no major direct source of freshwater input at its head. It has instead the East River tidal strait. We have heard that there is direct freshwater inflow to the Sound from rivers in Connecticut. These rivers discharge into the central and eastern Sound rather than near the head.

There are a few basic aspects of East River exchange processes that are relevant to our discussion. There are strong tidal currents within the East River and very strong mixing in the vicinity of the Hell Gate sill near the central part of the strait. Due to the characteristics of the tidal wave itself within the strait there is a residual volume flux of water of a few hundred meters/second directed from the Sound to the Harbor.

East of the Hell Gate sill there is a reasonably well-defined two-layer residual density-driven flow superimposed on the oscillating tidal currents. This circulation involves the flow of lower salinity water towards the Sound in the upper layers, and the flow of higher salinity water towards the Harbor at depth. This region of the East River should actually be considered part of the Long Island Sound estuarine system. Current velocity observations from surveys conducted by the National Ocean Survey both in the 1950s and more recently in 1981 have confirmed the two-layer residual flow pattern in this section of the strait. To the west of the Hell Gate sill this flow pattern is not detectable.

In addition to the two-layer flow that carries fresher water into the western Sound in the upper layer, the very strong oscillating tidal flow through the strait tends to produce a diffusive exchange between the waters of the western Sound and the fresher waters of the Upper Bay. It is through the combination of these two exchange processes that salinity of waters in the western Sound is reduced, thereby setting up the density-driven estuarine circulation within the Sound as discussed below.

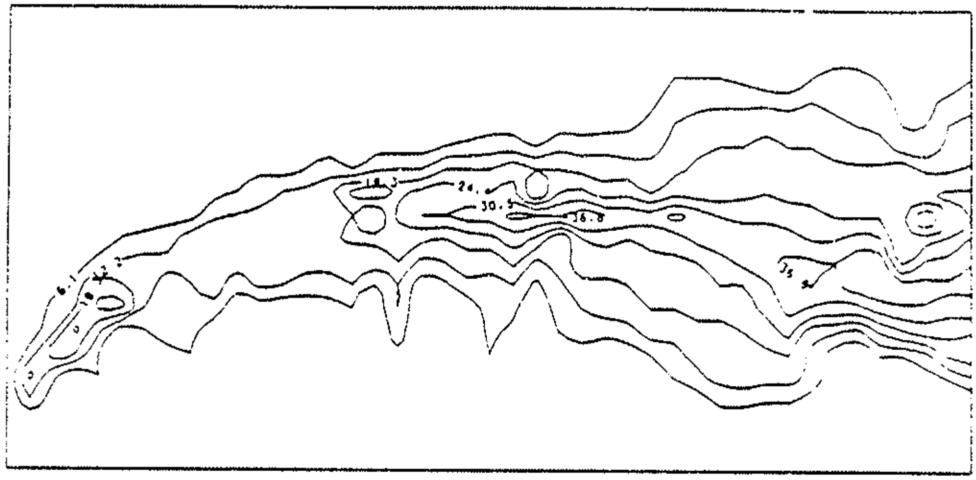
The distribution of salinity in the Sound shows an overall increase in salinity from west to east, with the highest east-west salinity gradients being found in the western and eastern Sound. East-west salinity gradients in the central Sound are weak. Associated with this distribution of salinity, we expect a two-layer estuarine flow pattern involving flow towards the east in the surface layers and flow towards the west at depth. Moored current meter observations in the west central Sound confirm the existence of this flow pattern in the deep channels.

Very limited data show that the distribution of salinity across the Sound exhibits a maximum in the central Sound, with reduced salinity both near New York and Connecticut. These data may provide some insight into the lateral structure of the estuarine flow pattern. Moored current meter observations in a section across the Sound suggest, in fact, that surface flow directed towards the east is confined primarily to the New York side of the Sound and that on the Connecticut side of the Sound there may be flow towards the west at all depths.

Let us now leave our discussion of estuarine circulation associated with the distribution of salt and consider tidal phenomena. The tidal wave enters the Sound through the Race at its eastern end. Because of its length and its mean depth the Sound exhibits resonance: its natural sloshing period is close to the period at which it is being forced by the semidiurnal tide. This resonance causes an increase in tidal range from approximately 0.6 m at the Race to a maximum of approximately 2.6 m in the far western Sound on spring tides. Tidal currents associated with this large tidal range can be very high.

Of fundamental interest to us here is the fact that when these strong oscillating tidal currents sweep over the rugged bathymetry of the Sound basin, residual currents are produced that can contribute to or dominate the steady circulation pattern. My preliminary results of three-dimensional simulations for the tidally induced residual circulation pattern in the Sound are presented below. Figure 1 shows the bathymetry used in these simulations. It is broken into two pieces because of the length of the Sound relative to its width. Figure 2 shows the simulations for residual vorticity for the upper level, which extends from the surface to a depth of 15 m. The vorticity is useful because it provides a measure of the torque experienced by the tidal currents as they sweep over the bathymetry, leading to the production of residual currents. In regions of high vorticity, the residual currents can be expected to be high. A negative vorticity implies a clockwise residual circulation tendency; a positive vorticity implies a counterclockwise tendency. The residual currents themselves for the upper level are presented as vectors in Figure 3 and discussed below.

For the tidally induced residual currents in the eastern Sound (lower diagram in Figure 3) we see that residual currents are very strong in the far eastern Sound. In the vicinity of the Race, currents show an outflow near New York, an outflow close to the Connecticut shore and inflow in the central part of the section. The outflow near Connecticut could contribute to the advection of much of the fresh water from the Connecticut River



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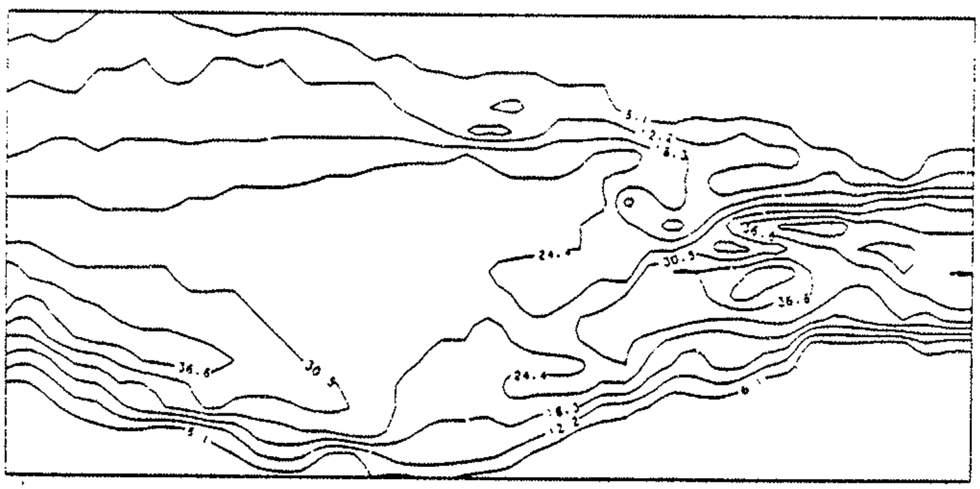
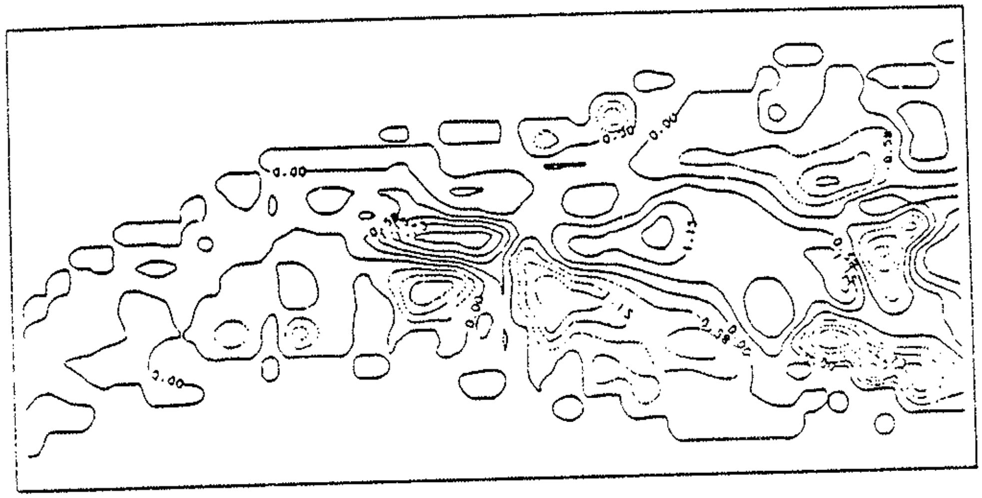


DEPTHS IN METERS

Figure 1. Bathymetry used for three-dimensional numerical simulations of tidally induced residual currents in Long Island Sound. Upper and lower figures are for western and eastern Sound, respectively.



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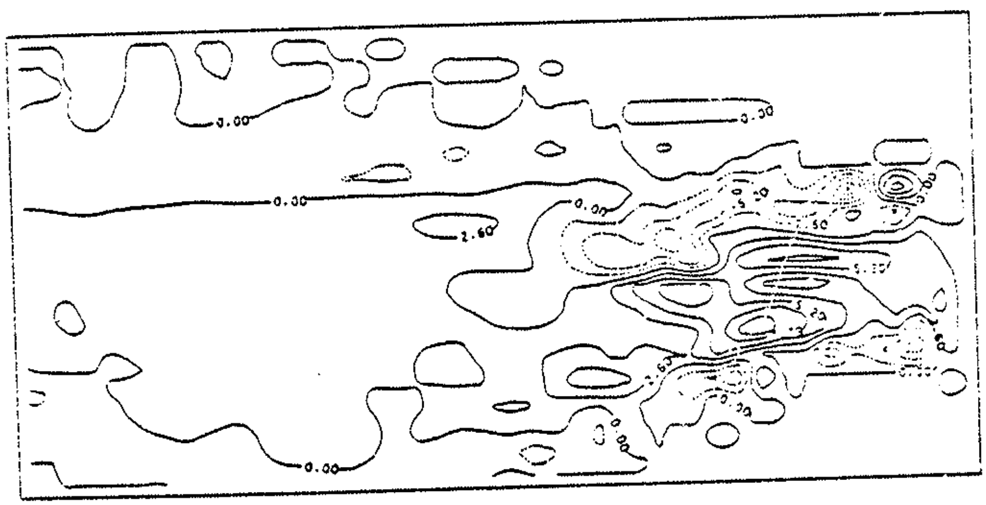

AVERAGED VERTICAL VORTICITY. LEVEL 1
X 10** 5

Figure 2. Results of numerical simulation for tidally induced residual vorticity field (see text). Upper and lower figures are for western and eastern Sound, respectively.

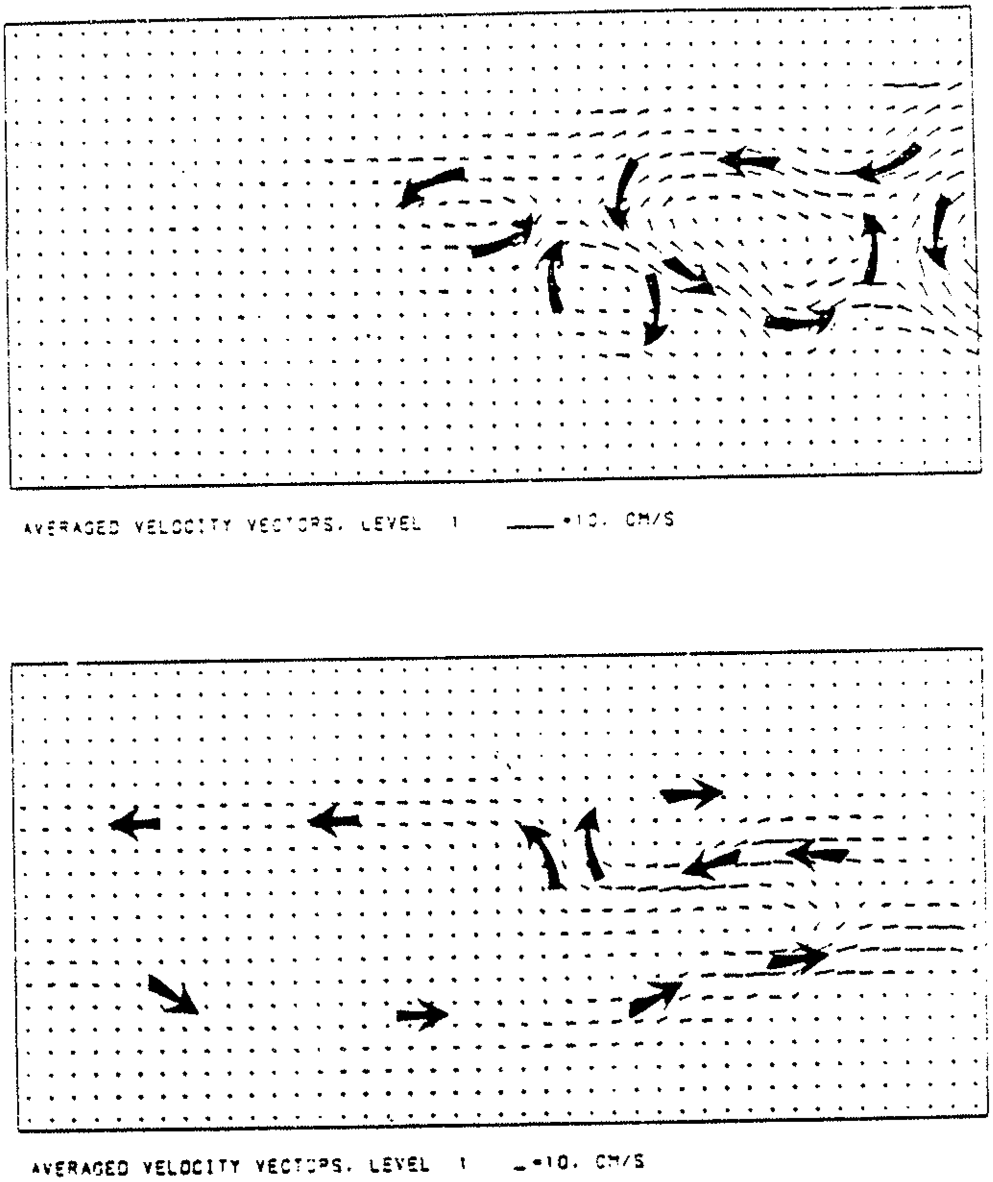

Figure 3. Results of numerical simulation for tidally induced residual velocity field. Upper and lower figures are for western and eastern Sound, respectively. (Note difference in scale for velocity vectors).

out of the Sound. Currents in both the eastern and western sections of the Sound show that a major feature is the basin wide counterclockwise gyre. Currents within this gyre tend to be strongest over approximately the 20-m isobath.

In the vicinity of the prominent shoal area in the central Sound there is considerable cross Sound drift. To the west of the shoal area there tends to be a partially closed counterclockwise gyre. Further to the west the residual current pattern is characterized by a pair of counter-rotating eddies in the vicinity of the pronounced coastal promontory on the New York shoreline.

Observations discussed earlier from moored current meters support the contention that tidally induced residual currents contribute very significantly to the overall circulation pattern. Analyses of the residual currents from these meters show clearly that they strengthen during spring tides and weaken during neap tides, suggesting that they are produced by the interaction of the oscillating tidal currents with the bathymetry.

In summary, we expect the tidally induced residual currents to contribute very significantly, if not to control, the residual circulation pattern in much of the Sound. We expect the density-driven currents to be most well developed in deeper areas of the Sound.

Finally, we can outline a few of the implications for developing a modeling strategy for the Sound. It would seem that present modeling efforts should concentrate on describing the structure of the steady circulation patterns in the Sound. This includes specifically the three-dimensional structure of the combined density-induced and tidally induced circulation. This could be accomplished, for example, by including freshwater inflow in the three-dimensional tidal simulations described above. Our main point is that it would seem that process-oriented modeling should precede the development of a predictive model for management purposes.

A VIEW OF THE PROBLEMS AND OPPORTUNITIES FROM THE LONG ISLAND SIDE OF THE SOUND

G.C. Colvin
Division of Marine Resources
New York Department of Environmental Conservation

As a resource manager with responsibility for living marine resources or living aquatic resources, my goal is to manage those resources in a way that will maximize harvestable quantities of usable resources and maintain and stabilize that harvest over time.

I'd like to talk a little bit today about some of the opportunities and problems we see for the harvestable resources in Long Island Sound. I think it will be obvious that many of these problems are not unique to Long Island Sound, nor are they unique to New York State. We will talk about some problems that New York and Connecticut together cannot manage, but will require some coordinated effort and coast-wide fishery management. We will also talk about problems that exemplify some social and political limitations on the productive use of our marine resources in the Sound and elsewhere.

The illustration before you is to some degree a reiteration of Dr. McHugh's subject this morning (Table 1). On the New York side of the Sound, our principal harvested marine resources, as expressed by commercial statistics, are shellfisheries--hard clams, lobsters, and oysters. In 1983, the fourth species in rank by weight was scup, followed by a number of other finfish species, including winter flounder, bluefish, summer flounder, mackerel, and other species.

It's important to note that most of the important species other than the shellfish are migratory. With the probable exception of winter flounder in the western part of the Sound, and tautog, another important species, virtually all of our major finfish species are migratory and enter Long Island Sound only during portions of the year. On the other hand, our shellfish species and most of the lobsters are residents in the Sound and can be managed to some degree by an individual state or its political subdivisions or by the two states working together.

Even for resident species, however, the management of an individual political jurisdiction is complicated by interstate commerce in these species. These complications are illustrated by the difficulties that we in New York have had with enforcing very limited hard clam management regime. That regime is based only on a minimum size limit, but problems arise because there are active markets in other states for hard clams below our size limit.

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TABLE 1. COMMERCIAL FISHERIES PRODUCTS, LONG ISLAND SOUND

	1983 (NMFS)	
Hard Clam	752,400 lb	$2,465,270
Lobster	631,500 lb	$1,812,956
Oyster	423,400 lb	$1,410,863
Scup	249,200 lb	$ 144,117
21 spp. F'SH/8 spp. SHELLFISH		
	TOTAL VALUE	$6,231,898

What are some of the problems and impediments to stabilizing and enhancing use? The first subject I would like to address is contaminants.

Over the years we have identified a number of contaminant problems that impede the productive use of marine organisms in New York. The data presented here (Table 2) were collected by the New York Department of Environmental Conservation from samples of fish and lobsters in Long Island Sound.

The first group of data represents a variety of analyses done under EPA funding from collections in 1978 and 1979 for PCBs. You can see that there is a definite PCB problem in the striped bass, with mean concentrations of about 3 parts per million (ppm) in 40 fish. There is a possible problem in eels, in which the 1.3 ppm mean starts to approach the new FDA action level of 2 ppm. Menhaden are clearly well in excess of the standard, which may be a problem in the future if, as expected, some interest develops in use of menhaden for food products. That interest does not now exist, but the technology does.

The historical data on bluefish are very shaky. There's a great deal of variability. The 65-fish sample that we ran actually represented a number of different smaller samples, and two of the individual samples from eastern Long Island Sound did exceed 2 ppm. The overall mean was, however, under 2, though not by much. There is some indication that some mackerel have PCB concentrations above 2.0 ppm, or what might be in excess of the FDA standard.

Other species were well below the FDA standard. Table 2 lists the species for which PCB concentrations approach or exceed the FDA standard, but additional species, including winter flounder, summer flounder, tautog, scup, and weakfish were 0.5 ppm or less. Of course none of this begins to address the question of the effect of these toxic substances on the animals themselves and their development. It only affects their usability as a resource, given government action to establish tolerance levels.

Our 1984 collection, which has been publicized lately, led to limited closure of our striped bass commercial fishery. We had samples from May through July of 47 fish from the Sound with an average of almost 5 ppm. The highest value was 100 ppm in a single fish from the vicinity of Old Field Point, which is pretty far out the island. That specimen did bring the mean up quite a bit. But even without that fish, the mean was about 3 ppm. In the fall we had a very small sample of a few fish each from the months of October, November, and December. The nine fish in this sample, all from the eastern basin of the Sound, had a mean concentration of only about 1 ppm PCB. We don't know whether something real is happening there or whether the small sample size is obscuring a larger trend. We're actively engaged in reassessing that problem this year. But if one only looked at

TABLE 2. MAJOR CONTAMINANT ISSUES

YEAR	SPECIES	COMMENT
	PCBs	
1978,79	Striped Bass	Mean approximately 3 ppm; 40 fish
	Eel	30 from Hempstead Harbor; mean 1.3 ppm
	Menhaden	Mean over 3 ppm
	Bluefish	Highly variable; overall mean 1.54 ppm; 60 fish
	Mackerel	Mean 0.99 ppm; high 2.24 ppm 15 fish
	Others (Winter flounder, Summer Flounder, Tautog, Scup, Weakfish)	Mean 0.5 ppm or less
1984	Striped Bass	May-July mean 4.77 ppm; 47 fish from entire Sound. Oct.-Dec. mean 1.04 ppm; 9 fish from eastern Sound.
	CHLORDANE	
1980	Composite samples from City Island	Winter flounder = 30 ppb Bluefish = 30 ppb
	DIOXIN	
1983	Sample of Striped Bass from Little Neck Bay	N.D. to 39 ppt
	CADMIUM	
1980	Lobster sample from Eatons Neck; 5 males, 5 females Mean of males: muscle 0.3 ppm; hepatopancreas 11 ppm Mean of females: muscle 0.15 ppm; hepatopancreas 2.35 ppm	

those two numbers, there is obviously quite a bit of difference, and we're not sure why.

We did find some historic data, very limited, on chlordane in small composite samples from fish in the City Island area in 1980. Winter flounder and bluefish composites have concentrations of approximately 30 ppb, which is about one-tenth the FDA action level.

We have been doing work on tetrachlorodibenzodioxin (TCDD) as well, mostly in the Hudson River area. The studies done last year indicate that the Hudson River and Newark Bay areas of New York and New Jersey are probably the main source of TCDD and tetrachlorodibenzofuran (TCDF) contamination of striped bass and other species in the northeast. We had one sample from Long Island Sound, four fish from Little Neck Bay, one of which reached 30 parts per trillion (ppt). That level is high enough to warrant concern on the part of health authorities. The other three fish did not contain TCDD at measurable concentrations. Levels in the Hudson River consistently exceeded 10 to 20 ppt and have been the subject of consumption advisories by the New York State Health Commissioner.

The very limited data on cadmium does suggest the possibility of health-related problems with lobsters. Very small samples were taken from Eatons Neck around 1980, five males and five females. We see two things. First, as one might expect, the tomalley levels were far in excess of the muscle levels, up to two orders of magnitude higher. Second, there was quite a significant difference between males and females. Again, although the differences appear to be significant, we were dealing with only five samples. We believe that additional work on cadmium--and for that matter PCBs and lobsters from the Sound, particularly the western basin--would be very important from a health perspective.

The point here is that these contaminant problems are limiting the use of resources. We don't yet know to what extent, because of the rather skimpy examination of the issue. From the perspective of responsible public agencies, we believed the first step was to gain a thorough, comprehensive knowledge of the contaminant levels, as well as to work toward assessing their sources and possibilities of abatement.

We do not yet know, but it appears that our 1984 striped bass data suggest that Hudson River discharges of PCBs may not be the only, or even the primary, cause of the contamination of fish taken in Long Island marine waters.

Other major difficulties in management are problems of resource over harvest and difficulty in management compounded by social conflicts. Table 3 provides some data on lobsters, which are interesting from a couple of perspectives.

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TABLE 3. NEW YORK COMMERCIAL LOBSTER LANDINGS, LONG ISLAND SOUND

	1977	
322,104 lb	172 Licenses	19,113 Pots
	1983	
824,943 lb	251 Licenses	31,618 Pots
	MORTALITY	
TOTAL ANNUAL -	APPROXIMATELY 92%	
ANNUAL FISHING -	APPROXIMATELY 85%	

These are our own data based on surveys of our license holders. In 1977 approximately 322,000 pounds of lobsters were landed by 172 licensees who set over 19,000 pots. By 1983 catch had gone up to 825,000 pounds. Licenses had jumped from 172 to 251, and the number of pots set had jumped from over 19,000 to over 31,600. That is a tremendous increase, which is still going on, in the effort, the catch, and the catch per unit of effort. We've estimated total annual mortality to be about 92 percent, and fishing mortality to be 85 percent.

Lobsters are managed not just by the individual states, but also, for a number of years, by cooperative interstate management. Now in the Fisheries Conservation Zone they are managed by the National Marine Fisheries Service. The management recommendations in all of these areas are very much equivalent. There are some minor interstate differences, but by and large we are managing on the basis of a minimum carapace length and a policy of requiring the release of females bearing eggs. Nonetheless, we find mortality rates increasing and catch per unit of effort increasing. Fishery managers are poised, and have been for many, many years up and down the coast, on the prediction of a crash in lobster catch which hasn't happened. It's hard to say why.

We heard some suggestions this morning that some of the impending problems, particularly in the western Sound, might explain some of these trends. Maybe they do. On the other hand, these patterns of increased effort and catch are pretty much uniform from one end of the Sound to the other. They embrace the eastern basin and in particular the central basin, where we are not so much aware of the bottom dissolved oxygen problem that exists further west. So it's a mystery. Management appears to be successful, but we are concerned that the levels of mortality themselves may well cause us problems in the future.

We can also look at the possibility that some finfish resources will be a problem. As I pointed out earlier, many of our Long Island Sound finfish resources are migratory and have to be managed not just by any one state, but by cooperation between states and the Federal Government. There are many such resources that are in considerable difficulty, such as weakfish, striped bass, and certain ground fish. Others, such as winter flounder and bluefish, are doing quite well coast-wide and within Long Island Sound. Tautog in the Sound also seem to be doing quite well.

There are signs of trouble coast-wide with species like scup and summer flounder. In those species there is an indication of excessive mortality rates, which may require coordinated interstate management along with Federal management in the fishery conservation zone. It is a little difficult and somewhat frustrating to make these things happen. But the systems appear to be in place to help them happen, and we hope they will take place in the future.

I'd like to talk a little bit about some of the possibilities and problems with shellfish. After all, these are the major resources. At present, with what we know now about the relationship between the habitat and the resource, I see two principal impediments to increasing shellfish production.

The first is the plain fact that about 16 percent of the growing waters on the New York side of the Sound are closed because of fecal coliform contamination. We can talk more in a minute about where this contamination occurs.

The second group of impediments to the development of aquaculture are the legal and institutional obstacles. I'd like to give you a quick geographic summary of New York shellfish landings. For Long Island Sound, about 5 percent of the landings of hard clams are from the town of Brookhaven, which is mostly within the Port Jefferson Harbor complex and Mount Sinai Harbor. A small number of landings are made in Smithtown, which takes in Smithtown Bay and a little bit of Stony Brook Harbor. The majority, probably about 85 percent, of the landings are from the Huntington Bay complex within the town of Huntington and immediately surrounding waters. Oyster Bay contributes approximately 10 percent of the hard clams.

For oysters, there are small, wild harvests from Brookhaven, Smithtown, and Huntington. These towns are from the same bays and harbor complexes I just mentioned. So nearly all of our oysters on the north shore are taken out of Oyster Bay, where they are grown, cultivated, and harvested by a single company.

There is an interesting dichotomy between oyster and clam harvests: Nearly all of our oysters are cultivated, but most of our clams are wild harvested. Most, if not all, of these products are coming from the harbors and embayments and coves along the shores of the Sound. Shellfish are not a deep-water resource, but a shallow-water resource.

The areas of the open Sound may well lend themselves to improved production through various kinds of culture, through leasing of beds, as has happened in the past. There have been economic, legal, and political limitations in New York to the expansion of this kind of activity.

We have been able to produce well in excess of 40,000 to 50,000 bushels of oysters per year through one culture operation on the north shore of Long Island. We have not been able to reach equivalent quantities of hard clams and oysters. Not because the habitat won't stand it, but because we've been unable to get the legal, economic and political problems out of the way. I'm hopeful that that can happen, but it has not as yet.

Growing water certification is our single biggest problem. Table 4 shows bays and harbors along the shoreline of the Sound, generally moving from west to east. By and large, the proportion

TABLE 4. SHELLFISH GROWING AREA CERTIFICATION, LONG ISLAND SOUND BAYS AND HARBORS, NEW YORK STATE

East River and Tributaries	Total Area Uncertified	= =	8,860 acres ALL
Westchester Shores and Tributaries	Total Area Uncertified	=	15,520 acres ALL
Manhasset Bay and Tributaries	Total Area Uncertified	= =	2,725 acres ALL
Hempstead Harbor and Tributaries	Total Area Uncertified	= =	3,465 acres ALL
Dosoris Pond	Total Area Uncertified	= =	105 acres ALL
Oyster Bay Harbor	Total Area Uncertified	= =	5,040 acres 900
Cold Spring Harbor	Total Area Uncertified	= =	1,325 acres 215
Huntington-Northport Complex	Total Area Uncertified	= =	6,270 acres 1,099
Smithtown Bay	Total Area Uncertified	= =	22,300 acres 1,000
Nissequogue River	Total Area Uncertified	= =	555 acres ALL
Stony Brook Harbor	Total Area Uncertified	= =	855 acres 16
Port Jefferson Harbor Complex	Total Area Uncertified	= =	1,555 acres 1,060
Mt. Sinai Harbor	Total Area Uncertified	= =	455 acres 60 acres
Wading River	Total Area Uncertified	= =	50 acres ALL
Mattituck Creek	Total Area Uncertified	= =	125 acres ALL
TOTAL BAYS & HARBORS	TOTAL AREA UNCERTIFIED	= =	69,205 35,755 (51.7%)

of the total area that becomes uncertified decreases as we move out. But please note that we have closures all the way out east; in Nissequoque River, Wading River, and Mattituck Creek.

The closures are predominantly related to waste water from discharges of publicly owned treatment plants, discharges from marine vessels, and runoff. We see closures in Wading River, Mattituck Creek, and Mount Sinai Harbor as predominantly related to runoff of storm water. In Port Jefferson Harbor and Huntington Northport Harbor, the closures are complex and related to a variety of problems, including sewage treatment plants that aren't operating the way they should, as well as very severe runoff problems.

Altogether, over 50 percent of those bays and harbors are closed by area (Table 4). Looking at the Sound itself (Table 5), only in the western Sound area, roughly from Matinecock Point to the Connecticut-New York line west, do we have any significant closures. The small one in the eastern Sound is a closure around a municipal plant outfall. On the whole, we have about 10 percent of the total Sound declared uncertified. About 16 percent of the Sound when we add the tributaries, and about 50 percent of those tributaries. That statistic is significant because it is mainly the tributaries, the coves, and the nearshore areas that are potentially productive of shellfish. Until we begin to resolve the problems of runoff and inadequate treatments and disinfection at municipal treatment plants, we will not be able to realize some of the potential for the wild production of shellfish that is already going on.

DR. SCHUBEL: We are ahead of schedule, so if there are any questions or comments, we've got some time.

QUESTION: What's the division between the eastern and western Sound for commercial lobster fisheries?

MR. COLVIN: I don't believe our data bases would tell us. The data that New York recovers is survey data from the individual lobstermen themselves. We don't have it by point of landing, we have it by a collection of those approximately 200 people sending in their forms. We know how many pots they set and what they say they catch. But we do not necessarily know where they set their pots or where they land their catch. Right now probably the central basin is probably the biggest producer, if for only because it's the biggest area.

QUESTION: Could you address the manager's perspective on dealing with a state split by multiple jurisdictions: three divisions of the environmental department, three counties, Albany, the Long Island Regional Planning Board, and the State of Connecticut. What's it like to manage a fishery in that morass?

TABLE 5. SHELLFISH GROWING AREA CERTIFICATION, LONG ISLAND SOUND, NEW YORK STATE

Western Sound	Total Area	=	101,860 acres
	Uncertified	=	40,210
Central Sound	Total Area	=	188,000 acres
	Uncertified	=	0
Eastern Sound	Total Area	=	121,000 acres
	Uncertified	=	300
Total Sound	Total Area	=	410,860 acres
	Uncertified	=	40,510 (9.9%)
Total Sound and Tributaries	Total Area	=	480,065 acres
	Uncertified	=	76,265 (15.9%)

MR. COLVIN: It's not as difficult to manage fisheries in that morass as it is to try to deal with the basic habitat and water quality problems. That's really tough. Fisheries are a little easier, as I indicated, because we are already dealing with institutions that have been crafted to establish fishery management relationships among the states, between states, and then between states and the Federal Government. And that is really going to have to happen.

When we get into water quality it gets really tough. I think that we have even more organizations than you mentioned in your question. The Interstate Sanitation Commission plays a part, and there is a little slice of Rhode Island out there that may also have a role. We have New York City as well as the three counties of Westchester, Nassau, and Suffolk. With the diverse community that exists, it is very difficult to get the key people together to make decisions that need to be made.

There has not been, as in our view there should be, a decision to delegate major responsibilities in some areas to certain of those entities. It is arguable that this is what is needed to get the work done.

DR. CAHN: Gordon, has the Atlantic menhaden commercial fishery come back at all?

MR. COLVIN: Yes and no. Certainly the menhaden fishery in the northern part of the species range, particularly, has been quite low within the last five to ten years, to the point that many of the companies have voluntarily suspended operations in northern New Jersey, New York, and New England. Operations were resumed in the New York area last year and the fall of the year before, mainly because some fish were here that they hadn't seen before. By and large, landings in that fishery remain fairly stable, with record numbers of individuals. That's the good news.

The bad news is that the average size and age of the fish continues to decline, and there are serious problems with failing to address that problem, which is mainly an issue at the southern end or the Atlantic part of the fishery.

DR. WELSH: Winter flounder are migratory fishes, and I was under the impression that at least within the Sound there was an indigenous fishery in which flounder just moved offshore into waters above Long Island Sound and then back into the basin.

MR. COLVIN: Maybe I didn't make myself clear. At least in the western part of the Sound, if not well into the central part, that's undoubtedly true. As we get out into the eastern Sound, some of the stocks of winter flounder are relatively local and some are probably mixed with offshore stock.

DR. WELSH: To follow that up, winter flounder had one of the lowest contaminant levels compared to other stocks. It's telling us something about their integrated life.

MR. COLVIN: Yes. For that reason we think that winter flounder and possibly tautog as well are probably very good finfish species to use to characterize concentrations of toxic contaminants. Lobsters and shellfish would also be good.

QUESTION: Do you harvest hard shell clams, and if so, how much has the hard shell clam and oyster population decreased over the past ten years?

MR. COLVIN: Yes, we do harvest hard shell clams. The question of population decline is complicated because, for the last 20 or so years, the north shore of Long Island has been an order of magnitude less important in hard clam production than the south shore. In New York, landings of hard clams have declined by two-thirds or more over the last decade. But most of that decrease has come from the south shore. Now, we've also seen decreases on the north shore, where historically the Huntington-Northport complex has been the most important producer of hard clams. Production was very good there in the 1960s, then dropped off; but in very recent years the population has stabilized at about the levels shown in Table 1.

QUESTION: How about oysters there?

MR. COLVIN: When we look at oysters, we're really looking at one aquaculture facility in Oyster Bay Harbor. Their production has been fairly stable, though it declined a little in recent years.

A VIEW OF THE PROBLEMS AND OPPORTUNITIES FROM THE CONNECTICUT SIDE OF THE SOUND

E.M. Smith
Bureau of Fisheries
Connecticut Department of Environmental Protection

The first thing I would like to mention is Gordon Colvin's response to Dr. Cahn's question about the menhaden fishery. I think you'll see after this presentation that I probably could have prepared a talk based on what Gordon would say, and we would both be speaking with the same words. This demonstrates that within disciplines there is a lot in common, in how we see problems and how we approach them. It's only the differences between disciplines that require some additional coordination.

In 1984 the Connecticut Department of Environmental Protection published a Marine Resources Management Plan, which documented the types of resources available in the Sound and the types of fisheries occurring historically and at the present. In addition, we identified some of the problems and opportunities facing us in managing those resources. I'd like to present the Connecticut perspective and hope you will see how similar our resource management problems are on both sides of the Sound.

Before we begin, I just wanted to emphasize that, depending on our perspective, Long Island Sound can look like quite a large body of water. No fishery manager's talk would be complete without at least a background of some of the important fisheries in the Sound.

The answer to Dr. Cahn's question is quite pronounced. Menhaden is probably one of the largest historical finfish fisheries from the Sound (Figure 1). And there's no question that the fishery declined, whether it was a resource collapse or a result of economics. There was a temporary rejuvenation of the fishery in the mid-1970s, but as Gordon Colvin pointed out, it has since declined again. To a large extent the management issue facing us along the coast today is the harvest of very large numbers of one-year-old and younger fish down in North Carolina. The fishery in the Sound traditionally was a fishery of about three-year-old fish, and the harvest of pre-recruit and, in fact, young-of-the-year fish in more southern waters is of great concern to interstate fisheries managers.

The American lobster illustrates the other extreme (Figure 2). Dr. Rhoads spoke about lobsters this morning. I've got more questions after hearing his talk than I have answers. The only point I would make is to reiterate Gordon Colvin's comment that this trend has been seen throughout the Sound, in central and eastern waters, as well as in southern New England waters south of Massachusetts. It is by no means a western Connecticut

MENHADEN CATCH FROM CONNECTICUT WATERS (MILLIONS OF POUNDS)

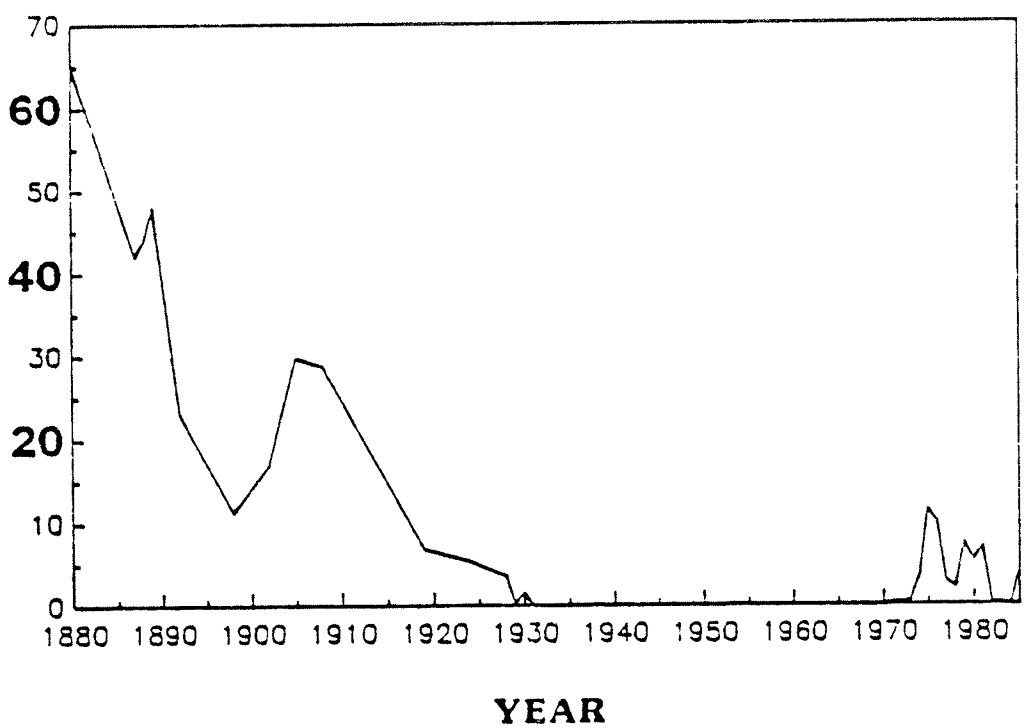

Figure 1. Historical trends in menhaden catch.

CONNECTICUT LOBSTER LANDINGS FROM LONG ISLAND SOUND (MILLIONS OF POUNDS)

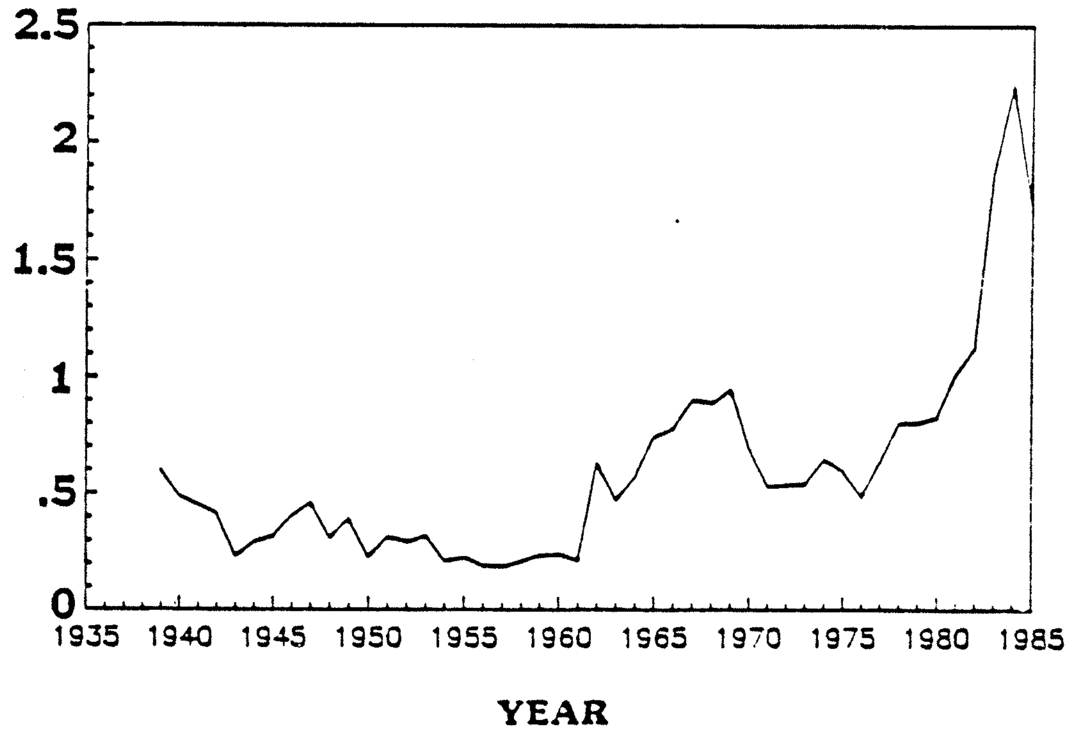

Figure 2. Historical trends in lobster catch.

phenomenon. That is not to say that the hypothesis that we heard about oxygen this morning is invalid, but it bears further scrutiny.

Connecticut maintains a pretty comprehensive commercial fisheries monitoring system by documenting landings and catches and effort in the Sound. We do this through a cooperative agreement with the National Marine Fisheries Service. Although we're not responsible for the management of shellfisheries, we cooperate very extensively with our agriculture department, which is the responsible agency.

We also have cooperated to some extent on national recreational fisheries surveys. More recently, we have conducted these surveys on our own. I've presented the most recent National Marine Fisheries Service data, and Dr. McHugh's point this morning was well taken (Table 1). The ink is hardly dry on the 1981-1982 statistics; in fact, we received the most current information only last week. Until last week the most recent data available were for 1979. I present this table to emphasize the five major finfish species of recreational importance in the Sound. The catch was on the order of 9 million pounds per year in the early 1980s, far exceeding the commercial take of those species. So we can begin to summarize some of the principal uses of fishery resources in the Sound. Those uses are recreational finfishing, lobstering, and shellfish production.

The production of seed oysters has been Connecticut's traditional claim to fame. If you will recall some of the coastal morphology of the Sound, all of the embayments and indentations and true estuaries on the Sound have enormous potential as shellfish production areas. The Housatonic River alone has produced more than 50 thousand bushels of seed oysters in one season. Commercial finfishing, historically a much larger fishery than at present, now produces landings from the Sound on the order of 1 to 1.5 million pounds of food fish per year.

In 1980, we determined that just documenting the extent and performance of fisheries was somewhat of a problem in trying to understand the resources because of the potential bias that differences in fishing gear, and fishermen, can inject into the system. As a result, we developed a program based on the sampling design used by the National Marine Fisheries Service in conducting their offshore resource assessment surveys.

Last year we reorganized a single-species trawl survey to include all of the major finfish species in the Sound that we sample by bottom trawl net. Thirty-five stations throughout the Sound are selected on the basis of bottom type and water depth. The most important species are measured and samples are taken for age and growth analyses. These species are winter flounder, summer flounder, scup, bluefish, and blackfish. Depending on the year, if we add another species, weakfish becomes the sixth most important fish.

TABLE 1. RECREATIONAL CATCHES OF FINFISH IN LONG ISLAND SOUND FOR 1981-1982

(Source - NMFS 1981-1982 Marine Recreational Fisheries Survey)

SPECIES	NUMBERS	WEIGHT (LB)
Winter Flounder	928,000	928,000
Summer Flounder	146,000	292,000
Scup	701,000	280,000
Adult Bluefish	765,000	6,120,000
Snapper Bluefish	3,060,000	459,000
Blackfish	145,000	580,000

We also sample our commercial lobster pot fishery. As Dr. Colvin pointed out, this fishery is very heavily exploited, probably the most heavily exploited marine resource, at least along the north Atlantic coast. There are fishing mortalities that simply could not be sustained on finfish populations, yet they have been sustained for 15 or 20 years. This boggles the minds of fisheries scientists.

Because of the sensitivity of the resource to very high levels of exploitation and, potentially, some of the water quality problems referred to this morning, we have begun a program to try to evaluate or estimate year-class strength at an early age by sampling larval and juvenile lobsters. Although we recognize the difficulties and the problems associated with such an exercise, we hope to be able to develop an index of recruitment for lobsters in the Sound.

Last summer we found a new problem to concern us. When the Food and Drug Administration (FDA) lowered its tolerance levels for PCBs in fish--from 5 parts per million (ppm) to 2 ppm--the change effectively created a whole new area of consideration in resource management. I point this out simply to emphasize that it is a problem. Depending on your perspective, it's a health problem, a resource-use problem, or a management problem. We've heard again and again that this problem requires attention, so in the past year we have begun to take fish samples and sediment samples for our Environmental Quality Division, the other half of our agency. Last year we sampled bluefish, and I reiterate the point that Gordon Colvin made. It's known that bluefish samples, across areas and even within size classes of fish, produce very variable results.

We were encouraged that none of the samples provided to the FDA had concentrations of PCB over 2 ppm, but we stress the point that the samples were composites, and a value of 1.7 ppm could conceivably represent a fish, here and there, in excess of 2.0 ppm. However, the results are satisfactory to FDA because they look at a composite sample of 2.0 ppm or below as being acceptable for interstate shipment.

Before I identify problems, issues, and opportunities, I think it's important to point out that before we could do this in our own planning process, we had to identify our own priorities in management. Admittedly, these are going to look a bit narrow, but we are a resource management unit as opposed to an organization that includes some of the other facets that we heard about this morning and that to many of us are still very important.

As we developed our priorities and goals, we treated protection of the resource as number one. We do make the observation that there is a cost associated with fishing. Whether it's hooking mortality in a recreationally caught fish or discard mortality in trawl fisheries, our attempt is to minimize damage and waste, but we understand that to some degree these things do occur. So we tried to look impartially at the protection issue without going overboard.

We consider management of marine resources as food to be a principal objective. There are clearly other types of opportunities that are very important: recreational fishing or commercial fishing for those people to whom it is a source of income. But regardless of conflicts between commercial and recreational fishermen, the first objective was to protect the resource simply as food for the public, whether one catches it or not.

Having said that, we get to the topic of the discussion. Management issues have been identified. Fishery exploitation is number one. Again, we used lobster as an example; there have been others. Also, we tend to think of things like toxic contaminants and habitat degradation as significant impacts on resources or use.

It's important to point out that in some species the simple capture process multiplied by the number of people engaged in it makes a real impact on a resource. Our principal responsibility is to document this type of situation, to look for change, and to look for management measures to reduce the impact from an unacceptable level.

Resource allocation is obviously an issue with us. It probably is becoming the single most important issue in a determination of who gets a share of the resource. I'll discuss this subject more later.

Habitat protection is rather broad and includes things like water quality monitoring. Again, this is not our principal emphasis, there are other bureaus in our department that deal with monitoring as a more specific responsibility. In our planning process we simply made the observation that our unit, because of our frequent trips on the water, provides an opportunity for other units in our department and other agencies to "piggyback" some sampling efforts. Basically, we provide the sampling opportunity for other programs that may need data but do not have the resources to collect it. "Interjurisdictional fisheries management" is a term that begins to slide easily off the tongue for those of us involved in it. It's essentially a recognition that fish swim across boundaries and that we have to tailor our management programs to follow those species. We can't do it alone in Connecticut or else we would be looking only at lobster and blackfish--resident species in Long Island Sound. There are many other species, and they move up and down the entire coast, and we have to follow them in our management activities.

Law enforcement and funding are a given, but they're absolutely essential. Many times we find a management measure that fails because no thought was given to its enforceability. Similarly, we can't really manage our resources without the type of information required to do it intelligently, and collection of that information requires funding.

To summarize, the information we need for management is fisheries statistics--the documentation of the performance of the fisheries. We also require fishery-independent monitoring so that we can eliminate the biases associated with the fishing effort. In some cases, we require applied fisheries research--the types of research that can give us a predictive capability or a further understanding of why a fishery resource performs the way it does.

A continuing and growing part of our management process is to make sure that technical reports and technical details don't just sit in a file, but get transformed and disseminated to the public. We have, admittedly, been remiss in this area. We generate all sorts of reports every year, and they're great big secrets. We had planned for a position in our unit that would do nothing except turn out public information. However, the well-known budget battles on Capitol Hill this year have put a stop to that plan.

Opportunities for resource use include shellfishery development. There was a period at the turn of the century when shellfish production in Connecticut approached 15 million pounds of meat. That level of harvest is widely believed to have exceeded the capacity to produce over the long term and to have represented overfishing. Nonetheless, it is evidence of what can be approached if you manage your resources with a little bit of wisdom. The recreational shellfishing effort is hampered right now by the closures that we've heard about in the nearshore shallow waters, which are most accessible to recreational fishermen. But there's a large effort by aquaculture companies in Connecticut to harvest seed oysters, purchase seed oysters, and relay them to an area of clean water. After the oysters have cleansed themselves over a required period of time, they become marketable resources. And in fact, the Long Island Sound oyster is known as a product superior to its Chesapeake neighbor. I say this with the recognition that on the New York market a bushel of Connecticut oysters yields about 60 dollars; whereas a bushel of Chesapeake oysters sells for about 35 or 40 dollars.

Public access is important to any commercial fisherman. And particularly for the sport fishermen, there's a very pronounced lack of public access in western Connecticut. Fairfield County is very heavily populated; there is a lot of residential development and a lot of private ownership. At the same time, there are a large number of fishermen in that area. Frankly, it's difficult to get to the water and fish from shore. Unfortunately, solving that problem takes money, and we don't have much of that at the present time.

The Wallop-Breaux Amendment to the Dingle Johnson Act in last year's Congress was expected to provide an infusion of funds to the states to begin to procure some fishing areas and similar resources. However, you probably are aware that the amendment is effectively being held hostage by the present Administration, so we don't know how that situation will be resolved.

Seafood consumption, as I mentioned before, is simply a recognition that the resource out there ought to be available for the entire public and not just a relatively few groups, sport or commercial, that are in a relative minority no matter how badly they would like to have the resource.

The development of fisheries support services is the commercial counterpart to public access. Lobstermen in western Connecticut, particularly, are being squeezed away from the coast by condominium development and the "reprogramming" of land that was formerly used as marinas and docks. Prior to recent amendments to the Connecticut Coastal Area Management Act, that land was in transition to essentially residential and other private uses. To the extent this occurs and keeps the fishing industry, sport or commercial, away from the water, it becomes an inappropriate use of that waterfront.

I saved resource allocation for last because, aside from the water quality problems and the purely resource protection issues that we're faced with on a continuing basis, this has become what we like to describe as the emotional and divisive controversy of the decade. It's getting worse, not better. We have these controversies almost nonstop between recreational and commercial fishing groups, and between commercial fishermen who compete for the same valuable resource and use a different type gear to do it. The problems don't go away, and we have to determine just why the level of concern exists.

Some of you may know that we've had an absolutely enormous controversy during the last two-and-a-half years over the taking of lobsters in Long Island Sound. Traditionally, this has been almost entirely a pot fishery. There's a small trawl fishery that takes from 5 to 10 percent of the resource each year. In the last two years, during the period of great lobster abundance, trawl fishermen began to take more lobsters and this is causing an enormous controversy among user groups.

Initially, there were resource concerns to be considered. Those have pretty much been addressed, leaving us with competition: gear conflict, which loses money for both sides, and competition purely for income. This is probably, as I said before, the single issue to which we have devoted most of our attention; not by choice, but by necessity, because it has the public stirred up. The situation is exacerbated by our political process. I'm not casting stones at our legislators by any means; I'm simply emphasizing that it's a point that we all have to deal with in agency work. We basically execute the mandates of the legislature. The best designed plan and best thought-out management measures can go awry in a very intense and competitive allocation struggle.

The last point I would like to discuss is what inevitably happens at the end of these controversies: someone draws a line in the Sound. You can't use a vessel over a certain size in a certain area, you can't take a certain species, you can't go north of a different line. Thus we end up with a Sound that is simply water in a container looking like a road map of Connecticut or New York State. This makes our management efforts much more difficult because of the recognition that the species moves across those boundaries as well.

To solve the competitive problems, we must look at continued communication and acknowledgment of the rights of other fishers who use the Sound. At certain times it's almost impossible to accomplish, but it will always be necessary.

DR. SCHUBEL: Thank you, Eric. Are there questions or comments?

QUESTION: How do you know those Connecticut striped bass in the Long Island Sound were from the Hudson River?

MR. SMITH: Well, until Mr. Colvin made his comments earlier, our understanding was that that was the principal source of the pollutant.

QUESTION: The pollutants are from there, but how do you know which bay they came from?

MR. SMITH: In two ways. A number of years ago it was determined by tagging and meristics that striped bass in Long Island Sound in Connecticut waters as far east as the Connecticut River were predominantly fish that originated in the Hudson river. East of the Connecticut River they were predominantly Chesapeake fish, and around the Connecticut River was a mixing zone. With the demise of the Chesapeake stock, we suspect that although there hasn't been an extension of the Hudson resource into new areas, just by proportion they became a greater part of the resource that's out there. So we're simply making that judgment. This point is also being investigated at the University of Rhode Island right now. States collect fish and send the frozen heads to URI, where they analyze the eye lens protein, which is a stock discriminator with a pretty high level of credibility, able to determine Hudson versus Chesapeake stock of origin.

QUESTION: Regarding the public access issue, does the State of Connecticut have a Coastal Area Management Plan?

MR. SMITH: Yes, it does.

QUESTION: What does the Management Plan say about the fact that the public has rights of access above a certain level of high water or low water.

MR. SMITH: It essentially says that the public has the right to the coastal zone. However, it doesn't say that you can take over someone's private property.

The problem is that virtually all of the private property in western Connecticut has previously been bought up. So there's relatively little available government-owned land to provide public access.

QUESTION: So people can own the beach?

MR. SMITH: Well, to the Mean High Water mark.

QUESTION: Is there any requirement that people who own property along the beach provide access, say, along pathways to the beach?

MR. SMITH: In one sense there is. I'm not sure if that's required of private landowners. I'm absolutely certain that it's not a question of our coastal program and its legislation coming in and saying, "Now you have to allow access." However, the issue does arise when there's a redevelopment. A good case in point was an area on the Mystic River that was formerly a car dealership, owned by the person who subsequently developed condominiums on the site. A stipulation in the permit was that the owner had to provide access, and he built a wharf along the whole river front. That wharf is open to the public. You can walk the shore in that area regardless of whether you live in the condominium. That is a standard part of such developments--at least our CAM people fight for it every time there's a similar development, thereby increasing the amount of public access.

QUESTION: You've addressed the catch of marine resources for the last ten years. But you haven't addressed the population of the fish. What are you projecting the marine resource population will be in the next ten years?

MR. SMITH: Well, it really depends on the species. We're projecting an increase in shellfish production, for example, because for many of the beds that just have not been utilized over the last 20 or 30 years, new aquaculture techniques are being developed, and those beds now are beginning to be worked again. The Town of Old Saybrook at the Connecticut River has effectively influenced the program of allowing commercial harvesters to harvest oysters and transfer them to clean water beds. They pay a fee to the town for the right, and 10 or 20 percent of their harvest goes into a town-owned clean water area for recreational harvesting. So it's a cooperative venture that gives something to the commercial operator while supplying funding to the town to buy cultch and other supplies to develop their beds. The program has been pretty successful at taking an area that two or three years ago was just a nice piece of coastal water and turning it into a productive area.

Lobsters are anybody's guess. We know our trend in abundance is declining. The peak of abundance was in 1983. It was a little bit lower in 1984. It's too early to tell whether the decline is going to continue this year. It's not necessarily anything to be concerned about because prior to 1983 we had about a five-year period of relative stability that followed two or three years of relatively low abundance. Not having any more to go on, I would suggest that the increase in abundance and landings that we saw in 1983 and 1984 was just a stock phenomenon, the recruitment of a strong year class into the fishery, and that, too, will pass.

As far as the finfish species, you have to go down the list point by point. Some are strong, some you could argue need some help.

QUESTION: Are you monitoring the nursery areas within the Sound to check on the populations that are spawning?

MR. SMITH: No. It's probably the highest priority new project, as opposed to the information and education discussion I mentioned earlier. In terms of new field projects, if we had enough money, the next area would be to go into the coastal fringe, that half mile or so of water on either side of the shoreline. But unless Congress frees up all the Wallop-Breaux money that was voted last year, I don't foresee us conducting new surveys.

QUESTION: Just to clarify, did I understand you to say that over the past 10 years your harvesting of hard shell clams has increased primarily because of new aquaculture methods and harvesting methods?

MR. SMITH: Yes.

QUESTION: In beds that were closed, did they increase or remain the same?

MR. SMITH: There are two areas of shellfish production. The real estuaries, the kind that produce the seed oysters, have effectively been "fallow" for several years because the water itself was polluted; it was a closed area and you could not harvest there. In the last five or six years there's been a recognition and an education process within the health services system so that they now understand that if you manage it properly, you can have a fishery on the resource, even though it's not a consumptive fishery. That product, properly cleansed, can then become a consumptive resource.

So that's one area. The other is the large companies that buy these seed oysters, put them on clean beds out in deep water, and effectively move them around to meet their requirements. When the oysters reach marketing size, they hit the market. This is the part of the industry that has developed greatly in the last 10 years.

QUESTION: One more point to follow this up. You said the water was polluted and there was a decrease in harvest. What pollutes the closed areas?

MR. SMITH: Sewage.

QUESTION: That's what you think was causing the decrease in harvest?

MR. SMITH: Yes. My understanding is that it was closure based on coliform counts.

INFORMATION FOR SOUND MANAGEMENT

P.K. Weyl
Marine Sciences Research Center
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In my title, we're dealing with essentially three words, "information," "sound," and "management." I want to discuss these items in turn.

First, let's look at the difference between information and data. Often there's a real confusion. For instance, we've been developing an information system and people want to know how much data is in the system. The answer is none.

What managers need is information, not data. The difference may at times be obscure, but basically data are the results of particular observations. These results are converted into information only after they are combined with other data and interpreted. Managers don't care that on a particular day somebody took a water sample at a particular place that had particular characteristics. Managers are interested in the implications: what can be inferred about the overall water quality from the available data.

When we make the transformation from data to information, several things happen. First, the bulk of the printed representation decreases fairly drastically. Second, the accuracy decreases; with data, you know exactly, or at least within the errors of measurement, what the particular data point is, but to generate information the data are generalized. Third, the degree of abstraction increases; you now look not at exact specific objects, but at general characteristics. And finally, what's most important, the relevance of the information for the particular management objective increases.

The next issue I want to examine is what we mean by Long Island Sound. From the management point of view, we can mean many different things. Basically, however, if we look at the physical object--the Sound--how it changes, how its characteristics change over space and time, we're dealing with an infinitely complex system. Every little bit of it changes spatially and temporally.

Now, in order to generate information about the Sound for some management objective, it becomes necessary to abstract this complex system. We have to look at the Sound in a simplified way. Of course, how we look at it depends upon our objective: what are we managing, what are we concerned about?

At one extreme, we may just be concerned about the general trend in water quality or environmental quality from west to east. In this case, we look at the Sound as a one-dimensional object that's hooked at the western end to New York City and at the eastern end to Block Island Sound. From this perspective, our view would be simple and one-dimensional. On the other hand, if we are concerned about the more detailed shoreline, we would have to look at the complex geometry. In yet another situation, our concern might be with a local area, looking at a particular bay in which we're growing oysters. In that case, what we mean by the spatial concept of the Sound is much more specific.

The important point is that there isn't just information about the Sound; the type of information needed depends on our approach to the space. It also depends on what our concern is, about the uses of the Sound; whether we're concerned with living or with mineral resources, with recreation, with conservation, or with waste disposal. The ways in which we need to look at the Sound can be very different.

The next issue I want to discuss is management. Here the question is, who manages? There's no such thing as "The Long Island Sound Manager," who takes all of the information and makes all of the decisions. Rather, the system of the Sound is managed by a large collection of individuals from various organizations at various hierarchical levels. These people are managing the Sound for a wide variety of objectives. Some are concerned with operating power plants; some are concerned with fisheries; some are concerned with recreational facilities; and so on. So really, the management of the Sound results from an interaction of all of these individuals and organizations that have a variety of objectives.

As a result, we have a broad range of information needs. We can look at information from three points of view. One is the managerial approach in which the objective is to find the best way to use the resources available in the Sound. Let's say we want to develop something in a particular area. We want to know what problems we are likely to encounter in developing a beach to enlarge recreational facilities. The managerial approach is an open-ended kind of search for information in order to make a better decision. This approach looks at lots of factors; it gets some information that leads to other information, in order to make a reasonable decision.

The administrative approach is different. For example, imagine administering a program for issuing permits, whether the permits are for building a structure on the shore or for getting a license. In this case, there are specific regulations by law or by administrative code that specify what you must consider in making the decision. Before issuing the permit, you must address issues one, two, three, and four. You have to examine how the proposed action will impact local water quality, whether any national monuments will be affected by this activity, and so on. Thus, in the administrative mode you have to examine specific information, you must look at these numbers, you must look at this map, before you make your decision.

The third approach is the scientific one, in which you are trying to discover how a particular system operates; for example, you might be interested in the population dynamics of certain stocks. Now you are more concerned with seeing large amounts of data; you want to combine data from different areas and analyze them in different ways. As you can see, managerial, administrative, and scientific information needs are quite different.

There are two approaches to information for managing an estuary such as Long Island Sound. In one case, we are concerned about a particular location or a particular location at a particular time. We want to know the characteristics at that location and we want to select that knowledge from the available information. The other approach is to find locations that have the attributes we want. Suppose our objective is to increase public access to the shoreline. We know what we are looking for, and we want to find the appropriate locations. We want to find the attributes of a specified place or at all of the places that have desired attributes.

Both approaches present similar problems of information retrieval. Even assuming that all the information is available, it is a large problem to retrieve it. The problem is the same whether we are making a managerial decision or an administrative one.

Once you have selected the information pertinent to your decision, you still have to translate that information into a form that you can use. A simple example is that different specialists use different units. Thus if you run a sewage treatment plant, you discharge water in millions of gallons per day. If you are measuring the flow of a river, you do it in cubic feet per second. And if you are a scientist, you can only think in meters. The problem is not that people are stupid and can't multiply, but if you hear numbers in units with which you are not familiar, you have to stop and think. You have to make the translation, and this impedes your thought processes. The problem is to select, to translate, to put items in a form that facilitates thinking. It is a reiterative process: you have selected something, this then leads you to new questions, you go back to the available information, and so on.

Using the available information to effect a management decision is a fairly complex process. The development of microcomputer information systems can greatly facilitate dealing with information.

In the last few years the microcomputer has drastically hanged our capability for dealing with information. The microcomputer presents a revolution because, first of all, the cost of equipment has gone down by a factor of 2 every five years or so, and the power of the systems has gone up significantly. Second, and even more important, microcomputer information systems have become easier to use. Before, if you wanted to computerize information, you either had to spend two years of your life learning how to program computers or you had to work through people who knew how to program. Now, in a week or two you can master the required techniques. You can use these systems to retrieve, update, and analyze information.

These information systems can organize and store information. It is easy to index information by space coordinates so that we can retrieve it for specific locations. Furthermore, we can automate the system to select the kind of information we want and to translate it into a language we can understand. The translation process can include converting units, explaining technical terms, mapping various attributes, and using different kinds of graphics.

Another aspect of microcomputer-based information systems is that we can build them to be extremely flexible. One of the problems with the large computer systems is that before you can design a system, you have to know exactly what you want that system to do. If you are designing a system for airline reservations, you have a well-defined task. But if you are trying to specify what environmental information will be needed five years from now in order to make certain decisions, no one can tell. We need information systems with flexibility so that as new concerns are identified, the required information can be added to the system.

The real point is that information systems allow us to move to management by exception. What this means is that most of the time decisions are made more or less automatically. At present it is very hard for people to obtain information. For instance, if you buy a piece of waterfront property, you assume you can do anything you want with it, because this is what the seller tells you. Later you find out that you need permits, that there are restrictions to what you can do, and so on. In order to get the relevant information, you have to hire a whole battery of experts to tell you about soil conditions, about shore erosion, about natural resources, etc. Using information systems, all of this information could be made available at low cost. This does not ensure that everybody will make the right decisions, but it does mean that a lot of the decisions are going to raise fewer problems because people will be better informed. This in turn will allow us to focus our management resources on the difficult problems--the ones that are the exceptions.

We now have the technical capability. We have developed two systems as prototypes to show what the microcomputer technology can do to facilitate access to information. One system, funded by the National Oceanographic Data Center, deals with the Hudson-Raritan estuary and also has a model that looks at the interaction between the estuary and Long Island Sound. The second system, funded by the Maritime Administration, deals with port development and environmental data for the port of New Orleans and its connections to the Gulf of Mexico. The two systems are very different: one is primarily a river system and the other is a very complex estuarine system.

I wish I could demonstrate this system to you, but the machine is small and its interactive use can be demonstrated to only a few people at a time. However, the system is available here in Washington at the National Oceanographic Data Center. If you're interested, I encourage you to make an arrangement to come and see both these systems. (Contact: Jim Audet, NODC 202-673-5539, FTS 634-7510).

A REGIONAL PLANNER'S PERSPECTIVE

L.E. Koppelman
Long Island Regional Planning Board

When I received the invitation, I accepted it with a certain amount of happy anticipation because I've had almost a two-decade good working relationship with Sea Grant and the Office of Coastal Zone Management and certainly with the Environmental Protection Agency. But as I sat here this morning, I must admit to an increasing sense of deja vu and trepidation.

The deja vu has to do with my assignment to talk about a regional planner's perspective on what today has been an excellent capsule review of some fine science that has been done since the 1950s in the Long Island Sound area. The reason for the trepidation is my concern that I'm not going to be able to adequately communicate with you scientists.

About 10 years ago I was asked to be a consultant to the Department of Health and Urban Development (HUD) after their Office of Research had paid the U.S. Geological Survey (USGS) in Menlo Park, California, about 10 million dollars for earth science research on behalf of what later became the California Coastal Conservation Commission. HUD was dismayed because after several years of superb science, the planners didn't know what to do with it. And so they figured that if they brought in a planner they might get an answer.

The USGS put on a presentation similar to the one I have listened to today. There was one series of maps that I found particularly fascinating. It had to do with land subsidence. Because I did recognize that there was a slight problem in California, I raised what I thought was a pertinent and yet simple question. Namely, what is the relevance of this scientific data on land subsidence to the planner? What's its meaning?

The gentleman from USGS couldn't get the drift of my question and asked if I could be more specific and give an example. I said, "Well, as a planner, I'm not interested in the science but in the application of the science. What does your work tell me in terms of the decisions I have to make as to whether there should be half-acre zoning, one-acre zoning, two-acre zoning or no housing whatsoever?" Whereupon, the director of the Menlo Park group, a distinguished scientist, got up and said, "Sir, how dare you sully this conference by introducing the subject of politics." And he walked out the door.

I was sort of uptight because here I was supposed to be helping the situation, and I evidently succeeded in alienating the entire distinguished group of scientists, because when the director walked out the door, all his subordinates walked out with him.

I turned to the HUD representative and said, "What did I do wrong?" He said, "Don't worry about it, Lee, they're angling for another 3 million bucks and the sons-a-bitches are going to be back after lunch."

Well, they came back after lunch and the rest of the afternoon was one of polite silence. I finally suggested that since I had difficulty in communication, perhaps the best recommendation I could make would be that HUD hire a "planning engineer," namely a person with at least quasi-scientific credentials who can also talk to planners. And that perhaps USGS should talk to this person, and then this person should translate the scientific work into the English language.

That is precisely what happened. After all the science was completed, a separate group of people translated the basic earth science into policy parameters that the California Coastal Commission could then translate into laws, regulations, administrative devices, and so on.

I have cited this experience because it illustrates the importance of communication. I feel I may have a communication problem here today because the regional planner's perspective is altogether different from what was presented here. Because many of these gentlemen are friends of mine, I'm familiar with some of the excellent science that was prepared, but only as an outsider looking in.

From a planner's point of view, my immediate question has to be, so what? A couple of years ago the Federal Government paid 13 million dollars--maybe more, maybe a little bit less--for a project called MESA, which was supposed to accomplish what Jerry Schubel and our colleagues from the States of New York and Connecticut hope to be able to accomplish for the Long Island Sound. Specifically, the undertaking of a comprehensive scientific program for the New York Bight.

When the MESA Program was virtually completed, they then called in some of us planners--i.e., managers--and said, "We have all of this wonderful science; tell us how you're going to use it." Well, the simple truth was that we couldn't tell them how to use it. We didn't know what they did because they called us in at the tail end.

I now have copies of four bills that are currently before the United States Senate and the House of Representatives on clean water, etc. And they are very optimistic in addressing the very things we've addressed here. That is, the provision of funding for some of the major embayments and sounds of the United States.

So there seems to be support to do what all of you evidently want done; at least in theory, if the Senate and House agree. But the thing I find troublesome is the same thing I found troublesome with the California USGS project and with the MESA project.

Namely, any attempt at "planning" or "planning management" is at the tail end of the process in the later years down the road. In my judgment this is absolutely the wrong way to go. Doing science for science's sake is fine for science, but it often has no relevance whatsoever to planning and management.

Ten years ago Peter Weyl and I wrote a book that was sort of a labor of love. At least it started out that way. I was supposed to do one chapter, and the scientists were supposed to do five chapters. But the scientists disappeared to the winds. (Peter at least did his chapter by long distance from Israel.) But the result was that the book became a planning book rather than a science book.

In the book we tried to address this body of water that we call Long Island Sound: The Urban Sea. In it we addressed the very question that I want to address today, a planner's perspective. Now 10 years later we're still addressing the same question. Let me just read one or two brief paragraphs to give you an idea of what we were concerned with. We said:

> Urbanization on Long Island Sound, as in other suburban coastal zones of the country, is destroying land and water resources. Open spaces that once provided aesthetic enjoyment, wildlife protection, and recreational opportunities are being lost to the homes, schools, factories, highways, commercial centers, and other manifestations of an urban society. This has been the pattern on Long Island Sound in the past decades. It will surely continue if growth is left solely to the workings of the market. What is economically best for the community does not equal maximum economic efficiency in real estate terms.

Then I raised the question that, since government has the responsibility:

> How can government decide what is in the public interest better than the private citizen can? How can government provide for long-term development without ignoring immediate needs? Planning deals with both of these questions.

Today, Peter talked about an information system. This is an absolutely important and integral element in the decision process. But it is not comprehensive planning. What is required for Long Island Sound is comprehensive planning.

Between the years of 1971 and 1975 the Federal Government funded a major (in terms of dollars) study to do planning for Long Island Sound. They picked the New England River Basin Commission, an administrative organization that had absolutely no competence in the marine environment. The net result of those millions of dollars and several years of effort was a non-planned plan. There were several elements that I thought were attractive when they dealt with the aesthetics or cosmetics of the Long Island Sound frontage, but it did not tackle any of the key questions. To this day we do not have a management plan for Long Island Sound.

What can planning offer in terms of these decisions? We don't want the scientists to make the management decisions, the policy decisions or, if you will, the political decisions. Yet, if these decisions are to have merit, they have to be based on the strongest scientific input it is possible to marshal.

Now, we planners make decisions every day of the week, and I suspect that many of them are the wrong decisions. But we don't have the luxury of waiting until all of the answers are in. On Long Island we have tried to integrate into the planning process whatever coastal science can be developed. That is the key.

When I talk about the planning process, I'm talking about something we didn't discuss here today. And that is planning as a decision-making model that looks to the future in order to guide our decision-makers into making rational, or at least more rational, decisions at the present time.

Our approach is this: After we've tentatively identified the goals and inventoried all of our resources, we then have to develop all of the alternatives. After we have the alternatives, we should be able to pick the best alternative, or those combinations that will produce a good alternative, and then develop an implementation program.

That's seemingly a large order. But there's one additional factor that has to be considered. We have talked about the Long Island Sound today as though it exists in isolation. Here is where the regional planner again departs from the scientist. The scientists of the Sound are interested in the physical oceanography, the benthic conditions, the biology, the marine fisheries, etc. The planner is only tangentially interested in what's under the water or the water itself, except as an extension of the land mass. As a planner, I don't believe that Long Island Sound can be considered in terms of a management program unless the comprehensive land use decisions of the State of Connecticut, the two counties of Long Island, the City of New York, and the County of Westchester are part and parcel of that process.

So it's not only the integration of coastal science into this thing called planning, but it's the comprehensive interrelationship of land-use planning with water planning. When we planners look at the Sound, we see a physical entity that's subject to uses, misuses, and abuses. But quite often it's difficult to properly decide what is a misuse or an abuse. What is a very well-defined suitable use for one class of users is absolutely a misuse and abuse to others.

For example, one of the scientists this morning said in regard to dredging that the New England Corps of Engineers has a program, and he's fairly confident that somehow good decisions are made because of the excellent work of the Corps. At least, I think that was his opinion on the subject. Let me offer a slightly counter opinion from someone on the other side of the Sound. We don't view the Corps in New England as such a benign beneficial group because our point of view is slightly different. And maybe we don't have the science and maybe we're wrong. But as resource managers, whenever Connecticut says, "We're going to dredge this river or we're going to dredge that river," we get somewhat paranoid about the suggestion that cost effectiveness mandates that the cheapest possible spoil site is in Long Island Sound. We get paranoid because we receive some of the metals and contaminants that are coming out of those rivers.

Now, we can appreciate that Connecticut does not want to deposit spoil upland. They don't want to contaminate their beautiful heritage, and they don't want to pay the cost. I can understand that. But by the same token, we on the other side of the pond who are not doing such dredging do not want Long Island Sound further degraded. For people who want to dredge the sand and gravel, that's a beneficial use (according to them). When they louse up benthic conditions so that spawning grounds are disturbed, that obviously becomes a misuse; but for a different group of potential beneficiaries.

Boating is another example. In 1975, when we did the book, there were one-quarter of a million private boats on Long Island Sound. Long Island Sound had the dubious distinction of being called "the Times Square of Yachting." Just on the immediate shore area there were more than 100 marinas. For anyone who buys a boat, uses a boat, spends money on both shorelines in restaurants, theaters, etc., this is a marvelous use. But when you look at what kinds of nutrients are being added to Long Island Sound, there are severe management questions of when a use becomes an abuse.

I'd like to submit for your consideration the idea that the combination of science with the regional planning process can provide precisely the kind of management options, alternatives, and recommendations to answer the question that wasn't asked today. That question has to do with a comment that Dr. McHugh made when he cited the fish landings. The question was raised, "Well, if your fishery is so good and you compare so favorably with the Chesapeake, then what's the problem? What are you complaining about?"

The implication is that we have it made. But the real question is not one of geological time. Namely, that siltation indicates that the Long Island Sound is going to be around for ages if not eons. The real question in biological terms is whether the Sound in any danger of death. And if so, how soon? Thus the question of how good the catch is now could be reversed. How much greater could the catch be if in fact we already had in place the proper management and plan?

Mr. Colvin discussed the closings of the grounds on Long Island Sound alone. Dr. McHugh cited the loss of the oyster industry because the seeding grounds on the Connecticut side have been lost. The planner's question is, is it an irretrievable loss? Are there land-use decisions we can make to reverse this process? These are the questions that can only be answered by the combination of planning and hard science.

So I would hope that any detailed program of science would be outlined in advance with consideration given to the question of what this science is supposed to resolve in terms of management. Is it science for science sake? That's fine. But if it's going to be science for management, then let's ask the questions in advance that managers need answers for. Then let's direct that science--whether it's marine fisheries, dredging, sand and gravel mining, the location of marinas, or whatever the case may be--to find the answers that managers need.

Let me end on this one point by quoting the closing paragraph in our book:

> Lest the reader be misled to assume that the discussion of needs and preferred solutions is tantamount to problem-solving, let it be emphasized that the end of this recycle is only the beginning. Adopting a comprehensive management plan and devising a means for implementing it for the Long Island Sound region are still to be achieved. And the selection of development and testing of the administrative agency or agencies required to make a plan operational is yet to be accomplished. Each of these elements is the subject for additional work. The unique feature of the Long Island Sound region is its marine environment. I couldn't conceive of New York, Westchester, Connecticut or Long Island in terms of the quality of life without this priceless, unique, natural resource.

The unique feature of the Long Island Sound region is its marine environment. Few communities have been endowed with such a handsome, but delicate, gift. Well managed, it will continue to serve as its greatest asset. Unmanaged or mismanaged, it will become a costly and dangerous liability.

DR. SCHUBEL: Thank you, Lee. That was an excellent statement. I'm glad we saved you for last. Any questions or comments for Dr. Koppelman before we have our panel discussion?

QUESTION: Do you planners want enforcement power over our work?

DR. KOPPELMAN: I don't want to enforce anything; I'd rather have a cooperative effort. What I'd like to see in some of the current proposals is that planning and management be included in the legislation right at the outset, in the preparation of the scope of work. Even though the science may proceed in terms of chronology of what's done, the shaping of what science is to be undertaken should have planning management input. So at the very least, the scientists will be aware of what the planners see as the problems they have to deal with.

In this fashion I think both will benefit. For example, we very fleetingly talked about runoff as a problem. Thanks to EPA, my office just completed a multimillion-dollar runoff study. We think we have some answers. We stopped at the shoreline. What's the interaction for what we developed with the Long Island Sound? I can't tell you, but it should be plugged in. And the only way it can be plugged in is if the management end of the program is brought in right at the onset of any Federal effort.

DR. CAHN: Lee, didn't the New England Rivers Basin Commission bring the planners in right at the beginning? Yet you ended up with what you call a disaster. You had the planning and the management and you had the science.

DR. KOPPELMAN: No, you didn't have the science. That's the problem. That was the reversal. What happened was that the New England River Basins came in, and the end product that came out of this work was sort of a potpourri. There were a number of problems. First of all, we had a lot of discrete jurisdictions in this effort. Although the New England River Basins started the effort, New York had "a representative" from New York State Department of Environmental Conservation. It was never really a Long Island joint effort. The scope of work, the project, etc., was set forth on the Connecticut side of the pond. When it came to some of the other information that had to go in, it just was not there. Whatever science existed, they tried to plug in. But if you look at the series of reports that came out of the project, there is nothing that one could call a comprehensive plan.

I think the Heritage Statement, which identified potential parks, was a beautiful piece of work. I think the piece of work that the landscape architect planner did in his book on cities by rivers was a valuable, again, aesthetic contribution. But in terms of a management program, a hard input as to where we go from here and how do we create a management entity for this thing called a Sound, those issues escaped the effort. That's what I think was unfortunate.

What I'm suggesting here is not primacy of science over planning or the reverse, but an absolute harmonious interrelationship, so that both move to the same end objective. And that's what has been lacking thus far, at least from my personal, biased point of view.

PANEL DISCUSSION

The afternoon panel discussion included the following participants:

- E.J. Carpenter
  Professor, Marine Sciences Research Center
  State University of New York

- G.C. Colvin
  Director of Marine Resources
  New York State Environmental Conservation Department

- M.S. Connor
  Coordinator, Long Island Sound Estuarine Study
  EPA Region I

- L.K. Koppelman
  Executive Director
  Long Island Regional Planning Board

- J.L. McHugh
  Professor Emeritus, Marine Sciences Research Center
  State University of New York

- J. Pearce
  Director, Estuarine Programs Office
  National Marine Fisheries Service
  National Oceanic and Atmospheric Administration

- D. Rhoads
  Professor, Department of Geology and Geophysics
  Yale University

- J.R. Schubel
  Professor, Marine Sciences Research Center
  State University of New York

- C. Sindermann
  Director of the Conservation Utilization Division
  Northeast Fisheries Center
  National Marine Fisheries Service

- E.M. Smith
  Assistant Director, Bureau of Fisheries
  Connecticut Department of Environmental Protection

- B.L. Welsh
  Professor of Marine Sciences
  University of Connecticut

- P.K. Weyl
  Professor, Marine Sciences Research Center
  State University of New York

- R.E. Wilson
  Associate Professor, Marine Sciences Research Center
  State University of New York

DR. SCHUBEL: Mike, I wonder if we could start with you? A lot of people have asked questions about the Long Island Sound Study, and you may want to say something about that. You might also discuss what you consider to be some of the research priorities for Long Island Sound.

DR. CONNOR: Lee Koppelman said more eloquently much of what I have to say. We are familiar with the work that he talked about and at this stage of the Long Island Sound Study, we are trying to get together the managers and the planners who are most concerned with the issues in the Sound. In addition, we are trying to put together a list of management needs for the Sound.

In these efforts, the question of value of information comes up. No information comes free, and with our limited budget we have to decide which sorts of information we think we can use, which sorts of information will actually affect decisions that we'll make on the Sound. In some cases the cost of getting that information is greater than its impact on our decisions.

You have heard a lot of concerns from the state fisheries people about the question of toxic contamination. Toxic contamination certainly is an issue of concern in the Long Island Sound Study. There's not very much organic geochemistry done on Long Island Sound. Neither the University of Connecticut staff nor the Stony Brook staff has much expertise in that area. I think it would be useful to include some organic geochemists to help frame future research plans in the Sound.

Barbara Welsh commented on the interaction between anoxic and low-oxygen concentrations and toxic concentrations. I think it's an interesting point that may be worth following up in the longer term future.

During the presentations, I was struck by the Stony Brook data from cruises during the summer. Even with high temperature stratification, the dissolved oxygen concentrations on the bottom didn't go down that low, just to about 3 parts per million (ppm). I think it's important to inventory other available data on oxygen from the National Marine Fisheries Service and their cruises to determine whether or not eutrophication and resulting hypoxia is a problem in the Sound and is, in fact, affecting the resources.

Another issue that needs more exploration is whether oxygen depletion is due to biological oxygen demand (BOD) inputs alone or whether nutrients play a role. Some data were presented on loadings of organic carbon, but the emphasis was on nutrient inputs that could account for the production through photosynthesis by phytoplankton and macrophytes of perhaps hundreds of grams of carbon per square meter.

Whitney Tilt at Yale has a paper in which he looks at BOD loads to the Sound. In the western Sound the value is 1700 pounds per square mile per day, which converts to an annual figure of almost 100 grams carbon per square meter. So BOD loads are of the same order as phytoplankton-produced carbon. Thus if we are concerned about eutrophication, we may want to consider both carbonaceous and nutrient sources.

As far as long-term goals, I think in the end we probably want to be able to make a waste load allocation model for the whole Sound and the western Sound in particular. The model would give us an idea of what amounts of waste water can be discharged without impacting water-related uses and the living marine resources in those areas.

To make these sorts of management decisions, though, returns us to the issue of the value of information. Much of our regulation is geared to nearfield effects of point source discharges. How much additional value is there in considering farfield impacts through a Sound-wide model? Perhaps, managing to simply protect the nearfield water quality will be sufficient to ensure that we protect the health of the Sound as a whole.

DR. SINDERMANN: Through the good offices of Dr. Pearce I've been involved a little bit in the Chesapeake Bay Program, particularly the emerging National Oceanic and Atmospheric Administration (NOAA) component of it. I was struck today by one fairly basic difference between the direction here in Long Island Sound and the direction in the Chesapeake Bay.

Down there, you'll recall, Chesapeake Bay has been subjected to an intensive five-year study by EPA. Unfortunately, in having to make decisions about what priorities to follow in research, living resources seem to have gotten fairly short shrift. And probably at the time this seemed like a reasonable decision.

Fortunately, I think both we and the Environmental Protection Agency (EPA) have learned from that. I see from the discussion today by Gordon Colvin and Eric Smith that we are not going to underestimate the significance of attention to living resources in any integrated program that we may develop. And that's entirely reasonable. Because in the end any cleanup campaign is going to require documentation in terms of improved conditions for resources.

In looking at what is going on in Long Island Sound, I was interested to see that Connecticut already had a fairly extensive marine resource survey that has been integrated to some extent with the east coast surveys of the National Marine Fisheries Service. This, I think, is going to be a key for this program in the Sound. At the Northeast Fisheries Center, for example, we have habitually bypassed Long Island Sound, except for several stations in the Sound, in our survey work. But mostly we have bypassed it as the business of the states. Now I think we have a chance to integrate what we're doing--all the surveys and objectives that others have been involved with over the years--not only with the Chesapeake Bay Program and the Delaware Bay Program, but with the Long Island Sound Program.

DR. PEARCE: I won't try to deal with exactly what NOAA is doing in the Sound, but in response to what Dr. Koppelman said earlier this afternoon, I do want to emphasize that it is true that management has to have better coordination with the science. Throughout the world, whether you look at some of these matters on a national or an international or a regional level, there are a number of issues that have been defined in recent months and years that seem to be common to all estuaries.

The International Council for the Exploration of the Seas; the Marine Environmental Quality Committee in Washington, DC, a NOAA level committee; and our Regional Action Plan have all tried to identify the major issues of concern. It is interesting that almost invariably you come up with something called eutrophication or nutrient enrichment and dissolved oxygen declines. You will also find that people generally identify an organic contaminant problem, and that many people would play down the importance of toxic metals, although that might not be the completely safe thing to do.

These are two major issues. Another one has to do with pathogens. Some years ago my mentor, Dr. Sindermann, used to say, "All environmental ills are really a form of disease; whether it's a physiologic anomaly or a genetic anomaly, it's a disease." And in one of the most recent issues of Science you'll find an article about disease in finfish from Boston Harbor. If you look at some other recent reports and publications, they are concerned with disease in fish in the Hylebos waterways and Commencement Bay in Puget Sound.

Another major issue has to do with pathogens and fish disease in marine habitat. And one could also say the diseases of shellfish.

A fifth issue that invariably comes up has to do with physical degradation. Planners, in their wisdom--and this is not a biting remark--planners tend to want to develop the coast; for example, Westways or the Gold Coast from Bayonne to Weehauken. These massive endeavors often compromise estuarine habitat in a very real way. Unfortunately, it's not a way that can be quantified to the satisfaction of the people who have to make a management decision.

So there are several issues, and I think we really waste our time to try to further define these issues that have been recorded. And as I said earlier, the important thing nowadays is to begin to put in place criteria or standards for use in judging whether particular activities are favorable or unfavorable; whether they have a high impact. We should begin to quantify those things that affect the environment, and then establish criteria and standards, whether it has to do with a particular process or a particular contaminant.

So I think this is where science, scientists, and managers should be working more closely. Agencies should be working more closely with, as you just heard Dr. Sindermann say, the Federal Government, and the State governments should be working together more closely.

DR. SCHUBEL: Thank you, Jack. Now I'd like to see if anyone else on the panel has anything else that he or she would like to say. After we've done that, we'll open up for questions from the audience.

DR. SMITH: I have a question from this morning. And I have to confess it's probably just a subject that I don't understand, so it may merely be a problem of interpretation. Resource managers over the last 10 or 15 years have basically been ingrained with the idea that the Sound is getting cleaner and more productive, and that this is a result of the Clean Water Act and various activities for abatement of pollution.

Now I get the feeling that we are not as well off as we thought we were. I wonder, is it a measurement phenomenon that the things of concern in the scientific community are things that previously were not measurable, or do we just have new knowledge, or are things really getting worse instead of better?

DR. SCHUBEL: Who would like to respond to that? Barbara?

DR. WELSH: I was concerned because there seems to be some misinterpretation, in that because everything hasn't gone to hell in a handbasket in Long Island Sound, then maybe it's in pretty good shape and we shouldn't look at it.

I think the scientists' concern is that we have seen some things happening to the south of us. We have a situation that has now gotten out of control. We have learned some things from that situation. Now we want to call attention to what we know about Long Island Sound and to some analogies that we see to earlier events in Chesapeake Bay. We hope that the coupling of EPA interests and mission, which often goes after the brush fires of problems that have occurred, and NOAA's mission, which is to look to our resources and keep disasters from occurring, will allow us to use our best scientific wisdom to identify points of concern so we can put together patterns in the environment.

So I think it's the scientists' concern that we do see a pattern here, one of low oxygen. We could have identified an entire shopping list today. But what we tried to do was to show the patterns and narrow the focus to some situations that we thought might be of prime concern. Some of us have tried to take our scientific patterns and point out places that we think we might look for analogies and feedback from you, the planners.

DR. SMITH: That's an excellent point, and that's essentially what I was looking for. I would suggest that in discussions like today's or in future discussions, points such as this be made during the presentation so that it doesn't simply look like, "Well, here's a problem, but there's no history to it." In other words, if water quality was worse 15 years ago, why did we not have the same problems that we now state are of very serious concern?

A little historical perspective in this type of a presentation would do a lot to help the public understand that there is now a problem.

DR. RHOADS: You asked whether or not the issue had something to do with measurement problems. I'd like to address that question and Dr. Connor's comments as well. I don't believe one can use any of the existing dissolved oxygen values to critically assess the very near boundary layer conditions with respect to dissolved oxygen. And that's been measured; we now know how to address that.

DR. CONNOR: Just to follow up on that, we do have some knowledge of the loads in relation to this Clean Water Act question. In fact, many of the treatment plants have converted from primary to secondary treatment, with the result that loads of BOD to the Sound have gone down by almost a factor of 2. That's an indication that at least some of the loads to the Sound are decreasing.

DR. RHOADS: I wouldn't dispute that. The loading rate may have decreased, but that doesn't address the problem of the ultimate sink where that would accumulate. Essentially the Chesapeake Bay problem.

DR. SCHUBEL: Phyllis, you had a question?

DR. CAHN: Yes. Based on what you already know about the physical processes in Chesapeake Bay, and based on the little bit you already know about these processes in Long Island Sound, can you predict what is really going to happen as far as this low dissolved oxygen problem is concerned? I realize that the urbanization patterns are quite different on Long Island and in

Connecticut than they are in the Chesapeake area, but have you been able to compare the two and perhaps help the planners in doing something for Long Island Sound?

DR. SCHUBEL: Let me make a comment, and then I'll ask if others want to say anything about it.

The processes that lead to the anoxic zone in the Chesapeake Bay are really quite different from the anoxic problem in western Long Island Sound. I think that with an appropriate kind of study, one could learn a great deal about the differences and the similarities in those two systems. That really has not been done.

Bob, do you want to say anything?

DR. WILSON: I can't answer your question exactly, but some simple oxygen modeling would help in the interpretation of the existing data, particularly the flow patterns.

DR. SCHUBEL: Don, do you want to comment on that?

DR. RHOADS: Well, many of the scientists who are here today, from both New York and Connecticut, have anticipated this meeting, and focused our attention on eutrophication. We have put together a proposal, which will be completed next week, that starts with a skeleton model, a primitive model, to the one developed by Officer et al. for the Chesapeake. That proposal defines the initial measurements that would be made to see if they are relevant to Long Island Sound. We think that some of them are relevant and some of them aren't, but we need a starting point.

Secondly, we have tried to anticipate some of the management needs from such a study, and of course we need input from managers. We have alluded to one such management question today, and that is, if there is a problem with dissolved oxygen, what is the potential of that problem for compromising fisheries?

The design model or the goal would be results that would suggest to what degree this problem can be mitigated by doing things to the input. So we've attempted to put the modeling up front, and the management question up front, to come out at the end with something that will be useful.

DR. D'ELIA: I was intrigued by the suggestion that the BOD problems are primary BOD problems, that is, directly from the sewage treatment plants' organic carbon loads; and not secondary BOD problems, that is, related to the stimulation by nutrients of algal growth. I suspect the calculations are wrong. I can't pull the figures out of my head, but it seems strange that the sewage treatment plant BOD would be exceeding that of secondary producers. Could you shed some more light on that?

DR. CONNOR: If you will remember Dr. Weyl's talk, he showed that 1 percent of water in the western Sound was sewage, basically diluted sewage. That's an incredibly large input.

DR. WEYL: It's probably even bigger because that value considers just the input in the East River. So it's the lower limit.

DR. D'ELIA: Well, is it not something like 10 mg? What importance do you place on the potential for nutrient stimulation in the growth of phytoplankton?

DR. SCHUBEL: Ed, could you comment on that at all?

DR. CARPENTER: Nutrient input from sewage treatment plants can certainly stimulate primary production. Just from gross observations, I think it's obvious that it has. But without any sewage treatment plants at all, primary production might be 250 to 300 grams carbon per square meter per year in western Long Island Sound. Even under the best conditions, primary production through the year, I doubt that it could exceed 1000. That's the primary production rate for a rain forest or a sugar cane field. So, really, I doubt that it would be much more than the double or triple the rate of primary production. I sort of suspect the carbon loading numbers--they seem awfully high. I'd like to look at those.

DR. CONNOR: I think the answer to your question, Chris, is that we have to figure out what the loadings are.

DR. THOMAS: New York Harbor, for one, is now close to 800 grams carbon per square meter. So I guess there is the ultimate potential to get a lot more than is now occurring in Long Island Sound.

Secondly, I'm starting to hear some mixed signals. The loadings seem to be decreasing, and yet the panel seems to be concerned about low dissolved oxygen. Unless I missed it today, I did not see any anoxia--no oxygen. It didn't look like the values were hypoxic. Did I miss something? Does anoxia occur in Long Island Sound? And what is the real trend: Is oxygen truly going down, yet loadings are also going down? Can the panel argue over this a little bit?

DR. CARPENTER: First of all, I think loadings of carbon particulate matter are going down as there's more and more primary and secondary treatment of sewage entering the Sound. But there isn't any tertiary treatment, so as the population increases, the nitrogen and phosphorous loadings are increasing, as you saw in that one slide that I showed.

Also, from the data set that I had of the 1977 thermal stratifications in Long Island Sound, the oxygen content got down to 1.1 mg/liter, which is pretty low. And if thermal stratification were to continue--if the winds didn't pick up, if the water didn't start to cool--it certainly would have gone lower.

The point I'm trying to bring out here is how dependent anoxia is on weather conditions. It's a fickle thing, you know, as to whether the wind is coming from one direction or another and what the temperatures are.

DR. THOMAS: Do you see this increasing, though; in other words, becoming more frequent over a larger area?

DR. CARPENTER: There are no data. As a matter of fact, the Interstate Sanitation Commission stopped monitoring oxygen at the Throgs Neck Bridge, one of the few cases in which there was monitoring of oxygen.

DR. WEYL: One of the real problems, particularly in the western end of the Sound, is the tremendous space-time variation. And it depends very critically on the weather. I can make measurements two days apart and get quite different values. To get meaningful numbers to show trends for 10 years is extremely difficult. Somehow you have to average out variability. You have a strong tidal signal. You have a very strong signal depending upon the weather. And then the water itself isn't well mixed; you get a very patchy water distribution. A very large effort would be needed in order to come up with a statistically significant answer to whether it's gotten better or worse in the last 20 years.

DR. WELSH: Let me broaden our perspective on this just a little bit. We concentrated on the western part of the Sound because I think that when you get incipient anoxia in deep waters, it's really pretty serious.

However, the phytoplankton in the smaller estuaries along the Connecticut coast that I'm familiar with and at Throg's Neck have shifted from the typical winter, spring, and summer bloom, the temperate water, to a summertime bloom. You have a figure showing that shift, and I have some information on it in the small estuaries.

In addition, many of the small estuaries along the Connecticut coast have gone anoxic, and are regularly going anoxic in the summertime to the point that they remain anoxic. Even the daytime tidal flushing can't purge that. One example is that the entire zone of passage of the Connecticut River becomes anoxic on the bottom in the summertime, and bottom communities are wiped out. There are several other coastal estuaries that we have good data on now showing anoxic periods at least at night for some of them and others becoming anoxic by June and remaining that way through August. The time period of anoxia is increasing. Where before it might have been a condition that would occur in mid-July, August or September, it's now seen in June and extends through October in some of these small systems.

Now, the small systems are only 5 percent, maybe, of the area of Long Island Sound. But let's not be misled by simple physical proportions, because we've heard about the importance of these small systems to shellfisheries, which is one of the major fisheries in Long Island Sound. Although these shellfish are quite resistant to low oxygen, they don't grow well under hypoxic conditions. Given a long enough period of hypoxia, they die.

On top of that, larval fish are not nearly as resilient to low oxygen conditions. So although I have become concerned with the deep water anoxia, I'm very disturbed also with these small estuaries along the Connecticut coastline because of their relative importance.

DR. SCHUBEL: Don, do you want to add anything to that?

DR. RHOADS: Yes. One reason I mentioned the importance of the sapropels--these black iron monosulfite muds on the bottom--was the direct point that Peter raised. The system is so dynamic that to measure the change from year to year in dissolved oxygen as measured in the water column would take more money than we have. It's not practical at all.

Given that kind of variability, what you need is a low-pass filter and an integrator, and that's the sediment. I suggest that a very sensitive index of the waxing and waning of this condition would be the map of where the sapropels terminate, whatever isobath that might be. Follow the edge of those sapropels. If they're encroaching upwards into shallow water, it's getting worse. If they're receding, it's getting better.

DR. SCHUBEL: Another question? Yes, Harold?

HAROLD: Dr. Welsh, you said that the number of embayments that are becoming anoxic is increasing. It was also pointed out that the amount of BOD from treatment plants is decreasing. It was also said that secondary BOD from algal blooms is not a factor. To what do you attribute the increasing number of embayments that are becoming anoxic?

DR. WELSH: I'm glad you asked that question. A major part of the story is benthic macrophytes along the coastal waters of Long Island Sound. Macrophytes are macroalgae rather than vascular plants. Macroalgae are not sensitive to the light limitations that affect phytoplankton blooms and will cut off submerged aquatic vegetation in Chesapeake Bay. They simply thrive. You may change from one type of macroalge to another, for example, from a green to a red to a brown or vice versa, because they have a variety of pigments that are able to take greater and lesser amounts of light.

So macroalgae are qualified to take advantage of this situation and thrive, even with heavy phytoplankton blooms. And that's where we see the heavy growth in these estuaries. Macroalgae can cause heat problems because they have a very fast decomposition time. Their rate of decomposition is much faster than dead aquatic vascular plants, so they cause a very heavy and immediate load on the oxygen demand in the system.

HAROLD: Do you have any measurements to show whether the macroalgae are the problem?

DR. WELSH: Yes. We have some publications on that, in fact.

DR. SCHUBEL: Other questions from the audience? Dr. Barber?

DR. BARBER: I would like to draw you away from the oxygen situation. I understand that shellfish beds are being closed. I would like to hear someone talk about why they're being closed; the measurements or the standards that are used to close those beds.

MR. COLVIN: The decisions that are the subject of certification or lack of certification or partial certification of shellfish growing waters are undertaken by states. Each state adopts standards. The standards are either fecal coliform or total coliform or, as in New York, a combination of the two, based on the Manual of Operations of the National Shellfish Sanitation Program, which was adopted by the Food and Drug Administration in consultation with the states. The program has now been changed slightly, and a new organization, the Interstate Shellfish Sanitation Conference, has been formed in which the states and industry have a somewhat greater role than they had under the old program.

There are two different standards applied in each case. There is a median value and a value not to be exceeded in more than 10 percent of the samples. That has a couple of effects. The 10 percent value gives a great deal of importance to events such as rainfall, which occur infrequently. Generally speaking, bathing water standards are not done that way. They usually depend on overall median or mean value.

In shellfish areas we find that many times the closures are predominantly caused by urban runoff, whether or not it's combined with sanitary sewage. Hence, the closures I showed you out in eastern Long Island, in Mattituck Creek and other places in which there's very little direct sanitary contamination, are largely due to street runoff. In contrast, in bathing areas, it's not so likely to occur.

In New York, at least, the primary agencies and entities that look at bathing water standards are county and city health departments with delegated authority and funding from the state. In addition, there are some interagency relationships between our shellfish sanitation sampling and the town health departments to try to come up with comparable and cooperative data collection.

The point is that this state program is based on a set of Federal guidelines, but there are no Federal regulations involved. I'll give you an example. About 17 percent of New York's total shellfish growing waters are closed. That includes the Atlantic Ocean, where we really have very little of those problems, except for just outside of New York Harbor. In the State of Maryland, the last figure I know of is 3 percent. Given the rather highly publicized problems of the Chesapeake, I find it hard to believe that we're both operating exactly the same kinds of decision-making models from the same Federal guidelines. I've got to believe that there's some differences in the way those guidelines are applied.

Some parts of the guidelines that are open to interpretation. The guidance includes terms like "ordinarily not more than 10 percent shall exceed a certain number," and "the samples shall be taken under the worst hydrographic and pollution-causing conditions." Whatever that means. There is a need, I believe, to firm up that guidance to achieve a greater amount of standardization in the application of those guidelines from state to state. That is a mission of the Interstate Shellfish Finfish Conference. One of their jobs is to amend those procedures and to make them more specific.

This is not just an issue in the general decision whether to certify or not certify. All the states have programs in place to use the shellfish from uncertified waters under different conditions. One of the things that many of us have done to use shellfish in waters principally affected by runoff is to operate conditional certification programs whereby after a certain amount of time of dry weather, the area can be opened until such time as it rains or it rains so much. The decisions that go into structuring such a program also differ from state to state. Rhode Island's program, for example, is more liberal than New York's program. And this causes quite a bit of controversy between the two states.

Similarly, there are other kinds of programs that provide conditions under which shellfish can be harvested and subject to artificial depuration or, as Eric pointed out, relayed to clean grounds for natural depuration. All of these things are written up in the national guidelines with some room for interpretation.

DR. SCHUBEL: Another question? Jim?

DR. THOMAS: Yes. In one of our earlier seminars on Delaware Bay, we heard a statement that Delaware Bay is actually cleaner now than it was previously. About a month ago at a meeting called Wetlands of the Chesapeake, we heard a report from Virginia Carter stating that the Potomac River is cleaner now than it was 20 or 25 years ago.

For the record, because we're taking this down today, is it the consensus of this panel that Long Island Sound is being degraded with time? In other words, is there a downward trend with time? Can you make a statement that it is deteriorating in the western part and along the edges, the periphery? Is it a consensus, or do some of you feel that there are areas of the Sound that are actually improving?

DR. SCHUBEL: I don't think we have the data to demonstrate that it has gotten worse. Clearly there are very serious problems in western Long Island Sound and in many of the embayments. Whether they're worse now than they were 10 years ago, I'm not sure we have the information to answer that question. It depends on how you define getting better or worse. Is Chesapeake Bay getting better or worse now than it was 10 years ago? I think you'll have to identify what criteria you used to answer that question. If you used landings of fish and so on, then it's clearly worse. But I suspect there are other measurements that one could use that would not show the same level of degradation.

Lee, do you want to say something on that?

DR. KOPPELMAN: In our studies, we found a decrease in the amount of contamination as we moved eastward from the Queens- Nassau line to the north shore line. Until we got to Huntington Harbor, the impact the pollution made in the East River was virtually nil. However, in the 10-year period since we started the study, background conditions would not indicate any improvement. I suspect that if and when the State of New York upgrades their treatment facilities, particularly on the East River or the lower Bight, we should have some marked improvement because we've traced it directly into that area.

QUESTION: One comment I wanted to make was that one of our tests for Chesapeake Bay was the compilation of a historical data base, which showed a trend analysis for dissolved oxygen, increasing both spatially and temporally. I was wondering if something similar could be done for Long Island Sound; collecting the historical data, and also showing that over a given space and time there has been a trend downward?

DR. SCHUBEL: Well, we'll let Mike comment on that. My quick response is that in Long Island Sound we do not have the rich data base that exists on Chesapeake Bay. And even there, what you can do with the data base on Chesapeake Bay is certainly severely limited. Mike?

DR. CONNOR: That's one of the first issues for the Long Island Sound Study to resolve. There is a large segment of opinion that the existing data base is insufficient to be very useful.

DR. PEARCE: As was noted earlier, a seminar workshop on the use of historical data will be coming up in a few months. It is worth noting that dissolved oxygen data are some of the few data that you can actually have some confidence in going back several decades. In other words, the techniques have been around.

Recently Martin-Marietta, under a contract with NOAA, has developed a report that, although sometimes controversial, nevertheless tried to look at those environmental changes on which we had some data and to correlate habitat changes, environmental changes, with changes in fish stocks.

Some fishery scientists would say, "Well, this is a really primitive type of analysis," and other people might say that the techniques available 50 years ago to measure oxygen might not be as good as now. But the fact is that they found certain correlations, which seem to be quite interesting. That is, fish probably did begin to change when there's evidence of decline of dissolved oxygen or there's increased dredging activities that may affect the fish stocks.

I think one of the more important things is that many small estuaries regarded as pristine may not be as untouched as they seem. People go and stand on the shores of the Maine coastline and look at their own little local habitat, and they think what a nice place it is; it's all clean and it doesn't smell and there's no fecal material floating around. Yet when we take samples from Casco Bay or Penobscott Bay, we're beginning to find contaminant loadings similar to what you find in western Long Island Sound.

Sewage treatment plants have improved the quality of the water coming out, but population has increased dramatically, for instance, in Monmouth County, New Jersey, from 100,000 people 45 to 50 years ago to 500,000 people today. Even though they are being better serviced by the communities' sewage treatment, the sheer presence of that number of people and their activity emphasizes the "Pogo" effect: "We have met the enemy, and he is us."

QUESTION: In lieu of a rich historical data base, is it possible to suggest what a healthy system would look like?

DR. RHOADS: We suggested one handle on this is the amount of labile organic mater as it changes through time going down a sediment core. This is a routine, standard carbon to pyrite sulfur ratio. The more pyrite sulfur you get, the more organically loaded it was and the more likely that you had low oxygen conditions right above the interface. Combined with lead-210 data to date the core, you can approach this problem indirectly.

QUESTION: Do we know enough about the natural variability of the system that we can determine the impact of anthropogenic inputs today? Are we looking enough at the natural processes associated with these systems?

DR. RHOADS: With respect to the means of measurements I just mentioned, yes, we do in the central Sound, both in pristine and contaminated systems.

DR. SCHUBEL: I think it is true, though, that certainly we don't have a very good understanding of the basic geological, physical, biological, and chemical processes that characterize Long Island Sound. There are exceptions to that, but our fundamental knowledge is not as good as it should be.

QUESTION: Could you give an indication of the extent of oxygen depletion in comparison to other places? If you look at the New York Bight Apex, typical organic concentrations are 10 grams carbon per square meter. Further off the shelf it's 1-5 gC/m^2. In that anoxic episode in 1976 it went up to about 100. In other areas you have concentrations on the order of 25-50 gC/m^2 and you get anoxic conditions. I would just suggest looking at some of the data to try to get a handle on a particular carbon gradient from west to east. That's the first step to a very simple box model approach.

DR. CARPENTER: We know very little about carbon cycling in the central Sound anyway. And as I mentioned a few times, there isn't a very good historical data base.

DR. SCHUBEL: Chris, you get the last question.

DR. D'ELIA: It's in regard to habitat. We may not know very much about water quality changes, but I think it's fairly safe to assume that the habitat has changed enormously. I grew up in Fairfield County, and I know that the varieties of habitats are no longer there. Would you agree with that?

MR. SMITH: I tried to allude to that briefly in talking about developments and using Fairfield County as an example. There has been extensive loss of wetlands and tidal marshes in Connecticut over the last 50 years. That type of impact can be documented. Its effects on the resource abundance of species is not as easily quantified, and we have to make an intuitive judgment that without the nursery habitat or that particular form of nutrient input, there is less of whatever is needed for aquatic life. But, again, to quantify it is impossible.

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