U.S. ENVIRONMENTAL PROTECTION AGENCY

NEW YORK BIGHT WATER QUALITY

SUMMER OF 1987

ENVIRONMENTAL SERVICES DIVISION
REGION 2
NEW YORK, NEW YORK 10278

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ABSTRACT

The purpose of this report is to disseminate technical information gathered by the U.S. Environmental Protection Agency (EPA), Region 2, during the 1987 New York Bight Water Quality Monitoring Program. The monitoring program was conducted using the EPA helicopter for water quality sample collection. During the period from May 18 to October 26, 1987, approximately 140 stations were sampled each week, weather permitting. The Bight sampling program consisted of five separate sampling networks. Sampling was conducted 5 days a week and extended to 6 days a week in July and August.

Bacteriological data indicated that fecal coliform densities at the beaches along both the New Jersey and Long Island coasts were well within the acceptable Federal limits for primary contact recreation (200 fecal coliforms/100ml). A total of 542 samples were collected for fecal coliform and enterococcus analysis along the New Jersey coast. Except for four occasions, fecal coliform densities along the New Jersey coast were all below the New Jersey water quality standard of 50 fecal coliforms/100ml. A total of 310 samples were collected for fecal coliform and enterococcus analysis along the Long Island coast. The highest density recorded was only 38 fecal coliforms/100ml. Enterococcus densities exceeded EPA's criterion of 35 enterococci/100ml only three times during the summer along the New Jersey coast, and only once along the Long Island coast.

Dissolved oxygen concentrations were excellent along the New Jersey perpendiculars, the Long Island perpendiculars and in the New York Bight Apex. Dissolved oxygen levels in 1987 were higher than in any previous year, since our intensive New York Bight monitoring program began in 1977.

The average dissolved oxygen level in the Bight Apex and along the coasts of New Jersey and Long Island did not fall below 5 mg/l. This is in sharp contrast to the summer of 1985, when in mid to late summer approximately 1600 square miles of ocean bottom off New Jersey were plagued with low dissolved oxygen concentrations for extended periods of time.

During the summer, phytoplankton blooms were observed over extensive areas (Appendix A). At some point during the summer, most beaches along New Jersey were affected by blooms of short duration. Algal blooms of longer duration occurred in the intercoastal bays of New Jersey and Long Island. A major bloom caused by a brown alga, Aureococcus anorexefferens, persisted throughout most of the summer in many of the bays of western Long Island (Flanders Bay, Great Peconic Bay, Shinnecock Bay, Moriches Bay, and the western portion of Great South Bay). Red and green algal blooms occurred to a lesser degree in many of the bays and coastal beaches in New Jersey. Red algal blooms were predominant in Raritan and Sandy Hook Bays. The green tide, which occurred along the southern New Jersey coast in 1984 and 1985, did not recur in 1987. The 1984 and 1985 blooms were caused by the organism Gyrodinium aureolum.

While the summer of 1987 was the best in terms of bacteriological and dissolved oxygen water quality (since EPA has been monitoring the near coastal waters), it was not uneventful. The summer began with a sewage related wash-up on the beaches of northern New Jersey in late May. This was attributed to sewage sludge digestor material from an unknown source, possibily the sewage sludge dump site or a shore municipality sewage treatment facility. An estimated 40 percent of the bottlenose dolphin population from Maine to Florida died from an apparent respiratory disease from which they are normally immune. Floating garbage, including; paper, bottles, cans, all types of plastics, wood, household garbage and medical waste, washed up on New Jersey beaches on several occasions. The most notable incident was a 50-mile long slick of garbage that washed up onto central and southern New Jersey beaches in mid-August. Reports of floating garbage, many substantiated and many of which could not be verified, were a favorite topic of the news media, environmental groups and politicians. EPA investigated the problem during the winter months (November 1987 through January 1988). The findings are presented in a separate report entitled "Floatables Investigation", which is available upon request.

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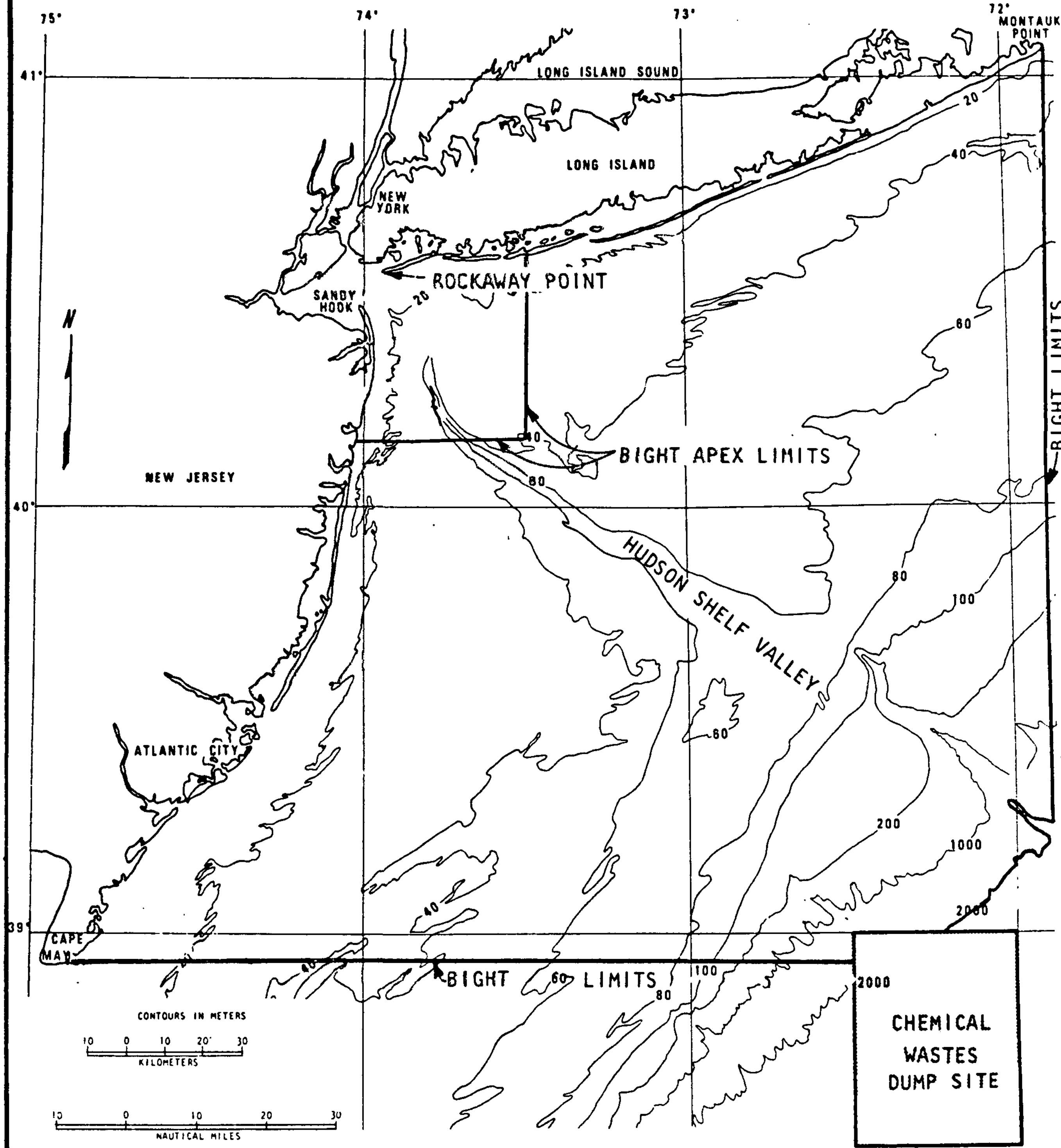
I. INTRODUCTION

The U.S. Environmental Protection Agency has prepared this report to disseminate environmental data for the New York Bight Apex and the shorelines of New York and New Jersey. The New York Bight is an area of ocean bounded on the northwest by Sandy Hook, the northeast by Montauk Point, the southeast by the 2000 meter contour line, and the southwest by Cape May. Figure 1 shows the limits of the New York Bight. The New York Bight Apex, which contains the sewage sludge, dredged material, acid waste, and cellar dirt disposal sites, is shown in Figure 2.

This report is the fourteenth in a series and reflects the monitoring period between May 18, 1987 and October 26, 1987. The New York Bight monitoring program is EPA's response to its mandated responsibilities as defined under the Marine Protection, Research and Sanctuaries Act of 1972, the Water Pollution Control Act Amendments of 1972 and 1977, and the Water Quality Act of 1987.

Since its initiation in 1974, the New York Bight ocean monitoring program has been modified several times to be more responsive to the needs of the general public, the states, the counties, and EPA; and to concentrate on specific areas of concern during the critical summer period. Most of these changes occurred after the summer of 1976, when anoxic conditions caused a fishkill in the Bight and an unusually heavy wash-up of debris occurred on Long Island beaches. It was clear that summer conditions in the Bight called for more intensive monitoring in order to predict environmental crises, to investigate the origins of these crises, and to direct any decisions regarding protection of the Bight's water quality.



THE NEW YORK BIGHT

Figure 1

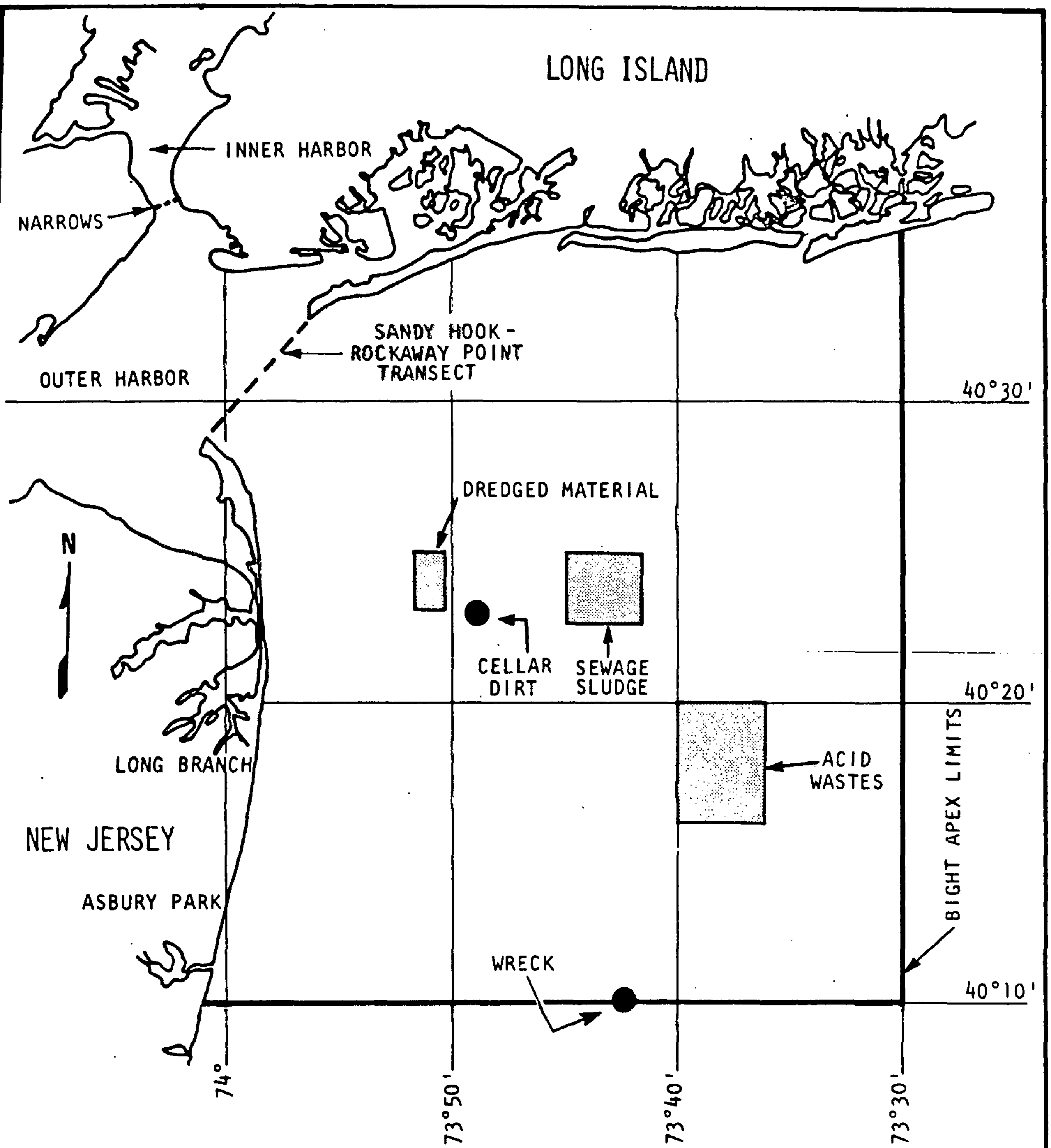
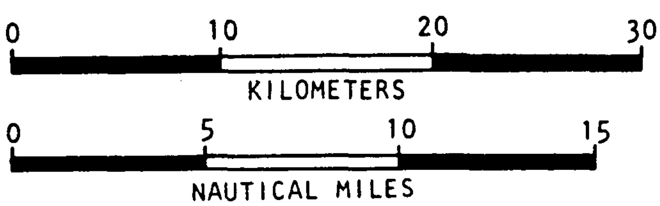


Figure 2

BIGHT APEX AND EXISTING DUMP SITES



In recent years, monitoring has been expanded to include analyses of Bight sediments for heavy metals and organics; collection of benthic organisms for species diversity and number; and analyses of water in the sewage sludge disposal site area for viruses and pathogens. The sediment and benthic organism samplings were conducted from EPA's ocean survey vessels "Anderson" and "Clean Waters". These data will be presented in separate reports. Ongoing revisions to the program are intended to improve the EPA's ability to track pollution sources and to protect New York Bight water quality.

In 1986 the monitoring program was revised to intensify sampling activities along the southern New Jersey beaches. During mid to late summer in 1985, beaches along the southern New Jersey coast were affected by green algal blooms, causing green tide, and high bacterial counts which resulted in beach closings. To improve monitoring coverage, four additional beach stations between Long Beach Island and Wildwood were sampled weekly for phytoplankton and nutrients. In addition, bacteria samples were collected weekly rather than bimonthly along the southern New Jersey beaches. These revisions were continued in 1987. Also, in 1987, four additional stations, between Atlantic City and Strathmere out to a distance of nine miles offshore, were sampled for phytoplankton and nutrients. Phytoplankton and nutrient samples were collected at all Long Island beach stations and Long Island perpendicular stations for the first time in 1987.

II. SAMPLE COLLECTION PROGRAM

During the period of May 1987 through October 1987, water quality monitoring was carried out primarily using the EPA Huey helicopter. Under the established protocol, sampling normally occurred 5 days a week and was extended to 6 days a week during July and August. Table 1 outlines the 1987 sampling program. Table 2 lists the parameters analyzed for each group of stations.

The monitoring program was composed of five separate sampling networks; The beach station network was sampled to gather bacteriological water quality information at 26 Long Island coast stations and 40 New Jersey coast stations. The New York Bight station network was sampled to gather chemical and bacteriological information at 20 stations in the inner New York Bight. The perpendicular station network consisted of 12 transects extending from the New Jersey and Long Island coasts. Three transects extended south from the Long Island coast, with 4 stations in each transect and 9 transects extended east from the New Jersey coast, with 5 stations in each transect. The transects covered the inner Bight from Jones Beach on Long Island to Strathmere, on the New Jersey coast. Samples were collected for dissolved oxygen and temperature. The New York Bight Contingency Network consisted of 24 stations which were sampled for dissolved oxygen, temperature, and fecal coliform and enterococcus densities. The phytoplankton sampling network consisted of 54 stations. Samples for phytoplankton identification and nutrient analysis were collected along the New Jersey coast and in Raritan Bay at 12 stations, at 4 New Jersey perpendicular stations, along the Long Island coast at 26 stations, and at the 12 Long Island perpendicular stations. The weekly sampling program

Table 1

Outline of 1987 sampling program

Station Group	Frequency per Week	Parameter	Sample Depth
Long Island Beaches (Rockaway Pt. to Fire Island Inlet)	1	Bacteriological Phytoplankton Chlorophyll	Top[1]
Long Island Beaches (Fire Island Inlet to Shinnecock Inlet)	Bimonthly	Bacteriological Phytoplankton Chlorophyll	Top[1]
New Jersey Beaches (Sandy Hook to Cape May)	1	Bacteriological	Top[1]
Long Island Perpendiculars	1	Dissolved Oxygen Phytoplankton Chlorophyll Temperature	Top[1], Bottom[2]
North Jersey Perpendiculars (Long Branch to Seaside)	1	Dissolved Oxygen Temperature	Top[1], Bottom[2]
South Jersey Perpendiculars (Barnegat to Strathmere)	Bimonthly	Dissolved Oxygen Temperature	Top[1], Bottom[2]
Bight Contingency	2	Dissolved Oxygen Temperature	Top[1], Bottom[2]
Bight Contingency	1	Bacteriological	Top[1], Bottom[2]
Phytoplankton	1	Phytoplankton Chlorophyll[3] Nutrients[4]	Top[1]
Inner New York Bight	1	Bacteriological Dissolved Oxygen Temperature	Top[1], Bottom[2]

1 One meter below the surface
2 One meter above the ocean floor
3 Long Island stations only
4 New Jersey stations only

Table 2

Parameters evaluated for each station group

Parameters	L.I. & N.J. Beaches[1]	L.I. & N.J. Perpendiculars[2]	N.Y. Bight[2]	Bight Contingency[2]	Phytoplankton[1]
Fecal Coliform	X		X	X	
Enterococcus	X		X	X	
Salinity Chlorinity		X			
Temperature		X	X	X	
Dissolved Oxygen (DO)		X	X	X	
Total Phosphorus (TP)					X
Phosphate Phosphorus (PO_4-P)					X
Ammonia Nitrogen (NH_3-N)					X
Nitrite Nitrogen (NO_2-N)					X
Nitrate Nitrogen (NO_3-N)					X
Silica (SiO_2)					X
Plankton					X
Chlorophyll	X[3]	X[4]			

[1]Sample Depth: 1 meter below the surface
[2]Sample Depth: 1 meter below the surface and 1 meter above the ocean floor
[3]Long Island beaches only
[4]Long Island perpendiculars only

averaged approximately 140 stations.

Beach stations along New York and New Jersey were sampled once a week for fecal coliform and enterococcus bacteria densities. This portion of the sampling program totaled 66 stations per week. At the beach stations, samples were collected just offshore in the surf zone while the helicopter hovered approximately 3 meters from the surface. Sampling was accomplished by lowering a 1-liter Kemmerer sampler approximately 1 meter below the water surface. The sample was transferred to a sterile plastic container, iced and subsequently transported (within 6 hours) to the Edison Laboratory for fecal coliform and enterococcus analyses.

The twenty stations in the Bight Apex were sampled once a week. Depending upon sea conditions, the EPA helicopter hovered or landed at the designated station and a 1-liter Kemmerer sampler was used to obtain water samples at 1 meter below the surface and 1 meter above the ocean bottom. After collection, portions of the water sample were transferred to a BOD bottle for dissolved oxygen analysis, and a sterile plastic bottle for fecal coliform and enterococcus analyses. The dissolved oxygen sample was immediately fixed at the station by the addition of 2 ml of manganous sulfate followed by 2 ml of alkali-iodide-azide reagent. The sample was shaken to facilitate floc formation and then placed in a metal rack. The samples were held for less than 6 hours before returning to the laboratory, where 2 ml of sulfuric acid was added and the samples were titrated with 0.0375M sodium thiosulfate.

The third scheduled sampling portion of the program consisted of sampling perpendicular stations once a week for dissolved oxygen and temperature. Again, as with the inner Bight stations, samples were collected while hovering or landing, at 1 meter below the surface and 1 meter above the bottom.

As part of the "Environmental Impact Statement on Ocean Dumping of Sewage Sludge in the New York Bight", a Bight Contingency Plan was developed in which criteria were established for the relocation of the sewage sludge dumpsite, if necessary. This necessitated the establishment of a fourth sampling component. Therefore, a 24-station network was developed and sampled twice a week for dissolved oxygen and once a week for fecal coliform and enterococcus densities. Part of the sampling requirements for the New York Bight contingency plan was satisfied by the regularly scheduled Bight and perpendicular sampling runs. Bacteriological samples for 18 of the stations were collected during the perpendicular sampling runs for dissolved oxygen. The bacteriological requirements for 6 of the stations were met by the regular Bight sampling since bacteriological assays were performed for all Bight stations. An additional sampling of dissolved oxygen for the 24 stations was carried out once a week.

The fifth routinely scheduled sampling component involved the collection of water samples for phytoplankton identification and quantification, nutrient analysis and chlorophyll analysis. Phytoplankton samples collected along the New Jersey coast were identified and quantified by the New Jersey Department of Environmental Protection (NJDEP) and the nutrient analyses were conducted by EPA. Phytoplankton and chlorophyll samples collected along the Long Island coast were analyzed by the Nassau County Health Department. The samples were collected as close to the surface as possible, using 1-liter Kemmerer samplers. A 1-liter plastic cubitainer was filled for phytoplankton analysis. The phytoplankton samples for NJDEP were preserved with Lugols solution and kept at 4°C. The phytoplankton samples for the Nassau County Health Department were not preserved. At the New Jersey beach stations a 1-liter plastic cubitainer was filled for nutrient analysis and kept at 4°C. The NJDEP picked up their phytoplankton samples at our Edison laboratory within 24 hours of collection. Along the Long Island beaches a 500 ml dark brown plastic bottle was filled for chlorophyll analysis. The Nassau County Health Department samples were delivered to the Health Department's laboratory within 4 hours of collection. The results of NJDEP's analyses are contained in Appendix A. A report from the Nassau County Health Department has not yet been completed.

III. DESCRIPTION OF SAMPLING STATIONS

Beach Stations

A total of 66 bathing beach areas were sampled routinely for bacteriological water quality along the Long Island and New Jersey coastlines. The Long Island sampling stations extend from the western tip of Rockaway Point 130 km eastward to Shinnecock Inlet for a total of 26 stations (LIC 01-LIC 28). Sample station locations, nomenclature, and descriptions are given in Table 3 and Figure 3. Forty New Jersey coast stations, from Sandy Hook at the north to Cape May Point at the south (JC 01A through JC 99), are described and identified in Table 4 and in Figures 4 and 5.

New York Bight Stations

The New York Bight stations, established as part of the original ocean monitoring program, cover the inner Bight area in approximately 3 km intervals via three transects as follows: New Jersey Transect (NYB 20-NYB 27), extending from Sandy Hook 20 km eastward to the sewage sludge dump site; Raritan Bay Transect (NYB 32-NYB 35), projecting along the Ambrose Channel from the mouth of Raritan Bay southeast to the sewage sludge dump site; and the Long Island Transect (NYB 40-NYB 47), extending from Atlantic Beach, Long Island southward to just beyond the sewage sludge dump site. The locations of the New York Bight stations are shown in Figure 6.

Table 3

Long Island coast station locations

Station No.	Location
LIC 01	Rockaway Point, Breezy Point Surf Club
LIC 02	Rockaway, off foot of B169 Road
LIC 03	Rockaway, off foot of B129 Road
LIC 04	Rockaway, off foot of B92 Road
LIC 05	Far Rockaway, off foot of B41 Road
LIC 07	Atlantic Beach, Silver Point Beach Club
LIC 08	Long Beach, off foot of Grand Avenue
LIC 09	Long Beach, off foot of Pacific Boulevard
LIC 10	Point Lookout, off Hempstead public beach
LIC 12	Short Beach (Jones Beach), off "West End 2" parking lot
LIC 13	Jones Beach
LIC 14	East Overlook
LIC 15	Gilgo Beach
LIC 16	Cedar Island Beach
LIC 17	Robert Moses State Park
LIC 18	Great South Beach
LIC 19	Cherry Grove
LIC 20	Water Island
LIC 21	Bellport Beach
LIC 22	Smith Point County Park
LIC 23	Moriches Inlet West
LIC 24	Moriches Inlet East
LIC 25	West Hampton Beach
LIC 26	Tiana Beach
LIC 27	Shinnecock Inlet West
LIC 28	Shinnecock Inlet East

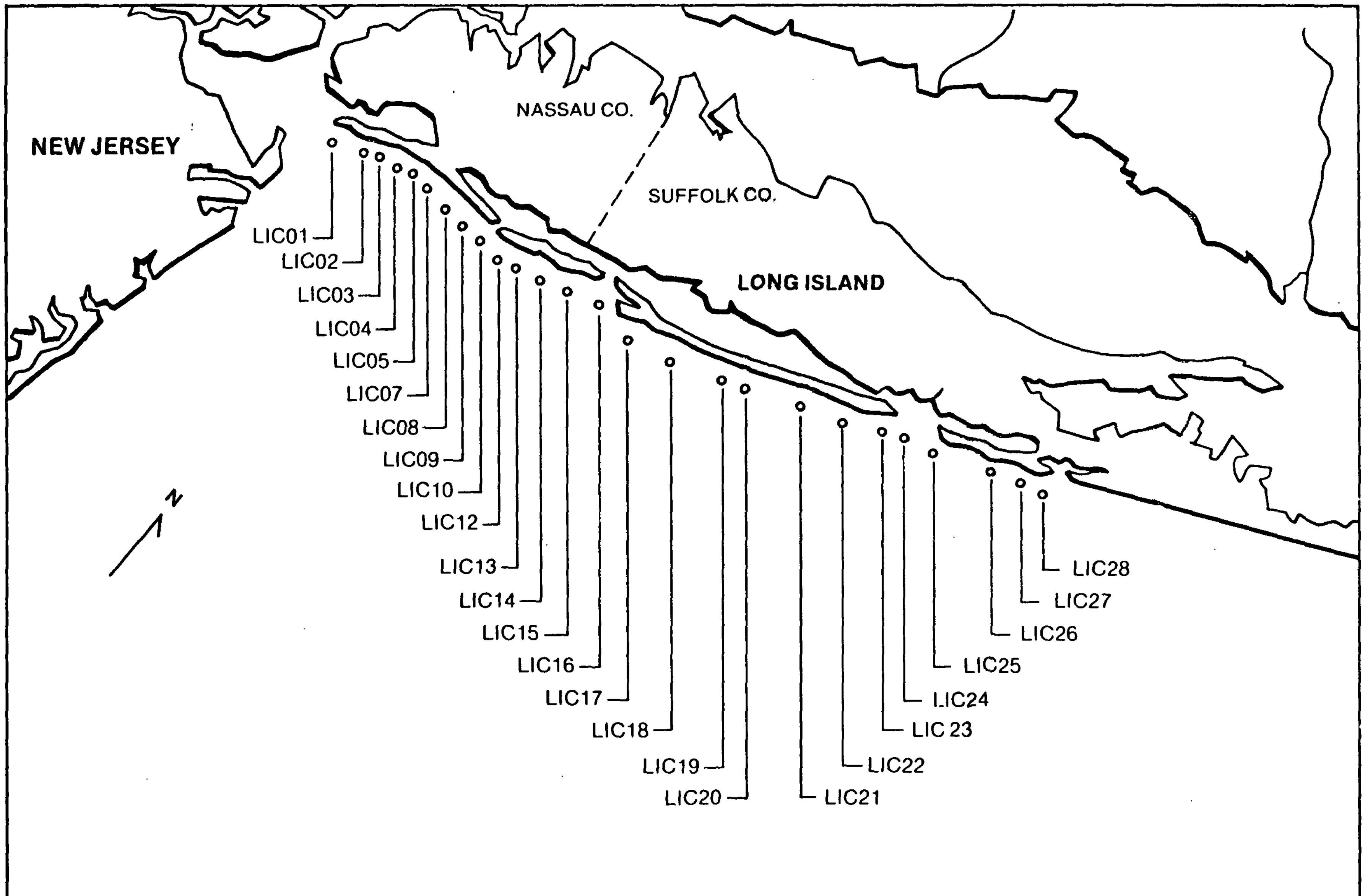


FIGURE 3
LONG ISLAND COAST STATION LOCATIONS

Table 4

New Jersey coast station locations

Station No.	Location
JC 01A	Sandy Hook, 1.2 km south of tip
JC 02	Sandy Hook, off large radome
JC 03	Sandy Hook, off Nature Center building (tower)
JC 05	Sandy Hook, just north of Park entrance
JC 08	Sea Bright, at public beach
JC 11	Monmouth Beach Bath & Tennis Club
JC 14	Long Branch, off foot of S. Bath Avenue
JC 21	Asbury Park, off building north of Convention Hall
JC 24	Bradley Beach, off foot of Cliff Avenue
JC 27	Belmar, off the "White House" near fishing club pier
JC 30	Spring Lake, south of yellow brick building on beach
JC 33	Sea Girt, off foot of Chicago Avenue
JC 37	Point Pleasant, south of Manasquan Inlet
JC 41	Bay Head, off foot of Johnson Street
JC 44	Mantoloking, off foot of Albertson Street
JC 47A	Silver Beach, off foot of Colony Road
JC 49	Lavallette, off foot of Washington Avenue
JC 53	Seaside Heights, between the amusement piers
JC 55	Island Beach State Park, off white building north of Park Headquarters
JC 57	Island Beach State Park, between two main parking lots in center of park
JC 59	Island Beach State Park, off white house next to the lookout tower

Table 4 (continued)

Station No.	Location
JC 61	Barnegat, first rock jetty south of Barnegat Inlet
JC 63	Harvey Cedars, opposite Harvey Cedars standpipe
JC 65	Ship Bottom, opposite Ship Bottom water tower
JC 67	Beach Haven Terrace, opposite standpipe
JC 69	Beach Haven Heights, opposite the most southern water tower on Long Beach Island
JC 73	Brigantine, off large hotel on beach
JC 75	Atlantic City, off the Convention Center
JC 77	Ventnor City, just north of fishing pier
JC 79	Longport, off water tower
JC 81	Ocean City, opposite large apartment building
JC 83	Peck Beach, opposite large blue water tower
JC 85	Strathmere, off blue standpipe
JC 87	Sea Isle City, opposite blue water tower with bridge in the background
JC 89	Avalon, off beige building on the beach
JC 91	Stone Harbor, off large blue water tower
JC 93	Wildwood, off northern amusement pier
JC 95	Two mile beach, opposite radio tower
JC 97	Cape May, off white house with red roof on the beach
JC 99	Cape May Point, opposite lighthouse

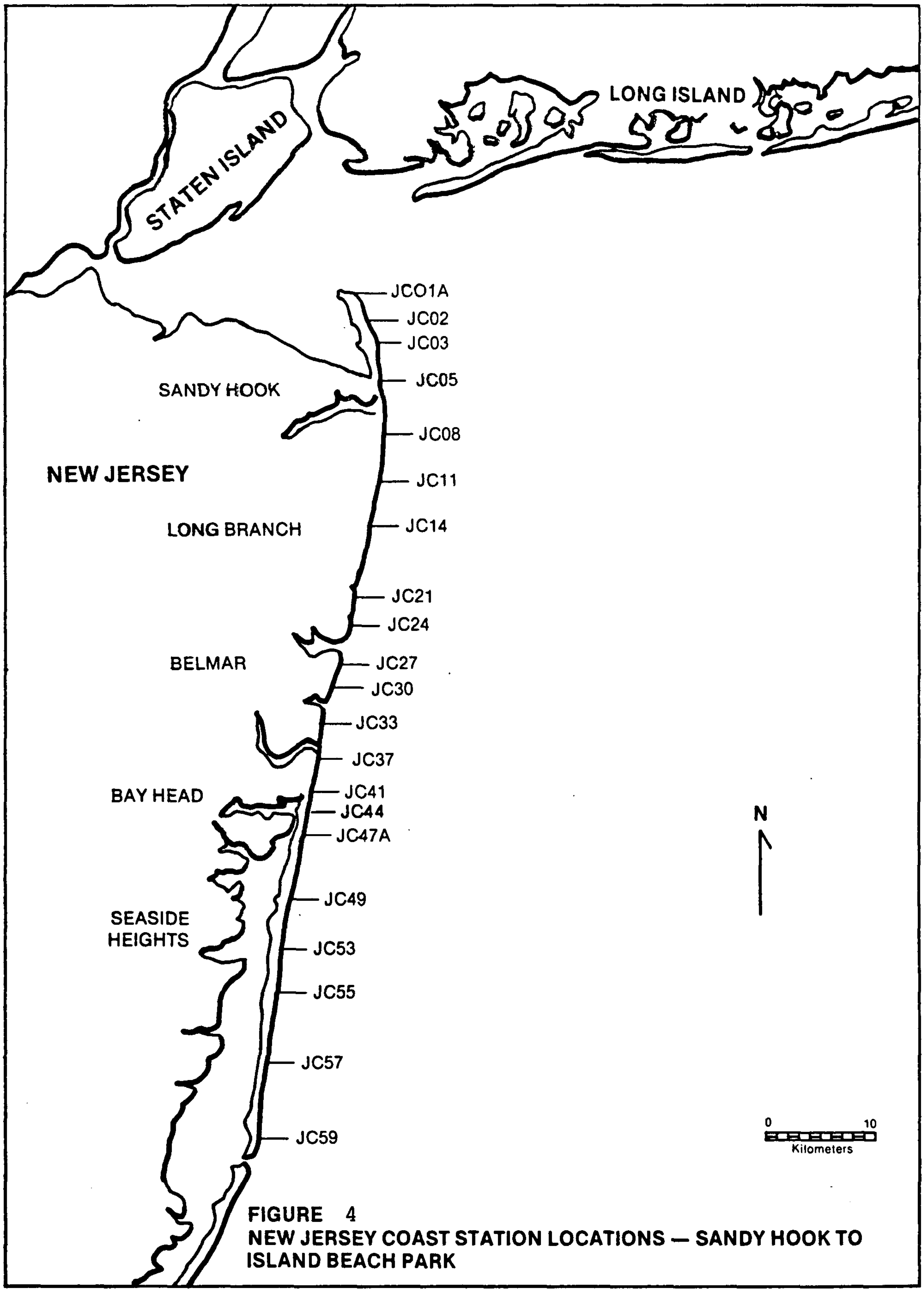


FIGURE 4
NEW JERSEY COAST STATION LOCATIONS — SANDY HOOK TO ISLAND BEACH PARK

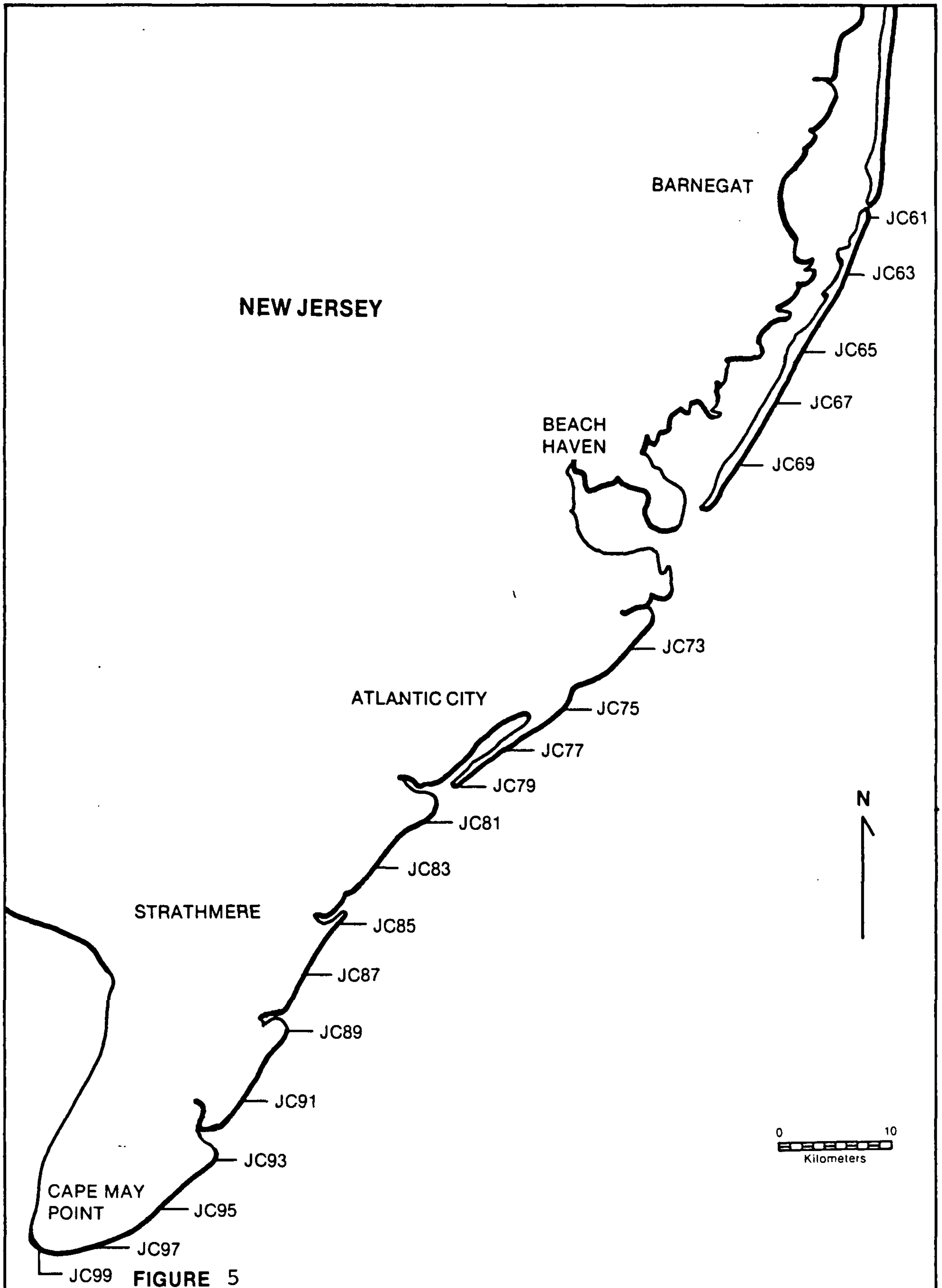


FIGURE 5
NEW JERSEY COAST STATION LOCATIONS — BARNEGAT TO CAPE MAY POINT

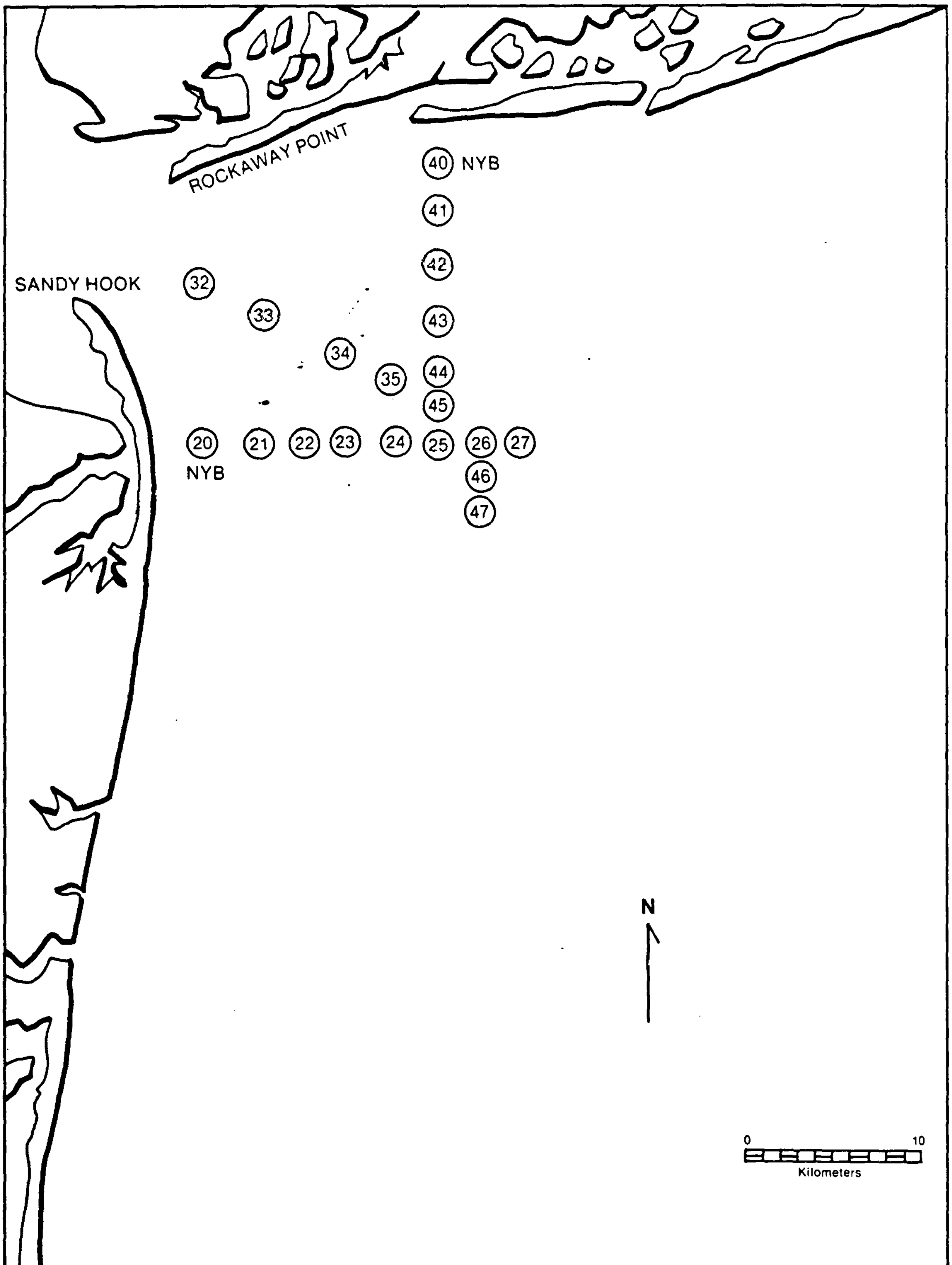


FIGURE 6
NEW YORK BIGHT STATION LOCATIONS

Perpendicular Stations

Sampling stations perpendicular to the Long Island coastline are 5.4 kilometers (km), 12.6 km, 19.8 km, and 27 km (3, 7, 11, and 15 nautical miles) offshore. Sampling stations perpendicular to the New Jersey coastline start at 1.8 km and are spaced every 1.8 km out to 18 km (1 nautical mile with 1 nm increments to 10 nm) offshore. These stations are identified by suffixes E through M, with the exception of the Manasquan (MAS) perpendicular stations which have corresponding suffixes 1 through 9. Normally, only every other New Jersey perpendicular station (3.6 km intervals) was sampled; the intermediate stations remained available should dissolved oxygen conditions warrant more intensive sampling.

The perpendicular stations were established to gather near-surface and near-bottom dissolved oxygen values in the critical areas of the New York Bight nearshore waters. Previous agreements had been made with the National Oceanic and Atmospheric Administration (NOAA) to provide dissolved oxygen profiles from stations further out in the Bight in conjunction with their Northeast Monitoring Program (NEMP) and Marine Fisheries Laboratory activities.

The perpendicular stations described above are plotted in Figures 7 and 8. Tables 3 and 4 describe the shore station locations from which the perpendicular stations originate.

New York Bight Contingency Plan Stations

The 24 stations sampled are:

NYB 20, 22, 24, 40, 42, 44,
LIC 09P, A, B, and C
LIC 14P, A, B, and C
JC 14E, G, I, K, and M
JC 27E, G, I, K, and M

Their locations are shown in Figures 6 and 7.

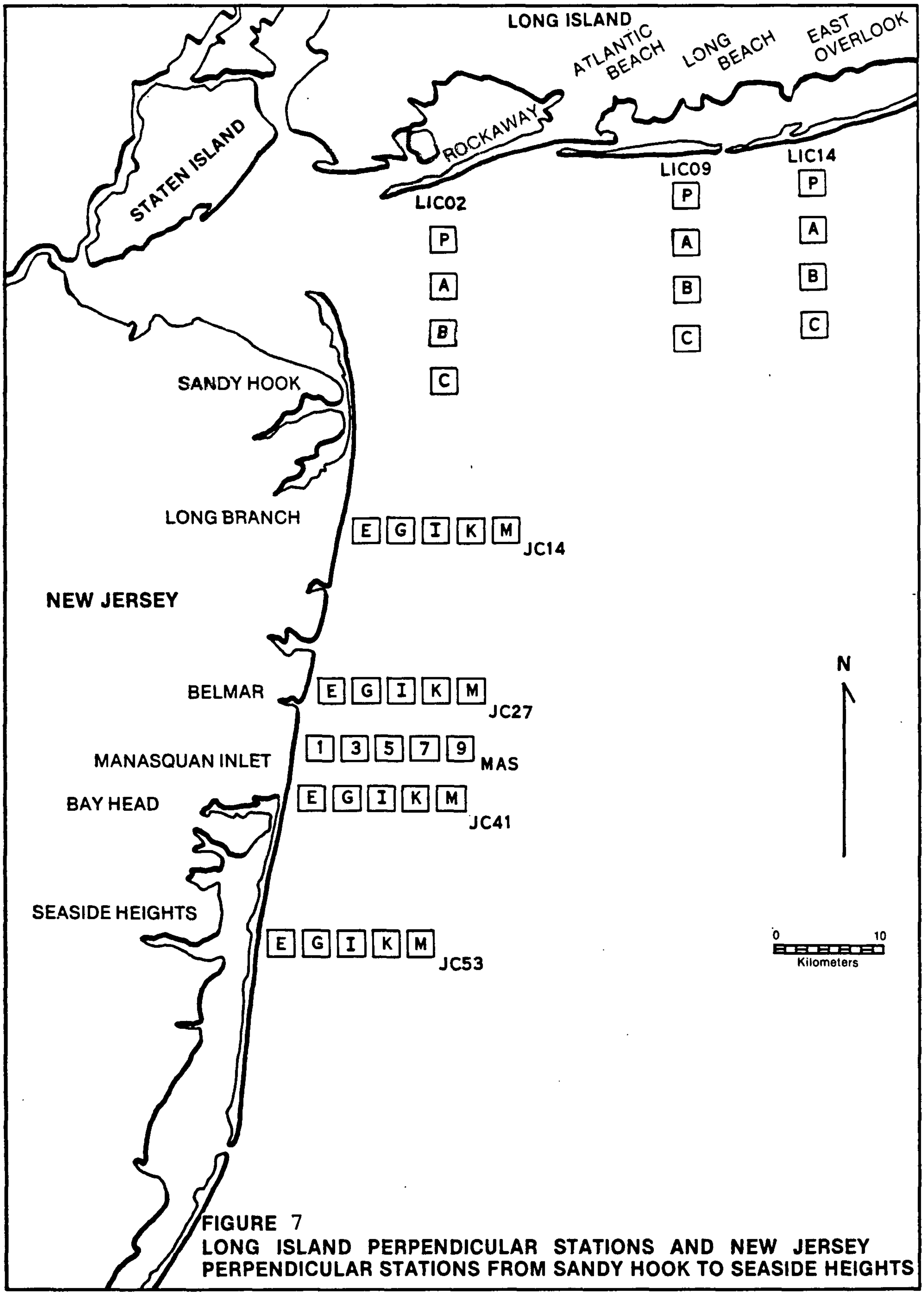


FIGURE 7
LONG ISLAND PERPENDICULAR STATIONS AND NEW JERSEY PERPENDICULAR STATIONS FROM SANDY HOOK TO SEASIDE HEIGHTS

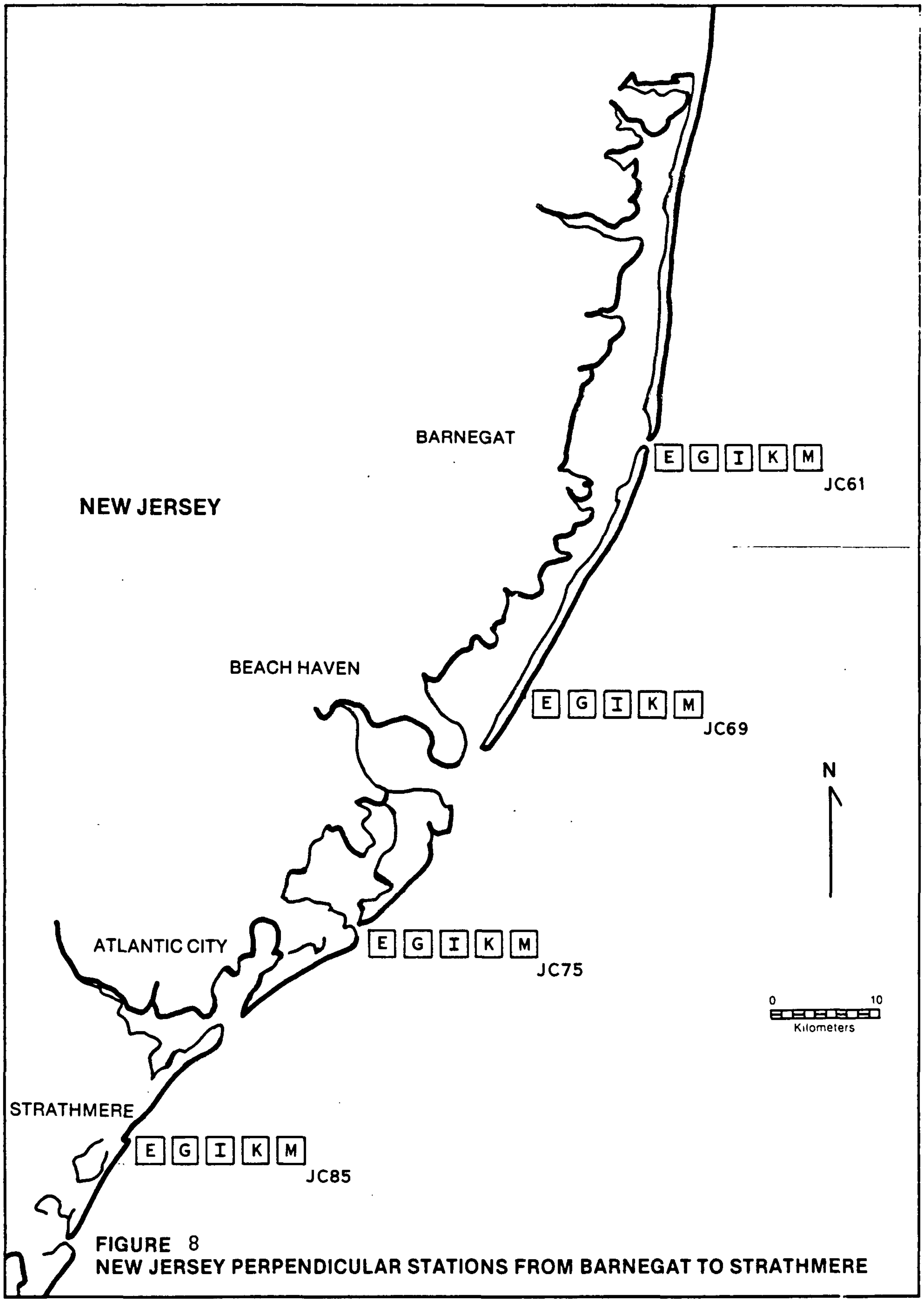


FIGURE 8
NEW JERSEY PERPENDICULAR STATIONS FROM BARNEGAT TO STRATHMERE

Phytoplankton Stations

Phytoplankton samples were collected once a week along the New Jersey coast at the following stations:

JC 05	JC 49	JC 65	JC 75I deep
JC 11	JC 57	JC 75	JC 75M deep
JC 21	RB 32	JC 83	JC 85I deep
JC 30	RB 15	JC 93	JC 85M deep

A discussion of phytoplankton dynamics and bloom incidence in New Jersey waters is presented in Appendix A.

Phytoplankton samples were collected at all Long Island beach and Long Island perpendicular stations once a week. A report on these samples is currently pending from the Nassau County Health Department.

IV. DISSOLVED OXYGEN RESULTS AND DISCUSSION

Normal Trends in the Ocean

Two major processes act to replenish dissolved oxygen in the water column of the New York Bight area. These are: the photosynthetic conversion of carbon dioxide to molecular oxygen, and the mechanical reaeration of oxygen across the air-water interface. Subsequent turbulent diffusion then distributes the dissolved oxygen throughout the water column or into the upper warmer surface layer when stratified conditions prevail. Concurrent oxygen utilization (depletion) processes, such as bacterial respiration and sediment oxygen demand, act to influence the amount of oxygen in the water column at any one time or location.

A general description of the oxygen cycle during a calendar year is as follows:

> In early January, the waters of the Bight are completely mixed throughout the water column with temperatures ranging from 4°C to 10°C while dissolved oxygen values are between 8 and 10 mg/l with slightly depressed values at the sediment-water interface. The warm spring air temperatures and solar heating increase the temperature of the upper water layer and, in the absence of high energy input from local storms or tropical hurricanes, a thermally stratified water column develops. This stratification effectively blocks the free transport of the oxygen-rich upper layer into the cool oxygen-poor bottom waters.

As hot summer weather conditions set in, the warmer upper layer of water remains completely mixed and rich in oxygen (7 to 9 mg/1). This upper layer ranges from 20 to 60 meters in depth depending on time and location. The cooler bottom water is effectively isolated from the upper layer by a 10°C temperature gradient. Respiration of bottom organisms, bacterial action on algal remains and detritus, and sediment oxygen demand depress the residual dissolved oxygen values in the bottom waters. In a typical year, the dissolved oxygen concentration in the bottom waters of the Bight reaches a minimum in mid to late summer of approximately 4 mg/1. At this time, cool evenings and reduced solar input cause the upper waters to cool, decreasing the temperature gradient between the two water masses. As the two masses become closer and closer in temperature, the energy required to break down the thermocline becomes less and less until finally, in many instances after a local storm, there is a complete mixing of the water column with concomitant reoxygenation of the bottom waters. The annual cycle begins again. Figure 9 depicts a representative history of dissolved oxygen concentration in the general ocean area off of New Jersey, New York, and New England.

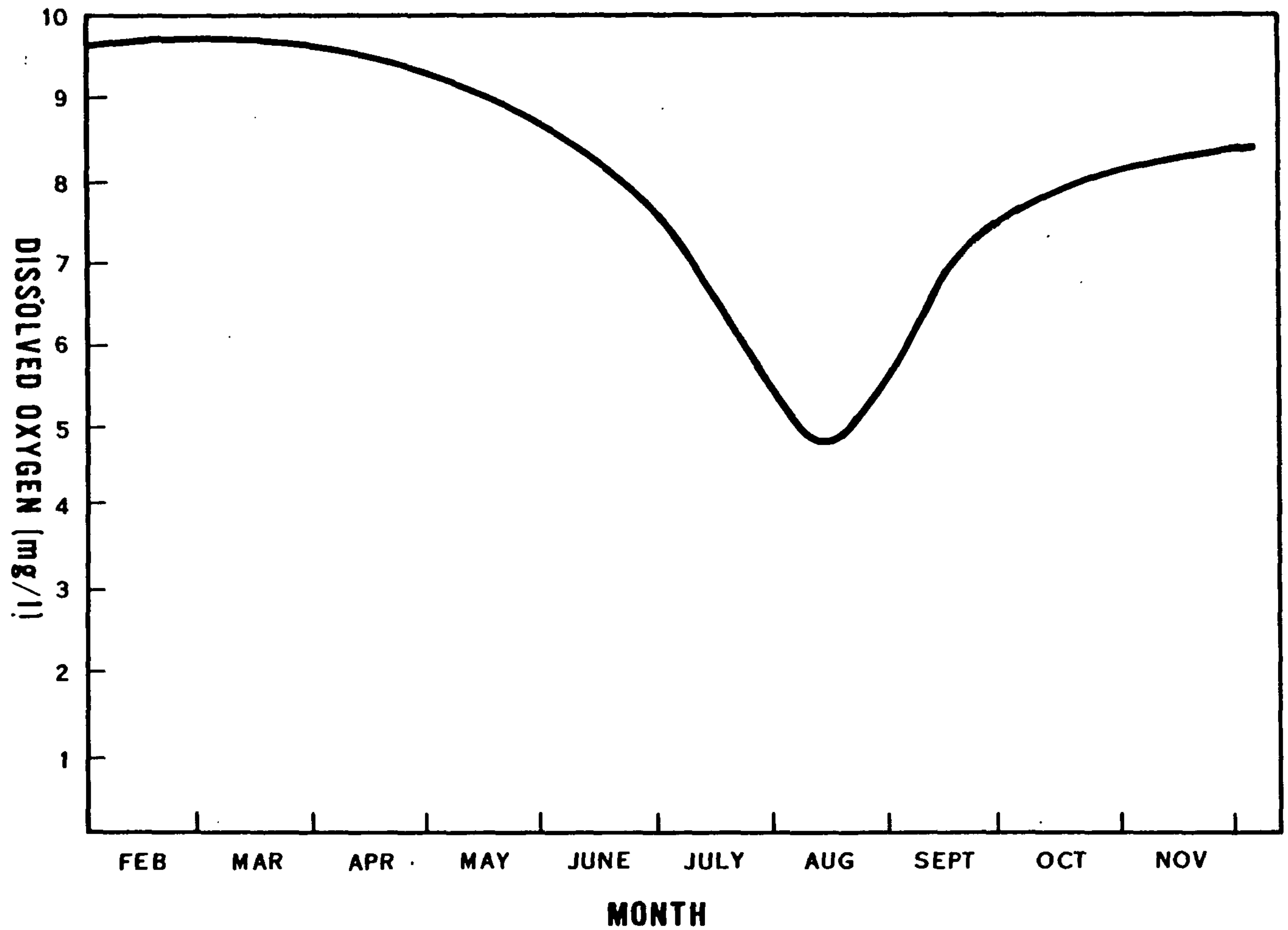


FIGURE 9
GENERALIZED ANNUAL MARINE DISSOLVED OXYGEN CYCLE OFF THE NORTHEAST U.S. (FROM NOAA)

Dissolved Oxygen Criteria

The dissolved oxygen levels necessary for survival and/or reproduction vary among biological species. Sufficient data have not been accumulated to assign definitive limits or lower levels of tolerance for each species at various growth stages. Rough guidelines are available for aquatic species for purposes of surveillance and monitoring. These are as follows:

5 mg/l and greater	healthy
4 - 5 mg/l	borderline to healthy
3 - 4 mg/l	stressful if prolonged
2 - 3 mg/l	lethal if prolonged
less than 2 mg/l	lethal in a relatively short time.

These criteria are consistent with biological information recorded in the New York Bight over the past 10-15 years. Most data concerning the lower tolerance levels were recorded during the summer of 1976. In 1976, widespread and persistent dissolved oxygen levels between 0.0 and 2.0 mg/l occurred over a large area of the Bight. This resulted in extensive fish kills and benthic organism mortality.

Surface Dissolved Oxygen - 1987

The completely mixed upper water layer had dissolved oxygen levels at or near saturation during the entire sampling period, May 22, 1987 through October 26, 1987, therefore no further discussion of surface dissolved oxygen will be presented in this report.

Bottom Dissolved Oxygen - 1987

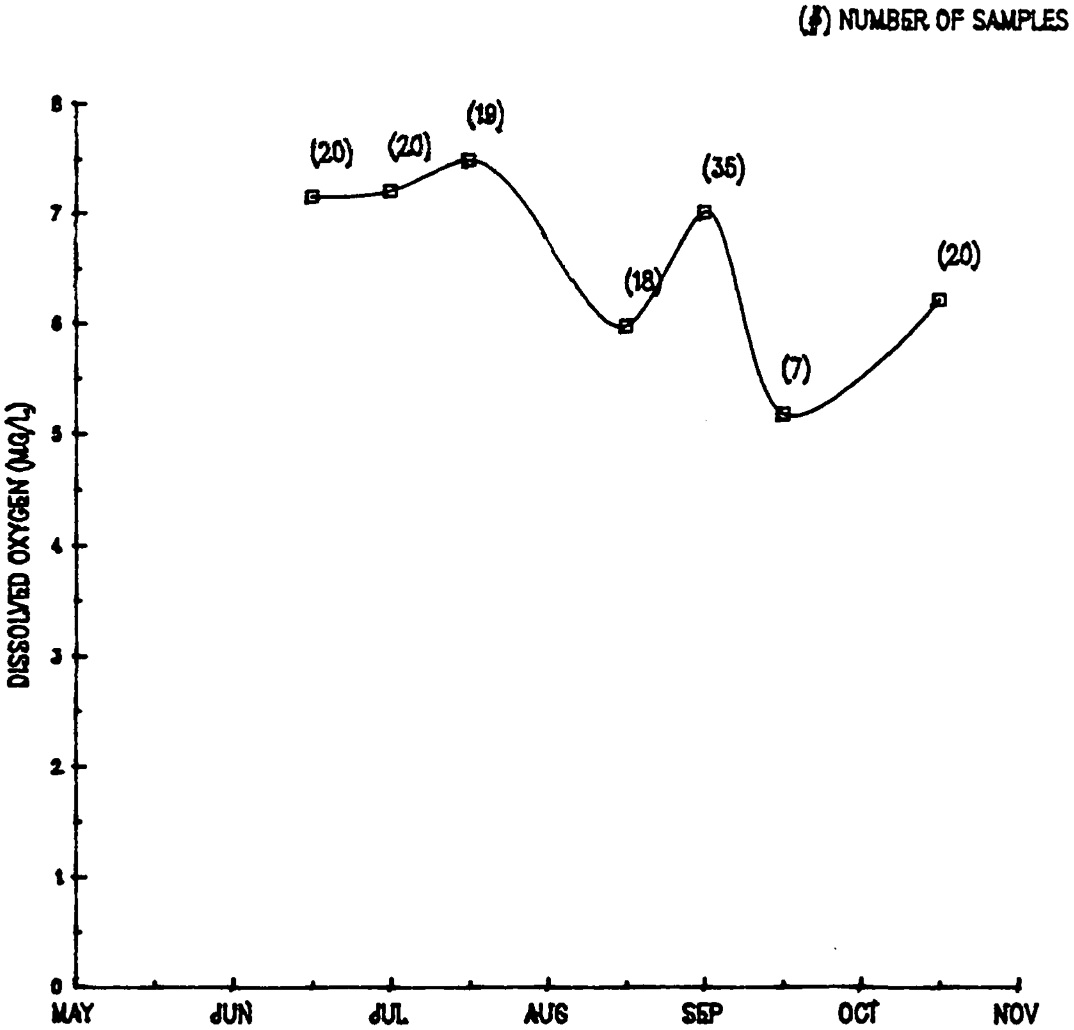
Long Island Coast

The Long Island perpendiculars were sampled only four times during the 1987 sampling period. A total of 46 bottom samples were collected for dissolved oxygen. None were below the 4 mg/l "borderline to healthy" guideline. Based on these data, dissolved oxygen remained well above the concentrations considered stressful to aquatic life. The dissolved oxygen average remained in the 6-8 mg/l range. No samples were collected in July or September, therefore, it is possible that dissolved oxygen concentrations may have been lower than 6 mg/l in July or September. However, no fishkills in the ocean off Long Island were reported, therefore, no prolonged periods of very low dissolved oxygen concentrations probably occurred. Additionally, data from previous years indicate that the dissolved oxygen averages off Long Island generally remain well above 4 mg/l, and there is no reason to suspect that 1987 was any different.

New York Bight Apex

Figure 10 illustrates the semi-monthly dissolved oxygen averages at the New York Bight Apex stations from June through October, 1987. A double minima was observed. The dissolved oxygen average increased slightly from 7.1 mg/l in June to 7.5 mg/l in mid-July. The dissolved oxygen subsequently declined to a first minima of 6.1 mg/l in mid-August, increased to 7.0 mg/l in early September, and declined to a second low of 5.2 mg/l in mid-September. The dissolved oxygen average began to recover in October.

FIGURE 10



NEW YORK BIGHT BOTTOM DISSOLVED OXYGEN, 1987 SEMIMONTHLY AVERAGE OF ALL NEW YORK BIGHT STATIONS.

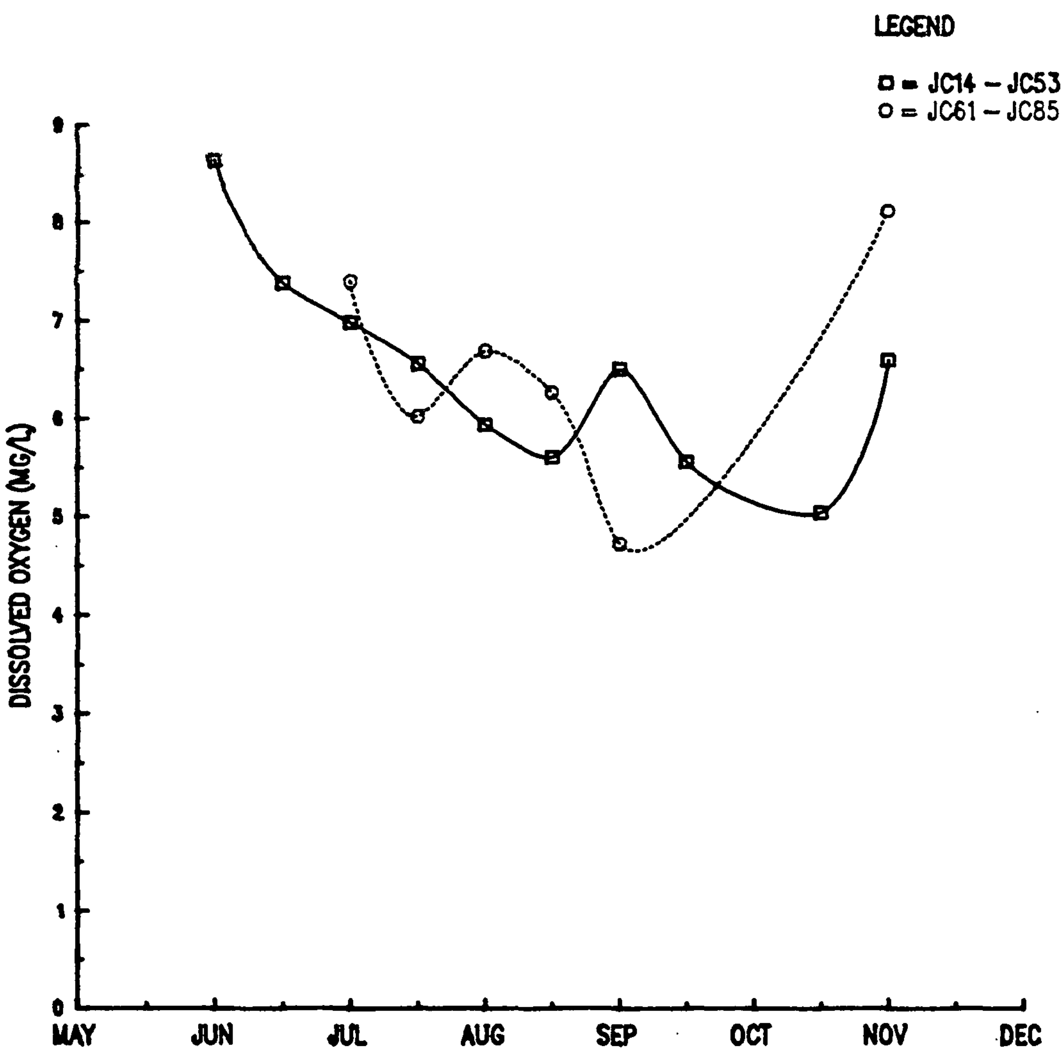
Out of 139 samples collected in the New York Bight Apex from May 18 to October 13 and measured for dissolved oxygen, 1 sample, or 0.7 percent, was between the 3-4 mg/l level considered "stressful if prolonged" for aquatic life. This one low dissolved oxygen value occurred at station NYB 44 on September 10, 1987. Eight dissolved oxygen values, or 5.8 percent were between 4-5 mg/l.

New Jersey Coast

Figure 11 illustrates the semi-monthly dissolved oxygen average off the New Jersey coast during the summer of 1987, with separate lines for the northern (JC 14-JC 53) perpendiculars and the southern (JC 61-JC 85) perpendiculars. Both lines show a dissolved oxygen double minima. The dissolved oxygen average along the northern perpendiculars was approximately 8.6 mg/l in late May, declined steadily throughout June, July and August, until mid-August when a low of 5.6 mg/l was reached. Between mid-August and early September the dissolved oxygen average rose sharply to 6.5 mg/l and then decreased in mid-September and early October to 5.0 mg/l. The dissolved oxygen average recovered in late October. Along the southern New Jersey perpendiculars, the dissolved oxygen average was 7.4 mg/l in late June and decreased to 6.0 mg/l in early July. The dissolved oxygen increased to 6.6 mg/l in late July, then decreased substantially to a low of 4.6 mg/l in late August. This was followed by a dissolved oxygen recovery in September and October.

Table 5 summarizes the bottom dissolved oxygen values for the New Jersey coast perpendiculars. There were 431 samples collected along the New Jersey perpendiculars between May 22 and October 26, 1987 and analyzed for dissolved oxygen. Of these samples, 60 values (13.9 percent) were below 5 mg/l. Of the 60 samples, 44 values (10.2 percent of all samples collected) were between 4-5 mg/l, 16 values (3.7 percent) were between 2-4 mg/l. There were no values between 0-2 mg/l. In comparison, during the summer of 1986, 598 samples were collected. Of these, 161 values (26.9

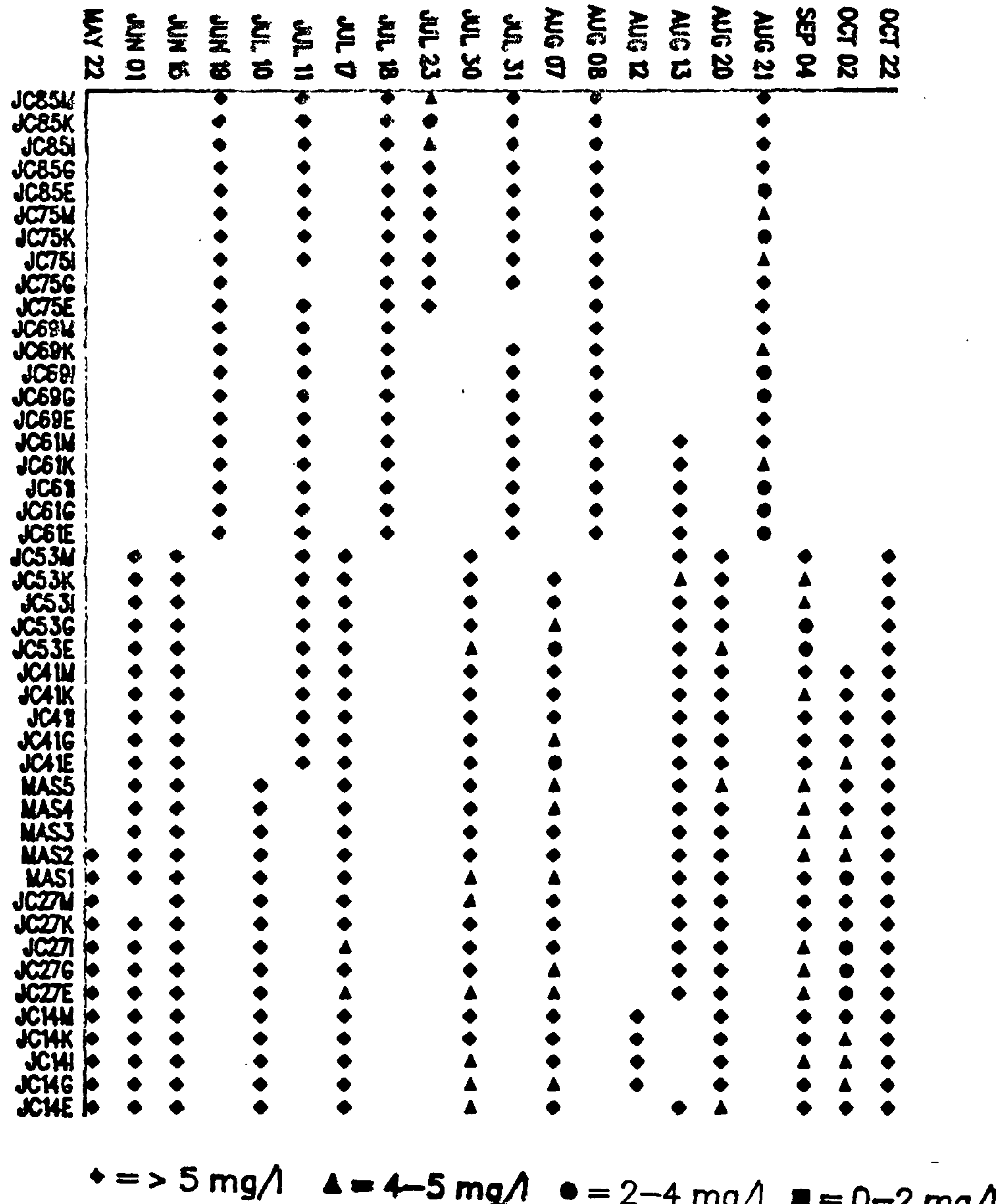
FIGURE 11



NEW JERSEY COAST BOTTOM DISSOLVED OXYGEN, SEMIMONTHLY AVERAGES OF ALL NORTHERN (JC14–JC53) AND SOUTHERN (JC61–JC85) PERPENDICULAR STATIONS.

TABLE 5

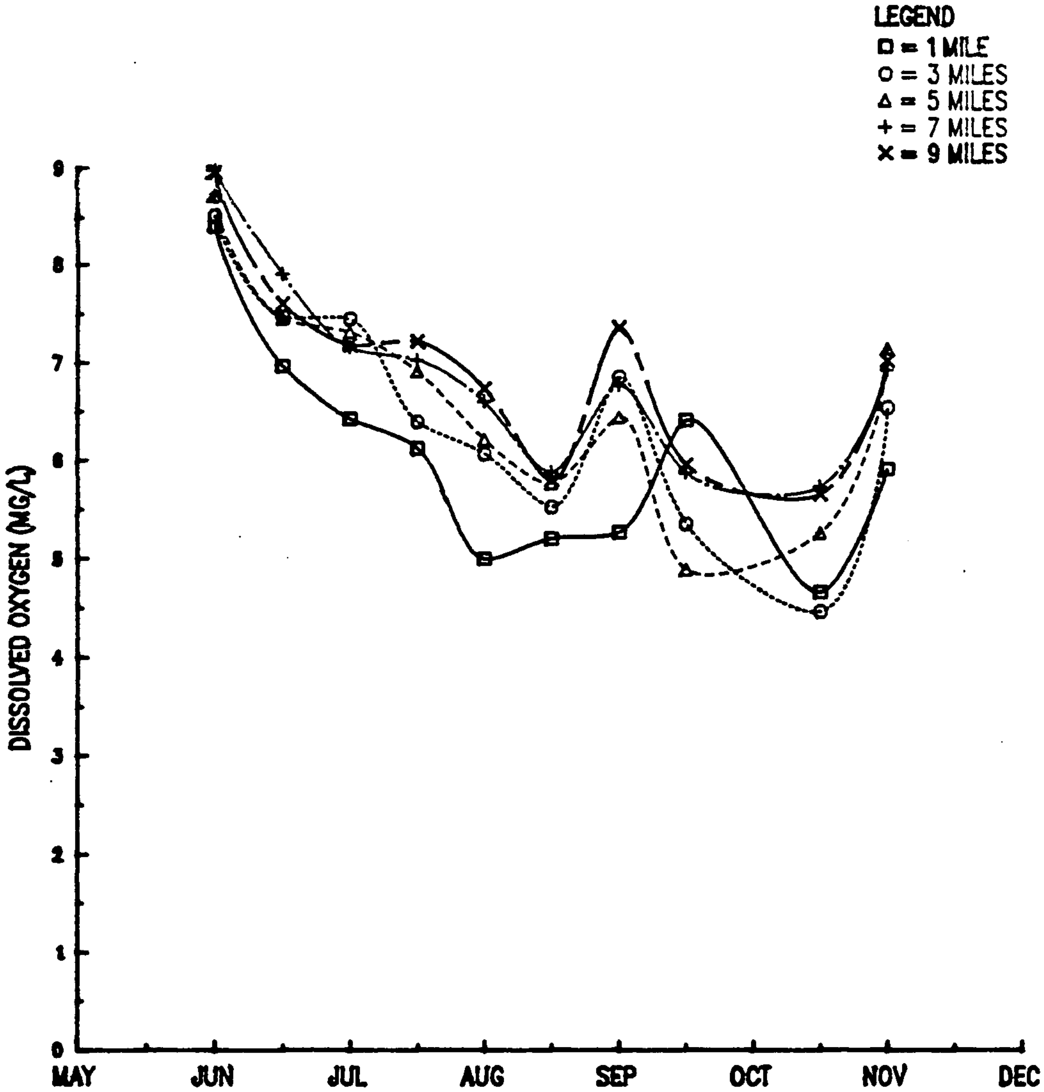
1987 NJ DO DISTRIBUTION (BOTTOM VALUES)



percent) were between 4-5 mg/l, 105 values (17.6 percent) were between 2-4 mg/l, and 2 values (0.3 percent) were between 0-2 mg/l. Dissolved oxygen values in 1987 were higher than those encountered in 1986.

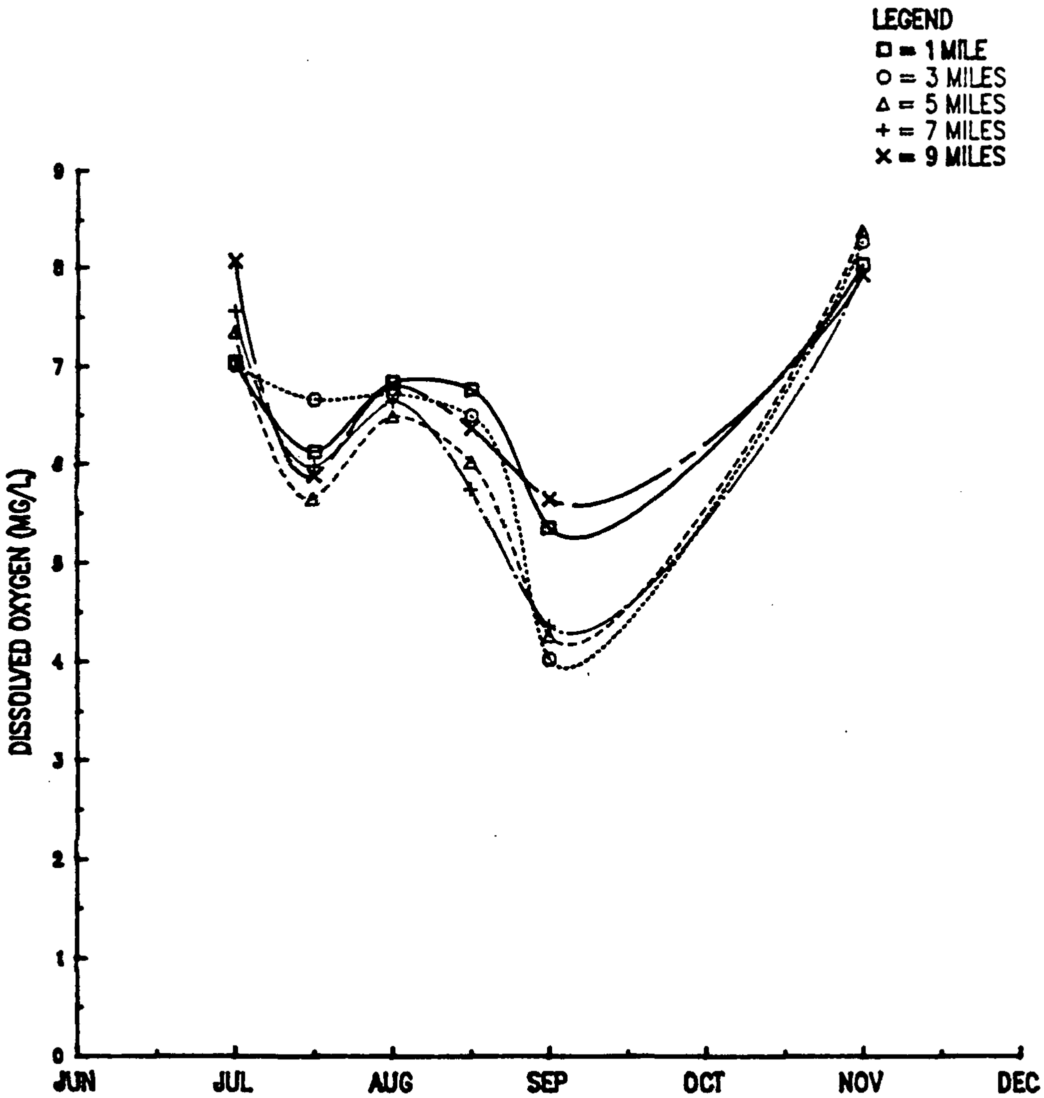
Figures 12 and 13 compare the shore to seaward distribution of dissolved oxygen along the northern New Jersey perpendiculars and the southern New Jersey perpendiculars, respectively. Generally, along northern New Jersey, Figure 12, the dissolved oxygen values increase with distance offshore. This trend is not evident along southern New Jersey, Figure 13. The lower dissolved oxygen values found at the nearshore stations along northern New Jersey are attributed to the influence of river discharges, treatment plant effluents, stormwater runoff, benthic oxygen demand from inlet dredged material disposal sites, and the Hudson-Raritan River Estuary system.

FIGURE 12



SHORE–TO–SEAWARD DISTRIBUTION OF BOTTOM DISSOLVED OXYGEN, 1987 SEMIMONTHLY AVERAGES OF ALL NORTHERN PERPENDICULAR STATIONS (JC14–JC53), AT FIXED DISTANCES FROM SHORE.

FIGURE 13



SHORE-TO-SEAWARD DISTRIBUTION OF BOTTOM DISSOLVED OXYGEN, 1987
SEMIMONTHLY AVERAGES OF ALL SOUTHERN PERPENDICULAR STATIONS
(JC61-JC85), AT FIXED DISTANCES FROM SHORE.

Dissolved Oxygen Trends

Figures 14, 15 and 16 display the number of dissolved oxygen observations below 4 mg/l during July, August and September 1983-1987, for each perpendicular. The graphs indicate that, similar to 1984 and 1986, the dissolved oxygen concentrations from July to September 1987 were generally good with few values below 4 mg/l, as contrasted with 1983 and 1985 which had numerous dissolved oxygen values below 4 mg/l. In July 1987, 1 dissolved oxygen value below 4 mg/l was observed along the New Jersey perpendiculars, Figure 14, as compared with 132 during the same period in 1985. In 1987, the largest number of dissolved oxygen values below 4 mg/l, 9 observations, occurred in August, as shown in Figure 15. This is contrasted with 108 dissolved oxygen values below 4 mg/l during August in 1985. In September 1987, 2 dissolved oxygen values were below 4 mg/l, and in 1985 there were 81 values below 4 mg/l, Figure 16.

Figure 17 displays the five year dissolved oxygen arithmetic mean of all semi-monthly averages for the northern New Jersey perpendicular stations. The average dissolved oxygen in early May was 8 mg/l. From May through late July the dissolved oxygen gradually decreased to approximately 4.8 mg/l. The dissolved oxygen remained at this level in early August and then decreased to a low of approximately 4.2 mg/l in late August. During September, October and November there was a rapid dissolved oxygen recovery.

Figure 18 displays the five year dissolved oxygen arithmetic mean of

FIGURE 14

DISSOLVED OXYGEN CONCENTRATIONS BELOW 4 MG/L NEW JERSEY COAST JULY

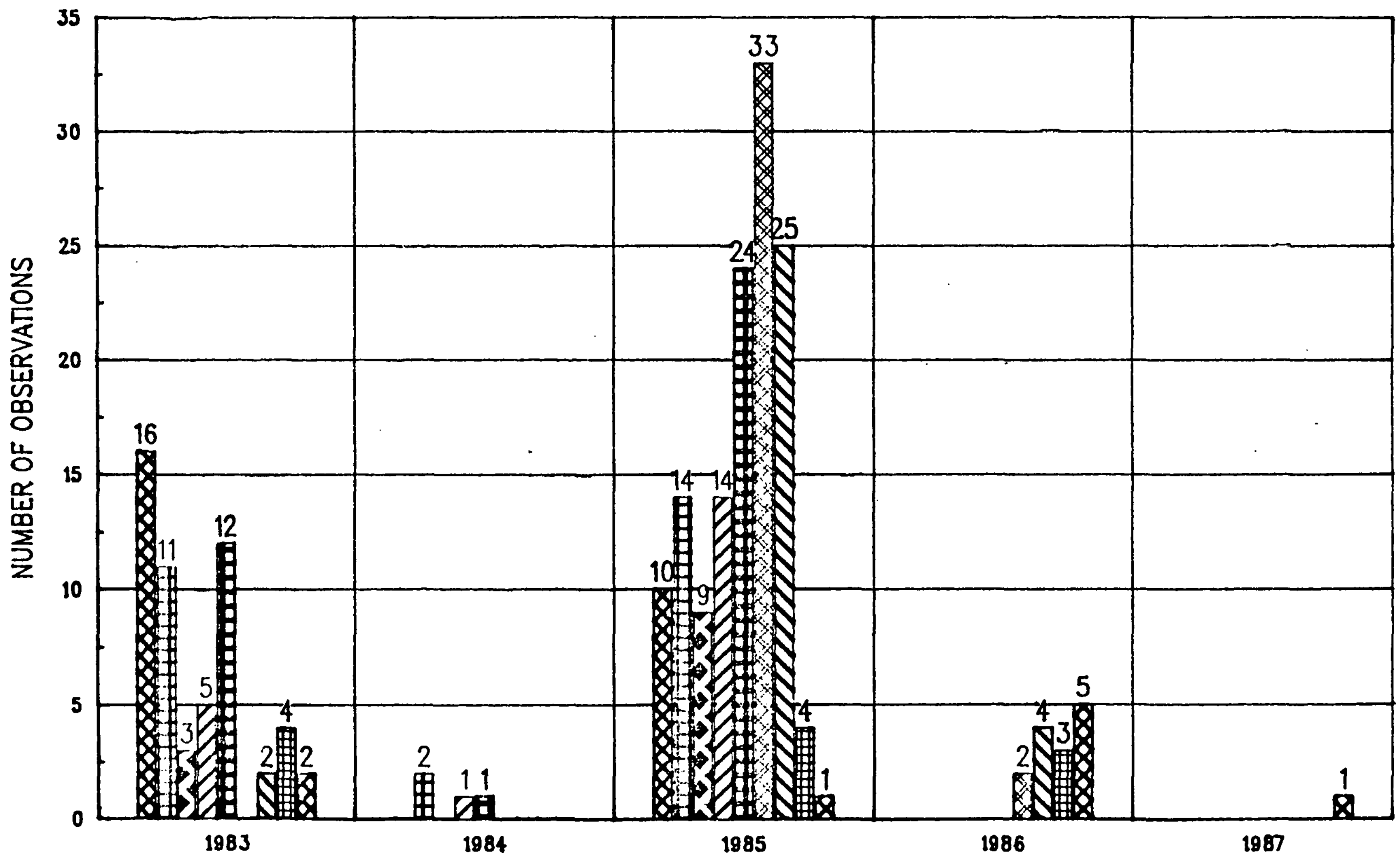


FIGURE 15

DISSOLVED OXYGEN CONCENTRATIONS BELOW 4 MG/L NEW JERSEY COAST AUGUST

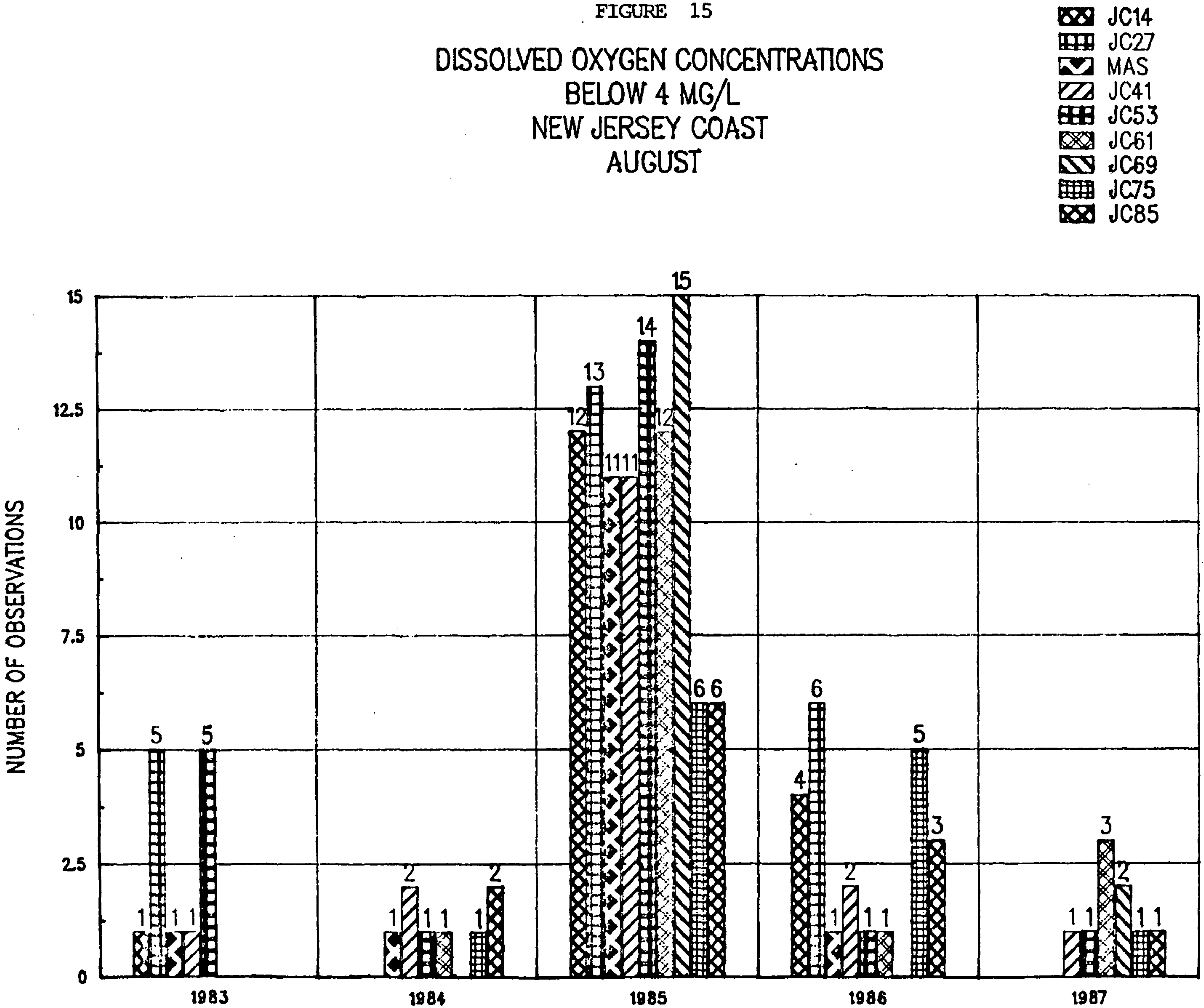


FIGURE 16

DISSOLVED OXYGEN CONCENTRATIONS
BELOW 4 MG/L
NEW JERSEY COAST
SEPTEMBER

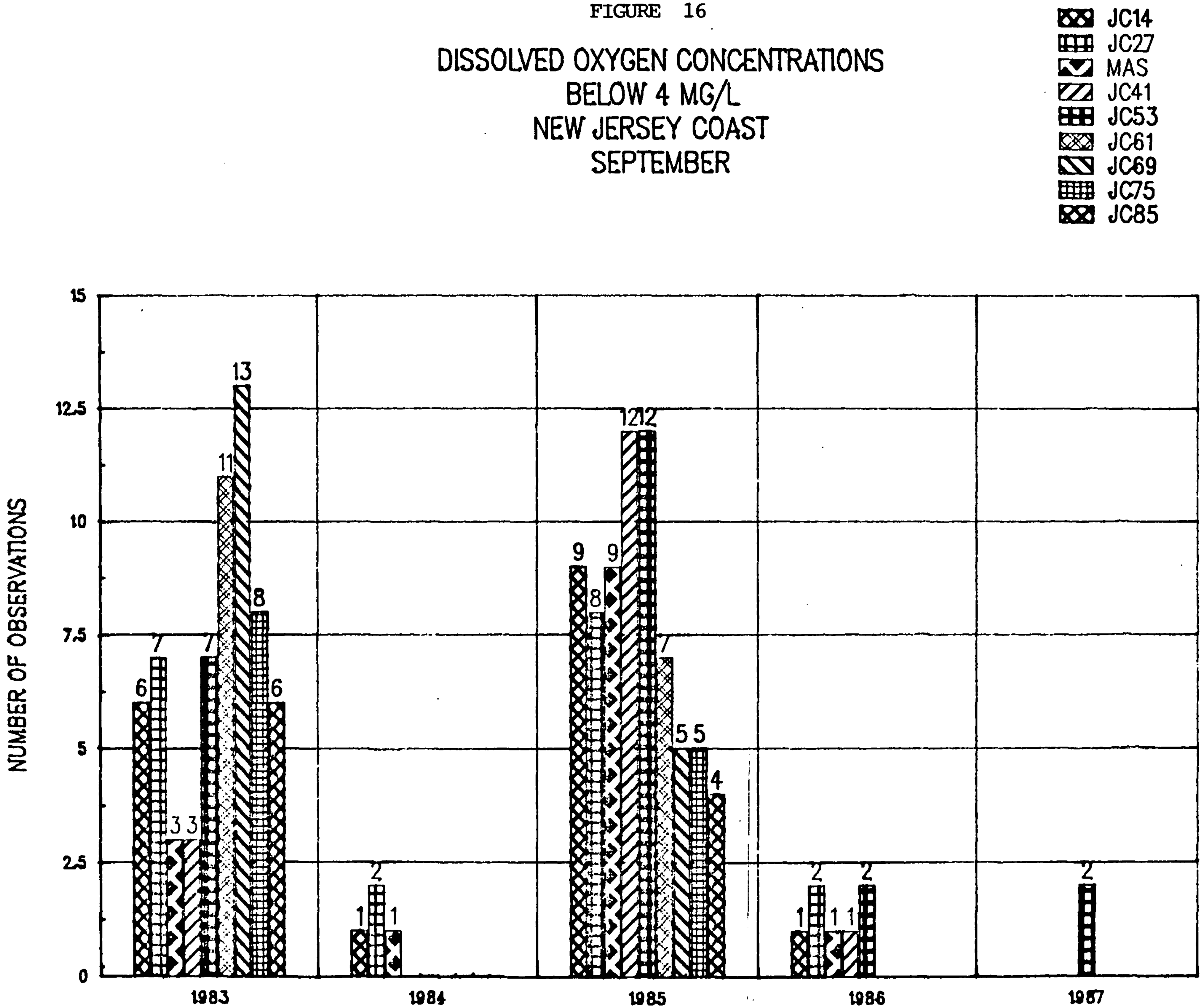
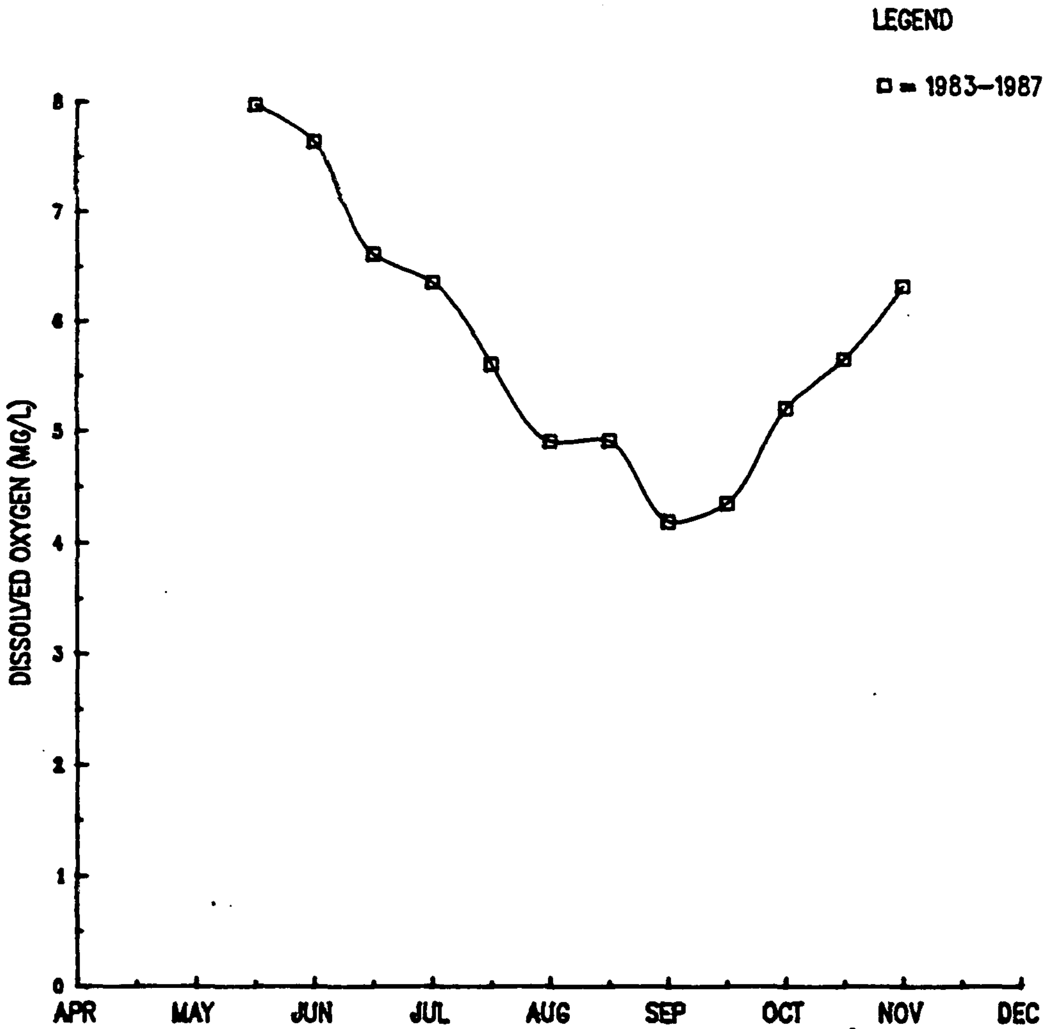
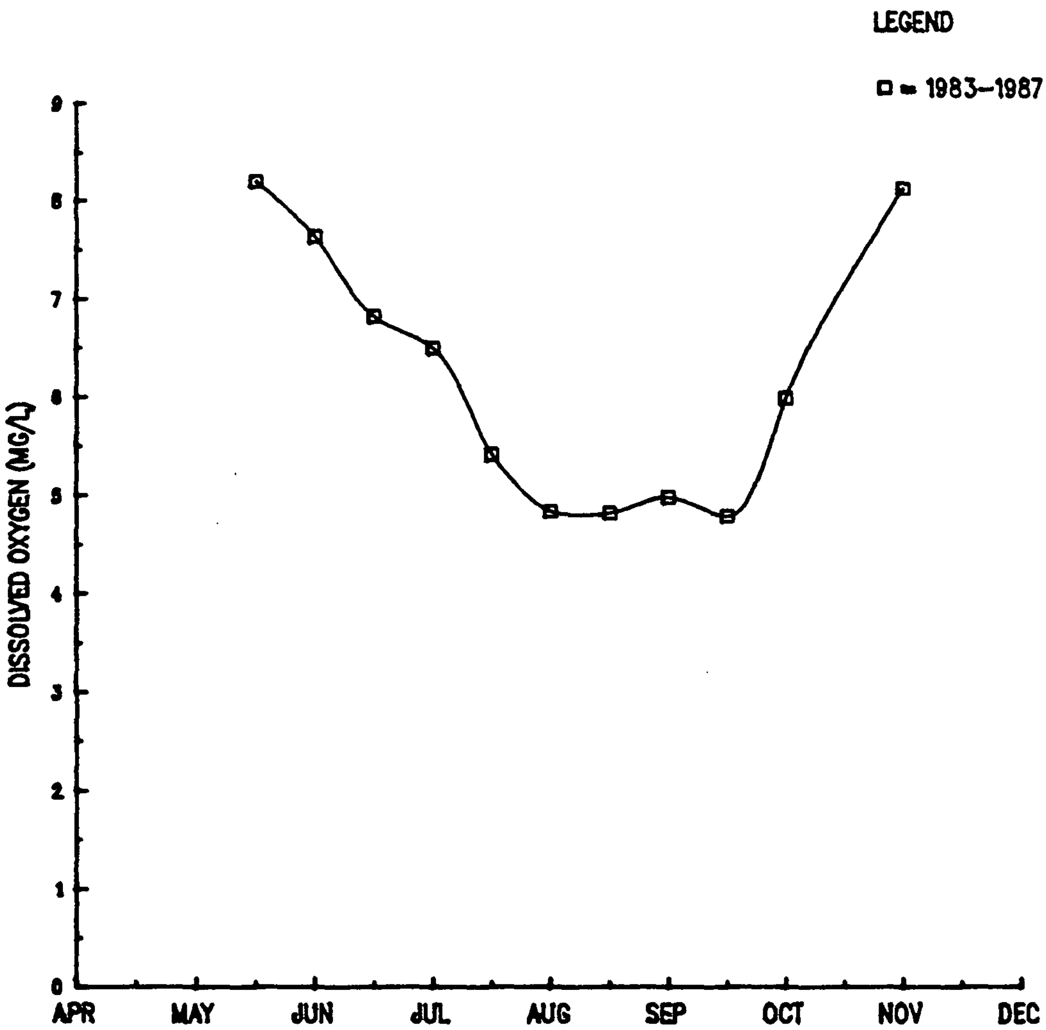


FIGURE 17



NORTHERN NEW JERSEY COAST BOTTOM DISSOLVED OXYGEN, FIVE YEAR AVERAGE OF THE INDIVIDUAL SEMIMONTHLY AVERAGES, 1983 TO 1987.

FIGURE 18



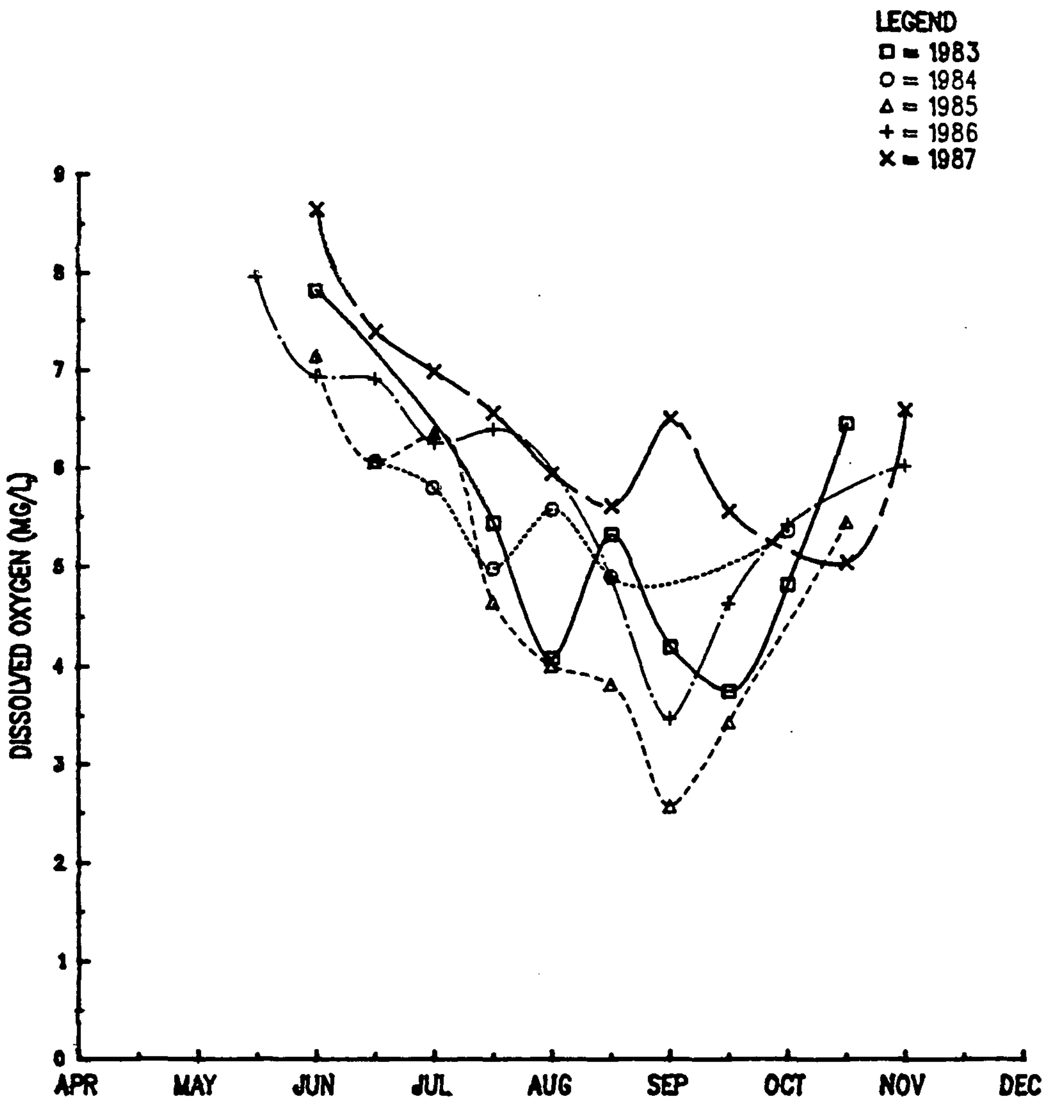
SOUTHERN NEW JERSEY COAST BOTTOM DISSOLVED OXYGEN, FIVE YEAR AVERAGE OF THE INDIVIDUAL SEMIMONTHLY AVERAGES, 1983 TO 1987.

all semi-monthly averages for the southern New Jersey perpendicular stations. In early May, the dissolved oxygen average was 8.2 mg/l. From May through July, the dissolved oxygen gradually decreased to 4.8 mg/l. The dissolved oxygen rose slightly in late August, then decreased to a low of 4.7 mg/l in mid-September. During late September and October the dissolved oxygen increased substantially.

Figures 19 and 20 illustrate the five year dissolved oxygen trends for the northern New Jersey perpendicular stations and the southern New Jersey perpendicular stations, respectively. Figure 19 shows that in 1983 and 1984 a dissolved oxygen "double minima" occurred. During 1983, the first low occurred in late July, followed by a second low in early September. The "double minima" in 1984 was not as prominent as in 1983, with the first low occurring in early July and the second in early August. During the last five years, the dissolved oxygen values were lowest from July through September 1985. In late August 1985, the average dissolved oxygen concentration dropped to a low of 2.5 mg/l. During June through September of 1986, the dissolved oxygen levels were approximately 1-2 mg/l greater than the same time period in 1985. With the exception of early October, the dissolved oxygen averages along northern New Jersey were higher than any of the previous four years.

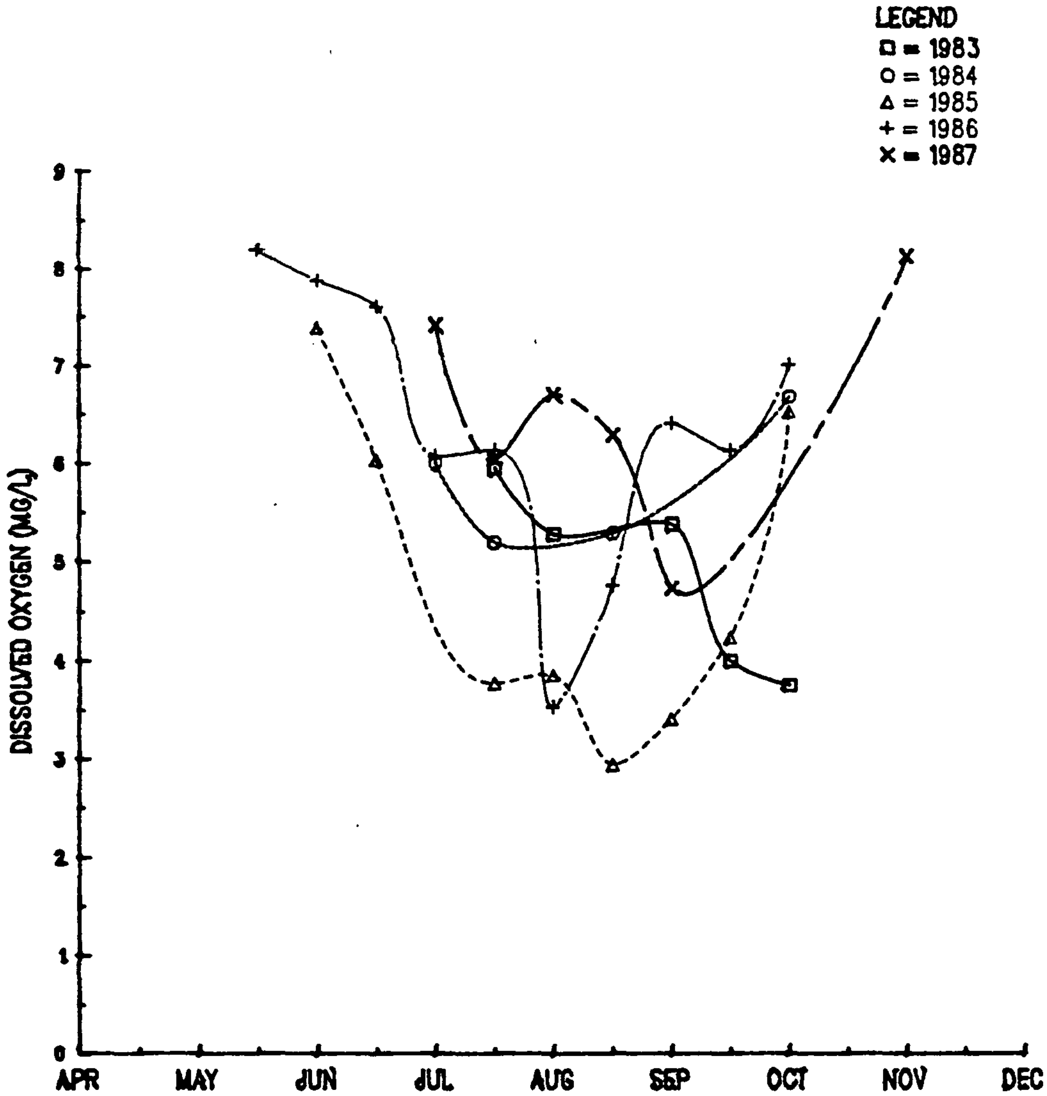
Figure 20 illustrates that, for the most part, the lowest dissolved oxygen levels along the southern New Jersey perpendicular stations during the last five years occurred in 1985. With the exception of late August, the dissolved oxygen levels along the southern New Jersey perpendiculars in 1987 were equal to or above the dissolved oxygen averages of the previous

FIGURE 19



NORTHERN NEW JERSEY COAST BOTTOM DISSOLVED OXYGEN, 1983–1987 COMPARISON. SEMIMONTHLY AVERAGES OF ALL JC14–JC53 PERPENDICULAR STATIONS.

FIGURE 20



SOUTHERN NEW JERSEY COAST BOTTOM DISSOLVED OXYGEN, 1983–1987 COMPARISON. SEMIMONTHLY AVERAGES OF ALL JC61–JC85 PERPENDICULAR STATIONS.

four years.

Figure 21 displays the percentages of bottom dissolved oxygen samples with concentrations below 4 mg/l along the New Jersey perpendiculars over the last five years. The highest percentage of low dissolved oxygen values, 44.4 percent, occurred in 1985. In 1987, the percentage of low dissolved oxygen values was lower than any of the previous four years, only 3.7 percent. The graph indicates that the percentage of dissolved oxygen values below 4 mg/l fluctuates considerably from year to year. In 1983 and 1985, the percentage of dissolved oxygen concentrations below 4 mg/l was significantly greater than in the other three years.

Figure 22 shows a five year comparison of the semi-monthly averages for the New York Bight Apex stations for the years 1983-1987. The average dissolved oxygen concentrations remained above 4 mg/l throughout the five year period, except for early September in 1985 when the dissolved oxygen average fell to 3.5 mg/l. A dissolved oxygen "double minima" was observed in 1983, 1985 and 1987. In general, the New York Bight Apex dissolved oxygen levels improved from 1985 to 1987. The highest dissolved oxygen averages in the Apex occurred in 1987.

All of the dissolved oxygen trend graphs presented of the New Jersey perpendicular stations show that after an unusually large number of low dissolved oxygen concentrations in 1985, there was considerable improvement in 1986 and 1987. The prolonged depressed dissolved oxygen levels in 1985 were attributed to the decomposition of the organisms responsible for the numerous algal blooms that occurred, the lack of meteorological

PERCENT OF BOTTOM DO VALUES BELOW 4mg/l

OFF THE NJ COAST OVER THE LAST 5 YEARS

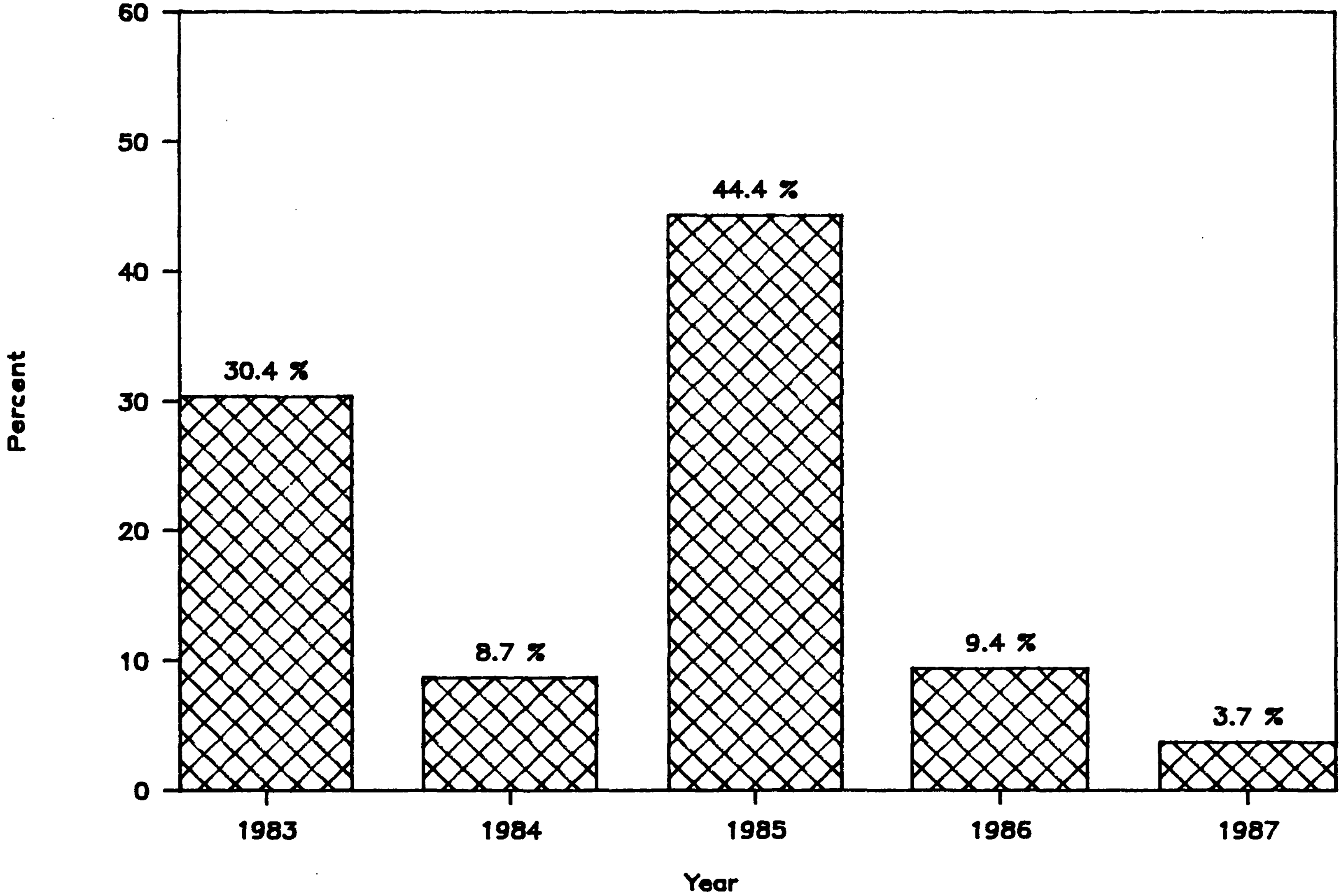
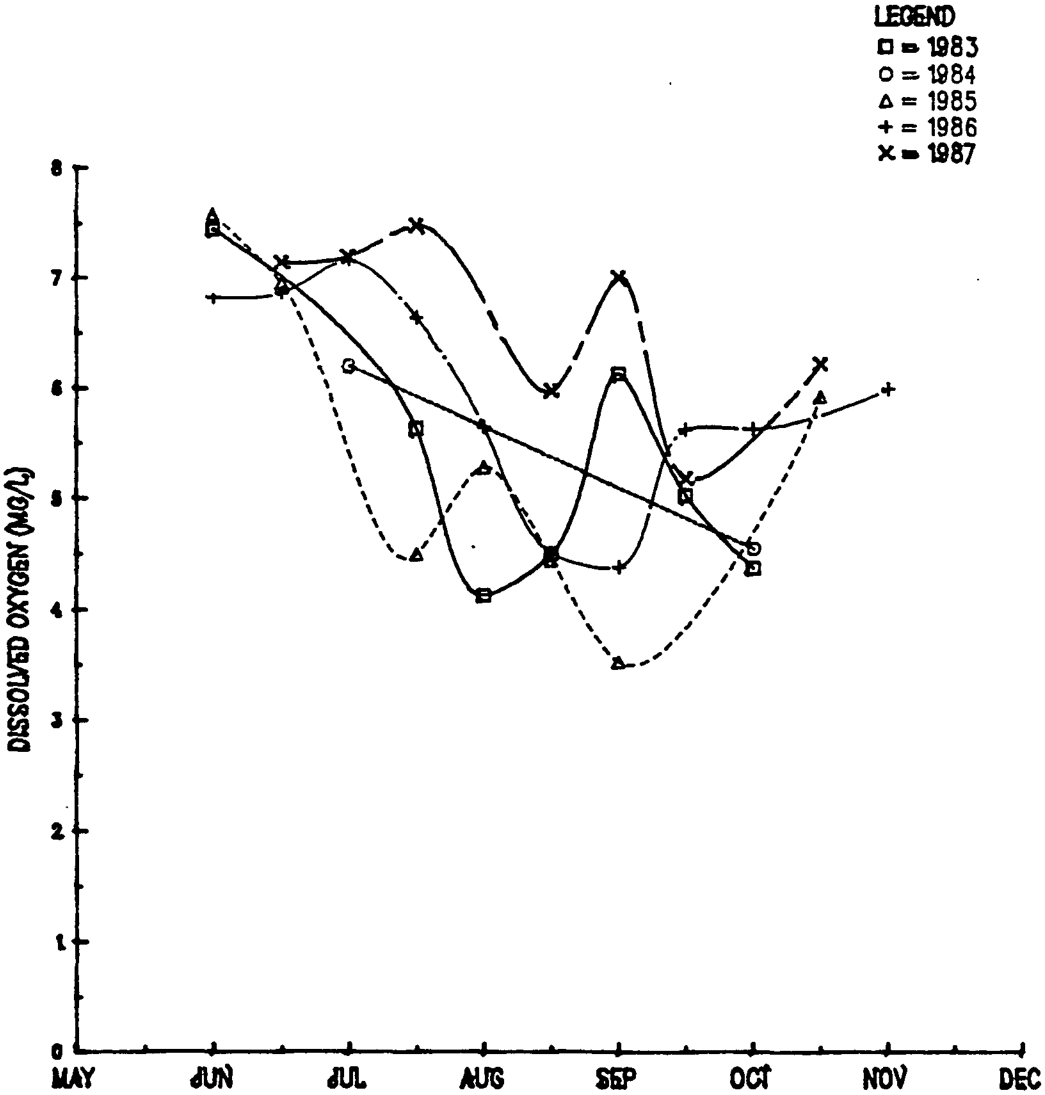


FIGURE 21

FIGURE 22



NEW YORK BIGHT BOTTOM DISSOLVED OXYGEN, 1983–1987 COMPARISON. SEMIMONTHLY AVERAGE OF ALL NEW YORK BIGHT STATIONS.

events favoring reaeration, such as substantial winds and storm activity, and the presence of a strong thermocline. During the summers of 1986 and 1987 fewer algal blooms were observed, higher winds occurred, and there were numerous storms promoting reaeration. However, 1987 was plagued with dead dolphins, floating garbage and sewage sludge digester material washing up on New Jersey beaches.

V. BACTERIOLOGICAL RESULTS

FECAL COLIFORMS

New Jersey

Table 6 presents a summary of the fecal coliform data collected along the coast of New Jersey between May 21, 1987 and October 5, 1987. The geometric mean for each station is plotted in Figure 23. The overall State water quality standard for New Jersey is 50 fecal coliforms/100ml. The State standard for primary contact recreation along the New Jersey coast is a geometric mean of 200 fecal coliforms/100 ml based on five or more samples analyzed within a 30 day period. Due to the low values found and the relatively small number of samples collected, only one geometric mean was calculated for each station over the entire summer. The highest geometric mean, 4.5, was at station JC 93 at Wildwood. The second highest geometric mean, 3.1, was at station JC 27 at Belmar. All of the geometric means are very low. Figure 23 clearly shows that the New Jersey coastal stations are well below the bacteriological standard. Based on fecal coliform data, New Jersey coastal waters have excellent water quality.

Throughout the summer sampling period, a total of 542 samples were collected for fecal coliform analysis along the New Jersey Coast. Of the 542 samples, four or 0.7 percent were above 50 fecal coliforms/100ml. These samples were:

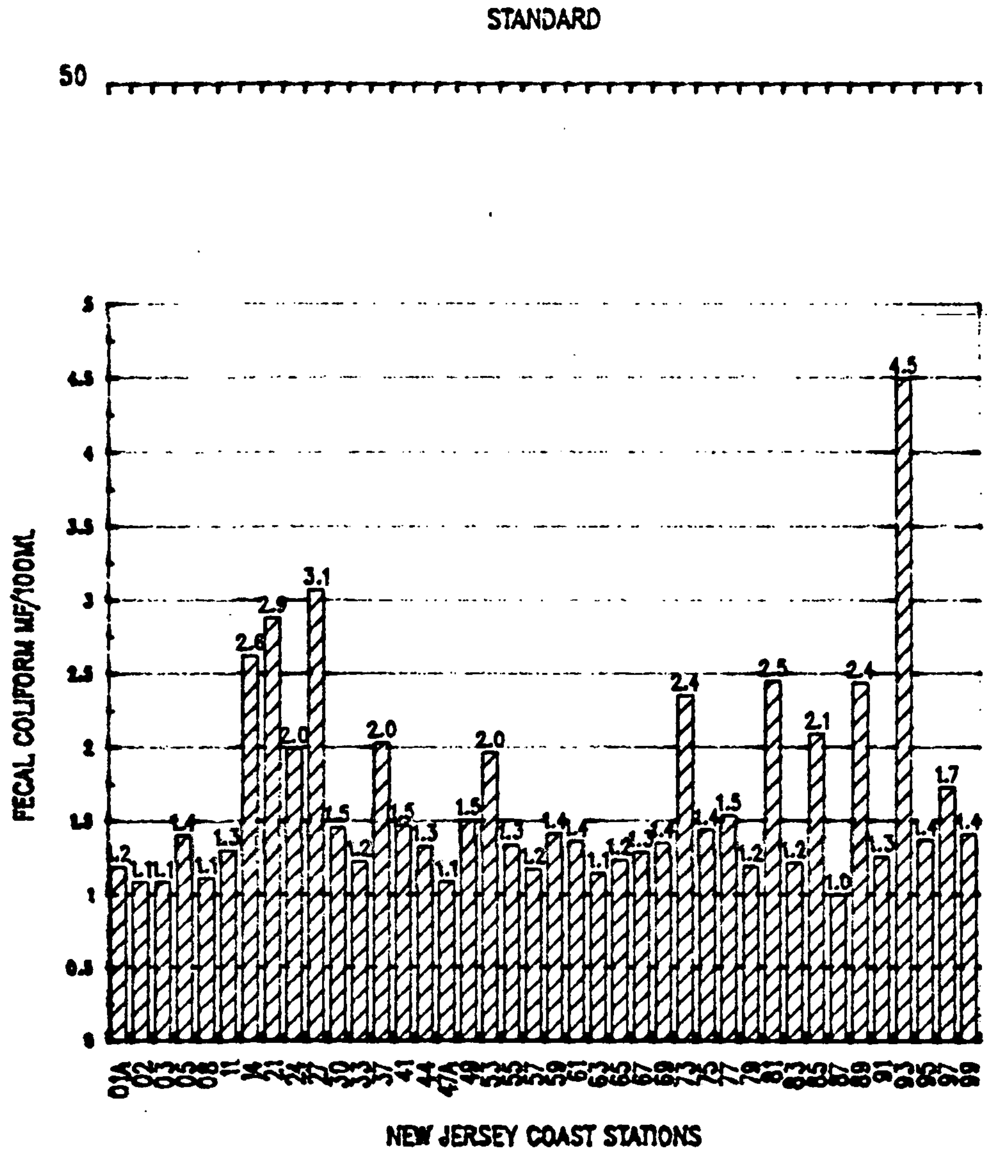
Station	Date Sampled	Fecal Coliforms/100ml
JC 21	8/5/87	216
JC 24	8/12/87	75
JC 59	7/29/87	53
JC 85	7/8/87	56

TABLE 6

Summary of fecal coliform data
collected along the New Jersey coast
May 21, 1987 through October 5, 1987

Station	Number of Samples Collected	Maximum Value Fecal Coliform/100ml	Geometric Mean Fecal Coliform/100ml
JC 01A	16	2	1.2
JC 02	16	2	1.1
JC 03	16	2	1.1
JC 05	16	12	1.4
JC 08	16	3	1.1
JC 11	16	6	1.3
JC 14	16	34	2.6
JC 21	17	216	2.9
JC 24	17	75	2.0
JC 27	17	31	3.1
JC 30	16	24	1.5
JC 33	16	3	1.2
JC 37	16	8	2.0
JC 41	16	8	1.5
JC 44	16	6	1.3
JC 47A	15	2	1.1
JC 49	16	12	1.5
JC 53	17	17	2.0
JC 55	17	6	1.3
JC 57	17	4	1.2
JC 59	16	53	1.4
JC 61	16	6	1.4
JC 63	14	7	1.1
JC 65	14	10	1.2
JC 67	14	12	1.3
JC 69	14	4	1.4
JC 73	9	17	2.4
JC 75	9	9	1.4
JC 77	9	12	1.5
JC 79	9	5	1.2
JC 81	9	40	2.5
JC 83	9	3	1.2
JC 85	9	56	2.1
JC 87	9	1	1.0
JC 89	9	20	2.4
JC 91	9	2	1.3
JC 93	9	49	4.5
JC 95	10	8	1.4
JC 97	10	20	1.7
JC 99	10	4	1.4

FIGURE 23



GEOMETRIC MEANS OF FECAL COLIFORM DATA COLLECTION ALONG THE COAST OF NEW JERSEY, MAY 21, 1987 TO OCT 5, 1987.
(ACTUAL VALUES PRINTED ABOVE BARS)

Long Island

Table 7 presents a summary of the fecal coliform data collected along the coast of Long Island from May 18, 1987 through October 6, 1987. The geometric mean for each station is plotted in Figure 24. The New York State standard for primary contact recreation along the Long Island coast is 200 fecal coliforms/100 ml. This value is a monthly geometric mean of five or more samples. As with the New Jersey data, due to the low values found and the relatively small number of samples collected, only one geometric mean was calculated for each station over the entire summer. The highest geometric mean was 2.6, which occurred at station LIC 05, Far Rockaway Beach. The second highest geometric mean was 2.1, which occurred at LIC 10, Hempstead Beach. From Figure 24, it is apparent that the standard was not approached. Based on fecal coliform data, the New York coastal waters along Long Island are of excellent quality.

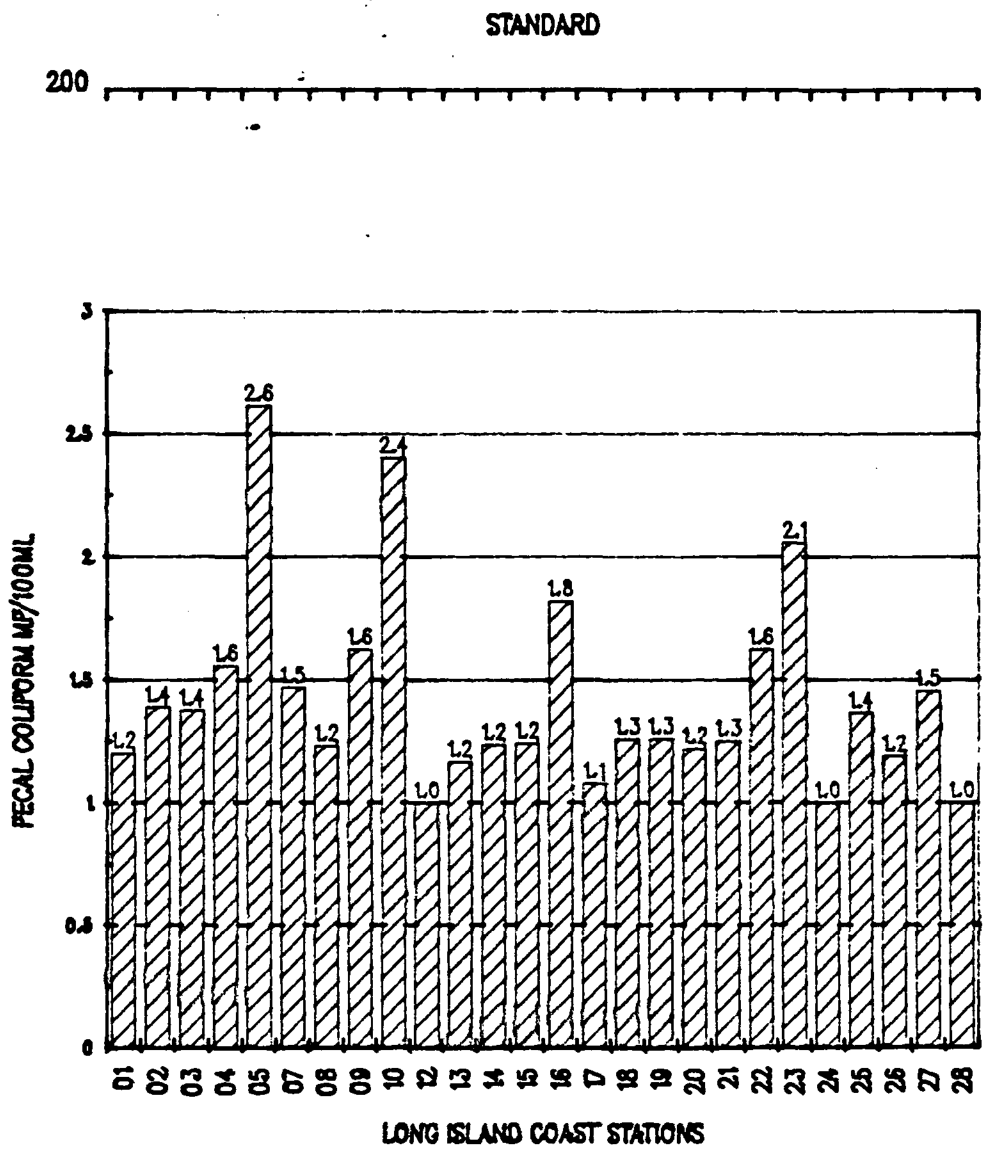
A total of 310 samples were collected during the summer along the coast of Long Island and analyzed for fecal coliform bacteria. The highest density found all summer, 38 fecal coliforms/100 ml, was at station LIC 16. This value is well below the New York State standard.

TABLE 7

Summary of fecal coliform data
collected along the Long Island coast
May 18, 1987 through October 6, 1987

Station	Number of Samples collected	Maximum Value Fecal Coliform/100ml	Geometric Mean Fecal Coliform/100ml
LIC 01	15	4	1.2
LIC 02	15	23	1.4
LIC 03	15	8	1.4
LIC 04	15	8	1.6
LIC 05	15	16	2.6
LIC 07	15	7	1.5
LIC 08	16	7	1.2
LIC 09	16	4	1.6
LIC 10	16	9	2.4
LIC 12	15	1	1.0
LIC 13	16	3	1.1
LIC 14	15	4	1.2
LIC 15	16	4	1.2
LIC 16	15	38	1.8
LIC 17	9	2	1.1
LIC 18	9	4	1.3
LIC 19	9	2	1.3
LIC 20	9	3	1.2
LIC 21	8	3	1.3
LIC 22	8	12	1.6
LIC 23	8	10	2.1
LIC 24	8	0	1.0
LIC 25	8	6	1.4
LIC 26	8	4	1.2
LIC 27	8	5	1.5
LIC 28	8	0	1.0

FIGURE 24



GEOMETRIC MEANS OF FECAL COLIFORM DATA COLLECTION ALONG THE COAST OF LONG ISLAND, MAY 18, 1987 TO OCT 6, 1987.
(ACTUAL VALUES PRINTED ABOVE BARS)

New York Bight Apex

During the summer of 1987, a total of 366 samples were collected in the inner New York Bight (NYB) for fecal coliform analysis. The stations sampled were the 20 inner NYB series stations, the LIC 09 and LIC 14 perpendicular stations, and the JC 14 and JC 27 perpendicular stations. None of the fecal coliform densities exceeded 50 fecal coliforms/100ml. The highest fecal coliform count, 38/100ml, occurred at station NYB 25 on June 18. There is no fecal coliform standard for the New York Bight Apex waters. The value of 50 fecal coliforms/100 ml was chosen for use in comparison with previous years. In 1982, 1983, 1984, 1985 and 1986, the percentage of samples having densities above 50/100 ml was 2.1, 0.9, 0.4, 1.3 and 0.0 respectively. Fecal coliform levels in the New York Bight Apex have declined over the last five years.

ENTEROCOCCI

The 1987 sampling program marked the third year that samples were collected for enterococcus bacteria. Enterococcus bacteria are members of the fecal streptococci group. The occurrence of fecal streptococci in bathing waters indicates the presence of fecal contamination from warm-blooded animals. The enterococcus group of bacteria includes the following species: *Streptococcus faecales*; *S. faecalis*, subsp. *liquefaciens*; *S. faecalis*, subsp. *zyogenes*; and *S. faecium*. Recent research (Cabelli 1982, 1983) has demonstrated that enterococcus bacteria show a better correlation than fecal coliforms to gastroenteritis caused by swimming in contaminated water. The EPA criterion for marine waters, a geometric mean of 35 enterococcus bacteria/100ml, was published in the Federal Register on March 7, 1986.

New Jersey

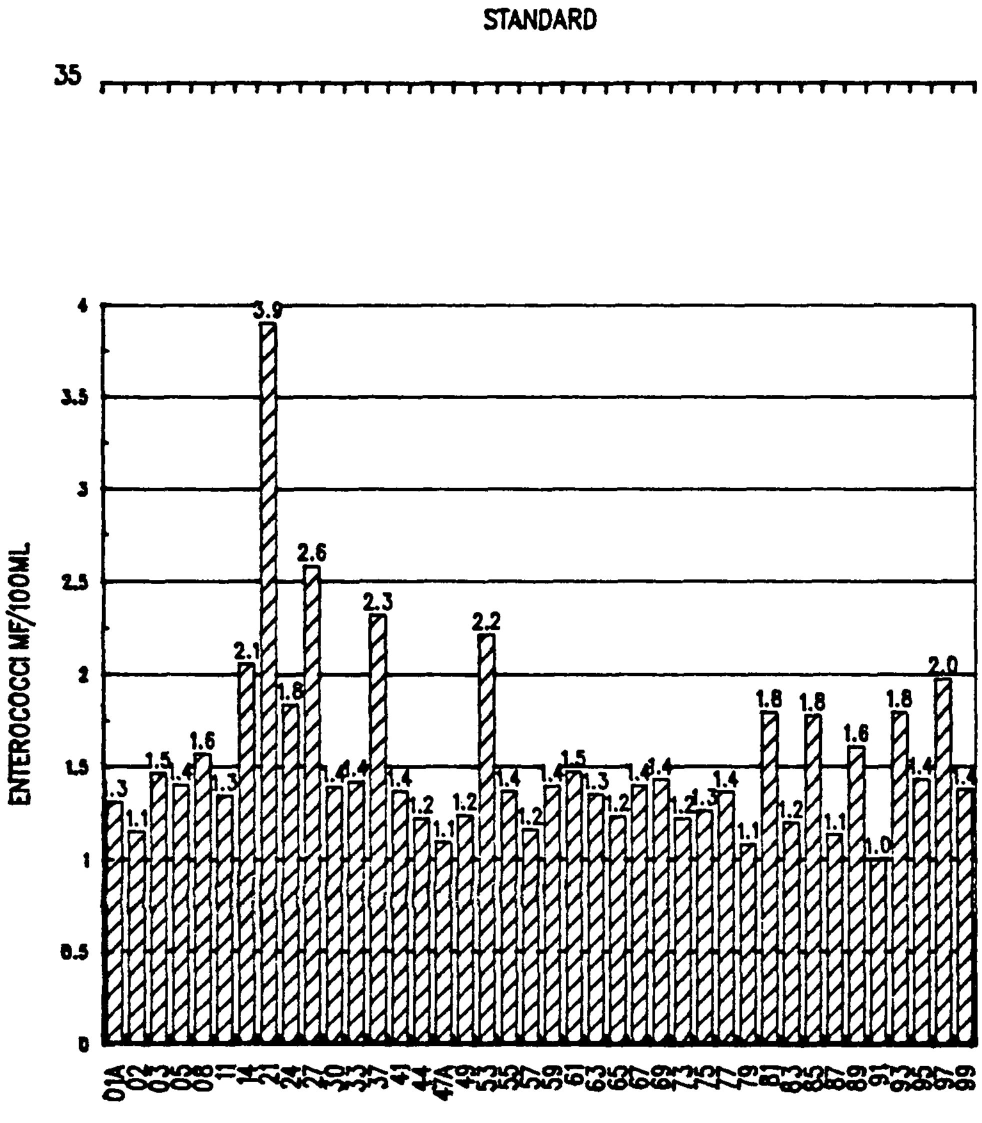
Table 8 presents a summary of the enterococcus data collected along the New Jersey coast from May 21 to October 5, 1987. The State of New Jersey does not have a water quality standard for enterococcus bacteria. The EPA criterion for enterococci in marine waters is 35 bacteria/100ml. This criterion is based on a geometric mean of a statistically sufficient number of samples, generally not less than five samples equally spaced over a thirty day period. Due to the low values found and the relatively small number of samples collected, only one geometric mean was calculated for each station over the entire summer. The geometric mean for each station is plotted in Figure 25. Figure 25 shows that the geometric mean of enterococcus densities at each station is well below the EPA criterion. All the geometric means

TABLE 8

Summary of enterococci data
collected along the New Jersey coast
May 21, 1987 through October 5, 1987

Station	Number of Samples Collected	Maximum Value Enterococci/100ml	Geometric Mean Enterococci/100ml
JC 01A	16	6	1.3
JC 02	16	3	1.1
JC 03	16	44	1.5
JC 05	16	6	1.4
JC 08	16	6	1.6
JC 11	16	6	1.3
JC 14	16	92	2.1
JC 21	17	620	3.9
JC 24	17	18	1.8
JC 27	17	11	2.6
JC 30	16	4	1.4
JC 33	16	5	1.4
JC 37	16	32	2.3
JC 41	16	8	1.4
JC 44	16	6	1.3
JC 47A	16	4	1.1
JC 49	16	5	1.2
JC 53	17	14	2.2
JC 55	17	6	1.4
JC 57	17	3	1.2
JC 59	16	17	1.4
JC 61	16	6	1.5
JC 63	14	11	1.3
JC 65	14	3	1.2
JC 67	14	9	1.4
JC 69	14	5	1.4
JC 73	9	3	1.2
JC 75	9	8	1.3
JC 77	9	4	1.4
JC 79	9	2	1.1
JC 81	9	4	1.8
JC 83	9	5	1.2
JC 85	9	11	1.8
JC 87	9	3	1.1
JC 89	9	12	1.6
JC 91	9	1	1.0
JC 93	9	4	1.8
JC 95	10	9	1.4
JC 97	10	6	2.0
JC 99	10	3	1.4

FIGURE 25



GEOMETRIC MEANS OF ENTEROCOCCI DATA COLLECTION ALONG THE COAST OF NEW JERSEY, MAY 21, 1987 TO OCT 5, 1987.
(ACTUAL VALUES PRINTED ABOVE BARS)

are low. The highest mean, 3.9, occurred at station JC 21, Asbury Park.

A total of 543 samples were analyzed for enterococcus bacteria along the New Jersey coast. Three enterococcus densities were above the criterion of 35/100ml. These samples were:

Station	Date	Enterococci/100ml
JC 03	8/5/87	44
JC 14	7/8/87	92
JC 21	8/5/87	620

The cause of the elevated value at JC 21 was probably poorly treated sewage from the Asbury Park Sewage Treatment Plant.

Long Island

Table 9 presents a summary of the enterococcus data collected along the Long Island coast from May 18, 1987 to October 6, 1987. The geometric mean for each station is plotted in Figure 26. New York State does not have a water quality standard for enterococcus bacteria. As with the New Jersey data, the enterococcus data along the Long Island coast are compared to the EPA criterion of 35 enterococci/100ml. Due to the low values found and the relatively small number of samples collected per station, only one geometric mean was calculated for each station over the summer. The highest geometric mean, 3.3, occurred at station LIC 05, Far Rockaway Beach. Figure 26 shows that all of the geometric means are well below the EPA criterion.

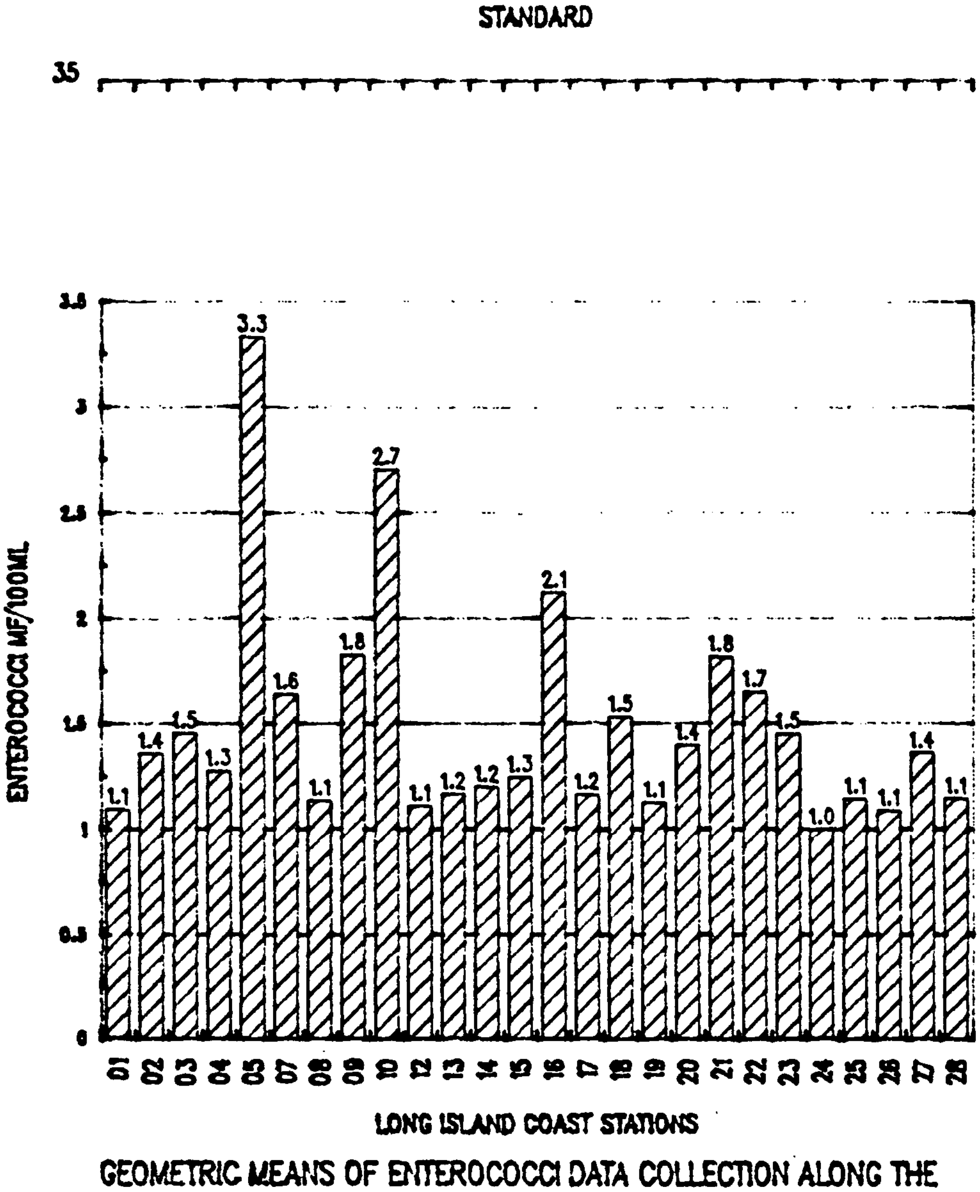
A total of 315 enterococcus samples were collected along the coast of

TABLE 9

Summary of enterococci data
collected along the Long Island coast
May 18, 1987 through October 6, 1987

Station	Number of Samples collected	Maximum Value Enterococci/100ml	Geometric Mean Enterococci/100ml
LIC 01	15	2	1.1
LIC 02	15	13	1.4
LIC 03	15	6	1.5
LIC 04	15	5	1.3
LIC 05	15	40	3.3
LIC 07	15	16	1.6
LIC 08	16	4	1.1
LIC 09	16	8	1.8
LIC 10	16	10	2.7
LIC 12	15	5	1.1
LIC 13	16	3	1.2
LIC 14	15	4	1.2
LIC 15	16	6	1.3
LIC 16	15	13	2.1
LIC 17	9	2	1.2
LIC 18	9	6	1.5
LIC 19	9	3	1.1
LIC 20	9	7	1.4
LIC 21	8	10	1.8
LIC 22	8	7	1.7
LIC 23	8	5	1.5
LIC 24	8	1	1.0
LIC 25	8	3	1.1
LIC 26	8	2	1.1
LIC 27	8	4	1.4
LIC 28	8	3	1.1

FIGURE 26



GEOMETRIC MEANS OF ENTEROCOCCI DATA COLLECTION ALONG THE COAST OF LONG ISLAND, MAY 18, 1987 TO OCT 6, 1987. (ACTUAL VALUES PRINTED ABOVE BARS)

Long Island during the summer. Only one sample exceeded 35 enterococci/100ml. On August 26, a count of 40 enterococci/100ml occurred at Far Rockaway Beach, station LIC 05.

Based on the enterococcus densities, the water quality of the Long Island coast is excellent.

New York Bight Apex

During the summer of 1987 a total of 366 samples were collected in the inner New York Bight for enterococcus analysis. The stations sampled were the same as those sampled for fecal coliforms. One sample had an enterococcus density above the EPA criterion of 35/100ml. On August 17, a count of 36 enterococci/100ml was detected at station NYB 25. The cause of this elevated value was a recent sewage sludge dump at the sewage sludge disposal site.

A further discussion of the bacteriological data prepared by the EPA Regional laboratory, which includes a discussion of the standards, indicator bacteria, materials, methods, and results, is presented in Appendix B.

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5. U.S. Environmental Protection Agency; "New York Bight Water Quality Summer of 1983", Environmental Services Division, Region 2, Edison, New Jersey, February 1985.

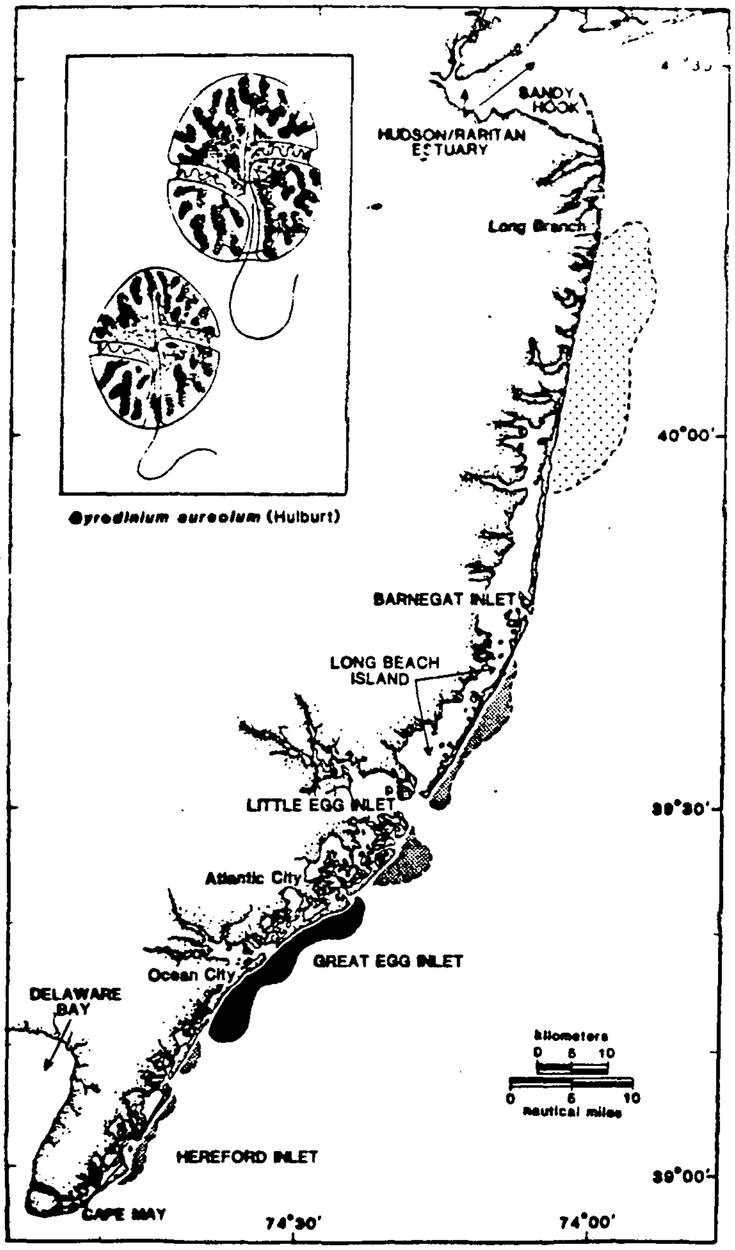
6. U.S. Environmental Protection Agency; "New York Bight Water Quality Summer of 1984", Environmental Services Division, Region 2, Edison, New Jersey, August 1985.

7. U.S. Environmental Protection Agency; "New York Bight Water Quality Summer of 1985", Environmental Services Division, Region 2, Edison, New Jersey, August 1986.

8. U.S. Environmental Protection Agency; "New York Bight Water Quality Summer of 1986", Environmental Services Division, Region 2, Edison, New Jersey, July 1987.

APPENDIX "A"

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION



Gyrodinium aureolum (Hulburt)

APPENDIX "A"

SUMMARY OF PHYTOPLANKTON BLOOMS AND RELATED CONDITIONS IN NEW JERSEY COASTAL WATERS SUMMER OF 1987

U.S. ENVIRONMENTAL PROTECTION AGENCY

Summary of Phytoplankton Blooms and Related Conditions in New Jersey Coastal Waters Summer of 1987

New Jersey Department of
Environmental Protection
Division of Water Resources
Bureau of Monitoring Management
Biological Services Unit

Summary of Phytoplankton Blooms and Related Conditions in New Jersey Coastal Waters, Summer of 1987

Introduction

The New Jersey Department of Environmental Protection (DEP) annually examines marine phytoplankton assemblages with regard to coastal water quality conditions. This information, obtained cooperatively with the U.S. Environmental Protection Agency (EPA), Region II, is summarized for the 1987 season. These results compliment the physio-chemical and sanitary bacteriological data also gathered during their annual New York Bight Water Quality survey (USEPA, 1978-1988 inc.) and the Coastal Cooperative Monitoring Program involving DEP and the New Jersey shore county health agencies (NJDEP, 1987). Routine helicopter surveillance by the EPA in the New York Bight has been conducted since 1977.

We have observed recurring red tides of a few phytoflagellate species in the Hudson/Raritan estuary and adjacent New Jersey waters for over 25 years. While none of these have been of the acutely toxic varieties, some have caused minor discomfort to bathers (Mahoney and McLaughlin, 1977). A serious bloom of the dinoflagellate, Prorocentrum micans, along the Monmouth County shore in 1968 first aroused the DEP to investigate the problem. In 1969, the Interagency Committee on Marine Plankton Blooms was formed including the National Marine Fisheries Service (NMFS) at Sandy Hook, and the U.S. Food and Drug Administration as well as the EPA, NJDEP and the Long Island, New York county health agencies. The committee has functioned to the present to coordinate government response in the event of serious blooms. In 1973, the NJDEP and NMFS cooperatively instituted a long-term, intensive phytoplankton study of Lower New York Bay and adjacent New Jersey estuarine and coastal waters (see Olsen and Cohn, 1979). Our methods, based on recommendations of the Scientific Committee on Oceanic Research (1974) and the American Public Health Association (1976), essentially employed the Sedgewick/Rafter and Palmer/Maloney counting techniques; they have been incorporated by the DEP laboratory presently as Standard Operating Procedures.

Helicopter surveillance by the USEPA commenced following the catastrophic, Bight-wide Ceratium tripos bloom of 1976, which caused extensive anoxia and consequent fish kills in bottom waters (in Swanson and Sindermann ,eds. , 1979). An additional interagency group, the New York Bight Advisory Committee, was formed then, primarily to respond to hypoxia problems. Routine helicopter sampling along New Jersey for phytoplankton and nutrients was done initially at nine stations from Raritan Bay to Island Beach. Red tides rarely occurred in the southern New Jersey shore; however, in 1984-85, extensive "green tides" of

Gyrodinium aureolum occurred primarily from Long Beach Island to Cape May County (Mahoney et al, unpublished). Although these were associated with some incidents of mild sickness in bathers and localized kills of mussels and lady crabs, their most obvious consequence was diminished aesthetic value of the affected beaches. Following this, in 1986, three stations were added to include south Jersey in the phytoplankton sampling scheme (see Figures 1 and 2).

The events of 1984-1985 were the last major phytoflagellate blooms observed in New Jersey coastal waters. Red tides have generally been less extensive along the oceanfront (USEPA 1977-1986, inc.); however, blooms (especially of Katodinium rotundatum) have continued to develop in late spring/early summer in the Sandy Hook Bay vicinity. Other localized phytoflagellate blooms, such as in Delaware Bay have occurred just outside our areas of routine surveillance. Yellowish-brown water caused by a chlorophyte (Nannochloris sp.) normally dominant in summer has pervaded much of our intra-coastal system from Barnegat Bay southward, being somewhat less extensive in 1987 than the previous years. The same species has caused light green coloration in late summer from Raritan Bay southward along most of the New Jersey coast. Diatoms normally dominate the phytoplankton throughout the cooler months (October through May) with some pulses during summer. In 1987, several species of diatoms predominated through most of the summer season (Table 1); heavy blooms of Cerataulina pelagica and Cyclotella sp. caused brownish water discoloration in our northern sampling area early and late in the season, respectively. The summer of 1987 was also characterized by the presence of very clear and warm, apparently oceanic or shelf slope water in our nearshore areas despite the incidence of domestic floatable materials and the abundance of macro flora (sea lettuce) and fauna (salps, amphipods, etc.). Perhaps the most significant red tide in our region was somewhat removed from the Bight area; this was an extensive bloom of Prorocentrum triestinum (redfieldi) with some consequent fish kills, in Long Island Sound.

Results and Discussion

Table 1 shows the predominance of several diatoms, generally neritic species especialy Cerataulina pelagica, Thalassiosira spp. and Cyclotella sp., with frequent blooms during the 1987 summer season. These species are normally abundant periodically in New Jersey coastal waters from October to May (Olsen and Cohn, 1979) with occasional summer pulses. While phytoflagellate blooms were apparently minimal in 1987, the number of frequently-occurring species was about double the number of dominant diatom species for the summer period. This is indicated in Table 2, which shows a tendency toward greater phytoflagellate activity at certain locations (particularly RB15, JC30, and JC83) over others. A few species notably Olisthodiscus luteus, Katodinium rotundatum, and especialy Prorocentrum triestinum (redfieldi) which caused red tide in Long Island Sound, were more frequent spatially and temporally than others. The appearance of the green tide species, Gyrodinium aureolum in late August-early September at several locations, especially RB15 and JC83 (Tables 1 and 4) is notable in view of the blooms about this time in previous years (Mahoney et al, unpublished).

Following early season diatom blooms, and aside from conditions incidental (Table 4), ocean waters remained generally clear through mid-summer of 1987. The minute chlorophyte, Nannochloris atomus, was not quite as abundant at most coastal stations as in previous years (USEPA 1977-1986, inc.). The N. atomus bloom which caused yellowish-brown water in Barnegat Bay and other intracoastal areas developed a few weeks later and was somewhat less extensive than in previous years (see Table 4). The mid-August event where several thousand blue claw crabs were found dead in Barnegat Bay near the inlet was associated with a bloom of the dinoflagellate, Exuviaella marina, which apparently occluded crab gills. The presence of the brown tide species, "Aureococcus anorexefferens" which caused mortalities of bay scallop in eastern Long Island embayments (Bricelj and Siddall, 1987), was suspected in Barnegat Bay, but it has thus far not been identified in New Jersey. A pulse of N. atomus with resultant greenish water occurred from early to mid-August adjacent to the coast, possibly augmented by wash-out from tidal inlets (Table 4); several diatom species were also abundant around this time (Table 1). This was followed by increased turbidity, due possibly to weather and localized upwellings and, subsequently, to diatom blooms again in early September.

Historically, the phytoflagellate blooms in Lower New York Bay and adjacent New Jersey waters have been associated with hypertrophication (Mahoney and McLaughlin, 1977) in this highly urbanized region. Extensive red tides, particularly of Olisthodiscus luteus, have been less frequent in recent years

(USEPA 1977-1986 inc.); growth suppression, possibly by certain trace metals (Mahoney, 1982), may partially account for this. Available nutrient supplies are greatest in spring toward the inner estuary before being assimilated by phytoplankton growth in the lower estuary (Jeffries, 1962) and in the N.Y. Bight apex (Malone et al, 1985). Table 3 shows a general decrease in nutrient concentrations, especially nitrogen, from north to south; phosphorus is seen to be generally more available than nitrogen. However, some periods of concentration peaks are probably missed since sampling was done only in late spring and summer, and sampling frequency was lower at southern N.J. stations. With ambient nutrients depleted, summer phytoplankton blooms could be sustained by regeneration within the water column, by replenishment from external sources via drainage or discharge, or from upwelling of deeper bottom waters.

The bays and estuaries form natural basins concentrating nutrients and phytoplankton, thus the tendency for red tides to develop within their confines, often to wash out with current and wind to adjacent coastal areas. In our northern coastal area, phytoplankton assemblages found between Sandy Hook and Island Beach often resemble those in Lower New York Bay (Olsen and Cohn, 1979) suggesting the southward influence of the Hudson/Raritan estuary. Conversely, the plume of Delaware Bay at New Jersey's southern extreme can flow northward during periods of low runnoff and southerly winds (Bumpus, 1969). This is suggested in the abundance at station JC83 of Amphidinum fusiforme (Table 1), a dominant species in Delaware Bay providing sustenance for the oyster fishery, and at times causing patches of red water (Pomeroy et al, 1956). The green tides of 1984-85, caused by Gyrodinium aureolum, in the south-central New Jersey coast appear to have developed in the neritic waters of the region; similar green tides were not observed in either of the major estuaries or locally in the smaller coastal estuaries and back bays in the areas where the blooms were most intense. (Mahoney et al, unpublished).

Development of blooms in the New York Bight along our coast appears to be strongly dependent on weather and inner shelf circulation patterns (USEPA, 1986, 1987), optimally to concentrate phytoplankton and/or bring them in contact with nutrient-rich water. In European waters, where G. aureolum is the most important bloom species, red tides have resulted from vertical movement of the dinoflagellates in combination with wind-driven upwelling, or convergence of different water masses, especially near a coastline (Tangen, 1977). In the western north Atlantic, net flow alongshore from Cape Cod to Cape Hatteras is from northeast to southwest. This is often reversed toward the northeast in summer by prevailing southwesterly winds (Bumpus, 1973), which can result in offshore transport of surface water and upwelling of cooler bottom waters in the nearshore zone (Ingham and Eberwine, 1984). In the New York Bight, this may result in some degree of stagnation and accumulation of phytoplankton and other decomposing materials, with consequent hypoxia, in nearshore bottom areas (Han et al., 1979). Conversely, winds from a more easterly direction could cause retention of surface waters with resultant accumulations of phytoplankton and other materials along the coast. Maximum convergence onshore by northeast winds can result in downwelling of oxygenated surface water with corresponding increases in bottom dissolved oxygen in nearshore areas (NOAA data).

The latter situation was in evidence in 1987 with a predominance of easterly breezes (NOAA data, Table 4) and minimal hypoxia in bottom waters (USEPA data). Winds probably exacerbated the incidence of domestic floatable materials in our coastal waters (see Table 4). The onshore flow was apparently reinforced or influenced by offshore circulation patterns, evidenced in the presence of very clear and warm, Gulfstream-like surface waters in our nearshore areas through most of summer (Table 4 and 5). Table 5 shows periods of unusually warm water around July 10-11, July 23 and August 20 (NOAA, EPA data); accompanying atmospheric conditions were possibly associated with incidents of respiratory difficulty in bathers around these times (Table 4). The deaths of several hundred bottlenose dolphins, a species normally inhabiting inshore areas of the Mid-Atlantic Bight, was apparently due to an epidemic among the dolphins (see NJDEP, 1988) rather than to water conditions. The presence of nutrient-poor offshore water, plus the small, pelagic salps which are plankton feeders, may have been factors limiting phytoflagellate populations in 1987.

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TABLE 1. Succession of dominant phytoplankton species found in the 1987 survey. Relative abundance is defined as follows: frequent (.)=concentrations of 100-1000 cells/ml; dominant (+) = cell counts exceeding 1000/ml. Blooms (*) occurred where counts approached or exceeded 10,000/ml, often imparting visible coloration to the water. No designation indicates that the species either was present in very low concentrations or was not observed. For Nannochloris, because of its minute size (5um), the criterion is increased by a factor of ten (e.g. 10,000 for dominance, 100,000 for blooms). All species are listed under one of four taxonomic groups: (1) diatoms = Bacillariophyceae, (2) dinoflagellates = Dinophyceae; (3) other phytoflagellates = Chrysophyceae, Prasinophyceae, Euglenophyceae, Cryptophyceae, etc., (4) non-motile coccoids = Chlorophyceae.

Species/Dates	Sampling Location											
	RB32	RB15	JC05	JC11	JC21	JC30	JC49	JC57	JC65	JC75	JC83	JC93
May 30 - June 3												
1) Leptocylindrus danicus			+					.				
Skeletonema costatum	+	+										
Cerataulina pelagica	*	*	+	*	.	*	+	+				
3) Eutreptia lanowii				+				.				
Chroomonas sp.	+				.	+						
4) Chlorella sp.	*					+						
June 8[a]												
1) Cyclotella sp.	.	+			.	.		.				
C. pelagica			.		.		+	.				
2) Prorocentrum minimum		+										
Gymnodinium sp.		+										
3) Olisthodiscus luteus		+	.									
Calycomonas gracilis	+											
4) Chlorella sp.	*											
Nannochloris atomus	+	*	+	.	.		.	.				
June 24 - July 1[b]												
1) L.danicus			+					+	+			
S. costatum		+										
Thalassiosira gravida	*	*	+	*	.	+		+				
T. nordenskioldii	.	+	+									
C. pelagica	.	*	*	+		+						
Chaetoceros sp.	+	+	.	+		.	.	+	+			
Nitzschia sp.	.	+		.		.		.				
N. seriata		+	+	+	.			*				
3) Calycomonas ovalis	+			.								
4) N. atomus	+	.	+	+		+	.	+	.			
July 8 - 15												
1) L. danicus				.	.				.	+	*	+
S. costatum		+		+								
T. nordenskioldii		.			.	.		.		+		
C. pelagica		.				+			+	.		
Chaetoceros sp.		+				.					+	*
N. seriata		.									+	
Phaeodactylum tricornutum		.		.			.		.			+
Cylindrotheca closterium		+							+	.		
2) P.minimum (triangulatum)		.		.		.				+	.	
P. redfieldi										+		.
Amphidinium fusiforme											+	
Katodinium rotundatum		+		.	.	+				+	.	
Oblea rotunda		.				+					.	
3) Olisthodiscus luteus	+	+		.		+					+	
Ca. ovalis	+											
Pyramimonas obovata	.			.		+	.			+	*	
Eutreptia lanowii						.				+	.	.
Chroomonas sp.							.	.	.	+	.	
4) Chlorella sp.		+		+	.					.	+	+
N. atomus	+	*	.	+	.	*	.	.	+	+	+	+

Footnotes:
a - no samples from JC65 - 93 for the period
bb- no samples from JC75 - 93 for the period

TABLE 1.

Species/Dates	RB32	RB15	JC05	JC11	JC21	JC30	JC49	JC57	JC65	JC75	JC83	JC93
July 23 - 29												
1) Leptocylindrus sp.									•		+	
S. costatum	*	+	*	+		+	•					*
T. nordenskioldii	+	*	+	+		•						•
Chaetoceros sp.	*	+	+								•	
Ch. sociale			+									•
Thalassionema nitzschioides								.	.	•	+	
2) P. redfieldi				.		•		•	•		•	+
3) O. luteus		•		•		•		•	•		+	+
Py. obovata				•		•		•			+	•
Euglena sp.	•				+	.						•
Chroomonas sp.					•	•					+	•
4) Chlorella sp.											+	•
N. atomus	•	+	•	+		+	•	•	+	+	+	+
August 5 - 12												
1) Leptocylindrus minimus											+	
S. costatum	*			•	+	+				+		•
Cyclotella sp.		+		+		•	•					
T. gravida	+	•		+	+	+	+	+	•	+		
T. nordenskioldii	*			+						•		+
Biddulphia aurita	+			+	•		+	•				
Chaetoceros sp.		•		+						+	+	
Tn. nitzschioides			•								+	
Ph. tricornutum		+	•				+		•			
Cy. closterium											+	
3) Py. obovata				•		•	+		+			
Euglena sp.	•	+				•	•			•		
Chroomonas sp.		+				•	•					
4) N. atomus	*	*	+	+	+	+	*	•	*	+	*	+
August 19 - 25												
1) S. costatum	+		+	+		•		+	+		+	•
Thalassiosira sp.		•	+						•		•	•
T. nordenskioldii	+			+		•			•		+	•
B. aurita	+	•	+	•	•	•	•				•	
Ch. sociale	+	•	•	+								
Asterionella glacialis		.									+	•
2) P. redfieldi	•	•		.	.					+	•	
Gyrodinium aureolum	•	+		•	•				•		+	
4) N. atomus	*	+		•	•	+	•	•		•	+	+
September 2 - 9												
1) L. minimus		+								•		+
S. costatum		+						+	*	+	*	*
Cyclotella sp.		+				*				•	+	
T. nordenskioldii							.		.			+
B. aurita		.	•				•		•	•	+	+
Chaetoceros sp.		•	•							•	+	+
Rhizososenia alata									•	.		+
A. glacialis										•		+
Cy. closterium		+				•						
2) P. redfieldi	•	•				•		••		+	•	•
G. aureolum		+	•	•	•	•					•	
3) O. luteus	+	•								•		
4) N. atomus	+	*	+	+	•	*	•	•	+	+	+	+
Ulva sp. (zoospores)						+	•					
October 5[a]												
1) L. danicus			+	+	•	+	•	+				
L. minimus	+	+		.								
S. costatum				•	•	•	+	+				
4) N. atomus	+	+	+	+		+	•	•				

TABLE 2. Frequency of occurrence in our samples of common phytoflagellate species at selected locations along the New Jersey coast for the period July 8 to September 9, 1987. Letters indicate times of dominance as follows: a- early summer (July 8-15), b- midsummer (July 29-August 5), c- mid/late summer (August 19-25), d- late summer (September 2-9).

	RB15	JC11	JC30	JC57	JC65	JC83
Chrysophyceae						
Olisthodiscus luteus[1]	7a	3a	5a	3	4	4b
Calycomonas gracilis			2a			
C. ovalis	2b		1	1		
Prasinophyceae						
Bipedinomonas sp.			2a			
Pyramimonas sp.			2a	2		
Py. micron	1					
Py. obovata	2a	1	5a		2b	4ab
Tetraselmis sp.	1	1	1	1		2
Euglenophyceae						
Euglena sp.	2	2	2		1	2
Eutreptia sp.		1	1			2
E. lanowii	3b			1		2a
Dinophyceae						
Prorocentrum micans[1]			1		1	
P. minimum[2]	5a	2	1		1	8
P. minimum (triangulatum)[3]			1		1	4
P. triestinum (redfieldi)[3]	3d	1	4	3	3	4
Amphidinium fusiforme[4]			1	1	1	1a
Gymnodinium sp.	3a	1	3a	1		3b
Gyrodinium aureolum[5]	1c	3d	1			2c
G. estuariale	1		1			
Katodinium rotundatum[1]	4a	2	4a	2	2	7
Heterocapsa triquetra	2					
Oblea rotunda	2		2a	1		
Diplopsalis lenticula					1	
Peridinium sp.	2	2	2		2	1
P. brevipes	2			2		2
Scripsiella trochoidea (Peridinium trochoideum)	2	1	1	1	2	1
Gonyaulax diegensis		1				
G. tamarensis (excavata)[6]	2					
Cryptophyceae						
Chroomonas sp.	3b	4a	3a		2	3b
C. minuta						1c
Cryptomonas sp.	2		1			

Footnotes:

1. caused previous red tides in Lower New York Bay and adjacent New Jersey estuarine and coastal waters
2. caused previous red tides in Long Island (NY) south shore embayments
3. caused red tides in 1987 in Long Island Sound
4. caused previous red tides in Delaware Bay
5. caused green tides in southern NJ coastal waters in 1984-85
6. responsible for recurring red tides causing paralytic shellfish poisoning (PSP) in New England and Canadian waters.

Table 3. Nutrient concentrations (mg/l) for New Jersey coast stations; mean, maximum and minimum values[1] for twelve sampling dates, except where noted. *Sampling period from June 3 to September 2, 1987.*

		RB32	RB15	JC05	JC11	JC21	JC30	JC49[2]	JC57[2]	JC65[3]	JC75[4]	JC83[4]	JC93[5]
NH_3+NH_4	mean	.30	.18	.09	.06	.06	.06	.06	.06	.05	.05	.05	.05
	max.	.73	.51	.26	.14	.12	.16	.12	.10	.06			
	min.	.08	.05	.05	.02	.05	.05	.05	.05	.05	.05	.05	.05
NO_2+NO_3	mean	.42	.08	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
	max.	.92	.20	.07									
	min.	.22	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
Total P	mean	.12	.11	.06	.05	.06	.06	.05	.06	.06	.06	.06	.06
	max.	.25	.20	.09	.06	.08	.08	.08	.08	.08	.08	.08	.10
	min.	.05	.07	.05	.04	.05	.05	.04	.04	.05	.05	.05	.05
Ortho P	mean	.16	.10	.07	.05	.06	.06	.05	.05	.05	.06	.06	.06
	max.	.20	.20	.09	.08	.08	.09	.07	.07	.08	.08	.08	.08
	min.	.07	.05	.03	.05	.03	.05	.05	.05	.05	.05	.05	.05

Footnotes:

1. Most of the values given in this table are either approximate, or they are actually less than shown since .05 mg/l is apparently the lower detection limit (USEPA data).

2. Mean of eleven sampling dates.

3. Mean of nine sampling dates.

4. Mean of seven sampling dates.

5. Mean of six sampling dates.

TABLE 4. New Jersey coastal water conditions, summer of 1987, highlights and events reported to NJDEP.

Date	Weather[1] Sandy Hook Wind	Sandy Hook ppt.	Atlantic City Wind	Atlantic City ppt.	Locale	Surface Water Temp. °F	Observation/Condition
May 26					Hudson/Raritan estuary; New York Bight apex	56-60	brown flocculent material washing in, especially heavy in the estuary and adjacent coastal areas; brown water continuous in patches from 1-2 miles off Sandy Hook to 9 miles off Bay Head[2]; probable bloom die-off of the diatom, *Cerataulina* sp. (See Table 1); simultaneous narrow band of "sludge" and floatable materials present along beaches from Seaside Heights to Beach Haven, apparently unrelated to the diatom bloom.
27							
28							
29							
30							
31							
June 1	WSW15	.01	522		Upper Barnegat Bay (Toms River to Bay Head)	63-65	clumps of brown slime floating in bay and adjacent lagoons[3], clogging crab traps; likely diatom bloom remnants or decomposing vegetation (eelgrass, etc.).
2	NW18		E13	0.4			
3	ENE18	.27	ENE16				
4	ENE8	.26	ENE9	.19			
5	NW14	.82	S13	.01			
6	NW17		NNE15				
7	SE14		SSW25				
8	W35		SW23		Seaside Heights to Barnegat	62-66	in the ocean, brown water remnant of the above *Cerataulina* bloom observed southward of the previous area; brown material already dissipated to the north.
9	WSW23	.02					
10	NW23	.38					
11	SSW19						
12	SSW21			.02	Delaware Bay		red tide bloom (of the dinoflagellate, *Amphidinium fusiforme*) mid-bay on the New Jersey side, in vicinity of Fortescue and oyster seed beds;[4] reported fish kill on Delaware side (unconfirmed) apparently not related to the *Amphidinium* bloom.
13	SSW10	.03					
14	SSW18	.52					
15	W23						
16	S10	.05	NE15	.01			
17	N17		NE23				
18	SSW21		S22				
19	SSW21		SSW21				
20	WSW17		S17				
21	E13	.06	S13	.18			
22	ESE12	.07	SW10	0			
23	E17	.53	NE21	.15	Raritan/Sandy Hook Bay	64-68	red water in the estuary; elsewhere clear, except for a smaller area of yellow water in the ocean south of Sandy Hook[2]; diatom bloom of *Thalassiosira* sp. in bay and adjacent Bight (Table 1).
24	NE13	.05	NE18				
25	SE14		SSE12				
26	ENE19	.07	ESE14	.01			
27	WNW21	.44	E14	.10			
28	W23	.08	WNW17				
29	SSW25		S23				
30	WSW19		S23				
July 1	E13	.11	S17	.38			
2	E15	1.04	S23	1.41	Long Island NY, southwestern shore		small invertebrates (isopods, *Idotea* sp.) becoming abundant in surf at Nassau County and Queens.[5]
3	W17	.97	S17				
4	W19		SW17				
5	SE14		NE17	.03			
6	E15		SE14		Manasquan to Seaside Heights;		seaweed and trash in surf.
7	SE13		ESE10	.20			
8	SE10	1.01	SSW15	.01	Sandy Hook Bay; Shrewsbury River	68-72	brown water in bay[2]; phytoflagellates, *Katodinium* sp., plus a few diatoms abundant (Table 1); apparent red tide in river (Oceanport vicinity)[6] and local fish kill, probably caused by hypoxia from decomposing algae.
9	W12	.51	N16				
10	W14	.25	N12				
					Belmar - Seaside Heights	72-76	small jelly-like invertebrates(salps, *Thetys* sp.)[7] abundant in surf, causing nuisance to bathers;
11	W10		E10		Long Beach Island		small invertebrates (isopods or amphipods) also abundant, creating nuisance condition in surf.
12	SE15	.08	S17		Seaside Heights to Atlantic City	75-77	several incidents of respiratory difficulty experienced by bathers, especially at Long Beach Island[8]; water in in surf very clear and warm, no red tide present.
13	SSW18	.17	SSE14				
14	NW25		SSE18	.87			
15	NW21	1.38	N16		Barnegat Bay		water in bay, previously clear, becoming yellowish-brown due to blooms

TABLE 4. (cont.)

July	16	SSE11		ENE14		(behind Long	78-80	of minute coccoid algae (*Nannochloris sp.*);
	17	SW17		E13		Beach Island		this condition prevalent here in recent years,
						and		persisting until autumn; this year apparently
	18	WSW17		SSW17		Toms River to	77-79	concentrated towards the southern and northern extremes.
	19	W15		SE15		Bay Head)		
	20	SSE12	.16					
	21	W16		WSW18	.04	Long Island		dense red tide of the dinoflagellate, *Prorocentrum*
						Sound		*triestinum* (*redfieldi*) in western sound across to
	22	SSW12		NNE13		(New York)		Connecticut shore; some fish kills reported[5].
	23	N10		S14				
	24	W16		S18		New Jersey	75-77	more incidents of bather respiratory difficulty
	25	SW16	.12	SSW18				reported; possible result of hot, humid weather, very warm water and atmospheric ozone[8].
	26	WSW25	.40	SW15	.17			
	27	WSW15	.55	NE14				
	28	NNW13		NE18		eastern		brown tide bloom (*Aureococcus anorexefferens*)
						Long Island		redeveloping[9]; this species caused bay scallop
	29	NNE15		NE18		NY,		mortality here (Peconic system) in recent years.
						Flanders Bay		
	30	SSW16		SE20				
	31	NNE13	.41	NE18				
Aug.	1	SSW17		ENE14		southern NJ to Virginia		reports received of dead and dying bottlenose dolphin coming ashore; began in early July,
	2	SSE20		SSE18				occurrences becoming more frequent; condition apparently endemic among the dolphins[8].
	3	S18	.07	S20				
	4	SSW17	.16	SSE14		Manasquan to	69-72	small invertebrates (salps) previously abundant, now
	5	E19		NE18	.42	Seaside Heights		dying and thick in surf; seaweed (*Ulva* sp.) also heavy
	6	ENE21	.38	NE23	2.27			in surf, from a distance giving the appearance of green tide[7].
	7	SSE15		S17				
	8	W17		SSW18				
	9	ESE12		SSW21				
	10	NW23	2.90	NNE18				
	11	ENE16		NNE14				
	12	NE17		NE16				
	13	SE12		NE18		Ocean County		floatable debris (domestic materials and lumber)
	14	SE10		NE14		(Bay Head to		concentrated along the shore; all beaches in county
						Beach Haven)		temporarily closed; a line of floating debris
	15	SSW18		SSE15				subsequently sighted several miles off Long Beach Island[8].
	16	SSE17		SE12		Atlantic City		a small segment of beach temporarily closed due to high fecal coliform bacteria counts.
	17	SSE15		S16		Ocean City	74-77	water light green in surf due to minute coccoid alga (*Nannochloris* sp.), normally dominant in summer
	18	W17		NNE12				(Table 1); the green tide dinoflagellate, *Gyrodinium aureolum*, also abundant but no bloom materialized;
	19	S17		ENE10				heavy deposits of *Ulva* and aluminum cans (many partially incinerated) on beaches at low tide.
						Barnegat Bay	78-82	crab kill, localized in vicinity of Barnegat Inlet; pinkish patches seen on submerged sandbar and on crab gills;[10] the dinoflagellate, *Exuviaella marina*, abundant in water sample.
	20	WNW17		NNE14		Ocean City		chlorophyll levels high both in the surf and in the
	21	SSW19		E14				bay (Great Egg Harbor); change in surf conditions from
	22	SW28		S23				clear/green to turbid/brown and slightly cooler
	23	NNW24	.10	N20				temperature, apparent onwelling of deeper water;
	24	WNW20		N16				much seaweed and jellyfish remnants in suspension.
	25	WNW15		SSW14				
	26	S12		SE9				
	27	ESE17	.61	NE14	.17			
	28	ENE20	.30	NE14	.01			
	29	WNW26	.24	N14				
	30	SSE13		NNE15				
	31	SSE18		S16		Long Beach Island		oil slick (about 15 miles long x 1/4 mile wide) sighted several miles out, moving
Sept.	1	WNW21		SW16				offshore[2].
	2	WSW17		SSW16		Sandy Hook Bay	70-73	water reddish-brown; diatoms, especially *Cyclotella* sp., dominating the phytoplankton (Table 1).
						Manasquan River;		red water sighted; not confirmed.[2]
						Barnegat Light		brownish water from the inlet plume, extending southward about 2 miles.
	3	NNE13		NE17				
	4	NNE12		E14		Sandy Hook to	69-70	brown water from the beach out at least 3 miles;
	5	ESE10		E14		Bay Head		extensive diatom bloom of *Cyclotella* sp. (see Table 1).

TABLE 4.

Footnotes:

1. Wind (fastest measured one minute) direction and speed (mph), and precipitation (inches) from the National Oceanic and Atmospheric Administration, NMFS Sandy Hook Laboratory and National Weather Service, Atlantic City

2. EPA helicopter

3. R. Kantor, DEP Division of Coastal Resources

4. H. Haskin, Rutgers U. Shellfish Research Laboratory

5. A. Freudenthal, Nassau County Dept. of Health

6. Red tides caused by K. rotundatum have occurred previously in this locale

7. J. Tiedemann, N.J. Sea Grant Extension Service

8. DEP Press Office or citizen call

9. R. Nuzzi, Suffolk Co. Dept. of Health

10. DEP, Bureau of Marine Fisheries

TABLE 5. Summer of 1987 ocean temperature data (^{o}C) for New Jersey coast EPA perpendicular stations, one and nine miles off; NOAA infrared satellite surface contours, nearshore to mid-shelf and offshore.

Northern Transects		JC14 1 mi	E,M 9 mi	JC27 1 mi	E,M 9 mi	JC41 1 mi	E,M 9 mi	JC53 1 mi	E,M 9 mi	NOAA Satellite Inner shelf	outer shelf	shelf slope
Sampling date												
May 22	surface	13.9	12.1	13.7	12.5							
	bottom	13.8	11.2	12.6	11.2							
May 31	surface									17-18	15-16	17-18
June 1	surface	20.1	19.9	19.5	20.5	18.7	18.9	18.0	19.3			
	bottom	14.7	11.8	14.0		14.4	12.0	14.0	13.6			
June 15	surface	17.2	19.0	17.6	19.0	16.3	18.0	15.6	18.0	18-19	17-18	19-20
	bottom	14.6	11.6	13.8	11.5	12.7	11.1	13.4	11.1			
June 29	surface									19	19-20	20-22
July 10-11	surface	23.4	22.2	22.9	22.7		23.3	24.4	24.2			
	bottom	20.6	13.6	14.4	18.0	15.5	15.8	17.0	14.6			
July 17	surface	19.4	21.2	21.7	21.1	21.6	20.8	21.2	21.2	20-21	21-22	22-23
	bottom	17.9	14.7	17.8	15.3	16.4	14.7	18.0	15.5			
July 23	surface									25-26	23-24	24-25
July 27	surface									21-22	23-24	23-24
July 30	bottom	17.9	15.8	15.6	15.2	14.9	14.7	16.7	17.4			
August 13	surface									22-23	23-24	23-24
	bottom	22.5	17.6	21.3	19.4	21.4	16.6	21.9	18.2			
August 17	surface									23-24	24	24-25
August 20	surface	24.0	23.9	23.3	23.7	23.5	24.1	23.4	24.1			
	bottom	20.1	16.5	18.0	15.3	19.8	16.3	18.9	17.6			
August 30	surface									22-23	22-23	23-24
September 4	surface	21.1	20.9	20.7	20.8	21.1	20.7	20.9	21.1			
	bottom	20.3	14.0	19.8	15.6	19.8	17.5	18.1	16.6			
September 15	surface									21-22	21-23	23-24
September 24-28	surface									20	20-21	21-23
October 2	surface	18.7	18.4	17.0	18.4	18.9	18.4					
	bottom	19.0	14.6	17.8	16.0	18.8	18.3					
October 22	surface	13.1	13.7	13.8	13.8	13.5	13.7	14.7	14.2			
	bottom	14.2	14.3	14.3	14.7	14.1	14.7	14.0	14.4			

Southern Transects		JC61 1 mi	E,M 9 mi	JC69 1 mi	E,M 9 mi	JC75 1 mi	E,M 9 mi	JC85 1 mi	E,M 9 mi	NOAA Satellite Inner shelf	outer shelf	shelf slope
Sampling date												
May 31	surface									17-19	16-17	16-20
June 15-19	surface	18.1	17.6	15.9	17.5	18.6	17.4		18.2	19-20	20-21	20-22
	bottom	15.1	13.3	13.1	12.2	16.4	13.1	14.2	13.9			
June 28-29	surface									19-20	21-22	20-22
July 11	surface	24.1	24.8	23.3	24.4	25.2	25.1	25.0	25.2			
	bottom	19.3	14.4	19.5	15.5	21.0	17.1	18.7	16.4			
July 17	surface									19-21	21-22	22-23
July 18	surface	22.7	22.7	22.4	22.5	22.5	22.2	22.4	21.8			
	bottom	20.7	14.9	21.6	16.3	21.6	16.8	21.2	18.6			
July 23	Surface					24.4	24.0	24.9	24.2	25	24-26	23-25
	bottom					21.6	18.8	22.6	18.8			
August 8	bottom	22.0	15.3	22.3	17.6	22.3	18.4	21.4	20.1			
August 13	surface									22-23	23-25	24-25
August 21	surface	23.6	23.8	22.3	24.1	24.4	24.2	25.1	14.3			
	bottom	22.1	16.3	23.7	18.6	24.4	20.8	24.3	19.9			
August 30										22-23	23-25	24-25
September	surface									20-22	19-21	20-23

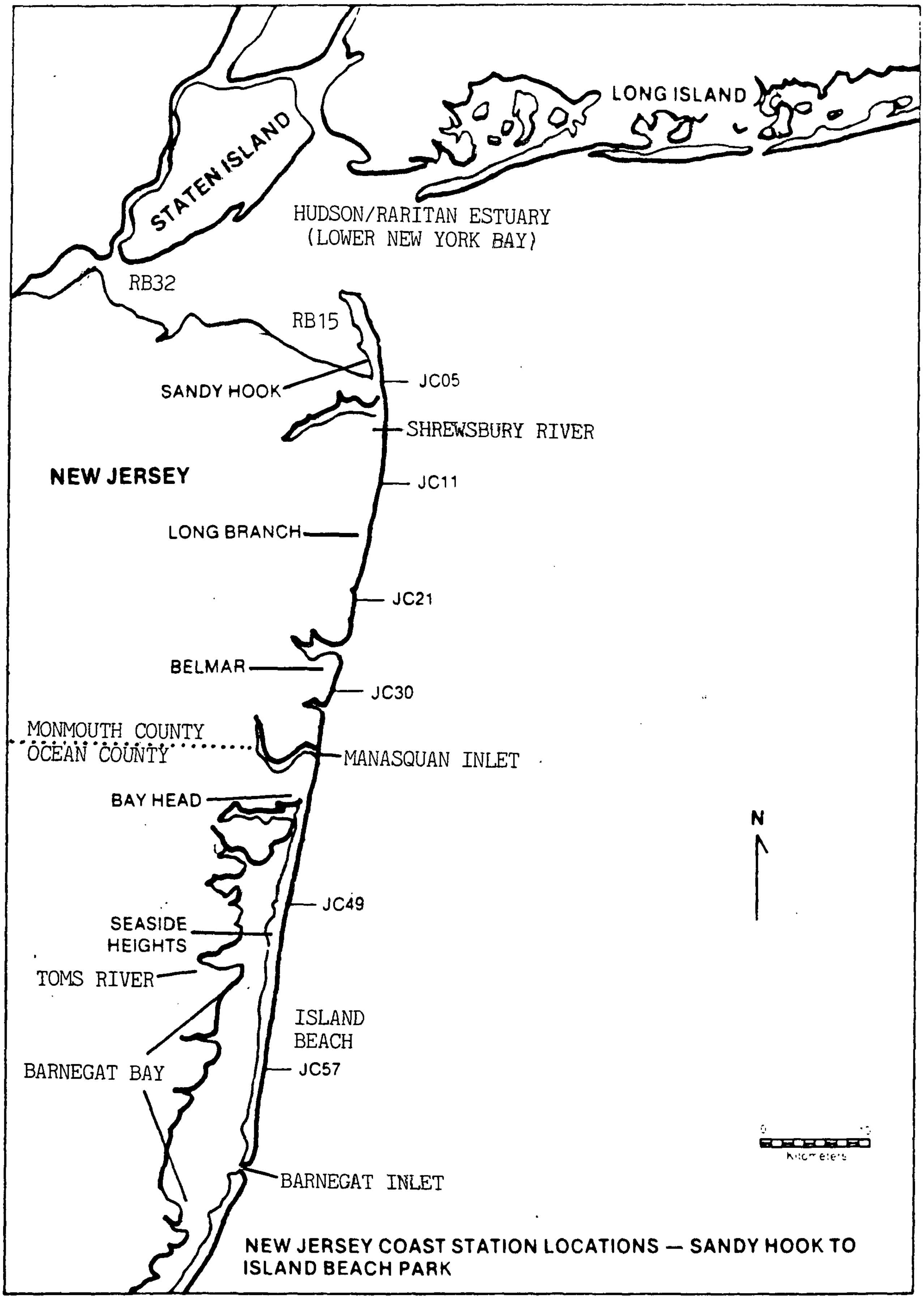
LONG ISLAND
STATEN ISLAND
HUDSON/RARITAN ESTUARY
(LOWER NEW YORK BAY)
RB32
RB15
SANDY HOOK
JC05
SHREWSBURY RIVER
NEW JERSEY
JC11
LONG BRANCH
JC21
BELMAR
JC30
MONMOUTH COUNTY
OCEAN COUNTY
MANASQUAN INLET
BAY HEAD
N
JC49
SEASIDE HEIGHTS
TOMS RIVER
ISLAND BEACH
BARNEGAT BAY
JC57
BARNEGAT INLET
NEW JERSEY COAST STATION LOCATIONS — SANDY HOOK TO ISLAND BEACH PARK

FIGURE 1.

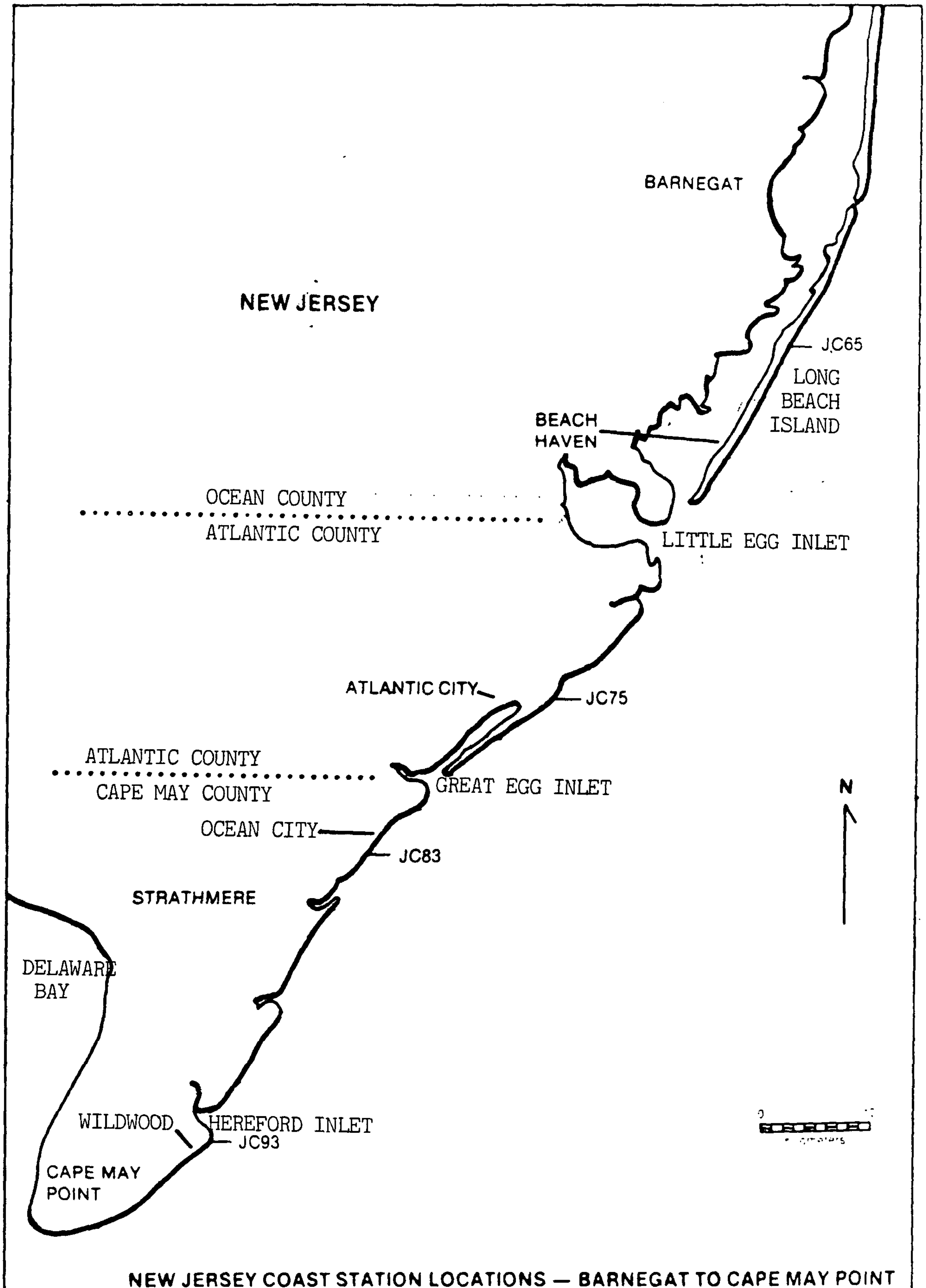
BARNEGAT
NEW JERSEY
JC65
LONG
BEACH
ISLAND
BEACH
HAVEN
OCEAN COUNTY
ATLANTIC COUNTY
LITTLE EGG INLET
ATLANTIC CITY
JC75
ATLANTIC COUNTY
CAPE MAY COUNTY
GREAT EGG INLET
N
OCEAN CITY
JC83
STRATHMERE
DELAWARE
BAY
WILDWOOD
HEREFORD INLET
JC93
CAPE MAY
POINT
NEW JERSEY COAST STATION LOCATIONS — BARNEGAT TO CAPE MAY POINT

FIGURE 2.

APPENDIX "B"

APPENDIX "B"

MICROBIOLOGICAL WATER QUALITY

NEW YORK BIGHT

SUMMER 1987

Introduction

A study of the density* of fecal coliform (FC) and enterococcus organisms was conducted in 1987 as part of the continuing annual monitoring of the nearshore waters off the Long Island and New Jersey coasts. Monitoring at selected stations in the New York Bight was also conducted together with stations perpendicular to the New Jersey and Long Island coast.

By determining the bacteriological water quality, one can estimate potential health risks associated with the presence of sewage pollution. Epidemiological studies have attempted to assess the incidence of illness with bathing in water containing fecal contamination. Evidence exists that there is a relationship between bacterial water quality and transmission of certain infectious diseases (Cabelli, V.J., et al, 1979, 1980).

Investigations have shown that agents of bacterial disease, enteropathogenic/toxigenic *E. coli*, heterogeneous group of *Pseudomonas* spp., *Klebsiella*, *Salmonella* and *Shigella* are excreted in large numbers in the feces of infected individuals, and are thus potentially present in sewage. It is common practice to use an indicator organism to detect fecal contamination because of the ease of isolating and quantitating certain microorganisms on membrane filters. Elaborate procedures are usually required for the detection of most pathogens in mixed populations. When numerous indicator organisms are present, the likelihood of pathogens being isolated is also far greater.

A fecal coliform bacterial guideline for primary contact recreational waters was recommended by the U.S. Environmental Protection Agency (USEPA) in 1976, and subsequently adopted by most of the states. The EPA standard stated that fecal coliforms should be used as the indicator to evaluate the suitability of recreational waters, and recommended that fecal coliforms, as determined by MPN or MF procedure and based on a minimum of not less than five samples taken over not more than a 30-day period, shall not exceed a log mean of 200/100 ml, nor shall more than 10% of the total samples during any 30-day period exceed 400/100 ml. Rationale for the limits was developed using data collected from studies at the Great Lakes, Michigan and the Inland River, Ohio which showed an epidemiological detectable health effect at levels of 2300-2400 coliforms/100 ml. Subsequent investigations conducted on the Ohio River suggested that fecal coliforms represent 18% of the total coliforms. This would indicate that detectable health effects may occur at a fecal coliform level of approximately 400/100 ml. A limit of 200 FCs per 100 ml would therefore provide a quality of water which should exceed that which would cause a detectable health effect.

New York State, for its primary contact recreational coastal waters, adopted the log mean of 200 fecal coliforms/100 ml. New Jersey, however, chose to adopt more stringent limits. Fecal coliform levels shall not exceed a geometric average of 50/100 ml, within 1500 feet of shore line in (SC) general surface water classification applied to coastal saline waters. By 1978, most of the states adopted the fecal coliform indicator with geometric mean limits at 200 fecal coliforms/100 ml.

*Bacterial density in this study is referred to as the number of fecal coliforms and enterococci per 100 ml of water.

Fecal Coliform Indicator Bacteria

Fecal coliforms comprise all of the coliform bacteria that ferment lactose at 44.5 ± 0.2°C. This group according to traditional theory, more accurately reflects the presence of fecal discharges from warm-blooded animals. As indicators, fecal coliforms have the advantage of being less subject to regrowth in polluted waters. Their increased specificity to fecal sources made them the choice over other coliform organisms.

EPA has recently published the results of two research projects which compared the relationship between illnesses associated with bathing in recreational waters and ambient densities of several indicator organisms (Cabelli, 1980 and DuFour, 1984). One study was performed on marine bathing beaches and one on freshwater beaches. The results caused EPA to reevaluate the current use of fecal coliforms as indicator organisms. The studies indicated that enterococci have a far better correlation with swimming associated illnesses both in marine and freshwater than do fecal coliforms. New methodology has also made it easier to detect enterococci (Levin, et al, 1975 and Miescier & Cabelli, 1982). The studies also demonstrated that E. coli, a specific species in the fecal coliform group, has a correlation equal to enterococci in freshwater, but not in marine waters. Enterococci are members of the fecal streptococci group. This group is used to describe the streptococci which are indicative of the sanitary quality of water and wastewater. The occurrence of fecal streptococci in water indicates fecal contamination from warm-blooded animals. One is able to pinpoint the source of fecal contamination (such as human, equine, bovine, avian) by identifying the species utilizing biochemical tests. The enterococcus group include the following species: S. faecalis; S. faecalis, subsp. liquefaciens; S. faiecalis, subsp. zymogenes; and S. faecium. S. faecalis, one of the group D streptococcal species, grows in broth containing 6.5% NaCl, hydrolyzes arginine and utilizes pyruvate. S. faecium grows in 6.5% NaCl broth, hydrolyzes arginine, but does not utilize pyruvate. S. bovis does not grow in 6.5% NaCl broth, does not hydrolyze arginine, and does not utilize pyruvate. These are the three most common species of group D streptococci found as pathogens in human infection. S. durans is located occasionally, and S. equinus is found rarely (Facklam 1980).

More information about both fecal coliforms and enterococci can be found in the following references:

1. Standard Methods, 16 edition, Section 909 and 910. (1985).

2. Microbiological Methods for Monitoring the Environment, Water and Wastewater. EPA-600/8-78-017. Part III, Section C & D. (1978).
3. Bergey's Manual of Systematic Bacteriology. Volume I. (1984).

EPA has issued a criteria guidance document recommending enterococci and E. coli for inclusion into state water quality standards for the protection of primary contact recreational uses in lieu of fecal coliforms. The (EPA, 1986) recommended criterion for enterococci for marine waters is 35/100 ml. This information was published in the Federal Register on March 7, 1986.

Materials and Mathods

Marine water samples were collected by helicopter from May to September 1987. The samples were collected using a Kemmerer sampler and transfered to 500 ml sterile, wide-mouthed plastic containers, and then transported in an ice chest to Region II Edison laboratory for analysis.

Fecal coliform determinations were conducted according to the membrane filtration (MF) procedures described in Standard Methods, 16 edition, 1985 and Microbiological Methods for Monitoring the Environment, Water and Wastewater, EPA-600/8-78-017, 1987. Enterococci determinations were conducted according to the MF procedure described by Levin, et al. (1975) and Dufour (1980), using the modified mE media. Confirmation of enterococci colonies was conducted following procedures outlined in Microbiological Methods for Monitoring the Environment, Water and Wastewater, EPA-600/8-78-017, 1978.

Results and Discussion

Along the New Jersey Coast, FC densities greater than 50/100 ml occurred on four occasions at four different stations (Tables 1 & 2). The observations were made at stations JC-2I (Asbury Park, off building north of Convention Hall), JC-24 (Bradley Beach, off foot of Cliff Avenue), JC-59 (Island Beach State Park) and JC-85 (Strathmore off Blue standpipe). Enterococci densities exceeding the standard of 35/100 ml (Tables 3 & 4 and Figure 2), were observed on three occasions at station JC-03 (Sandy Hook, off Nature Center Building), JC-14 (Long Branch, off foot of S. Bath Avenue) and JC-21 (Asbury Park, off Building north of Convention Hall).

The FC and enterococci densities observed at the New Jersey coast perpendicular stations were all low (Tables 5 & 6).

Along the Long Island coast, FC densities were never above 50/100 ml (Tables 7 and Figure 3). The enterococci densities along the Long Island coast were slightly higher (Table 8 and Figure 4), however only one exceeded 35/100 ml, at station LIC-05 (Far Rockaway, off foot of B41 St. Road).

Both bacterial indicators were often non-detectable at the Long Island coast perpendicular stations (Tables 9 & 10). Enterococci were detected more frequently than fecal coliforms and were only found in bottom samples.

New York Bight

The densities of FC and enterococci found in the New York Bight are presented in Tables 11 & 12. Elevated fecal coliforms and enterococci densities were occasionally observed at or near the 12-mile sewage sludge dumpsite (Station NYB-25). Enterococci densities at stations NYB-23 (3 miles west of the sewage sludge disposal site), NYB-25 (1 mile west of the sewage sludge disposal site), NYB-44 (2 miles northwest of the sewage sludge dispodal site) and NYB-45 (1 mile northwest of the sewage sludge disposal site) were 10, 36, 10 and 20 respectively. Elevated counts were all observed in samples collected near the ocean bottom (Tables 11 & 12), except at station NYB-23, which was a surface sample.

The fecal coliforms and enterococci counts obtained at these stations may be attributed to recently dumped sewage sludge or resuspension of contaminated sediments at the dump site. Fecal coliforms and enterococci indicator organisms are often found in sediments. The enterococci are known to be facultative with respect to oxygen and the fecal coliforms can also remain viable at reduced oxygen levels. This data supports the suggestion that there is survival after sedimentation (Van Donsel, et al, 1971. Rittenburg et al, 1958). Elevated bacterial densities outside the dump site proper may be attributable to movement of contaminated sludge and sediments by tidal and ocean currents into the Christiansen Basin.

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Table

FECAL COLIFORM DENSITIES >50 PER 100ML
NEW JERSEY COAST STATIONS
SUMMER 1987

OBS	STATION	DATE	FECCOLI
1	JC21	870805	216
2	JC24	870812	75
3	JC59	870729	53
4	JC35	870708	56

Table 2

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
NEW JERSEY COAST STATIONS
SUMMER 1987

OBS	STATION	MEAN	MINIMUM	MAXIMUM	N
1	JC01A	0.55508	0	2	15
2	JC02	0.30642	0	2	16
3	JC03	0.36425	0	2	15
4	JC05	0.52526	0	12	16
5	JC08	0.45051	0	3	15
6	JC11	0.75452	0	6	16
7	JC14	1.98775	0	34	15
8	JC21	2.55817	0	216	17
9	JC24	1.51457	0	75	17
10	JC27	2.52633	0	31	17
11	JC30	0.35223	0	24	16
12	JC33	0.54221	0	3	15
13	JC37	1.50770	0	8	15
14	JC41	0.76923	0	3	15
15	JC44	0.49609	0	5	15
16	JC47A	0.36425	0	2	16
17	JC49	0.65343	0	12	15
18	JC53	1.52164	0	17	17
19	JC55	0.45238	0	5	15
20	JC57	0.35726	0	4	17
21	JC59	0.53438	0	53	15
22	JC61	0.50891	0	5	15
23	JC63	0.16013	0	7	14
24	JC65	0.34835	0	10	14
25	JC67	0.46412	0	12	14
26	JC69	0.53312	0	4	14
27	JC73	1.54857	0	17	9
28	JC75	1.21435	0	9	9
29	JC77	0.35494	0	12	9
30	JC79	0.42350	0	5	9
31	JC81	2.28281	0	40	9
32	JC83	0.31793	0	3	9
33	JC85	1.31059	0	56	9
34	JC87	0.16653	0	1	9
35	JC89	2.31530	0	20	9
36	JC91	0.58243	0	2	9
37	JC93	4.16698	0	49	9
38	JC95	0.53367	0	8	10
39	JC97	1.74339	0	20	10
40	JC99	0.37603	0	4	10

ENTEROCOCCUS DENSITIES >35 PER 100ML
NEW JERSEY COAST STATIONS
SUMMER 1987

OBS	STATION	DATE	ENTERO
1	JC03	870805	44
2	JC14	870708	92
3	JC21	870805	620

Table 4

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
NEW JERSEY COAST STATIONS
SUMMER 1987

OBS	STATION	MEAN	MINIMUM	MAXIMUM	N
1	JC01A	0.76612	0	6	16
2	JC02	0.47683	0	3	16
3	JC03	0.58706	0	44	16
4	JC05	0.83220	0	6	16
5	JC08	0.68014	0	6	16
6	JC11	0.71062	0	6	16
7	JC14	1.69435	0	92	16
8	JC21	3.60864	0	620	17
9	JC24	1.46960	0	18	17
10	JC27	2.14164	0	11	17
11	JC30	0.97091	0	4	16
12	JC33	0.92936	0	5	16
13	JC37	1.96451	0	32	16
14	JC41	0.73770	0	8	16
15	JC44	0.54069	0	6	16
16	JC47A	0.43408	0	4	16
17	JC49	0.55361	0	5	16
18	JC53	1.59659	0	14	17
19	JC55	0.72326	0	6	16
20	JC57	0.33956	0	3	17
21	JC59	0.63438	0	17	16
22	JC61	0.73599	0	6	16
23	JC63	0.51514	0	11	14
24	JC65	0.52966	0	3	14
25	JC67	0.59991	0	9	14
26	JC69	0.62088	0	5	14
27	JC73	0.42350	0	3	9
28	JC75	0.73707	0	8	9
29	JC77	0.78068	0	4	9
30	JC79	0.31798	0	2	9
31	JC81	1.15443	0	4	9
32	JC83	0.22028	0	5	9
33	JC85	1.19852	0	11	9
34	JC87	0.25992	0	3	9
35	JC89	1.20813	0	12	9
36	JC91	0.25992	0	1	9
37	JC93	1.48396	0	4	9
38	JC95	0.68084	0	9	10
39	JC97	1.26336	0	6	10
40	JC99	0.83463	0	3	10

Table 5

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
NEW JERSEY PERPENDICULAR STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	JC14E	B	0.122462	0	1	6
2	JC14E	S	0.000000	0	0	5
3	JC14G	B	0.000000	0	0	6
4	JC14G	S	0.148598	0	1	5
5	JC14I	B	0.122462	0	1	6
6	JC14I	S	0.000000	0	0	5
7	JC14K	B	0.000000	0	0	6
8	JC14K	S	0.000000	0	0	5
9	JC14M	B	0.000000	0	0	6
10	JC14M	S	0.000000	0	0	5
11	JC27E	B	0.122462	0	1	6
12	JC27E	S	0.000000	0	0	5
13	JC27G	B	0.000000	0	0	6
14	JC27G	S	0.000000	0	0	5
15	JC27I	B	0.000000	0	0	6
16	JC27I	S	0.000000	0	0	5
17	JC27K	B	0.000000	0	0	6
18	JC27K	S	0.000000	0	0	5
19	JC27M	B	0.000000	0	0	6
20	JC27M	S	0.000000	0	0	5

Table 6

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
NEW JERSEY PERPENDICULAR STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	JC14E	B	0.259921	0	1	6
2	JC14E	S	0.000000	0	0	5
3	JC14G	B	0.122462	0	1	6
4	JC14G	S	0.000000	0	0	5
5	JC14I	B	0.000000	0	0	6
6	JC14I	S	0.515717	0	1	5
7	JC14K	B	0.122462	0	1	6
8	JC14K	S	0.000000	0	0	5
9	JC14M	B	0.348006	0	2	6
10	JC14M	S	0.148698	0	1	5
11	JC27E	B	0.348006	0	2	6
12	JC27E	S	0.000000	0	0	5
13	JC27G	B	0.259921	0	1	6
14	JC27G	S	0.148698	0	1	5
15	JC27I	B	0.259921	0	1	6
16	JC27I	S	0.319508	0	3	5
17	JC27K	B	0.200937	0	2	6
18	JC27K	S	0.148698	0	1	5
19	JC27M	B	0.000000	0	0	6
20	JC27M	S	0.245731	0	2	5

Table 7

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
LONG ISLAND COAST STATIONS
SUMMER 1987

OBS	STATION	MEAN	MINIMUM	MAXIMUM	N
1	LIC01	0.34984	0	4	15
2	LIC02	0.83732	0	23	15
3	LIC03	0.64375	0	3	15
4	LIC04	0.95153	0	3	15
5	LIC05	2.42572	0	15	15
6	LIC07	0.87341	0	7	15
7	LIC08	0.48774	0	7	16
8	LIC09	0.92650	0	4	15
9	LIC10	2.03421	0	9	16
10	LIC12	0.14670	0	1	15
11	LIC13	0.48774	0	3	15
12	LIC14	0.31384	0	4	15
13	LIC15	0.36775	0	4	15
14	LIC16	1.04253	0	33	15
15	LIC17	0.42350	0	2	9
16	LIC18	0.57606	0	4	9
17	LIC19	0.44225	0	2	9
18	LIC20	0.31798	0	3	9
19	LIC21	0.48774	0	3	8
20	LIC22	0.83757	0	12	8
21	LIC23	1.17183	0	10	8
22	LIC24	0.00000	0	0	8
23	LIC25	0.59553	0	5	8
24	LIC26	0.22284	0	4	8
25	LIC27	0.56823	0	5	8
26	LIC28	0.00000	0	0	8

Table 8.

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
LONG ISLAND COAST STATIONS
SUMMER 1987

OBS	STATION	MEAN	MINIMUM	MAXIMUM	N
1	LIC01	0.21251	0	2	15
2	LIC02	0.87144	0	13	15
3	LIC03	0.85486	0	6	15
4	LIC04	0.76866	0	5	15
5	LIC05	3.13877	0	40	15
6	LIC07	1.02393	0	15	15
7	LIC08	0.29152	0	4	16
8	LIC09	1.34652	0	8	15
9	LIC10	2.38447	0	10	15
10	LIC12	0.23599	0	5	15
11	LIC13	0.69422	0	3	16
12	LIC14	0.34984	0	4	15
13	LIC15	0.50214	0	6	16
14	LIC16	1.80463	0	13	15
15	LIC17	0.48910	0	2	9
16	LIC18	0.81144	0	6	9
17	LIC19	0.36079	0	3	9
18	LIC20	0.46973	0	7	9
19	LIC21	1.34806	0	10	8
20	LIC22	0.98393	0	7	8
21	LIC23	0.91927	0	5	8
22	LIC24	0.18921	0	1	8
23	LIC25	0.54221	0	3	8
24	LIC26	0.25103	0	2	8
25	LIC27	0.58583	0	4	8
26	LIC28	0.41421	0	3	8

Table 9

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
LONG ISLAND PERPENDICULAR STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	LIC09A	B	0.000000	0	0	3
2	LIC09A	S	0.000000	0	0	2
3	LIC09B	B	0.000000	0	0	3
4	LIC09B	S	0.000000	0	0	2
5	LIC09C	B	0.000000	0	0	3
6	LIC09C	S	0.000000	0	0	2
7	LIC09D	B	0.000000	0	0	3
8	LIC09D	S	0.732051	0	2	2
9	LIC14A	B	0.000000	0	0	3
10	LIC14A	S	0.000000	0	0	2
11	LIC14B	B	0.000000	0	0	3
12	LIC14B	S	0.000000	0	0	2
13	LIC14C	B	0.000000	0	0	3
14	LIC14C	S	0.000000	0	0	2
15	LIC14D	B	0.000000	0	0	3
16	LIC14D	S	0.000000	0	0	2

Table 10

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
LONG ISLAND PERPENDICULAR STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	LIC09A	B	0.000000	0	0	3
2	LIC09A	S	0.000000	0	0	2
3	LIC09B	B	0.259921	0	1	3
4	LIC09B	S	0.000000	0	0	2
5	LIC09C	B	0.259921	0	1	3
6	LIC09C	S	0.000000	0	0	2
7	LIC09D	B	0.000000	0	0	3
8	LIC09D	S	0.000000	0	0	2
9	LIC14A	B	0.000000	0	0	3
10	LIC14A	S	0.000000	0	0	2
11	LIC14B	B	0.000000	0	0	3
12	LIC14B	S	0.000000	0	0	2
13	LIC14C	B	0.259921	0	1	3
14	LIC14C	S	0.000000	0	0	2
15	LIC14D	B	0.000000	0	0	3
16	LIC14D	S	0.000000	0	0	2

Table 11

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
NEW YORK BIGHT STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	NYB20	B	0.00000	0	0	5
2	NYB20	S	0.58489	0	4	5
3	NYB21	B	0.00000	0	0	5
4	NYB21	S	0.00000	0	0	5
5	NYB22	B	0.12246	0	1	5
6	NYB22	S	0.14870	0	1	5
7	NYB23	B	0.00000	0	0	5
8	NYB23	S	0.00000	0	0	5
9	NYB24	B	0.12246	0	1	5
10	NYB24	S	0.00000	0	0	5
11	NYB25	B	4.19496	0	39	5
12	NYB25	S	0.00000	0	0	5
13	NYB26	B	0.00000	0	0	5
14	NYB26	S	0.00000	0	0	5
15	NYB27	B	0.00000	0	0	5
16	NYB27	S	0.00000	0	0	4
17	NYB32	B	0.00000	0	0	5
18	NYB32	S	0.31951	0	3	5
19	NYB33	B	0.00000	0	0	5
20	NYB33	S	0.43097	0	2	5
21	NYB34	B	0.00000	0	0	5
22	NYB34	S	0.00000	0	0	5
23	NYB35	B	0.24573	0	2	5
24	NYB35	S	0.00000	0	0	5
25	NYB40	B	0.12246	0	1	5
26	NYB40	S	0.00000	0	0	5
27	NYB41	B	0.12246	0	1	5
28	NYB41	S	0.00000	0	0	5
29	NYB42	B	0.00000	0	0	5
30	NYB42	S	0.00000	0	0	5
31	NYB43	B	0.00000	0	0	5
32	NYB43	S	0.00000	0	0	5
33	NYB44	B	0.34801	0	2	5
34	NYB44	S	0.00000	0	0	5
35	NYB45	B	0.12246	0	1	5
36	NYB45	S	0.00000	0	0	5
37	NYB46	B	0.00000	0	0	5
38	NYB46	S	0.00000	0	0	5
39	NYB47	B	0.12246	0	1	5
40	NYB47	S	0.24573	0	2	5

Table 12

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
NEW YORK BIGHT STATIONS
SUMMER 1987

OBS	STATION	DEPTH	MEAN	MINIMUM	MAXIMUM	N
1	NYB20	B	0.12246	0	1	5
2	NYB20	S	0.00000	0	0	5
3	NYB21	B	0.12246	0	1	5
4	NYB21	S	0.37973	0	4	5
5	NYB22	B	0.00000	0	0	5
6	NYB22	S	0.00000	0	0	5
7	NYB23	B	0.24573	0	2	5
8	NYB23	S	0.61539	0	10	5
9	NYB24	B	0.69838	0	5	6
10	NYB24	S	0.24573	0	2	5
11	NYB25	B	8.63332	1	36	6
12	NYB25	S	0.00000	0	0	5
13	NYB26	B	0.69838	0	5	6
14	NYB26	S	0.00000	0	0	5
15	NYB27	B	0.25992	0	1	6
16	NYB27	S	0.00000	0	0	4
17	NYB32	B	0.00000	0	0	5
18	NYB32	S	0.14870	0	1	5
19	NYB33	B	0.00000	0	0	5
20	NYB33	S	0.00000	0	0	5
21	NYB34	B	0.00000	0	0	5
22	NYB34	S	0.00000	0	0	5
23	NYB35	B	0.31951	0	1	5
24	NYB35	S	0.14870	0	1	5
25	NYB40	B	0.12246	0	1	6
26	NYB40	S	0.00000	0	0	5
27	NYB41	B	0.74258	0	5	6
28	NYB41	S	0.00000	0	0	5
29	NYB42	B	0.12246	0	1	5
30	NYB42	S	0.00000	0	0	5
31	NYB43	B	0.12246	0	1	6
32	NYB43	S	0.00000	0	0	5
33	NYB44	B	1.45699	0	10	6
34	NYB44	S	0.00000	0	0	5
35	NYB45	B	0.61887	0	2	6
36	NYB45	S	0.00000	0	0	5
37	NYB46	B	1.10902	0	10	6
38	NYB46	S	0.31951	0	1	5
39	NYB47	B	0.30766	0	4	5
40	NYB47	S	0.00000	0	0	5

FIGURE-1 GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
NEW JERSEY COAST STATIONS
SUMMER 1987

PLOT OF MEAN*STATION SYMBOL USED IS *
PLOT OF MAXIMUM*STATION SYMBOL USED IS U

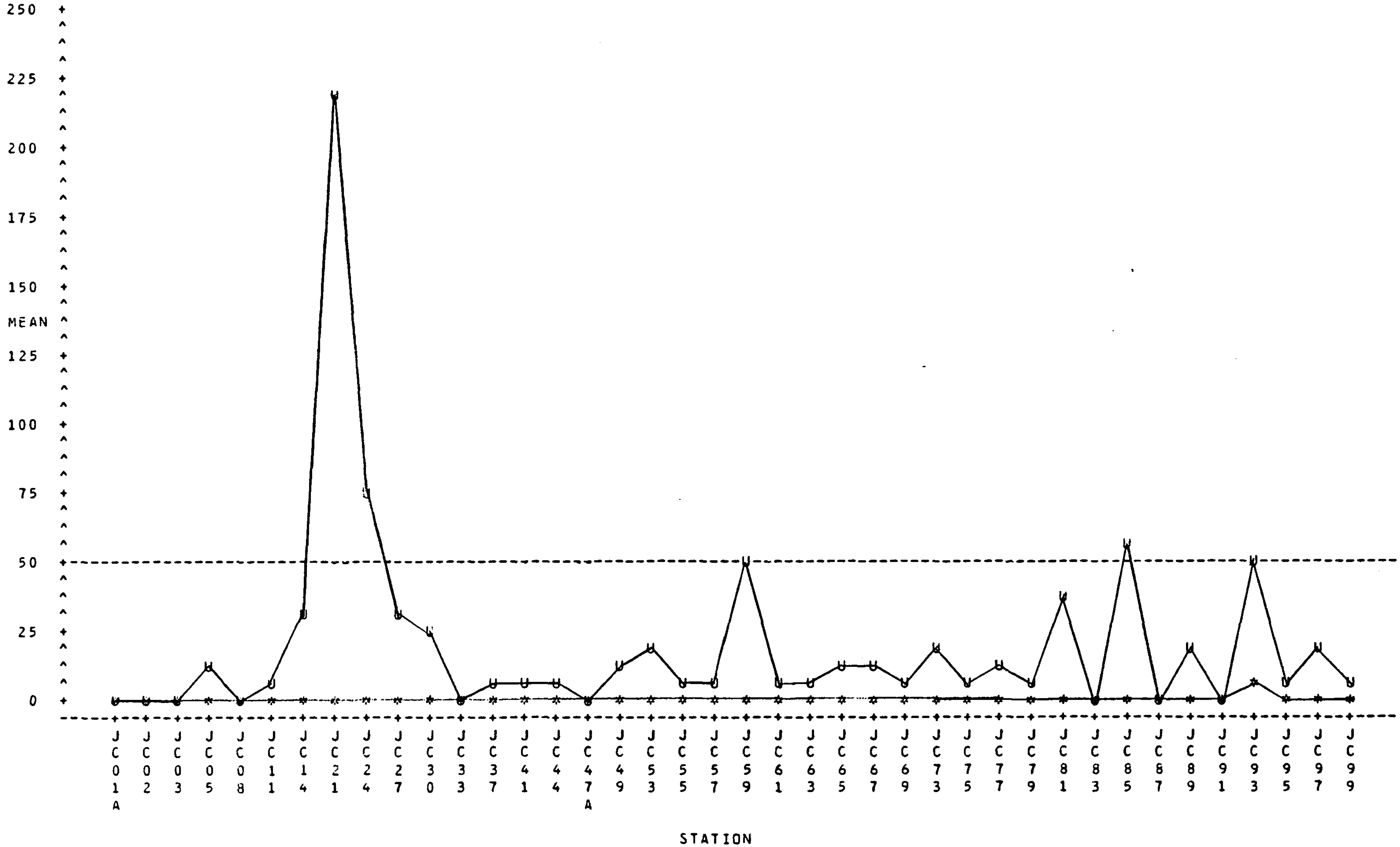
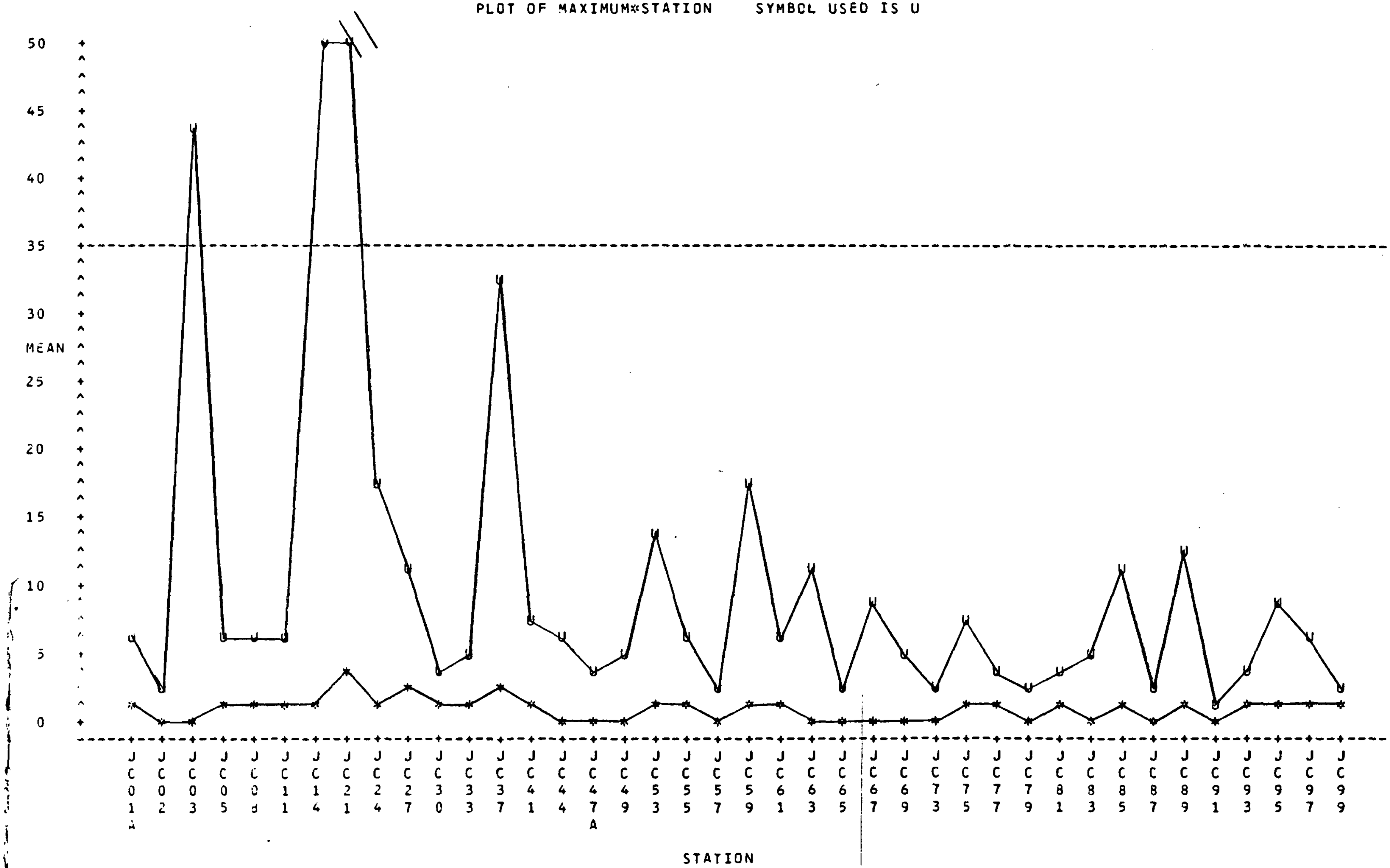


FIGURE-2

GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
NEW JERSEY COAST STATIONS
SUMMER 1987

PLOT OF MEAN*STATION SYMBOL USED IS *
PLOT OF MAXIMUM*STATION SYMBOL USED IS U



NOTE: 2 OBS HAD MISSING VALUES OR WERE OUT OF RANGE

FIGURE-3

GEOMETRIC MEANS OF FECAL COLIFORM DENSITIES
LONG ISLAND COAST STATIONS
SUMMER 1987

PLOT OF MEAN*STATION SYMBOL USED IS *
PLOT OF MAXIMUM*STATION SYMBOL USED IS U

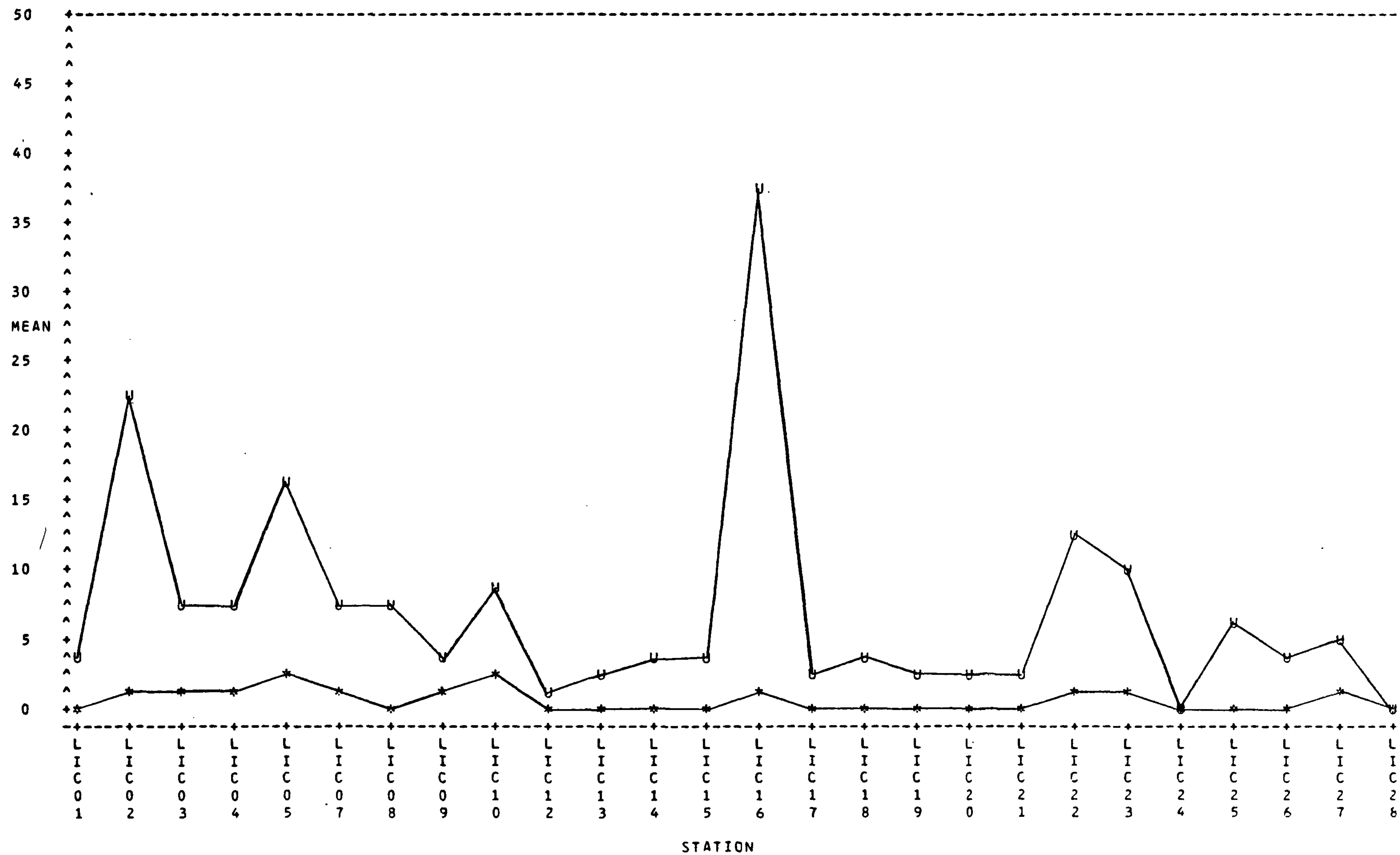
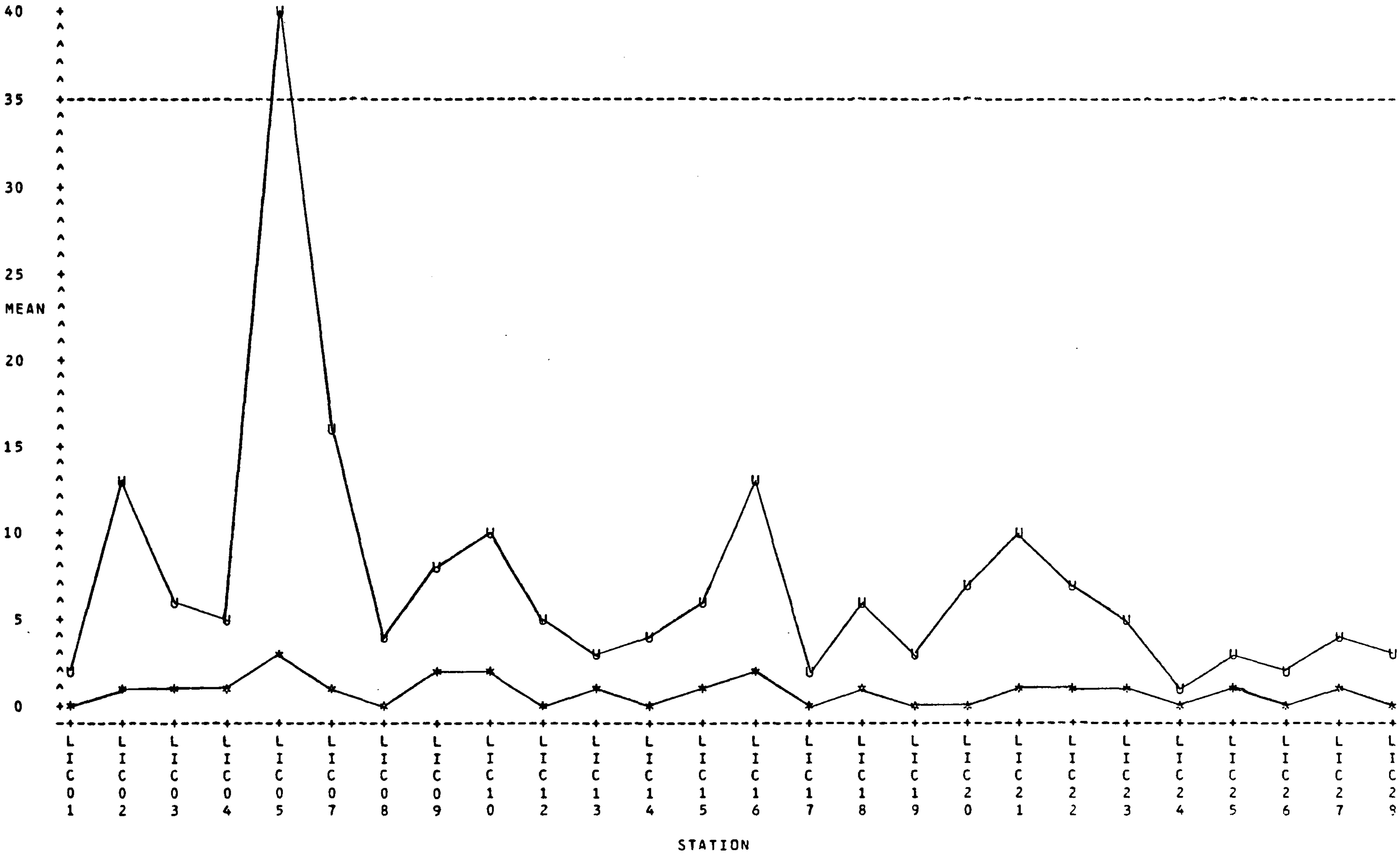


FIGURE-4 GEOMETRIC MEANS OF ENTEROCOCCUS DENSITIES
LONG ISLAND COAST STATIONS
SUMMER 1987

PLOT OF MEAN*STATION SYMBOL USED IS *
PLOT OF MAXIMUM*STATION SYMBOL USED IS U



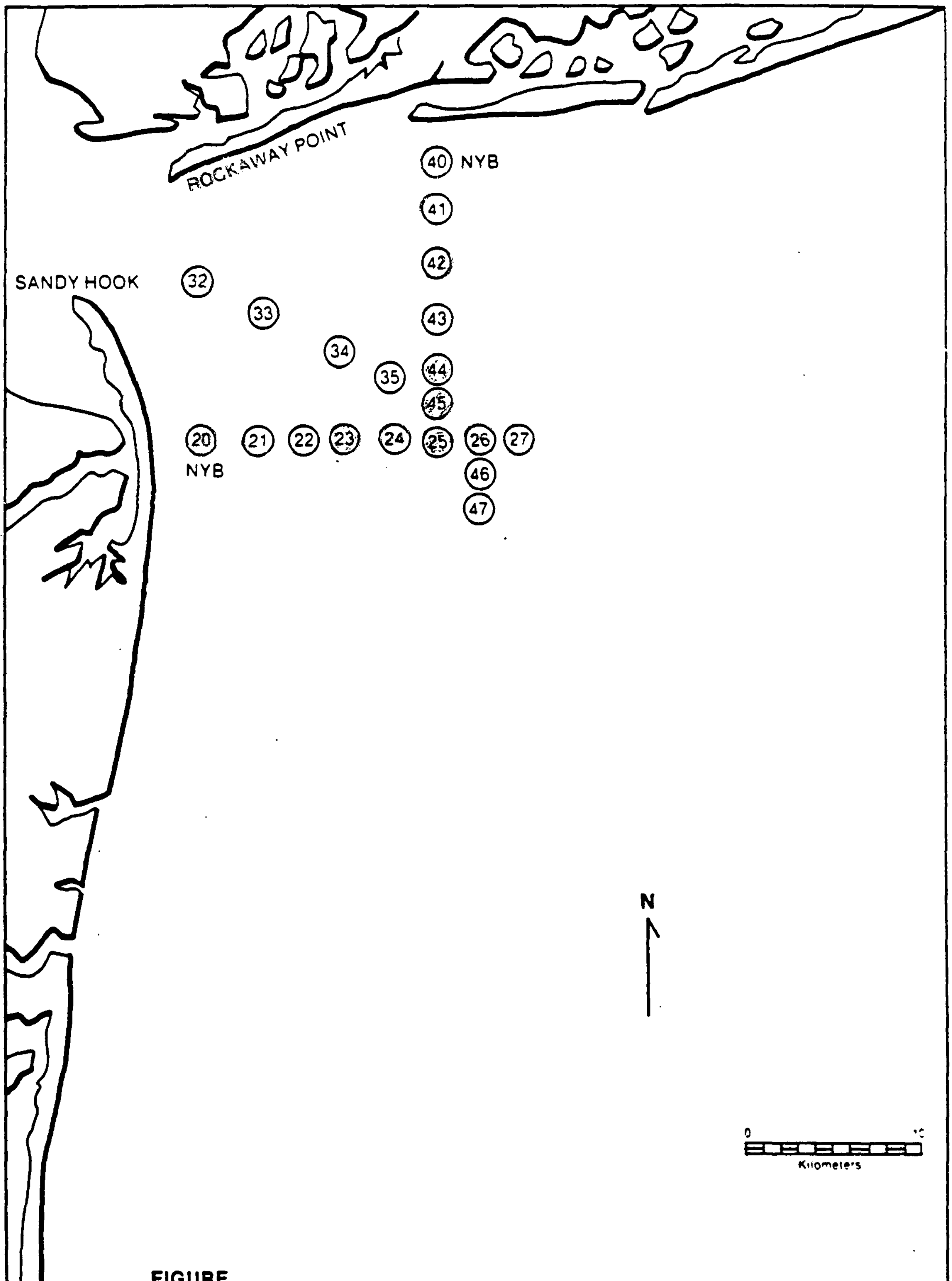


FIGURE
NEW YORK BIGHT STATION LOCATIONS