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Annual NEMP Report on the Health of the Northeast Coastal Waters, 1982

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The Northeast Monitoring Program (NEMP) Management Team would like to thank all those individuals who contributed to this year's annual report. Several drafts of this report were prepared and reviewed by the NEMP writing team, which was divided into sections on Water Quality and Phytoplankton, Sediment and Benthos, and Sublethal Effects of Pollutants on Marine Biota. The Team Leaders for these sections were Catherine Warsh, Robert Reid, and Edith Gould, respectively. The final manuscript, as well as the many drafts, were edited by CDR C. R. Berman, Jr., Dr. J. B. Pearce, and Ms. Marlene Rosen. The final product, however, is the result of work performed by many members of the NOAA Organization and of scientific research and analyses carried out by NOAA personnel, contractors, and academic investigators involved in NEMP.

EXECUTIVE SUMMARY

The following pages summarize the findings set forth in more detail within the' body of the report. This brief overview will serve to alert the reader to particular areas of interest which he or she may wish to investigate further by referring to the chapter involved.

1. WATER QUALITY AND PHYTOPLANKTON

With the increased incidence of eutrophication and hypoxia in the nearshore coastal waters of the United States, water quality monitoring in the northeast region has grown in importance. Some of the 1982 results are summarized below.

1.1 Waste dispersion modelling of particles with different sinking velocities was initiated to demonstrate variability in depositional patterns under mean westerly wind conditions.

1.2 Average sea surface temperatures in the Middle Atlantic Bight were found to be cooler and the salinity fresher in the nearshore region than in 1982. The Gulf of Maine was warmer in the spring.

1.2.1 Seaward stream flow increased by 30% from that recorded in 1981-82.

1.2.2 The "cold pool" intersected the New Jersey coast in September.

1.2.3 Studies of plume behavior resulting from tidal. phase and wind direction has shown that plumes are more dispersed with ebb tides; plumes tend to move seaward away from bay mouths with southwest and westerly winds and tend to flow southward and nearshore with northerly winds. Estuarine plumes have overlapped ocean disposal areas confounding the partitioning of plume versus dumping effects on living marine resources.

1.3 Levels of dissolved oxygen in bottom waters remained above critical levels during the 1982 field season.

1.4 Highest concentrations of nitrogen occurred in the Hudson River plume in April and September; highest concentrations of ammonia occurred at the Hudson River mouth in April and June. Nitrogen enrichment occured in subeuphotic depths on the inner shelf from April through September returning about half of the nitrogen used by productivity processes during the spring bloom. Levels of ammonium in bottom waters over the shelf increased from April through August and decreased through September.

1.4.1 No significant differences in chlorophyll levels were found in the New York Bight Apex between the periods 1956-58 and 1977-82.

1.4.2 Georges Rank, a highly productive area, had high biomass concentrations of plankton with the netplankton found in greater numbers.

1.4.3 In the Middle Atlantic Bight, highest biomass concentrations occurred in spring with a secondary maximum in November and December. Netplankton dominated the early spring blooms; nannoplankton dominated after thermal stratification.

2. SEDIMENT QUALITY AND BOTTOM ORGANISMS

The most important findings from our recent monitoring of sediment quality and bottom organisms are:

2.1 There is an area of elevated concentration of several trace metals, often to half of their highest concentrations in the New York Bight Apex, beyond 200 m depths in Hudson Canyon (the extension of the Hudson Shelf Valley, which runs from the Apex to the shelf edge). This may imply that the Shelf Valley is a 'seaward conduit for contaminants introduced in the inner Bight.

2.2 Trace metal levels in Penobscot Bay, Maine are (as previously reported for Casco Bay) comparable to other, more industrialized New England embayments.

2.3 Statistically significant increases in sediment PCB concentrations between 1981 and 1982 have been detected at stations off Delaware Bay, in the New York Bight Apex and in Buzzards Bay, Massachusetts. Concentrations at other stations were unchanged from 1981.

2.4 Potentially carcinogenic polynuclear aromatic hydrocarbons (PAHs) were found again in nearly all sediments analyzed. With the exception of the New York Bight Apex, analyses indicated the PAHs generally had combustion rather than liquid petroleum sources. Mean concentrations in Casco and Penobscot Bays, in the northern Gulf of Maine, exceeded all others we have measured in the NEMP Region except the Bight Apex. Distributions in Penobscot Bay are indicative of contemporary, anthropogenic activities rather than long-term natural phenomena.

2.5 Incidences of potentially pathogenic protozoa (*Acanthamoeba*) at the Philadelphia Dumpsite in June 1982 were essentially unchanged from incidences found before sludge disposal ended in November 1980. Numbers of coliform bacteria had diminished, however.

2.6 Preliminary estimates indicate that productivity of the anthropogenically stressed Bight Apex benthic macrofauna is similar to that of the unpolluted Georges Bank, within comparable bathymetric zones. Whether the quality of the Apex fauna is the same or not remains unanswered.

2.7 Grazing sea urchins have continued to destroy kelp beds off Maine and New Hampshire. Increases in urchin populations have been attributed, in part, to reduced predation by diminished lobster stocks. Kelp provides shelter for lobsters, and its removal may in turn further reduce lobster populations.

2.8 No major short-term changes have been revealed by NEMP submersible observations and indirect sediment-fauna sampling (in agreement with studies by other groups) in regard to contaminant concentrations or biological effects due to oil exploration on Georges Bank. Petroleum hydrocarbons were present at low levels in the demersal species analyzed prior to any drilling.

2.9 There was no significant change in overall seabed oxygen consumption in the New York Bight Apex between 1974/75 and 1982. There was a 66% decrease in oxygen consumption in and near the dredged material dumpsite, apparently in response to a substantial decrease in the rate of dumping of dredged material over the same time period. Oxygen utilization increased by 79% in and near the sewage sludge dumpsite, probably due to an increase in the volume of sludge disposed of between 1974/75 and 1982.

2.10 Larval surf clams and amphipods had significantly lower settlement and/or survival in sediment trays with sewage sludge added, as compared to trays of uncontaminated sediment, deployed off the southern Long Island coast.

3. SUBLETHAL EFFECTS IN MARINE ANIMALS

3.1 In 1982, as in previous years of NEMP monitoring, the incidence of marine biological anomalies was highest in coastal and inshore waters, where concentrated monitoring activities have located particular "hot spots". Such aberrant metabolism, disease, and genetic mutations result in fish which are not thought to grow normally nor reproduce successfully.

3.2 In offshore waters, biological anomalies are sporadic and thinly distributed. The few exceptions to this general observation, most notably the Block Island midshelf station and the outer Hudson Valley slope, have been identified as potential or actual trouble spots through our seasonal monitoring activities.

3.3 The coastal waters and coastal sediments, therefore, must claim our close attention. They are marine sinks into. which a highly variable mixture of contaminants is rained, poured, and dumped; these include heavy metals and organic hydrocarbons (PCBs, PAHs, pesticides, petroleum hydrocarbons). Because the greatest concentrations of these pollutants are to be found in estuarine and coastal areas (especially the New York Bight and Raritan Bay), and because the highest frequencies of marine biological anomalies are observed in these inshore waters, the inescapable conclusion is one of cause and effect.

INTRODUCTION

In this, the third annual Northeast Monitoring Program (NEMP) Report on the Health of the Northeast Coastal Waters of the United States, 1983, we present our most recent results of monitoring and research which were conducted throughout 1982 and earlier, at stations located over the continental shelf and slope between the Canadian border and Cape Hatteras.

The goals and objectives of the NEMP have been described previously in the first and second annual NEMP reports (NOAA, 1981, 1983). It should be emphasized that the NEMP is a long-term monitoring program designed to assess the condition of fisheries habitats, to establish benchmarks against which temporal and spatial changes can be measured and from which data can be developed for use in formulating testable hypotheses. Recent interpretations of previous research, some of it conducted over 100 years ago, suggest that fisheries habitats have changed markedly in recent decades. Often there was very little warning provided and consequently no management steps were taken to reverse the effects of physical degradation and contamination by a range of wastes materials. Where warnings have been made in the past, environmental managers, legislators, and the public often did not heed them or were unable to implement effective pollution abatement because the data were insufficient to justify expensive mitigation processes.

The present program was implemented so as to establish benchmarks for levels of contaminants in the physical compartments of the habitats, sediments and water, and biota, and the effects of these contaminants (and other environmental stresses). Such measurements are essential to answer the sources, fates, and effects "equation" by providing information as to where the various contaminants become sequestered. In the present sense, contaminants are taken to mean those materials which impact adversely on the habitats necessary to the production of fish. For instance, excessive nutrients, abrasive suspended materials, a range of inorganic and organic chemicals, and changes in temperature due to man's activities are regarded as contaminants.

As we establish information on the sources and fates of contaminants we are, at the same time, using techniques that have been developed in the past to assess the effects of man's activities at the individual, population, and community levels (see Figure 1).

The program to date has been effective in establishing benchmarks for the abundances and distributions of contaminants in sediments and in a range of key or indicator species. Information on levels of contaminants in selected commercially and recreationally important resource species has already proven important in helping to elucidate the issues associated with PCBs in species found within the New York Bight. Our previous data suggest that, while many inshore recreational species have been reported to have PCB levels that exceed the so-called action level of 5 ppm (now lowered to 2 ppm), the vast majority of individuals that have been examined do not. This has allowed several agencies to assure' the citizenry and fishermen, both recreational and commercial, that there is little immediate danger from consuming most species taken from shelf habitats, even those fairly close to shore.

1 IDENTIFICATION OF CONTAMINANT OR PHYSICALLY DEGRADED "HOT SPOTS" USING CHEMISTRY AND BIOLOGICAL EFFECTS MONITORING,

2. IDENTIFICATION OF TRENDS; SPATIAL AND TEMPORAL,

3. QUANTIFICATION OF EFFECTS:

    3.1 SUBLETHAL EFFECTS,

    3.2 MORTALITY, AND

    3.3 EFFECTS ON STOCKS,

4. RISK ASSESSMENTS (SEE FIG, 3).

5. ANALYSES OF CAUSATION (FIELD AND LABORATORY EXPERIMENTS),

6. MANAGEMENT OF FISHERIES HABITATS:

    6.1 REGULATIONS,

    6.2 LEGISLATION, AND

    6.3 FISHERIES MANAGEMENT PLANS LEADING TO:

        6.3.1 MAINTENANCE OF YIELDS OR INCREASED YIELDS, AND

        6.3.2 HABITAT ENHANCEMENTS OR MITIGATION,

Figure IN1. The steps that have been agreed upon as leading to effective marine habitat management.

Moreover, our information on the levels of petroleum hydrocarbons also indicated that the majority of indicator species that have been collected and analyzed for their body burdens of petroleum hydrocarbons had detectable levels of petroleum hydrocarbons in their tissues, even though extensive petroleum exploration and development activities had not occurred on the continental shelf off the northeast coastline. Had these analyses been done after petroleum exploration or development on Georges Bank or in the Middle Atlantic Bight, the accusation might have been that any excess body burdens of petroleum hydrocarbons were due to the development activities themselves. Thus, such data can be used for various purposes.

A generalized fisheries mortality equation indicates that several variables can affect the mortality rates of living marine resources. These include effects due to fishing pressure, anthropogenic activities, predation, disease, and "natural variability", i.e. climatology, etc. The latter might include sudden changes in temperature, effects of storms as they impact resources along the coastlines, and so forth. Of the variables which constitute the fisheries mortality equation, only two actually can be affected by man's management decisions. Mankind can establish limits to the taking of fin- and shellfish; by establishing such quotas he can affect the rate at which the resources are removed (mortality) and can assure adequate standing stocks of adults for future reproduction and recruitment. Such actions have been recommended since the mid to late 19th century (Baird, 1873). In regard to man's effects on living marine resources, managers can emphasize the conduct of coastal and shelf development activities in a multiple-use framework so as to avoid many of the effects of physical degradation and waste discharge. For instance, governmental agencies can insist on pretreatment of industrial wastes to minimize the amounts of toxic inorganic and synthetic organic contaminants introduced into domestic sewer systems which are ultimately discharged through point sources or via ocean dumping in estuary and shelf waters. Society also can regulate the intensity, frequency, and spatial extent of dumping activities. By developing data on the effects of ocean dumping, environmental managers can determine whether dumping can occur without damaging principal fisheries or important coastal recreational areas and habitats. Such management might involve dispersing materials to be dumped over greater areas so that there is not a concentration of wastes within one particular area.

Increased multiple-use of coastal habitats, for recreation, transportation, sport and commercial fishing, and for waste disposal will occur in the near future. In order to manage the fisheries and their habitats more effectively, it will be necessary to have long-term trend data available as to 1) how contaminants have affected fisheries in the past, 2) how they are affecting them at the present time, and 3) how, through modeling and hazard assessment, man can predict biological effects in the future; is it possible to equate units of man's activities, and their effects, to units of fishing mortality? If so, is it possible that man's effects are increased where fish are exposed to unusual fishing pressures, or predation?

For these various reasons we deem the third annual NEMP report to be extremely important. During the past three years of active implementation of components of the NEMP we have been able to demonstrate where changes have occurred in the fisheries habitats. One of the most striking findings is that smaller estuaries and coastal waters in relatively remote areas that are being monitored have been shown to have higher than expected values for trace metals, PCBs, and petroleum hydrocarbons. These areas, located along the southern and central Maine coastline, previously had been thought to be relatively pristine and free from the effects of major industrialization and domestic development. This apparently is not the case. The important habitats of Casco and Penobscot bays have been shown to have levels of petroleum hydrocarbons which are deemed to be of concern since they affect fisheries resources. Levels of petroleum hydrocarbons found in sediments in these embayments are thought to be of a magnitude that can result in tainting of seafoods. It is significant that at the time of the U. S. Civil War, shellfish and finfish taken from Newark Bay were reported to be no longer saleable because they tasted of coal oil (kerosene). This was undoubtedly due to leakages into Newark Bay from the early refineries that had been sited along the shores of the lower Hudson estuary. We are now seeing the same kind of early warning signs in more remote portions of the area of interest to the NEMP. Obviously if pollution abatement, mitigation, and other expensive activities that would be used to improve fisheries habitats are to be expedited, there must be sufficient information available to justify the expenses. It is important to note, that a lack of action would be adverse to U. S. fisheries; this would happen at the very time when the U. S. is attempting to become more independent of imported fishery products and, in fact, is attempting to increase its fisheries for export. The following is illustrative of the current problems. At the present time there is a FDA action limit for PCBs in fish tissues. By law, fish sold on an interstate basis for human consumption may not contain over 5 ppm PCBs (now 2 ppm); many nations in the world, especially in Scandanavia, have established action limits for PCBs at the 2 ppm level. There is discussion in the United States about reducing the action limit in this country to 2 ppm. Some fisheries managers have suggested that it would be more reasonable to reduce the level to 3.5 ppm. The reason for this is that these individuals feel that the difference between 2 and 3.5 ppm of PCB would be negligible in terms of protecting the public health, while the calculated loss to the U. S. fisheries in 1983, if the action limit were established at 2 ppm, and not 3.5 ppm, would be $97 million. This example is given simply to indicate that, at the present time, fishery products may have been compromised to a significant degree by contaminants; i.e. a significant dollar value loss of concern to the industry will occur if the proposed new action levels are developed.

Other instances of the economic effects of pollution can be cited. Literally tens of thousands of acres of productive shellfish grounds presently cannot be harvested legally because of bacterial loading. In most instances such shellfish grounds are to be found in bays and estuaries. However, in recent years the FDA has ordered closed a large portion of the Middle Atlantic Bight to the harvesting of surf clams and ocean quahogs. This was done because of extremely high levels of bacteria in shellfish habitats. It is not impossible that in the near future closures to the harvesting of organisms might be made where levels of PCBs or other contaminants exceed certain guidelines within the physical habitats. Such steps have already been taken in some foreign waters. If additional closures were to occur they would compromise again valuable living marine resources. Our present data are extremely important in such decision making and will allow for effective early warnings.

Finally, this year's report has been developed in a somewhat different format from the previous reports that covered calendar years 1980 and 1981. We have attempted to shorten the report and to describe more briefly the changes or possible significant events that have been measured in the water column, sediments and benthos, and the effects on living marine resources of various anthropogenic activities. We have also begun, for the first time, to describe the habitat quality of the various Water Management Units (WMU's) that have been identified by the NMFS Northeast Regional Office and the Northeast Fisheries Center. These descriptions will be printed as NEMP Technical Memos, separate from the annual report. Moreover, our 1982 report indicates how we are shifting emphasis from the intensively studied New York Bight area to regions in New England and to the south; beginning this year and continuing into the future, considerable attention is being paid to the quality of marine habitats in the Massachusetts Bay and Gulf of Maine areas. In future years emphasis will shift from these northern sectors to Delaware Bay and the offings of Chesapeake Bay. As we continue our long-term temporal and spatial monitoring activities, we will make such periodic adjustments, returning eventually to reassess the benchmarks that had been established for waters intensively studied earlier, i.e. the New York Bight and outer continental shelf habitats. We are also modifying, based on the results of the last three years, some of our biological effects monitoring techniques. As we drop some particular techniques or hold them in abeyance until we wish to reassess previously established benchmarks, we will be implementing new techniques which have been recommended by national and international scientific groups or agencies.

Finally, we are giving inshore areas greater attention than was the case in 1980-82. The results of our monitoring suggest that the major problems or issues are associated with such areas. It is also recognized that our pollution monitoring data will be even more important in terms of the Exclusive Economic Zone Proclamation of 1983 (Boxer, 1984).

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Boxer, B. 1984. Marine Pollution Research in Exclusive Economic Zone Planning. In: Exclusive Economic Zone Papers, MTS/IEEE Oceans '84 Symposium, September 1984, NOAA Ocean Assessments Division, Rockville, MD 20852.

CHAPTER I, WATER QUALITY AND PHYTOPLANKTON

1. INTRODUCTION

The area of concern to the NEMP, the Gulf of Maine to Cape Hatteras, is oceanographically heterogeneous, embracing several distinct bathymetric shoreline features and water masses. Four principal basins drain into the area: the Canadian-New England, Southern New England, Delaware-Hudson, and Chesapeake. Three major estuarine systems influence the NEMP area: the Chesapeake, Delaware, and Hudson-Raritan bays (Figure WQ1). The NEMP area has been further divided into Water Management Units (WMU) each of which represents a relatively cohesive area, based on hydrography and biology, and provides a narrower context within which specific management decisions can be made (NEMP Annual Reports, 1981, 1982).

Within the Northeast Region in recent years, there have been numerous examples of marine environmental changes which are thought, in part, to be pollution-related, resulting from outfall discharges and ocean dumping. For example, nutrients derived from sewage sludge, sewage effluents, and dredged material have contributed to inshore and estuarine eutrophication (Malone, 1976; O'Reilly et al., 1976; Eppley et al., 1979). Hypoxia (levels of low dissolved oxygen in bottom 'waters) in shallow waters over continental shelves is also becoming an increasingly important problem. Hypoxia has been implicated in mortalities and habitat dislocation of benthic organisms including commercial species, as evidenced by the 1976 hypoxia incident in the Middle Atlantic Bight which caused extensive mortalities among commercial shellfish (Swanson and Sindermann, 1979). The purpose of-the NEMP Water Quality monitoring is to be able to predict low levels of dissolved oxygen which may occur in bottom waters, particularly in the New York Bight apex and on the continental shelf off New Jersey, and to define the extent of contamination and eutrophication in our coastal waters.

Processes that cause or lead to hypoxia or eutrophication are not well understood. A major problem in assessing the eutrophication of coastal and shelf water or in predicting hypoxic conditions is the absence of quantitative and standardized long-term monitoring programs with time series data referenced to the scale of pollution events and natural climatological cycles, and with clear baselines established prior to man's impact. The water quality portion of NEMP was established, in part, to help rectify this situation.

To define these processes and their relationships and interactions, it is necessary to monitor a number of variables which contribute to hypoxia or eutrophication. These variables include: dissolved oxygen, productivity, chlorophyll 2, nutrients, phytoplankton, and temperature and salinity. In addition to these variables, algal assays are performed to provide information on limiting effects of nutrients on phytoplankton growth and productivity.

Remote sensing technology is also used in the monitoring program to provide information on plume location and movement, surface movement of water masses, chlorophyll a concentrations and distribution, and sea surface temperatures. As a monitoring tool, remote sensing provides a synoptic overview of the study area which can be used to identify water masses, estuarine plumes, turbidity plumes from sewage sludge or dredged material, surface oil films, dispersion from acid waste dumps and spring blooms of

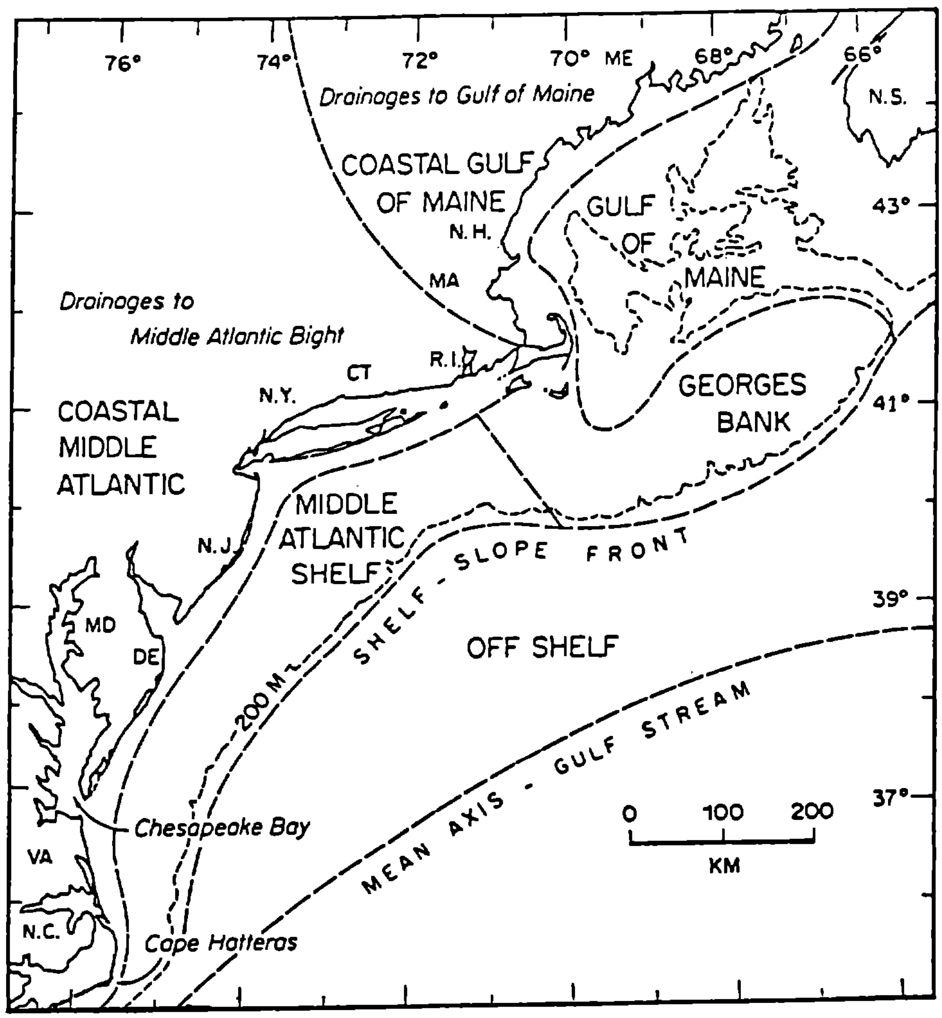


Figure WQ1. Water Management Units and coastal drainage areas from Cape Hatteras to Nova Scotia.

phytoplankton. The latter may also provide information on potential outbreaks of "red tide" organisms.

This year the emphasis in monitoring has been in sampling both the nearshore coastal band and the mid-shelf and offshore waters of the Middle' Atlantic Bight. This work will enable us to begin assessments of the relative contribution of the several nutrient sources to eutrophication and related oxygen problems which are known in the inshore areas.

2. HYDROGRAPHY

Temperature and salinity data are being used for the modeling of waste disposal and plume dispersion to determine the fate and effects of pollutants entering the environment through estuarine runoff and ocean dumping. These data also describe water masses over the continental shelf and in the nearshore zone, providing information on boundaries and movement of estuarine plumes, density stratification, the cold pool, and the shelf/slope front. Descriptions of interactions and movements of these water masses are necessary to understand dispersion and distribution of wastes, nutrients, and phytoplankton. General surface circulation in the NEMP area is shown in Figure WQ2.

This year, we developed models which demonstrate dispersion of dumped particles having variable sinking speeds (from 3 to 100 m/day) under mean westerly wind conditions (Hopkins and Dieterle, 1983). The dispersal, of pollutant particles dumped at the Philadelphia Dumpsite were simulated to demonstrate the variability in depositional patterns for particles of different sinking velocities when dumped at the surface under typical circulation conditions. The results, shown in Figure WQ3, show the distribution of particles remaining in the water column and those deposited on the bottom after 5 days. The contours indicate relative concentrations; the water column distribution shows the concentrations within a 5-m layer at the surface, mid-depth, and bottom.

Sea surface temperatures in the NEMP area for the first quarter of 1982 were close to long-term means (1948-67) except in the Middle Atlantic Bight, where they were anomalously cooler. Departures from the means in the area in January-March were widespread and as large as -4°C. During the 1982 sampling season, surface water temperature in the Middle Atlantic Bight (April-September) was cooler (1-2°C) than in the previous two years and salinity fresher (1-2 °/oo) in the nearshore to mid-shelf waters.

During April and May an area of warmer-than-average surface temperatures appeared in the Gulf of Maine, with departures from the norm of up to +2.9°C. During these two months the coastal weather station at Portland, Maine recorded above-normal air temperatures, with departures from long-term means of up to +7.2°C during the last half of April and of +3.3°C during the first half of May.

In June-September, sea surface temperatures were close to normal throughout the NEMP area, but in October-December anomalies as great as +1.8°C occurred in the Gulf of Maine and continued into 1983.

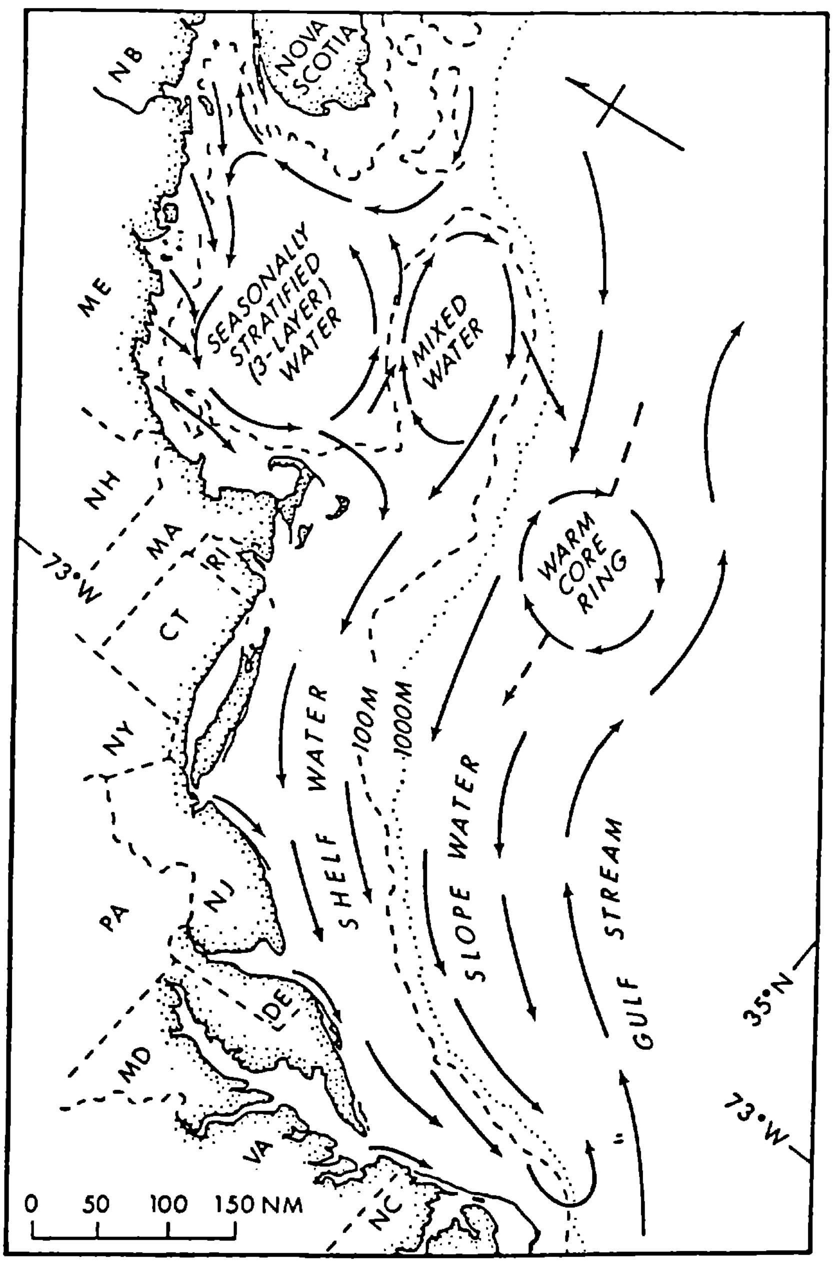


Figure WQ2. General surface layer circulation of northwestern Atlantic coastal and offshore waters.

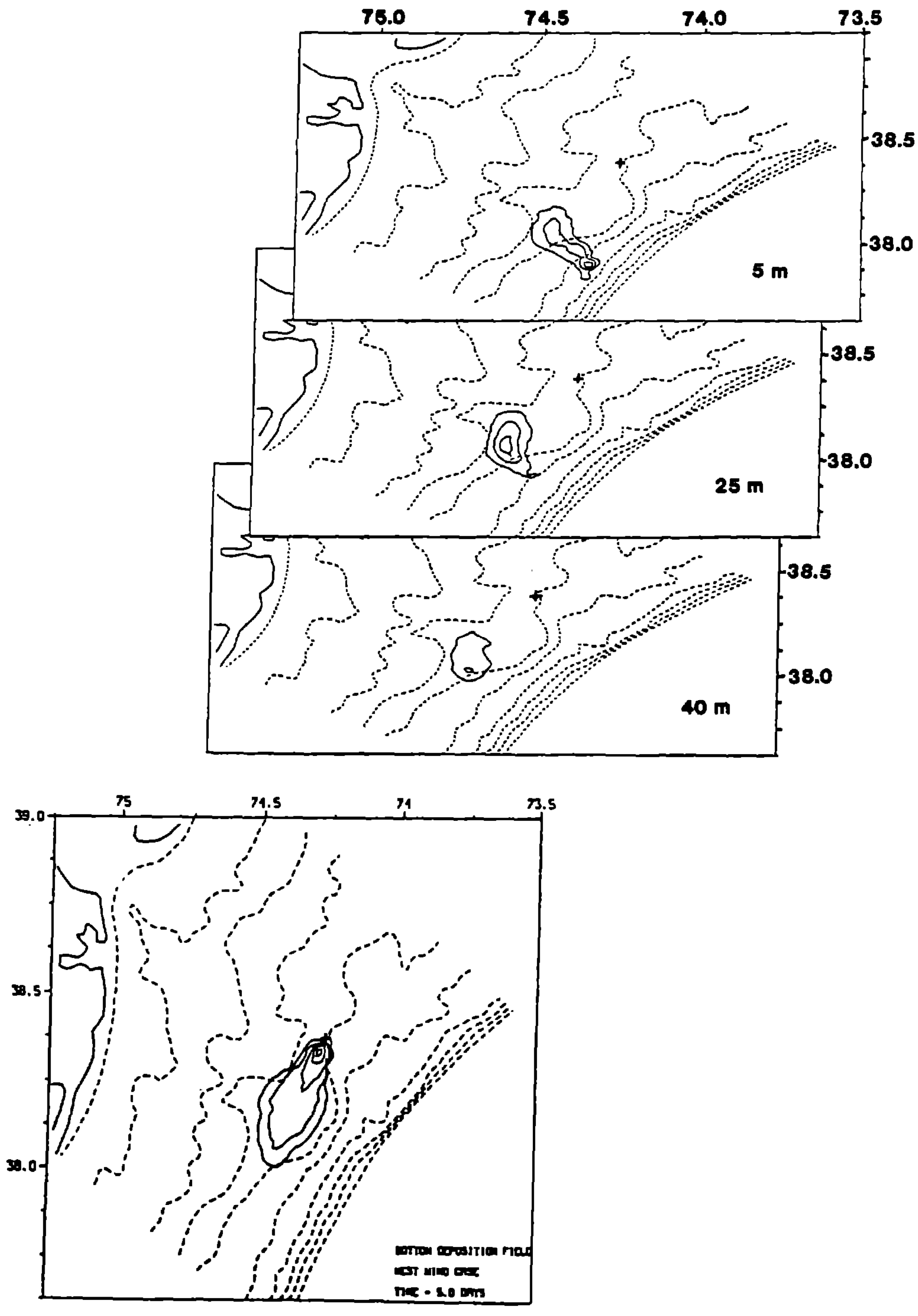


Figure WQ3. Distribution of particles after five days for westerly wind conditions for a simulated dump at the Philadelphia Dumpsite (+).

Stream flow in 1982 into the Middle Atlantic Bight, according to U.S. Geological Survey records for Chesapeake Bay and Long Island Sound, increased about 30% from the low values of 1980 and 1981 (Figure WQ4). This situation is reflected in the lower surface salinity data recorded in July 1982. The 1982 stream flow values, however, were still below the 1970-81 averages.

The surface front separating the shelf water and slope water masses normally found in the vicinity of the edge of the continental shelf was generally 25-35 km seaward of its long-term (1973-77) mean position throughout the NEMP area. Associated with this condition was the passage of a near-record number (11) of warm core Gulf Stream rings through the slope water, increasing the potential for exchange between shelf and slope water (Celone, and Price, unpubl. ms). In bottom waters the shelf/slope front was shoreward of the shelf break with the 34 °/oo isohaline along or inshore of the 60 m isobath. The "cold pool" was reported to be well shoreward of the 60 m isobath intersecting the northern New Jersey coast in September.

3. ESTUARINE PLUMES

Descriptions of estuarine volume kinetics have been developed from infrared satellite imagery for coastal waters receiving discharge from Chesapeake, Delaware, and Raritan Bays. Knowledge of plume behavior and settling properties of suspended solids permits an assessment of areas in which an impact on benthic and pelagic resources might be expected. Plumes emanating from the Hudson-Raritan, Delaware, and Chesapeake estuaries predominantly affect the shelf contiguous to and south of these estuaries (Fedosh and Munday, 1982).

Two-hundred and sixty-eight Landsat multispectral scanner images (1972-81) and 68 Heat Capacity Mapping Mission thermal infrared images (1978-79) have been studied and sorted according to tidal phase, wind vectors, and season to determine the influence of these factors on plume behavior (Figure WQ5). Ebb tide (compared to flood tide) plumes are more dispersed. Southwest and westerly winds appear to drive the plumes seaward or away from bay mouths. Northerly winds confine the plumes to nearshore regions, and accentuate net nontidal southward flow along the coast.

The area off Chesapeake Bay was shown to have estuary-associated plumes of salinity, nutrients, chlorophyll, bacteria and contaminants (Thomas, 1983). There was also evidence of suspended materials and associated contaminants (hydrocarbons, heavy metals) settling to the seabed down the length of the plume.

Of particular interest and different from the Chesapeake Bay Plume is an extension of part of the Delaware Bay Plume northward along the New Jersey coast much of the time (Figure WQ6).

These estuarine plumes overlap ocean disposal areas and confound the partitioning of plume and dumping effects on the living marine resources. Of the 82 Raritan Bay Plumes examined, 42 (51%) were in or beyond the New York dredge spoil area; 10 (12%) were in or beyond the 12-mile (19 km) sewage sludge area, and none were in or beyond the acid waste -disposal area 45 km-to the southeast (Figure WQ7). None of the 139 plumes examined off Delaware Bay reached any presently defined disposal area. Of the 60 detected plumes

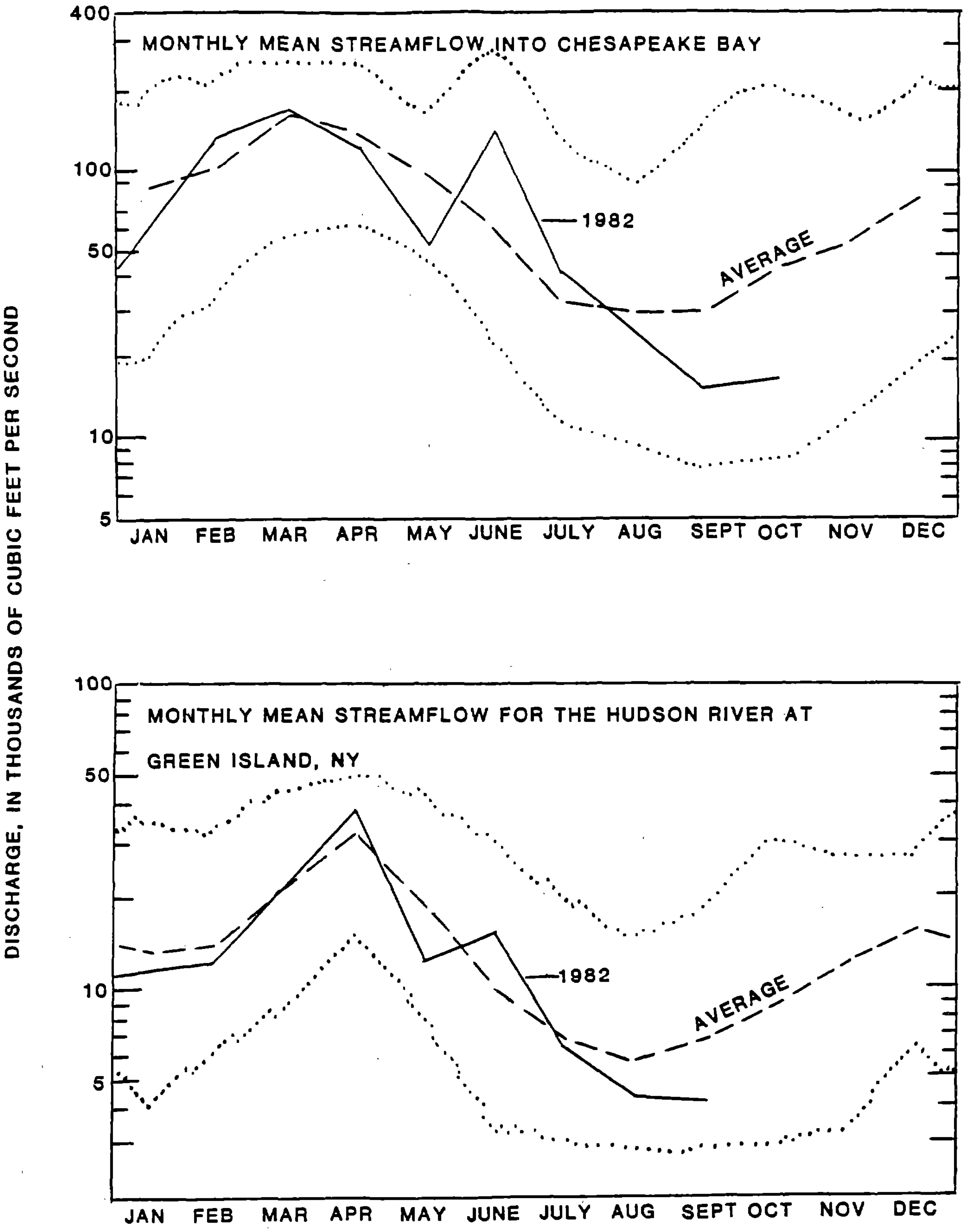
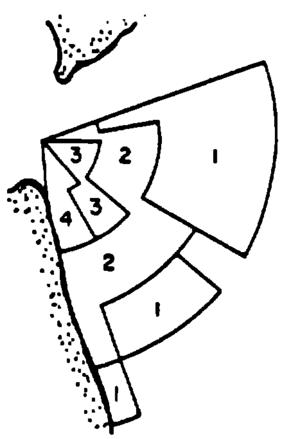
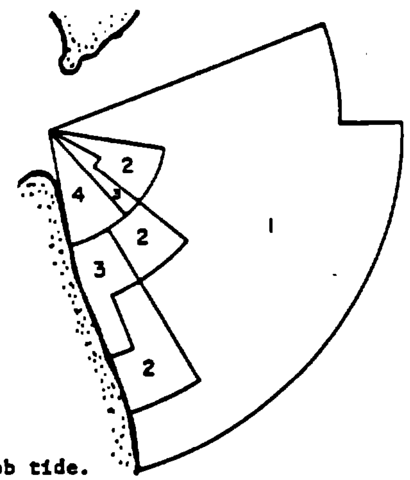


Figure WQ4. Monthly mean stream flow into Chesapeake Bay and for the Hudson River at Green Island, NY. Dotted line shows range between highest and lowest monthly mean flows for period of record.

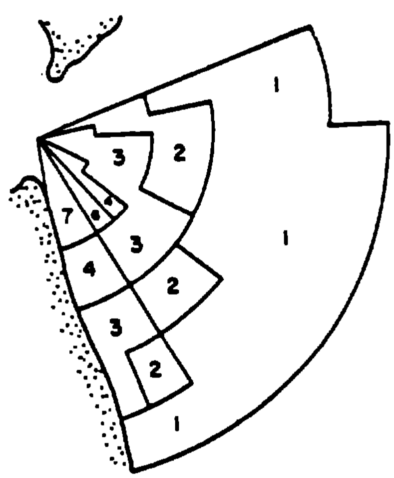


a. Flood tide.



b. Ebb tide.

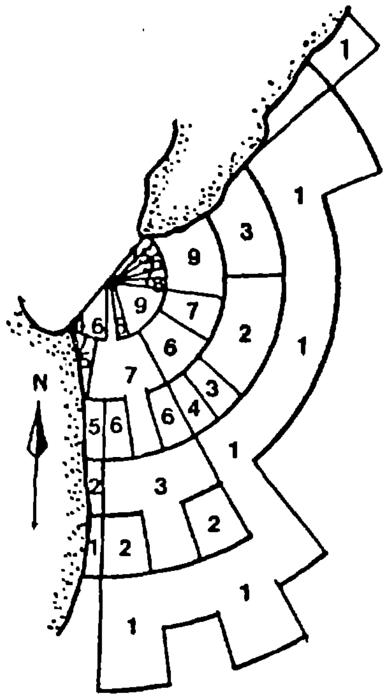
Areas visited by the plume under different tidal phases.



CHESAPEAKE BAY

c. All wind quadrants.

Figure WQ5. Areas visited by the Chesapeake Bay plume under different wind conditions. The numerals represent sector/zone counts as follows: 1 - 0-5 counts; 2 - 6-10; 3 - 11-20; 4 - 21-30; 5 - 31-40; 6 - 41-50; and 7 - >50.



DELAWARE BAY

Figure WQ6. Areas visited by the Delaware Bay plume under different wind conditions (from 112 Landsat Images).

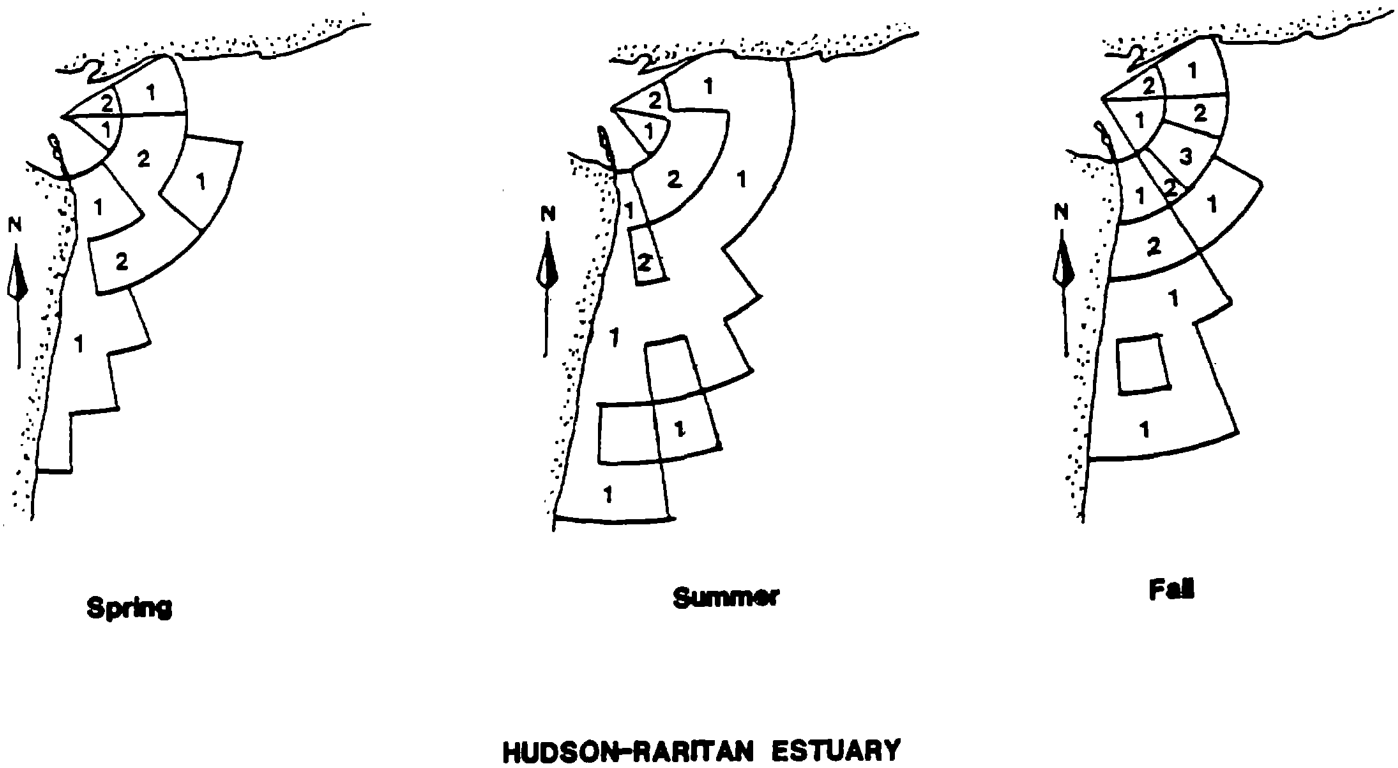


Figure WQ7. Areas visited by the Hudson-Raritan plume under different wind conditions by season (spring - 13 Landsat Images; summer - 15 Landsat Images; fall - 12 Landsat Images).

emanating from Chesapeake Bay, 16 (27%) were within or beyond a proposed disposal area 30 km offshore.

4. OXYGEN

Oxygen is a dependent variable which fluctuates as a result of variations in several other parameters. During the summer as temperature increases stratification (thermocline) intensifies, and nutrient loading continues, oxygen demand in bottom waters increases. Circulation, mixing, and oxygen exchange across the pycnocline are reduced and low concentrations of dissolved oxygen occur in bottom waters during late summer in the Middle Atlantic Bight, particularly on the New Jersey shelf. This process continues until cooling and the fall overturn occur. The areal extent, intensity, and duration of seasonally depressed oxygen concentrations vary. This condition is reflected in the monitoring data collected to date (Warsh, cruise reports, 1980-83).

From April through mid-September 1982 the average dissolved oxygen levels in bottom waters along the New Jersey shelf/New York Bight apex were higher than in the previous two years. For the nearshore sections the oxygen levels were within the historical range and above the mean annual level during most of the sampling period (Warsh, 1983). Early June was the only month in which the average dissolved oxygen fell below the mean annual level (Figure WQ8). It was, however, nearly equal to that found in 1980 and 1981, and was well above the danger level for biota. In the apex the average level of dissolved oxygen near the seabed was slightly lower than in the previous three years but still above 4 ml/l (Figure WQ9). A few areas with lower levels of dissolved oxygen (>3 ml/l) were found along the New Jersey/Delaware coast in July but were above critical levels.

In April 1982, an area of anomalously low oxygen concentration was found just north of 39°N between the 60 and 200 m isobaths, where values were between 4 and 5 ml/l (Figure WQ10). This area corresponded to an area of higher ammonia concentration; the source of the water appeared at that time to be slope water.

5. NUTRIENTS

Monitoring studies of phytoplankton, chlorophyll a, productivity, and nutrients are intricately related and we continue to find evidence of eutrophication in the nearshore zone. Here, eutrophication refers to increased algal biomass resulting from increased nutrient concentrations (carbon, nitrogen, phosphorous) and shifts in dominant species of phytoplankton toward unwanted or "weed" species. Eutrophication also connotes seasonally lowered oxygen concentrations resulting from increases in biological oxygen demand (BOD) caused by increased algal stocks and oxygen demanding substances in water below the thermocline and below the euphotic layer. While eutrophication and identification of causal nutrient/algal relationships have been documented for many freshwater ecosystems through direct nutrient manipulation and experimentation (Likens, 1972), it is far more difficult to determine precise relationships in the open ocean.

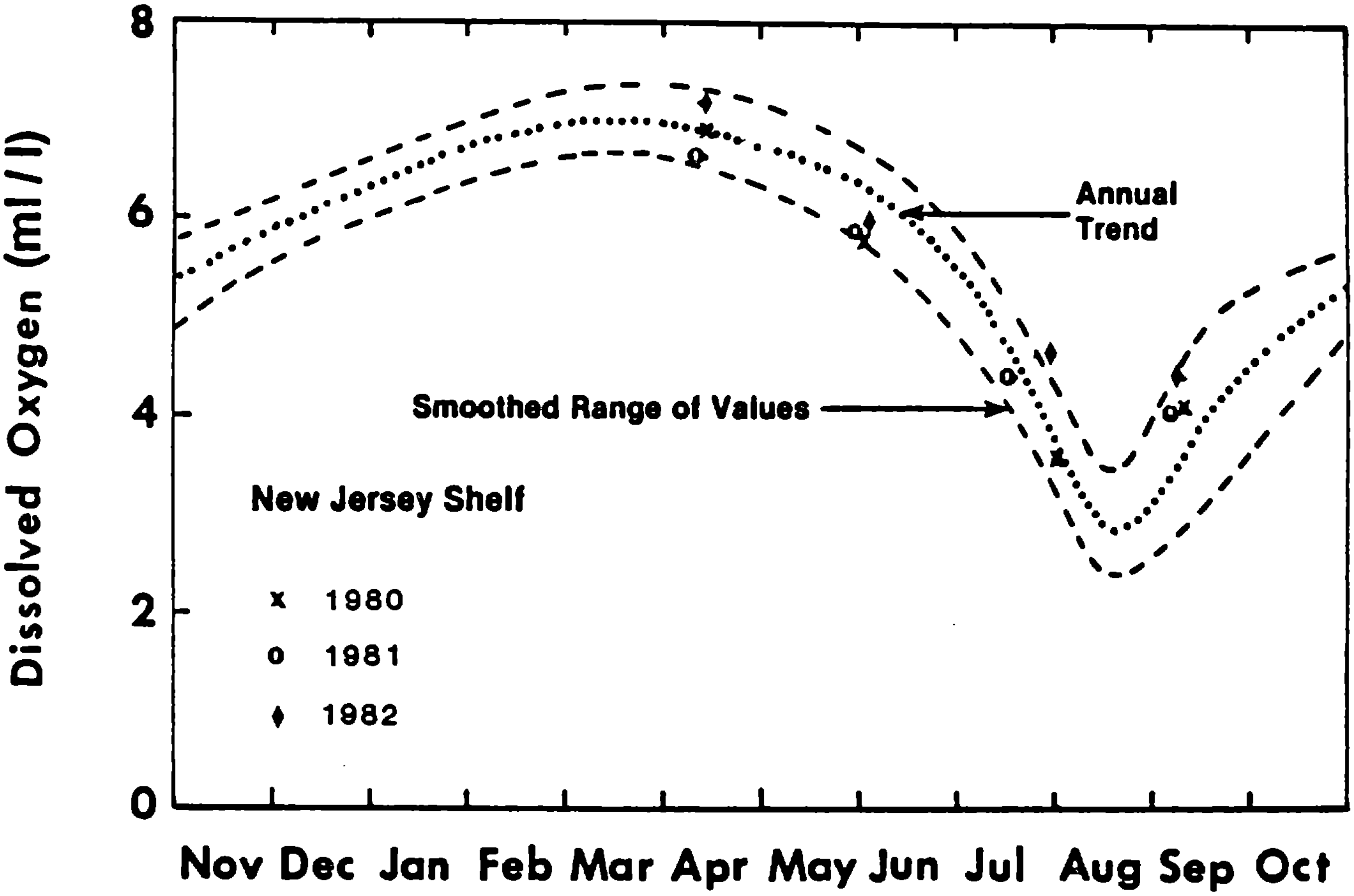


Figure WQ8. Dissolved ocygen levels in bottom waters of the New Jersey Shelf. (Historical data from NOAA Professional Paper No. 11.)

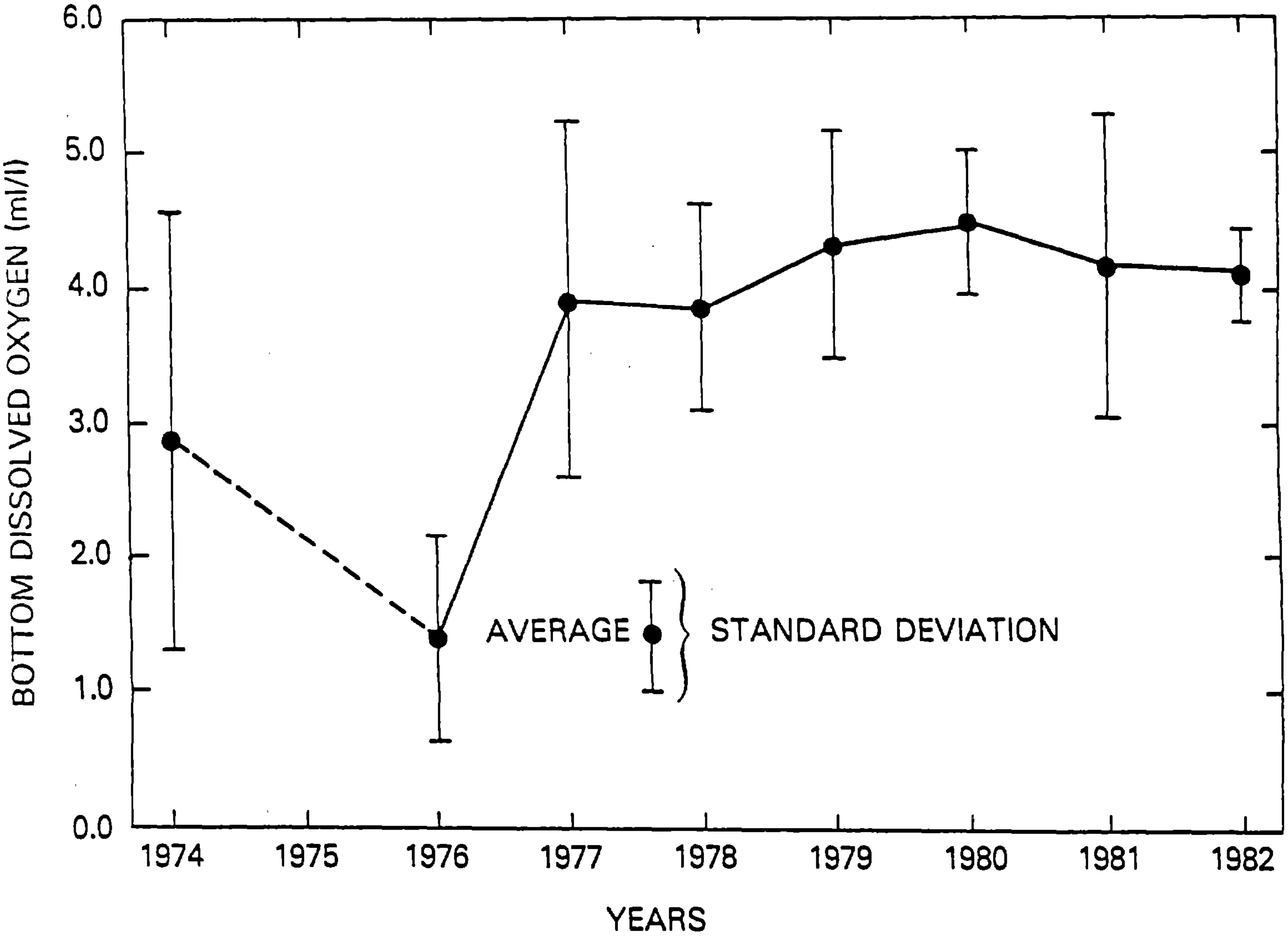


Figure WQ9. Average annual levels of dissolved oxygen in bottom waters of the New York Bight Apex (historical data prior to 1980 from NOAA Professional Paper No. 11).

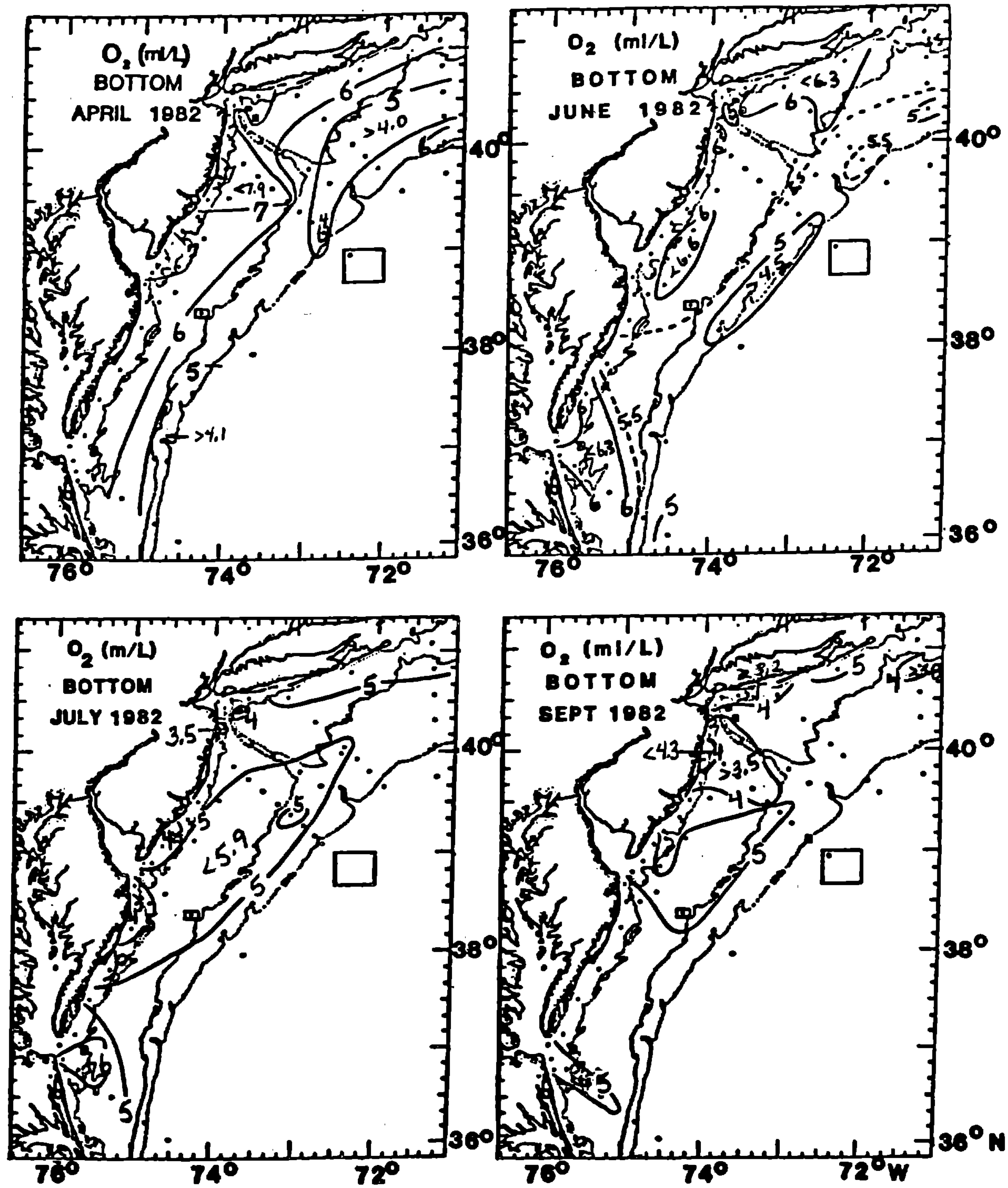


Figure WQ10. Distribution of dissolved oxygen concentrations in bottom waters of the Middle Atlantic Bight for 1982.

Ryther (1954) documented the extreme eutrophication of Moriches Ray and Great South Bay, Long Island, New York caused by inorganic and organic nitrogenous wastes from duck farms. The nutrient enrichment resulted in the displacement of "normal" phytoplanktonic flora by a small (<4 µm) species of chlorophyte. The shift toward the smaller species was believed to be the principal cause of the failure of a prosperous oyster industry in Great South Bay. Similar shifts in phytoplankton species composition and elevated production were reported for the sewage-polluted Raritan-Lower Hudson Estuary (O'Reilly, 1976).

Nutrient loading from the major estuaries and land runoff appear to be important contributing factors to eutrophication and hypoxia. As summer progresses and density stratification develops, increased oxygen utilization in the paths of plumes emanating from major estuaries is evident. Areas of hypoxia are consistently found in these regions (Figure WQ11) along the Atlantic seaboard.

Several sources of nutrients are involved in stimulation of summer plant production to the high levels measured by the NEMP in the inshore coastal band of the Middle Atlantic Bight. The Hudson, Delaware and Chesapeake estuaries as well as other land drainage systems represent important nutrient sources which supplement the natural enrichment of inshore water caused by mixing in shallow areas (Riley 1967). Also, large landward movements of the cold pool can greatly enrich nearshore bottom water with inorganic nutrients from the mid-shelf region (September monitoring survey, Warsh, 1983).

Monitoring studies continue to indicate the importance of nitrogen to phytoplankton growth and reproduction in coastal/shelf waters of the New York Right and the importance of estuarine plumes and sewage sludge as sources of this nutrient. During summer, when the thermocline restricts the replenishment of nutrients in the upper euphotic layer, concentrations of all forms of nitrogen required by phytoplankton (nitrate, nitrite, and ammonium) are quite low, and anthropogenic additions to stratified surface water are detectable up to 50 km from the New Jersey coast (Draxler, 1982). Earlier studies (Malone, 1976) indicated that estuarine outflow entering the New York Bight apex can supply 50-70% of the nitrogen required by phytoplankton. Ryther and Dunstan (1971) indicated that coastal enrichment of shelf water was detectable up to 140 km southeast of Sandy Hook. Bioassay studies by Mahoney (1980) supported the idea that nitrogen is most often the "limiting" nutrient in these waters.

During the 1982 field season the upper 25 m remained low in nitrogen with the exception of the Hudson River Plume in April and September. In August no Hudson River input was observed (Whitledge, 1983). Subeuphotic depths showed increased nitrogen from April through September, especially on the inner shelf. This process of nitrate enrichment of the subpycnocline between May and October returns about one half of the nitrogen used by productivity processes during the spring bloom (Whitledge, 1983; Figure WQ12).

Highest concentrations of ammonia occurred at the Hudson River mouth in April through June. As with nitrate, no Hudson River input was evident in August. Generally, the euphotic zone, seaward of the influence of the Hudson, remained depleted of ammonium. The amount of ammonium along the bottom over the shelf increased from 2 µg-at 1^{-1} to 6 µg-at 1^{-1} (Whitledge, 1983) from

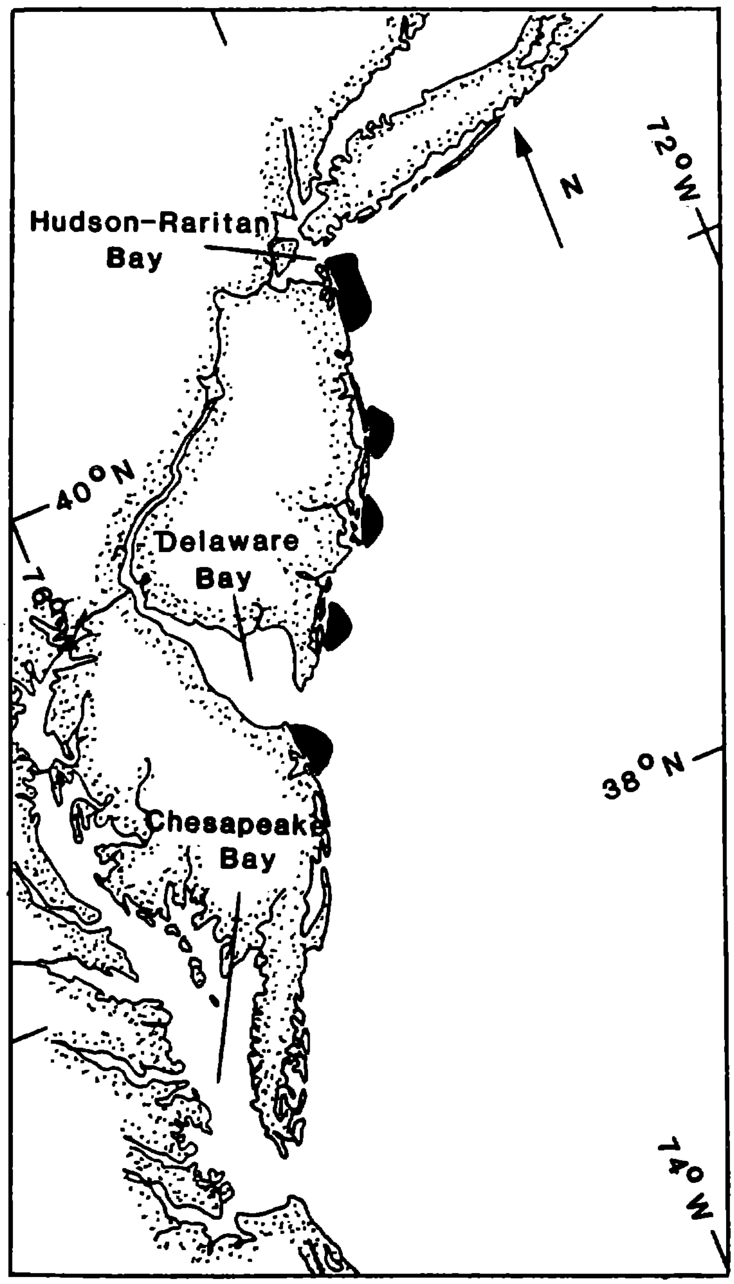


Figure WQ11. Recurrent areas of low dissolved oxygen (<3 ml/L) in bottom waters along the Northeast Coast.

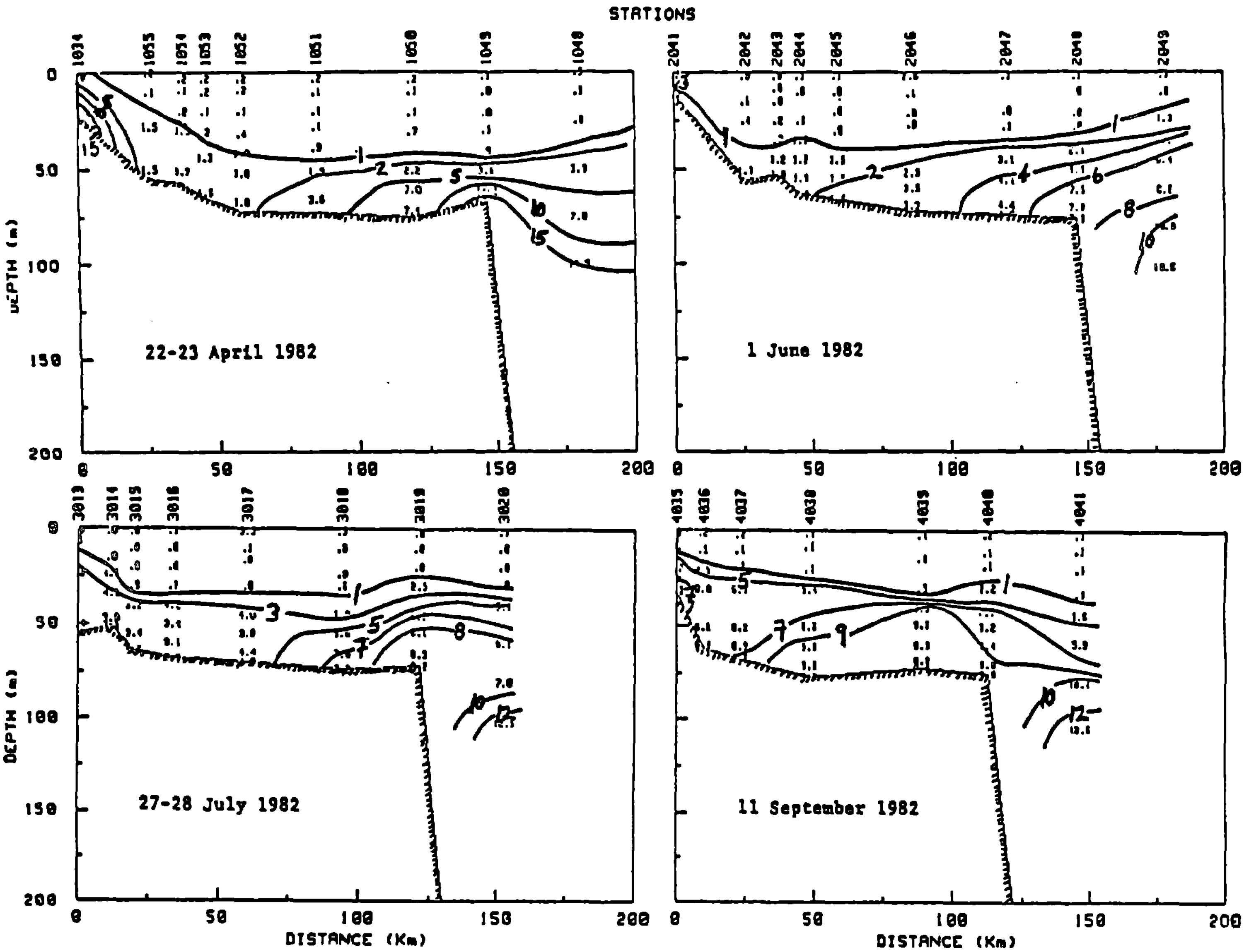


Figure WQ12. Nitrate concentrations (µg-at. liter^{-1}) on Hudson Shelf Valley transect.

April through August. The areal extent of ammonium decreased from early August to September, possibly a result of a smaller amount of organic material deposited from the spring bloom and/or the influx of nitrate-rich and ammonium-poor water throughout the summer (Whitledge, 1983).

During the summer period of intense stratification, low nitrate concentrations are consistently found near bottom over the New Jersey shelf, while over the Long Island shelf much higher values are found. This implies that the physical processes lowering the concentrations are less significant north of the Hudson Shelf Canyon, or that replenishment processes are less vigorous over the New Jersey shelf where the 1976 oxygen depletion occurred (Whitledge, 1983). The lowest concentrations of dissolved oxygen have been found on the New Jersey shelf during periods of intense stratification and where the pycnocline is strongest.

6. PRODUCTIVITY

The 1977-82 NEMP and MARMAP data establish well-defined temporal and spatial baselines for primary production throughout the northeastern continental shelf. The baseline information shows no significant differences in chlorophyll levels between 1977-82 and 1956-58 for the mid and outer New York Bight shelf. These data establish an understanding of spatial and temporal variability. Comparison of these areas with global patterns demonstrates the importance of primary production on the shelf. Community analysis shows species specific relations and consistency within Water Management Units (WMUs).

The primary production component of the ecosystem is monitored on a region-wide basis and will be continued to be studied through integration and analysis of remotely sensed data with temporally and spatially consistent water column algorithms, based on 1977-82 MARMAP and NEMP data. However, the processes affecting the distribution of chlorophyll a and related coastal Middle Atlantic units having areas of evident eutrophication need to be the initial focus of such process-oriented studies.

Studies characterizing phytoplankton community structure developed the net/nannoplankton ratio as an indicator of efficiency in energy transfer to the food chain and subsequent living marine resources. This year's analysis of the Gulf of Maine - Georges Bank - Southern New England showed that trends in percentage nannoplankton data followed the total pigment data, with higher concentrations of nannoplankton on Georges Bank than in surrounding waters (Figures WQ13, WQ14). The fact that high biomass concentrations are found on Georges Bank and that no larger netplankton are generally found in greater quantities than nannoplankton, makes Georges Bank a more highly productive area where energy may be transferred efficiently through the system. This statement is based on an hypothesis advanced by Ryther (1969), Parson and LeBrasseur (1973), and Steele and Frost (1976). Such findings are also consistent with the high potential for "usable" particulate carbon on Georges Bank (O'Reilly and Busch, 1984) and are realized in the valuable fishery resource production of Georges Bank.

In the Middle Atlantic Bight, the monthly distribution of biomass was bimodal with the highest biomass concentration in the spring and a secondary maximum between November and December. Additional maxima were seen in August

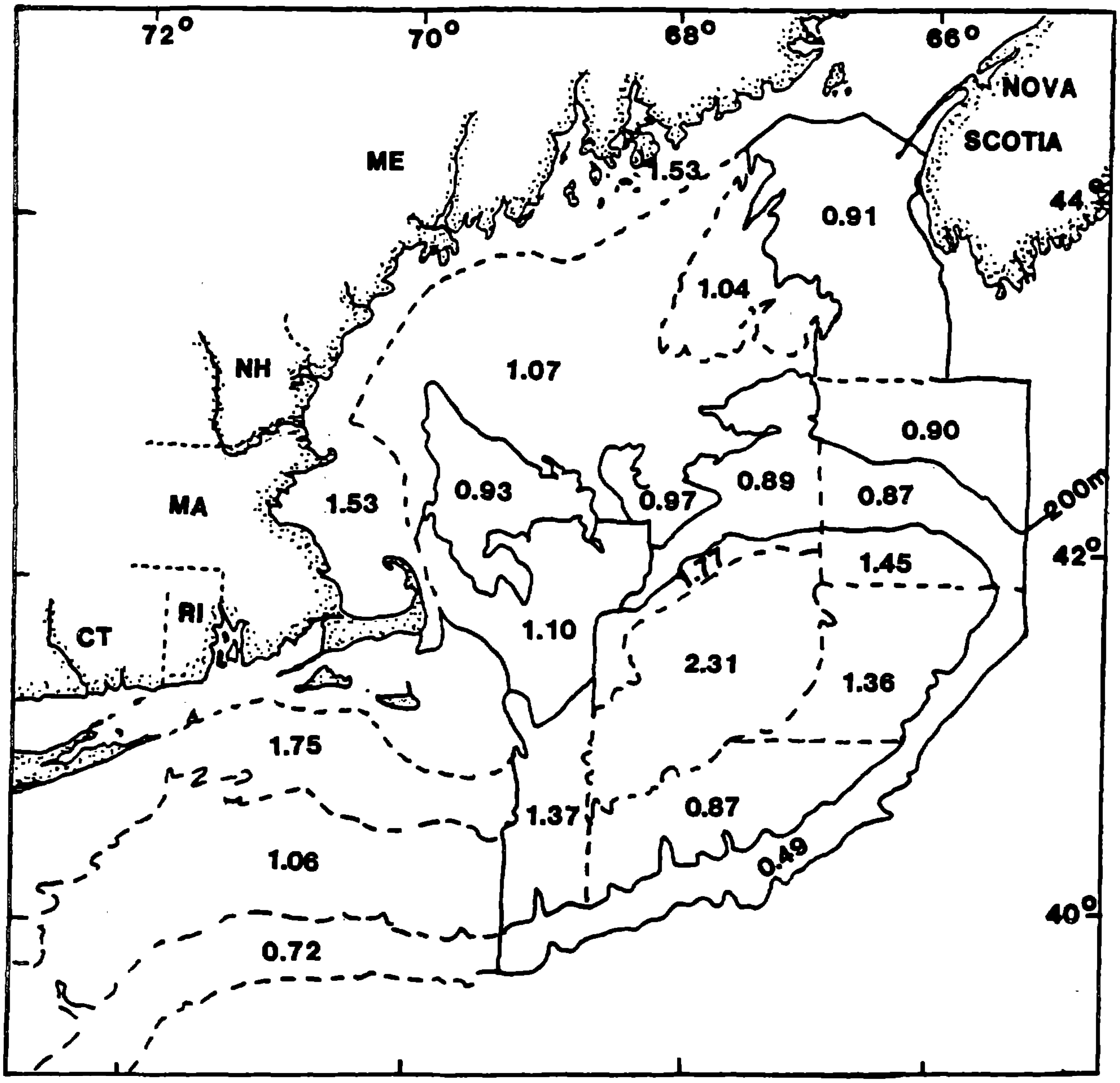


Figure WQ13. Average of all chlorophyll a (mg m^{-3}) measurements in the upper 27 m of the water column by subarea.

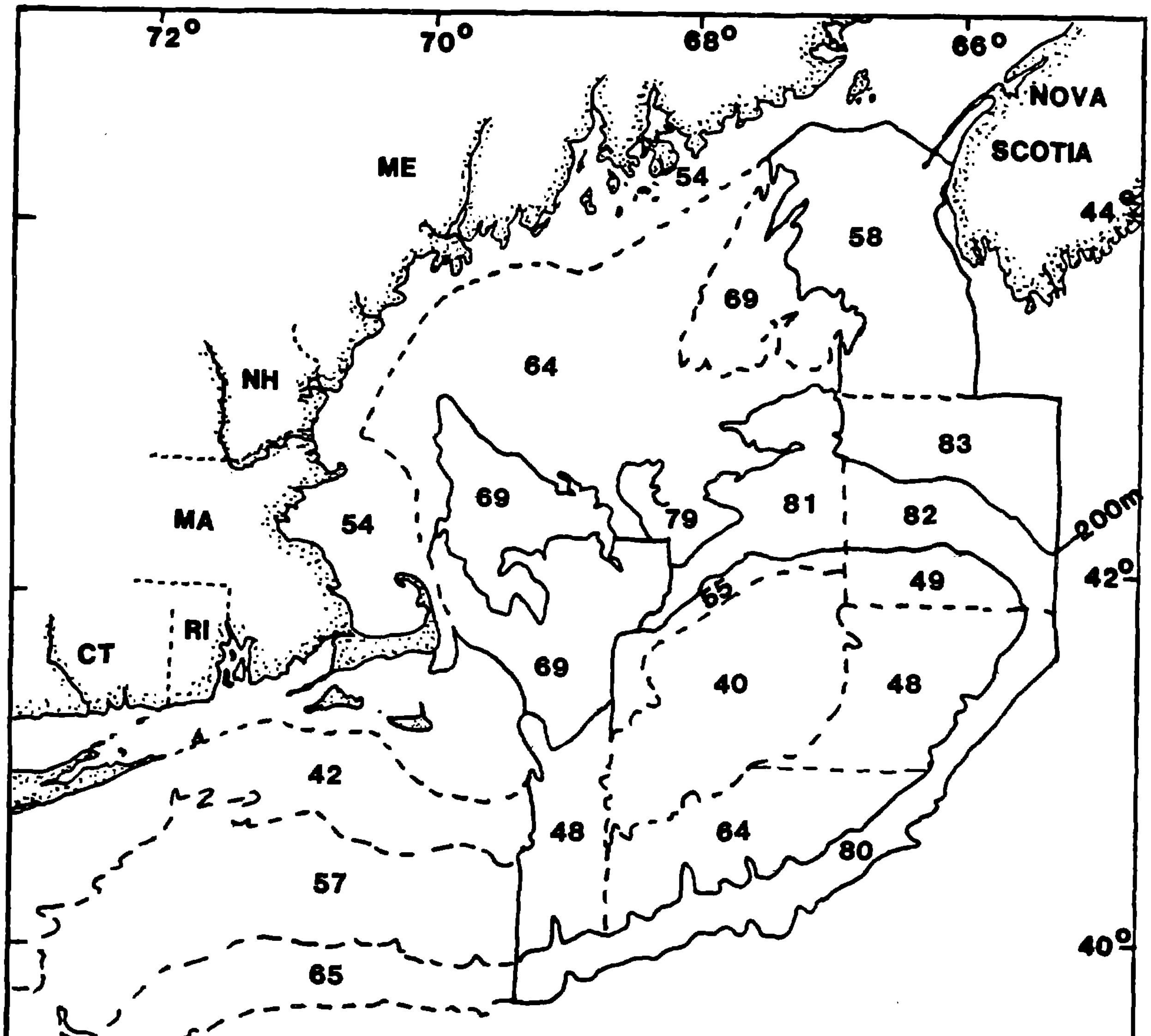


Figure WQ14. Average percent nannoplankton in the upper 27 m of the water column by subarea.

and September in the inshore regions <40 m. The lowest biomass concentrations were found during late spring and early summer (Figure WQ15). Netplankton dominated the early spring bloom, whereas nannoplankton dominated after thermal stratification and were of nearly equal dominance by the November-December peak. Nannoplankton dominated the phytoplankton population (>90%) in the high chlorophyll regions, and, in September, the nearshore water concentration of chlorophyll a resulted in an inshore phytoplankton population consisting primarily of nannoplankton (78%) and diatoms (16%). Nannoplankton (96%) dominated the phytoplankton on the outer shelf (Whitledge, 1973).

An exception to this pattern was observed inshore during the August period where increasing biomass was reflected in netplankton dominance. However, this shift was short-lived and the biomass peak of September reflected a nannoplankton dominance.

The significance of the post-thermal stratification pattern is that the growing short-lived, and slower trophic-energy-transfer-efficient, nannoplankton are available to use any anthropogenic nutrients introduced to the system. This factor should be considered in the summer eutrophication potential noted off the New Jersey coast.

7. SUMMARY

With increased incidences of hypoxia and eutrophication in the nearshore coastal waters of the United States, water quality monitoring in the Northeast Region has grown in importance. Some of the 1982 results are summarized below.

- Waste dispersion modelling of particles with different sinking velocities was begun to demonstrate variability in depositional patterns under mean westerly wind conditions.

- Average sea surface temperatures in the Middle Atlantic Bight were cooler and salinity fresher in the nearshore region than was the case in 1982. The Gulf of Maine was found to be warmer in the spring.

- Seaward stream flow increased by 30% from that recorded in 1981-82.

- The cold pool intersected the New Jersey coast in September.

- Studies of plume behavior resulting from tidal phase and wind direction has shown that plumes are more dispersed with ebb tides; plumes tend to move seaward away from bay mouths with southwest and westerly winds and tend to flow southward and nearshore with northerly winds. Estuarine plumes have overlapped ocean disposal areas confounding the partitioning of plume versus dumping effects on living marine resources.

- Levels of dissolved oxygen in bottom waters remained above critical levels during the 1982 field season.

- Highest concentrations of nitrogen occurred in the Hudson River Plume in April and September; highest concentrations of ammonia occurred at the Hudson River mouth in April and June. Nitrogen enrichment occurred

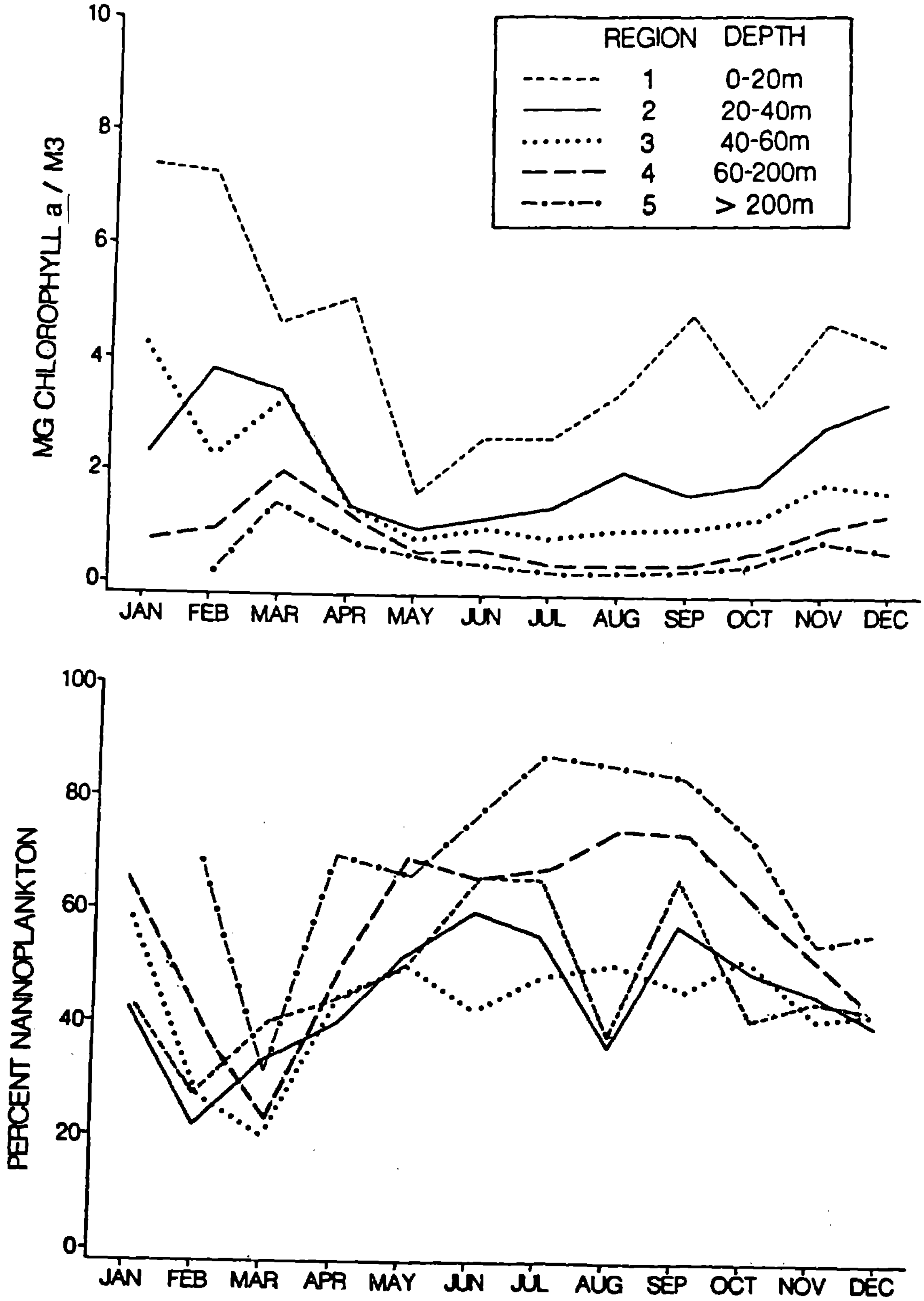


Figure WQ15. Average community biomass and community composition (% nannoplankton plotted by month for five regions) in the Middle Atlantic Bight.

in subeuphotic depths on the inner shelf from April through September returning about half of the nitrogen used by productivity processes during the spring bloom. Levels of ammonium in bottom waters over the shelf increased from April through August and decreased through September.

o No significant differences in chlorophyll levels were found in the New York Bight apex between 1956-58 and 1977-82.

o Georges Bank, a highly productive area, had high biomass concentrations of plankton with netplankton found in greater numbers.

o In the Middle Atlantic Bight highest biomass concentrations occurred in spring with a secondary maximum in November and December. Netplankton dominated the early spring blooms; nannoplankton dominated after thermal stratification.

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CHAPTER II. SEDIMENT QUALITY AND BOTTOM ORGANISMS

1. INTRODUCTION

Monitoring sediments and their associated organisms is critical to any assessment of the health of Northeast marine ecosystems. Sediments are studied because 1) distribution and abundance of bottom fish, shellfish and the smaller benthic invertebrates are often strongly influenced by sediment type, and 2) sediments, especially the finer sizes (silts and clays), are a "sink" which accumulates organic detritus and contaminants; in some cases sediments hold over 99% of the total amount of a pollution in an ecosystem (Renfro, 1973 and others).

The animals living in or near the bottom include many of the fish and shellfish species of most interest to man. Whereas smaller bottom organisms can be an important source of food and contaminants (including pathogenic microorganisms) for these sought after species, which may also take up contaminants directly from the sediments. Because of these relationships, NEMP has several integrated efforts focused on monitoring benthic ecosystems. Figure SED1 shows sampling locations for both our region-wide sediment-bottom organism work and the spatially more intensive sampling being done in several selected areas within the region. Specific rationales for many of the variables we monitor, and major findings of that monitoring, follow.

2. SEDIMENT CONTAMINANTS

2.1 Heavy Metals

We routinely examine concentrations of seven trace metals (cadmium, chromium, copper, lead, nickel, silver and zinc) in sediments. These metals are all reported to be potentially toxic both to marine organisms and to man. Analyses over the past year have concentrated on the inner New York Bight, the Hudson Shelf Valley running southeast from the inner Bight, and the Hudson Canyon in depths >200 m beyond the Shelf Valley. Summer 1981 sampling revealed similar patterns of concentrations for all metals, as illustrated by the concentrations of zinc (Figures SED2). Highest metal levels were again found in the Christiaensen Basin, between the dredged material and sewage sludge dumpsites; this pattern is unchanged from earlier studies (Reid et al., 1982; Caracciolo and Steimle, 1983). Secondary concentration peaks occurred in the Middle Shelf Valley, and elevated concentrations (often half as high as the largest values found in the apex) were also measured at the head of Hudson Canyon.

Ranges of metal concentrations found in the bight in 1980 and 1981 are shown in Table SED1. In general, peak levels of copper, nickel, and lead in the Bight apex were 60 to 80% higher than those found in 1980 (Table SED2). The moderately high levels found in the Hudson Shelf Valley near the 60 m depth contour showed smaller increases (approximately 30 to 40%) for lead and zinc over the 1980 levels. Grain size and organic carbon content of the sediment samples were not available at the time of writing, so we do not yet know whether the observed increases are due to differences in particle size and carbon content of the samples collected (which could in turn be due partly to differences in station locations). The wider ranges of values in 1981

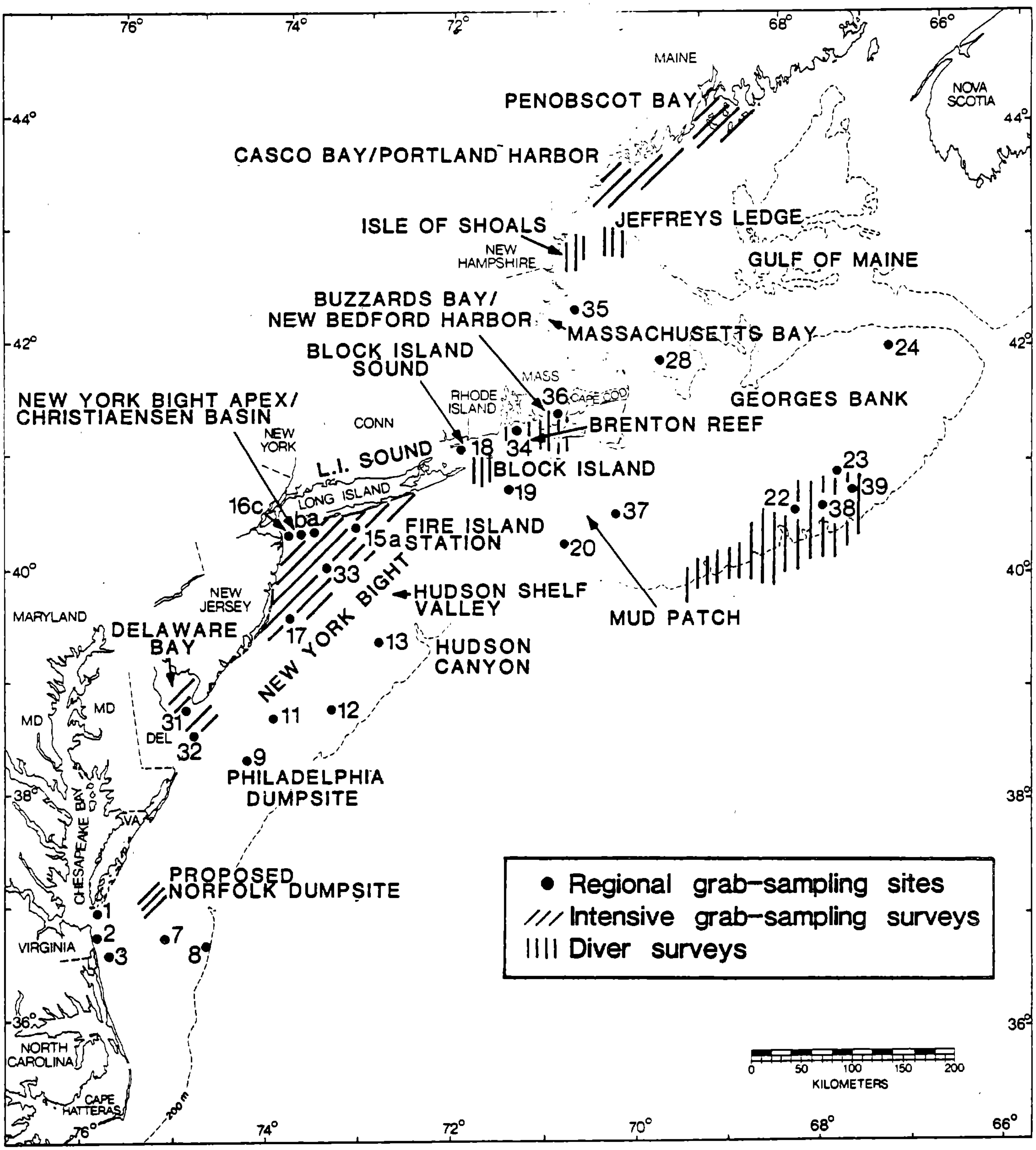

Figure SED1. Locations of NEMP regional grab sampling sites, intensive grab surveys, dive surveys, and other features discussed in text.

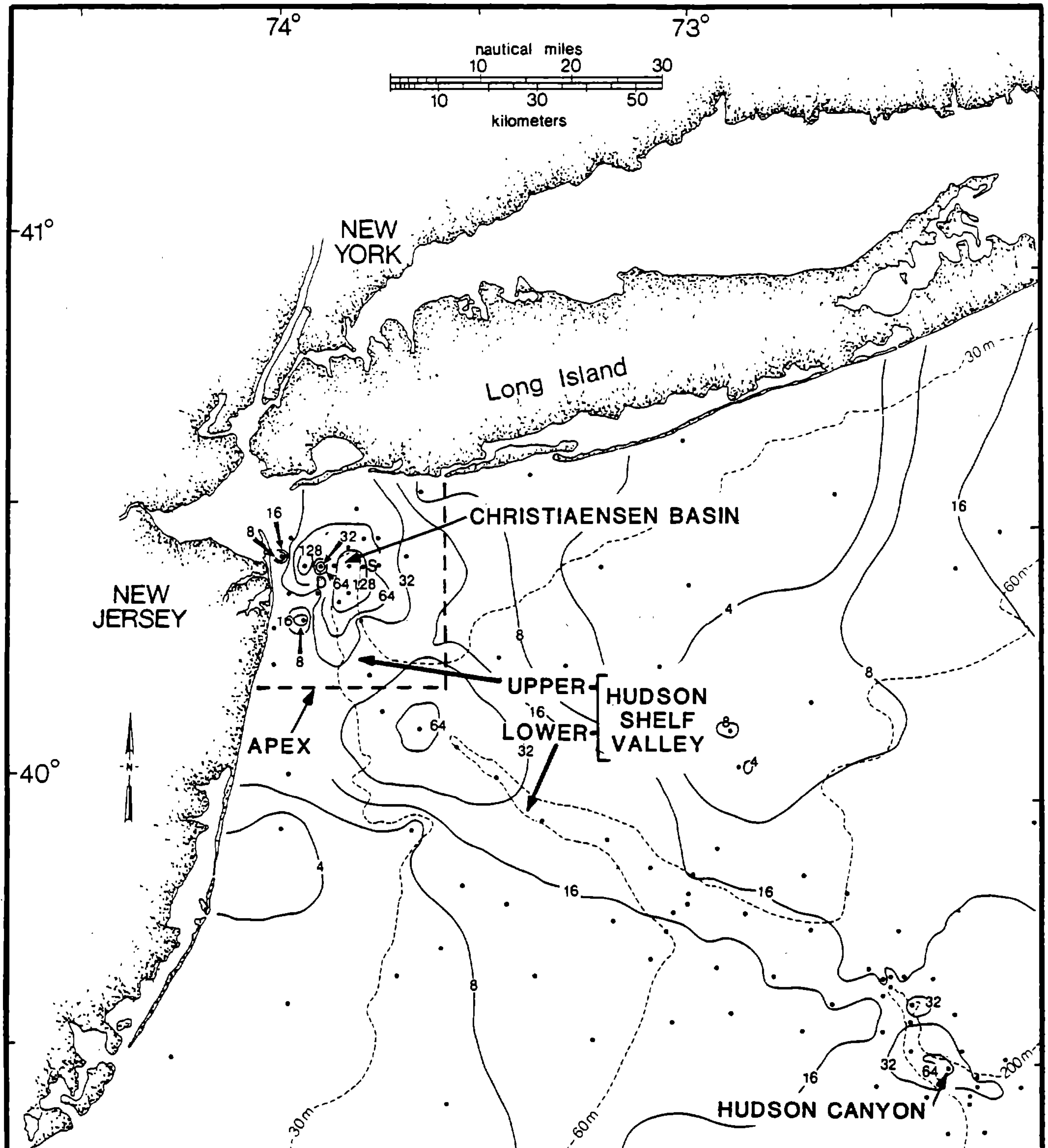

Figure SED2. Concentrations of zinc (ppm, dry weight) in surficial sediments of the New York Bight, August 1981. D = dredged material dumpsite, S = sewage sludge dumpsite.

Table SED1. Ranges of concentrations of trace metals in New York Bight sediments (ppm dry weight), summer 1980 and 1981.

	1980[1] (n = 33)[3]	1981[2] (n = 103)
Silver	-	<0.10-4.0
Cadmium	<0.25-3.7	<0.10-4.0
Chromium	<1-65	1-120
Copper	0.5-120	0.3-120
Nickel	0.5-16	<0.2-35
Lead	0.2-130	1-240
Zinc	3-230	2-260

[1]Reid et al. (1982)

[2]Zdanowicz and Bruno (1982)

[3]Number of stations

Table SED2. Percent increases over 1980 trace metal concentrations in sediments of the New York Bight Apex and the Upper Hudson Shelf Valley (ppm).

	Apex			Hudson Shelf Valley near the 60 m depth contour		
	1980[1]	1981[2]	Percent increase[3]	1980	1981	Percent increase
Cadmium	3.7	4.0	8	0.50	0.77	54
Chromium	65	120	85	27	35	30
Copper	120	120	0	15	22	32
Nickel	16	35	120	11	14	27
Lead	130	240	85	36	50	39
Zinc	230	260	13	62	85	37

[1]Reid et al. (1982)

[2]Zdanowicz and Bruno (1982)

[3]Increases may be due in part to more and different sampling locations.

probably also reflect the greater number of stations sampled. No consistent trends are seen when concentrations of metals for 1973, 1974, 1980 and 1981 are compared. The Hudson Canyon values represent the first NEMP data for this area, so temporal comparisons cannot be made; the elevated concentrations may indicate that the Shelf Valley is acting as a conduit for metals introduced into the inner Bight.

Metal data are also available this year for Penobscot Bay, Maine (Larsen, et al., 1983). Figure SED3 shows a typical distribution pattern (copper) for metals in Penobscot Bay sediments as determined by an intensive (55 stations) baseline sampling.. This pattern features increases in metals inward from the bay mouth, with highest values in the Belfast Bay-Searsport Harbor area. Concentrations in Penobscot Bay are similar to those reported for Casco Bay (Larsen, Johnson and Doggett, 1983), and thus are comparable to levels reported for more industrialized New England estuaries. Peak values were only 14% (for lead) to 39% (zinc) as high as New York Bight maxima, however, except for comparable peaks for nickel in the two areas.

2.2 Polychlorinated Biphenyls (PCBs)

PCBs are extremely persistent contaminants which have only entered the marine environment since their manufacture and wide use began in the late 1940's. They are toxic to marine life and thought to be carcinogenic to man. Many of the PCBs presently in the environment are concentrated near areas of original input, such as the upper Hudson River and New Bedford Harbor. More of these materials will undoubtedly enter coastal and marine waters in the future.

Total PCB concentrations were measured in 1982 in sediments at a number of NEMP monitoring sites (stations 3, 9, 16B, 22, 33, 35, 36 and 37 in Figure SED1). Differences observed between 1981 and 1982 data (Table SED3) ranged from slight decreases, i.e. at Hudson! Shelf Valley (station 33) and Mud Patch (37) sites, to 2-4 x increases, at Christiaensen Basin (16B), Buzzards Bay (36) and Philadelphia Dumpsite (9) stations. Spatial patterns of contaminants at all sites remained the same as in 1981 (Table SED4), with the Christiaensen Basin (290 ppb) being the most contaminated and sites in Casco Bay (near non-detectable), at the mouth of Chesapeake Bay, and on central Georges Bank having the lowest levels of PCBs. A special survey of sediment PCB concentrations in Buzzards Bay was initiated in 1982 to determine the extent of any spread from highly PCB-contaminated New Bedford Harbor. The survey indicated a gradient from the mouth of the Harbor (8.3 ppb) to <0.1 ppb at Coxens Ledge at the mouth of the Bay.

2.3 Coprostanol

This is a steroid specific to mammalian feces. It is not toxic but can be used to trace sewage related materials and associated contaminants and pathogens. Again in 1982, the only site surveyed that had coprostanol levels indicative of gross sewage contaminaation was the Christiaensen Basin station in the New York Bight apex. Levels at nine other sites showed little or no variation between the two years for which data are available, 1981 and 1982.

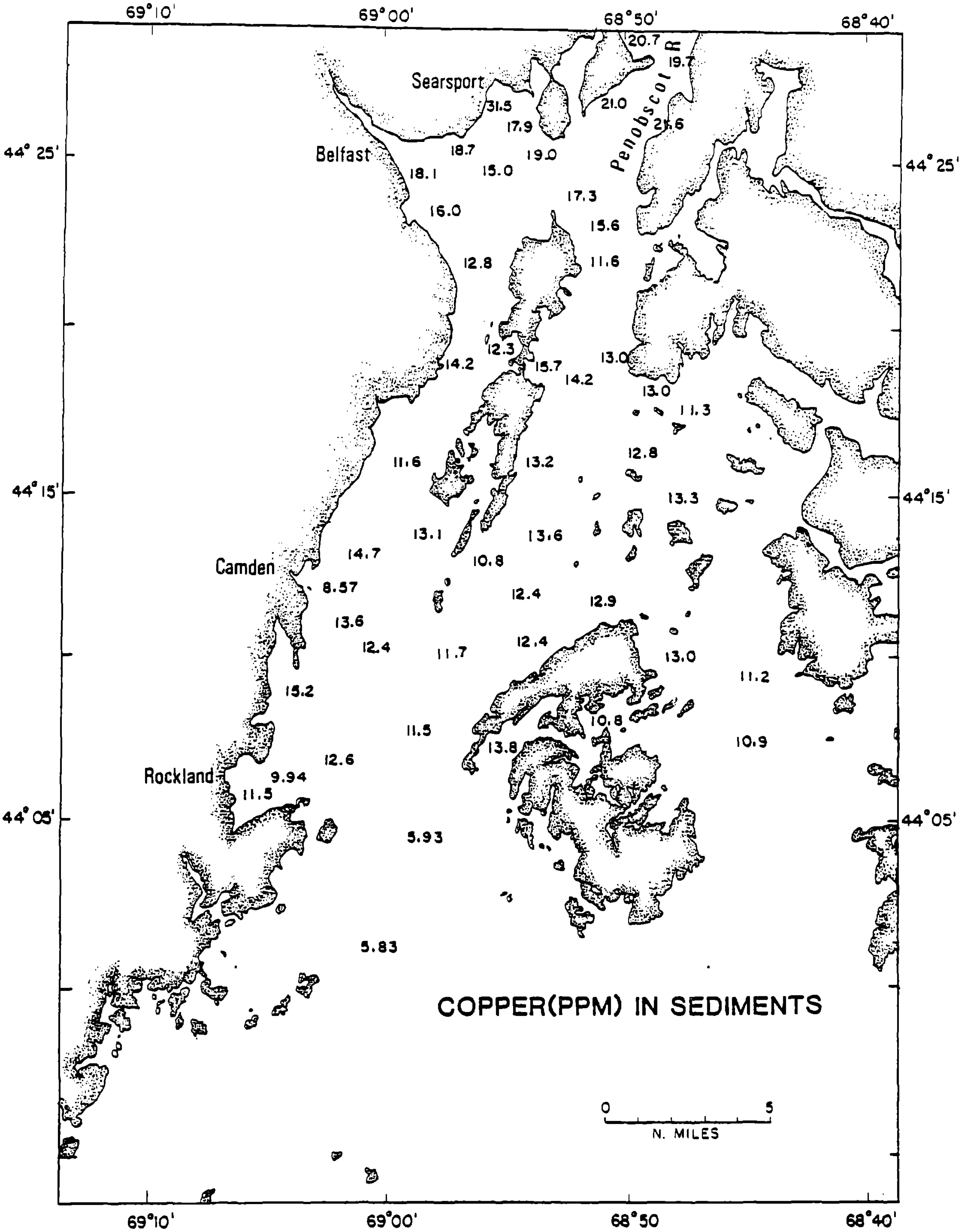

Figure SED3. Concentrations of copper (ppm, dry weight) in surficial sediments of Penobscot Bay, Maine.

Table SED3. Order of magnitude levels of PCB in sediments at several NEMP monitoring sites (1981 and 1982 data).

PCB ranges (ppb)	NEMP monitoring sites
<1.0	Chesapeake Bay mouth, Casco Bay, Georges Bank
1.0-10	Massachusetts Bay, Philadelphia Dumpsite, Hudson Shelf Valley, Mud Patch, parts of Buzzards Bay
10.1-100	Parts of Buzzards Bay
100.1-1000	Christiaensen Basin

Table SED4. PAH levels in sediments at NEMP monitoring sites, 1982.

PAH (ppb)	NEMP monitoring sites
<10	Mouth of Chesapeake Bay
10.1-100	Philadelphia Dumpsites, Georges Bank
100.1-1000	Hudson Shelf Valley, Mud Patch, Buzzards Bay, N. Casco Bay, coastal Gulf of Maine off Casco Bay
1000.1-10,000+	Christiaensen Basin, Massachusetts Bay, S. Casco Bay-Portland Harbor area

2.4 Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs are a carcinogenic class of petroleum hydrocarbons. They include many compounds, with a wide range of toxicity and persistence in the environment. PAHs were detected in sediments at all of the nine standard sites monitored in 1982 (sites are the same as for PCBs and coprostanol), and also in all sediments analyzed in a more spatially intensive survey of Casco Bay. Concentrations ranged from 10 ppb off Chesapeake Ray to 14,425 ppb in outer Portland Harbor (ME). An ordering of monitoring sites according to mean PAH levels is presented in Table SED4. Trends in PAHs differ from those for PCBs, suggesting different transport routes and sources for these two pollutants. For example, while PCB levels appeared to increase at the Christiaensen Basin site, from 1981 to 1982 PAHs decreased. Also, while PAHs increased in Massachusetts Bay and Georges Bank, PCBs remained the same or decreased slightly. At other sites, PAH and PCB levels remained the same between years. With the exception of the Christiaensen Basin and southern Casco Bay, the PAHs are mostly not from direct petroleum sources, but from sources such as fossil fuel combustion.

2.5 Bacteria/Protozoa

NEMP monitors several types of bacteria (total and fecal coliforms and *Clostridium perfringens*) in sediments as indicators of fates of sewage materials and of presence of less easily detected microorganisms which may be pathogenic. The program has monitored *Vibrio* bacteria, several species of which are known to be pathogenic to both marine animals and man, and *Acanthamoeba*, a protozoan which can also be harmful to man.

Our New York Bight sampling continues to show consistently high levels (10^5 -10^6 /gm) of C. *perfringens* in the top layer of sediments, with evidence of dispersion to peripheral areas of the sewage sludge dumpsite and migration down the Hudson Shelf Valley. Additional major inputs of sewage contamination to coastal areas are indicated by the elevated numbers and patterns of distribution of this organism off Chesapeake Bay, Delaware Bay, Massachusetts Bay and western Long Island Sound. High counts of C. *perfringens* observed in sub-surface sediments demonstrate its persistent survival in the ocean environment.

With the exception of *Vibrio anguillarum*, most of the target group of *Vibrio* bacteria have been demonstrated in the samples tested. *Vibrio* spp. in waters and sediments were found at the mouths of most estuaries and inshore areas. One species (*Vibrio vulnificus*), however, has been observed to be more widely distributed in offshore areas. Isolated occurrences of V. *parahaemolyticus* and V. *cholerae* have also been recorded at offshore stations. *Vibrio* numbers in sediments, waters and host animals from the same areas also appear to be correlated. The distribution of this taxon does not necessarily follow patterns of sewage pollution. Seasonal variation of *Vibrio* numbers occurs, with maximum numbers being observed in late summer. Concentrations of *Vibrio* seem to be limited to the top layers of sediment, in contrast to the distribution of C *perfringens.*

Sediments from the Philadelphia sewage dumpsite have been studied periodically since 1978 for the presence of sewage-associated bacteria and the potentially pathogenic protozoan, *Acanthamoeba*. During dumping, both types of organisms had been found to be distributed for approximately 32 km (20 miles) to the northeast and southwest of the center of the dumpsite, and for 16 km (10 miles) to the east and west (Figure SED4). Coliform bacteria were found in 16% of 438 sediment samples, and Acanthamoeba were found in 18% of 229 samples. A survey was conducted in June 1982 to determine changes in the distribution of both groups of organisms subsequent to the cessation of sewage disposal at the site in November 1980. Cultures of sediment from 27 stations showed that four stations (15%) remained positive for coliforms, and six stations (23%) remained positive for Acanthamoeba. These data suggest that contamination of sediments by bacteria and amoebae can persist nearly unchanged for at least 18 months after inputs have ceased.

3. BENTHIC MACROFAUNA AND MEGAFAUNA COMMUNITY STRUCTURE

Analyses of distribution and abundance of benthic macrofauna (here concentrating on those small invertebrates, such as clams, snails, shrimp and polychaete worms, which are collected using bottom samplers and retained on sieves of 0.5 mm mesh) are emphasized for several reasons. The macrofauna, being relatively immobile and intimately associated with sediments, is the group best suited for measuring integrated biological effects of contaminants and natural environmental stresses in the sediments and bottom water. As mentioned above, benthic macrofauna are also important as food for many harvestable bottom fish as well as lobsters and crabs, and can accumulate and pass contaminants up food webs to these species and to man.

Benthic megafauna are larger, more motile species consisting mostly of echinoderms, and fin- and shellfish. They include many commercially and recreationally valuable species. A number of the megafauna species are also valuable as indicators of environmental change.

Monitoring of macrofauna community structure continued, with both region-wide sampling and more intensive surveys (Figure SED1) in several areas. Among the findings of the regional surveys are:

1) Large decreases in numbers of species (a variable usually inversely related to environmental stress - Green and Vascotto, 1978) were seen at many stations between summer and winter 1980. Only a few of the decreases could be attributed to seasonality (e.g., values comparable between winters but lower than summer values), since in most cases, decreases between winter 1979 and winter 1980 (an average of 24%) were even larger than between summer and winter 1980 (18%). By summer 1981, numbers of species returned to typical values at almost all stations for which data are available. Also, densities of pollution-sensitive amphipod crustaceans were stable from 1979-81 at most stations. The decrease in species numbers in December 1980 are therefore' not considered indicative of continued or increased environmental degradation. They apparently represent instead a greater natural variability than had been seen in the data previously.

2) Declines in species numbers did continue through July 1981 at four New York Bight stations: The Fire Island and Hudson Shelf Valley "control" areas, sewage sludge dumpsite, and sludge depositional area in eastern Christiaensen Basin. The latter two stations, plus the dredged material dumpsite, still contain faunal assemblages which are apparently the most structurally altered of any NEMP sites, as shown by cluster analysis and

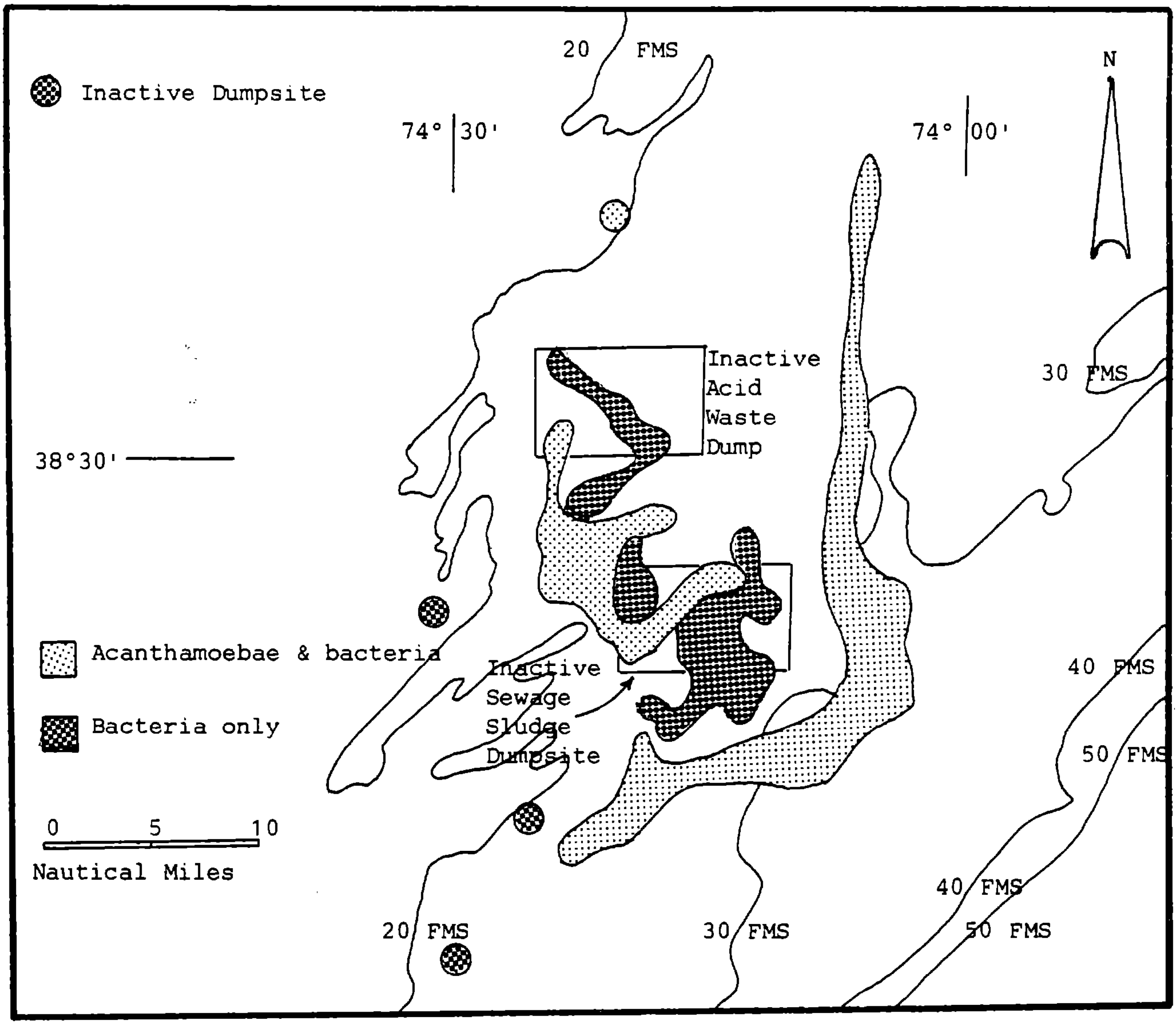

Figure SED4. Microbiological indications of the distribution of sewage related materials at the Philadelphia-Camden Dumpsite (inactive). Dumping at this site ceased on 25 November 1980. The prevailing seasonal current regimes are northeast-southwest and the downslope region is to the right in the figure (Prom: Berman, 1983; data from O'Malley et al. 1982; Sawyer? et al.. 1982).

dominant species lists as well as by their low numbers of species and amphipods. At the Shelf Valley site, numbers of the apparently pollution-sensitive amphipod, Ampelisca agassizi dropped by 80% from summer 1980 through winter 1980, to summer1981, paralleling the decline in species richness at that site (which had been considered the shoreward limit of A. agassizi dominance, and thus of uncontaminated conditions, in the Shelf - Valley). Preliminary data indicate that Rhepoxynius epistomus, another sensitive amphipod (Swartz, De Ben and Cole 1979), has become scarcer at the Fire Island site since the early 197Os, and more recently (summer and fall 1982) at our midshelf station off Delaware Bay. These trends could signal increasing degradation of the mid-Atlantic central shelf. To ascertain whether the trends are real and are ecologically important, it must be determined whether they persist in macrofauna samples presently being analyzed, and whether similar trends are found in NEMP data on concentrations and/or sublethal effects of contaminants (sediment metals have been low and have not increased recently at the Fire Island' or Shelf Valley sites).

Faunal baselines have now been established for several areas along the New England coast. The benthic fauna has been sampled at 50 stations in Penobscot Bay to relate sediment quality to basic benthic community parameters. Results of this effort will be available soon. Benthic monitoring of Casco Bay and Portland Harbor continues; parts of these areas have high sediment pollutant loads and a correspondingly altered community structure (Larsen, Johnson and Doggett 1983). Monitoring will attempt to separate natural from pollution induced variability and establish whether the region is experiencing further degradation or recovery, or is static. Preliminary 1982 results do not show a significant change from 1981.

The past year of sampling at the proposed Norfolk Dumpsite supported previous conclusions that: 1) the disposal site is characterized by a highly diverse macrobenthic community indicative of healthy inner shelf habitats, and 2) no commercially important macroinvertebrate resources exist at the site. In addition, microcosms utilizing indigenous fauna from the dumpsite were used to confirm the acceptability of sediments from the Hampton Roads Harbor for disposal offshore. Results of this study are currently being analyzed.

SCUBA monitoring of macro- and megafauna at permanently marked stations on hard substrates has now established baselines of two years of data at Isles of Shoals, New Hampshire, three years at Jeffries Ledge off Massachusetts, and one year at Brenton Reef, Rhode Island and Block Island, New York. Five permanent diver-sampled stations were established in summer 1982 to examine contaminant concentrations and effects on a presumed gradient of PCB contaminant from outer New Bedford Harbor into Rhode Island Sound. The Isles of Shoals work has documented the presence of "fronts" of grazing sea urchins and a transition to barren areas from kelp forests by urchin activities (see inside front and back covers). This phenomenon was first reported in Canadian waters, where the high urchin densities have been attributed in part to reduced predation by dwindling lobster stocks. Reduction of kelp can in turn cause further decreases in lobster populations by removing valuable habitat. Such interactions must be understood in order to demonstrate any additional impacts of contaminants on species of interest or their habitats.

Submersibles are being used for ecosystem monitoring in deeper waters on Georges Bank and in adjacent canyons. Ten years of observations on the geology of these productive areas, and abundance and behavior of their megafauna, are now available. Specimens have been collected to establish contaminant baselines for the past three years. Recent observations have not revealed any major short-term impacts of oil exploration on the Georges Bank ecosystem; this is also true for the remote sediment-macrofauna sampling, and agrees with findings for other areas (EG & G 1982).

3.1 Benthic Production

Studies of benthic macrofauna biomass and rates of its production are carried out for many of the same reasons as the community structure work discussed above. The biomass and production studies are used both to monitor stress effects and to understand ways in which organic energy (and contaminants) flow from the benthos to species of interest to man. Alteration in the productivity of any portion of the ecosystem supporting these resource species can be very important to resource managers. NEMP benthic production studies involve two widely accepted approaches: 1) production estimates based on growth measurements of dominant species in a community and 2) estimates based on the use of a derived relationship between production and biomass (P:B ratios).

The growth measurement studies include baseline studies at and near the mouth of Delaware Bay, and a new study in the New York Bight apex that is comparing production of selected species along a pollution gradient. Only the results from the Delaware Bay study are available at this time (Howe and Leathem 1983). They indicate that: 1) production studies can be related to community structure studies; 2) production is variable and dynamic inside or just at the mouth of Delaware Bay, and equal to or greater than most of the limited number of estimates available for other estuaries, and 3) production is less variable. in a coastal area south of the mouth of Delaware Bay and appears to be comparable to other shallow sandy marine areas for which estimates are available.

The studies that use P:B ratios to estimate production have developed baseline production estimates for Georges Bank (Steimle, unpublished data), a very important fishing ground, and the New York Bight (Steimle, in prep.), a stressed coastal area. The Georges Bank study found mean production estimates there to be 70-102 Kcal m^{-2} y^{-1}, higher than most other reported estimates for shelf areas in the North Atlantic, especially in waters of moderate depth, i.e. 60-120 m. The New York Bight estimates are generally comparable to those for similar depths and sediment types on Georges Bank. Biomass levels and estimated total community production in the vicinity of the dredged material and sewage sludge dumpsites and the depositary Christiaensen Basin between them appear to be equal to or perhaps greater than levels found in other areas of similar depths in the New York Bight. This suggests. that alterations to apex benthic populations have not diminished the potential amounts of food available to higher levels. However, extensive predation on the Christiaensen Basin benthos could increase the flow of contaminants to resource species. This question is being addressed with detailed studies of fish feeding habits and prey contaminant burdens in the Bight apex.

3.2 Seabed Oxygen Consumption

Measuring seabed oxygen consumption (SOC) provides information on both chemical and biological oxygen uptake rates in sediments. Spatial_-temporal differences in SOC rates can reveal changes in organic loading to the sediments or in contaminant effects on respiration.

Extensive measurements of seabed oxygen consumption in the New York Bight were made in summer 1982 and compared to data from 1974 and 1975. There was a general trend toward lower rates in 1982, though overall differences from the earlier years were not statistically significant. Large changes were seen at the two major dumpsites: a 66% decrease in oxygen consumption in and near the dredged material dumpsite, possibly due to a substantial decrease (67%) in the rate of dredged material disposal detween 1974/75 and 1982[1], and a 79% increase in SOC around the sewage sludge dumpsite, corresponding to a substantial increase (59%) in the volume of sludge dumped over the same period[2] Both of these changes in oxygen consumption were significant at the $P<0.025$ level. Analysis of data from outside the New York Bight indicates only small variability over time, so it has been determined that sampling every three years will be sufficient for detecting trends; thus no sampling was conducted outside the Bight in 1982.

3.3 Contaminant Effects on Larval Settlement/Survival

Many of the foregoing field monitoring studies have shown correlations between contaminant concentrations and effects on the benthos. Monitoring, however, cannot prove causal relationships between concentrations and effects. For this it is necessary to conduct experiments in which all variables are kept identical except the ones whose effects we are attempting to determine. Where feasible, it is usually preferable to conduct this work in the field, as laboratory experiments introduce more artificiality, and extrapolation to field situations often cannot be made with confidence. We have therefore begun field experiments, using trays of azoic sediments, to examine effects of different grain sizes and contaminant concentrations on larval settlement and survival of coastal benthos. In summer 1982, trays of silt-sized particles (Fuller's earth) with and without sewage sludge added, and also clean sands and sands from the sewage sludge dumpsite, were exposed on the ocean bottom off southern Long Island for 27 days. Results are shown in Figure SED5. The trays with sewage sludge collected only 21% as many invertebrates as trays with clean sand and Fuller's earth, including 15% as many of the commercially valuable surf clam and 6% as many amphipods (important in fish diets). Conversely, sediments with sludge collected 57% more polychaetes. These differences were all significant at $P = .05$ or lower level. The data show that sludge is toxic or repellent to settling larvae of surf clams and amphipods; in the past, it had not been established whether the low numbers of these taxa in the dumpsite area were due to avoidance or mortality early in the life cycle or in later stages. Further ongoing or planned sediment tray experiments will test responses to sludges from

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[2] P. Anderson, U. S. EPA, 26 Federal Plaza, New York, New York 10278.

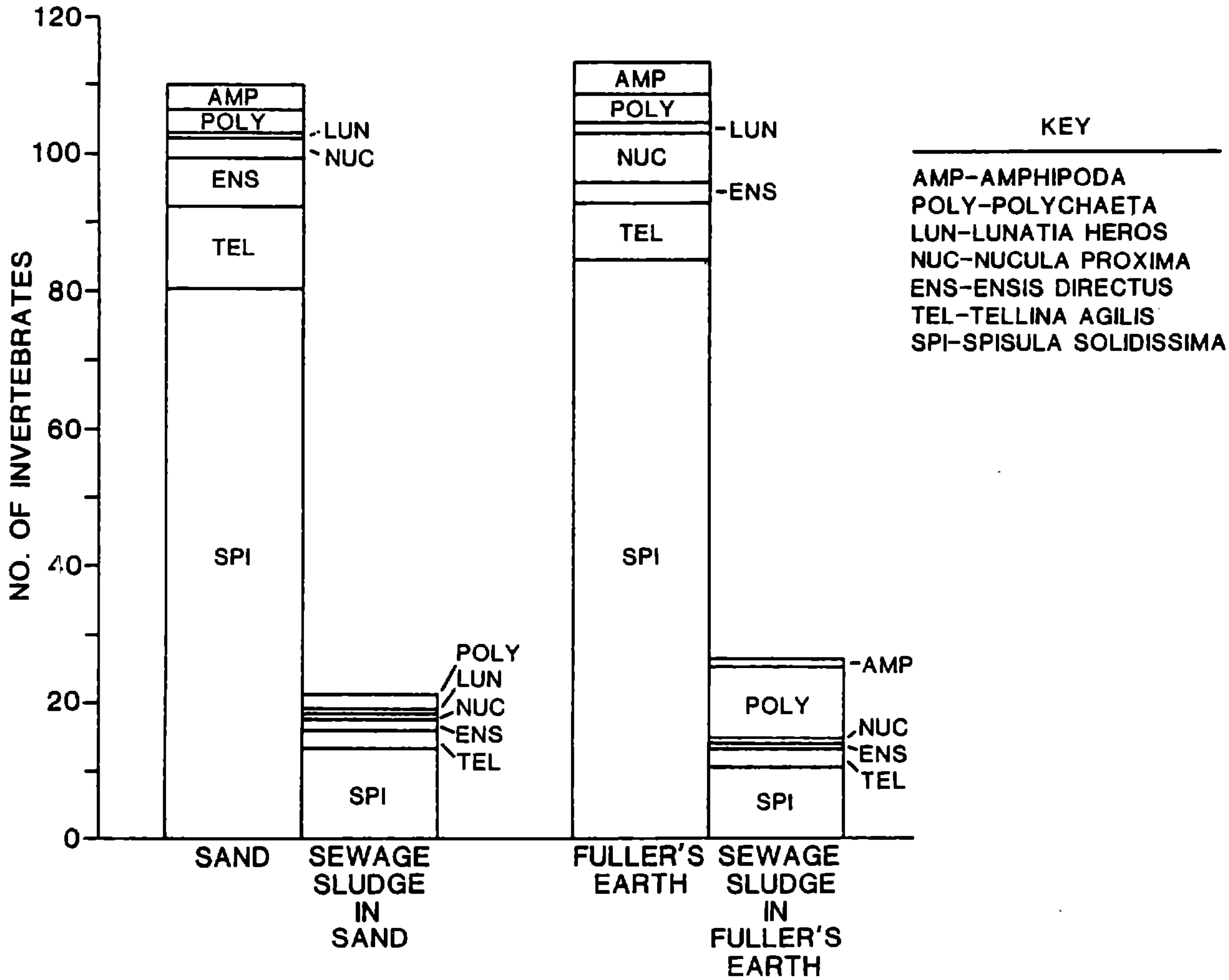

Figure SED5. Numbers of various taxa found in trays of coarse and fine sediments, with and without sewage sludge, exposed for 27 days on the bottom off southern Long Island. Numbers are means of eight replicate trays per treatment.

different treatment plants, as well as components of the sludges, such as individual trace metals, to aid in predicting effects of disposing of wastes in increased quantities or at new locations.

4. SUMMARY

The most important findings of our recent monitoring of sediment quality and bottom organisms are:

- There is an area of elevated concentrations of several trace metals, often to half of their highest concentrations in the New York Bight apex, beyond 200 m depths in Hudson Canyon (the extension of the Hudson Shelf Valley, which runs from the apex to the shelf edge). This may suggest that the Shelf Valley is a seaward conduit for contaminants introduced in the inner Bight.

- Trace metal levels in Penobscot Bay, Maine (as previously reported for Casco Bay) are comparable to other, more industrialized New England embayments.

- Statistically significant increases in sediment PCB concentrations between 1981 and 1982 have been detected at stations off Delaware Bay, in the New York Bight apex and in Buzzards Bay, Massachusetts. Concentrations at other stations were unchanged from 1981.

- Potentially carcinogenic polynuclear aromatic hydrocarbons (PAHs) were found again in nearly all sediments analyzed. With the exception of the New York Bight apex, analyses indicated the PAHs generally had combustion rather than liquid petroleum sources. Mean concentrations in Casco and Penobscot bays, in the northern Gulf of Maine, exceeded all others we have measured in the NEMP region except the Bight apex. Distributions in Penobscot Bay are indicative of contemporary, anthropogenic activities rather than long-term natural phenomena.

- Incidences of potentially pathogenic protozoa (*Acanthamoeba*) at the Philadelphia Dumpsite in June 1982 were essentially unchanged from incidences found before sludge disposal ended in November 1980. Numbers of coliform bacteria had diminished, however.

- Preliminary estimates indicate that productivity of the anthropogenically stressed Bight apex benthic macrofauna is similar to that of the unpolluted Georges Bank, within comparable bathymetric zones.

- Grazing sea urchins have continued to destroy kelp beds off Maine and New Hampshire. Increases in urchin populations have been attributed in part to reduced predation by diminished lobster stocks. Kelp provides shelter and habitat for lobsters, and its removal may in turn further reduce lobster populations.

- No major short-term changes have been revealed by NEMP submersible observations or through indirect sediment-fauna sampling (in agreement with studies by other groups) in relation with contaminant concentrations or biological effects due to oil exploration on Georges Bank. Petroleum hydrocarbons were present at low levels in the demersal species analyzed prior to any drilling.

- There was no significant change in overall seabed oxygen consumption in the New York Bight apex between 1974/75 and 1982. There was a 66% decrease in oxygen consumption in and near the dredged material dumpsite, apparently in response to a substantial decrease in the rate of dumping of organically enriched spoils over the same time period. Oxygen utilization increased by 79% in and near the sewage sludge dumpsite, probably due to a large increase in the volume of sludge dumped between 1974/75 and 1982.

- Larval surf clams and amphipods had significantly lower settlement and/or survival rates in sediment trays with sewage sludge added, as compared to trays of uncontaminated sediment, deployed off the southern Long Island coast.

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CHAPTER III. SUBLETHAL EFFECTS ON MARINE ANIMALS

1. INTRODUCTION

The primary purpose of NEMP's biological-effects monitoring is to detect and measure pollutant effects in marine resource species, and to identify both real and potential "trouble spots" in our coastal and offshore waters. From a manager's viewpoint, pollutant effects can diminish a fishery stock through mortality and loss of reproductive efficiency, and ultimately can lead to its collapse. From a fishery processor's standpoint, pollutant effects can reduce marketability of seafood through tainting and contaminant concentrations thought hazardous to consumers. The NEMP monitoring effort, therefore, emphasizes the collection of data from animals in the field, supported by carefully designed field studies and by rigorously controlled, relevant laboratory studies to aid in interpreting field data.

NEMP's biological-effects measurements fall into five general categories: 1) the impact of pollutants on animal metabolism and how this may affect health, survival and ability to reproduce (Physiology and Biochemistry); 2) the frequency of mutational defects, and how this could affect stock recruitment (Genetics); 3) the occurrence and frequency of disease, and measurement of the animal's capacity to fight it (Pathology and Immunology); 4) the response of the whole animal to a contaminated environment, and how such response may affect its survival (Behavior); and 5) tissue concentrations of pollutants that have implications for both animal health and survival and as potential consumer hazards (Contaminant Body Burden).

Most significant field observations in 1952 were in nearshore or coastal waters. These areas receive high concentrations of pollutant input (human waste, PCBs, pesticides, heavy metals) via riverine runoff, ocean disposal, atmospheric fallout, and current patterns. Degraded habitats generally are reflected in the impaired health of resident animals. Of particular note are the following:

- Flounders from coastal waters between Boston and Cape Cod and from an area southeast of Block Island were found to have abnormal blood characteristics.

- Chromosomal mutation frequencies in fish blood cells indicated a potential relationship with chemically-degraded marine habitats, again in coastal areas.

- Skeletal malformations in sand lance were most frequently found in shallow coastal waters, associated with major estuarine outflows and dumpsites.

- Up to 40% of sea scallops collected from the coastal waters of the Gulf of Maine had systemic bacterial infections.

- High levels of antibodies against bacteria found associated with human waste material were found in flounder collected in or near coastal areas of degraded quality, directly relating an animal response to habitats polluted by human waste.

- Chemical analyses of animal tissues, water column, and sediments for heavy metals and organic pollutants showed that areas with characteristically high concentrations occurred almost entirely in coastal marine habitats.

- In areas found to highly polluted, some species have been diminished in number or have disappeared (see Contaminant Body Burdens section), and the normally diversified mix of animal species has tended to change to a dominance by a few pollution-tolerant species that are not commercially useful and may not be important in marine food chains.

Different contaminants produce different biological responses. A wide range of parameters must be used to detect pollutant effects on marine animals, many of which are tested by NEMP monitoring. Some are good indicators of environmental stress, others have been discarded for lack of sensitivity, impracticality, economics, or difficulty in interpretation. Another category is the group of measurements that have not been sufficiently field-tested to establish their usefulness. The aforementioned parameters are the tools used to detect stress in marine animals; each is considered, in the sections below.

2. PHYSIOLOGY AND BIOCHEMISTRY

2.1 Physiology

Parameters: Blood measurements known to reflect stress, such as ion concentrations, osmolality, and red blood cell tests, were used to detect metabolic imbalances such as the capacity of the blood to carry oxygen to body tissues, or the ability of an animal to adapt to changing salinities. Collaborative experimental field studies and supportive laboratory exposures helped to assess field data. Currently being developed for field use with lobsters to detect pollutant stress in that animal is the measurement of the "cough" response (a means of cleaning the gills).

Observations: Over the past two years, general observations throughout the waters bordering the mid-Atlantic and New England states support the following conclusion: inshore flounder of several species near sources of pollution often show abnormal blood profiles, with changes occurring along the pollution gradient, whereas offshore populations thus far observed have had normal hematology. These field interpretations are based on seasonal hematological profiles established for windowpane flounder collected at monthly intervals across a pollution gradient in Long Island Sound, with Hempstead Bay, at the western end of the Sound, being the most polluted site.

Yellowtail flounder with mild anemia were collected in 1982 from waters between Boston and Cape Cod and from the Block Island Midshelf station, near the Mud Patch (Fig. SLE1). Although fish of the same species taken near Plum Island (MA) showed similarly low hematocrits in the previous year, as well as high biosynthetic activity in the kidney, yellowtails taken from that area in 1982 seemed normal. Winter flounder off Narragansett Bay had abnormal hematology.

In field-collected sea scallops, lower-than-normal hemolymph calcium was found in specimens from sites in the Mid-Atlantic Water Management Unit (WMU) Block Island Midshelf (BIMS), and the Baltimore Canyon (BC) stations), as well as near an oil-drilling site in southcentral Georges Bank and a site on North Georges Bank. Physiological assessment of stress is also being conducted on blue mussels deployed along a pollution gradient in Narragansett Bay and at dumpsites in the New York Bight Apex. Because the levels of contaminant loading are much higher in inshore habitats (although the effects of such loading in some areas may extend to the shelf), these inshore field studies possibly offer the best opportunity to link cause and effect.

2.2 Biochemistry

Parameters: Biochemical measurements used to detect metabolic stress in marine animals focused on the cellular energy balance, reserves, and rate of expenditure in animal tissues, as well as on biosynthetic rates in vital organs. These data provide a basis for predicting whether a given population of sea scallops, for example, will spawn successfully, and whether a disproportionate fraction of any population is under sublethal metabolic stress. In larval fish, the major biochemical parameter used has been the RNA/DNA ratio in tissues, which is linearly related to the growth rate. Measurement of muscle protein also reflects general larval condition, high protein levels being associated with normal growth. Biochemical field work is supported by concurrent collaborative laboratory exposures and field studies, in conjunction with other disciplines and agencies such as the EPA and the FWS.

Observations: Biochemical-stress parameters for sea scallops, corroborated by findings in physiology (see above), suggest that not all offshore marine habitats (particularly depositional areas) are, pristine, and that some scallop populations may not support a commercial fishery without endangering recruitment. Specific examples are the Block Island midshelf station, a sandy substrate extending into the Mud Patch, and the silty, depositional area between the outer Hudson Valley (OHV) and the Baltimore Canyon (RC) stations. Scallops from these areas frequently have low cellular energy and low glycogen reserves in muscle tissue as well as low biosynthetic activity in the kidney. Scallops with similarly suspect biochemistry have occasionally been taken from a site on southcentral Georges Bank and from off the northeastern tip of Cape Cod (Fig. SLE1). Other than these exceptions, most offshore NEMP stations from which sea scallops are collected appear to be environmentally sound from a biochemical effects point of view.

Collections of deepwater (130-190 m) scallops made throughout the year showed consistently low muscle glycogen, indicating a lack of the energy reserves necessary for gamete maturation. Highest (but still low) muscle glycogen levels in these scallops were observed in specimens collected from five deepwater stations in late October, a phenomenon suggesting gamete resorption. Food (vegetative detritus) at these depths is sparse, and the animals, although apparently normal, are not well nourished. Because of the abnormally low glycogen patterns, and because bottom temperatures at deepwater sites rarely reach 10°C, the temperature that generally initiates spawning in this species, these populations probably do not reproduce. Recruitment is probably adventitious, from nearby ledge populations. Such information is significant from the managerial point of view, i.e. what would the effects of increased contaminant stress be?

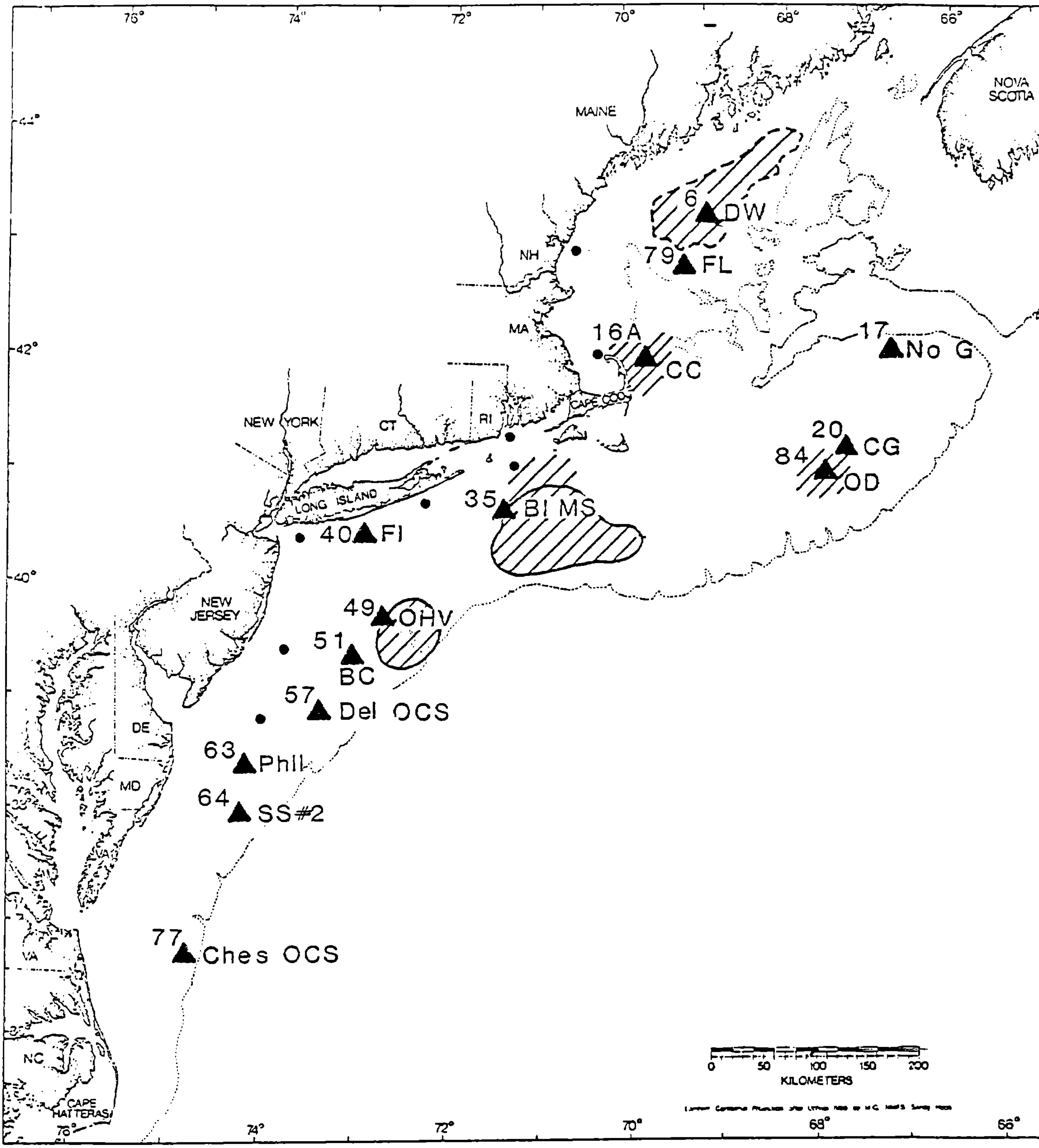

Figure SLE1. Fixed stations (triangles) at which sea scallops are most frequently collected during seasonal NEMP monitoring cruises. Numerals are Reference Station Numbers, Initials are: DW = deepwater; FL - Fippennies Ledge; CC = Cape Cod; No G & CG = north & central Georges; OD = former oil-drilling site; BIMS = Block Island midshelf; FI = Fire Island; OHV = outer Hudson Valley; BC = Baltimore Canyon; Phil = Philadelphia Dumpsite. Black dots indicate other NEMP stations at which collections of flounder are often made. Shaded areas indicate general sites where scallops with abnormal metabolism have bee found; line-enclosed areas (largest = Mud Patch) have provided the greatest number of stressed scallops, and are probably poor habitats for successful recruitment.

Interpretation of biochemical data from field collections has been strongly supported by baseline information acquired by a continuing monthly sampling of a scallop population off the NJ coast. Seasonal patterns of muscle glycogen and the reproductive cycle have been related (Fig. SLE2), permitting an assessment of the relative health of scallops at NEMP stations.

In work with fish, body burdens of PCBs and DDT isomers in field-collected adult female striped bass were correlated with mortality of their larvae reared in the laboratorty. Juvenile striped bass collected from the Hudson River had low levels of liver DNA and muscle protein, indicating that growth was not proceeding normally. The Hudson River fish also had lower swimming stamina and higher incidences of parasitic infestation and liver necrosis than did fish from other areas.

3. GENETICS

Parameters: A modified micronucleus test was used to measure rates of chromosome mutation in the red blood cells (RBC) of fish. Among expected consequences of any increased mutation in fish are increased numbers of tumors and decreased reproductive efficiency. The test has been applied to mature RBC in blood smears of adult fish, to immature RBC from their blood-forming fore-kidney, and to blood from the heart of larval fish. Mutation frequencies as measured in the circulating blood are expected to reflect integrated environmental conditions over a few months, and in the immature cells over days, or a few weeks at the most. Experimentally-induced mutations in adult killifish and in salmon larvae support the use of this test to monitor mutation frequencies in field surveys. The test has been further adapted for use in the spermatogenesis of bivalve molluscs, because mutation frequencies in these sedentary animals are thought likely to be an indicator of local environmental quality.

Winter flounder may be a particularly good species of finfish for monitoring because of its limited migratory habits. Mutation frequencies are also being measured in Atlantic mackerel because mackerel complete gametogenesis in coastal waters, and germinal mutation rates are likely to be influenced by uptake of new pollutants during the annual spring migration through the mid-Atlantic coastal waters.

Observations: Mature RBC in winter flounder from 27 sites showed higher mutation frequencies in coastal mid-Atlantic areas than in offshore areas, Georges Bank, and the Scotian Shelf border (Fig. SLE3). Highest mutation frequencies were found in western Long Island Sound, at Hempstead Bay. Values from fish in the New York Bight Apex and Long Island Sound were statistically higher than those from the other areas, and fish with outlier frequencies, identified statistically, were clustered in those areas (Fig. SLE 4).

Prior work on windowpane flounder also showed significantly higher mutation frequencies in both mature and immature RBCs in fish from Hempstead Bay, 2-3 times higher than in fish from the cleanest site in Long Island Sound. Analyses of both mature and immature RBCs of Atlantic mackerel, also, showed mutation frequencies 2-3 times higher in Hempstead Bay fish than in an offshore group.

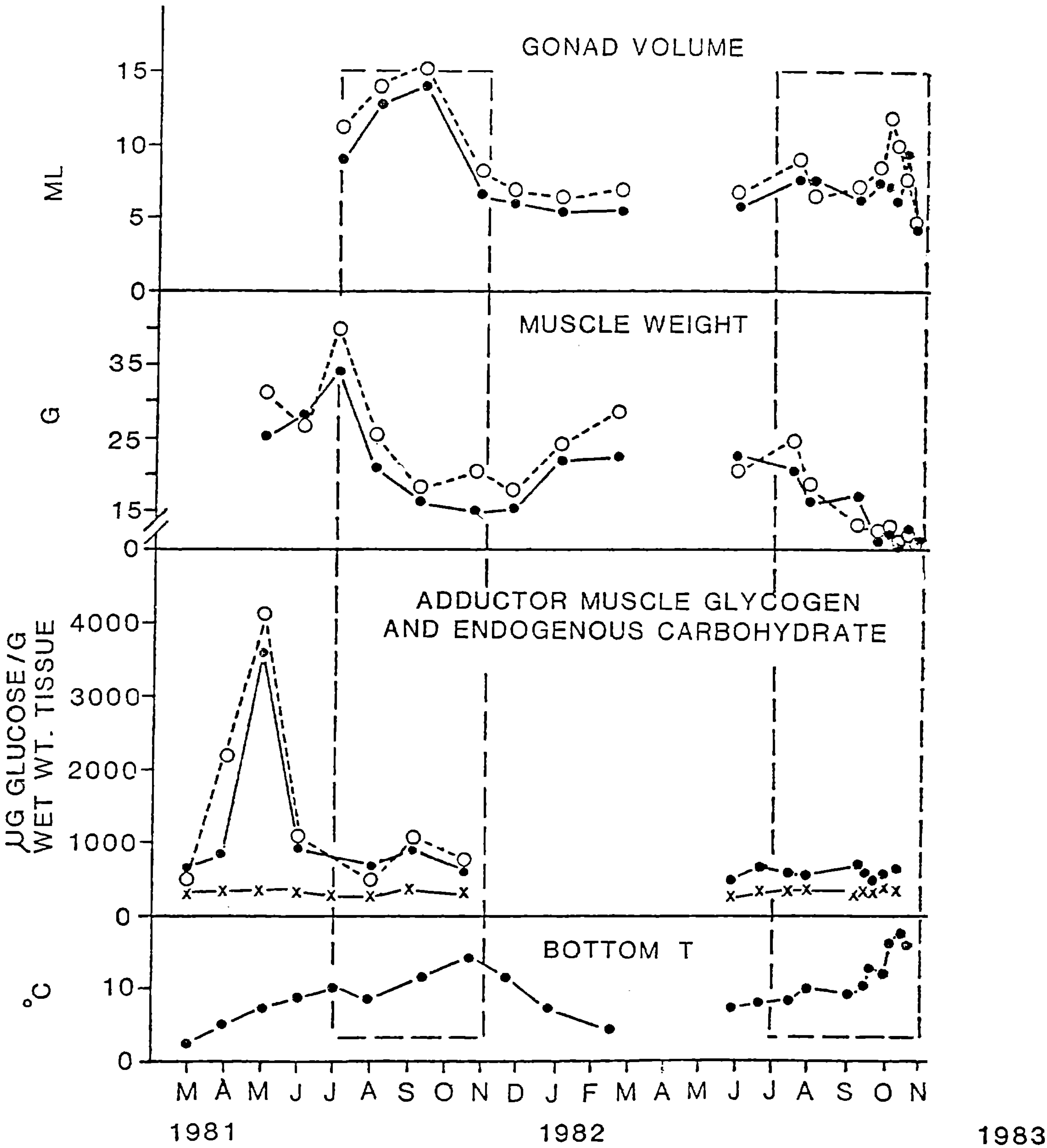

Figure SLE2. Biological and chemical data for sea scallops collected at monthly intervals from a population off New Jersey (6 of each sex/month). The females are represented by o----o, the males by ●——●, and pooled endogenous carbohydrate (which did not vary with sex) by x-x. Dashed rectangles indicate the period of final gamete maturation and spawning.

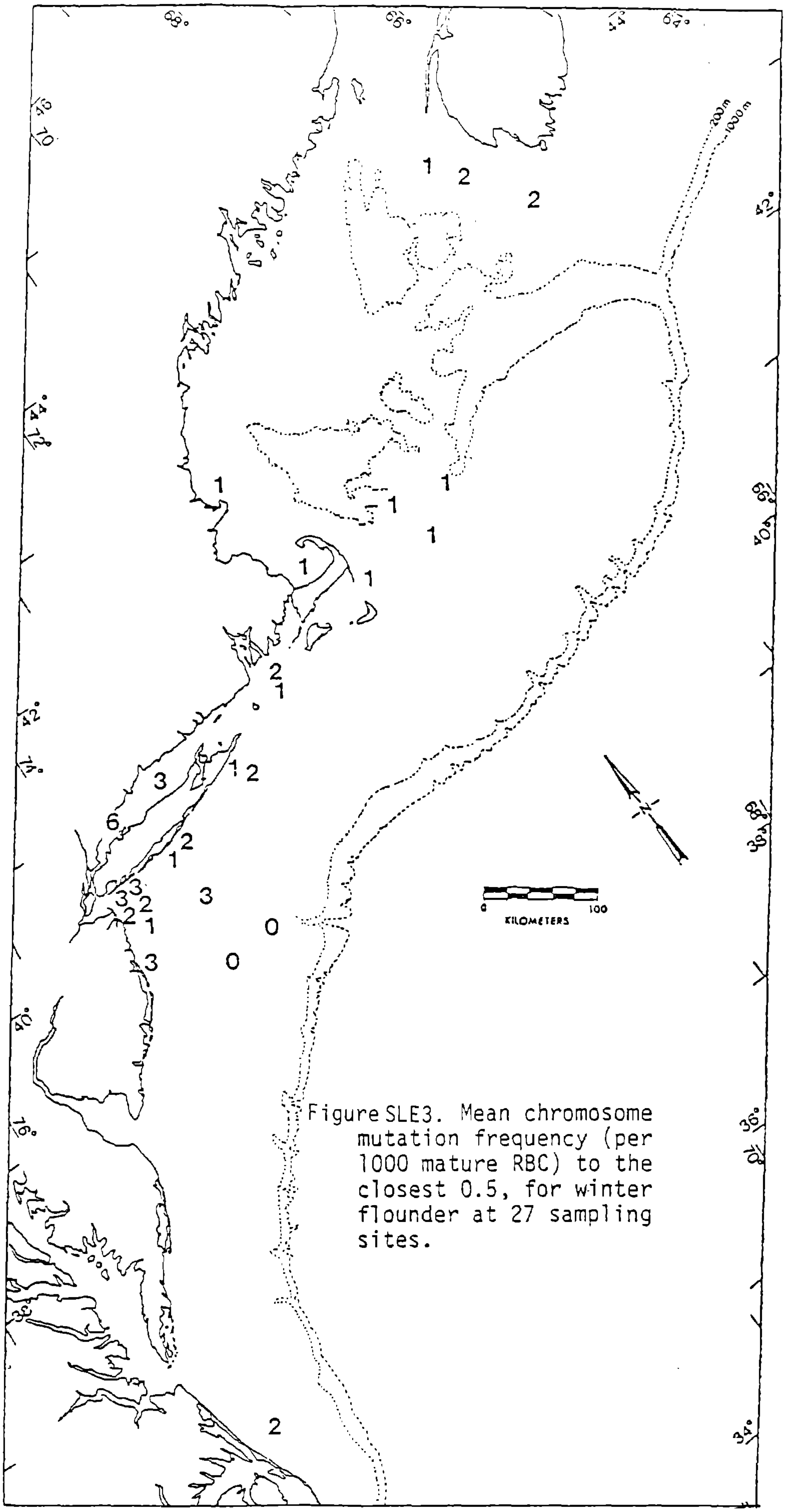

Figure SLE3. Mean chromosome mutation frequency (per 1000 mature RBC) to the closest 0.5, for winter flounder at 27 sampling sites.

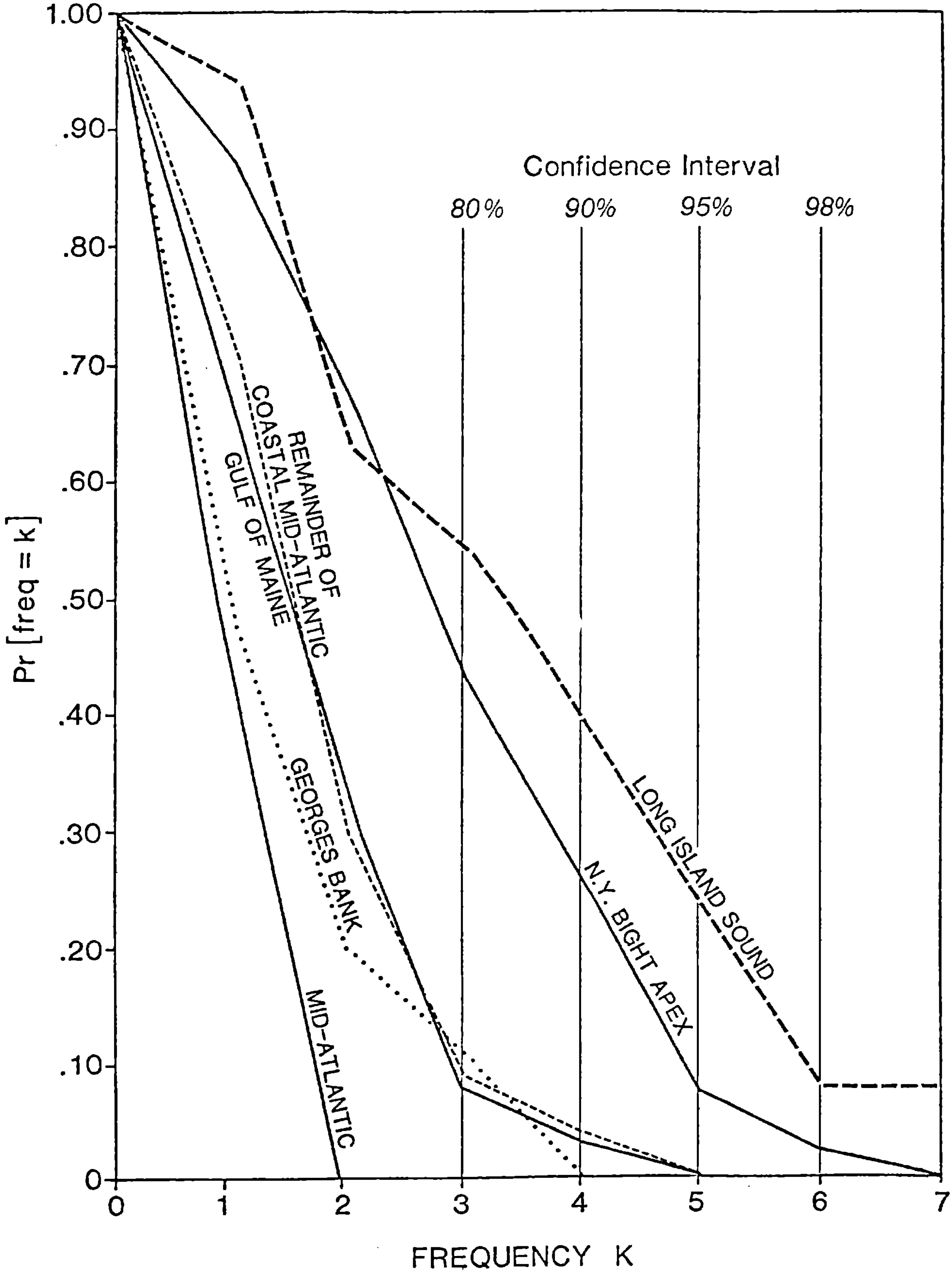

Figure SLE4. Statistical probability of winter flounder, collected from 6 major water masses, having 1 to 7 or more chromosomal mutations/1000 mature RBC, as measured by the micronucleus test. Note how closely all lines lie except for the New York Bight Apex and Long Island Sound. All fish with statistically identified outlier frequencies of mutation occurred in these two regions.

An extensive analysis of mackerel collected from three offshore locations in the New York Bight (near and at the edge of the continental shelf), as the fish were migrating coastward to their spawning grounds, shows that the most northerly group (closest to the Bight Apex, in the outer Hudson Valley) had a slightly higher mutation frequency than the two other groups. As with winter flounder, it has not been possible to attribute this difference to any disparity among sample groups in natural factors such as size, age, sex, or maturation, which might be expected to influence mutation rate. These are undoubtedly of some influence, particularly in combination with pollution, but present data point to water quality as the predominant influence.

Although differences in mutation rates in larval red hake collected at various coastal sites have not proved statistically significant, every instance of a larva with unusually high frequency and/or depressed hematopoiesis has been from the most heavily contaminated areas.

4. PATHOLOGY AND IMMUNOLOGY

4.1 Pathology

Parameters: Microscopic and radiographic techniques, together with detailed macroscopic observations, were used to detect and assess a variety of pathological abnormalities such as tissue lesions and vertebral anomalies.

Observations: Radiographic examination (X-rays) of sand lances indicates a statistically significant pattern of vertebral anomalies associated with the nearshore shallow waters of the coastal Middle Atlantic region (Fig. SLE5). General distribution suggests that these anomalies may also be associated with major estuarine outflows and/or dumpsites (Fig. SLE 6). This relationship, observed in sand lance, may indicate that other small coastal species may be similarly affected. Such abnormalities, if widespread, could lead to an overall decline in the relative health of these species, with consequent diminished survival rate and reproductive capability. There was no correlation, however, between the prevalence of anomalies in the sand lance and the north-south distribution of this species.

Fin rot in winter flounder was most prevalent in water shallower than 40 m in the coastal areas of the Gulf of maine and the Middle Atlantic. A higher incidence of lymphocystis disease was seen in winter flounder and American plaice south of Long Island and Georges Bank than in other NEMP areas. Parasitic infections were found in 25% of the winter flounder from inshore New Jersey-New York waters, and in 50% of these fish from Cape Cod Bay, Massachusetts. Skin and skeletal anomalies were rare and randomly distributed, however, in a comprehensive survey of more than 100,000 bottom fish throughout the NEMP region; only lymphocystis and fin rot in winter flounder were geographically distributed in a manner suggesting a relationship between increased disease prevalence and compromised environmental quality.

"Black-gill" disease found in rock crabs from the New York Bight Apex and from the Philadelphia-Camden sewage-disposal site was related to the presence of organic mud or silt, and occurred independently of microbial fouling of the gills. The disease was not seen in crabs from the relatively clean area of the Sheepscot River, Maine. Prevalence of gill blackening and incidence of coliform bacteria and protozoans in sediments at the

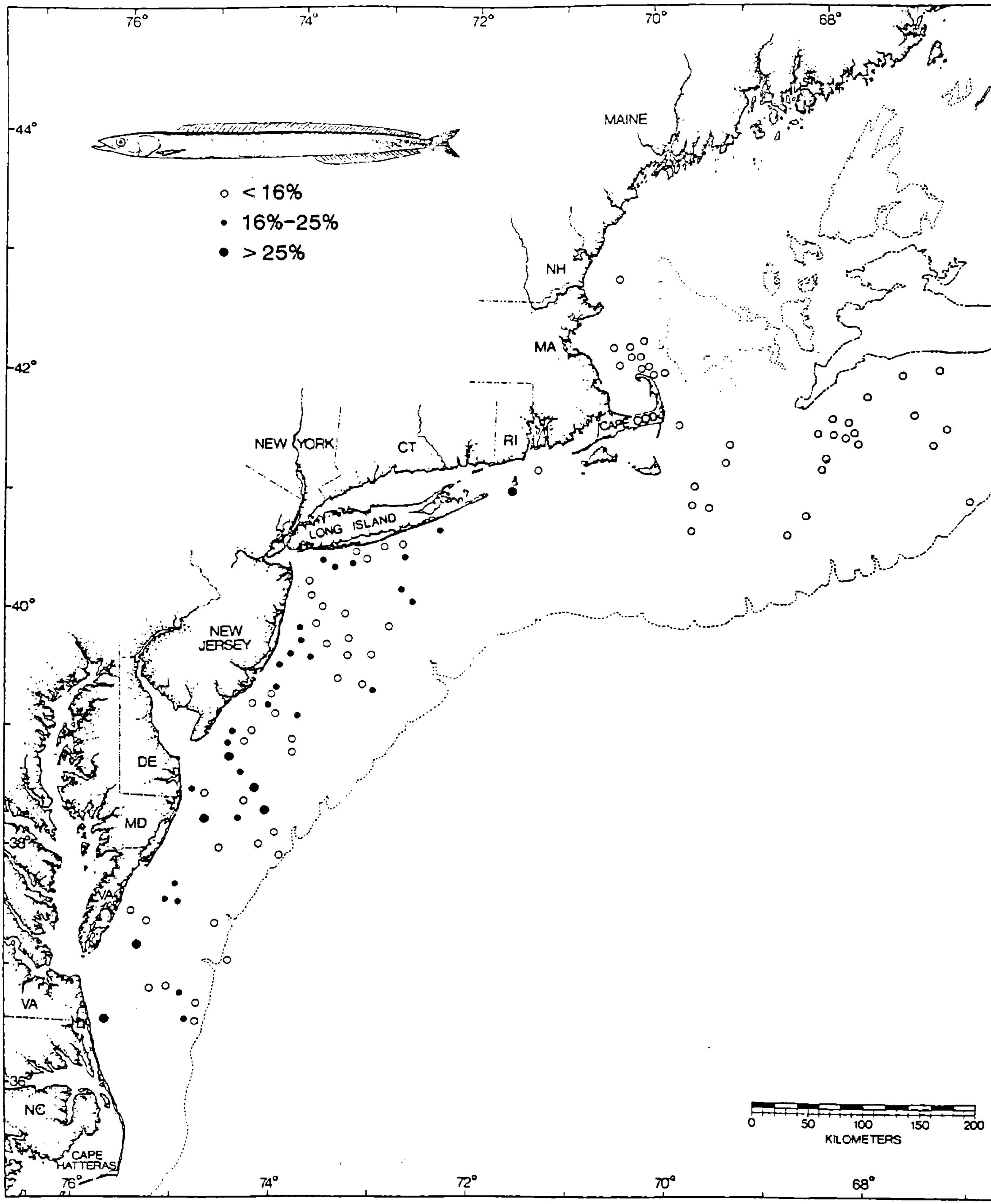

Figure SLE5. Frequency of vertebral anomalies in sand lance, showing collection sites.

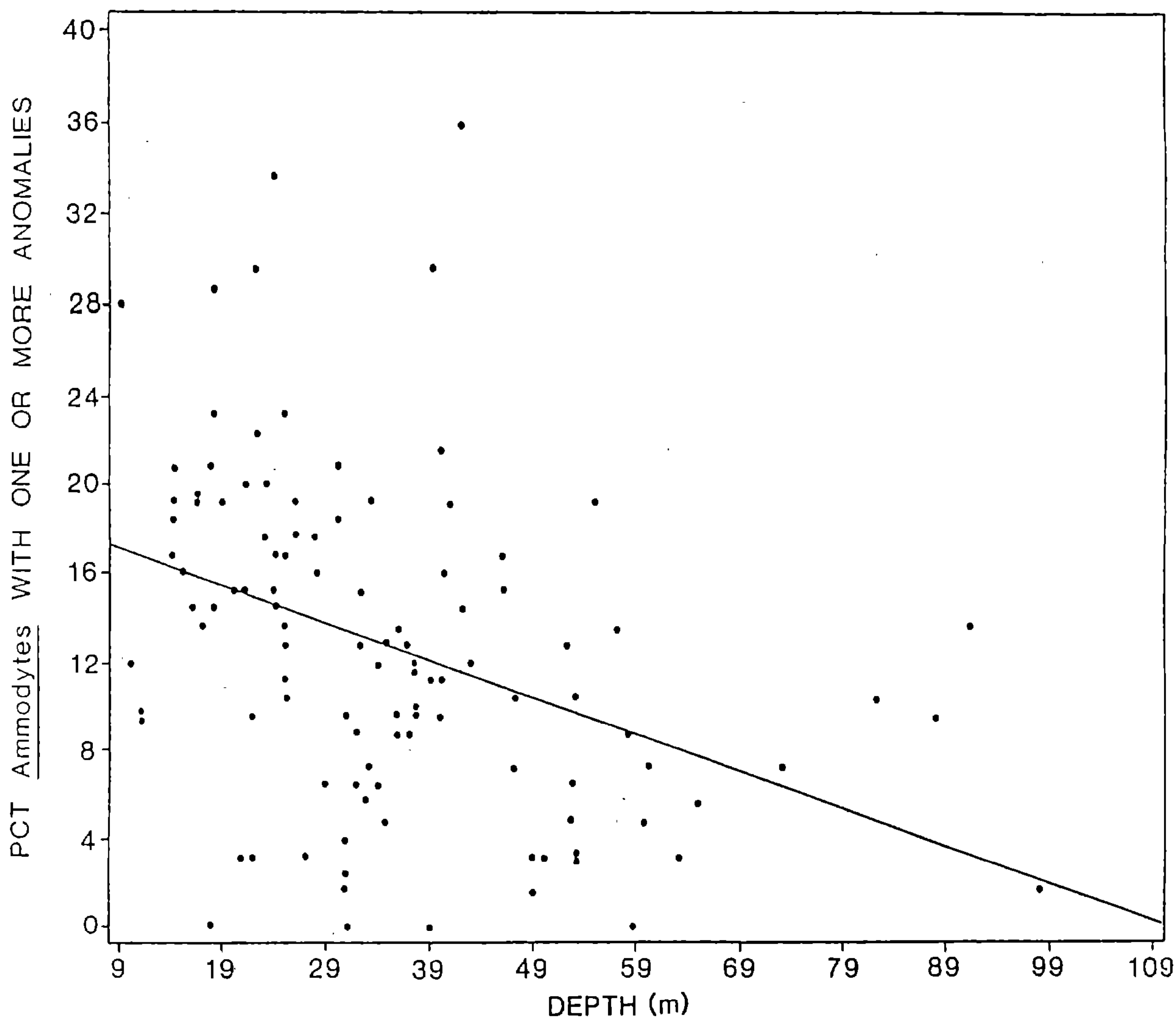

Figure SLE6. Regression for percent sand lance having vertebral anomalies, plotted against depth.

Philadelphia-Camden Dumpsite have decreased since sewage disposal was halted. The obvious inference is that sewage dumping degrades the marine environment but recovery may occur with pollution abatement.

Studies of parasites in two mussel species suggest that environmental changes may cause changes in the relative abundance of the parasites and of the hosts. None of the amphipod populations under study in 1982 for parasites and pathological conditions, however, underwent changes that might be dependent on pollution stress.

Systemic bacterial lesions were found in up to 40% of the sea scallops from the coastal Gulf of maine but were rare in contiguous offshore waters. Bacterial lesions in blue mussels are possibly responsible for extensive mortalities observed in Great Bay, New Jersey, and the incidence of gill pathology in mussels from Raritan Bay, New Jersey, was significantly higher than that seen in mussels from other areas. Increased incidence of disease in such inshore areas is the hallmark of degraded habitat. Other bivalve molluscs (ocean quahogs, surf clams, ribbed mussels, and blue mussels) from coastal and continental shelf habitats were examined for macroscopic abnormalities, microscopic lesions, and parasite burdens. Offshore populations had low parasite burdens and few detectable pathological lesions; distribution of anomalies were site-specific for coastal regions, with the greatest numbers found in areas of high population and industrial activity.

4.2 Immunology

Parameters: Examination of fish and shellfish for immune responses was incorporated into the NEMP program in 1982, because stress caused by pollutants or disease organisms is-a known suppressor of the immune system in man. Fish were examined for the presence of serum antibodies against either pathogenic bacteria or bacteria associated with human waste. Detection of any such antibodies would provide evidence of current or recent residence of the fish in polluted areas. Scallop serum is also being tested for substances (opsonins) that render invading bacteria more vulnerable to attach by the scallop's defense system (phagocytosis).

Observations: Significant antibody responses to the sewage-sludge bacteria were found in tautoqs (a coastal fish) caged for six weeks in the vicinity of the New York Bight municipal sewage sludge dumpsite. Residence of fish in sludge-contaminated areas, therefore, can result in a serum antibody record of sludge contact.. A high percentage of sera from summer flounder from the New York Bight area contained the antibody to a bacterium (pathogenic to humans) found in sewage sludge, particularly sera from fish collected in Raritan Bay during the summer months of 1982 (Fig. SLE7). Antibodies to two other sewage related bacteria were found in Raritan Bay fish only during the month of June. Laboratory studies of antibody production in summer flounder showed significant responses when the fish were held in water of temperatures above 12°C, but showed inhibition of responses in water below 8°C; this observation will be essential to the interpretation of antibody profiles in field-collected fish. A related study of natural isoantibodies to red blood cell antigens in summer flounder may help in interpreting other environmental data, such as determining whether a given population of a fish species is homogeneous or mixed.

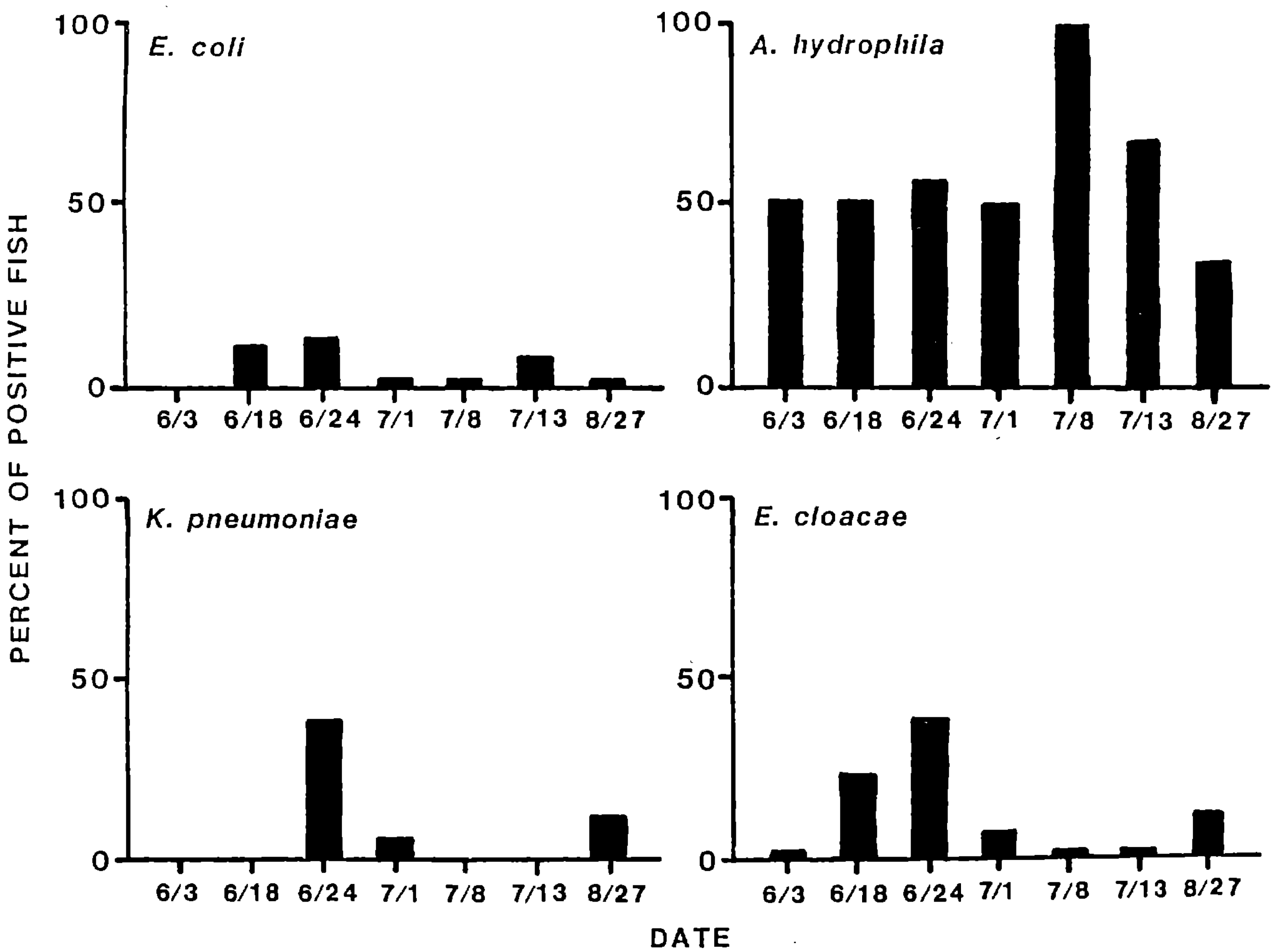

Figure SLE7. Antibody to bacterial isolates from sludge, in summer flounder caught in Raritan Bay during the summer of 1982.

A substance (opsonin) that aids in the immune defense against pathogenic bacteria (by making them more vulnerable to phagocytosis) was demonstrated for the first time in sera of sea scallops. This substance may prove to reflect environmental stress in scallop populations. Recent laboratory studies indicate that in scallops exposed to low levels of heavy metals, normal operation of this substance was altered, interfering with the immune response. A simple test is being developed to measure scallop opsonin, and to determine its effectiveness in stressed animals.

5. BEHAVIOR

Parameters: Behavioral studies examine the ability of marine life to detect and avoid increasing environmental contamination. Behavioral responses of benthic animals to challenges by contaminants were measured by observing either burrowing activities or the degree to which swimming activities were extended above the protective substrate.

Observations: Three different marine species showed avoidance behavior when placed in a degraded environment. Although the avoidance activities mitigated the pollutant threat, each species became more vulnerable to predation as a result. Specifically, exposure of hard clams and sand lance to oiled sediments caused both species to decrease their normal burrowing actions (protection from predators) to avoid contact with the oiled sediments, such as might be found after an oil spill.

Juvenile red hake moved away from their normal, protective bottom-water habitat when dissolved oxygen concentrations were experimentally lowered, demonstrating their ability to detect low oxygen levels which may occur in anoxic episodes like those observed in recent years off the New Jersey coast. These young fish have a strong dependence on shelter at this life-stage, especially that afforded by scallops; moving off the bottom and into the water column, away from shelter, makes the young fish highly vulnerable to predation. Anoxic events, therefore, could deplete not only relatively sessile benthic stocks, but also more mobile fish species.

6. CONTAMINANT BODY BURDENS

Parameters: Chemical analysis for contaminants was performed on both the edible tissues of marine fish and shellfish, whose pollutant content is of interest to the consumer, and the remaining organs, whose continued healthy function is of importance to the survival of the animal itself. For detection of heavy metals, animal tissues were dried and acid-digested prior to conventional atomic absorption spectrophotometry in conjunction with a graphite furnace. For determining organic pollutant levels, both electron-capture and flame-ionization techniques were used with computerized gas chromatography. In addition to measuring body burdens of these obvious and widespread contaminants, bioassays with oyster larvae were performed using highly chlorinated effluents from sewage-treatment plants. During secondary treatment of sewage, a common chlorine compound is routinely added, and the effluent is discharged into the coastal waters; the combination of chlorine, sewage, and seawater results in toxic by-products. Calculated concentrations of chlorine and the toxic chlorine compounds were added experimentally to clean seawater to provide dose-effect confirmation of field observations with actual sewage plant effluent.

Observations: Clams and lobsters taken in 1982 from Buzzards Bay, where PCBs and spills of fuel oil have contaminated areas of the Bay, were found to contain 21-45 ppb (wet weight) PCBs. These concentrations-are far below the 5000 ppb EPA/FDA "action level" set for consumer protection, but they may affect the health of the marine animals themselves. The most contaminated specimens were found at stations closest to New Bedford. Clams contained a range of PCB components, whereas lobsters contained primarily the hexachlorobiphenyls. A comprehensive survey of PCBs in ocean quahogs from the Gulf of Maine, the Scotian Shelf, and Georges Bank south to the Delmarva Peninsula, was completed in 1982. All values from all areas were in the 2-25 ppb range, providing an excellent baseline against which to detect any influx of PCBs into the offshore habitats of this animal.

Concentrations of cadmium in livers of winter flounder collected from the New York Bight appeared to be related to concentrations of cadmium in the sediments from the collecting areas. The apparent relationship is highly tentative, however, because no length-of-residence time in the area can be established for the fish.

Compounds produced by the addition of chlorine to seawater in the presence of organic material were shown to be associated with developmental abnormalities and increased mortality in larvae of the American oyster. These chlorine compounds are of considerable concern, as secondary treatment of sewage routinely employs sodium hypochlorite and the treatment effluent is discharged into the sea. By the addition of such toxic chlorine by-products to the environment where oysters spawn, the health and survival of the larvae and, therefore, species recruitment, are at risk.

7. SUMMARY

7.1 Specific Observations on Animal Health

1. Anemic flounder were collected from coastal waters between Boston and Cape Cod and from the Block Island midshelf station near the Mud Patch; other abnormal blood profiles were found in flounder off Narragansett Bay. Offshore populations appear to have normal blood chemistry.

2. Two offshore depositional areas from which sea scallops were collected appear to be less than pristine, with scallop populations that probably could not support a commercial fishery without endangering recruitment. They are the Block Island midshelf station and the outer Hudson Valley slope. Less frequently, a station in southcentral Georges Bank and one off the northeastern tip of Cape Cod have produced scallops with abnormal metabolism. These are the exceptions; most offshore scallop beds appear to be environmentally sound.

3. Deepwater scallops in the Gulf of Maine show signs of nutritional inadequacies, although they are otherwise apparently healthy. Seasonally-obtained biochemical evidence points to non-spawning populations at these depths.

4. Concentrations of organochlorine compounds in field-collected female striped bass may be related to increased larval mortality. Juvenile striped bass taken from the Hudson River had poor swimming stamina, and high incidences of parasitic infestation and liver necrosis compared to striped bass taken from other areas.

5. Mutation frequencies in winter flounder were found most frequently in specimens taken from the New York Right and near-coastal areas, particularly in the western end of Long Island Sound and along the New Jersey coast. They were sometimes three times as prevalent as in fish from cleaner areas.

6. Vertebral anomalies in the sand lance were most frequently seen in shallow coastal waters, and were associated with major estuarine outflows and dumpsites. Severe skeletal deformities have been related to spawning failure. Pathological abnormalities and parasitism in offshore populations of fish, crustaceans, and molluscs were found to be rare and randomly distributed, but this was not the case for these marine groups where they were associated with the coastal waters of the Gulf of Maine and the middle Atlantic states.

7. Up to 40% of the sea scallops collected from the coastal Gulf of Maine had systemic bacterial infections with macroscopically observable lesions. In scallops collected from offshore waters, this diseased condition is only rarely seen.

8. Fish caged for six weeks at a sewage-sludge dumpsite developed antibodies to sludge bacteria. Antibodies to these bacteria were also found in the sera of fish caught in several inshore areas of the New York Bight. Serum antibody profiles could be useful in tracing residence of fish in sewage-disposal areas; high serum antibodies in fish collected from "clean" areas, for example, would indicate that the fish had recently been in a sludge-contaminated area. Laboratory studies showed that lower temperatures inhibit antibody production, an observation that will help to interpret antibody profiles in fish from sampling sites.

9. A substance that aids in immune defense against pathogenic bacteria was demonstrated for the first time in sea scallop serum, and will be used as a marker for detecting environmental stress. We have recently found that sublethal metal exposure interfered with the normal functioning of this component of the scallop's immune defense.

10. Avoidance behavior in hard clams and sand lance exposed to oil and in juvenile red hake exposed to low dissolved oxygen, although providing escape from a degraded environment, increased their vulnerability to predation.

11. PCR body burdens were low in a comprehensive offshore collection of ocean quahogs, taken from the Gulf of Maine and the Scotian Shelf south of waters off the Delmarva Peninsula. Levels were only 2-5 ppb (wet weight), reflecting global transport phenomena and providing a baseline against which to compare data from inshore sites. Quahogs from inshore regions of the New York Bight and Rhode Island and from Buzzards Bay were moderately contaminated

(to 25 ppb). In offshore waters, comparatively elevated levels were found only at the outer New Jersey shelf (12-16 ppb) and in the Hudson Canyon area (20 ppb).

12. Clams and lobsters taken in 1982 from Buzzards Bay, where PCB input and oil spills have contaminated areas of the Bay's coastline, were found to have elevated PCB concentrations that were nevertheless far below the 5000 ppb "action limit" set for consumer safety. The most contaminated specimens were found at stations closest to New Bedford.

7.2 General Conclusions

1. In 1982, as in previous years of NEMP monitoring, the incidence of marine biological anomalies was highest in coastal and inshore waters, where concentrated monitoring activities have located particular "hot spots". Such aberrant metabolism, disease, and genetic mutations produce fish that appear to neither grow normally nor produce successfully.

2. In offshore waters, biological anomalies are sporadic and thinly distributed. The few exceptions to this general observation, most notably the Block Island midshelf station and the outer Hudson Valley slope, have been identified as potential or actual trouble spots by seasonal monitoring activities.

3. The coastal waters and coastal sediments, therefore, require our close attention. They are marine sinks into which a highly variable mixture of contaminants is rained, poured; and dumped: these include heavy metals and organic hydrocarbons (PCBs, PAHs, pesticides, petroleum hydrocarbons). Because the greatest concentrations of these pollutants are to be found in estuarine and coastal areas (especially the New York Bight and Raritan Bay), and because the highest frequencies of marine biological anomalies are observed in these inshore waters, the probable conclusion is one of cause and effect.

4. The study of cause (contaminant input and other environmental change) and effect (biological anomalies in living marine resources, reduction in growth, loss of stock recruitment) should be focused on coastal Water Management Units. Monitoring of offshore areas identified as real or potential trouble spots (Block Island midshelf, outer Hudson Valley, 106-Mile Dumpsite) should be continued seasonally.

5. Field observations should be augmented by exposures of selected marine species, deployed across pollutant gradients and at specific dumpsites, with appropriate controls. Effects of these exposures should be assessed by a variety of well-tested parameters. Such studies have already been performed in collaboration with the U. S. EPA, and are also currently in progress. We strongly recommend that these activities continue.

6. Adverse effects can rarely be assigned to a single contaminant, and different species can react differently to individual contaminants. Nevertheless, determining the effects of single or mixed contaminants on a single species is necessary for the ultimate understanding of pollutant

impact. Such studies are useful not only in interpreting field data but also in developing new techniques. Controlled laboratory exposures can and should be used to perform this essential task.

7. Flounders with abnormal hematology were collected from coastal waters between Boston and Cape Cod and from the Block Island midshelf. Attempts should be made to relate this observation to local environmental conditions, including the possibility of pre-existing disease.

8. Genetic abnormalities in fish have suggested some relationship to chemically degraded marine habitats. Sampling of fish and shellfish for such abnormalities should be continued and expanded.

9. Deformed vertebrae in the sand lance have been found more frequently in nearshore, shallow waters than in offshore waters, and appear to be associated with major estuarine outflows and dumpsites. Pathology and parasitology surveys of offshore fish and shellfish have not yet provided data that are practical for pollution monitoring, although they have provided useful baseline information. It is recommended that these investigations be concentrated in coastal and estuarine areas.

10. High levels of antibodies against bacteria found in human waste material have been found in flounder collected at or near areas of dredged quality. Because of the relatively transient nature of antibodies and the importance of temperature in their formation, a thorough study should be made of this parameter's feasibility as a monitoring tool, and standardization of its methodology undertaken.

Surveys of animal tissues and sediments for contaminant burdens (heavy metals PCB PAH) have identified areas of high contamination, with some linear relations between levels in habitat and in biota. Sampling intensity should be maintained and should be increased in those areas where contaminant concentrations are either known or suspected to be high.

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