NOAA Technical Memorandum NMFS-F/NEC-10

Northeast Monitoring Program

Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1980

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts

August 1981

NOAA TECHNICAL MEMORANDUM NMFS-F/NEC

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1. *Overview Document of the Northeast Fishery Management Task Force, Phase I*. By Richard C. Hennemuth, Brian J. Rothschild, Lee G. Anderson, and William A. Lund, Jr. October 1980. vi + 12 p., 2 figs.

2. *History and Status of the Atlantic Demersal Finfish Fishery Management Plan*. By Guy D. Marchesseault, Richard P. Ruais, and Der-Hsiung Wang. October 1980. vi + 8 p., 5 figs., 2 tables.

3. *Definition of Management Units*. By Emory D. Anderson and Guy D. Marchesseault. October 1980. vi + 4 p., 4 figs., 1 table.

4. *Fishery Management Techniques, A Review*. By Michael P. Sissenwine and James E. Kirkley. October 1980. vi + 10 p.

(continued on inside back cover)

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldridge, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
Northeast Fisheries Center

Woods Hole, Massachusetts

August 1981

PREFACE

An interest in the health and use of the marine environment is becoming a major media topic, nationally and internationally. For example, in recent months there has been increasing concern in regard to the possible impacts of offshore oil exploration and development in or near productive fisheries grounds. At the same time, municipalities and industry have indicated a dissatisfaction with the legislated termination of ocean dumping of sewage sludge and various industrial wastes. Finally, the United States and other nations must face the problems associated with disposal of various radioactive wastes or by products from the nuclear power industry.

Many scientists and managers believe that the oceans are capable of receiving and assimilating increased amounts of wastes and contaminants. Planning documents or feasibility studies are appearing which propose the possibility of increased loading of marine waters; they also suggest an urgent need for increased monitoring and research of ocean disposal of various wastes. Environmental managers, the public, and legislators must have the information from such studies if appropriate decisions are to be made. The need for long-term monitoring and research in regard to the effects of wastes and activities has been recognized, especially in regard to effects on the living resources of the Continental Shelf waters and adjacent estuaries, and the production of foodstuffs from the sea.

Given the imperative nature of the foregoing, in October 1979 three principal NOAA organizational elements began to develop plans to combine their various research and monitoring activities into a single, unified monitoring program called the Northeast Monitoring Program (NEMP). The Ocean Pulse (OP) program being conducted since 1977 by the Northeast Fisheries Center (NEFC) of the National Marine Fisheries Service (NMFS) formed the basis for the combined monitoring program. Planned activities conducted by the Office of Marine Pollution Assessment (OMPA) and the Oceanic and Atmospheric Services (OAS) were to be included in the single coherent program.

A program development plan (PDP) and the technical development plan (TDP) were completed in September 1980. During the planning phase, however, it was essential to begin to combine monitoring activities. Numerous cruises and monitoring studies were initiated throughout 1980 and these activities culminated in a series of reports which were submitted to the Program Manager by over 50 principal investigators. While elements of NMFS, OMPA, and OAS were involved in the actual field monitoring efforts and ancillary studies, a considerable portion of the work was done through contracting with academic institutions, consulting firms, and other governmental agencies.

The results of these 1980 studies have been synthesized into this NEMP annual report. The report has been written for use by environmental managers, conservationists, administrators within several state and Federal agencies, and for the informed public. The report attempts to indicate the general status of the ecological health of the northeast continental shelf of the United States and adjunct estuaries and includes statements which reference the considerable data provided in the individual reports. In addition, there is a series of

recommendations which have evolved from the monitoring activities conducted in 1980.

While providing a synthesis and assessment based on the various individual reports and existing literature, the NEMP annual report also serves as a referral to the individual reports and the data which have resulted from these studies.

The citations used as sources for this annual report are included in Appendix A; Appendix B is a list of NEMP principal investigators; Appendix C contains a listing of reports produced by these PI's during 1980; Appendix D consists of a tabulation of external interactions the program has had during the last year, many of which are continuing relationships; lastly, to assist the reader, Appendix E is a listing of acronyms and abbreviations used throughout the report.

The NEMP will take advantage of the results of the first year's monitoring activities to assess program effectiveness and appropriate changes in protocol, and emphasis will be made on the basis of these evaluations. In this regard, your comments and suggestions are earnestly solicited and can be directed to the attention of the NEMP Program Manager, at the following address: Dr. John B. Pearce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Sandy Hook Laboratory, Highlands, New Jersey 07732.

ACKNOWLEDGEMENTS

This report was compiled by a team of individuals who dedicated time and effort from otherwise busy schedules in order to make this information available in as timely a fashion as possible.

The following persons were responsible for overall management of the Northeast Monitoring Program as well as specific contributions to this annual report:

John B. Pearce - Program Manager, Northeast Fisheries Center

Merton Ingham - Deputy Program Manager, Northeast Fisheries Center, October 1979 to March 1981.

Millington Lockwood - Deputy Manager, National Ocean Survey, March 1980 to present.

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TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF FIGURES, continued

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LIST OF TABLES

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SUMMARY

During the past year the Northeast Monitoring Program (NEMP) has conducted assessment and monitoring activities to document the status of health of the living resources and their habitats on the continental shelf off the northeast coast. The results of these activities allow us to make the statements in this annual report on the relative health of the resources and their habitats, as well as to identify possible trends and future problems.

One of the principal findings of the program was that many of the fishery resources of the Western North Atlantic are contaminated with petroleum hydrocarbons and PCB's. Species occurring over a wide range, from the coastal waters of the New York Bight apex to the outer continental shelf-slope break, showed unexpected high levels of these contaminants.

Measurements of trace metals and organic contaminants in sediments collected over a broad area of the continental shelf indicate that the seaward extent of pollution may be greater than earlier expected. Moreover, certain offshore areas, especially the "Mud Patch" southwest of Nantucket Island and the "Mud Hole" in the upper Hudson Shelf Valley also showed higher levels of trace metals; as yet it is unknown whether these are exclusively derived from anthropogenic sources.

Continued dumping at the 106-mile industrial waste site has also resulted in questions of possible contamination of food fish in shelf water masses at this site. This possibility has resulted in the development of a plan which would use remote sensing techniques for directing dumping of industrial and other wastes at the site.

Studies of benthic populations and communities indicate that benthic diversity and standing stocks are low in "impact" areas such as the New York Bight, Portland Harbor (Maine), and the Mud Patch. Studies also suggest a slow recovery in the benthos at discontinued dumpsites. In impacted areas there is evidence of a reduction in benthic forage species available for juvenile and adult fish; there is a trend in such areas for amphipods and other epibenthic taxa of importance in terms of forage for fish to be replaced by a variety of small burrowing polychaete worm species.

Microbiological studies have found that *Acanthamoeba*, a human pathogen which flourishes on bacteria and sewage, was found to decrease seaward from upper Narragansett Bay to open coastal waters. This amoeba was also found elsewhere in sediments contaminated by ocean dumping. *Clostridium* sp., a pathogenic bacterium, was found in greater abundance nearer to shore and in the vicinity of sewage dumpsites.

Evidence points to severe coastal eutrophication in waters of the Middle Atlantic Bight. High levels of primary production and phytoplankton biomass were consistantly reported for water masses adjacent to the New York metropolitan and New Jersey coastline. Higher incidence of blue-green algae was also seen in coastal waters and estuarine plumes. This is suggestive of excessive nutrient enrichment from the coastal zone. This eutrophication may have increased the organic loading in areas to beyond their assimilation capacity,

thus causing local areas to have bottom oxygen concentration below that which is healthy for most marine life. Hypoxia (very low oxygen) causing mortality has occurred several times in the last decade and a half.

In addition to eutrophication, the greater concentrations of contaminants in sediments and coastal waters, as well as in living resources from these, suggest that increased efforts of this program should be in the coastal zones, and those areas being affected by pollution emanating from highly contaminated estuaries. New efforts in biological monitoring should be concentrated more in such habitats.

In addition to increased contaminant levels, seabed oxygen demand was found to be greater nearshore and in areas receiving inputs of organic carbon due to ocean dumping or by terrigenous exports contained in estuarine plumes.

Outflow plumes from major estuaries such as Chesapeake Bay, Delaware Bay, and the Raritan/Hudson River complex carried particulates and adsorbed contaminants out to the continental shelf. Such materials eventually settle to the seabed and may be one of the principal influences on benthic communities and demersal finfish populations. Preliminary results suggest that greater emphasis should be placed on investigation of seaward flowing estuarine plumes and their effects on living resources.

As indicated for other variables in the foregoing paragraphs, evidence points to a higher incidence of skeletal deformities, mutagenic aberrations and various shell or skin lesions in organisms collected inshore and in and around dumpsites, strongly supporting evidence for deleterious effects of ocean dumping and coastal discharge.

Monitoring efforts indicated that continued and greater attention should be paid to monitoring these effects. For example, we are developing new techniques, such as the evaluation of chromosomal damage related to contaminant impact as reflected in micronucleii in fish red blood cells, and in the eggs of small peracarid crustaceans. The latter are important forage for various developmental stages of demersal and pelagic fish and are known to be easily and quickly affected by petroleum hydrocarbons and other contaminants.

In addition to these biological effects monitoring activities we have continued to develop and improve techniques within the areas of physiology and biochemistry to show early effects on important components of the food chain. Laboratory and field studies have shown changes in burrowing activities of clams and concomitant changes in feeding activities of predator crabs when challenged by pollutants such as petroleum.

During the past year there was no recurrence of a widespread hypoxic water mass off the coast of New Jersey even though concentrations of <u>Ceratium tripos</u>, a dinoflagellate thought important to the catastrophic 1976 low oxygen episode, occurred in relatively high numbers in March. Our monitoring activities also continue to document the recovery of the benthos affected by hypoxia in 1976, in order to assess more accurately impacts of future recurrence or similiar situations.

During the extensive incidence of paralytical shellfish poisoning (PSP) off Maine and Massachusetts coastal waters in 1980, that closed down most of the

fisheries in those areas, we did not find the PSP inducing dinoflagellates or red tides in offshore waters. Future activities of NEMP should involve more studies closely coordinated with those conducted by state agencies within territorial waters. Our monitoring activities have also allowed us to document conditions during a period of extremely reduced stream flow which has resulted in drought conditions. The drought is now thought to have commenced in early summer 1980 and continued into 1981. State agencies have reported an increase in contaminant concentrations in many major streams flowing into estuaries and coastal waters off the northeast states resulting from decreased dilution of sewage by streamflow. Measurements in coastal waters will be increased in intensity throughout the spring and summer in order to determine if increased stream contaminant loading has impacted on marine habitats of the estuaries and coastal waters.

Finally, during the implementation phase of the NEMP program, several new sources of pollutants to shelf water have been identified. For instance, proposed dredging to accommodate new "super colliers", or coal freighters, in the lower portion of Chesapeake Bay would result in increased quantities of contaminated dredge materials being dumped in shelf waters. Petroleum exploration and development in the Middle Atlantic Bight and on Georges Bank is also likely to result in possible new sources of contaminants and will require continual monitoring over and beyond what the NEMP program has done to date. Projects for the development of other mineral resources off the northeast, including sand and gravel mining, burial of solid wastes in aggregate excavations, and pipeline burial, also indicate the necessity for greater monitoring activities to establish benchmarks against which change can be measured. The same is true for projected use of shelf habitats for the development of various forms of energy, e.g., offshore nuclear power plants.

The measurements performed during the assessment and monitoring activities of the past year have resulted in a significant series of benchmarks for various contaminants as well as clues indicating possible change in tissue loading of biota due to a variety of contaminants. In addition, we have developed benchmarks for populations and communities and a variety of biological responses to contaminant loading. The various benchmarks are to be integrated permitting us to evaluate the health of the coastal waters based on a set of diagnoses. In many cases it has been necessary to resort to special kinds of sampling techniques or data gathering. For instance, remote sensing has allowed us to assess standing stocks of chlorophyll over a broad geographic range in a synoptic fashion. The use of deep diving submersibles has allowed us to survey areas beyond the depths of normal diver capabilities or areas having topography that prohibits normal trawling or grab sampling activities. One such area includes the major submarine canyons off the south flank of Georges Bank. Thus, we now have available a set of tools or diagnoses which permit the evaluation of the status of the health of coastal and shelf habitats.

SECTION I. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA), as the nation's principal civilian ocean agency, has a commitment to determine the effects of man's activities on coastal/estuarine waters, the ecosystems contained therein, and their resources. Part of this commitment is to develop a data base, through long-term monitoring, that will allow the assessment of the effects of pollutants on ecosystems and resources, and will enable early detection of and response to significant environmental changes.

By drawing upon several ocean related elements of NOAA an integrated program has evolved which provides a system of physical, chemical, and biological monitoring at selected stations in waters of the northeast continental shelf from the Gulf of Maine to Cape Hatteras. Monitoring approaches include both standard measurements of physical-chemical factors, including contaminant levels, and newer approaches to biological effects monitoring, using behavioral, physiological, biochemical, pathological, and genetic criteria. This program is designated the Northeast Monitoring Program (NEMP). It includes provision of the broad scale resource-oriented data required under the Fishery Conservation and Management Act of 1976 and intensive site-specific dumpsite data required by the Marine Protection, Research, and Sanctuaries Act of 1972 and meets the general NOAA requirement to monitor and assess the health of the marine ecosystem. The program emphasizes the development of products essential to meeting the objectives of State and Federal programs concerned with fisheries and fisheries habitat management, general marine environmental quality, and coastal zone management. Details describing the extent, rationale, and area of coverage can be found in the NEMP Program Development Plan (1).

The program monitors variables of importance to fisheries resource management and pollution assessment at approximately 140 stations along the continental shelf from Cape Hatteras to the Gulf of Maine. Special emphasis is given to nearshore stations affected by waste discharges. Figure I shows the overall area of coverage of the Program.

PROGRAM GOALS AND OBJECTIVES

The Northeast Monitoring Program is designed around three basic goals:

- Maintain an assessment of the health of the coastal marine ecosystem of the Northeastern United States.
- Provide information necessary to ensure present and future protection of human health and the safety and wise management of the living marine resources of the Northeast.
- Develop a pilot monitoring program to determine cost-effectiveness, user requirements, and the applicability of monitoring methodologies to other U.S. coastal areas.

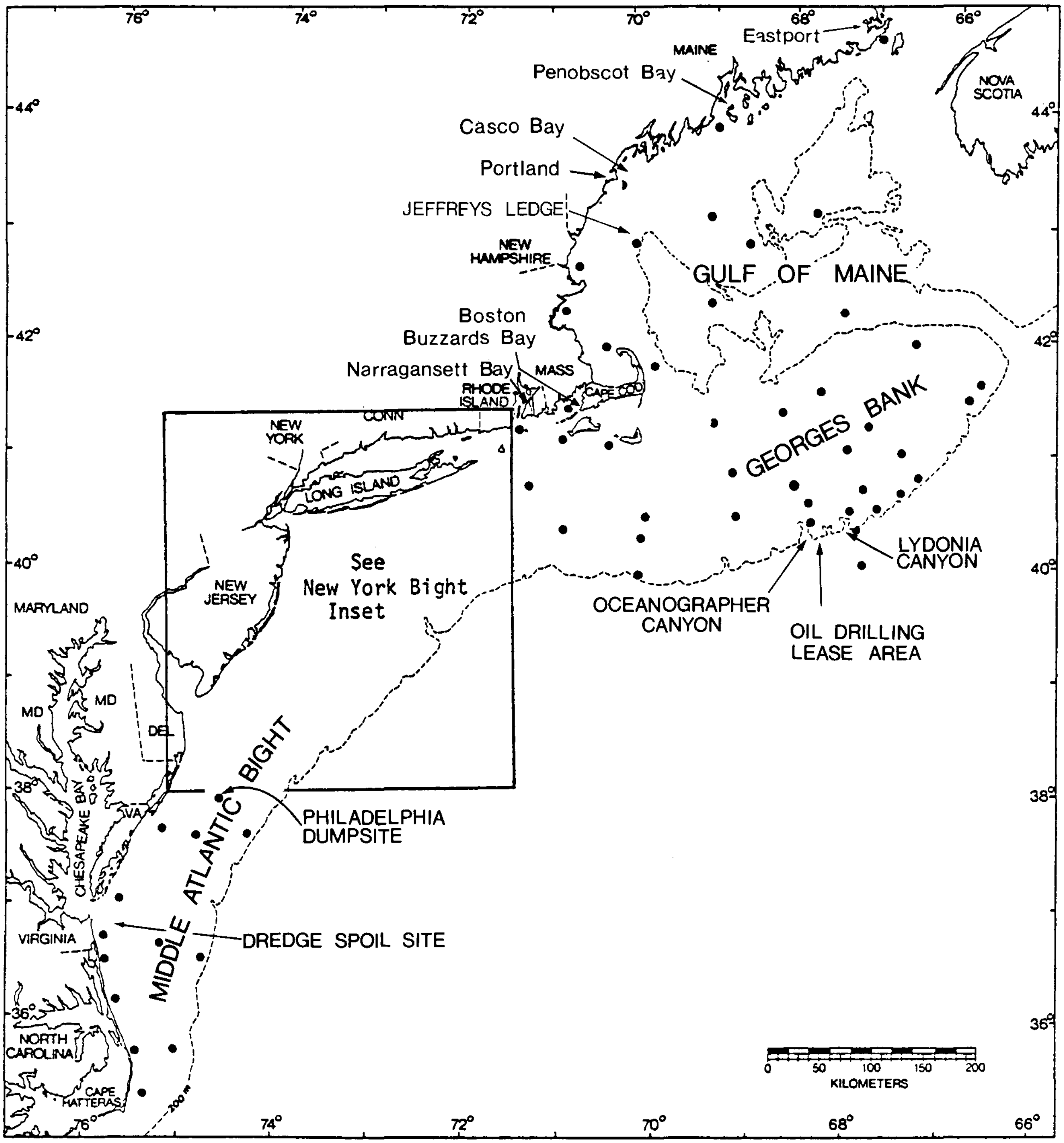

Figure I. Northeast Monitoring Program area of interest, with major ecosystems indicated.

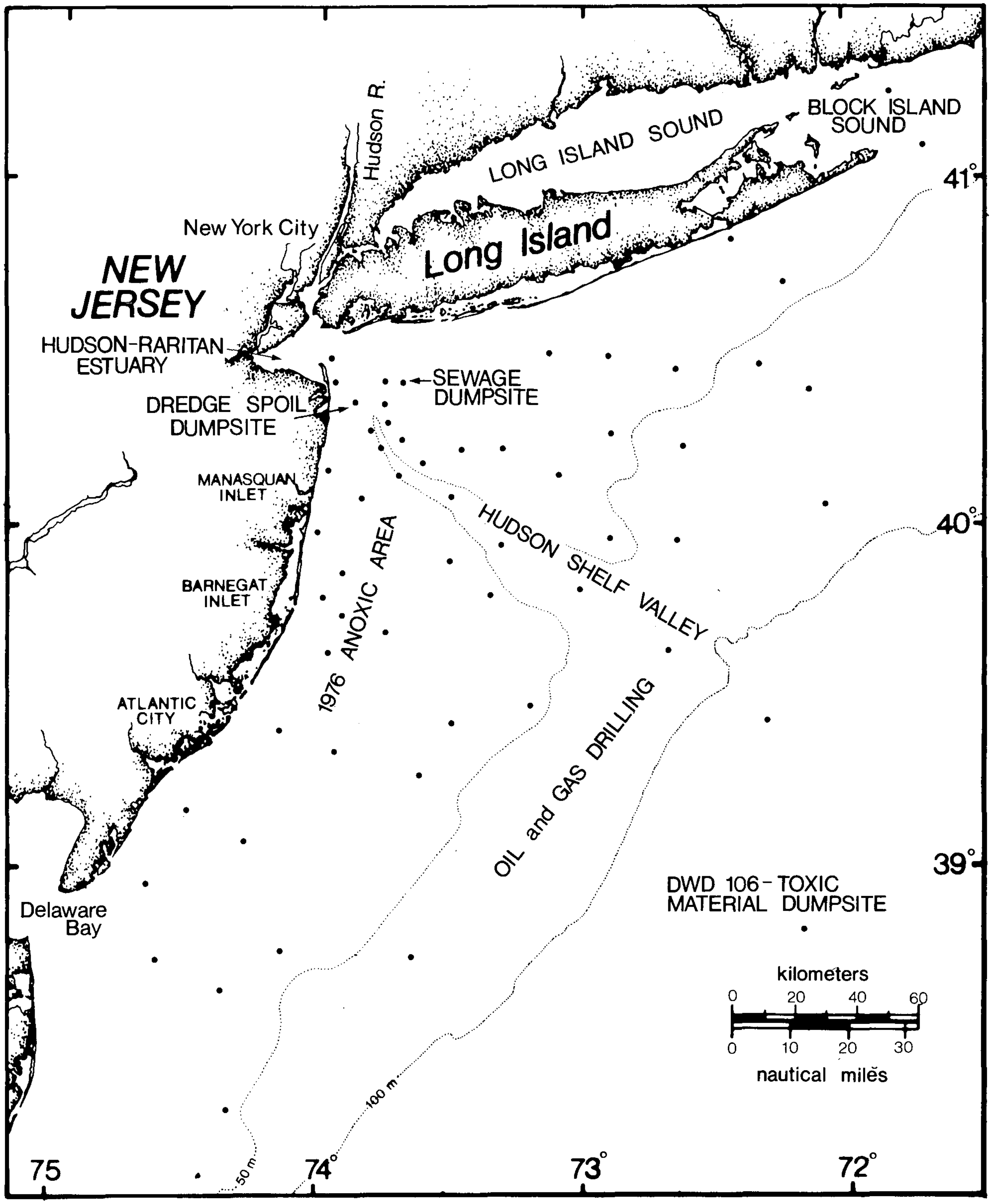

Figure I, continued. New York Bight portion of study area.

To attain the Marine Pollution Monitoring Program goals, the following objectives are currently being pursued:

- o Determine or confirm the existing levels, trends, and variations of contaminants in water, sediments, and biota, and effects of these contaminants on living marine organisms.

- o Establish and maintain an interactive archive of data resulting from other marine pollution monitoring programs in the Northeast and foster cooperation and coordination of estuarine/shelf environmental monitoring and research efforts off the Middle Atlantic and New England States.
- o Summarize, in collaboration with other responsible agencies, information on pollutant inputs and effects to estuarine and coastal waters.
- o Provide data and relevant information, in a timely manner for planning and management, to regulatory organizatons and the general public.
- o Determine the effects of major activities such as offshore oil exploration, drilling, and development; dumping; and toxic waste discharge on the coastal marine environment and its resources.
- o Detect, and provide appropriate and early warnings of severe or irreversible changes in the coastal marine ecosystem and in its resources. This includes interaction with agencies responsible for coordination of both routine and crisis response activities (oil spills, harmful waste and toxic chemical discharge, etc.).

The primary emphasis during the early stages of the program has been to meet the first objective. Thus, the major activity during the past year has been to establish or continue field observation and laboratory programs, for the systematic collection of data from various components of the marine environment. Details regarding these activities can be found in the Program's Technical Development Plan (2).

During the ensuing years, as the Program stabilizes and available information is increased, additional objectives will be emphasized.

PROGRAM DESIGN

A critical aspect of the program is the selection of a proper array of variables to be monitored. Several international, Federal, State, regional, and local agencies have in the past recommended monitoring activities for site- or problem-specific reasons. Such recommendations were highlighted as priority needs in the Federal Plan for Ocean Pollution Research, Development and Monitoring and in task forces within the Council on Environmental Quality (CEQ). Variables measured were selected because of their impacts on resource organisms and human health, or because they serve as indicators of contamination or processes leading to it. Many of the variables selected were recommended by NOAA research programs following consideration of the results of several years of research and monitoring in the region, by the International Council for the Exploration of the Sea (ICES) workshop on monitoring of biological effects of marine pollution, and by a UNESCO (GESAMP) working group concerned with similar problems. The list of variables will be evaluated and modified as the significance of additional variables or indicators is understood, and it will be amended if experience shows some variables to be less important or sensitive than anticipated. Interaction between research and monitoring components of the program will provide the principal guidance for addition or deletion of variables.

In addition to the selection of variables to be monitored, it is important that monitoring be conducted at appropriate locations and time intervals. Monitoring sites that are located in the offings of major estuaries have been designated as fixed sites at which specific contaminants are monitored on a regular basis. Heavy metals in sediments and water vary seasonally; thus, it is important that such variables be monitored quarterly. Guidance provided by discipline review committees has suggested that ecological measurements involving benthic community structure should be made only twice a year. Plankton measurements must be made frequently to understand temporal and spatial variability. Initial biological effects monitoring measurements are made quarterly, and for certain variables more frequently.

Stations that are located offshore over the continental shelf have been selected to represent specific habitat types or are representative of areas likely to be affected by major environmental events. Measurements made at these stations reflect general dispersion and movement of low levels of contaminants from the coastal zone to the shelf and beyond. Since only limited information exists on the generalized patterns of movement of specific contaminants, offshore stations have been located within selected bathymetric regimes. An exception to this is the 106-mile dumpsite, located off the continental shelf, which is affected by present or past dumping, and may receive increased amounts of wastes in the near future.

1980 CRUISES, ACTIVITIES, AND PARTICIPANTS

As with most environmental monitoring programs, the backbone of the NEMP is in the collection of data in the field. The vast majority of the principal investigators (PI's) participating in the program (Appendix B) require an adequate supply of samples or measurements from the field, necessitating substantial numbers of sea days aboard research vessels to meet these requirements. In 1980, NEMP involved: (1) 21 major cruises responsive to program needs (Table I); (2) some short-term, small vessel use; and (3) a substantial amount of cooperative time and accomodations aboard ships from other NOAA research efforts, e.g., the MARMAP and Resource Assessment Surveys of the Northeast Fisheries Center (NEFC), to satisfy NEMP sampling and monitoring requirements. These cruises, dedicated to NEMP, can be discussed as two groups: (1) surveys that are annual or seasonal in nature with a totally monitoring basis, and (2) cruises to satisfy special monitoring or research oriented requirements.

There were ten cruises entirely of a monitoring nature:

(1) Five were region wide surveys; these five cruises supported the monitoring needs of at least ten PI's (Table I, Biological Effects Monitoring).

TABLE 1. NEMP CRUISES AND FIELD ACTIVITIES DURING 1980. ALL VESSELS LISTED ARE NOAA EXCEPT AS NOTED.

CRUISE NO.	DATES (1980)	VESSEL	ACTIVITY
NEMP 80-01	4 Feb - 5 Apr	ALBATROSS IV	Atlantic & Gulf petroleum hydrocarbon assessment
NEMP 80-02	25-27 Feb	G.B. KELEZ	Chesapeake Bay Disposal Monitoring
NEMP 80-03	27 Feb-5 Mar	G.B. KELEZ	New York Bight Disposal Monitoring (weathered out)
NEMP 80-04	12-20 Mar	G.B. KELEZ	Chesapeake Plume Remote Sensing
NEMP 80-05	24 Mar-10 Apr	G.B. KELEZ	Spring Biological Effects Monitoring
NEMP 80-06	21-26 Apr	G.B. KELEZ	New York Bight Water Column Monitoring
NEMP 80-07	6-10 May	G.B. KELEZ	DWD 106 Monitoring and Research
NEMP 80-08	2-7 June	G.B. KELEZ	New York Bight Water Column Monitoring
NEMP 80-09	18-27 June	G.B. KELEZ	Chesapeake Plume Remote Sensing
NEMP 80-10	7-16 July	MT. MITCHELL	DWD 106 Monitoring and Research
NEMP 80-11	8-23 July	ALBATROSS IV	Summer Biological Effects Monitoring
NEMP 80-12	14-19 July	G.B. KELEZ	New York Bight Water Column Monitoring
NEMP 80-13	28 Jul-6 Aug	G.B. KELEZ	New York Bight Sediment Monitoring
NEMP 80-14	1-10 Aug	EVERGREEN[1]	Phila. Dump Monitoring
NEMP 80-15	8-28 Aug	G.B. KELEZ	Dumpsite Monitoring
NEMP 80-16	2-7 Sept	G.B. KELEZ	New York Bight Water Column Monitoring
NEMP 80-17	3-18 Sept	ALBATROSS IV	Fall Biological Effects Monitoring I
NEMP 80-18	14-24 Oct	G.B. KELEZ	Chesapeake Plume Remote Sensing
NEMP 80-19	29 Oct-7 Nov	G.B. KELEZ	Fall Biological Effects Monitoring II
NEMP 80-20	2-19 Dec	DELAWARE II	Winter Biological Effects Monitoring
NEMP 80-21	24 Jul-9 Aug	JOHNSON-SEALINK[3]	Submersible Studies on Georges Bank
NEMP 80-22	18-20 Aug	ALVIN/LULU[2]	Submersible Study of Oceanographer Canyon

1 Coast Guard Vessel
2 Woods Hole Oceanographic Institute
3 Johnson Foundation

With few exceptions, the objectives of these surveys were to sample 30-40 standard sites for a variety of biological, geochemical, and certain physical variables, and an additional 40-50 sites for planktonic and other water column variables on a seasonal basis.

(2) Four other monitoring cruises surveyed the water column characteristics of the New York Bight from April through September; their purpose was to monitor and predict possible conditions leading to hypoxia conditions which have caused extensive shellfish mortalities in the area in the past as well as oceanographic factors that could influence the distribution and behavior of pollutant inputs into the Bight.

(3) A final cruise occurred in late summer, during which the sediments of the New York Bight were sampled. This survey, more intensive than the standard quarterly surveys, was designed to monitor the levels and distribution of pollution related contaminants in sediments and benthic species to assess trends in contaminant loading in the apex of the New York Bight.

Other cruises occurring on a less regular basis in 1980 included:

(1) A major benchmark survey of the hydrocarbon and organohalogen (PCB,DDT) contaminant burdens in sediments, water column, and fish along the East Coast and Gulf of Mexico conducted during the winter and early spring.

(2) Six cruises investigating the impacts of ocean dumping at four sites: The 106-mile dumpsite; a material disposal site off the Chesapeake Bay mouth; the Philadelphia sewage site off Delaware Bay; and the dredge disposal site in the New York Bight.

(3) Three cruises in support of remote sensing of the Chesapeake Bay plume outflow with a lesser effort in the offings of Delaware Bay. (The SUPERFLUX program)

(4) Two cruises in support of divings monitoring studies of potential drilling sites on Georges Bank which involved the research submersibles ALVIN and Johnson SEA LINK.

The individual NEMP PI's routinely generate large quantities of data. These data have been and are being supplemented, when appropriate information is available, by historical information and by data from other contemporary monitoring and research programs. To integrate effectively multidisciplinary studies in assessing environmental health, it has been essential that the program have adequate capability to store and systematically manipulate, update, merge, and retrieve extensive data sets.

Data management activities during 1980 involve the combined efforts of personnel from the Northeast Fisheries Center and the National Oceanographic Data Center. Assistance in the design and systems analysis were provided through consultants contracted by the program. A data management plan has been prepared for use by the program's investigators. Details regarding the numbers and types of data collected by the participants are found in the various Level 1 (data summaries) reports available from the program manager or the authors identified in Appendix C.

THE SYNTHESIS PROCESS

Program results are integrated through a process of information/data assessment and synthesis as illustrated in Figure II. Field and laboratory results are analyzed and reduced by the PI's responsible for individual work units. Reports/synopsis of the data were issued at various times throughout the year based upon the requirements of the program and demands of users. Each principal investigator was responsible for the preparation of an annual data report in November. These reports were subsequently summarized into 20 topical activity reports based upon the information contained in the reports written by the PIs. Following this, the material was summarized into four synthesis reports on water quality sediment quality, biological effects, and resource contamination, which are included in the main body of this report. The source material is available from the NEMP manager, Sandy Hook Laboratory, Highlands, New Jersey 07732.

Among the most important interactions are those with agencies also responsible for monitoring contaminant inputs to estuarine and coastal waters. These inputs include domestic and industrial wastes, dredge materials, specific toxic substances, and urban and rural runoff. Several agencies at different levels of government are responsible for the estimation and surveillance of specific contaminant loadings and continually accumulate data which should be summarized over the entire northeast coastal zone. Knowledge of trends in these loadings is essential to redefinition of the most appropriate suite of contaminants to monitor as well as to provide management with knowledge of relationships between changing contaminant loadings and levels in the environment.

Arrangements for exchange of data are exceptionally important because environmental and ecological degradation typically first occur in the estuarine and nearshore coastal regions within the primary purview of these agencies. Interaction with these agencies will include encouragement and assistance in developing effective monitoring strategies which are comparable to those of adjacent jurisdictions. The NEMP program offers the only mechanism for integrating the findings of the many regional and local monitoring programs to provide a broad perspective for the entire northeast. Regional meetings chaired by NEMP personnel have served to coordinate, integrate, and focus several programs, especially in the context of the use of remote sensing activities for pollution monitoring and research.

The NEMP findings have been made available to governmental agencies, public interest groups, and the public. The nature of some marine environmental problems dictates that monitoring findings and appropriate interpretations be made available to agencies which are required to take action and to the public and public interest groups with strong concerns about particular issues. In some cases it has been appropriate to keep the users informed on a daily or weekly basis as monitoring of an event progresses. In Appendix D are the more important interactions and the nature of these interactions.

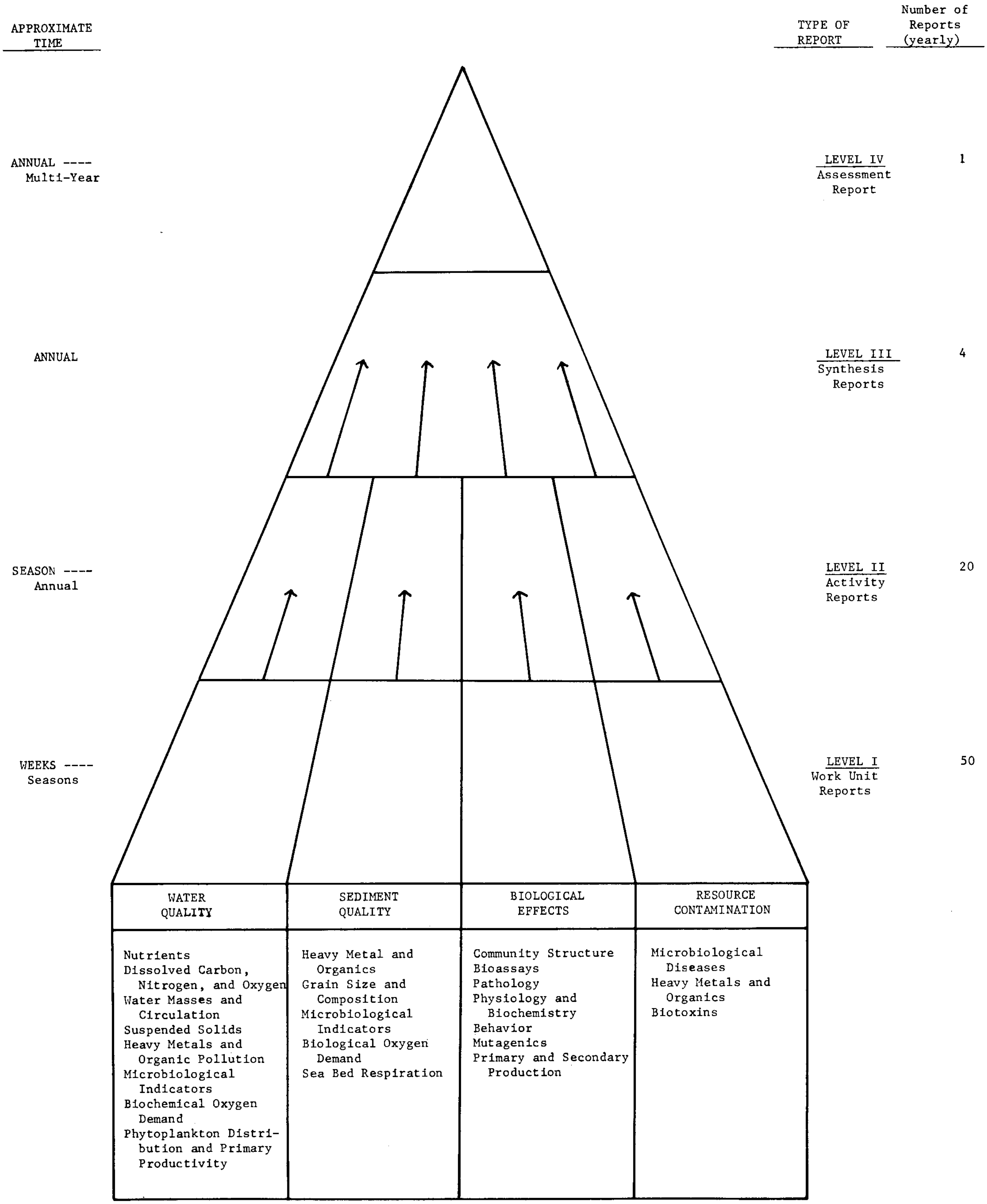

Figure II. Integration of program results.

SECTION II. OCEANOGRAPHIC SETTING

The area of concern to the NEMP, extending from the Gulf of Maine to Cape Hatteras, is oceanographically heterogeneous, embracing several distinct bathymetric or shoreline features, water masses, and two biogeographic provinces, the Virginian and Boreal (Figure I). The Boreal Province includes the Gulf of Maine and the northern edge of Georges Bank, and the Virginian Province coincides with the Middle Atlantic Bight and the southern Georges Bank. The New York Bight, a subset of the Middle Atlantic Bight, is often considered to be a discrete biogeographic area. Four principal drainage basins adjoin the area: the Canadian-New England, Southern New England, Delaware-Hudson, and Chesapeake basins. Three major estuarine systems influence the NEMP area: Chesapeake Bay, Delaware Bay, and the Hudson-Raritan estuary.

The Gulf of Maine is a semi-enclosed continental sea of 90,700 Km^2 separated from the Atlantic Ocean by Georges and Browns Banks. Major features include a limited and complex water exchange between the ocean and the Gulf, a boreal climate, a large tidal range (2.1-8.5 m) and a tortuous coastline. The circulation is only generally understood, and most estuaries are poorly known hydrographically. Salinities in the coastal zone are generally between 30 and 32 o/oo. Most coastal areas are rocky, while the deeper basins are floored by gravelly silts and clays interrupted by rock outcrops and ledges.

Georges Bank is shallow and has a well mixed water column for most of the year. Surface currents form a large gyre around the bank's periphery. The gyre entrains particulate matter, concentrates nutrients on the bank, and limits exchange with other waters. Shelf-slope frontal systems are present on the northeast and southwest borders, and these entrain additional materials, including nutrients and metals. Primary productivity is high throughout the year. Annual phytoplankton productivity is comparable to that observed in the Middle Atlantic Bight (400-500 $gC/m^2/yr$). In the shallow areas (less than 40 m) it may exceed 650 $gC/m^2/yr$, a value two to five times that for most temperate shelf areas. The shallow, well-mixed water column enhances organic input to the benthos and rapid regeneration of nutrients. Sediments consist of coarse sand, gravel, and shell in the shoaler areas, grading to finer sands and silts toward the shelf edge. This results in changes in concentrations of organic and inorganic substances associated with sediments.

The Middle Atlantic Bight includes the shelf area between Nantucket Shoals and Cape Hatteras. Water column concentrations of nutrients, dissolved organic carbon, seston, phytoplankton, heterotrophic bacteria, and zooplankton generally decrease in the Bight from inshore to offshore. The shelf itself is characterized by varied topography, including ridges and swales which run obliquely to the shoreline and extend nearly to the shelf break. Sediments on the inner shelf are medium and coarse sands (although fine sands are found off Virginia), and those of the outermost shelf and shelf break are slightly muddy, fine sands. Density and species diversity of total meiobenthos were found to be uniform across the shelf. Macrobenthos densities were highest on the outer shelf and lowest on the continental slope, while species diversity and richness showed an obvious offshore increase with depth.

A feature that shows up during the warm months is a phenomena called the "cold pool." The "cold pool" or cold cell is a persistent feature which lies along the mid-shelf region of the mid-Atlantic Bight. It is overlain by a thermocline during the period of stratification. The temperature of the cold cell varies from year to year depending upon the severity of the previous winter and the nature of the water advected into it from the north. In this feature there is a seasonal cycle in the concentration of dissolved oxygen, progressively decreasing from the onset of stratification to a minimum in August or September.

The New York Bight is that section of the Middle Atlantic Bight between Delaware Bay and Montauk Point, New York. The northwestern corner, adjacent to New York City, is designated as the New York Bight apex and constitutes one of the most heavily polluted bodies of water in the world. Detailed descriptions of the oceanographic conditions can be found in the NEMP Technical Development Plan (2) available from the Program manager.

BIOLOGICAL RESOURCES

Major resource species can conveniently be discussed by dividing the region into geographical subregions. Fishery resources of the Gulf of Maine include cod (Gadus morhua), haddock (Melanogrammus aeglefinus), redfish (Sebastes marinus), Atlantic herring (Clupea harengus harengus), lobster (Homarus americanus), northern shrimp (Pandalus borealis), and several minor species. Cod, haddock, white hake (Urophycis tenuis), and Atlantic herring are increasing from low biomass levels reached in the early 1970s. Redfish and northern shrimp, however, are at very low levels of abundance. United States landings of the important resource species from the Gulf of Maine exceed 35,000 metric tons (MT) and are expected to increase as some stocks rebuild from overfishing in the early 1970s (3).

On Georges Bank, Atlantic herring, cod, haddock, pollock (Pollachius virens), red hake (Urophycis chuss), and sea scallops (Placopecten magellanicus) are the presently important resource species. Cod, haddock, and silver hake (Merluccius bilinearis) are increasing in stock size from lows reached earlier in the decade. Pollock, red hake, and sea scallop stocks are relatively low due to recent poor recruitment, while Atlantic herring stocks on Georges Bank are severely depressed at this time. The combined United States catch of these major species exceeded 41,000 MT (3). Most stocks are expected to increase in the future.

Species most sought commercially and recreationally in the Middle Atlantic Bight include silver hake, red hake, summer flounder (Paralichthys dentatus), Atlantic mackerel (Scomber scombrus), striped bass (Morone saxatilis), and bluefish (Pomatomus saltatrix). Species of primarily commercial importance include cod, sea scallops, lobsters, Atlantic menhaden (Brevoortia tyrannus), squid (Illex and Loligo), and surf clams (Spisula solidissima). Silver hake, bluefish, menhaden, and Illex squid are at fairly high levels of abundance or increasing, while other species are at low levels or currently decreasing. However, increases of cod and Atlantic mackerel are expected. The Middle Atlantic Bight differs from Georges Bank and the Gulf of Maine in that (1) the recreational catch of several finfish species, such as bluefish, summer flounder, striped bass, and Atlantic mackerel greatly exceeds the commercial harvest; and (2) there is a considerable seasonal change in species during the year.

POLLUTION STRESS

Important sources of pollutants to the NEMP region are via direct ocean dumping of wastes and from point and non-point source inputs into northeastern estuaries. All major estuaries within the study area (Figure III) are valuable in supporting fin- and shellfish stocks and for other uses by humans. The estuarine habitats are among the first marine areas to experience degradation of water quality, subsequent alteration of ecosystems, changes in important biota, and concentration of contaminants harmful to man. Many estuaries and tributaries have similar problems -- i.e., elevated nutrient levels, with attendant algal and bacterial growth and depression of dissolved oxygen; inputs of a wide variety of contaminants for which estuarine sediments and the biota form a sink; changes in biota which may be linked to pollutant increases; tainting or contamination of resource species, rendering them unsuitable for human consumption; and sedimentation of habitats and loss of wetlands to development. Individual estuaries or riverine systems also have special problems, such as presence of Kepone and disappearance of rooted aquatic vegetation in portions of Chesapeake Bay; hydrocarbon pollution in Delaware Bay (which handles 70 percent of the oil delivered to the east coast of the U.S.), and PCBs in the Hudson-Raritan system and Buzzards Bay. Details of environmental settings and contaminant loads for many of these estuaries were given in a series of special papers prepared for the ICES, for Chesapeake Bay (4), Delaware Bay (5), Raritan Bay (6), Long Island Sound (7), Narragansett Bay (8, 9), and Gulf of Maine estuaries (10).

Pollutants from these estuaries are carried into surrounding coastal waters in dissolved and suspended form and as body burdens in the biota. Large quantities of pollutants are also introduced into waters of interest to NEMP via direct ocean dumping. The most important of the ocean disposal activities include dredge spoil dumping in Casco Bay, Maine, Massachusetts Bay, Narragansett Bay, and the New York Bight apex; sewage sludge dumping in the New York Bight apex; and toxic chemical and fly ash disposal at a deepwater dumpsite 196 Km (the 106-mile dumpsite) southeast of New York City. The dumpsites off Philadelphia previously used for industrial wastes and sewage sludge have recently been closed. A site approximately 27 km off the mouth of Chesapeake Bay has been proposed for dumping of dredge materials taken from the Bay.

Atmospheric fallout of pollutants occurs over the entire NEMP region. Lead and hydrocarbons from vehicle emissions are among the most important contaminants entering shelf waters via this route. Little information exists on actual quantities of contaminants so introduced; estimates are that 17 percent of the lead entering the New York Bight is from atmospheric fallout (11). Other direct pollutant inputs to the northeast continental shelf are from oil-related activities, tanker spills, and intentional discharges. Sand and gravel mining, offshore energy generation, and thermal discharges and disposal of radioactive wastes are impacts which may increase in importance in future years and thus require data evolving from NEMP as benchmark references.

Indications are that levels of contaminants (petroleum hydrocarbons, PCBs, and trace metals) higher than to be expected in finfish and shellfish are found considerable distances from known sources of contaminants.

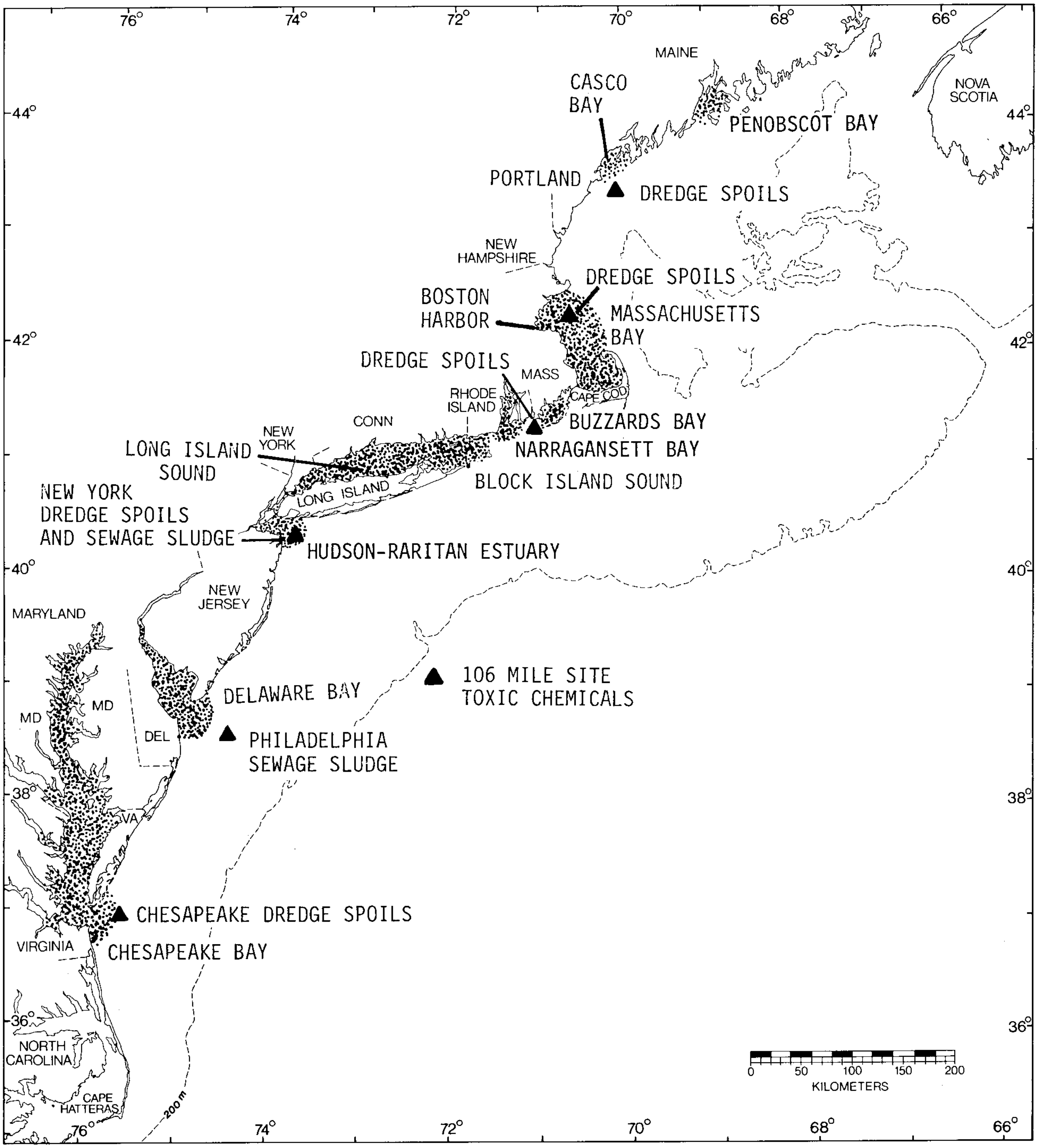

Figure III. Major estuaries, embayments (stippled) and dumpsites (▲) included in NEMP studies.

SECTION III. 1980 PROGRAM RESULTS

In developing this annual report a process of information synthesis was utilized to aggregate or "synthesize" the information which was available within specific areas by the program's Principal Investigators (PIs). These synthesis products were then further distilled to identify the most salient points which relate to each of the four major thrusts of the NEMP. Figure II depicts schematically the areas of expertise which were incorporated into each area. The specific information and reference to a particular cruise or work unit is referred to in the textual material of each section.

WATER QUALITY

Measurements of water quality variables in the NEMP have been focused mainly on areas in the Middle Atlantic Bight where contaminant concentrations are known or suspected to be a potential problem. These areas are the New York Bight, which receives a significant load of inorganic and organic dissolved and suspended nutrients from the Hudson-Raritan estuary and the area off the Virginia Capes, which receives a similar load from Chesapeake Bay. In addition, a research effort involving pollutant concentrations has been conducted mostly by the NOAA Ocean Dumping Program at the 106-Mile Dumpsite. The principal variables sampled in the Middle Atlantic Bight areas were dissolved oxygen, organic carbon and nitrogen, inorganic nutrients, chlorophyll *a*, particulates, and primary productivity, because the main impacts of estuarine outflows in these coastal waters appear to be related to over-stimulated plankton productivity. At the 106-Mile Dumpsite the variables of interest are dissolved or adsorbed heavy metals and organic substances dumped there by chemical industries.

Dissolved Oxygen: During the late summer when the water is highly stratified, dissolved oxygen concentrations consistently decrease to relatively low levels in bottom water near the New York Bight apex dumpsites and in nearshore water off the coast of New Jersey between Barnegat Inlet and Cape May. In 1976 the amount of dissolved oxygen decreased to values near 0 ml/l resulting in mass mortalities of fish and shellfish (1). The lowest levels of oxygen detected during the 1980 season were measured during the month of September off the southern New Jersey coast (Figure IV).

The annual cycle of near-bottom oxygen concentrations in the New York Bight during "normal" years (no hypoxia) has been described (2). Over the year, dissolved oxygen levels in the New York Bight were within the "normal" range of values for this area (Figure V). The extremely stressful hypoxic and anoxic conditions in 1976 were not present during the summer of 1980.

The normal rate of decrease in dissolved oxygen concentration is on the order of 0.025 ml L^{-1} d^{-1}. During the April through June period of 1980 decline rates were as high as 0.035 ml L^{-1} d^{-1} in nearshore waters off New Jersey, and extrapolations based on these rates indicated that values might approach 2.0 ml L^{-1} by late August. However, during the July through September 1980 period the rate of oxygen decline had reduced significantly resulting in oxygen concentrations ranging from 2.85 ml L^{-1} in the New Jersey nearshore to between 3.73 and 5.24 ml L^{-1} over the remainder of the shelf.

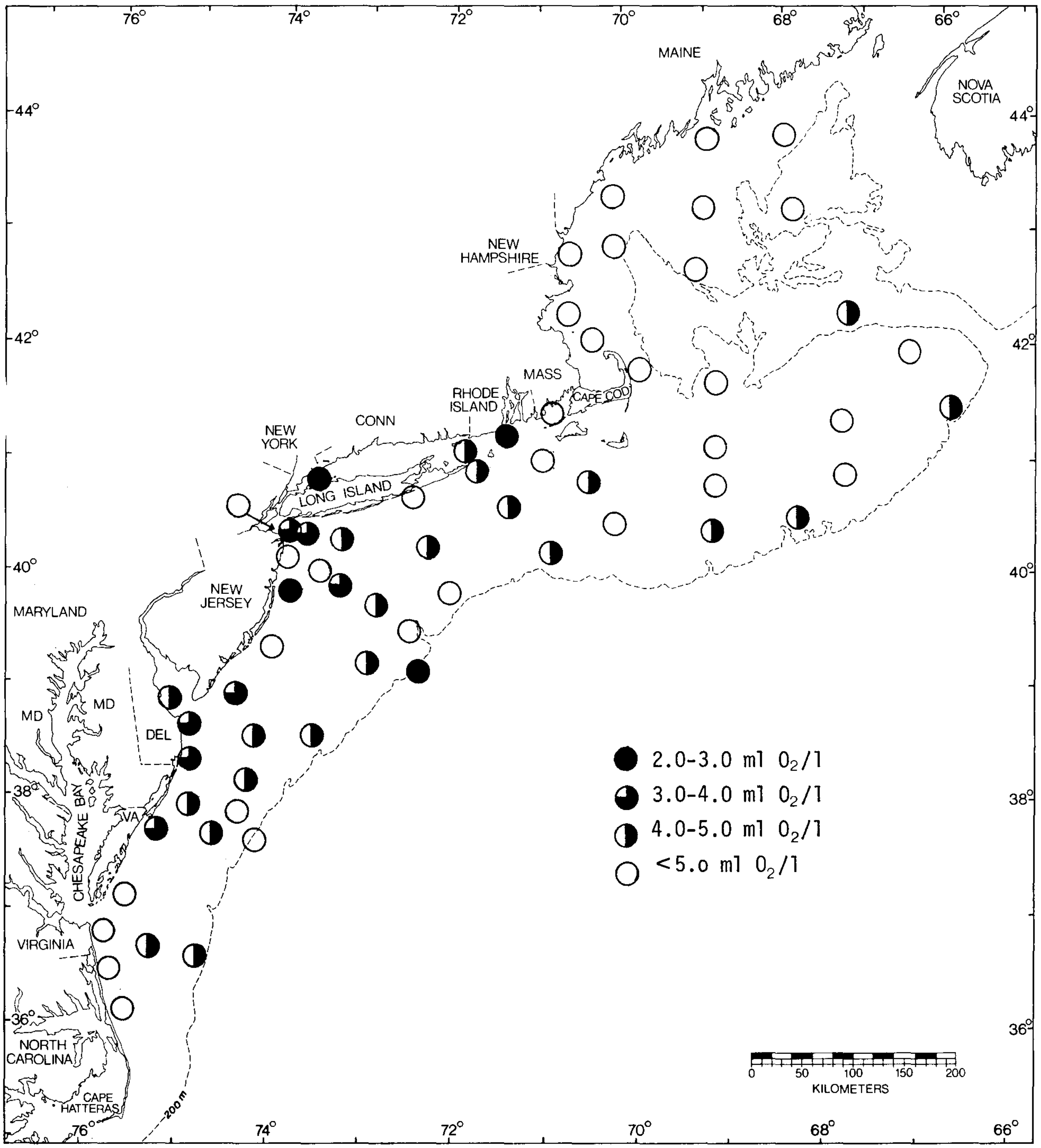

Figure IV. Lowest levels of dissolved oxygen concentrations observed during the 1980 season.

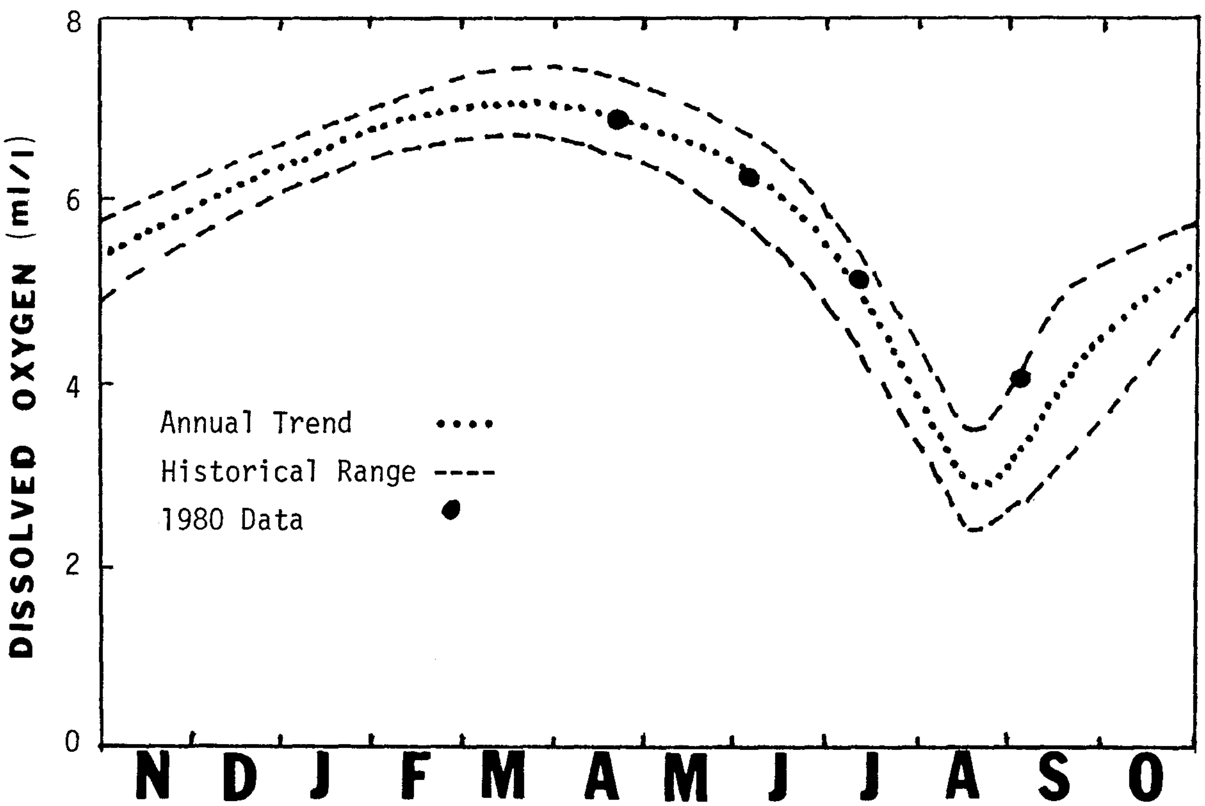

Figure V. Dissolved oxygen levels in bottom waters of the New Jersey-Cape May Shelf Waters (Historical and Annual data from NOAA Professional Paper 11).

New York Bight

Review of the climatological records during the severe oxygen depletion of 1976 indicate that the winter of 1975 through 1976 was unusually mild, followed by a high Hudson River flow during the months of February through April. This situation caused the development of an early spring pycnocline or discontinuity which resulted in little vertical exchange between bottom and surface layers.

The monthly temperatures recorded for the 1979 through 1980 winter were near normal, averaging slightly above normal during December and January and slightly below during February and March. Precipitation averaged lower than normal for the first half of the winter and was followed by record breaking rainfalls during the spring (March, April) and coupled with a very mild April (Table II). The thermocline for the 1980 season developed in June and became stronger throughout the remainder of the summer.

Table II: Air temperature and precipitation values recorded from JFK International airport for 1979-80 compared to normal values.

	Dec. 1979	Norm	Jan. 1980	Norm	Feb. 1980	Norm	Mar. 1980	Norm	Apr. 1980	Norm
Temp. (°C)	3.4	1.6	0.1	-0.3	-1.5	0.1	3.6	4.0	11.0	9.9
Precip. (cm)	5.31	9.14	3.94	6.83	2.69	7.75	20.75	9.57	19.13	9.12

The cold pool in 1976 displayed unusual characteristics relative to its vertical and horizontal location across the shelf and is believed to have contributed to the anoxic event of that summer. The prolonged period of southwesterly winds during the summer of 1976 created an offshore drift in the surface waters along the New Jersey coast. In response to this, the net bottom drift was opposite to the surface movement resulting in an onshore transport of the bottom water. This onshore transport appears to have thinned and extended the cold pool across most of the shelf further intensifying the gradients between surface and bottom layers and therefore reducing further oxygen exchange (Figure VI).

During the summer of 1980 the location of the cold pool was centered along the 60 meter isobath, and extended over its usual region of the shelf with temperatures ranging between 5 and 7°C (Figure VI). This temperature range compares to the normal range of 5 to 10°C during the August through September period and was indicative of normal air temperatures during the preceding winter. During 1976 the cold pool was warmer than normal, reflecting the warm winter of 1975 through 1976.

Primary Productivity: Two important determinants of quality of the marine environment are the quantity and type of phytoplankton (species, sizes) produced at the base of the marine food chain, since phytoplankton represent a major source of energy, nutrition and contaminants to the food web. Estimates of annual phytoplankton production have been made for the NEMP shelf area from C-14 uptake measurements made during surveys between August 1978 and spring 1980 (Figure VII). Estimates of annual production (particulate and dissolved) for 13 regions of the shelf ranged from 405 to 726 grams carbon fixed per square meter per year, indicating that the continental shelf in the northeastern region of

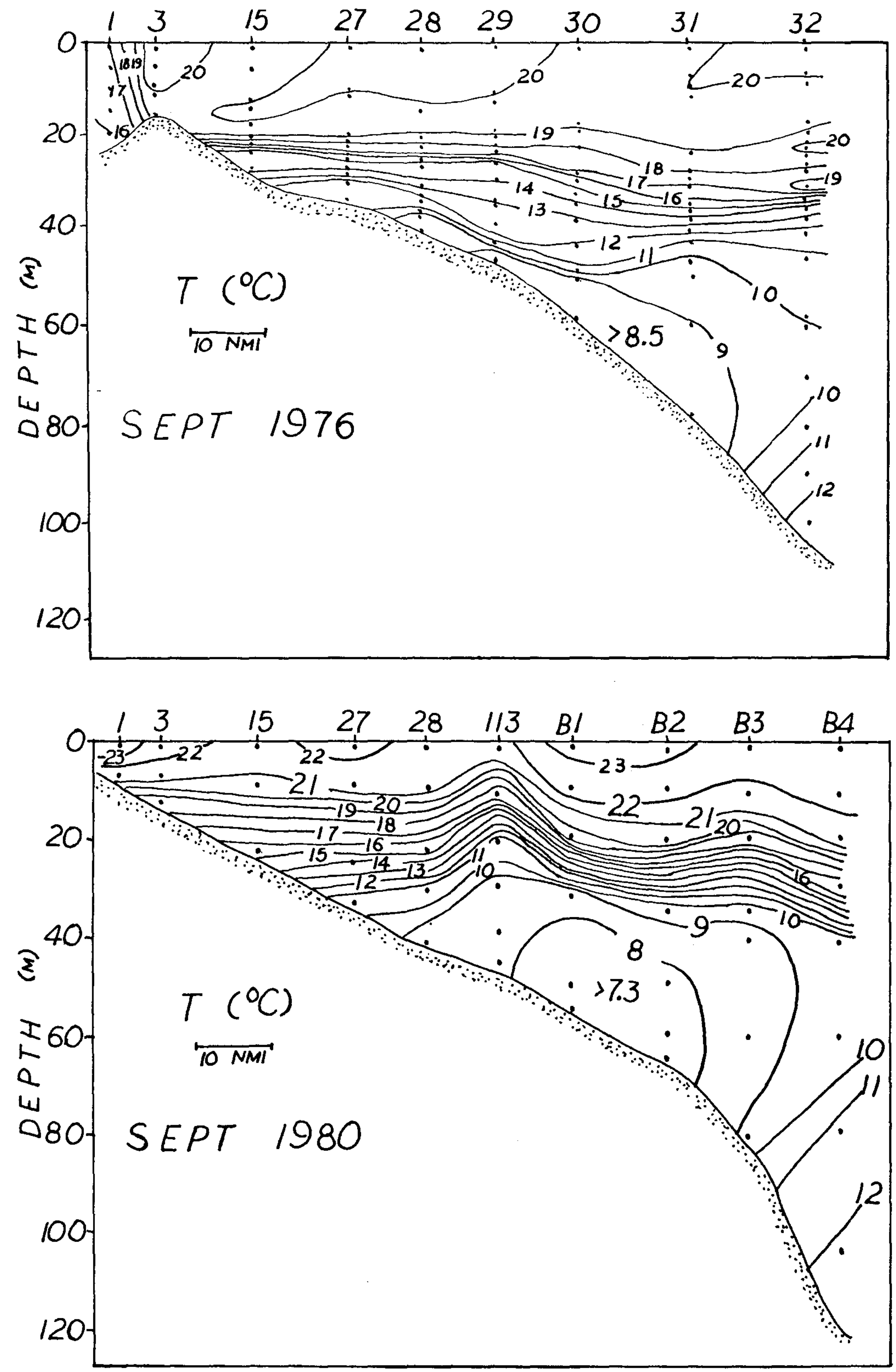

Figure VI. Temperature distribution and location of Cold Pool for September 1976 and 1980 along a section north of the Hudson Shelf Valley.

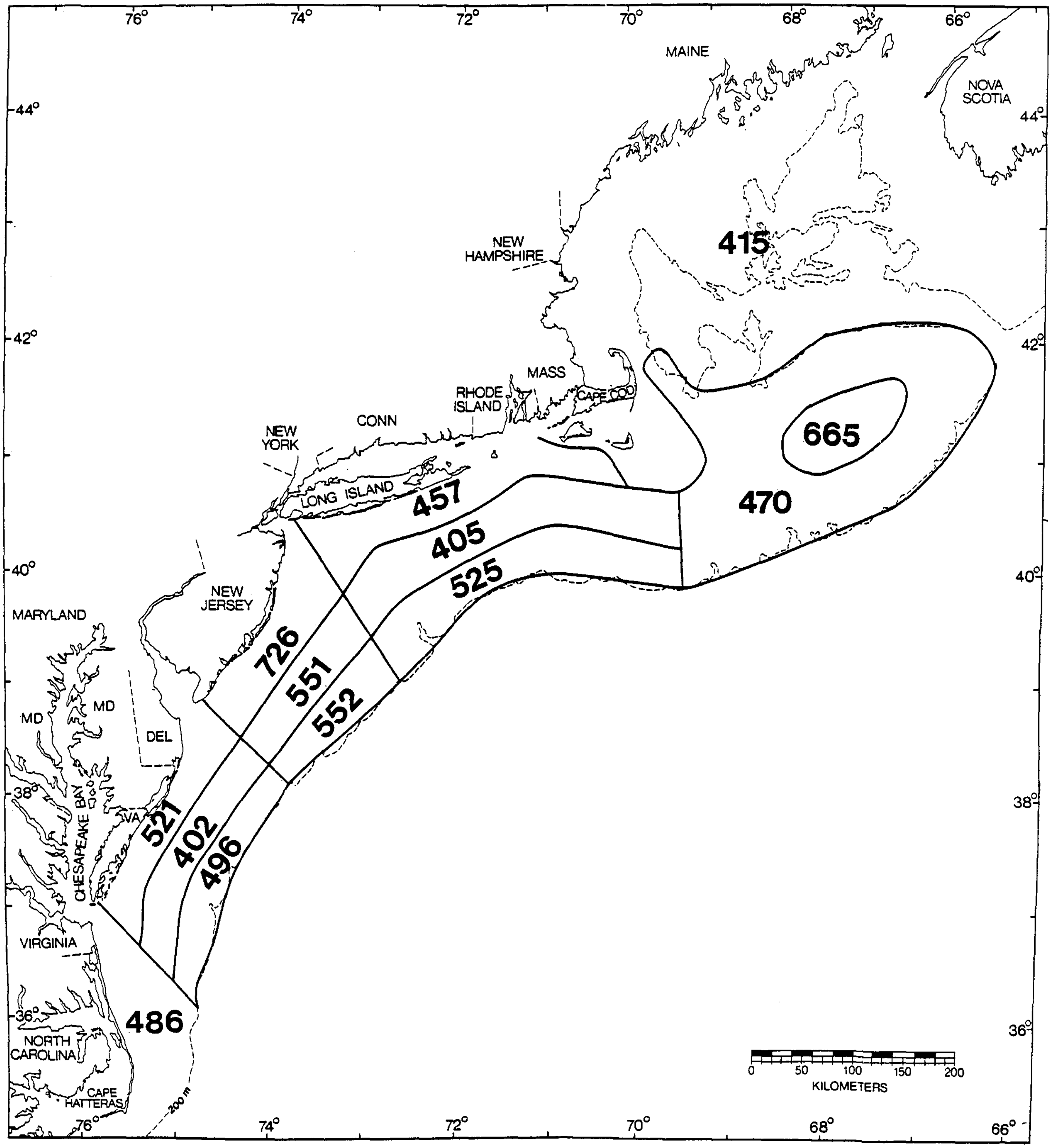

Figure VII. Annual total (particulate and dissolved) primary production by selected NEMP region, g C m^{-2} yr^{-1}.

the United States is one of the most productive in the world (Table III). The nearshore region off New Jersey and the central area over Georges Bank appear to be the most productive and the mid-shelf off Long Island and the Gulf of Maine the least productive.

Seasonal trends in phytoplankton production parallel the seasonal trend in phytoplankton abundance. Relatively high rates of daily production ($1\text{-}2 gCm^{-2}d^{-1}$) were observed during most of the months sampled except February and late December. A "bloom" in March and a vigorous October "fall bloom" are main events in the annual cycle. Additionally, over the entire shelf, production is sustained at high levels ($1\text{-}2 gCm^{-2}d^{-1}$) throughout the summer stratified season. This finding is contrary to the "classic" description of annual cycles of production on continental shelves at temperate latitudes (3) and partly accounts for the relatively high annual production in the NEMP area compared with other areas (Table III).

Phytoplankton Biomass - Chlorophyll *a*: Broad areal distributions of water column concentrations of phytoplankton biomass have been developed from chlorophyll *a* data collected on 18 surveys in the NEMP area between October 1977 and December 1979 (4). Recurrent patterns of chlorophyll *a* abundance are apparent in the data. The concentrations were consistently greater in nearshore waters off New Jersey, Delaware, and Virginia than in water near the continental shelf edge and in the Gulf of Maine. The nearshore high concentration band in the Middle Atlantic Bight often was partitioned into parcels of water located near the mouths of the three major estuaries. This suggests a relationship between the nutrient contributions of the estuaries and phytoplankton concentrations (Figure VIII). However, wind-driven upwelling also may provide the nutrients needed to produce a portion of the larger concentrations observed nearshore. Off Long Island the concentrations are also usually greater nearshore and decrease offshore. Generally, phytoplankton concentrations in nearshore Long Island waters are half those of nearshore New Jersey. The inner third of the shelf adjacent to Long Island has a deeper water column (60 m) than the inner third of the shelf off New Jersey (40 m). This, and differences in mixing and estuarine runoff, may partially explain why phytoplankton are more abundant south of the Hudson Shelf Valley off New Jersey than north off Long Island. On Georges Bank, the concentrations of chlorophyll *a* were highest in the shallow, well-mixed central portion and progressively decreased (five to tenfold) outward toward deeper water.

Some temporal features of the baseline on phytoplankton biomass abundance include these observations. In offshore regions of the Middle Atlantic Bight seasonal variation in phytoplankton biomass (chlorophyll *a*) is relatively smaller than that observed in inshore regions. Offshore, water column concentrations of chlorophyll *a* are about 0.5 mg m^{-3} throughout most of the year. Elevated levels of phytoplankton were maintained for longer periods of time in spring and fall in coastal water than in mid-shelf and offshore water.

Inorganic nutrients: Three NEMP reports describe macro-nutrient (nitrate-nitrite, ammonium, phosphate, silicate) concentrations in seawater (4, 5, 6). The report by Wong describes the distribution of inorganic nutrients in and around the plume of the Chesapeake estuary during the June 1980 Superflux survey. Wong found that the elevated concentrations of nutrients observed in the southern part of Chesapeake Bay did not extend far offshore or southward in the easily identified plume defined by the 32 o/oo salinity isopleth.

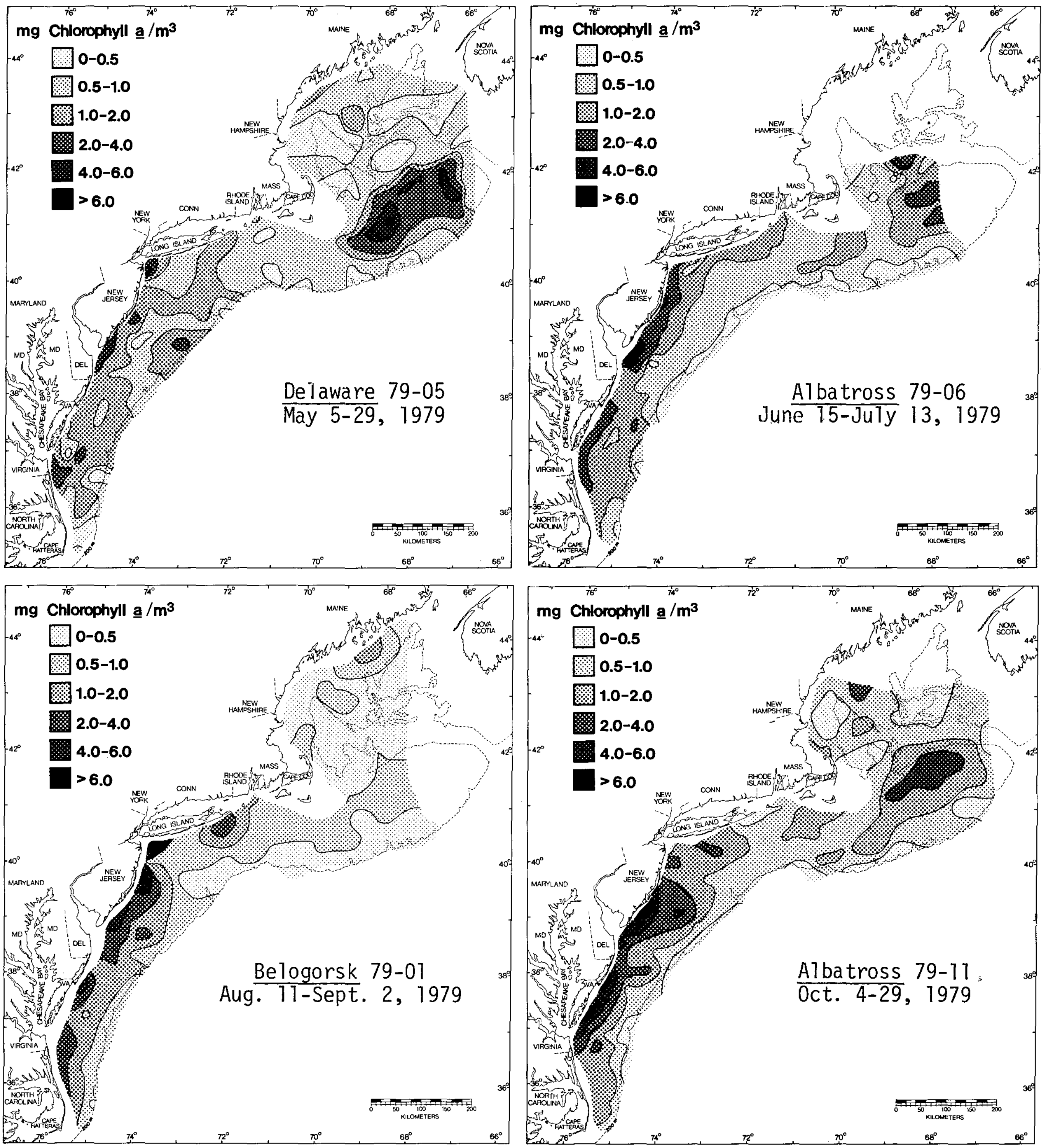

Figure VIII. Distribution of average water column concentration of chlorophyll a, an index of phytoplankton abundance, during four surveys of the NEMP area.

In the apex of the New York Bight, the highest concentrations of ammonium nitrogen occurred near the Hudson River mouth and decreased seaward. Beyond the perimeter of the New York Bight apex (50 km seaward of the Hudson estuary mouth) concentrations of ammonium were extremely low in the highly productive euphotic layer during the stratified season. Ammonium nitrogen is biologically very labile, may represent the preferred and predominant form of nitrogen used by phytoplankton in coastal water enriched with sewage (7) and consequently is not a conservative property useful in tracing the actual seaward extent of nutrient enrichment of coastal water by estuaries. Ammonium nitrogen was also highly concentrated in the cold pool below the pycnocline (also below the euphotic layer) during the 1980 June and July New York Bight water column monitoring surveys (8).

Table III. Comparison of estimates of annual primary production for Cape Hatteras-Gulf of Maine shelf with annual estimates for other systems.

Area	$gC/m^2/year$		Reference
Oceanic	55-70	P*	(27)
North Sea	90-100	P	(28)
Coastal Water, Japan	90	P	(29)
Eastern Scotian Shelf	102-128	P	(30)
Northern Baltic	127	P	(31)
Block Island Sound	300	P	(32)
Off Long Island Coast, 20 m	343	P	(33)
New York Bight Apex	370-480	P	(34)
Coastal Water off India	434	P	(35)
Cape Hatteras-Gulf of Maine	402-726 344-660	T P	(36)
Georgia Coast off Altamaha River	547	P	(37)
Raritan-Lower New York Bay	750-1053	T	(38)

* Note: "P" represents particulate production estimates, and "T" represents total (particulate and dissolved) production estimates.

The highest standing stocks of nitrate and nitrite were consistently observed in water deeper than 80 m at the shelf-slope front. From the cross shelf profiles of nitrate distribution there appears to be a slope water intrusion of nitrates onto the shelf along the bottom in the vicinity of the Hudson Shelf Valley. A depletion of nitrate in the surface water occurred from April to June when thermal stratification was established, and when rates of phytoplankton production (and nutrient uptake) were high. It is clear from the Hudson Shelf Valley nutrient profiles that estuarine/neritic sources of nutrients are superimposed on nutrient stocks actively supplied by in situ benthic and in situ water column mineralization of organic matter, by slope water inputs to the shelf, by fixation in blue-green algae, and by nutrients stored in water masses such as the "cold pool". Monitoring combined with special "process oriented" studies will reveal the relative magnitude of importance of these various sources in providing the large quantities of nutrients required by the very active phytoplankton communities in these areas. More shelf-wide descriptive studies of "background" in situ heterotrophic mineralization of organic matter and concomitant release of nutrients are required before an accurate assessment can be made regarding man's role in the eutrophication of coastal water of New Jersey.

Special studies in the New York Bight and over Georges Bank have shown that mineralization of organic matter in the water column may represent a major source of recycled nutrients available to phytoplankton (9, 10, 11). During the September 1980 Biological Effects Monitoring survey, Draxler and Phoel (Sandy Hook Laboratory) measured rates of nutrient flux from the seabed at sites located throughout the NEMP region to quantify the potential role which the seabed plays as a source of nutrients. The measured rate of release of ammonium nitrogen was equivalent to about 1.4 percent of the daily nitrogen requirement of the ambient phytoplankton community. Based on ammonium flux data from bell jar observations (12), it is unlikely that all forms of inorganic nitrogen released from shelf sediments exceeded 5 percent of the daily phytoplankton nitrogen demand. This contrasts greatly with estimates for other shelves which range from 30 percent, inshore, to less than 20 percent at the shelf break (13). The implication of these benthic nutrient flux data is while there is a great deal of organic matter recycled or transformed into inorganic nutrients in the water column of the New York Bight, the benthos seems not to be substantially involved in supplying nutrients to the very productive phytoplankton community. This is particularly evident when this area is compared with other productive shelves such as off the coast of South Western Africa where large accumulations of organic matter (14) in the sediments results in anoxic conditions throughout most of the year and results in an area of 15,000 km^2 which is devoid of benthic macrofauna (15).

Organic carbon and nitrogen: At present, very little information exists concerning the distribution of dissolved (DOC, DON) and particulate organic nitrogen and carbon (POC, PON) within the NEMP region. During a late summer survey of the New York Bight in 1976, the highest average water column concentrations of DOC (4-6 mgC/l) were measured in the Bight apex and inside the Hudson-Raritan estuary. Seaward of the apex to Cape May, DOC concentrations were between 1.6 and 2.2 mgC/l (16).

Dissolved Organic Carbon was measured throughout the water column during four New York Bight surveys. DOC concentrations were usually between 1 and 2 mgC/l throughout the four surveys. DOC concentrations were usually highest nearest the mouth of the Hudson-Raritan estuary and inversely related to sigma-t; this was interpreted to mean that the estuary is a major source of DOC.

Samples of seawater filtrates for DOC were also taken during a joint remote sensing-oceanographic study (SUPERFLUX) of the Chesapeake Bay Plume during October 1980. Concentrations of DOC ranged from 1.4 to 2.8 mg/L, being highest in the Bay mouth and decreasing offshore and down the length of a relatively well-defined plume emanating from the Bay mouth (Figure IX).

Dissolved organic carbon and DON represent the largest pools of organic carbon and organic nitrogen in most marine environments. DOC and DON are major constituents of sewage effluents entering the New York Bight via the Hudson-Raritan estuary (17). Yet, with the exception of the limited studies cited above, extremely little is known about the distribution, sources, biological and chemical fates, and chemical composition of the DOC/DON pool in shelf waters within the NEMP region. An extensive series of seawater samples was collected during 24 shelf-wide surveys and frozen-archived for future analyses of DON. These samples will be extremely useful in constructing budgets for nitrogen and useful in mapping organically bound nitrogen in coastal water adjacent to the estuaries. Additionally, ratios of ammonia/nitrate/nitrite/DON will provide a "fingerprint" on water masses (estuarine, slope water) and provide insight into the relative roles played by nutrient sources from estuaries, slope water, and _in situ_ nitrogen recycling in supplying nitrogen to primary producers.

Microbial Indicators of Water Quality

The presence of microbial pathogens is usually indicated by and related to fecal and total coliform indices since most human pathogens are introduced into the aquatic environment by fecal contamination. However, there are indications, supported by studies, that the coliform indices may not relate to the presence of all human pathogens. In addition, it should be recognized that bacterial pathogens can also be native to the aquatic environment. This is probably the case with fish pathogens.

During the seasonal Biological Effects Monitoring cruises, water samples were analyzed for the presence of two groups of organisms, _Clostridium perfringens_ and the _Vibrio_ group. The former, being present in feces, can be an indicator of fecal pollution; the latter group includes both human and fish pathogens. _C. perfringens_ was detected in water samples during monitoring surveys. The highest counts were found in inshore water, and it was not detected in water samples from offshore stations. A count of 2,700 colonies per 100 ml was observed in bottom water collected at the New York Bight sewage dumpsite. A station at the mouth of Chesapeake Bay contained 150 colonies per 100 ml of water. Counts of _C. perfringens_ were usually higher in bottom waters, whereas _Vibrio_ counts were usually greatest in the upper water column.

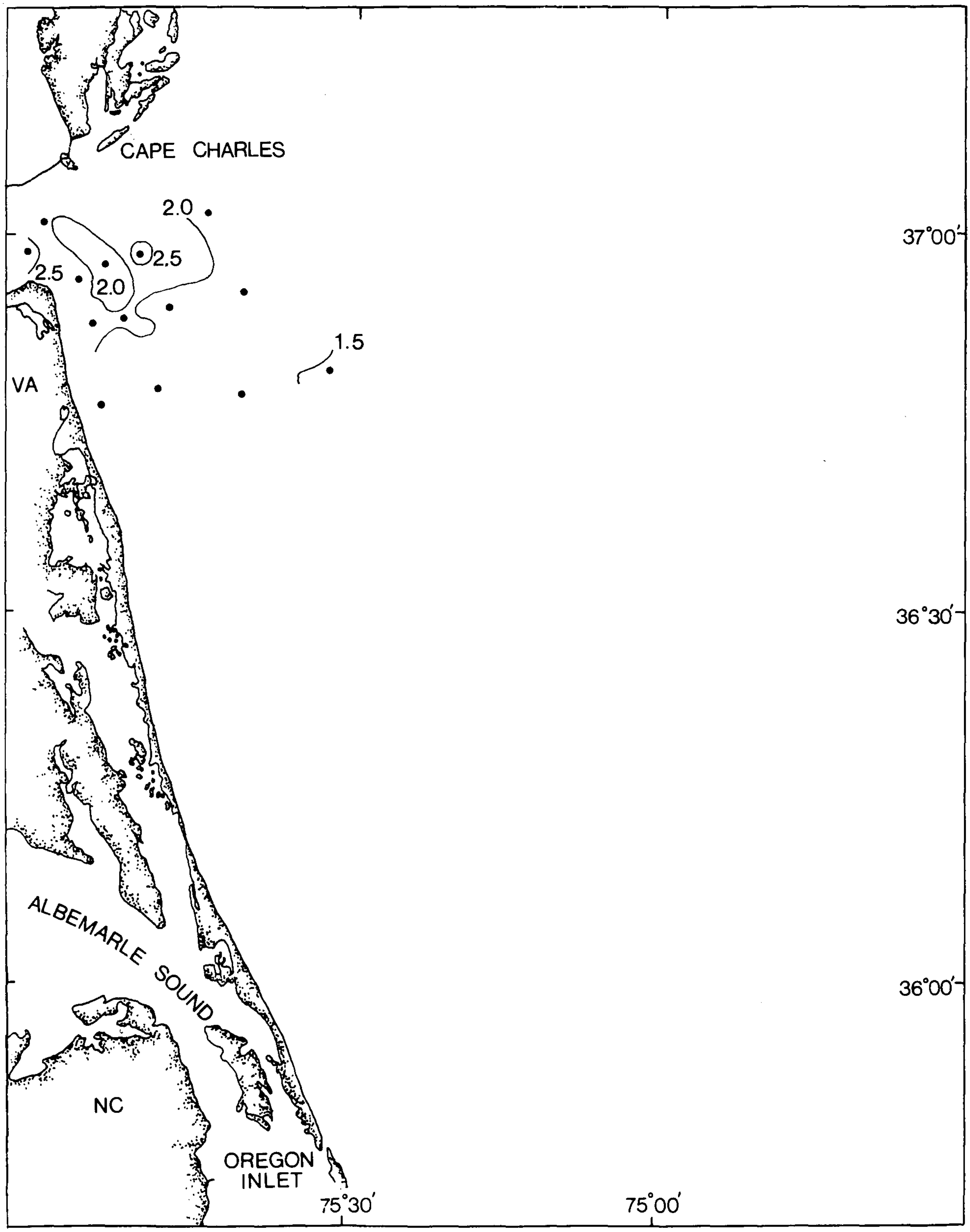

Figure IX. Dissolved organic carbon, mg C/l, 1 meter depth, SUPERFLUX III, October 1980.

In offshore waters, the counts on Vibrio medium varied from greater than 100 colonies per 100 ml of water to 1 per 100 ml of water. Although high Vibrio counts were obtained from the sewage dumpsite, relatively high counts were observed in other areas not considered to be contaminated with sewage. Vibrio sp. in waters include the pathogens V. parahaemolyticus and V. cholorae (NAG).

106-Mile Dumpsite: Water quality monitoring efforts in 1980 at this deep-water site consisted of: defining waste plumes, field studies on the organic chemicals in wastes, studies with drogued buoys to describe long term waste trajectories, and analysis of satellite and ship-of-opportunity data to define changes in water masses and circulation.

Trajectories, determined by tracking shallow drogued buoys deployed at the site, were highly variable ranging from northeastward to northwestward and southwestward, depending upon wind conditions, location of Gulf Stream meanders and eddies, as well as mean southward drift (18). The longest experiment, utilizing satellite-tracked buoys, showed southwestward displacement for the first 33 days at an average speed of 0.3 knot.

Field studies of volatile organic compounds in DuPont-Grasseli and American Cyanamid waste dumps showed that there was not a persistent organic residue in the waters of the dumpsite before test dumps were made (19). Also, volatile organic materials in the test dumps were rapidly diluted and/or volatilized into the atmosphere. These volatile organic substances, therefore, are not a useful "finger print" of the dumped wastes and do not constitute a long-term contaminant for the biota of the upper water column.

By monitoring weekly positions of fronts and eddy locations, produced from satellite infra-red imagery, the dumpsite was found to be partly covered by shelf water about 32 percent of the time during October 1979 through September 1980. Surface slope water was present 51 percent and Gulf Stream Eddy water 42 percent of the time. During 16 weeks of the period two of the water masses were present, and during 1 week all three were present. Longer periods of shelf water presence in the dumpsite were associated with major seaward excursions of the surface shelf-slope front of up to 140 Km from the edge of the continental shelf. During these intervals most of the wastes dumped at the site were discharged into surface shelf water. From the standpoint of water quality this is the least desirable recipient among the three water masses.

If wastes are dumped in surface shelf water near the location of the shelf edge, the chances of the contaminants being carried onto the shelf is greater; hence, the risk of contaminating major fisheries is increased. Surveillance of satellite infrared imagery depicting locations of fronts and eddy positions could be used to guide the dumpers to the quadrant which is best suited to receive wastes.

Heavy Metals - Superflux

As part of the Superflux study of the Chesapeake Bay plume waters, the heavy metals iron, copper, lead, zinc, and manganese associated with total suspended matter were examined during June, 1980 (20). These samples were obtained by filtering a volume of seawater and analyzing the filter for heavy metals. The data were presented both as heavy metals associated with particulate matter per volume of seawater and as heavy metals per gram dry weight of total suspended matter. The former presentation generally shows that the highest concentrations for all heavy metals examined were near shore and toward the bottom. This suggests a chronic source from the plume even though the overriding plume waters generally have lower concentrations. The high values observed in bottom waters may be the result of long term accumulation from overriding plume waters and resuspension. For several of the heavy metals, notably copper and lead, there appears to be an offshore or longshore source as well. In general, higher concentrations of trace metals can be correlated with higher concentrations of total suspended matter. Concentrations ranged from 2 to 400 ppb for iron, 0.03 to 0.52 ppb for copper, 0.039 to 0.74 ppb for lead, 0.30 to 4.3 ppb for zinc, and 0.27 to 12 ppb for manganese. These values do not represent the total heavy metal concentrations (dissolved plus particulate) in the water column but rather only that portion associated with suspended particulates. Even though these values are not directly comparable to concentrations of total (particulate plus dissolved) heavy metals we list some total values. For instance, Waldhauer, et al. (21) measured total copper and lead concentrations in Lower New York Bay. They found a range of 8 to 65 ppb for copper and 2 to 14 ppb for lead with the lowest values occurring near the mouth of the bay. Gilbert et al. (22) measured a total lead concentration of 27 ppb in the waters of Boston Harbor. Segar and Cantillo (23) in the New York Bight apex found total dissolved copper concentrations of from 1.3 to 10 ppb, total dissolved manganese concentrations of from 1.4 to 14 ppb, and total dissolved iron concentrations of from 2.2 to 92 ppb during June 1974. They also measured total dissolved zinc concentrations of from 6.2 to 150 ppb during August 1974. Spencer and Brewer (24) found total copper concentrations ranging from 2 to 4 ppb in the Gulf of Maine. Riley and Taylor (25) measured 1 ppb of total copper in the northeast Atlantic Ocean. Based on these values, heavy metals concentrations in the Cheasapeake plume appear to be lower or comparable to concentrations from other areas. However, the real probability of a large unmeasured dissolved component could greatly increase the total metal contribution in the Chesapeake plume.

We can also discuss these data in terms of heavy metal concentrations per gram of dry weight of sediment. This data is more variable and more difficult to summarize because of the variability in the measurements of both the total suspended matter and the heavy metals. Most notable are the high concentrations of iron, zinc, and manganese in the middle of the water column near the seaward boundary of the plume. Concentrations of copper and lead are highest offshore at depth.

Concentrations of heavy metals per gram dry weight of suspended sediments collected in and around the plume area ranged from near zero to 80,000 ppm for iron, 100 to 1,300 ppm for copper, 20 to 1,300 ppm for lead, 47 to 12,000 ppm for zinc, and 71 to 6,500 ppm for manganese. These suspended particulates in the Chesapeake Bay plume in general have higher concentrations of lead, copper, and zinc than the most contaminated sediments in the waste disposal areas of the New York Bight Apex.

Hydrocarbons

Hydrocarbons associated with total suspended matter were determined during Superflux II (July 17-27, 1980) for the Chesapeake Bay plume and adjacent shelf waters from Cape Henry to the Virginia-North Carolina state line. Samples were obtained by the filtration of approximately 16 l of sea water.

Samples were analyzed for particulate hydrocarbon concentration (ug/l) and total suspended solids (mg/l). Particulate hydrocarbon concentrations ranged from 32 ug/l to below the detection limit (<0.7 ug/l) with an average value of 5.0 ug/l. In general, the highest concentrations of hydrocarbons and suspended matter were found in the Bay entrance with decreasing values offshore. All samples analyzed in the Bay mouth contained hydrocarbons, whereas a number of samples from adjacent shelf water were below detectable limits for hydrocarbons.

On a weight basis (ug hydrocarbon/mg suspended solid), hydrocarbon concentrations ranged from 13.8 ug/mg to the detection limit (0.3 ug/mg), with a mean of 2.2 ug/mg (Figure X). The highest concentrations were in the Bay entrance (average 5.4 ug/mg). These concentrations are similar to those found in sediments from highly polluted areas. For comparison C_{15+} hydrocarbons in the bottom sediments of the New York Harbor and dredge spoil disposal area in the New York Bight apex ranged from 0.006 ug/mg to 6.5 ug/mg (26).

Fractionation studies of water samples from Chesapeake Bay showed at least 90 percent of the hydrocarbons were associated with suspended materials. The hydrocarbon distribution in the Chesapeake Bay plume samples indicated the hydrocarbons were of an anthropogenic origin and have been weathered quite extensively (loss of most resolved peaks), meaning they have been in the marine system for more than a few weeks. The general trend of higher concentrations at the Bay entrance and lower concentrations further from the entrance suggests that the Bay is either a source or sink for particulate hydrocarbons, probably the former. Based on comparative measurements from 1973 (Wade, pers. comm.), the Bay is believed to be a chronic source of hydrocarbon contamination to the adjacent continental shelf.

Summary - Water Quality

In summary, existing or potential impacts on water quality have been identified in the following areas:

(1) New York Bight Apex and offshore New Jersey. In summer 1976, levels of dissolved oxygen in bottom waters fell to very low levels in a large area of New Jersey, eventually leading to anoxic conditions that were lethal for most benthic and epibenthic organisms. Since then, NOAA elements have monitored oxygen concentrations and suspected contributing factors in this area to predict or detect the onset of another hypoxic event. During 1980, most contributing factors monitored indicated that a hypoxic event was unlikely, and indeed none occurred.

(2) Estuarine Plumes. Effluent plumes from the Hudson-Raritan Estuary, Delaware Bay, and Chesapeake Bay carry high concentrations of inorganic and organic nutrients, particulates, organic carbon, and pollutants into the adjacent coastal waters. The nutrients involved stimulate increased phytoplankton

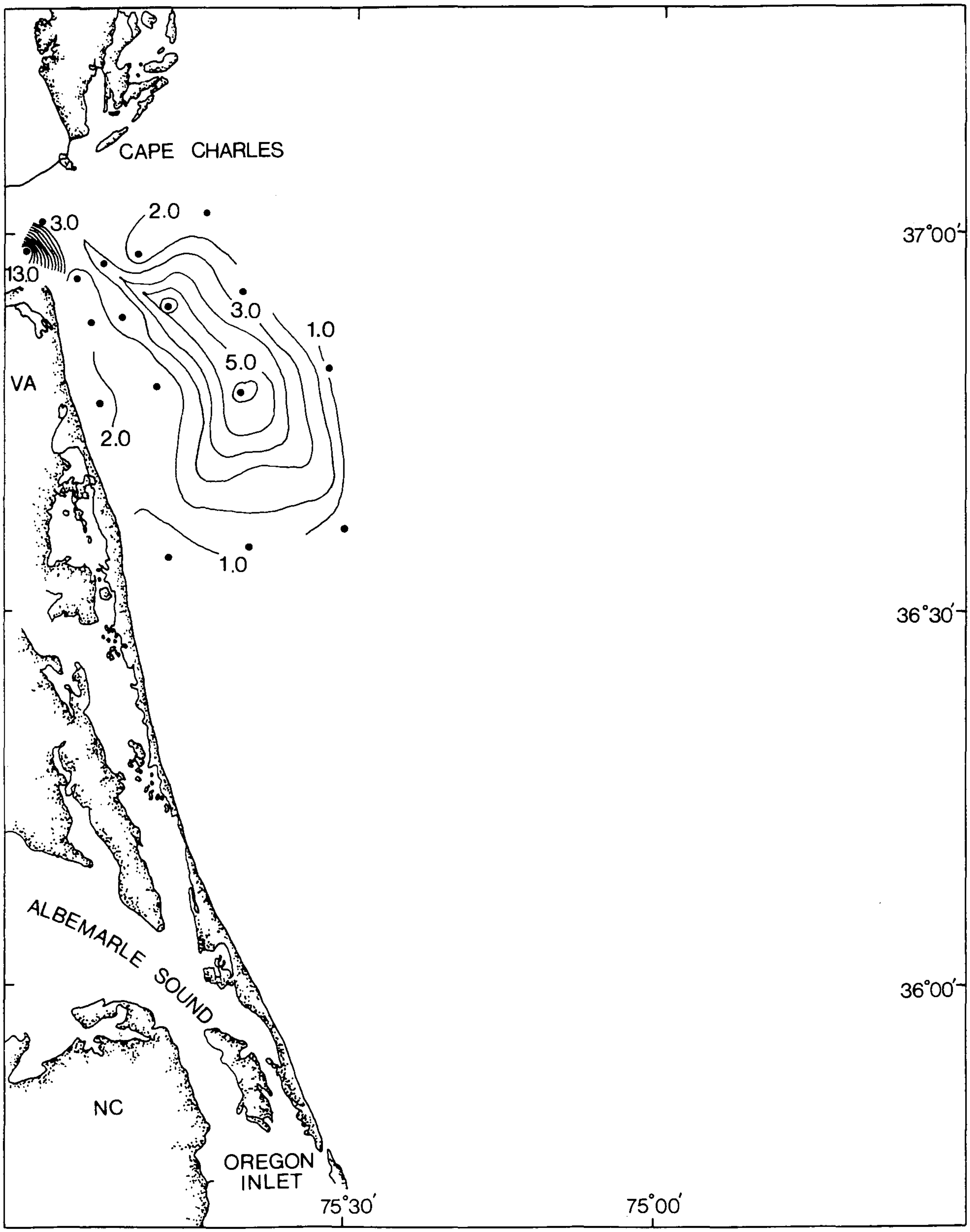

Figure X. Particulate hydrocarbons, µg HC/mg dry wt. sus. sed., 1 meter depth, SUPERFLUX II, June 1980.

production "downstream" in the plumes. Although there is the potential for eutrophication and unusual oxygen demand in and downstream from the plumes, no anoxia was detected in 1980, although local maxima in nutrient concentrations, phytoplankton standing stock, and heavy metal concentrations (Chesapeake) were detected.

(3) 106-Mile Dumpsite. The potential for contamination of foodfish by chemical wastes at this dumpsite has been realized and a procedure for reducing the potential by directing the dumping away from shelf water, occasionally present at the site, has been proposed.

(4) Inshore and Sewage Dumpsite Waters. Microbial indicators of fecal pollution, in the *Clostridium* and *Vibrio* groups, were found in some inshore waters and in the vicinity of the New York Bight sewage dumpsite. These organisms are potentially pathogenic to humans and fish, and accordingly their distribution and abundance should be monitored on a continuing basis.

SEDIMENT QUALITY

An assessment of sediment quality, as indicated by the accumulation of contaminants in sediments, and subsequent monitoring are significant elements of the NEMP. Sediments serve as a potential end-point (sink) in the pollutant transport system. By observing sediment characteristics over a period of time (5 to 10 years) an indication can be gained of the overall quality of a particular sediment and hence the associated habitat or area.

The NEMP currently monitors a standard suite of measurements for sediment quality. These include trace metals (cadmium, chromium, copper, nickel, mercury, lead, and zinc), total organic carbon (TOC), total organic nitrogen (TON), grain size, coprostanol, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAH), seabed respiration, and bacterial and viral indicators. Available data for each of these variables are summarized below.

Trace Metals: Evidence of sediment contamination, based upon trace metal levels, generally indicates higher than ambient values in three areas: the New York Bight apex, the mud patch southwest of Nantucket Island, and a site east of Cape Cod. Based upon the data collected during 1980,levels of cadmium were approximately 4 ppm in the New York Bight apex versus less than .3 ppm throughout the remainder of the NEMP area. Chromium levels were nearly 130 ppm in the apex versus 10 ppm or less elsewhere, except in the mud patch where levels of 20 ppm were found. Copper was high in the inner New York Bight (121 ppm) with significantly lower levels at other stations (Figure XI).

The highest levels for nickel were found off the Portland, (Maine) harbor entrance with the next highest levels in the New York Bight apex. High concentrations were also found at the dredge disposal site in the New York Bight apex, in Portland Harbor, Jeffries Ledge, Massachusetts Bay, Buzzards Bay, and a station south of Nantucket Island. Zinc levels were found to be exceedingly high, above 200 ppm, in the New York Bight apex relative to the remainder of the study area. Elevated zinc levels, but less than that measured in the apex, were found at Portland Harbor, Buzzards Bay, south of Nantucket Island, and at one station near the mouth of Delaware Bay.

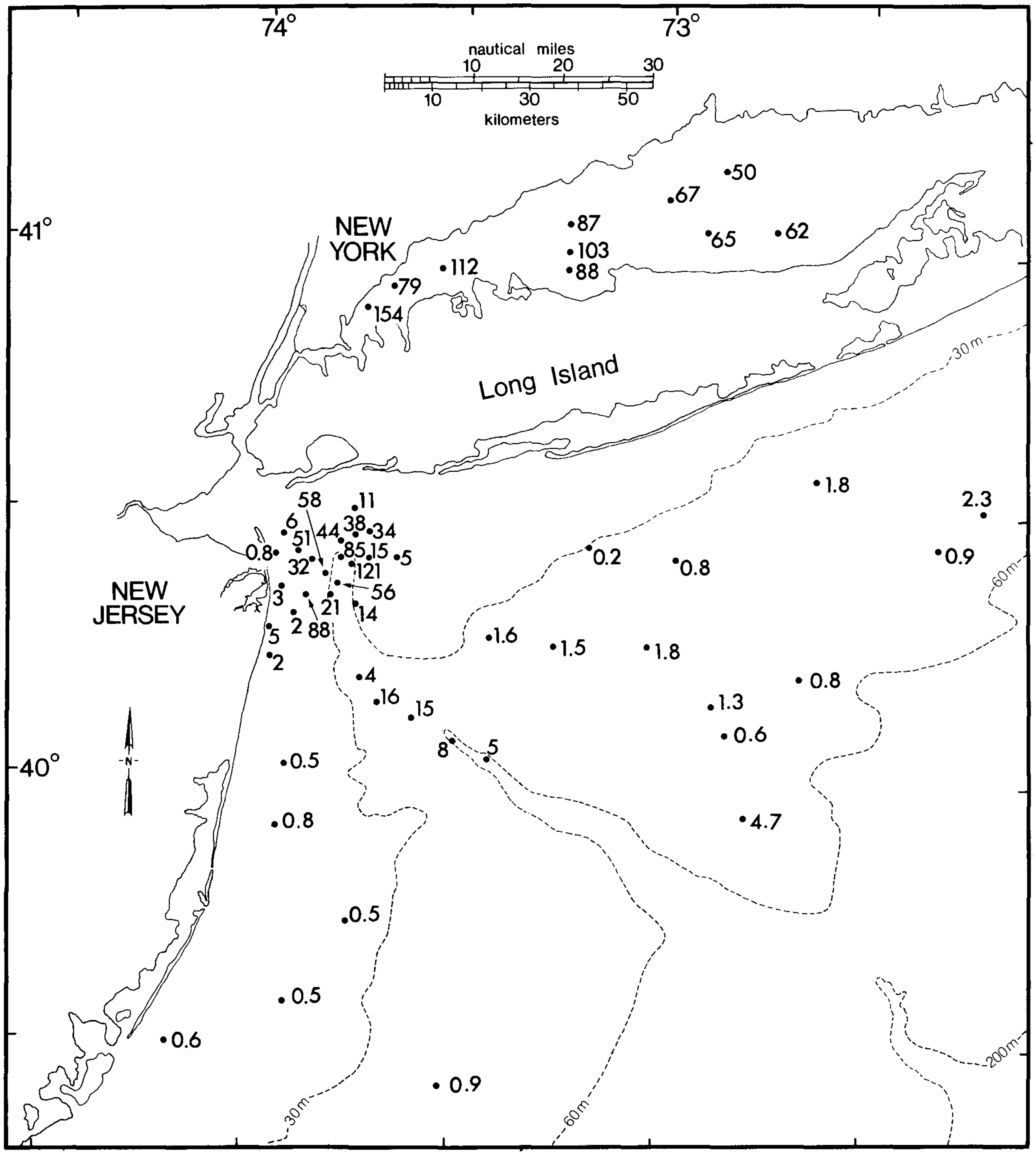

Figure XI. Copper distribution in sediments of the New York Bight (ppm, dry wt.).

Data from stations down the Hudson Shelf Valley (HSV) indicate a gradient in trace metal levels from the Bight apex to the Hudson canyon, at the edge of the shelf. Data from selected sites in the New York Bight apex collected during shelf-wide surveys as well as data collected during an intensive summer 1980 survey of seabed contaminants in the New York Bight are compared with an earlier 1973 through 1974 apex study in Table IV. Trace metal concentrations in these data sets are comparable to previous studies (1). In the recent 1979/1980 data and the data from prior work, metals in sediments decrease from the apex dump site areas in Christiaensen Basin to the Hudson Shelf Valley to the Hudson Canyon. Metal levels in sediments near the Hudson Canyon are relatively higher than levels in adjacent areas. It appears from the 1980 monitoring data set that the distributional pattern of sediment metals in the New York Bight apex has not changed significantly over the past 5 years. Sediments on Georges Bank contain relatively low concentrations of all six metals analyzed. In general, "medium" concentrations of all metals have been observed in the fine sediments of the Gulf of Maine (2), and are probably accumulated from decay of New England bedrock which contains traces of metals.

Sediment samples were taken near a proposed oil drilling site on Georges Bank and at stations in Lydonia and Oceanographer Canyons (3). The samples were analyzed for seven trace metals (barium, cadmium, copper, chromium, mercury, lead, and zinc); the resultant values ranged from insignificant levels (in the case of mercury) to nearly 60 ppm for barium. Generally, these levels do not seem to be elevated compared to other values found in the region.

Total Organic Carbon: Total organic carbon (TOC) in New York Bight sediments was highest in the Christiaensen Basin, which includes the sewage and dredge spoil dumpsites (Figure XII), and along the Hudson Shelf Valley. TOC values there were generally 1 to 2 percent (dry weight), approximately an order of magnitude higher than values in sediments adjacent to the Christiaensen Basin. This summer 1980 pattern is similar to that found in 1971 (4), although methodological differences preclude exact comparisons.

Total organic carbon levels were relatively high in other areas that are not normally considered "polluted", for example Block Island Sound, the Gulf of Maine, and the mud patch south of Nantucket. However, carbon/nitrogen ratios suggest that the high TOC in these areas is mostly of marine origin, while most of the TOC in the New York sewage sludge area has a terrestrial source (5).

Total Nitrogen: The total Kjeldahl nitrogen (TKN) picture is similar to TOC distribution in that the nitrogen in the sediment of the New York Bight is higher at the sewage sludge dumpsite and down the Hudson Shelf Valley than in adjacent areas. Again, there are other areas with high sediment nitrogen that are not usually regarded as being polluted. These include Block Island Sound, Narragansett Bay mouth, Massachusetts Bay, and locations in the Gulf of Maine (6).

Seabed Oxygen Consumption and Ammonium Flux: Seabed oxygen consumption measurements are a measure of the rate of oxygen consumption by bottom dwelling micro-, meio-, and to a lesser extent, macrofauna as well as chemical oxidation in bottom sediments (7).

TABLE IV

COMPARISON OF TRACE METALS (PPM) IN SEDIMENTS OF THE NEW YORK BIGHT APEX, 1973-1974-1980

1973

SYMAP STA. #	Cr	Cu	Ni	Pb	Zn
23 (1[1],1[2])	77.3	69.3	14.2	90.0	150.0
24 (1,1)	43.0	35.8	8.2	46.0	80.0
25 (1,1)	53.0	45.0	9.0	56.0	95.0
36 (1,1)	12.4	18.4	8.0	24.0	56.0
34 (1,1)	76.7	76.7	15.8	80.0	146.0
33 (1,1)	24.2	41.0	5.6	52.0	76.0
32 (1,1)	13.6	19.2	2.6	32.0	32.2
43 (1,1)	24.2	28.0	10.0	28.0	62.0
45 (1,1)	65.0	58.0	18.4	80.0	147.0
57 (1,1)	4.6	2.2	3.4	90.0	28.2
55 (1,1)	20.8	13.4	9.6	4.0	55.0
37 (1,1)	74.0	81.0	17.0	92.0	164.0
62 (1,1)	11.2	1.6	5.0	18.0	28.8
19 (1,1)	9.4	4.8	3.2	22.0	25.6
11 (1,1)	20.8	3.8	6.4	30.0	61.0
30 (1,1)	11.4	5.8	2.0	~20.0	25.6
35 (1,1)	67.3	76.7	16.8	82.0	142.0
39 (1,1)	2.2	1.6	2.0	4.0	8.6
40 (1,1)	12.8	1.6	4.0	16.0	60.0
59 (1,1)	14.0	2.8	3.8	8.0	47.0

1974

SYMAP STA. #	Cr	Cu	Ni	Pb	Zn
23(1,1)	19.3	25.4	6.6	24.0	48.4
24(1,1)	45.0	53.5	13.2	60.0	116.0
25(1,1)	16.5	20.2	5.2	22.0	45.3
36(1,1)	3.4	6.4	4.4	13.0	20.9
34(1,1)	95.0	108.0	21.0	111.0	198.0
33(1,1)	373.0	548.0	56.3	53.0	845.0
32(1,1)	17.1	31.0	-4.0	29.0	47.7
43(1,1)	9.1	4.6	-4.0	25.0	29.0
45(1,1)	30.2	37.0	33.9	45.0	85.3
57(1,1)	4.7	-4.0	-4.0	-8.0	20.8
55(1,1)	9.6	9.8	7.3	15.0	29.1
37(1,1)	44.6	63.2	11.3	63.0	110.0
62(1,1)	8.3	-4.0	5.9	19.0	30.3
19(1,1)	7.7	4.8	4.6	17.0	32.8
11(1,1)	11.3	6.5	5.9	20.0	53.8
30(1,1)	35.7	31.5	8.8	45.0	73.4
35(1,1)	14.6	16.5	4.7	19.0	33.3
39(1,1)	-4.0	-4.0	-4.0	-8.0	5.9
40(1,1)	6.7	-4.0	4.2	17.0	41.8
59(1,1)	7.1	-4.0	-4.0	10.0	23.1

1980

KELEZ STA. #	Cr	Cu	Ni	Pb	Zn
1(3[1],3[2])	46.67	43.67	9.88	66.7	91.17
2(3,3)	42.00	38.17	8.87	60.0	86.33
3(3,3)	39.22	34.40	7.86	52.4	78.78
4(8,7)	22.64	31.78	8.44	45.1	63.14
5(3,3)	75.06	85.06	15.81	104.8	156.5
6(7,7)	65.26	120.80	12.52	134.9	228.90
7(7,7)	11.93	14.96	2.70	30.2	33.99
8(3,3)	65.63	88.41	19.29	90.2	147.80
9(3,3)	54.56	55.84	14.71	80.3	113.80
10(3,3)	23.97	20.70	6.80	29.6	47.72
11(3,3)	18.08	14.22	5.97	26.2	37.00
18(3,3)	34.08	50.61	10.38	53.1	71.96
19(3,3)	27.10	5.24	4.56	24.7	41.34
20(3,3)	7.21	5.75	5.20	19.5	27.74
21(3,3)	23.67	10.95	6.33	33.2	59.67
22(3,3)	8.34	4.46	1.93	15.6	22.66
40(7,7)	47.72	57.93	17.57	88.6	125.08
41(7,7)	2.35	0.78	0.58	4.2	6.60
42(7,7)	14.54	2.83	3.61	21.1	45.84
43(7,7)	6.58	1.84	1.22	7.4	13.75

NOTE: 1980 KELEZ stations coincide with 1973-1974 SYMAP Stations

1 Grabs per station

2 Total cores

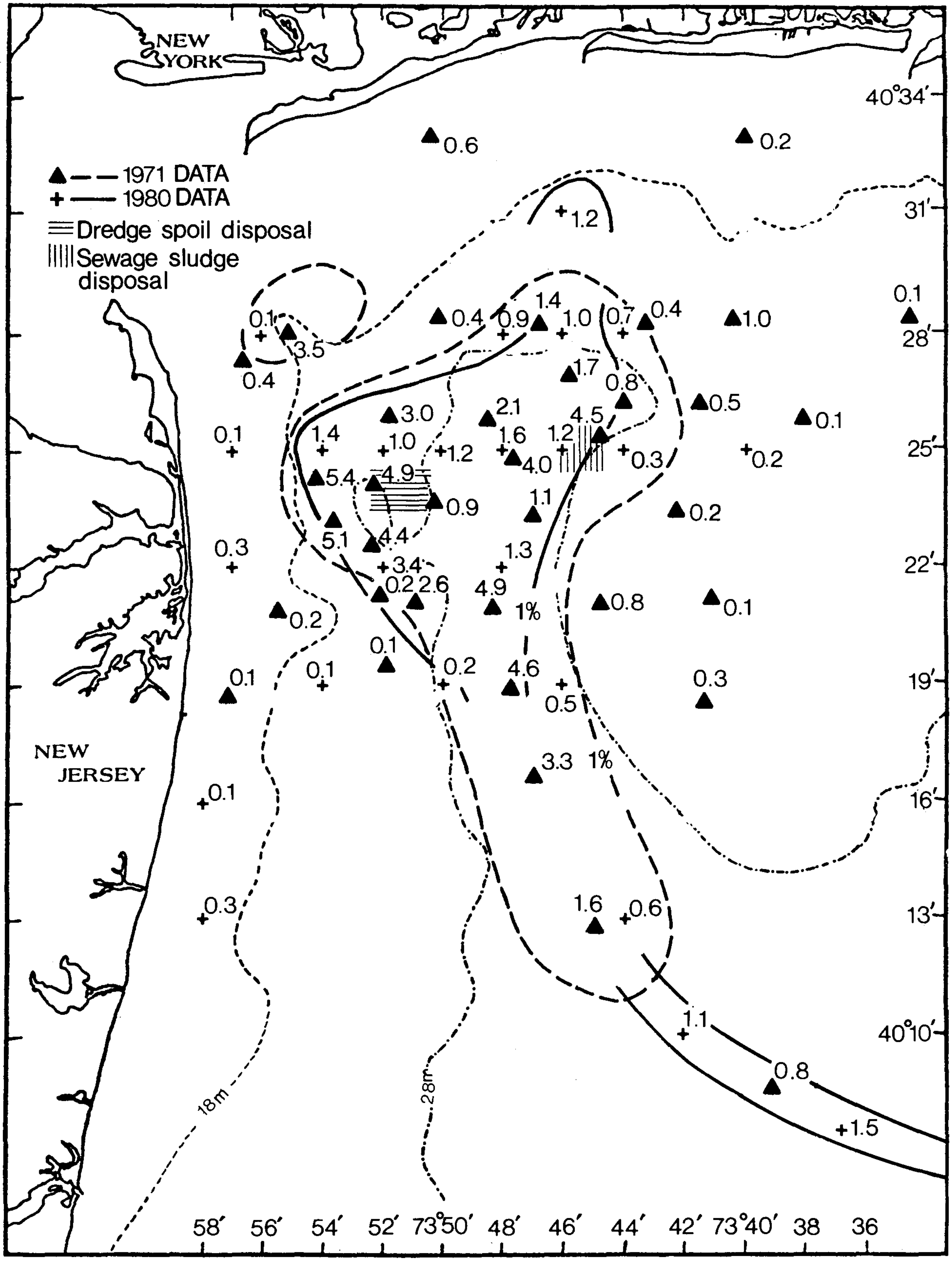

Figure XII. Concentrations of total organic carbon (wt. %) in New York Bight sediments, based on surveys made in 1971 and 1980. Data from each survey are contoured at 1% level. Values and contour for 1971 are from Gross (1976); these values are systematically higher due at least in part to differing analytical methods.

The measurements indicate organic loading to the seabed and may be used to identify areas of organic loading. Such organic loading and concomitant oxygen consumption influences dissolved oxygen concentrations in bottom waters. Such measurements have been made on approximately a quarterly basis for up to 6 years at stations in the New York Bight (Figure XIII). The dredged material and sewage sludge dumpsites show very high oxygen consumption values, up to 40 or more ml $O_2m^{-2}h^{-1}$. Respiration at other sites in the Bight as well as at other stations throughout the NEMP region, are generally less than half that rate. There were no sampling sites that show uniformly low respiration, except perhaps one location in the northeast region of Georges Bank, a coarse sand, gravelly environment.

Temporal variation in seabed respiration existed at all the NEMP sampling sites. There was no clear seasonal trend, nor was there evidence of a year-to-year increase or decline in respiration at a given site. However, at the New York Bight dumpsites, there appeared to be a large year-to-year variation in the data. Peaks in oxygen consumption occurred in 1974, 1977, and the last quarter of 1980; minima occurred in 1975 through 76 and during the period from 1979 to the first quarter of 1980. These cyclic trends are not evident at other stations outside the Bight, although in most instances there is not yet sufficient data to determine long-term trends.

By combining stations with similar oxygen consumption rates within a geographical area, and by using proximity to estuaries, water depth, and sediment type to discriminate further between areas, a map of zones (strata) was produced (Figure XIV). The respiration rates of all samples within a zone for the last three NEMP cruises were averaged for each zone (Figure XV). Here the overall geographic trend is obvious: there is a general elevation in seabed respiration rates between Delaware Bay and Cape Cod, culminating in peak rates at the New York dumpsites and Block Island Sound, zones that receive large inputs of organic carbon (albeit the latter zone may receive its organic input from more natural sources).

Ammonium-nitrogen flux from the seabed was measured at stations throughout the NEMP area in September 1980 (7). Again, the New York Bight dumpsites show values one to three orders of magnitude higher than elsewhere. The one surprising exception is in the mouth of the Delaware Bay, where values of 300 to 400 u mole $NH_3m^{-2}h^{-1}$ are comparable to the New York dumpsite values; variables such as respiration, TOC, TKN, or grain size characteristics would not have suggested this anomaly. Although not nearly as high as the dumpsite values, ammonium fluxes at several inshore stations south of Cape Cod (Buzzards Bay, Narragansett Bay mouth, and Block Island Sound) are in the range of 40 to 70 u mole $NH_3m^{-2}h^{-1}$, still an order of magnitude higher than other NEMP stations. The relevance of these data to water column flux is discussed in the previous section of this report on water quality.

Bacteriology: Certain fecal bacteria can be used to indicate fecal contamination of the sediment environment and thus the possibility of pathogen contamination. Fecal coliforms, confirmed as *Escherichia coli*, were detected at 9 of 44 stations in the New York Bight and Long Island Sound during the summer 1980 NEMP cruise (8) (Figure XVI). However, significant concentrations were only found at the New York dumpsites. On the other hand, *Clostridium*

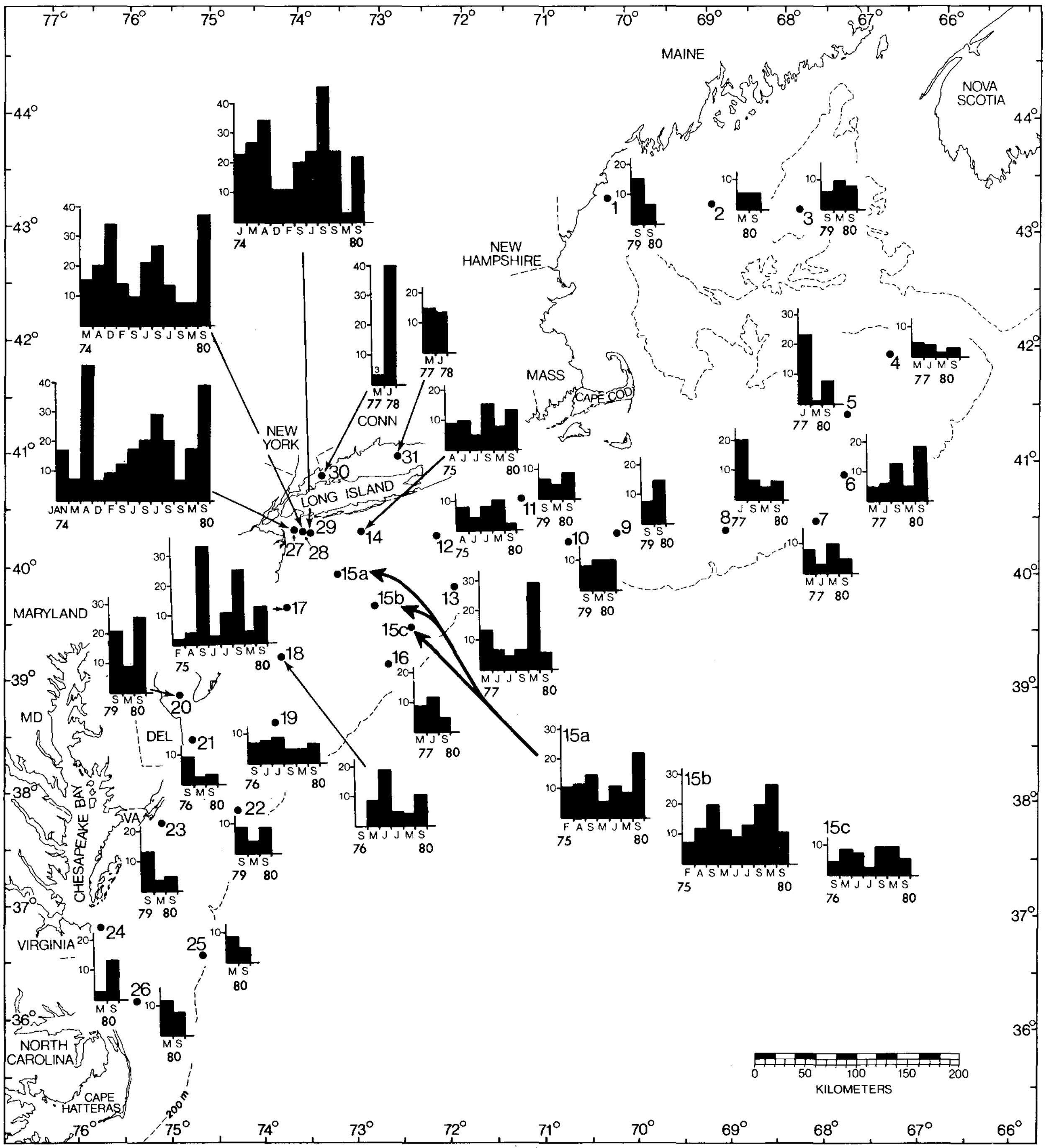

Figure XIII. Selected NEMP stations with seabed oxygen consumption values by cruise, in ml O_2 m^{-2} hr^{-1}.

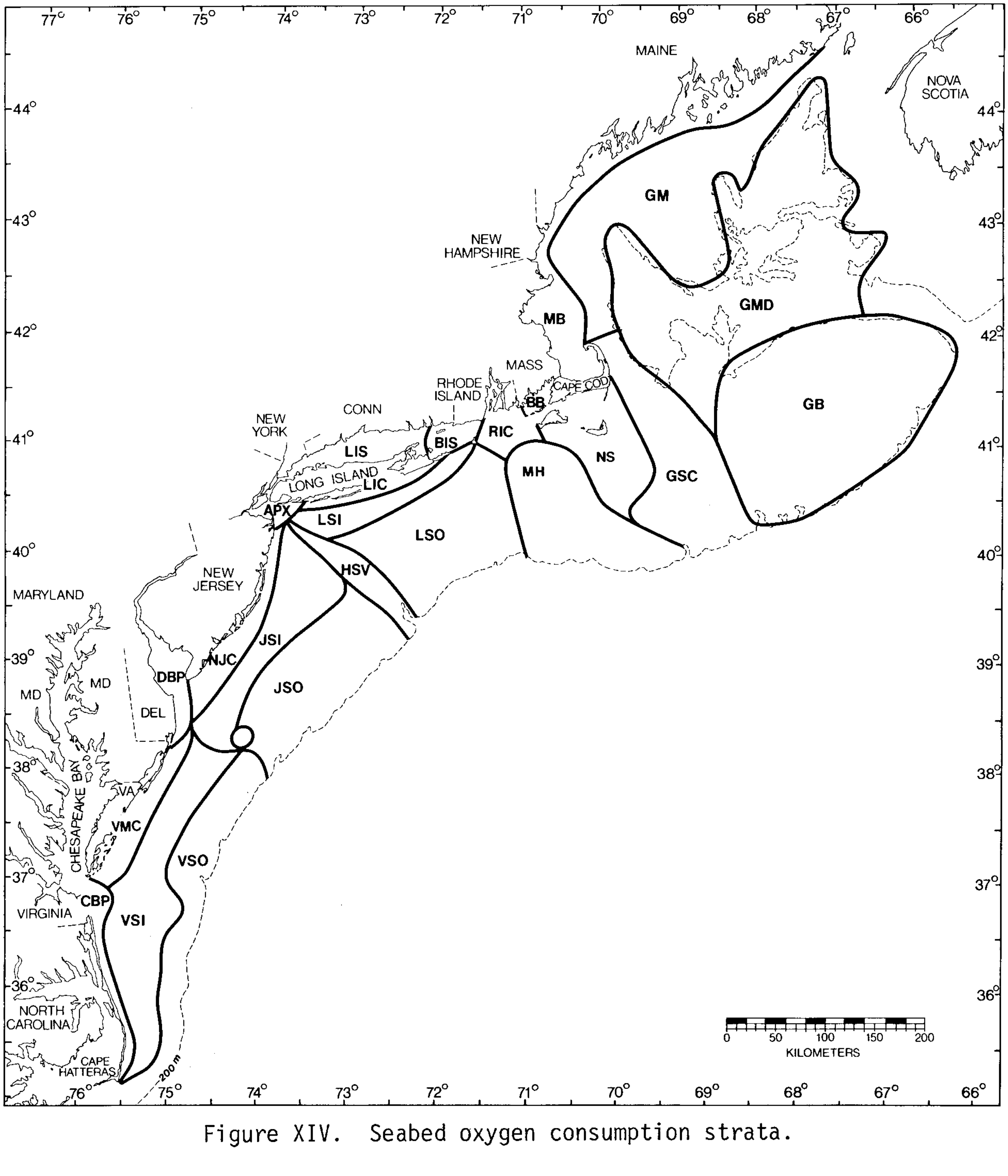

Figure XIV. Seabed oxygen consumption strata.

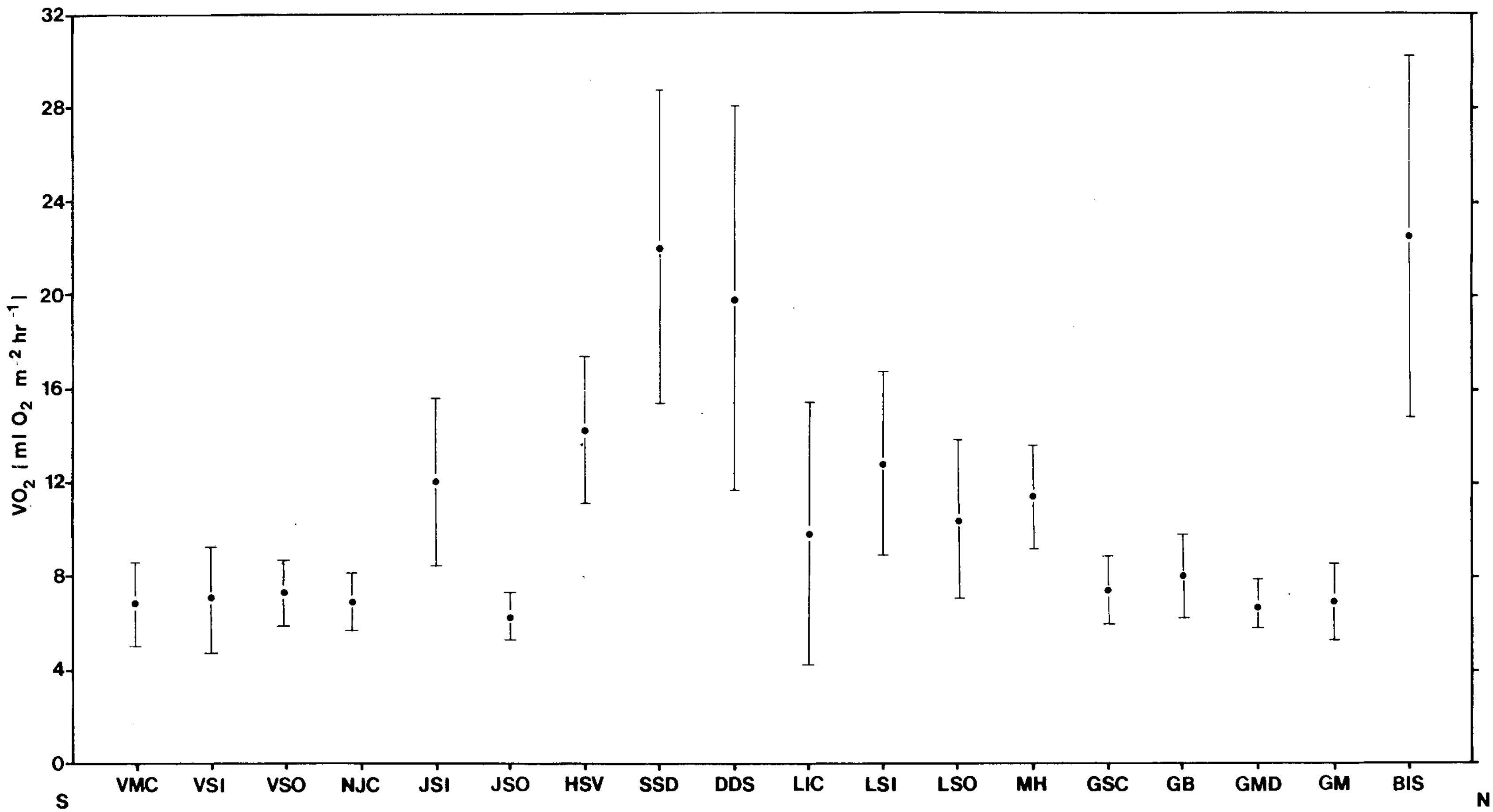

Figure XV. Core Means by Strata S→N for cruises, Al-79-10 Sept., DE-80-04 Mar./Apr., AL-80-09 Sept., with 95% confidence limits.

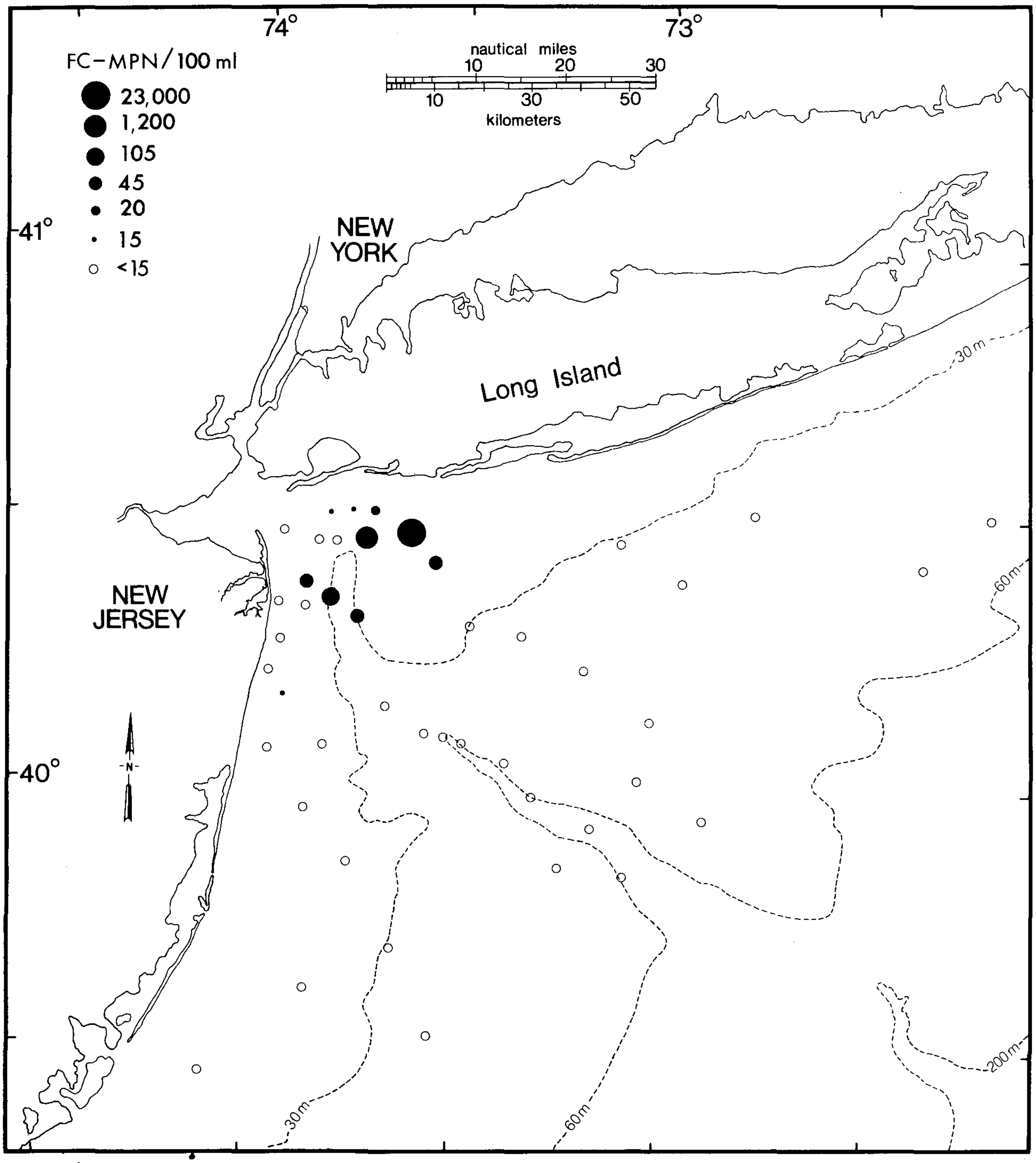

Figure XVI. Fecal coliforms in top layer of sediments, New York Bight. Values are x 10^{-3}.

perfringens, a human pathogen, was detected in sediments with a more consistent frequency at concentrations up to 10^5 to 10^6 colonies per gram of sediment, not only at the New York sewage sludge dumpsite but also at stations south and west of the dumpsite (Figure XVII). Other high counts were observed at stations off New Hampshire, presumed to be uncontaminated, and to a lesser extent off Chesapeake Bay, Delaware Bay, and Rhode Island; the values were three or four orders of magnitude lower than those found in the New York Bight. Hence, high *C. perfringens* counts serve as a good indicator of fecal contamination of sediment (8).

Polychlorinated Biphenyls (PCBs): PCBs in sediments were measured at 40 stations in the New York Bight, and ranged from not detectable to 160 ppb (8). The maximum concentrations are centered south and west of the New York Bight apex sewage sludge and dredged material dumpsites and quickly fall to undetectable levels within 20 miles seaward of those sites (Figure XVIII). PCBs of 0.2 to 35 ppm (wet weight) have also been reported in the sediments of Buzzards Bay, affected by New Bedford industrial wastes.

Coprostanol: Coprostanol (a fecal steroid) in sediments was determined for the New York Bight stations (9). This variable ranged from 11 ppm, at the sewage sludge dumpsite, to undetectable values offshore and alongshore (Figure XIX). However, the distribution of coprastanol is not the same as the distribution of PCBs in that the distribution of coprostanol extended to the south and east of the site. The distribution of the coprostanol/total steroids ratio indicates that the only region where sewage sludge contributes significantly to the sediment organic load is in the vicinity of the dumpsite itself. The coprostanol/PCB ratio indicates that sediment PCB's are derived from sewage at the sewage dumpsite and adjacent areas to the south and east, whereas PCB's are derived from dredge spoils at the dredge spoil site and adjacent areas. Although this latter ratio is not yet fully exploited, it appears that it is not so diagnostic for PCB source material. The coprostanol/steroid ratio seems to be much more useful in diagnosing coprostanol sources (10).

Polynuclear Aromatic Hydrocarbons (PAH): The concentration and distribution of PAH in sediments was patchy in the inner New York Bight, and decreased on either side of the Bight apex and along the Hudson Shelf Valley, with values ranging from 0 to 2,000 ppb. Waterborne petroleum sources and airborne combustion products are both potential origins for the PAH load found in the apex, but the contribution of each to total loading is unknown at this time.

Summary - Sediment Quality

Based upon the data available from collections during 1980 there appears to be a pattern of levels of heavy metals above background at several areas in the NEMP region. Four areas, the inner New York Bight apex, Portland Harbor mouth, Buzzards Bay, and the depositional mud patch south of Nantucket Island, appear to be locations of highest heavy metals accumulation. The source of heavy metals at the mouth of major estuaries and near disposal areas is obvious; however, there is no conclusive evidence to indicate the source of the elevated levels in the sediments at the area south of Nantucket. Although there are

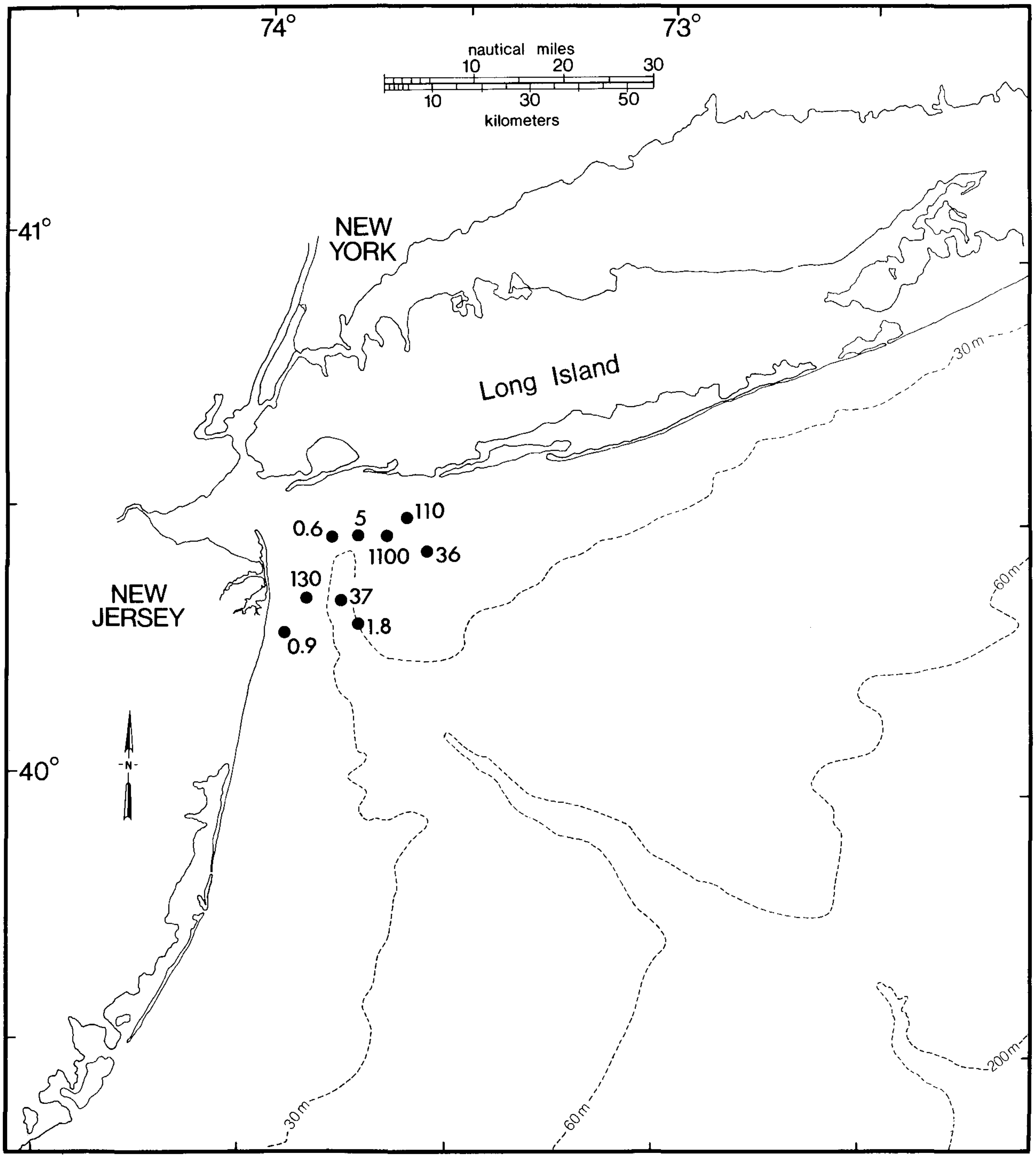

Figure XVII. Clostridium perfringens in top layer of sediments, New York Bight.

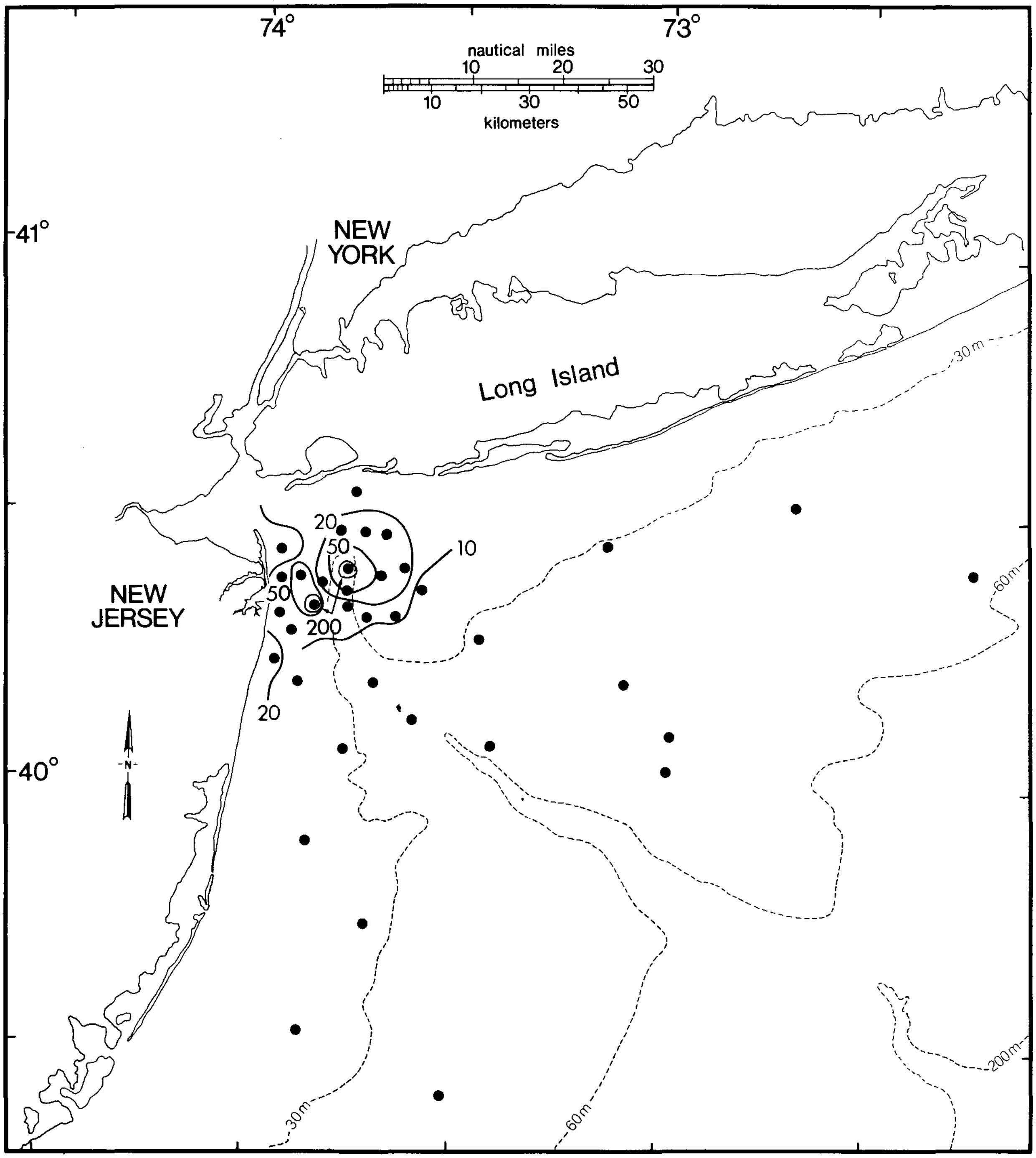

Figure XVIII. PCB concentration contours (concentrations in ppb).

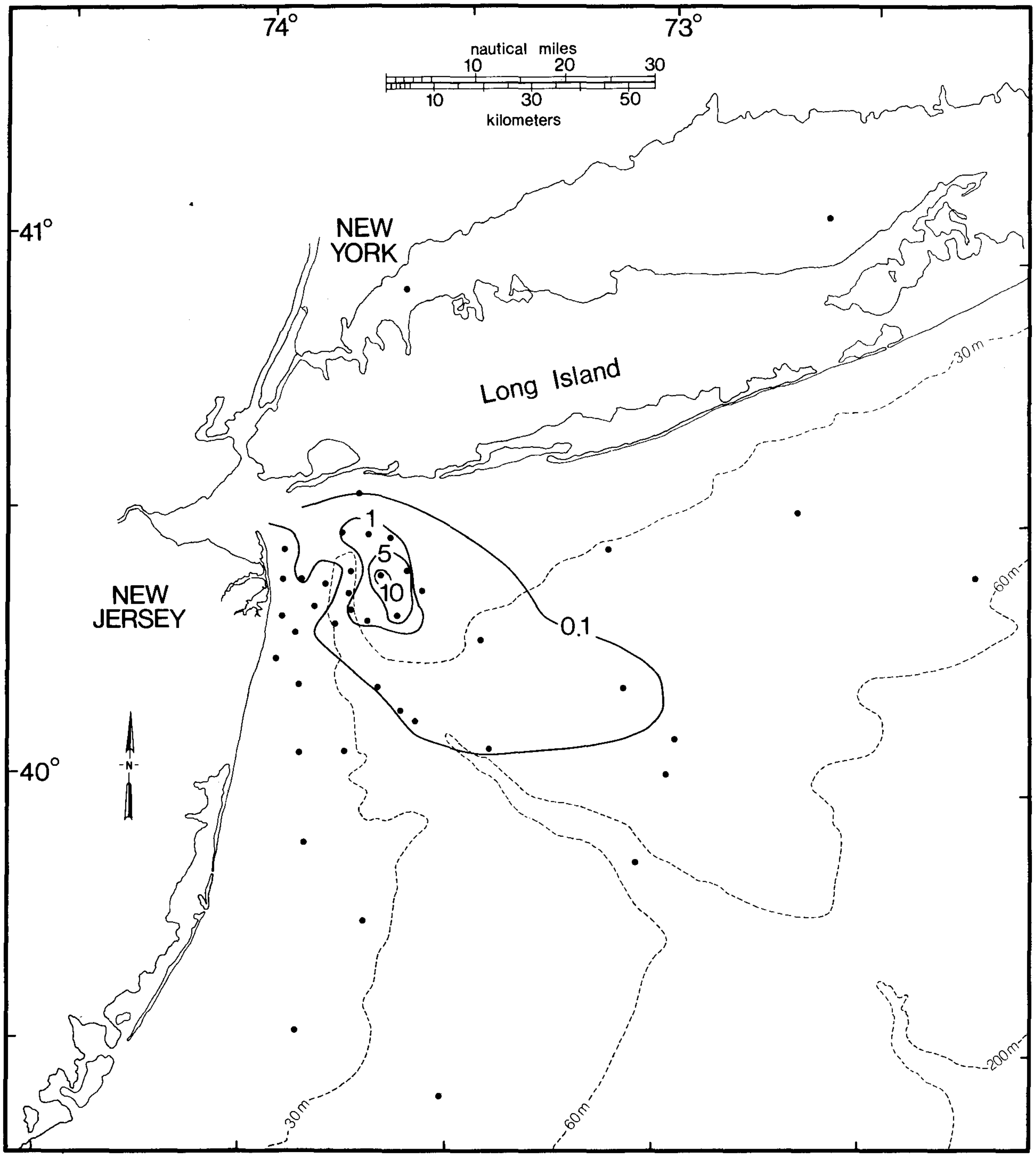

Figure XIX. Coprostanol levels in New York Bight sediments.

several hypotheses available to provide explanation, none are addressed as yet by monitoring data. This region will require further study to determine probable sources and fates.

It is evident from the examination of several variables by NEMP, that sediments in the New York Bight apex are the most contaminated in the area of interest to NEMP. A variety of heavy metal pollutants are concentrated by an order of magnitude, or more, in apex sediments relative to their general level elsewhere in the northeast. Total organic carbon and nitrogen levels also are well above background in the sediments of the apex, especially in the vicinity of the sewage sludge and dredge spoil dumpsites. Seabed oxygen consumption and nitrogen flux is noticeably elevated at these dumpsites, and bacterial indicators of fecal contamination are present in substantial numbers only at these sites. Several organic contaminants also exist in high concentration in the apex.

Relative to the New York Bight apex, other contaminated sediments are generally found in the mouths of estuaries such as Portland Harbor and Massachusetts and Naragansett Bays. In addition, a few unsuspected areas in the NEMP region have somewhat elevated levels of heavy metals and pollution indicators, but it is unknown whether sedimentary materials in these areas are of natural origin.

BIOLOGICAL EFFECTS

Introduction

Conventional monitoring programs have measured contamination in terms of chemical loadings; pollution, as presently defined, implies deleterious effects, and these are usually assessed in relation to a biological system. In monitoring, therefore, biological information is required, but there has been considerable discussion as to what aspects of biology will be informative, and at what stage in a monitoring program it may be most effectively applied. Those who manage and control resources have tended to avoid the wide use of biological variables because of the degree of variability in natural systems and the complexity of reactions by organisms to stress from physical and chemical factors. They have preferred the use of chemical analyses as a routine procedure, and biological criteria from laboratory studies and the literature have been introduced only at some stage of evaluation (1).

Reliance on chemical analyses alone for studies of biological effects has serious shortcomings. Slight and, in analytical chemical terms, insignificant changes in the concentrations of certain chemicals can markedly affect water quality from the biological standpoint. Chemicals, which by themselves would have been innocuous, may cause effects by interacting in the general milieu of contaminated waters, and chemicals whose identity is unknown or whose presence is not even suspected may produce effects. Without observations linking levels in the water or sediment with tissue concentrations, with effects on organisms and populations, and with the well-being of the ecosystem as a whole, an adequate assessment of pollution is impossible. To project or predict the assimilative capacity of receiving waters, it is essential to have an understanding of how particular loading levels will affect reproduction, recruitment, feeding and metabolism, growth, and survival of the most sensitive species important to food webs culminating in commercially important populations. Aberrant behavioral responses and genetic change due to pollutants will affect the foregoing and lead, ultimately, to changes in population and community structure. It is, therefore, imperative that lethal and sublethal effects be measured in species which are (1) representative of various trophic levels, (2) known to be especially sensitive to a variety of pollutants, or (3) known to be critical elements in marine food chains. Studies of effects conducted in a monitoring mode should be made in conjunction with measurements of ambient levels of contaminants in sediments and the water column. Thus, it will be possible to develop the long-term benchmarks for loading in the physical environment and biota and to relate these to effects measured in the field and under controlled laboratory conditions.

Recognizing the imperativeness for including biological variables in marine pollution monitoring programs, it has been necessary to consider the selection of suitable variables and the context in which their measurements may be applied. Not all biological variables will be equally appropriate for inclusion in the NEMP, and their suitability for inclusion has been assessed in terms of several criteria put forth by GESAMP (1). Some of these criteria (category A below) refer to the fundamental scientific aspects of assessing the biological impact of an environmental change. Other criteria (category B) refer to the efficiency of the biological measurements and to their practical value as indices of impact. A third group of criteria (category C) is related to management questions which may be important in selecting indices for inclusion in monitoring programs such as NEMP.

A. 1. Ecological significance: can the effect be shown, or convincingly argued, to be related to an adverse or damaging effect on the growth, reproduction, or survival of the individual or the population, and ultimately on the well-being of the community/ecosystem?

2. Relevance to other effects: can the effect be related to other effects at higher or lower levels of organization?

3. Specificity: how specific is the effect in relation to the causative agent?

4. Reversibility: to what degree can the variable return to its original level when the causative agent is removed?

5. Range of taxa: is the effect specific to particular taxa? This criterion may be relevant also to categories B and C.

B. 1. Quantitative aspects: does the effect bear a quantitative or predictable relationship to the cause (i.e., pollution)?

2. Sensitivity: what intensity of stressor is required to elicit the effect?

3. Scope: over what range of intensity of stressor is the effect observable?

4. Response rate: how quickly is there an observable effect (hours, days, years)?

5. Signal-noise ratio: can the effect (signal) be easily detected above the natural variability (noise)?

6. Precision: can the effect be measured accurately and precisely?

C. 1. Cost: how expensive is the measurement of the variable in terms of capital equipment, running costs, training costs, and manpower?

2. Application: to what extent has the effect been used in a field monitoring program and shown to be related to pollution?

Effects measurements at any one level of biological organization or function will not score high by all the above-mentioned criteria because some, such as "ecological significance" and "sensitivity"/"specificity", may be inversely related over the range of organizational levels. For example, effects at higher levels of organization (community, population) are generally more significant ecologically but relatively insensitive and non-specific, in contrast to changes in effects at lower levels of organization (cellular and molecular) which are usually more sensitive and specific but less significant ecologically. In any biological effects monitoring program there may be a requirement for highly specific or for non-specific biological effects measurements, or both. Each biological variable selected will then be either: (1) a general (non-specific) stress response to the total environmental stimulus since pollution is often due not to a specific causative agent but rather to a complex combination of factors acting in concert with natural environmental variables, or (2) a specific (selective) response to a particular class of contaminants chosen in an attempt to establish a cause-effect relationship. To meet both basic requirements (i.e., generality and specificity), it has been necessary to include biological effects at several levels of organization.

Results

The following discussion of results are derived from biological effects monitoring conducted in 1979-80. A number of results have been compared with those from previous efforts, and in other cases effects monitoring efforts were done for the first time and are being evaluated in view of the GESAMP and ICES recommendations for evaluation of biological effects monitoring techniques.

Community Structure; Benthos:

Benthic macrofauna communities are considered useful monitoring tools, since benthic species are: (1) relatively sessile, therefore, unable to avoid contaminants in the surrounding water or which accumulate in the sediments; (2) important in the food webs (especially for juvenile fish) culminating in resource species; and (3) possible sources for contaminant transfer to food species and thus to man. According to several indices, benthic macrofauna community structure in the apex of the New York Bight, especially near the dumpsites, is altered relative to other parts of the NEMP region. This agrees with the conclusions of several previous studies (2, 3, 4).

Numbers of species of benthic macrofauna per unit area of seabed (species richness) provide one index of contaminant impacts. Species richness is among the most stable community parameters under natural conditions (5, 6) and is often reduced by physical and chemical stresses (7). Relatively low species numbers (<30) in our region-wide surveys are characteristic of most shallower waters and Georges Bank stations, where stresses such as wide temperature fluctuations (at the inshore stations) and coarse, shifting sediments probably prevent establishment of populations of many benthic species (Figure XX). In areas of stable sediments, only 4 stations averaged fewer than 30 species. At one of these, on the outer shelf southwest of Nantucket (station 20), numbers of species were perhaps limited by the fine nature of the sediments, as discussed below. The remaining three stations with low species numbers are all in the New York Bight (NYB) apex; the dredge spoils dumpsite (16C) and designated sewage sludge (16A) dumpsite, and a deeper area in the Christiaensen Basin, where much of the settling sludge from the point of dumping is eventually deposited (16B). Sediments at these sites are neither as dynamic and coarse as those at the Georges Bank and inshore stations, nor as fine as station 20 sediments.

The low numbers of species at the NYB apex sites are due, in part, to dumping activities; contaminants flowing out of the Hudson-Raritan estuary probably add to the pollutant stress at these sites. Comparison of 1978 through 1980 data on NYB apex sites with 1973 through 1974 information for the same sites (Figure XX) indicates that no conspicuous temporal changes in environmental quality, as shown by trends in numbers of species, have occurred at any of the sites over this time period.

Data on populations of amphipod crustaceans also point to the effects of contaminants on New York Bight benthos. Amphipods have been documented as particularly sensitive to pollutants; the family Ampeliscidae is considered especially susceptible to the effects of low levels of oil pollution (8, 9, 10). Ampeliscids, and amphipods in general, were rare or absent at sites characterized by fine sediments in the NYB apex. Those species which were present, such as Unciola irrorata, are often recognized as tolerant of a wide range of ecological conditions. Dense populations of Ampelisca agassizi appear approximately 90 km down the Hudson Shelf Valley (Station 33, Figure XX), indicating that significant contaminant effects do not presently extend this far from the head of the valley.

Surveys indicate that amphipod densities on the New Jersey inner shelf (station 17, Figure XX) are consistently lower than at a control station (15A) off Long Island. While the latter is in a physically similar environment, it is presumed to be less influenced by contaminants from the apex dumpsites and Hudson-Raritan plume. It is important to note that surf clam spatfall follows a similar pattern, with higher settlement densities seen off western Long Island than off northern New Jersey. However, further study, including information from other disciplines, is required before additional statements can be made concerning relative contaminant impacts "upstream" and "downstream" of the apex dumpsites and estuary mouth.

Recovery of benthic macrofauna has been monitored following extensive mortality caused by hypoxia along the New Jersey coast in 1976. Amphipods, and other orders of crustacea which brood small numbers of young (and thus have

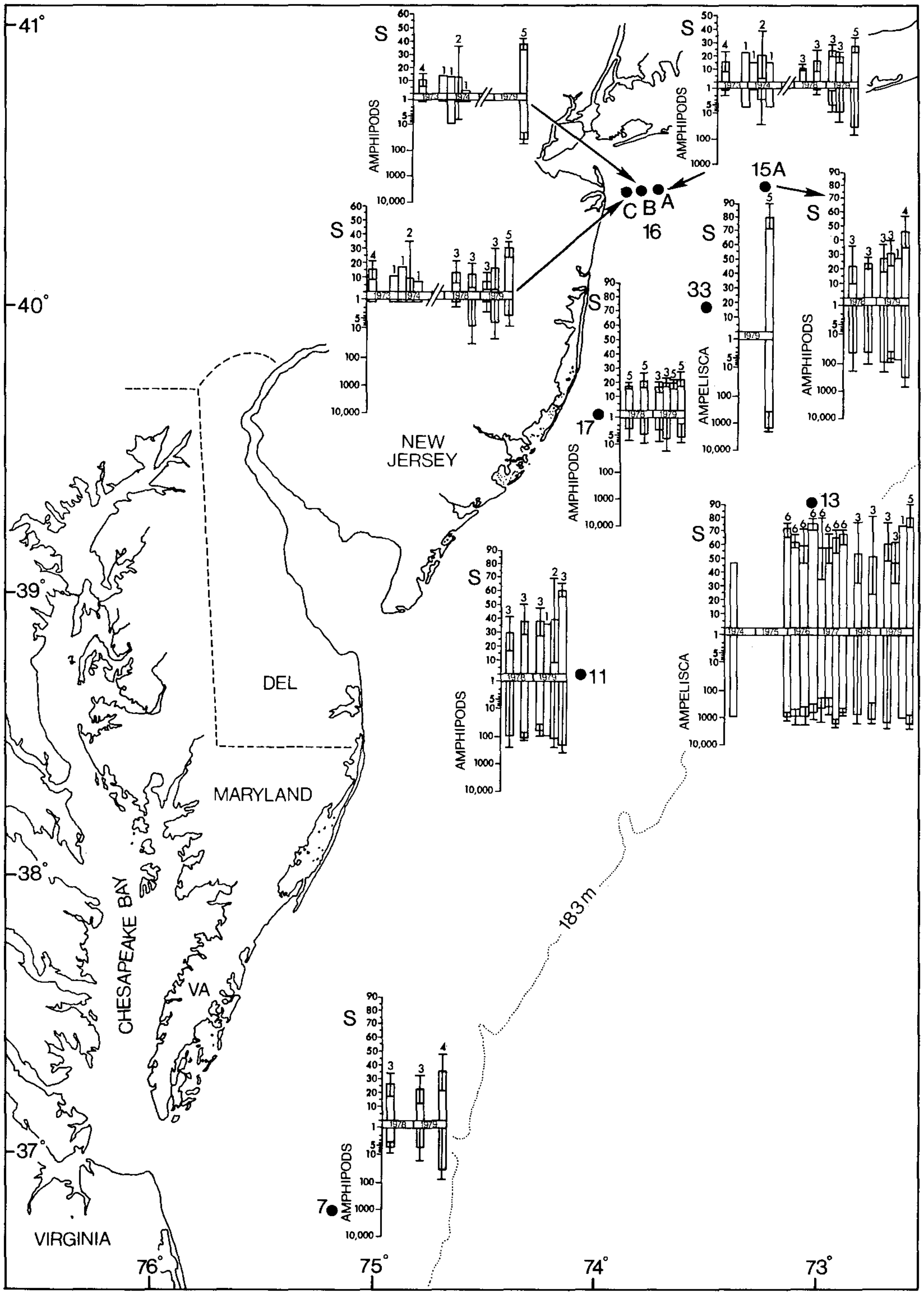

Figure XX. Means and 95% confidence limits for numbers of species (upper bars) and total amphipods or selected amphipod species (lower bars) collected at standard NEMP stations, 1978-1979, with some earlier data also presented. Numbers of replicate samples analysed are indicated above the upper bars. All data are based on 1.0mm sieves except for December 1979 (0.5mm), 1975-76 at station 13 (0.5mm, Boesch et al. 1977), and 1970 and 1974 at station 34 (0.75mm, Saila et al. 1972 and Pratt unpublished). Data for station 18 in 1976-77 are from Steimle 1980.

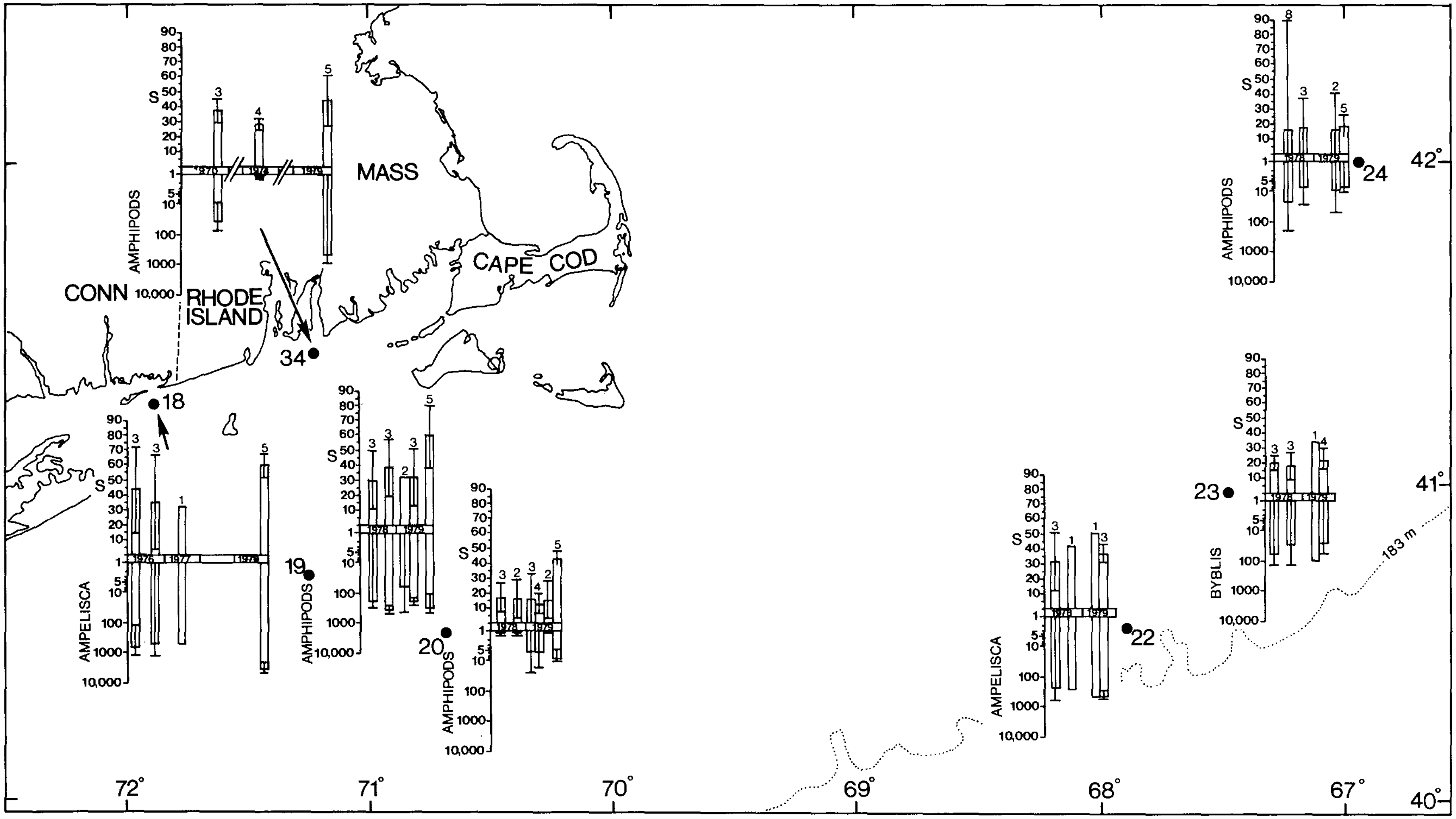

Figure XX, continued.

limited dispersal ability), recolonized the affected area very slowly (11, 12). The recovery pattern of the affected area after hypoxia may simulate similar responses which might follow other severe habitat alterations (although not those with residual toxic effects). Therefore our information on rates of recovery is valuable.

Quantitative differences in species composition at NEMP benthic sites have been analyzed through Q-mode cluster analysis. This technique uses information on population densities of most or all species present in each sample, to determine similarity among faunal collections over space and time. The analysis generates dendrograms, or "trees" showing the relationships of various sites and sampling dates. Figure XXI is a dendrogram based on available data from three cruises for the NYB sites. Using 0.3 similarity as an arbitrary cutoff level yields six site/date groups. Groups C and D each consist of a single site at which collections on different dates had fairly high similarity ($\geq$0.6). This clustering by site is also seen within groups A and E, and in dendrograms from other portions of the NEMP region; it indicates that within-site temporal variability in species composition is usually small relative to differences between most NEMP sites.

The most significant feature of the dendrogram is the similarity between the Hudson Shelf Valley and Baltimore Canyon Trough samples, and their low similarity to other NYB collections. The Baltimore Canyon Trough is considered uncontaminated; the fact that the shelf valley site is quite similar to it, and dissimilar to the inshore Bight sites, is another indication that major contaminant effects have not extended far down the shelf valley. Addition of data from future collections to the dendrogram will tell us whether this remains the case, or alternatively, whether species composition at the shelf valley site is becoming more similar to that at the impacted dumpsites.

Contaminant-related effects on benthic macrofauna community structure have been noted in several areas outside the NYB. Portland Harbor (Maine) appeared to be impacted, based on the low numbers of species and altered faunal composition found there. Particularly affected were areas downstream from a pulp mill, which had the highest organic carbon loading (39 percent) seen in the Casco Bay area and was almost abiotic (13). A domestic dumpsite with high carbon content (15 percent), however, did not show similar changes. Sites offshore of Casco Bay were rich in species and probably had not undergone significant degradation in the past 100 years. At the Massachusetts Bay site, faunal biomass was dominated by polychaetes; this is the only soft-substratum station, aside from the New York Bight dumpsites, where this predominance, possibly stress-related (14), was found.

In the Delaware Bay area, stations inside the Bay and 8 km south of the Bay mouth (the direction usually followed by the Bay's plume) were dominated by the bivalve, Tellina agilis, and the polychaete, Mediomastus ambiseta, (15), both of which are often found in polluted environments. Surf clams were found in abundance 32 km south of the Bay mouth but not 8 km south. This may relate to the above observations on clam distribution in the inner New York Bight and could possibly be a contaminant effect. Contaminant buildup and associated changes in benthic community structure have been recorded in swales (sediment valleys) in the vicinity of the Philadelphia industrial waste and sewage sludge dumpsites located approximately 72 km off Delaware (16). Populations of Ampelisca agassizi were reduced in contaminated as opposed to uncontaminated swales.

GROUP	STATION	DATE	n
A	13 - Baltimore Canyon Trough	9/78	3
	13 -	4/78	3
	33 - Hudson Shelf Valley	12/79	5
	13 -	12/79	5
B	16B- N. Y. Bight Sewage Area (Sludge)	12/79	5
	16A- N. Y. Bight Sewage Area (Sands)	12/79	5
	15A- Fire Island "Control"	12/79	4
	16C- N. Y. Bight Dredge Spoil Dumpsite	12/79	5
	17 - N. J. Coast Anoxia Area	12/79	5
C	16A-	9/78	3
	16A-	4/78	3
D	15A-	9/78	3
	15A-	4/78	3
E	17-	9/78	5
	17-	4/78	5
	16C-	4/78	3
F	16C-	9/78	3

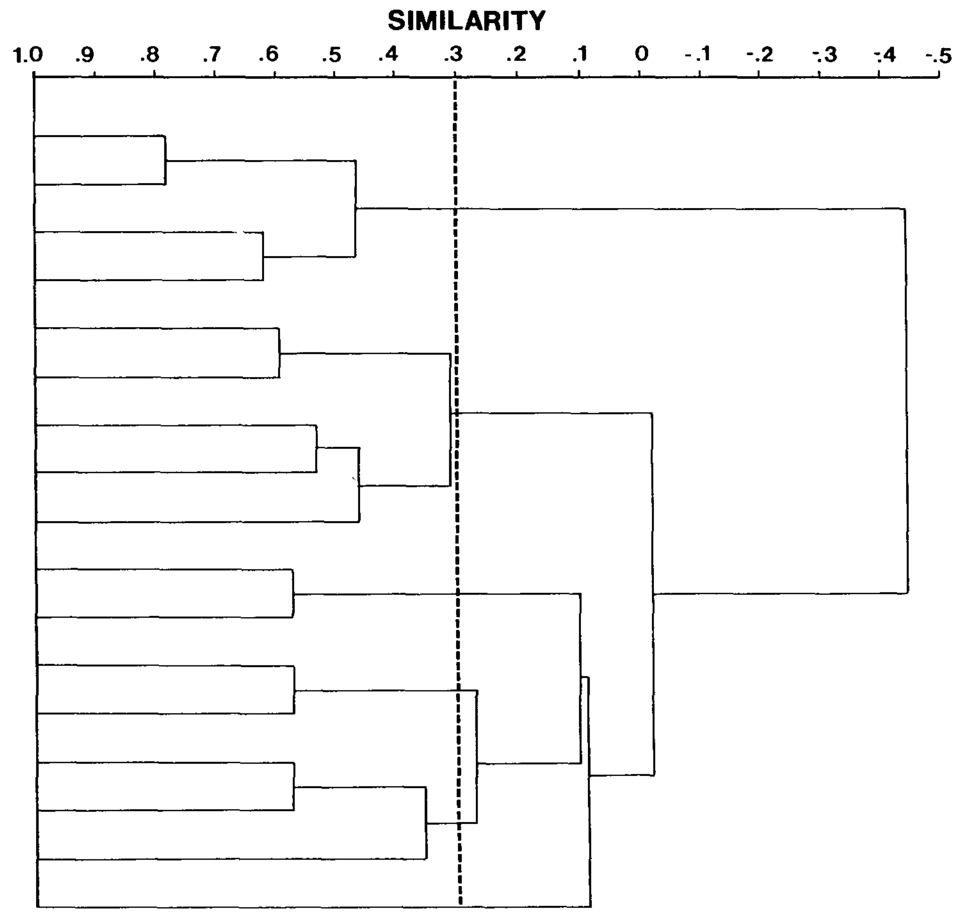

Figure XXI. Dendrogram showing similarities of sites/sampling dates in central NEMP area, based upon benthic macrofauna species composition.

There was also a possible indication of recent mortalities of the ocean quahog, Arctica islandica, associated with disposal activities. Since these dumpsites have recently been closed to dumping, they provide an opportunity to determine rates of recovery from ocean dumping.

Region-wide NEMP benthic studies have uncovered no other significant examples of spatial or temporal trends in numbers of species, species composition or amphipod populations that are suspected of being contaminant-related. Low numbers of species and few amphipods were found at a mud bottom station southwest of Nantucket and at several Casco Bay stations, but in these instances it is likely that the extremely fine nature of the sediments is largely responsible for limiting numbers and types of species present; such an effect has been previously documented (17). Cluster analyses also showed no obvious impacts of contaminants on community structure, aside from the New York Bight dendrogram discussed previously.

Benthic macrofauna data from the remaining NEMP sites are valuable in establishing benchmarks against which to measure future impacts and changes. The relatively pristine outer Casco Bay stations will enable us to detect any spread of contamination from Portland Harbor. Three years of in situ quantitative data from dive studies at Jeffries Ledge in the southwestern Gulf of Maine have established benchmarks for this major fisheries area (18, 19). A combination of remote sampling and in situ submersible observations has yielded descriptions of benthic fauna and their habitats in areas scheduled for oil exploration drilling on Georges Bank, as well as downstream from the oil lease tracts and in potential deposition/impact areas such as the adjacent mud patch, and Oceanographer and Lydonia Canyons (20). Benchmark sampling and monitoring since 1974 in the Baltimore Canyon Trough, a petroleum development area off New Jersey, will, similarly, permit detection of effects there. At least 2 years of benchmark benthic data on the proposed Norfolk dredged material disposal site will be available before any dumping occurs at that site. Six years of data on the sensitive and trophically important ampeliscid amphipods afford a specialized tool for detection of impacts at the Casco Bay, Georges Bank, Block Island Sound, Hudson Shelf Valley, Baltimore Canyon Trough, and Philadelphia and Norfolk dumpsites.

Phytoplankton

In recent years there have been numerous examples of marine environmental changes which are thought, in part, to be related to pollution. Nutrients derived from various forms of sewage have been implicated in inshore and estuarine eutrophication. Consequently, there is growing concern that research and monitoring of environmental variables related to the health of the seas must consider the topics of: (1) the addition of nutrients to coastal and oceanic systems and (2) the effects of added nutrients on biological systems.

Stress, such as nutrient pollution, can lead to small phytoplankton cells, relatively smaller herbivores, and altered food webs (21). The importance of the size of the phytoplankter, as well as the quantity of phytoplankton being produced and available or not available to higher links in the marine food webs, is also related (22). In this scheme, the smaller nannoplankton are grazed by microzooplankton and then by macrozooplankton followed by fish of various development stages, whereas the carbon and energy of the relatively larger netphytoplankton is consumed directly by macrozooplankton which in turn are direct prey for fish. The consequences of this scheme is that netphytoplankton dominated algal communities may lead to greater energy and matter inputs to higher (fish) trophic levels since the netplankton grazing scheme has fewer trophic transfers (and associated losses) than nannoplankton-based food chains. In a paper entitled "The Structure of Plankton Communities", Steele and Frost (23) state "... the primary conclusion is that size structure is as important and probably more significant than total biomass in determining modes of transfer between trophic levels".

With the above references and concepts in mind, it is clear that changes in the structure (species composition, size composition) of the phytoplankton community can result from nutrient pollution stress and that these structural changes can lead to major alterations in the structure and function of adjacent trophic links in an ecosystem. Research on eutrophication should therefore focus not only on the increased quantities of organic matter production stimulated by nutrient pollutants, but also focus on the "quality" of the primary producing phytoplankton community, that is the size structure and species composition. A corollary of this proposition is that total plankton biomass may not increase with increased nutrient stimulants, and yet drastic alterations in the phytoplankton community composition and associated food webs may result from pollution due to nutrient increase.

Marshall previously described the distribution and composition of phytoplankton for the eastern coast of the United States (24). These results were obtained from 22 cruises over the continental shelf that go back to the 1960's. This earlier work provided an extensive data base for the phytoplankton community in this region. The results from the current study were systematically incorporated with the earlier data set. Due to numerous changes in the systematics of the various phytoplankton components since the earlier work was completed, a revised checklist of phytoplankton for the eastern coastal waters was prepared (25). A major outcome of this revision was the number of cyanophyceans (blue-green algae) that were added to the list. These cyanophyceans were concentrated in the near shore areas, being most common downstream from estuarine outflows. A total of 20 bluegreen species were recorded, many of which are more typically associated with terrestrial habitats and the intertidal wetlands areas along the coast. The high concentrations of bluegreens in the Chesapeake Bay plume and adjacent shelf waters found during the "Superflux" study suggest this phytoplankton component should be further investigated, especially its role in supplying nutrients to the coastal system.

The first of a series of eight cruise reports on phytoplankton by Marshall and Cohn (26) has been completed. The report included both coastal and shelf stations and recorded 368 phytoplankton species, with the diatom Skeletonema costatum the dominant species for the entire shelf, at this time. Smaller sized S. costatum, Leptocylindrus danicus, Asterionella glacialis, Chaetoceros simplex, and Rhizosolenia delicatula were common dominants. Also abundant at nearshore locations were Nanochloris atomus and an unidentified ultraplankton component. A species transition occurred along transects seaward. Among these changes were increased concentrations of other dinoflagellates, coccolithophores, and specific diatoms.

Results of two Chesapeake Bay plume studies indicate the plume phytoplankton is distinct from the shelf populations (27, 28). The March 1980 study indicated an assemblage composed of small sized diatoms (Asterionella glacialis, Cyclotella sp., Skeletonema costatum, Leptocylindrus minimus), with the pyrrhophycean, Prorocentrum minimum, and the cyanophycean, Gomphosphaeria aponina, as the prominent species. An ultraplankton component, later classified as cyanophycean, was also a major constituent. During June 1980 the plume assemblage was again discernible from shelf populations. However, there was a different composition present than what was noted in March. The major constituent was Skeletonema costatum, several sub-dominant diatoms, and the ultraplankton component. The ultraplankton was comprised mainly of cyanophyceans. Plume patches showed degrees of mixing with the shelf plankton in relation to the presence of Emiliania huxleyi, the characteristic coccolithophore for the shelf waters. An examination of vertical samples taken within the plume indicated basically a homogeneous condition for the phytoplankton.

Abundance of Ceratium and Other Large Species of Phytoplankton: Ceratium tripos contributed to the extensive and persistent anoxia off the coast of New Jersey in 1976 (29). Therefore, the abundance and shelf-wide distribution of C. tripos and other large (greater than 53 um) netphytoplankton was monitored from December 1979 to the present at a frequency of six surveys per year (30). Quantitative collections of netphytoplankton were taken twice daily at stations where primary productivity was measured.

Extensive quantitative shelf-wide monitoring was not conducted prior to 1976. Monitoring in the NEMP program, as well as the species monitoring conducted off Long Island (Brookhaven National Laboratory), is aimed at defining the role played by the relatively large sized members of the shelf phytoplankton community. The value of this work and the particular collection method (net tows) is that the relatively low concentrations of Ceratium may be detected, and the shelf locations of "inoculum" populations may be detected at an early stage in the population growth cycle.

Net plankton monitoring between late winter and early summer 1980 indicated that C. tripos was abundant in the New York Bight. The population in early March 1980 in the mid-shelf area of New York Bight was approximately 5 percent of the density found in March 1976. By mid-June 1980, C. tripos population levels in the mid-shelf areas off New Jersey were 64 times the early March levels, indicating a population net growth rate of about two divisions per month. This growth rate is comparable to the average water column net rate of growth calculated for the 1976 spring population in the New York Bight (29). As the season progressed, however, extensive areas of hypoxia did not appear, possibly because meteorological and oceanographic conditions and population levels or concentrations of cells were considerably different from those of 1976.

Bioassays

Environmental science makes wide use of the bioassay/toxicity tests in controlled laboratory situations and has often extrapolated these results to predict field impacts of toxic substances. Very recently, bioassays have been conducted *in situ* to determine ambient field environmental quality as measured by a defined response of test organisms.

The NEMP concentrated this last year on establishing a variety of bioassays, in the laboratory and *in situ*, utilizing organisms from several trophic levels. The intent was to examine environmental quality from a broad enough scope to lend credence to statements regarding the general health of the marine region.

Two bioassay studies were directed at biological effects of pollution in the New York Bight area. In the first study, several life stages of a number of vertebrates and invertebrates were exposed in the laboratory to a series of heavy metals (31). In both acute and chronic tests, it became clear that early life stages are particularly vulnerable to heavy metal effects. Cadmium and mercury have the most pronounced effects, and suboptimal salinities and temperatures can alter response to metals. These bioassay results highlight the potential biological impact of heavy metal contaminants in the New York Bight.

In a second series of bioassays (32), sediments from New York Harbor and from eastern Long Island were put in separate trays. Working *in situ*, divers placed surf clams (*Spisula solidissima*) on the surface of two sediment-filled trays. Clams rapidly burrowed into the relatively unpolluted sediment from Long Island, but burrowed into the New York Harbor polluted sediment very slowly and after a long delay. Normal burrowing behavior is a means of defense and is of paramount importance to this organism. Hence, contaminants in New York Harbor sediments exert a demonstrable sublethal effect that has a direct bearing on the survival of this species.

Caged mussels (*Mytilus edulis*) were placed at four stations along a transect through Narragansett Bay (33). Animals held at a polluted station near the head of the Bay showed changes in a number of enzymatic rates relative to animals placed near the less polluted Bay mouth. These tests indicate that sensitive, sublethal assays can be used *in situ* to demonstrate an impact of pollution in contaminated estuaries.

A different approach was taken (34) in examining the quality of water at Deepwater Dumpsite 106, a chemical waste dumpsite beyond the shelf-slope break off Delaware. In this instance the actual pollutant, the chemical waste itself, was obtained and diluted to concentrations that are expected in the vicinity of a discharging barge. Toxicity of the waste to phytoplankton primary production (measured using the C^{14} technique) and cellular ATP levels in the phytoplankter, *Skeletonema costatum*, was measured in laboratory bioassays. Actual concentrations of waste as exists at the dumpsite had no effect on these processes, although higher concentrations had some effect. These data are very helpful in predicting field impacts of dumping activities.

Similarly, sediments from the Hampton Roads Harbor (Virginia) were prepared and assayed on several benthic invertebrates (35). These sediments were taken from areas of potential dredging activity. The tests warrant further development because the results were not consistent, but again they offer the prospect of predicting field impacts of dredge material disposal.

Lastly, laboratory studies were conducted to determine the toxicity of several pollutants that are found within the NEMP region. For instance, cadmium exposure affected enzyme activity in lobsters (36), and copper interfered with the orientation behavior of sand lance larvae (37). It was observed that demersal organisms did not avoid sediments containing up to 6,000 ppm of oil. Once again, the utility of this suite of bioassays lies in its power to predict the field impact of such contaminants on indigenous organisms.

NEMP's bioassay studies have identified several concerns for monitoring, including the following:

- o Different species and different life stages of the same species exhibit a wide variety of response to pollutants.

- o A multitude of environmental factors interact with and influence an organism's response to a pollutant.

- o It is possible to develop _in situ_ bioassays that overcome many of the artifacts introduced in laboratory tests. However, _in situ_ tests require rigorous and often elaborate controls.

The inclusion of bioassay tests in pollution monitoring programs can be of high utility. These tests must be standardized, however, throughout the geographical area and temporal extent of the monitoring program, so that the relative health of the environment and its biota can be consistently tracked.

Behavior Studies

Behavioral-ecological studies were performed to develop predictive capabilities for detecting and assessing the effects of environmental perturbations on marine and estuarine ecosystems. These studies included the establishment of normal benchmark information on the behavior, life habits, and habitat requirements of selected marine fishes and invertebrates for use in identifying the capabilities of a species to mitigate, i.e., avoid contaminant effects or, when avoidance is not possible, determine how sublethal levels may disrupt critical life habits, thus affecting the survival of the individual as well as the population. Ultimately, the aim is to use selected, highly quantifiable behaviors as indices of normality to serve as a reference, departures from which, for animals from polluted areas, will be indicative of organismic effect.

Laboratory studies (37) were conducted to determine: (1) the concentration of oil in the sediment at which avoidance by blue crabs, _Callinectes sapidus_, and red hake, _Urophycis chuss_, occurs; (2) whether shelter requirements for red hake are such that they will enter oiled areas to obtain shelter; and (3) the extent to which social behavior, e.g., agression, will affect avoidance. Tests were conducted in avoidance tanks in which blue crabs or red hake were presented with a choice between clean and oiled sediment. Variables included: (1) concentration of oil; (2) for red hake, type of shelter; and (3) number and/or size of individuals per tank. Observations of activity, distribution, social behavior and, where applicable, relation to shelter, were made day and night.

Results of studies of the effects of petroleum hydrocarbons on blue crabs and red hake showed that: (1) blue crabs detected food cues (freeze-dried clam extract) at 10^{-12} mg/l; (2) blue crabs detected the water soluble fraction (WSF) of Prudhoe Bay crude oil at 10^{-6} mg/l; (3) blue crabs exhibited no avoidance behavior of oiled sediments at any concentration up to and including levels of 6,000 ppm; (4) red hake detected food cues (freeze-dried clam extract) at 10^{-4} mg/l (5) red hake avoided oiled sediments at concentrations of 6,000 ppm, but exhibited no avoidance at concentrations of 1,200 and 600 ppm; (6) when red hake were provided shelter only on oiled sediment, they no longer exhibited avoidance behavior but entered highly oiled areas (6,000 ppm) to obtain shelter.

Four categories of behavioral patterns that were readily quantifiable, reliably exhibited under controlled laboratory conditions, and of demonstrated importance to the juvenile red hake, were established: (1) the fish exhibited distinct patterns of activity, being predominantly nocturnal; (2) agonistic behavior was an important component of the red hake's daily activity patterns; (3) foraging behavior and levels of feeding were correlated with feeding schedules and prior deprivation periods; and (4) juvenile red hake were strongly motivated to seek shelter, but their relationship to sea scallops, Placopecten magellanicus, is apparently not obligatory.

A preliminary field experiment (37) was conducted to examine the effects of oiled sediment on the feeding behavior of the blue crab on a natural prey item, the hard clam, Mercenaria mercenaria. Caged boxes which contained both blue crabs and hard clams were placed on the bottom of Sandy Hook Bay. Half the cages contained oil-contaminated sediment with the other half containing uncontaminated sediment to serve as controls. Feeding rates were monitored daily. The analyses of this study are still in progress.

Studies (38) on the behavioral and benthic ecology of juvenile red hake, in cooperation with the Environmental Protection Agency (EPA), were conducted in both the laboratory and field to identify and establish measures of spatial and temporal changes in food habits, shelter requirements, habitat selection, settling behavior, activity, and social interactions. These will serve as experimental models for studying the effects of a variety of contaminants.

Physiology and Biochemistry

Physiological and biochemical measurements on marine animals can be used to detect general and specific stresses. A variety of physiological/biochemical measurements initially chosen for testing within the NEMP include (1) respiration or oxygen consumption, (2) hematological measurements, (3) enzyme activity, (4) RNA/DNA ratio in larval fish, and (5) in situ oxygen-nitrogen ratios in starfish.

Oxygen Consumption Studies

Approximately 25 stations were sampled seasonally from 1978 to 1980 to collect finfish, crustaceans, and molluscs for measurement of oxygen consumption (39). Oxygen consumption was selected as a parameter because of its ease of measurement and its use as a general sign of stress. Although when used alone it may not have major significance as a sign of stress; when used with other physiological/biochemical measurements it can provide a more complete assessment of stress. Respiratory alterations generally indicate that other biochemical, pathological, or physiological abonormalities exist, and that further studies are needed. Detecting abnormalities in oxygen-consumption rates in the field and laboratory depend, of course, upon the establishment of proper benchmark values. Measurements were made on gill tissues of windowpane flounder, winter flounder, yellowtail flounder, rock crabs, and sea scallops as a means of gathering benchmark information necessary for further interpretation.

Hematological Measurements

Hematological measurements have come into increasing use in assessing the condition of fish and their responses to environmental change. Laboratory studies have shown that pollutants can cause hematological changes in finfish; thus, hematological measurements, including hematocrit, hemoglobin, osmolality, sodium, potassium, calcium, and magnesium ion levels were made on a variety of finfish (40). Similarly, serum ion measurements were made on rock crabs, Jonah crabs, and sea scallops. Again, animals were collected seasonally from 25 stations and have provided a substantial data base to compare with future measurements.

Three stations in Long Island Sound were sampled on a monthly basis for physiological testing methodologies (41). Windowpane flounder hematology was used as an investigative tool in an attempt to determine whether this parameter used in a monitoring effort in a clearly defined and limited size body of water could be used as a physiological tool in the larger NEMP program. The stations sampled were of varying degrees of pollution as determined by heavy metal levels in sediments. Based on this sampling to date, it appears that there are seasonal changes in hematology of this fish. Differences in hematocrit and hemoglobin were slight and only rarely statistically significant, either between stations or months. The differences in blood plasma were more pronounced. Of four variables measured, namely sodium, potassium, calcium, and total osmolality, all varied significantly, both between months and between stations for a particular month.

The results of laboratory exposure studies of windowpane flounder to mercury corroborated those of the field study (42). There were no significant changes in hematocrit, hemoglobin, or erythrocyte counts following mercury exposure, but plasma sodium and calcium changed significantly. The results of this study should provide a solid base for comparison of much of the data collected on the major NEMP cruises.

Enzyme Studies

Very early signals of metabolic stress can be observed at the subcellular level by examining enzyme activity in extracts prepared from various tissues. Any undue utilization of energy reserves, for example, or abnormal change in metabolic rates, can be detected by such sensitive monitoring activities. Studies were performed on a number of tissues from several animals: fish kidneys, crustacean hearts, bivalve adductor muscle and gill, and whole krill (euphausids) (43). Of these, on the basis of widespread offshore populations, ease of sampling, and biochemical stability during frozen storage (-80 to -40°C), and because it has been observed to reflect polluted field conditions, the sea scallop adductor muscle was selected for our intensive monitoring effort. A good start has been made in gathering data by which to obtain a seasonal biochemical profile of this tissue. There are gaps, however, especially seasonal; it has become important to sample a single scallop population at monthly intervals for at least 2 years. This monitoring effort is being performed in cooperation with resource assessment and other personnel at the Northeast Fisheries Center.

Exploratory work with the scallop kidney tissue has indicated its potential for revealing early metabolic stress (44); as a result, the scallop kidney will be sampled for biochemical analysis on future NEMP cruises.

Supportive laboratory activities in 1980 included several experimental exposures of sea scallops to very low levels of heavy metals (45). As ambient water temperatures were elevated to the range of early heat stress (greater than 15° C), cellular redox activity, as measured by adductor muscle malate dehydrogenase (MDH), increased in the controls but not in the cadmium-exposed animals. This observation reflects earlier findings with crustaceans and finfish subjected to sublethal metal stress, namely, the attenuation of a normal metabolic response to environmental change (46).

RNA/DNA Studies

Another method using biochemical techniques for assessment of the ability of a fish species to maintain normal population density is the use of the RNA-DNA ratio to estimate condition and growth rate of larval fish. Recent studies of fish have shown a correlation between this ratio and exposures to industrial chemicals. In an attempt to test the hypothesis that fish larvae in Massachusetts Bay (presumably polluted) were in poorer condition than larvae in Plymouth Harbor, 12 field-collected samples comprising 259 winter flounder larvae were analyzed for the RNA-DNA ratio (47). Analysis of the results indicate no significant difference between the two groups. The normally large field variation in viability of eggs and larvae, however, made it difficult in this first test to measure growth rates, especially in small planktonic life forms.

Laboratory studies with summer flounder larvae reared at different temperatures showed no relationship between temperature and either RNA-DNA ratio or growth rate. RNA-DNA ratio, however, was found to be the best predictor of growth rate. Similarly, results from larval studies of winter flounder confirm the relationship between RNA-DNA ratio and growth rate in this species.

The relationship between RNA-DNA ratio and growth rate has now been established in the laboratory for a number of commercially important marine fish larvae. The effects on the relationship between the RNA-DNA ratio and growth by two of the most important environmental factors affecting growth, food availability and temperature, have been studied in some detail (48). The effect of age and size of larvae on the RNA-DNA ratio-growth relation has also been studied in several species. The results of these laboratory studies will help to interpret results from field monitoring programs by defining the range of RNA-DNA ratio values corresponding to good, marginal, or poor growth rates for each species and temperature range.

In Situ Oxygen Consumption

An attempt was made to measure *in situ* the oxygen:nitrogen (O:N) ratio of the starfish, *Asterias vulgaris* (49). This was done to determine whether O:N ratio can be used as a measurement of stress. Oxygen consumption and nitrogen excretion measurements were successfully obtained from starfish incubated *in situ* at Jeffries Ledge, an uncontaminated NEMP station. The O:N ratio indicated a sublethal stressful condition, whereas the rate of oxygen consumption alone did not. An extension of this study will be to determine changes in oxygen consumption and O:N ratio of *A. vulgaris* when subjected to stressful conditions other than hypoxia. These will include studies on exposure to heavy metals and/or petrochemicals. Benchmark studies of *in situ* oxygen consumption rates and O:N ratios will be performed on other indicator species such as mussels, surf clams, and other starfish.

Mutagenics

Studies were performed (50) to determine the occurrence of chromosome-mitotic abnormalities at the critical gastrula stage of egg development of Atlantic mackerel at different sampling sites in and about the New York Bight. Three years of data indicate that average incidence of mitotic telophases with abnormal chromosome bridges in gastrula-early embryo stages are least frequent in offshore areas which are presumed to be less polluted. Yet, some coastal sites which are presumed to be polluted show similarly low incidences. Sites with the highest frequency of mitotic abnormality occur as far offshore as the Hudson Canyon (Figure XXII). The mitotic telophase chromosome bridges are indicators of both cytotoxicity and mutagenicity. In addition, it was found that cytologically estimated mortality, i.e. gross embryo abnormality, rate of development, and abnormal differentiation of Atlantic mackerel eggs, differed strikingly from site to site in the New York Bight. These variations had little relationship to temperature and salinity optima for egg development. Because of the life history and migratory route of mackerel, these eggs are believed to reflect the quality of the water into which they were spawned more than the contaminant load acquired from the female spawner.

Circulating Blood and Erythropoiesis in Fish - Micronucleus Test for Chromosome Mutation

The estimation of heritable as opposed to non-heritable genetic effects on the soma and the occurrence of abberations in the germ line or gametes is not always an easy task to study. Somatic tissue is first studied and extrapolations then made to reproductive cells. Hematological methods are coming into increasing use in assessing general condition of fish in relation to the environment, thus, use of blood to estimate mutation in fish populations is timely. To avoid the seasonality which spawning imposes on the study of fish gametes, estimates of chromosome mutation are being made in several fish species using erythrocytes or red blood cells in the so-called micronuclear test.

Samples of circulating blood were taken from approximately 1,000 fish of 13 species over the entire NEMP region (51). Kidney tissue, the chief site of erythropoiesis, was sampled selectively. Initial findings indicated that the overall incidence and variability in micronuclei in circulating erythrocytes are

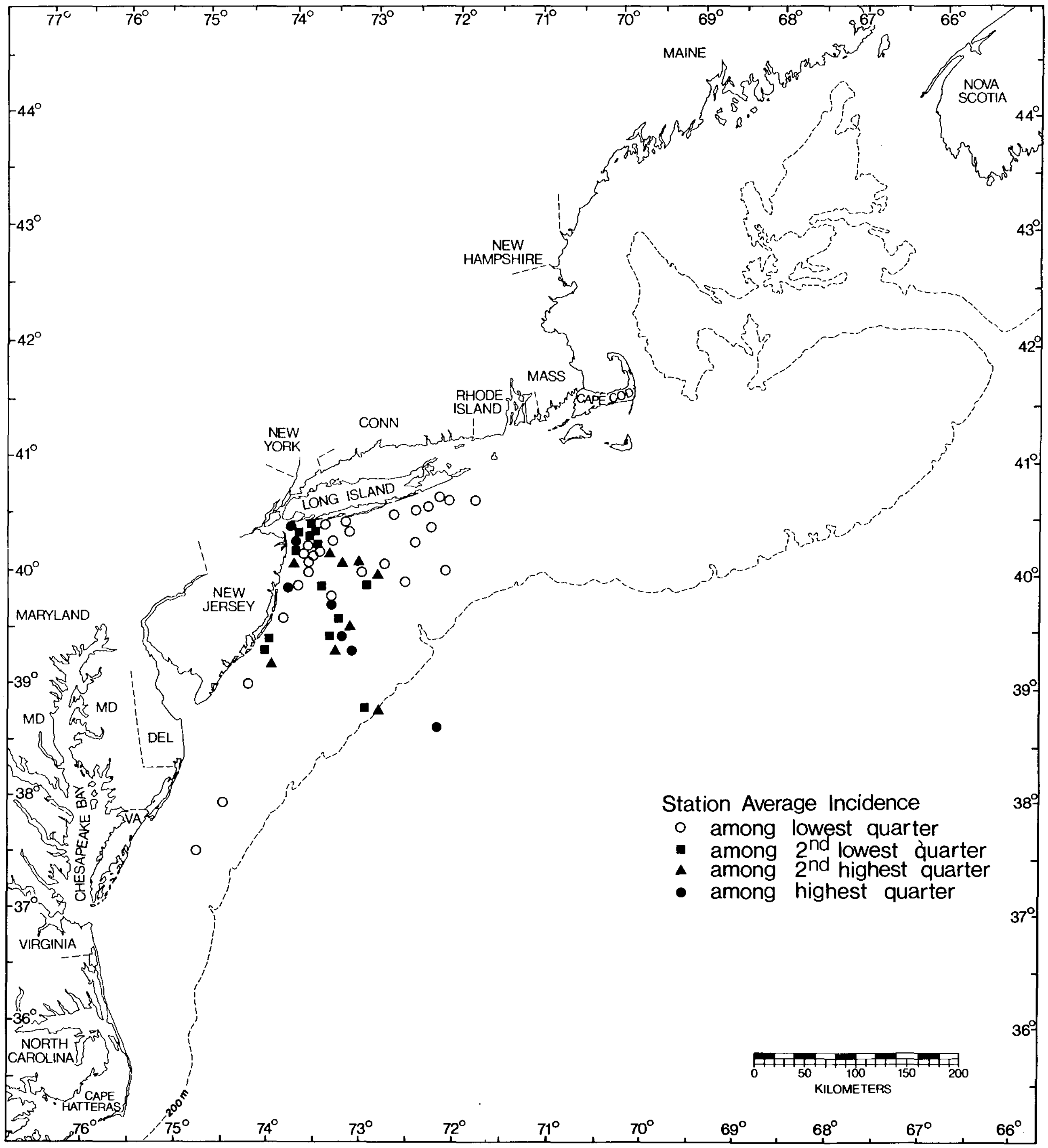

Figure XXII. Station incidence of mitotic telophases with chromosome bridges in gastrulating Atlantic mackerel embryos.

generally low. Background incidences range about 0.1 to 0.2 percent based on 2,000 to 7,000 erythrocytes per fish and a measurable sample size of fish from all sites studied to date. Some individual fish have either no micronuclei or moderately elevated incidences on the order of 2 percent. Adequate numbers of fish of each species have not yet been fully analyzed to ascertain whether there are statistically valid populations or areal differences in micronuclear incidences.

It has been observed, however, that roughly 5.0 percent of the cod and red hake sampled had unusually high incidence of micronuclei. Windowpane flounder from a polluted station near Hempstead Bay, Long Island, may be demonstrating slightly elevated incidence relative to fish from two other Long Island Sound stations which are less polluted. All of these stations are sampled on a monthly basis. Red hake with unusually high incidence were sampled midway between the Philadelphia dumpsite and Deep Water Dumpsite 106.

Affected codfish were collected from nearshore stations off Massachusetts and New Hampshire, an area considered to be less polluted than the New York Bight, but yet containing no less than 19 dumpsites of various kinds. A poorly defined cod disease, tentatively ascribed to a DNA virus, may be influencing the micronuclear incidences here through virus-induced chromosome breaks with subsequent micronucleation, as well as by mistaken scoring of viral inclusion bodies as micronuclei. The disease prevalence, possibly increased through stress, appears to be elevated in the near-shore as opposed to the offshore cod sampled.

Pathobiology

The health of aquatic ecosystems can often be measured by assessing the relative health of the biota that inhabit them. Moreover, it is documented that infectious disease agents can cause extensive mortalities or abnormalities in fish and shellfish populations; age, pressure of infection, and genetic susceptibility all affect disease pathogenesis. Evidence is accumulating which indicates that infectious disease is enhanced by environmental or man-induced stresses. Lowered disease resistance favors the transmission and viability of the infectious agents. Stress from non-infectious pollutants may cause disease syndromes and direct lethal or sublethal effects on populations of fishes, crustaceans, and molluscs. The results of monitoring surveys to assess fish and shellfish health are included in the following sections.

Skeletal Anomalies in Fishes

Skeletal anomalies are known to occur in wide varieties of bony fishes from many locations throughout the world. Many of these observations refer to single or occasional cases of gross anomalies. However, recent reports indicate increased numbers of skeletal anomalies in fishes from polluted marine habitats in Japan, West Germany, California, New York, and Florida. Experimental studies report skeletal anomalies which have been induced through exposure to organochlorides. Although a few studies report anomalies in a population of a single species, seldom has any effort been made to monitor a species for the presence of radiologically (x-ray) detectable skeletal anomalies.

Fish were obtained from stations extending from the Southern Gulf of Maine to the mouth of the Chesapeake Bay (52). Over 3000 individuals were collected. The average prevalence of vertebral anomalies was 14 percent. The highest prevalence of any specific anomaly was the occurrence of fused vertebrae in 25 percent of a sample taken in 9 meters of water south of Virginia Beach, Virginia.

In general, samples from relatively shallow inshore stations had the highest levels of anomalies while samples from offshore stations had the lowest levels (Figure XXIII). There does not appear to be any relation between length of fish and the presence of anomalies.

Final interpretations of the results of these studies must await computerization and statistical analyses. However, because of the types of anomalies observed, and the fact that preliminary analyses indicate no correlation with fish length, one may speculate that the anomalies occur during embryogenesis and may, therefore, be related to toxic substances in the fishes' habitat.

Molluscan Histopathology

The current study (53) monitors specific histopathologic characteristics (lesions, parasites, and infectious diseases) of inshore and offshore molluscs, collected seasonally and spatially. Species from inshore stations were mussels (*Mytilus edulis*), clams (*Mya arenaria*), and hard clams (*Mercenaria mercenaria*). Offshore species were sea scallops (*Placopecten magellanicus*), mahogany clams (*Arctica islandica*), and surf clams (*Spisula solidissima*). Portions of tissue from all molluscs sampled were excised and frozen for mutagen testing.

Only a relatively small number of offshore molluscs were collected and examined histologically; however, none had any significant lesions that could be attributed to environmental quality. The absence of lesions and diseases in offshore molluscs may correlate with good environmental quality. To date, of the molluscs examined histologically from inshore stations, a number of lesions were observed which commonly occur in many populations of oysters and mussels. However, pigment cell increases (ceroidosis), increase in mucous cells of the gills (adenoplasia), arrested gametogenesis, and absence of common parasites (also noted in finfish) were conditions that appeared to be associated with molluscs from degraded inshore environments.

Integumental Lesions of Marine Fish

Integumental lesions such as fin erosion, epidermal papillomas, ulcers, and lymphocystis constitute the more obvious disease symptoms found in marine fish. The prevalence of such disease appears in many cases to be related to stressed environments.

It continues to be a working hypothesis that fishes which inhabit ecologically degraded environments may exhibit a higher prevalence of integumental lesions than fishes from ecologically similar non-degraded environments. To test this hypothesis, a monitoring program was implemented to examine fish collected from the Gulf of Maine to Cape Hatteras for the presence of specific integumental lesions (54). Fishes examined included cod, fluke, haddock,

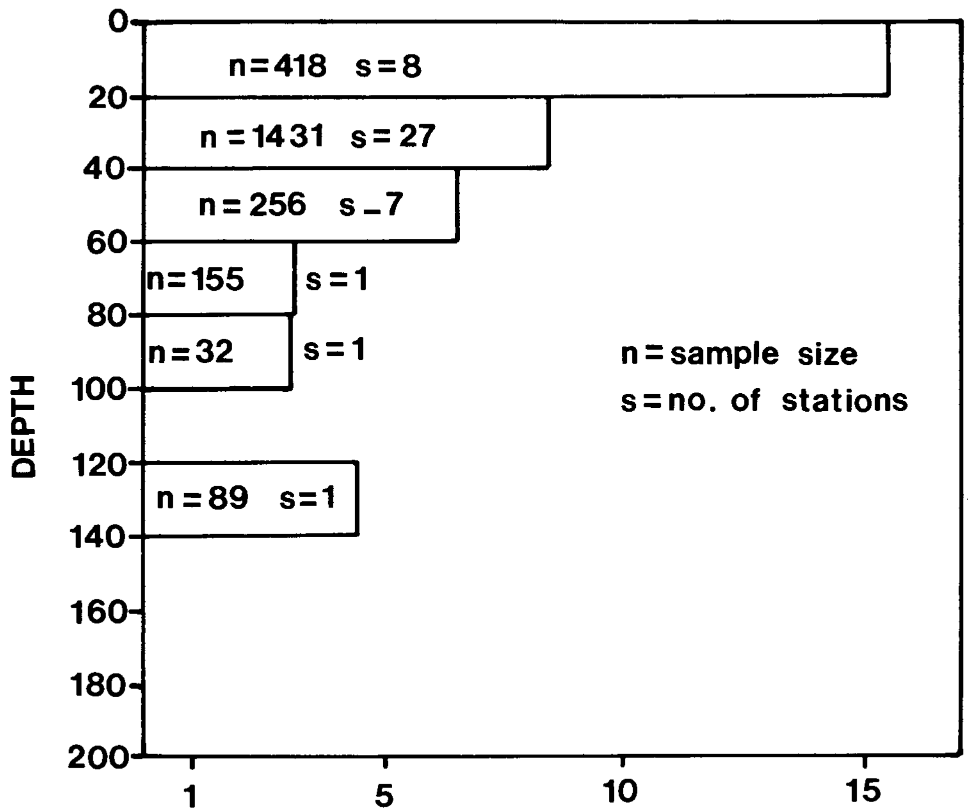

Figure XXIII. Occurrence of fused vertebrae in Ammodytes, 1980 bottom trawl survey.

plaice, pollock, red hake, silver hake, winter flounder, and yellowtail flounder. These species were generally abundant in the areas of interest. Other fish, e.g., butterfish, herring, redfish, white hake, windowpane flounder, also were examined, but were not always numerically abundant. With a few exceptions, most of the fish examined were commercially and ecologically important species. Altogether, we have examined 27,433 fish since mid-1979.

The frequency of occurrence of gross integumental lesions is very low: 0.54 percent of the aforementioned fish had fin erosion; 0.16 percent had lymphocystis; 0.21 percent had gross skeletal anomalies; and 0.20 percent had ulcers. Fin erosion usually was limited to cod and winter flounder, and lymphocystis was noted only in American plaice. Ulcers were noted primarily in cod, haddock, white hake, and winter flounder. Most of the ulcers were large, chronic lesions, probably injury or fish-induced traumas (bites). Trematode metacercariae and parasitic copepods were abundant in several fish species caught at nearshore stations. For the trematodes this is probably due to the presence in these areas of appropriate intermediate hosts.

Results of the bottom trawl surveys indicate the absence of substantial numbers of lesions on recently examined fish (55). The absence of integumental lesions in the fish may be a function of the area sampled. The bottom trawl survey area is offshore in an environment relatively unaffected by terrestrial activity and heavy pollutant loads. Consequently the environment may be a relatively healthy one for the fish taken during the assessment surveys. Results of these activities provide baseline or benchmark information for assessment of future environmental effects on fish health, particularly in relation to oil and gas leasing activities, other mineral and energy development schemes, and ocean dumping on the continental shelf and beyond.

Black Gill Conditions in Crustacea

It should be emphasized that all types of gill blackening which have been observed should not be confused with the black gill syndrome discussed below. Black spots or local discoloration of gills of some crustacea do not necessarily indicate a specific response to stress or pollution and focal melanization may be due to localized fungal infections or they may be encysted ciliates. Nevertheless, gross and microscopical observations on the effects of known ocean dumping on crustacean health have shown that shell erosion and tissue necrosis are useful qualitative indicators of disease and possible stress in rock crabs, *Cancer irroratus*, and lobsters, *Homarus americanus*. Studies presented here summarize a 5-year survey on the incidence and geographical distribution of "black gill" and associated histopathology in the rock crab. Background information also suggests that severely diseased gills may interfere with respiratory function and may increase the susceptibility of stressed crabs to predation.

Rock crabs from coastal sewage dumpsites near New York, New Jersey, Delaware, and Maryland were examined for evidence of stress of disease attributable to the effects of ocean dumping (56). Excessive gill fouling by bacteria, debris, diatoms, copepods, amoebae, and stalked ciliates frequently was noted in microscopical studies but could not be used as evidence for environmental stress. Gills that were black over 50 percent or more of their tissue mass were observed in crabs collected from ocean disposal sites and appeared to be useful indicators of environmental degradation. The "black gill" condition is believed to be caused by accumulation between the gill lamellae of particles possibly derived from black sludge contaminated sediments. Summarized data showed that blackened gills were present in 4.5 percent of the crabs on a year-round basis, or in up to 10 percent when only intermolt animals were considered. Blackened gills were not observed within a second group of 268 crabs collected from control locations (Georges Bank; Montauk Point, New York; Sheepscott River, Maine). An additional 846 specimens were collected at stations from Cape Cod, Massachusetts to Cape Hatteras, North Carolina during NEFC surf clam and scallop assessment cruises. Eight percent of the crabs from surf clam stations and less than one percent of the crabs from the scallop cruise had black gills. Station data from the two cruises showed that affected crabs usually were collected from locations in or near solid waste disposal sites. Observation on the incidence of black gills in rock crab provided evidence that the condition occurs primarily in areas where bottom sediments are altered by the accumulation of sewage sludge deposits.

Summary - Biological Effects

During the past 15 months the NEMP has conducted extensive cruises, in part, to establish benchmarks for biological effects assessment. Several biological disciplines have been involved during these cruises. For the first time relative synoptic measurements have been made at locations along the entire eastern seaboard. Certain stations or sites are located in relatively unpolluted habitats such as Jeffrey's Ledge and Georges Bank. Other stations have been located along gradients of pollutants emanating from major industrialized or developed areas such as Portland Harbor (Maine), the Hudson-Raritan estuary, Delaware Bay, and Chesapeake Bay. Extensive data have been gathered on benthic community structure and function at sites located from southern Maine to Chesapeake Bay. At the same time as information on the benthic community is being developed we have also collected a variety of environmental samples and data useful in establishing the relative degree of contamination within the particular habitats.

We also have investigated planktonic components of the marine ecosystem to establish benchmarks for community structure and abundance of phytoplankton species as well as rates of production. Again, we have noted that in areas affected by contaminated water flowing from major estuarine systems there appears to be demonstrable differences between these and similar, but uncontaminated, areas. Large stocks of chlorophyll and high rates of primary production have been delineated in coastal areas which received estuarine waters, and are thus indicative of eutrophication. There is a growing indication that in the past decade there may have been significant changes in coastal and shelf phytoplankton species and cell size over large areas of the continental shelf.

The foregoing studies have largely been concerned with ecological aspects of the marine ecosystem over the northeast continental shelf. We have continued our monitoring and research activities in relation to diseases of marine organisms. Current evidence suggests that organisms inhabiting degraded habitats, such as the New York Bight dumping grounds, show a higher incidence of disease than do similar organisms taken from relatively uncontaminated areas. Monitoring activities for physiological and biochemical effects also have resulted in preliminary evidence that suggests there are trends or gradients in certain physiological/biochemical responses when such phenomena are measured in degraded, moderately degraded, and relatively unpolluted habitats. Such gradients continue to be studied in Long Island Sound, Narragansett Bay, and other coastal and shelf waters where known sources of pollution occur.

Studies of the effects of contaminants on genetic aberrations have also continued. Scientists are looking at chromosomes of fish eggs and larvae to determine relationships between deteriorated habitats and genetic change. During the past year, studies have begun on red blood cells of teleosts to establish the relationship between the presence of micronucleii, genetic damage, and extent of pollution. Finally, the geneticists have begun collections and examinations of the eggs of benthic amphipods to determine if these sensitive organisms show genetic damage due to pollution.

We have begun the development of assays which use critical behavioral responses to monitor the effects of specific contaminants and gross pollution on marine fish and invertebrates.

In conclusion, monitoring activities continue to suggest that highly perturbed habitats, such as the New York dredged material and sewer sludge disposal areas, do affect marine life in a variety of ways. Other habitats impacted by industrialization, such as Casco Bay and Portland Harbor (Maine), also appear to show evidence of biological effects of contaminants.

It is important that these monitoring efforts proceed so that long-term benchmarks can be established along the eastern seaboard, especially in areas that are likely to continue to be degraded by pollution, physical development, and major industrial development. To date, it has generally been impossible to assess the effects of spills of toxic substances, largely because of the lack of appropriate benchmarks. Perhaps more important, industrialization of coastal habitats, especially in metropolitan areas which are sited on major rivers or estuarine systems, has resulted in almost complete destruction or degradation of major estuarine habitats and associated marine life. Many developmental activities have proceeded over decades with results that have been imperceptible over the short range but which have had great significance over longer periods. Only through long-term monitoring activities, using a variety of biological measurements, can scientists hope to establish the data base necessary to assess the effects of a variety of pollutants entering marine habitats through a multiplicity of sources as well as the effects of physical degradation.

BODY BURDENS OF CONTAMINANTS

Body burdens of contaminants are of significance because of possible effects on the well-being or survival of marine animals, and because of possible effects on human consumers who utilize seafood containing undetected toxic or pathogenic substances.

Contaminants of principal concern at present are heavy or trace metals, petroleum hydrocarbons (particularly the polynuclear aromatics), and the chlorinated hydrocarbons (especially PCBs and DDT or its derivatives).

Among those invertebrates which are consumed as whole animals, often uncooked or only partially processed, body burdens of microbial contaminants can also be of significance. Certain viral and bacterial diseases of humans have been associated with consumption of raw or improperly processed oysters, mussels, and crabs. Microbial indicators (principally fecal coliforms) have offered a reasonable measure of degree of risk.

General Concepts

Through research carried out in the New York Bight and in many other polluted estuarine/coastal environments, a number of generalizations about contaminants have emerged. Such generalizations may be useful background for later discussions of contaminant body burdens in Northeast estuarine/coastal waters.

- For many contaminants, there is a dynamic state of accumulation and elimination. Accumulation occurs either directly across membranes or by ingestion of contaminants and passage across digestive membranes. Elimination is through metabolism or by passive movement across membranes if environmental concentrations of contaminants decline.

- Bioaccumulation - the concentration of a pollutant against a diffusion gradient and/or biomagnification (further concentration at higher trophic levels) can be critical phenomena in marine species, both for the well-being of the organism and for possible effects on humans.

- Retention of lipophilic contaminants (DDT, PCB, etc.) occurs in fatty tissues of many marine animals and may result in reduced spawning and other physiological disturbances, particularly during times of stress.

- Long-term ingestion by humans of fish and shellfish with even low body burdens of contaminants may be harmful to health; this is especially true for the fat-soluble contaminants, and those for which ingestion rates may exceed detoxification and excretion (certain heavy metals).

- Although specific evidence does not exist in most instances, low levels of carcinogenic contaminants in food may result in increasing risk to the consumer.

Heavy Metals

There is a growing body of information about levels and effects of heavy metals in marine species of economic importance, and a growing concern about acute and chronic effects on human consumers of contaminated food. Localized estuarine/coastal waters in different parts of the world ocean have been found to contain high heavy metal levels in sediments and water column, either because of natural outcropping of metallic ores or because of contamination from adjacent industrialized areas. One such area is the New York Bight, where high metal levels were found in sediments (1, 2), water column (3), and biota (4). Also see the Water and Sediment Quality sections of this report.

An extensive survey of heavy metal levels in fish and shellfish was conducted by the National Marine Fisheries Service (5). High concentrations were found in certain species from specific coastal areas, but in most instances these were below existing or projected action levels. The survey, of course, did not result in information about effects of resource species body burdens on individual persons or human populations.

As was pointed out in a recent ICES report, there are few studies which attempt to associate environmental metal levels, body burdens, and effects on marine animals. Some studies (6) disclosed physiological effects in the absence of measurable tissue uptake. Other studies (7) found significant metal uptake and physiological effects in bivalves after chronic exposures, and bivalve species differed in rates and amounts of metals accumulated (8). Still other studies (9) have indicated that marine animals which have been adapted to environments with high heavy metal concentrations often have high body burdens without suffering observable negative effects. Such animals were more tolerant to experimental exposures to metals than were animals from environments with low metal concentrations.

A more recent survey of heavy metal concentrations in surf clams and ocean quahogs of the Middle Atlantic Bight (10), disclosed latitudinal changes in levels of several metals, which showed decreasing levels southward from the New York Bight to Cape Hatteras. Concentrations in all samples were below guidelines developed by the Food and Drug Administration (FDA), but indicated that a portion of the biota of a large area of the northeast coast has been affected by the introduction of heavy metals.

A definitive review of heavy metals in fish and shellfish of the New York Bight has been prepared (11). Principal findings were that highest concentrations of metals were found in fish taken from the New York Bight apex, with decreasing levels as distance from the apex increased. Metal levels in crustaceans, molluscs, and samples of whole fish were higher than in samples of fish flesh. Marked species variations in heavy metal body burdens were found with the highest overall relative burdens of seven selected metals in ocean pout, cod, and rock crabs.

<u>Chlorinated Hydrocarbons</u>

Pesticides and related synthetic halogenated organic compounds exist in measurable quantities throughout the world's oceans, and a number of them increase in concentration at higher trophic levels. A large body of evidence, probably the best that exists concerning contaminant effects on resource species, clearly indicates harmful activity of chlorinated hydrocarbons at remarkably low environmental levels (12). For example, 50 parts per trillion of DDT will kill newly hatched crab larvae; this is a level 1,000-fold lower than found in adult crabs in certain areas. Pesticide exposure levels well below those causing mortalities may produce adverse effects on growth and reproduction of marine animals.

Polychlorinated biphenyls (PCBs) from industrial sources are presently as abundant or more abundant than chlorinated hydrocarbons of agricultural origin in many marine ecosystems. Effects of PCBs on marine organisms are similar to those of organochlorine pesticides. Surprisingly high levels of PCBs in fish have been reported (13). Median concentration on a wet weight basis was 1 ppm for eight fish species sampled in Long Island Sound. Zooplankton from the Middle Atlantic continental shelf also contained high PCB concentrations (1.5 ppm wet weight).

Unlike the present situation with heavy metals, there are a number of studies which relate body burdens of chlorinated hydrocarbons to physiological effects. Several studies have provided evidence that high tissue concentrations in spawning adults can result in mortalities in developing eggs and larvae. Reproductive failure of a Texas sea trout population was attributed to trophic magnification of DDT residues (14). The sea trout population inhabited an estuary heavily contaminated by DDT, and fed on menhaden which were also heavily contaminated. Sea trout spawning appeared normal, but eggs failed to develop. DDT concentration in the ovaries reached a peak of 8 ppm prior to spawning, compared to less than 0.5 ppm in sea trout from other less contaminated Texas estuaries.

In another example of larval mortality which seems related to increased environmental contamination, evidence was found that excessive mortalities of larval winter flounders in a Massachusetts estuary could be related to pesticide pollution. Adult females concentrated DDT, DDE, and heptachlor epoxide in their ovaries as spawning approached, and mortality of post yolk sac larvae approached 100 percent (15).

Still another study (16), found that eggs of trout exposed to PCBs sufficiently to produce levels of 30 ppm in body muscle and 80 ppm in ova, did not hatch.

During the first year of the NEMP, edible portions of finfish and benthic epifauna were examined for petroleum hydrocarbons (PHC), chlorinated hydrocarbons (PCB and DDT) and polynuclear aromatic hydrocarbons (PAH). A subset of 100 samples, from locations extending from off Chesapeake Bay to the eastern Gulf of Maine, was analyzed (17).

General conclusions concerning chlorinated hydrocarbons were:

(1) PCB and DDE compounds were widespread throughout the sampling area, more so than petroleum hydrocarbon compounds (PHC), but were present at low levels and varied from station to station independently of PHC distributions for most species.

(2) The geographic distribution of PCBs indicated no regional point source of these contaminants, despite high sediment levels in the vicinity of dump sites. A related NEMP-funded study of PCB concentrations in New York Bight sediments (18) disclosed values from 0.5 ppm to 2200 ppm in samples from the sewage sludge and dredge spoil dumpsites.

(3) PCB concentrations in major benthic epifaunal species varied, with lobsters containing high levels.

The results of this study agree well with previous observations of widespread occurrences but low levels of PCBs in fish and shellfish of the Maryland portion of Chesapeake Bay (an average of 0.26 ppm in fish and 0.02 ppm in oysters) (19).

Petroleum Hydrocarbons

Petroleum hydrocarbons in estuarine/coastal waters have increased in recent decades as a consequence of acute or chronic spillage, deliberate discharge, terrestrial runoff, and airborne fallout. Major spills have received public attention, and many studies of effects, in the field and in the laboratory, have been conducted. A vast literature on petroleum in the sea has been amassed. From this wealth of data, it seems clear that petroleum components, particularly the aromatics, can be extremely toxic to marine animals, in concentrations that have been reported in the vicinity of spills. It also seems clear that a variety of sublethal physiological effects result from exposure to oil. It is not clear, however, that petroleum can produce greatly increased mortality in marine populations, except in the immediate impact area of oil spills or chronic release. It may well be that concentrations of oil in the surface microlayer may affect populations of planktonic fish and invertebrate eggs and larvae.

Among the many components and degradation products of petroleum, the polynuclear aromatics (PAH) have received attention, because many of them have been shown to be carcinogenic. Some of these compounds have been detected in marine animals, but no association has yet been made between carcinogenesis in humans and ingestion of contaminated seafood.

There have been a number of studies of petroleum hydrocarbons in the estuarine/coastal waters of the Northeast (20). Some have resulted from local spills (ARGO MERCHANT, West Falmouth); others have been consequences of concern about chronic petroleum contamination in industrialized sites (Narragansett Bay and Raritan Bay, for example). High sediment loads have been found in those areas, and very limited information exists about tainting of fish and abnormalities in clams from contaminated zones. Nevertheless, such tainting can be an important problem for the fishing industry (21).

The ERCO study of hydrocarbons in organisms of the Middle Atlantic Bight during the first year of NEMP, referred to in the Chlorinated Hydrocarbons section, led to the following conclusions about petroleum hydrocarbons:

(1) PHC levels vary with species of fish, but were regionally quite high, compared with certain other geographic areas. Most samples of silver hake contained detectable levels of PHC (>1.0 ppm), and generally occurred at levels of 6 to 10 ppm.

(2) The geographic distributions of PHC compounds indicated no regional point source of these contaminants, despite high sediment levels in the vicinity of the dump sites.

(3) PHC concentrations were low (6 to 9 ppm) in most important fish species (cod, haddock, winter flounder).

(4) Major epibenthic species (lobster, scallop, rock crabs), as a group, contained no detectable PAH hydrocarbons (with a single exception). However, levels of PAH compounds were high in such invertebrates (phenanthrenes 59 ppb, fluorenes 58 ppb).

(5) Baseline hydrocarbon data from fish can be useful in monitoring future changes in pollutant loading. Benthic organisms should be an even better indicator.

Microbial Contaminants

During the past decade, there has been growing public health concern about microbial contamination of seafood, and outbreaks of certain diseases traceable to consumption of raw or improperly processed products. Hepatitis outbreaks have been traced to consumption of raw oysters, and cholera outbreaks to consumption of contaminated mussels in Europe. The first confirmed case of cholera attributed to consumption of oysters was reported from Louisiana in late 1980. Additionally, digestive disturbances in humans, caused by *Vibrio parahaemolyticus*, have been reported in the United States with increasing frequency; some outbreaks have been traced to consumption of raw oysters and others to consumption of improperly processed crabs.

Problems related to microbial contamination have been less severe in the Northeast, but the potential danger of outbreaks exists whenever products from contaminated waters enter avenues of commerce. Much productive shellfish acreage in the Northeast is presently closed to fishing because of pollution (as measured by fecal coliform tests) or the possibility of pollution. Other indicators of microbial contamination would be desirable and are being sought (see Microbial section of Water and Sediment Quality sections).

During the first year of NEMP, surveys have been made of a number of microbial contaminants. Shellfish harvested from contaminated areas have been found to harbor a number of potential human pathogens such as fecal streptococci, *Clostridium perfringens*, *Salmonella* sp., and the various *Vibrio* species. During the preliminary survey it became apparent that the correlation of fecal coliform indices with the presence of specific human pathogens needs further evaluation. At present, monitoring of the *Vibrio* species seems to be the microbiological approach of choice, even though many of them are of marine and not human origin.

Summary - Body Burdens of Contaminants

From previous and ongoing research concerned with body burdens of contaminants in organisms from estuarine/coastal waters of the Northeast, a number of conclusions seem warranted at present:

(1) A reasonable correlation is emerging between concentrations of heavy metals in fish and shellfish and the regional intensity of pollution. Greater emphasis should be placed on equating observed body burdens and effects on survival and well-being of the resource animals; although effects of various concentrations of selected heavy metals on marine organisms have been demonstrated experimentally, there is little information about biological consequences of measured body burdens of metals in samples from polluted waters.

(2) Chlorinated hydrocarbons are widespread in marine biota of the Northeast, but at low concentrations in most samples. No correlation with point-source contamination has been detected as yet.

(3) Petroleum hydrocarbons in fish from Northeast estuarine/coastal waters varied with species, but were regionally quite high, compared with certain other coastal areas. PHC levels were low, however, in the most important species.

(4) Shellfish harvested from polluted waters of the Northeast harbor a number of potential human pathogens; presence of such human pathogens is only marginally indicated by standard fecal coliform tests, and other indicators are desirable.

SECTION IV. SPECIAL STUDIES

Rapid, synoptic environmental quality measurements over broad geographical coastal areas require new methods such as remote sensing from fixed-wing aircraft and satellites. Environmental quality monitoring of fishery habitats also requires the use of special techniques including diving studies from submersible vessels such as the Alvin; deep waters or habitats having unusual topography or geological formations can best be sampled by diver biologists using a variety of submersibles.

Diving Studies. Environmental assessments and monitoring require a range of observations and collections. Certain habitats, because of unusual depths, currents, and substrata types necessitate the use of submersibles. Georges Bank is such an area, and considerable effort has been expended there in dive studies using submersibles. During 1980, 16 days were spent in dive studies using the Johnson SeaLink system and 10 days aboard the deep-diving Alvin. Two stations were occupied on the south flank of the bank in the center of the area proposed for petroleum exploration and development; two other stations were located in Lydonia Canyon, through which suspended materials and associated contaminants might move in the event that such matter is released at proposed drilling sites in the bank.

The principal objectives included the establishment of benchmarks in regard to (1) benthic megafauna and demersal finfish, (2) topographic features and associated geological structure, (3) contaminant (organohalogens, petroleum hydrocarbons, and trace metals) loading in the physical and biological compartments of the bank ecosystem, and (4) behavior of principal commercial finfish and shellfish. The principal Georges Bank diving stations are marked with longlife (5 year) 37 kHz pingers permitting return to these research and monitoring sites. Calibrated photographs (1,000) were taken in 1980; these are being filed and "read" in order to assess and document the condition (standing stocks, diversity, etc.) of the biota in relation to the observations made by diving biologists using shallow and deep-diving submersible units. Subsequent photographs can be used to monitor short-.and long-term changes.

The sampling of sediments and biota for PCBs and trace metals (reported in more detail in the Sediment Quality and Biological Effects sections of this report) indicated that (1) metals were relatively uniform in sediments, with the exception of zinc which was elevated at one station, (2) levels of metals were similar in the biota sampled, with the exception of lead which varied in the cancroid crab (Cancer sp.) and scallop musculature, and cadmium which was high in scallop viscera. As with other benchmark measurements, these findings are important in the evaluation of future petroleum exploration and development activities.

SUPERFLUX (Chesapeake Bay Plume Studies): Superflux is a joint NOAA/ National Aeronautics and Space Administration (NASA) study with state and academic participation, involving the coordinated use of remote sensors and sea-going oceanographic research vessels.

Its purposes are: (1) to advance the development and transfer of improved remote sensing systems and techniques for monitoring oceanic environmental quality and associated effects on living marine resources; (2) to increase our understanding of the influence of estuarine "outwellings" (plumes) on contiguous shelf ecosystems; and (3) to provide a synoptic, integrated, and timely data base for application to problems of ocean resource and environmental quality. As such it is a study which requires a multi-organizational, multi-disciplinary approach.

Chesapeake Bay is the largest estuary in the United States and is under ever-increasing stress from man. The potential for studying the effects of this increasing stress on the offshore environment plus the potential for developing a coherent study with a number of investigators, each providing different yet relevant talents, led us to select the Cheasapeake Bay mouth and offshore plume as the primary area for studying estuarine-shelf interactions in conjunction with remote sensing. The use of remote sensors in concert with sea-going oceanographic research vessels offered the potential to understand a tidally dynamic area. The remote sensors could provide a synoptic picture of the surface distributions and abundances of selected variables (temperature, salinity, chloryphyll a, phytoplankton color groups, and total suspended matter). The surface ships could provide the data required to calibrate the remote sensors (sea truth) as well as the three-dimensional view of the water column required to interpret the remotely sensed imagery. Additionally, ships could collect data not directly relatable to the remote sensors (certain contaminants and biostimulants as well as biological effects data), yet of high interest in terms of environmental quality and resource management. Such measurements, it is hoped, would be relatable indirectly to certain of the variables measured by the remote sensors. In this way remote sensing imagery could respond to the temporal-spatial problems encountered by ships in tidally dynamic areas by providing, in conjunction with shipboard data for interpretability, synoptic information relevant to environmental quality and resource management. The goal of Superflux has been to hasten the day this would occur.

To date three experiments, timed to coincide with periods of supposedly high, medium, and low freshwater discharge, have taken place. These were March 11 through 20, 1980 (Superflux I), June 17 through 27, 1980 (Superflux II), and October 13 through 22, 1980 (Superflux III). Drought conditions existed during Superflux experiments II and III.

Summary of Superflux

1. The "outwelling" plume waters of the Bay are usually enriched relative to shelf waters. Inorganic matter in the form of turbidity is generally higher in the plume as evidenced by Landsat and Ocean Color Scanner imagery as well as by shipboard measurements. Contaminants, particularly the hydrocarbons associated with total suspended matter were elevated in the plume. It appeared that 90 percent of the hydrocarbons in the water column are associated with suspended particulate material. Biostimulants, particularly those involved in primary production, were higher in the plume. According to Walsh (personal comm.) the plume with its enriched nutrients may be the dominant factor in sustaining primary production in the shelf waters off the Bay during the summer. Organic material in the form of biomass as bacteria, chlorophyll, and phytoplankton was higher in the plume. Also elevated was biological activity as total plankton

respiration and heterotrophic potential, both indicators of biological mineralization rates which are relevant to the processing of organic material (including wastes), nutrient regeneration for primary production, and dissolved oxygen concentrations within the water column, particularly below the pycnocline.

2. This enriched area is definable based on Landsat and other remote sensing imagery as well as on hydrographic survey data.

3. Shipboard survey information suggests the possibility of particulate material "raining out" of the water column to the benthos downstream along the length of the plume. It has not been determined whether the patterns seen are caused by sinking or resuspension; if sinking or settling of materials is the major factor, then the benthic area under the plume should be enriched in terms of organic matter available to support benthic populations. The same area would also receive the stresses associated with contaminant materials also deposited from the plume.

4. The size and shape of the shelf area influenced by the Chesapeake Bay plume is variable due to freshwater discharge, meteorological conditions (wind), and the physical oceanography of the open shelf, including tides, longshore drift, and shelf-edge upwelling. The predominant area of influence of the Bay plume extends from the Bay mouth east 10 to 20 km and south along the coast 20 to 50 km. During some periods the plume is close to the beach. In other cases, based on satellite imagery, it is not. During 1973, hurricane Agnes produced a definable plume of low salinity water at least as far south as Oregon Inlet, North Carolina, some 90 to 100 km south of the Bay mouth. Drought conditions occurred during 1980, with the freshwater discharge being at a 10 year low. Consequently, the major area of influence was much reduced, not extending much south of the Virginia-North Carolina state line. Based on Landsat data we know that wind changes the direction, shape, and size of the plume and, therefore, its area of influence. The plume may also move 10 to 20 km northeast of the bay mouth because of southwesterly winds. Likewise, longshore drift and upwelling across the shelf may modify the plume and its area of influence.

5. With only limited historical perspective, the Chesapeake Bay may be a chronic contributor of contaminants, particularly hydrocarbons and biostimulants, to the shelf waters. Thus, with ever increasing human population concentrations around the Bay, the loading from the Bay to shelf waters may be increasing. Such chronic and possibly increasing loading of shelf waters should have an impact on living marine resources.

SECTION V. RECOMMENDATIONS

The following section indentifies recommendations based upon the result of the initial year of the NEMP Program. Many of these recommendations have been submitted by the program's principal investigators, to the NEMP management team as potential areas of improvement or expansion of the scope of the program. While many of the recommendations will be implemented within the existing program, others will require higher authority as well as additional resources to implement effectively in the near future.

In terms of managing ocean disposal, NOAA should consider approaching EPA and the United States Coast Guard (USCG) with a proposal for directing dumping operations at the 106-Mile Dumpsite to specific water masses, rather than to preselected geographical locations. NOAA can monitor satellite infrared imagery or the derived charts of front and eddy positions and advise EPA, USCG, and the dumping contractors of the water mass locations on a regular basis, i.e. each week. However, EPA would have to modify the dumping permits to accommodate this operational guidance, and USCG, which has the mission responsibility of monitoring the locations of dumping, would need to modify its operational instructions accordingly.

The scientific rationale for this recommendation is based on the recognition that the Shelf Water mass is the least desirable recipient of chemical wastes, because of the greater abundance of organisms harvested by commercial and sport fishermen in that mass compared to the other two frequently found at the site (Slope Water and Gulf Stream Eddy water).

Much closer attention must be paid to the description and definition of effluent plumes entering the coastal waters of the Middle Atlantic Bight and to the flux of dissolved and suspended materials they carry. Studies such as SUPERFLUX, which is concerned with the plume from Chesapeake Bay, should be conducted in the offings of Delaware Bay, the Hudson-Raritan estuary, and other embayments receiving pollutants via terrigenous export and dumping or discharges.

The principal pathways into coastal waters followed by organic and inorganic nutrients derived from terrestrial processes, including man's activities, are the effluent plumes from estuaries. Heavy loads of such materials can be considered pollutants, because they stimulate over-abundant phytoplankton populations and excessive primary production, possibly leading to anomalously high oxygen demands and eventually hypoxic conditions and fish kills, such as that experienced in 1976 off New Jersey. In addition, the same pathways are followed by other contaminants, including toxic substances, whose impacts are not as dramatic or well known, but nevertheless may be as significant.

Results from descriptive-baseline monitoring programs such as NEMP must be used to identify and define areas where additional baselines and "process-oriented studies" are needed to "explain" and provide further insight into marine environmental problems which can only be managed through an appropriate scientific data base.

Continued shelf-wide descriptive baseline studies of in situ heterotrophic mineralization of organic matter and concomitant release of nutrients are needed before an accurate assessment can be made concerning the relative roles played by estuarine/neritic and slope water sources of nutrients in supplying the nitrogen required by the very productive phytoplankton communities throughout the Cape Hatteras-Nova Scotia shelf system (section 4.2 in O'Reilly et al., 1980).

Particular attention must be paid to nutrient and primary productivity data collected during the summers of 1979 and 1980. The discharge of freshwater from Mid-Atlantic Bight estuaries into the NEMP coastal region was generally reduced during the summer of 1980 than in 1979. The latter represents the first year of intensive (10 surveys/year) shelf-wide Ocean Pulse surveys of the distribution of nutrients and primary productivity. These data as well as the New York Bight water column monitoring surveys, and certain EPA results (1978 and 1979) represent a baseline for comparison against 1980 data. Comparisons of coastal standing stocks of nutrients, phytoplankton biomass, and organic production and bottom dissolved oxygen levels measured in the summer of 1979, with those measured in summer 1980, begin to provide insight into the relative role played by estuarine nutrient and anthropogenic sources in stimulating phytoplankton production.

Results from the work by NEMP in surveying trace metal levels in sediments have pointed out the unexpected presence of shelf areas [near the shelf break off Block Island, (mud patch)] which have relatively high levels of metals. Further sampling in and around these areas is needed to quantify the area encompassed by high trace metal concentrations. Similar patches, large areas having relatively high trace metal levels may exist elsewhere on the shelf but have gone undetected with the present Ocean Pulse station pattern. A one-time survey should be conducted, with sampling intensity approaching 300-400 stations/shelf, an intensity slightly greater than the NEFC MARMAP I effort. If a survey similar to the Gulf-Atlantic Survey (GAS I, Albatross 80-01) of hydrocarbon contamination distribution in fish tissue and sediments is planned, then a complimentary intensive sampling of sediments for trace metals and hydrocarbons should be conducted.

A plethora of data on coliform/fecal coliform abundances is being generated by city, state, and Federal agencies in relation to the sanitary quality of inshore areas of interest. It will be essential for these data to be included in the overall NEMP benchmark data assemblages.

Special recommendations are based upon the initial benthic community studies. With the entire NEMP region covered by 33 benthic stations, sampled only semiannually, it becomes very important to occupy each station on every cruise. Ideally, the summer and winter cruises should have additional time available to allow for any mechanical and weather problems. Addition of new activities to cruises should be avoided until more ship and personnel time is made available. Also, it has been recommended that present benthic stations not be relocated or deleted without good cause, since benchmarks have now been established.

Variability in the benthic data is in part real and in part due to imprecise station relocation between grabs and between cruises. To minimize variability, navigation should be as accurate as possible, to 0.1 minutes of latitude and longitude (or preferably to identical Loran C coordinates), with repositioning between individual grabs, if necessary. In areas where topographic features, such as swales, are an important characteristic of a station, depth finders should be used to aid in station-finding, and 1 to 2 hours should be allotted for exploratory sampling to locate the pertinent sediment or faunal features. A precision depth recorder must be used to pinpoint the topographic features. Depth and exact position should be recorded for each successful grab. Trawling should be conducted to avoid the benthic stations. Bridge personnel can be of great assistance in the solution of station location problems, as would additional shiptime devoted to the benthic sampling.

Integration of data sets from the various chemistry, benthic, and sediment projects has begun and must be increased to give the Program the interdisciplinary cooperation and coordination mandated for it.

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APPENDIX B

NEMP Principal Investigators, 1980-1981

PI	Organization	Investigation Titles
Reid. R.	NOAA, NMFS	Benthic community structure monitoring
Reid R. White, H.	NOAA. NMFS NOAA, OAS	New York Bight benthic monitoring
Alden, R. Dauer, D.	Old Dominion Univ.	Chesapeake dumpsite benchmarks
Larsen, P. Doggett, L.	Bigelow Lab.	Northern Gulf of Maine benthic monitoring
Harris, L.	Univ. of New Hampshire	Southern Gulf of Maine benthic monitoring
Mauer, D. Howe, S.	Univ of Delaware	Delaware Bay benthic monitoring
Cooper, R.	NOAA, NMFS	Diving assessment and monitoring
Lear, D.	EPA (NOAA)	Dumpsite monitoring
Steimle, F.	NOAA, NMFS	Benthic energetics monitoring and analysis
Phoel, W.	NOAA, NMFS	Seabed respiration monitoring
Fallon, P.	GEOMET Tech. Inc.	Sediment analysis
Lindsay, J.	Quantitative Ecology, Inc.	Benthic macrofauna analysis
Maurer, D.	Univ. of Delaware	Analysis of Georges Bank benthos
Olla, B.	NOAA, NMFS	Behavior of stressed organisms
Buckley, L.	NOAA, NMFS	Larval fish physiology and biochemistry
Calabrese, A.	NOAA, NMFS	Physiological and biochemical pollutant stress

APPENDIX B continued

PI	Organization	Investigation Titles
O'Reilly J.	NOAA, NMFS	Water column chemistry, chlorophyll and productivity monitoring
Warsh, C. Whitledge, T.	NOAA, OAS Brookhaven	New York Bight water column monitoring
Brooks, J.	Texas A&M Univ.	Organic contaminant monitoring at DWD 106
Boehm, P.	ERCO, Inc.	Hydrocarbon contaminants of plankton at DWD 106
Marshall, H. Cohn, M.	Old Dominion Univ. NOAA, NMFS	Phytoplankton community monitoring
Bisagni, J.	NOAA, OMPA	Water mass and circulation monitoring at DWD 106
Gadbois, Dk.	NOAA, NMFS	Hydrocarbon analysis
Hargroves, P.	Univ. of Rhode Island	Phytoplankton grids
Longwell, A.	NOAA, NMFS	Cytology and cytogenetics of marine organisms
Murchelano, R.	NOAA, NMFS	Disease and environmental stress of fish
Johnson, P.	NOAA, NMFS	Benthic crustacean pathobiology
MacLean, S.	NOAA, NMFS	Pelagic crustacean pathobiology
Stolen, J.	Drew Univ.	Immunocompetence of fish
Sawyer, T.	NOAA, NMFS	Histopathology of rock crabs
Burn, P.	Osborne Lab. NY Zool. Soc.	Parasitology of flounder

APPENDIX B, continued

PI	Organization	Investigation Titles
Essers, S.	N. J. Marine Science Consortium	*Ceratium* monitoring
Chang, S.	NOAA, NMFS	Statistical analysis
Godshall, F.	NOAA, EDIS	Data archival and management
Thomas, J.	NOAA, NMFS	Biological oceanography of stressed ecosystems
Harris, R.	VIMS	Analysis of metals in Chesapeake plume suspended sediments
Kator, H. Zubkoff, P.	VIMS	Analysis of bacterial biomass and heterotrophy of Chesapeake plume
Munday J.	VIMS	LANDSAT analysis of Chesapeake Bay plume
Campbell, J.	NASA	Remote sensing of Chesapeake Bay plume
Wade, T. Oertel, G.	Old Dominion Univ.	Analysis of suspended particulate hydrocarbons
Wong, G.	Old Dominion Univ.	Analysis of nutrients in Chesapeake Bay plume
Vukovich, F.	Research Triangle Institute	Analysis of satellite imagery of Chesapeake Bay area
Ruzecki, J.	VIMS	Physical oceanography of Chesapeake Bay plume
Klemas, V.	Univ. of Delaware	Remote sensing of Delaware Bay
Wethe, C.	Univ. of Delaware	Analysis of dissolved organic carbon and nitrogen

APPENDIX C
LIST OF NEMP REPORTS FOR 1980

NEMP REPORT NO.	AUTHOR	REPORT TITLE
NEMP-I-80-H-0001	Howarth, R.F.	Measurements of Ocean Spectral Irradiance for Correlation with Satellite Remote Sensing
NEMP-I-80-H-0002	Wong, George T.F.	Salinity and Nutrient Data from R/V DELAWARE II and R/V KELEZ to the Virginian Shelf
NEMP-III-80-B,F,G-0003	Millett, N. Whitledge, T. Warsh, C.	Northeast Water Column Monitoring
NEMP-I-80-H-0004	Wade, Terry L. Oertel, George F.	Hydrocarbons Associated with Suspended Materials
NEMP-III-80-C-0005	Ingham, M.C.	Circulation and Water Masses in the NEMP Area - October 1979 - September 1980
NEMP-III-80-H-0006	Thomas, James P. Robertson, Craig N.	Biological Oceanography of Stressed Ecosystem, Total Plankton Respiration and Remote Sensing
NEMP-III-80-A-0007	Nagle, James Stolen, Joanne	Monitoring the Immunocompetence of Fishes in Both Normal and Contaminated Locations Along the Atlantic Coast
NEMP-III-80-B.C.-0008	Sick, Lowell V. Johnson, Connie C.	Distribution and Partitioning of Trace Metals in the Gulf of Maine
NEMP-III-80-A-0009	Sawyer, T.K. Lear, D.	Microbial Ecology and Parisitology Philaledphia Dumpsite, Crab Histopathology
NEMP-III-80-A-0010	Sawyer, T.K.	Black Gill Disease in Rock Crabs, *Cancer irroratus*
NEMP-III-80-G-0011	Reid, R. Steimle, F. MacKenzie, C.	Coastal Ecosystems Investigation
NEMP-I-80-F-0012	Steimle, F., et al	Hydrographic Data, Ocean Pulse Environmental MOnitoring Surveys, April 1978 through April 1980

NEMP REPORT NO.	AUTHOR	REPORT TITLE
NEMP-III-80-A-0013	Phoel, W.	Seabed Metabolism Subunit of Biological Oceanography
NEMP-III-80-G-0014	Pecci, K. Hulbert, A.	Manned Undersea Research and Technology
NEMP-III-80-A,B,G-0015	O'Reilly, J.E. et al	Baseline studies on the distribution of phytoplankton biomass, organic production, seawater nutrients and trace metals in coastal water between Cape Hatteras and Nova Scotia
NEMP-III-80-A-0016	Olla, Bori L.	Behavior of Marine Fishes and Invertebrates
NEMP-III-80-A-0017	Newman, Martin W.	Disease and Stressed Environments -- Skeletal Anomalies of Ammodytes
NEMP-III-80-A-0018	Murchelano, R.	Disease and Stressed Environments -- Diseases of North Atlantic Groundfish
NEMP-III-80-H-0019	Munday, John C. Fedosh, Michael S.	Landsat Analysis of the Dynamics of Chesapeake Bay Plume on the Continental Shelf
NEMP-III-80-G-0020	Marshall, Harold Cohn, Myra	Phytoplankton in the U.S. Northeastern Shelf Waters
NEMP-I-80-G-0021	Marshal, Harold	Phytoplankton Distribution Along the Eastern Coast of the USA Part III: Checklist of Phytoplankton
NEMP-I-80-G,H,0022	Marshall, Harold	Phytoplankton Composition in the Chesapeake Bay Plume. II. June 1980
NEMP-III-80-G-0024	Marshall, Harold Cohn, Myra	Phytoplankton Community Structure in Northeastern Waters of the United States I. October 1978
NEMP-III-80-A,B-0026	McLean, Sharon	Comparative Shellfish Pathology; Deepwater Dumpsite 106 (DWD 106); Biological Effect of Ocean Dumping

NEMP REPORT NO.	AUTHOR	REPORT TITLE
NEMP-III-80-A-0027	Longwell, A.	Reproductive Success of Commercial Fish Species Relative to Natural Environmental Variables and to Ocean Pollution as Measured Cytologically and Cytogentically on Their Eggs Prior to and After Spawning
NEMP-III-80-B,G-0028	Lear, Donald	Ecological investigations at the Philadelphia sewage sludge site and Dupont acid waste site
NEMP-II-80-G-0029	Larsen, P.F Doggett, L.F.	Benthic Monitoring in the Northern Gulf of Maine
NEMP-III-80-H-0030	Klemas, V.	Remote Sensing of Coastal Water Properties
NEMP-III-80-A-0031a	Kern, Fred G.	Comparative Shellfish Pathology - Ocean Mollusk Pathology
NEMP-III-80-H-0031b	Kator, Howard Zubkoff, Paul	An Assessment of Bacterial Biomass and Heterotrophic Potential in Water Samples from the Chesapeake Bay Plume and Atlantic Continental Shelf
NEMP-III-80-A-0032	Johnson, P.T.	Comparative Shellfish Pathology, Histopathological Survey of Benthic Amphipods
NEMP-III-80-H-0033	Harris, Richard	Metal Distributions in Suspended Sediment in the Chesapeake Bay Plume and Adjacent Atlantic Continental Shelf
NEMP-III-80-G-0034	Harris, L., et al	Community Structure of the Macrobenthos of Pigeon Hill in the Gulf of Maine: A Baseline Report, 1978
NEMP-III-80-G-0035	Hargraves, Paul	Manual of Marine Plankton Diatoms for the Northeastern Coast of the United States - Program Report
NEMP-III-80-B-0036	Gadbois, Donald	Ocean Pulse Analysis of Petroleum Hydrocarbons and Polychlorinated Biphenyls in Marine Samples

NEMP REPORT NO.	AUTHOR	REPORT TITLE
NEMP-III-80-G-0037	Cooper, Richard	Georges BAnk and Submarine Canyon Living Resources and Habitat Baselines in Proposed Drilling Areas
NEMP-III-80-E-0038	Chang, Sukwoo	Environmental Statistics and Data Management
NEMP-III-80-H-0039	Campbell, Janet	Chesapeake Bay Plume Studies: Remote Sensing of Chlorophyll, Seston and Fronts
NEMP-III-80-A-0040	Calabrese, Anthony et al	Phsiological Effects of Pollutant Stress
NEMP-III-80-A-0041	Burn, Peter R.	Effects of Environmental Quality on Parasitism in the Winter Flounder, Pseudopleuronects americanus, and their Implications for Ecological Monitoring
NEMP-III-80-A-0042	Buckley, L. Laurence, G.	Larval Fish Physiology Biohemistry
NEMP-III-80-B-0043	Brooks, J.	Chemical Studies at the DWD-106
nemp-III-80-A-0044	Brooks, J. Schwab, C.	Laboratory Phytoplankton Toxicity Studies at the DWD-106
NEMP-III-80-B-0045	Boehm, Paul	Gulf and Atlantic Survey (GAS I): Cape Hatteras to Gulf of Maine Survey for Selected Organic Pollutants in Finfish and Benthic Animals.
NEMP-III-80-B-0046	Boehm, Paul	New York Bight Benthic Sampling Survey: Corprostanol, Polychlorinated Biphenyl and Polynuclear Aromatic Hydrocarbon Measurements in Sediments
NEMP-III-80-H-0047	Vukovich, Fred Cross,am, Bobby	Monitoring the Chesapeake Bay Using Satellite Data
NEMP-III-80-A-0048	Bodammer, Joel	Disease and Stressed Environment -- Ultrastructural Anomalies in Fish Tissues
NEMP-III-80-C-0049	Bisagni, J. Behie, G.	Water Mass Changes and Circulation Patterns in the Vicinity of the 106 Mile Industrial Waste Dumpsite

NEMP REPORT NO.	AUTHOR	REPORT TITLE
NEMP-III-80-A-0050	Alden, R.W. III Dauer, D.M. and Rule, J.H.	An assessment of the ecological impacts of open ocean disposal of materials dredged from a highly industrialized estuary
NEMP-I-80-B,F-0051	Whitledge, T.E.	Water Column Monitoring Cruise I, New York Bight - 21-25 April 1980, Data Report
NEMP-I-80-B,F-0052	Whitledge, T.E.	Water Column Monitoring Cruise II, New York Bight - 2-6 June 1980, Data Report.
NEMP-I-80-B,F-0053	Whitledge, T.E.	Water Column Monitoring Cruise III, New York - 14-18 July 1980, Data Report
NEMP-1-80-B,F-0054	Whitledge, T.E.	Water Column Monitoring Cruise IV, New York Bight - 2-6 September 1980, Data Report
NEMP-III-80-A-0055	Esser, Stephen C.	Report on Netphytoplankton in coastal/shelf waters of the Atlantic Ocean
NEMP-III-80-A-0056	Farley, C.A.	Comparative Shellfish Pathology -- Molluscan Histopathology
NEMP-III-80-A-0057	Maurer, D.	Monitoring of Delaware Bay Benthos

EXPLANATION OF NEMP REPORTING NUMBER

NEMP	LEVEL	YEAR (FY)	TYPE of DATA	REPORT NO.
NEMP	I-IV	80	A-H	0000

NEMP - All documents sponsored by the Northeast Monitoring Program will have this Prefix.

LEVEL - Level I reports include monthly, bimonthly, quarterly and other information or status reports. It also includes raw data reports with little interpretation.

Level II reports include data reports with substantial interpretation as well as red flag and other "crisis" reports directed at higher levels of management.

Level III reports consist of reports and manuscripts which have considerable content and are ready for publication or which summarize a substantial data set or period of research endeavor by a particular investigation, work unit or discipline.

Level IV reports would be summaries and annual reports involving substantial amounts of effort by the entire program over a one year period.

TYPE OF DATA

Principal types of data or subject content are coded as follows:

A - Biological effects
B - Chemistry/contaminant loading
C - Physical forces
D - Geological information
E - Statistics/data processing *per se*
F - Hydrography (in classical sense)
G - Ecosystem dynamics/change
H - Remote sensing

REPORT NO -

Each NEMP report is assigned a sequential number.

APPENDIX D

Some NEMP external interactions during FY 80

Agency or Institution	NEMP PI	Type of Interaction
EPA, Edison, NJ	R. Reid	We used Clear Water to collect samples during drought effect survey
EPA, Narragansett, RI	A. Calabrese	Cooperative study on blue mussels
EPA, Edison, NJ	F. Steimle	Data exchange during summer anoxia monitoring
EPA, VA	J. Thomas	Cooperation during NEFC Superflux Experiment
US Army Corps of Eng. (NY)	R. Reid	Cooperated on caged mussel study at NY Bight dredge spoil ocean dumpsite
Corps of Eng. (Boston)	F. Steimle	We supplied sediment samples for bioassays.
Corps of Eng. (Norfolk)	M. Lockwood	Cooperative grant with the Dept. of Biology (Old Dominion Univ) to study benchmark conditions at dredge spoils disposal site (covered under contract?)
US Coast Guard	R. Reid	Cooperated in simulated oil spill response experiment
NJ Dept. Env. Prot.	R. Reid	Cooperated on response to Raritan Bay oil spill
NJ Dept. Env. Prot.	F. Steimle	Data exchange during summer anoxia monitoring.
NJ Dept. Env. Prot.	S. Chang	Provided advice on freshwater tagging project.
NJ Dept. Env. Prot.	C. P. Farley	Shellfish pathology and mutagenesis testing.
Skidaway Inst. (GA)	R. Reid	We provided samples for PCB analysis.
Fairleigh Dickinson U.	R. Reid	Cooperated on resurveying benthic stations in Raritan Bay
Woods Hole Oceano. Inst.	R. Reid	Provided samples of organisms for analysis

(continued)

Agency or Institution	NEMP PI	Type of Interaction
Brookhaven Nat. Lab.	J. O'Reilly	Intercalibration
Brookhaven Nat. Lab.	R. Reid	Cooperated in Hudson River plume study
Brookhaven Nat. Lab.	C. Warsh	Grant for water column analysis (contract?)
U.S. Navy, Naval Underwater Systems Lab., Groton, CT	F. Steimle	Provide hydrographic data from Ocean Pulse cruises to plan experiment.
BLM	J. Pearce, F. Steimle, R. Reid	Cooperated in developing biological monitoring plan for oil drilling activity on Georges Bank.
Maryland State Dept. Nat. Resources	J. Thomas	Superflux cooperation
NASA, Wallops Island Center	J. Thomas	Remote sensing support of Superflux experiment
Chesapeake Bay Inst.	J. Thomas	Superflux cooperation
Nat. Inst. Health	S. Chang	Provided advice on multifactor biomassay problems.
Michigan State U.	S. Chang	Multifactor bioassay
Utah State U.	S. Chang	Consulting on software
NJ Mar. Sci. Cons.	J. O'Reilly	Trained personnel in primary productivity techniques
U. of Swansea, Wales, U.K.	C.P. Farley	Mutagensis testing
Maine Dept. Mar. Fish.	C.P. Farley	Shellfish pathology
Mass. Div. Mar. Fish.	C.P. Falrey	Shellfish pathobiology
Food & Drug Adm. Davisville, RI	T.K. Sawyer	Microbiology
Amer. Type Culture Collection, Rockville, MD	T.K. Sawyer	Biochemical and taxonomic studies on pathogenic amoebae

(continued)

Agency or Institution	NEMP PI	Type of Interaction
Communicable Disease Center, US Publ. Health Service, Atlanta, GA	T.K. Sawyer	Taxonomic and immunological studies on pathogenic amboebae
Univ. Maryland	T.K. Sawyer	Taxonomic studies on parasitic protozoans of oysters
NC Museum of Natural History	T.K. Sawyer	Taxonomic studies on fouling protozoa of crustacean gills

APPENDIX E - LIST OF ACRONYMS AND ABBREVIATIONS USED WITHIN THIS REPORT

ATP	Adenosine triphosphate
BOD	Biological oxygen demand
°C	Degrees Centigrade
C-14	Carbon 14
CEQ	Council on Environmental Quality
CNO	Carbon, nitrogen, oxygen
COD	Chemical oxygen demand
CY	Calendar year
DDE	Dichlorodiphenylethene
DDT	Dichlorodiphenyltrichloroethane
DNA	Deoxyribonucleic acid
DOC	Dissolved organic carbon
DON	Dissolved organic nitrogen
EPA	Environmental Protection Agency
FDA	Food and Drug Administration
GAS	Gulf and Atlantic Survey
$gC/m^2/yr$	Grams carbon per square meter per year
ICES	International Council for Exploration of the Sea
kHz	Kilohertz
km	Kilometer
l	Liter
m	Meter
MARMAP	Marine Resource, Monitoring and Prediction
MDH	Malate dehydrogenase
mg/l	Milligram per liter
mgC/l	Milligrams carbon per liter
ml	Milliliter
ml/l	Milliliters per liter
$ml/l\text{-}d^{-1}$	Milliliters per liter per day
$mlO_2/m^2\text{-}hr^{-1}$	Milliliters oxygen per square meter per hour
MT	Metric ton
NASA	National Aeronautics and Space Administration
NEFC	Northeast Fisheries Center
NEMP	Northeast Monitoring Program
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NYB	New York Bight
OA	Oceans and Atmospheres
OMPA	Office of Marine Pollution Assessment
O:N	Oxygen Nitrogen ratio
PAH	Polynuclear Aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PHC	Petroleum Hydrocarbon Componenents
PI	Principal Investigator
POC	Particulate organic carbon
PON	Particulate organic nitrogen
ppb	Parts per billion
ppm	Parts per million

APPENDIX E, continued

PSP	Paralytical shellfish poisoning
RNA	Ribonucleic acid
RD	Research and Development
TKN	Total Kjeldahl nitrogen
TOC	Total organic carbon
TON	Total organic nitrogen
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USCG	United States Coast Guard
WSF	Water soluable fraction
0/00	Parts per thousand
ug/l	Micrograms per liter
ug/mg	Micrograms per milligram
u mole NH_3/m^2-hr^{-1}	Micromoles ammonium per square meter per hour
um	Micrometer

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