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Contaminants in New York Bight and Long Island Sound Sediments and Demersal Species, and Contaminant Effects on Benthos, Summer 1980

Robert N. Reid, John E. O'Reilly,
and Vincent S. Zdanowicz, eds.

Sandy Hook Laboratory, National Marine Fisheries Service, Highlands, NJ 07732

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

Woods Hole, Massachusetts

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EXECUTIVE SUMMARY

In July 1980, as part of its Northeast Monitoring Program, NOAA's National Marine Fisheries Service (NMFS) and Oceanic and Atmospheric Services began a program of annual (summer) surveys of bottom sediments and organisms to monitor fates and effects of contaminants in the New York Bight. This report discusses the rationale, objectives and methodology, and results of the first survey. The sampling plan was largely developed by NOAA's Marine EcoSystems Analysis (MESA) program. Forty-four stations were sampled; 23 of these had been occupied in the 1973-74 surveys of the inner Bight which had been conducted by NMFS for MESA. The following measurements were made: sediment grain size; sediment concentrations of total organic carbon, total Kjeldahl nitrogen, coprostanol, heavy metals, polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs); trace metals, PAHs and PCBs in muscle of sea scallop, rock crab, lobster, red hake, winter and windowpane flounder; distribution/abundance of benthic macrofauna, human artifacts (such as tomato and melon seeds), viruses, and pathogenic and sewage-indicator bacteria; and the occurrence of gill-clogging agents in rock crabs.

For those variables which had been studied previously in the Bight, our results were in general agreement with the earlier work. Fine sediments were largely confined to the Christiaensen Basin and Hudson Shelf Valley. Concentrations of sediment contaminants were highly correlated with percentages of fine material in the sediments. Contaminant concentrations reached maxima in the sewage sludge accumulation area and at the dredge spoil dumpsite. Secondary maxima were often seen in the "Mud Hole" in the upper Hudson Shelf Valley. Contaminants in demersal biota did not appear to be in concentrations sufficient to cause concern for human health; body burdens were elevated compared to reported concentrations outside the Bight, however. Within our sampling area, there were usually no significant differences between levels of contaminants in tissues from the more contaminated inner bight and from cleaner offshore sites.

Pathogenic and sewage-indicator bacteria were more prevalent in shellfish from contaminated portions of the inner Bight. Indicator bacteria and viruses in sediments followed patterns similar to those for sediment contaminants. Incidence of gill fouling in rock crabs was lower than in previous studies, but this was in part related to our small sample sizes. Notable features of benthic macrofauna distribution/abundance included a small but highly impacted area, centered just west of the sewage sludge dumpsite, dominated by the classic organic enrichment indicators, the polychaetes *Capitella* spp.; an "enriched" zone surrounding this area and covering much of Christiaensen Basin, characterized by a paucity of crustaceans and high densities of several polychaetes, a small bivalve and an anthozoan; and an apparently unaffected amphipod-dominated assemblage which first appeared 45-50 km SE of the dumpsites, in the mid-Hudson Shelf Valley.

Comparison of 1980 faunal results with the 1973-74 data indicates the enriched zone may have spread since that time, although preliminary inspection of 1981 data does not confirm this trend. No other faunal variables examined (density, diversity, species richness, community structure, or distribution/abundance of amphipod crustaceans) revealed distinct changes from the early 1970s. The same was also true for sediment concentrations of organic carbon, heavy metals and coliform bacteria. In addition to permitting historical comparisons, the data established benchmarks against which future changes in contaminant concentrations and effects in the Bight may be measured.

1.0 INTRODUCTION

The New York Bight (NYB-Fig. 1) is an important natural resource for millions living in the densely populated areas which border it. Commercial shipping and fishing, and recreational swimming, fishing and boating, are among its most important uses. The Bight also serves as a receptacle for large quantities of barged sewage sludge and dredge spoils, and wastes introduced via the Hudson-Raritan estuarine system. Other estuaries, vessel discharges, local outfalls and atmospheric fallout are additional pollutant sources (Gross 1976).

These contaminant inputs have made the NYB one of the world's most heavily polluted open coastal water bodies. Some effects of this contamination have been clearly documented: buildup of organic carbon and metals in sediments; altered benthic (bottom) communities consisting of a few pollution-tolerant species; increased incidence of finrot compared to less impacted areas; closure of shellfishing grounds due to high bacterial counts; and development of tolerance to high concentrations of trace metals and antibiotics in some bacteria (Swanson 1977).

Contamination of the NYB may be leading to other, more subtle effects, although here the data are less conclusive. Waste inputs have definitely promoted eutrophication of the inner Bight and associated estuaries. This eutrophication may contribute to dissolved oxygen reductions, which are sometimes accompanied by mortalities of valuable fin- and shellfish. Migratory routes of some species may be altered. Uptake of contaminants by biota could lead to effects at the population level, to the spread of contaminants beyond the NYB, or to possible health hazards to humans consuming large quantities of fin- or shellfish. Introduction of pathogens could have impacts on consumers (and swimmers) beyond those noted above as associated with shellfish bed closures.

To manage effectively the NYB and its resources, it is therefore essential to increase our understanding of fates and effects of contaminants. Ideally, we should quantify the relative contributions of estuarine runoff, sewage sludge, dredged materials and background sources of pollution to the levels of sediment contamination and biological effects measured in the Bight. The extent to which the Hudson Shelf Valley (HSV), extending from the Christiaensen Basin (CB) to the edge of the continental shelf (Fig. 1), serves as a conduit for contaminants should be documented. If the sludge dumpsite is moved from the inner NYB to a deepwater site 106 miles from New York City, there will be an opportunity to study recovery of the present dumping area and to determine whether the increased costs of barging the sludge to more remote dumpsites are justified. Management of future waste inputs will rely more heavily on the concept of accommodative capacity, which attempts to predict what kinds of quantities of wastes can be introduced without unacceptable impacts. More and better data on contaminant fates and effects are needed to attain this predictive capability.

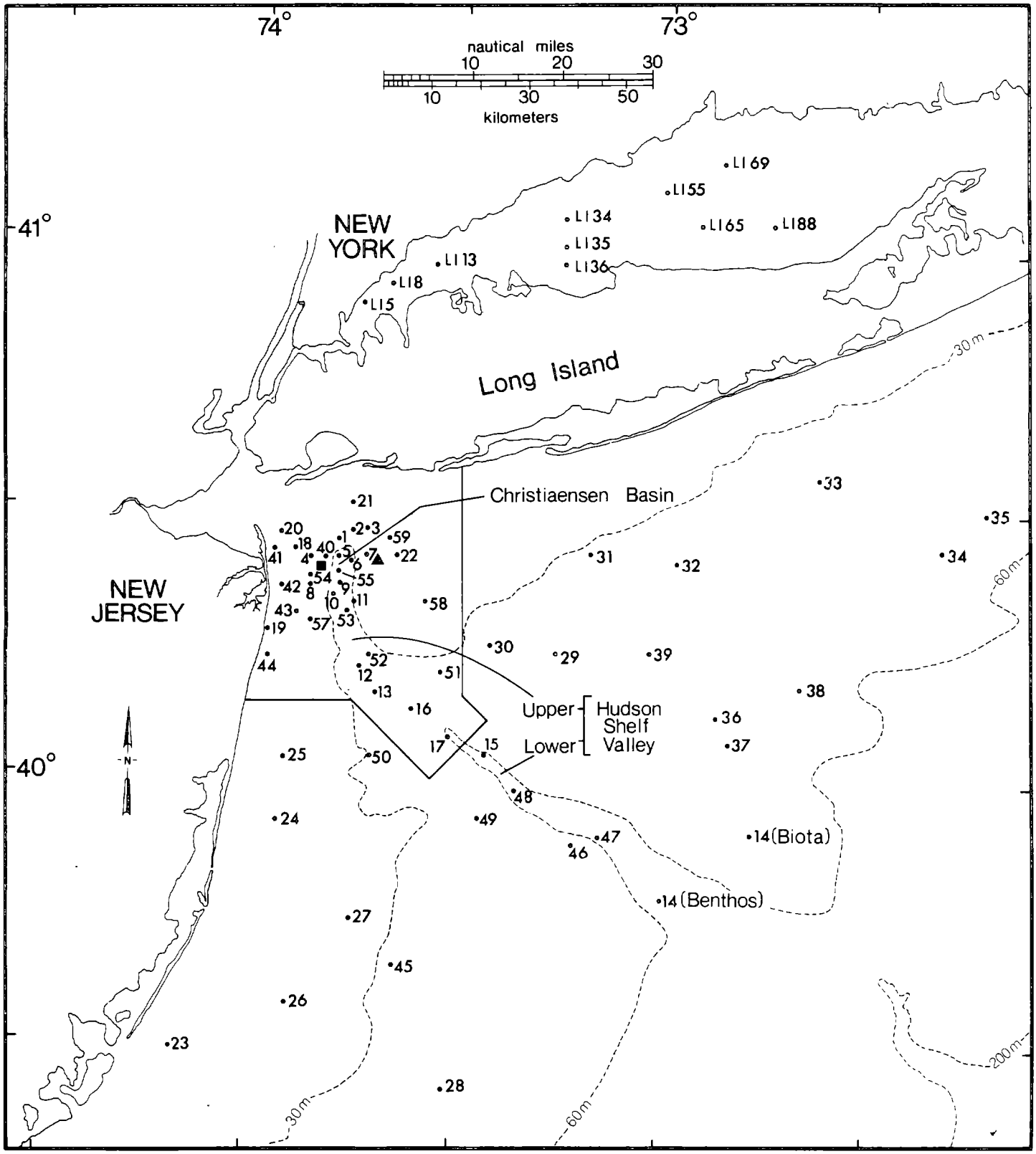

Figure 1. Station locations in New York Bight and Long Island Sound. Stations within box were a priori considered "contaminated" for comparison with other stations. "Replicate" stations (see text) are 4, 6, 7, 15, 26 and 31 (standard NEMP sites), and 40-43. Single grabs were taken at the remainder of stations 1-44. Higher-numbered stations were for body-burden samples only. ▲ = Sewage sludge disposal site; ■ = Dredged material disposal site.

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For many of these reasons, NOAA's National Marine Fisheries Service (NMFS) has been studying contaminant fates and effects in the NYB since the late 1960s. In 1972 NOAA established the Marine Ecosystems Analysis (MESA)-New York Bight Project, to review existing data on the NYB, to support studies to fill gaps in our understanding of the ecosystem and contaminant influences on it, and to design a program to monitor the NYB's condition. MESA's recommendations for monitoring centered on annual sampling of selected ecosystem components. Late summer was recommended for sampling; since the water column is relatively quiescent and scouring of the bottom is minimal at that time, areal distribution of contaminated materials should be greatest. It was also thought important to document conditions at the time when recreational use of the NYB was at a peak.

Variables identified by MESA as being effective monitoring tools include:

1) Trace metals, polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs) in selected fin- and shellfish species.[1] These contaminants should be monitored because of both possible ecosystem impacts and human health concerns (many are toxic when consumed in sufficient quantity; PCBs are suspected mutagens and carcinogens; PAHs are among the most toxic of hydrocarbons, and include mutagenic compounds).

2) Presence of pathogens (fecal streptococcus, Clostridium perfringens, Salmonella and Klebsiella spp.) and indicators of contamination (total and fecal coliforms), in the shellfish, largely to assess threats to human health;

3) Trace metals, PCBs, PAHs and coprostanol (the latter a sterol indicative of human sewage) in sediments, to determine whether contamination is increasing or spreading;

4) Fecal coliform bacteria, total organic carbon and human artifacts (such as tomato seeds) in sediments - these can indicate the presence of sewage sludge or other sewage-related materials;

5) Gill fouling in the rock crab - fouling by protozoans or foreign material may be another indication of anthropogenic contamination, and may also have implications for the health of populations of this ecologially important species;

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[1]Species recommended by MESA were winter flounder (Pseudopleuronectes americanus), windowpane flounder (Scophthalmus aquosus), summer flounder (Paralichthys dentatus), lobster (Homarus americanus), sea scallop (Placopecten magellanicus), and rock crab (Cancer irroratus). All these species are commercially sought and consumed by humans to at least some extent (except for windowpane, which is used mostly in a "trash", or industrial fishery). The flounders and lobster are also taken recreationally. The scallop is a filter feeder which integrates and may concentration water column contaminants. The remaining species are higher trophic level demersal or benthic feeders; they should reflect, and perhaps bioaccumulate, contaminants from the benthic organisms and/or sediments which serve as a sink for these contaminants. In practice, summer flounder could not be found over most of the study area, so red hake (Urophycis chuss), another demersal feeder with commercial and recreational uses, was substituted.

6) Abundance and community structure of benthic macrofauna, the small, relative invertebrates which are considered to be among the best indicators of biological effects of contamination (Boesch 1974; Swartz 1978).

To these recommended studies have been added analysis of sediment grain sizes (to help interpret observed contaminant and macrofauna patterns), sediment nitrogen (carbon/nitrogen ratios may indicate whether the source of the carbon is terrestrial or marine), and viruses in sediments and rock crabs (a potential health hazard, viruses can have a wider distribution or greater persistence than the various bacteria used to determine contamination of sediments and edible species).

The MESA plan's intent was to resurvey the above variables each summer, to detect any annual spatial or temporal trends in contaminant concentrations or impacts. Some aspects of the monitoring may change - for instance, MESA recommends measuring plutonium concentrations every three years. Work on contaminants in biota may concentrate alternately on burdens in muscle one year and in accumulative organs (i.e. kidney, liver) the next. Levels in edible flesh relate more directly to potential human health hazards, while the (generally higher) concentrations in the accumulative organs are more pertinent to ecosystem health. Variables sampled may change as some are found to be more effective than others in determining contaminant fates and effects, and as the state-of-the-art in this field develops.

In the 1980 survey, we sampled for most of the above variables along the east-west axis of Long Island Sound (LIS). Reduced funding, and the need to establish benchmarks in other portions of the NEMP region, will probably dictate curtailment of the LIS sampling and lowered overall effort in NYB in the near future.

2.0 SAMPLING PATTERN AND OVERALL METHODOLOGY

Most sampling was conducted aboard the NOAA Ship George B. Kelez from 28 July - 5 August 1980. Microbiological collections were supplemented with crabs and lobsters taken in September. Station locations are shown in Fig. 1. Loran C was used to locate stations.

The sampling pattern combines two philosophies. Based on earlier studies, the MESA monitoring plan divided the Bight into two "contaminated" strata (which included the CB and HSV) and nine uncontaminated strata. MESA recommended that most efficient monitoring of sediments and benthic macrofauna would be achieved by collecting single grab samples from two to four randomly-selected stations within each stratum. These stations are shown in Fig. 1.

This rationale was merged with that of the Northeast Monitoring Program (NEMP) to arrive at a final sampling plan. NEMP is a long-term, interdisciplinary program to monitor ecosystem health in continental shelf waters from Cape Hatteras to Canada; the program includes elements of NOAA's NMFS (the "Ocean Pulse" program), National Ocean Survey, and Office of Marine Pollution Assessment" (the MESA program). Since April 1978 Ocean Pulse, and more recently NEMP, have been occupying six benthic stations in the NYB (see "replicate" stations in Fig. 1) at which sediments, sediment metals, microorganisms and benthic macrofauna have been sampled on a quarterly or semiannual basis. Water column and sublethal biological effects phenomena have been monitored concurrently.

Unlike the MESA plan, NEMP benthic sampling is done at fixed stations and involves routinely analyzing five grabs per station for sediments, metals and macrofauna. To integrate the two sampling schemes, the six NEMP stations were substituted for the MESA-suggested stations nearest them. Replicate sampling was retained at these stations, and replicates were also taken at another four stations added to the sampling pattern between Sandy Hook and the dumpsites (Fig. 1) in an attempt to distinguish better dumpsite versus Hudson River plume influences. Thus a total of 10 replicate and 34 non-replicate stations was occupied in the NYB, although some disciplines sampled only a subset of these. Future sampling will be at most or all of these sites, rather than randomized. The LIS stations (Fig. 1) were those along the Sound's mud-bottom east-west axis which we have been sampling annually since 1972 (Reid 1979).

All bottom samples were taken with a 0.1 m^2 Smith-McIntyre grab. At the replicate stations, seven grabs were taken. A 2.7 cm inner diameter core was taken from each grab and frozen for trace metal analysis. Cores of the same size were taken from five of the grabs and frozen for sediment grain size, organic carbon and nitrogen measurements; the remainder of each of these grabs was then sieved for benthic macrofauna. Microbiological samples were taken from a sixth grab. Samples for PCB, PAH and coprostanol analysis (in jars which had been pre-rinsed with acetone and methylene chloride [glass-distilled, nanograde, Burdick and Jackson Co.[2]]) and for detection

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[2]Use of brand names does not imply endorsement by NOAA.

of viruses were collected from the final grab, which had been pre-rinsed. At non-replicate stations, three grabs were taken: one for sediment composition and macrofauna, one for microorganisms and one (pre-rinsed) for PCBs, PAHs, coprostanol and viruses. Cores for trace metals were collected from each of these grabs.

Fish and shellfish were collected using a 3/4 Yankee trawl or a two-meter-wide crab rake. Tows were 15-30 minutes at 2.5-3.5 knots. Tows were made at many of the bottom grab stations and in a number of other areas where concentrations of any of the six target species might be present (Stations 45-59 in Fig. 1). The objective was to obtain five or more composite samples, or blends of at least five specimens of each species, from "contaminated" and "uncontaminated" strata for comparisons of trace metal burdens, and a like number for PCB/PAH analysis. When sufficient numbers of a species were collected to form a composite, they were either dissected and frozen for analysis of trace metal concentrations in various organs, or wrapped in aluminum foil (pre-rinsed with acetone and methylene chloride) and frozen whole for measurement of PCBs and PAHs in muscle. Additional rock crabs were collected for the gill fouling studies recommended in the MESA plan and for supplemental work on metals in gills, carapace erosion, histopathology and viruses. Contour maps were generated using the SYMAP program (version 5), Harvard Center for Environmental Design Studies, Laboratory for Computer Graphics and Spatial Analysis. All regression lines are functional regressions which treat the variables on both axes as independent variables (Ricker 1973).

3.0 METHODS AND RESULTS OF SPECIFIC STUDIES

3.1 SEDIMENT GRANULOMETRY, ORGANIC CARBON AND NITROGEN

Mr. Robert Reid, NMFS, Sandy Hook Laboratory, Principal Investigator.

3.1.1 Methods

Grain size analysis of coarse sediments was based on a dry-sieving method (Ingram 1971). Pipette analysis (Galehouse 1971) was used for fines. Total organic carbon (TOC) was determined via a modified Schollenberger chromic acid oxidation technique (Walkley and Black 1934; Holme and McIntyre 1971), with 75-90% TOC recovery. Total Kjeldahl nitrogen (TKN) was measured by digestion/distillation followed by colorimetric determination (Standard Methods 1975).

3.1.2 Results

Values for the sediment variables analyzed are listed in Table 1. Grain size distributions have been presented in more detail elsewhere (Freeland et al. 1976; Freeland and Swift 1978). The summer 1980 data are included here chiefly for correlation with contaminant and biological variables. Distributions of silt (4-64 μm), clay (<4 μm), TOC and TKN are shown in Figs. 2-5, respectively.

The TOC distribution shows the previously documented pattern of higher concentrations in relatively depositional, fine-sediment areas such as the Christiaensen Basin (which is near the dumpsites) and the axis of the HSV (Gross 1976). The highest value in the Bight (34.0 mg/g) was found ~4 km south of the dredge spoil dumpsite. Most stations in sandy shelf areas had <1.0 mg/g TOC. The major exceptions were 12.0 at the station closest to western Long Island, 3.4-14.0 between the northern New Jersey shore and the dumpsites, and 3.4-3.9 at stations 34 and 35, which are both located more than 40 km off eastern Long Island. The correlation between fine sediments and TOC is demonstrated in Fig. 6 (correlation coefficient $r = 0.79$). Areas in which TOC was most elevated relative to percent clay were in the northern Christiaensen Basin: station 6, where much of the sewage sludge is ultimately deposited, and the nearby stations 9 and 40. (LIS data are not plotted; these sediments, with greater percentages of clay [9-39%] than the NYB sites, had consistently high TOC levels, ranging from 20-37 mg/g.)

A comparison of the NYB TOC data with concentrations measured in the inner NYB in 1971 and earlier years (Gross 1976) was presented in the Northeast Monitoring Program (1981) Annual Report. After correcting for methodological differences, no major changes in concentrations or distribution were noted in the high TOC area; the method is not sensitive enough to detect more subtle trends (see Section 5).

Table 1. Mean values for several sediment variables at New York Bight benthic stations, July-August 1980. See Figure 1 for station locations.

Station	Depth (m)	Mean grain size (phi units)	Sorting coefficient	Skewness	Kurtosis	% Silt (4-63 μm)	% Clay (<4 μm)	TOC (mg/g dry wt.)	TKN (mg/g dry wt.)
1	27	3.71	1.41	0.44	3.07	12.24	6.17	9.4	1.1
2	29	3.35	1.16	0.15	2.75	10.98	3.85	10.1	1.4
3	28	3.43	1.08	0.19	2.78	13.21	2.5	7.1	0.83
4 (=NEMP 16C)[1]	20	3.12	1.79	0.3	1.59	18.41	3.08	10.0	1.0
5	35	4.19	1.59	0.53	1.65	25.06	4.59	16.0	1.9
6 (=NEMP 16B)[1]	29	2.3	1.43	0.13	1.59	3.67	3.24	12.0	1.1
7 (=NEMP 16A)[1]	25	1.99	0.72	0.15	0.84	0.53	1.03	3.2	0.41
8	24	2.37	3.93	0.01	0.88	23.07	9.9	34.0	1.5
9	36	3.49	1.62	0.12	1.48	24.1	2.35	13.0	1.5
10	61	-0.24	1.64	-0.3	0.94	0.87	1.42	1.6	0.17
11	31	3.3	0.96	0.12	2.46	3.12	3.74	5.1	0.71
12	38	3.29	1.27	0.12	3.3	5.88	4.88	5.5	0.70
13	56	4.25	1.54	0.61	2.85	20.57	3.33	11.0	1.8
14	74	2.01	1.69	0.49	2.48	4.89	5.01	4.9	0.73
15 (=NEMP 33)[1]	67	3.45	1.31	0.27	3.25	8.4	8.07	9.6	1.5
16	71	4.68	1.83	0.67	0.83	28.98	7.92	15.0	2.2
17	73	3.62	1.34	0.4	3.35	9.12	8.36	11.0	1.5
18	24	2.22	2.73	0.13	1.22	14.81	4.01	14.0	1.1
19	14	1.76	0.6	0.26	0.97	0.3	0.71	0.86	0.15
20	12	1.96	0.71	0.06	0.8	0.18	0.8	0.95	0.17
21	21	3.15	1.4	0.14	2.21	8.17	4.96	12.0	1.5
22	24	3.07	0.63	-0.09	0.75	0.9	1.89	2.4	0.36
23	16	1.01	0.78	-0.17	0.89	0.05	0.37	0.46	0.09
24	18	-0.52	1.36	0.04	0.89	0.04	0.41	1.8	
25	19	0.26	1.37	-0.23	1.0	0.13	0.29	0.49	0.08
26 (=NEMP 17)[1]	26	1.44	0.71	-0.06	1.36	0.13	0.57	0.53	0.09
27	26	1.21	0.8	-0.18	1.18	0.1	0.54	0.58	0.10
28	40	2.27	0.56	-0.26	1.08	0.05	0.8	0.82	0.13
29	38	1.09	0.93	-0.18	1.12	0.04	0.75	0.63	0.13
30	34	1.86	0.72	0.1	0.88	0.14	0.89	0.81	0.16
31 (=NEMP 15A)[1]	31	1.3	0.75	-0.09	1.19	0.1	0.67	0.55	0.09
32	38	1.19	0.91	-0.19	1.17	0.12	0.63	0.51	0.14
33	40	2.37	0.82	-0.18	1.69	0.73	1.68	1.8	0.29
34	54	1.77	1.18	0.32	2.0	2.01	3.58	3.4	0.46
35	55	2.43	1.55	0.26	3.48	4.29	6.0	3.9	0.69
36	56	1.19	0.82	-0.15	1.12	0.19	0.83	0.81	0.15
37	54	1.41	0.87	-0.1	1.38	0.29	0.94	1.0	0.17
38	56	1.05	0.95	-0.19	1.08	0.63	1.25	1.1	0.17
39	42	1.42	1.0	-0.14	1.34	0.31	0.89	0.79	0.12
40 [1]	29	3.35	1.92	0.28	0.98	29.31	2.67	12.0	1.5
41 [1]	21	1.25	0.76	-0.28	1.49	0.08	0.54	0.3	0.05
42 [1]	13	0.27	1.98	-0.42	0.7	0.74	0.97	3.4	0.36
43 [1]	20	-0.19	1.53	-0.27	0.8	0.12	0.48	1.1	0.12
44	19	-0.2	1.24	-0.05	1.14	0.13	2.3	2.6	0.17
Long Island Sound									
5	28	6.92	2.18	.13	2.08	76.17	17.98	37	4.6
8	18	6.97	1.44	-.19	.97	70.57	26.81	36	4.8
13	18	5.69	1.95	-.09	1.03	74.32	8.36	30	4.2
34	24	6.66	1.65	-.18	.81	69.04	25.02	27	3.4
35	24	6.86	1.54	-.21	.95	68.63	26.82	28	4.0
36	16	6.08	1.99	-.38	1.12	75.09	9.02	28	3.6
55	24	6.34	1.38	-.16	.86	88.58	7.91	23	2.8
65	37	6.6	2.08	-.4	.76	46.2	38.85	20	2.6
69	21	6.3	1.53	-.1	.83	82.04	12.49	24	3.0
88	35	6.42	1.53	-.14	.84	79.54	15.13	24	4.0

e means of single analyses on each of five cores; other values represent single analyses.

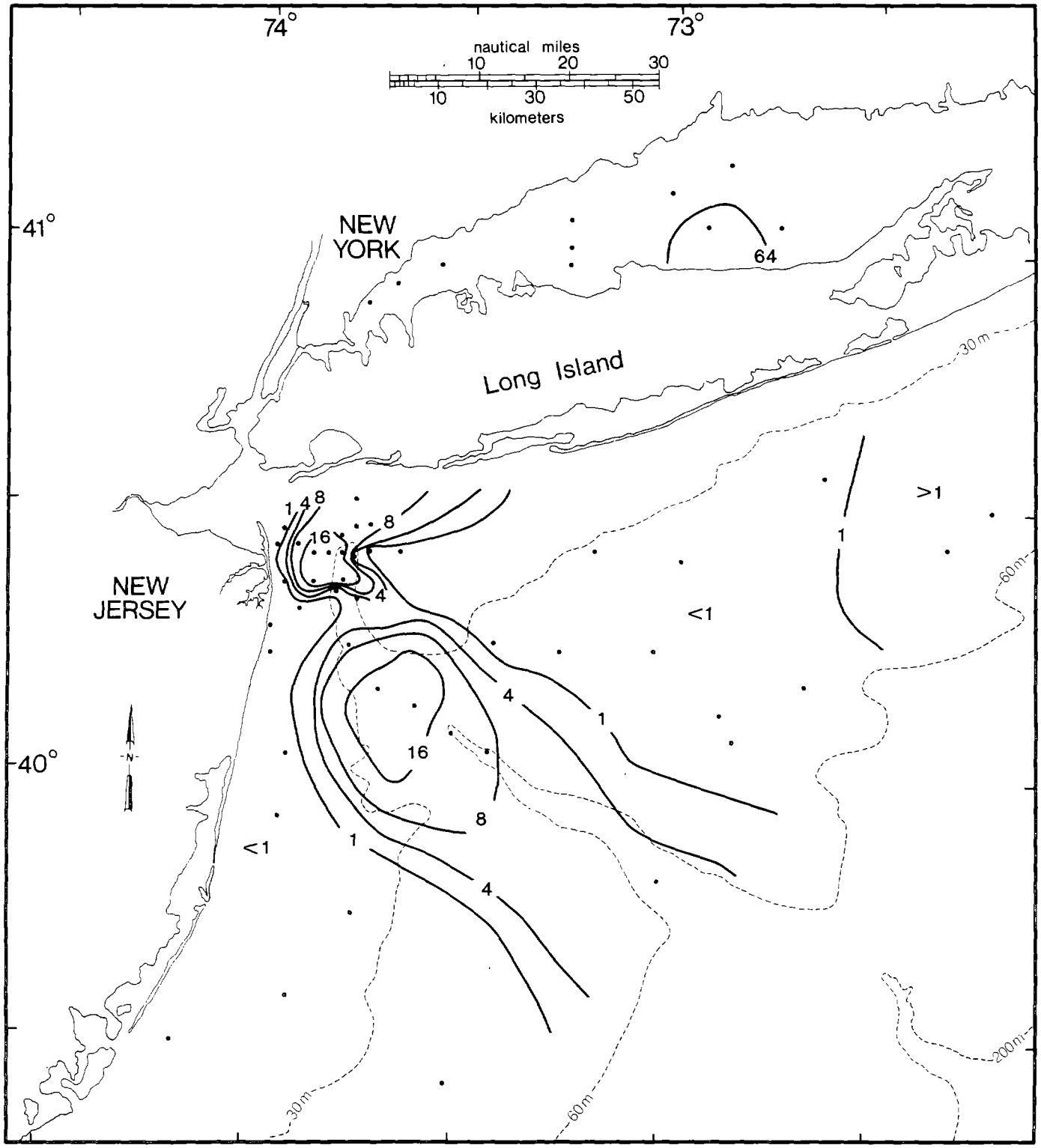


Figure 2. Percent silt (4-64 μm) in surface sediments.

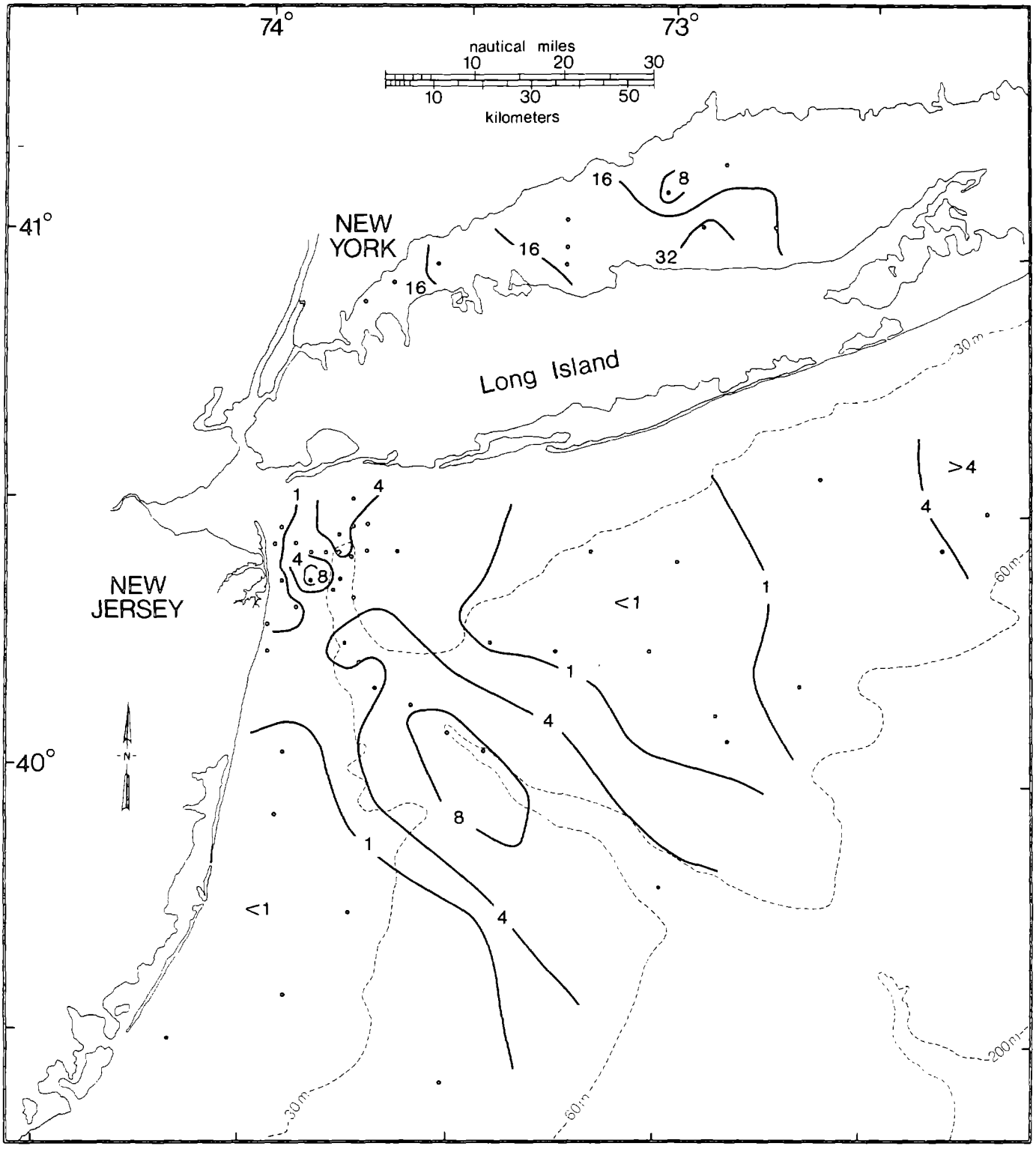


Figure 3. Percent clay (<4 μm) in surface sediments.

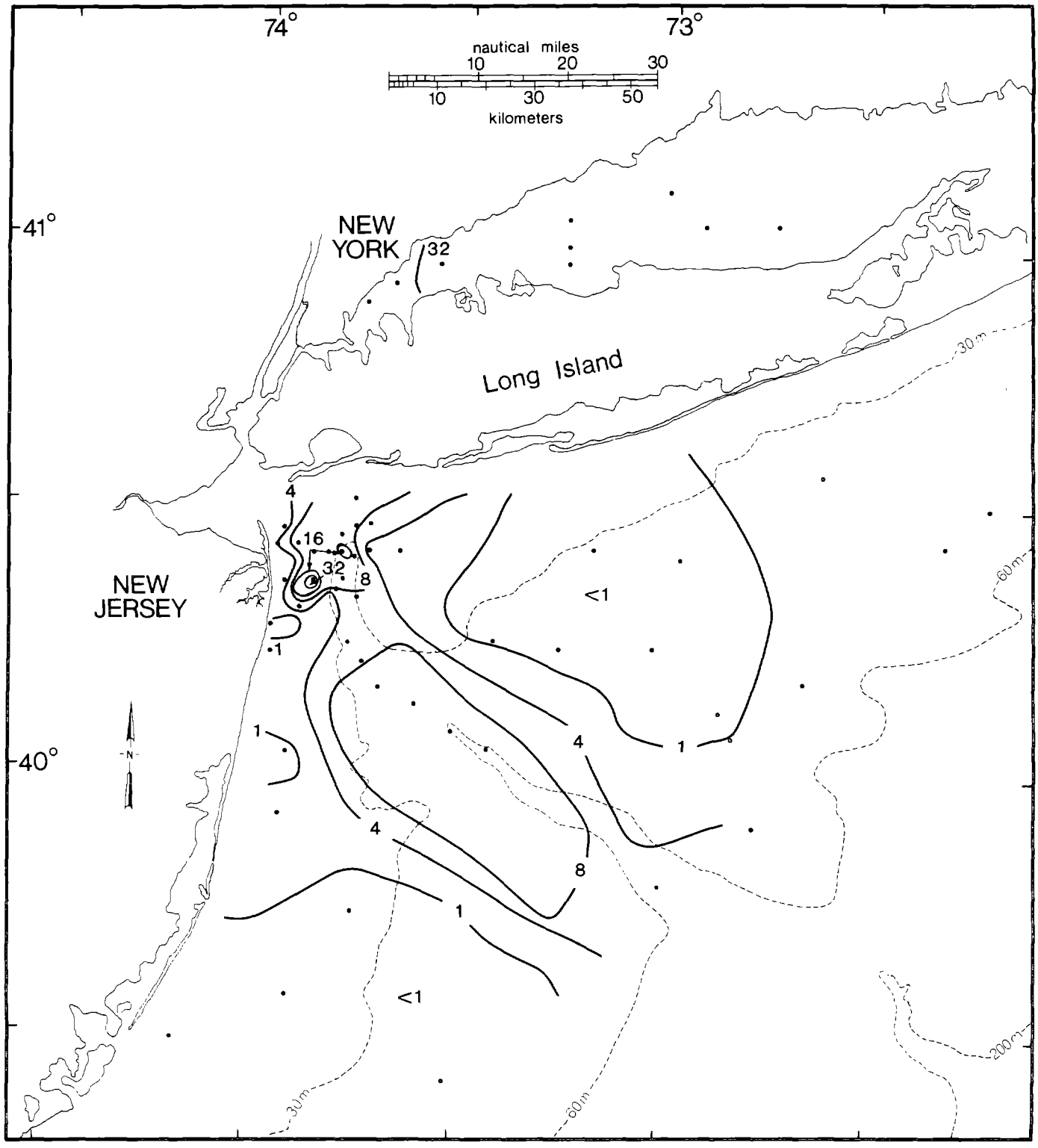


Figure 4. Distribution of total organic carbon (mg/g dry wt.) in surface sediments.

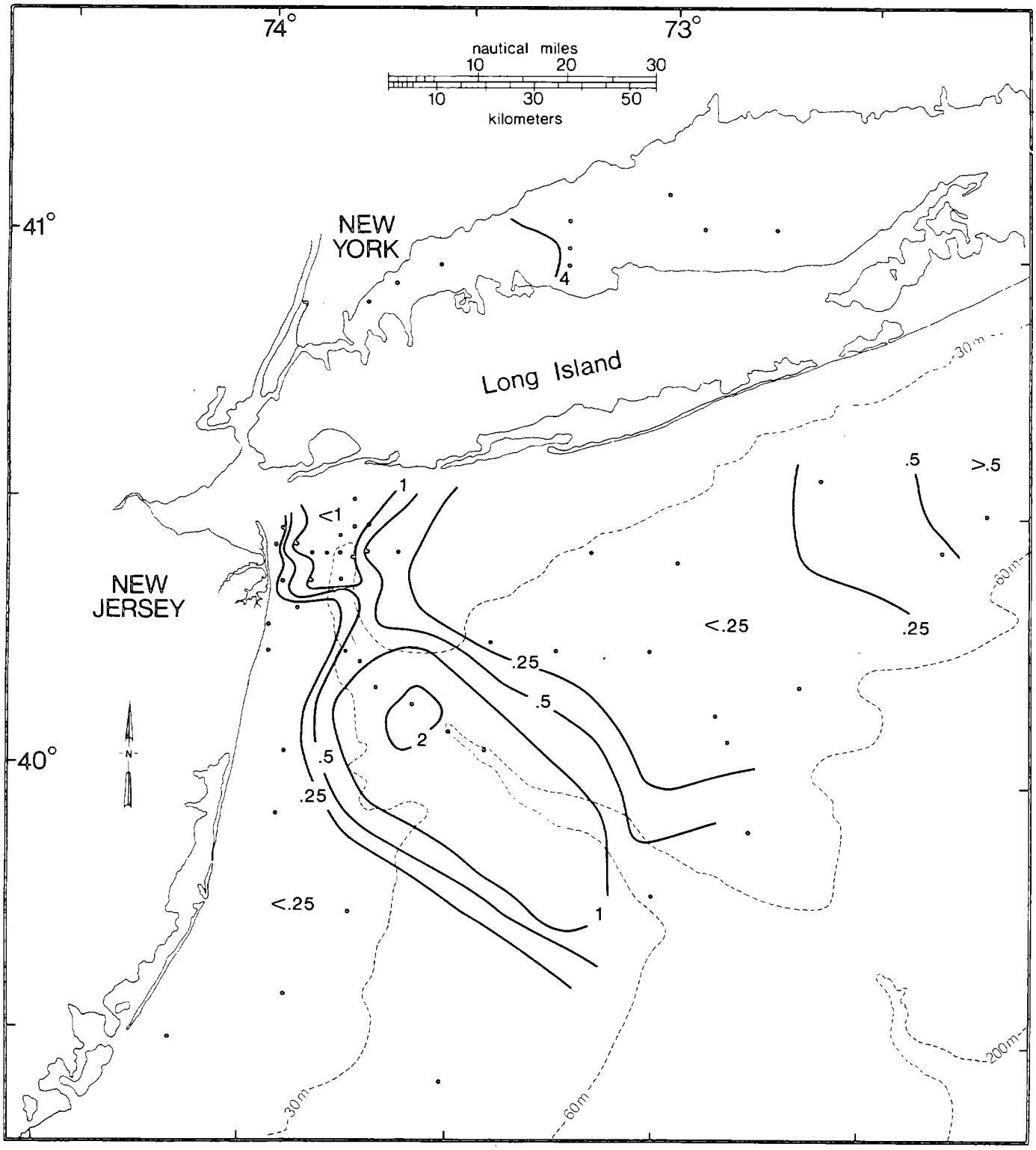


Figure 5. Distribution of total Kjeldahl nitrogen (mg/g dry wt.) in surface sediments.

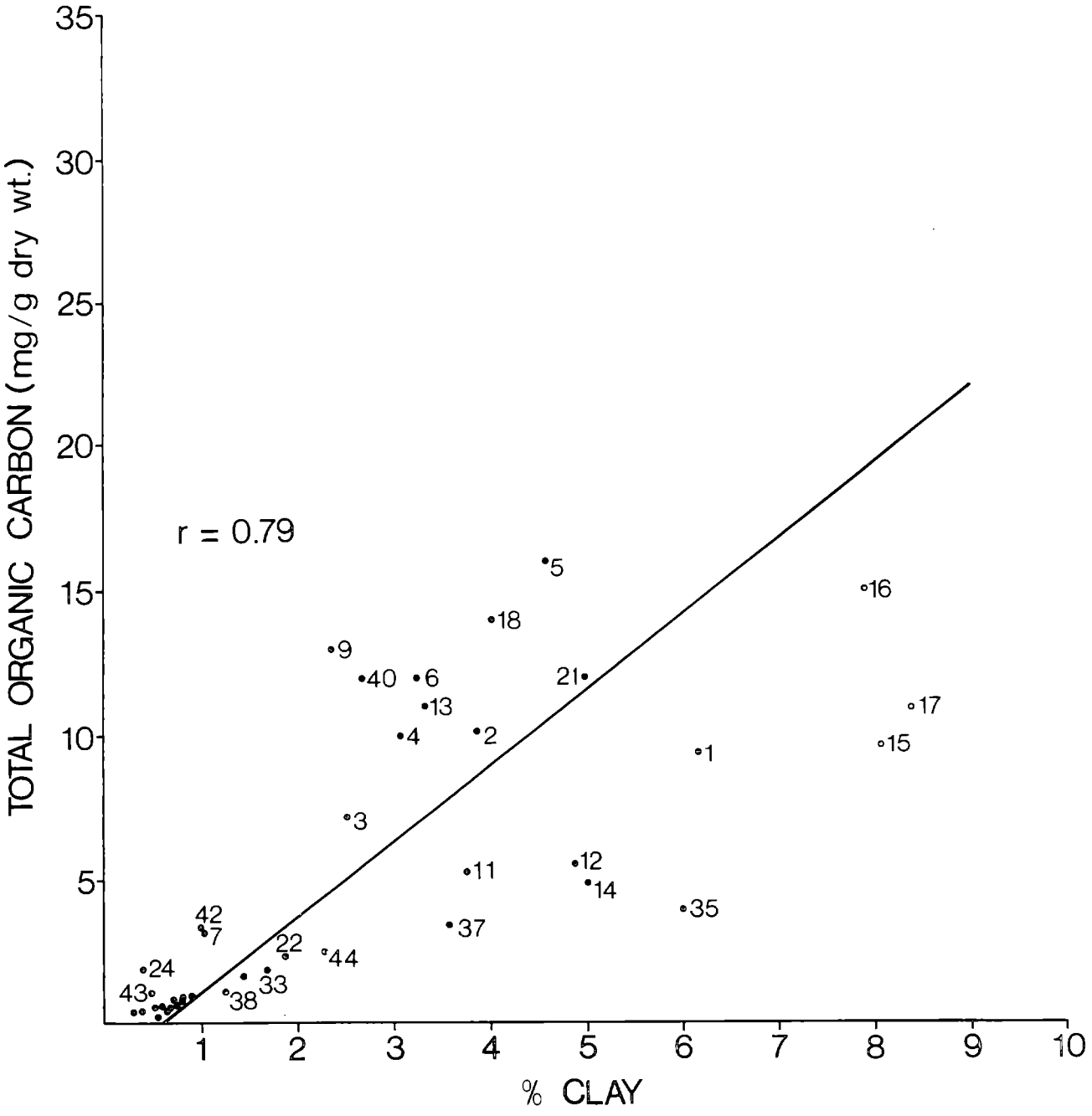


Figure 6. Relationship of total organic carbon to percent clay in surface sediments.

3.2 TRACE METALS IN SEDIMENTS AND BIOTA

Mr. Jay O'Reilly and Mr. Vincent Zdanowicz, NMFS, Sandy Hook Laboratory, Principal Investigators.

3.2.1 Methods

All reagents used in sample digestions were Analyzed Grade and suitable for trace metal determinations. Deionized (DI) water was of 18 megohm-cm purity. Instrumental determinations (except Hg) were done on a Perkin-Elmer Model 5000 Atomic Absorption Spectrophotometer using an air-acetylene flame. Mercury determinations were done using a Perkin-Elmer Model 50A Mercury Analyzer and strip-chart recorder.

Tissues

Muscle tissue was excised from animals using stainless steel implements and composited for analysis. Animals were either dissected at sea and the tissues of interest stored individually in acid-rinsed polyethylene vials and frozen immediately, or were frozen whole in plastic bags for subsequent dissection at the laboratory.

For multi-element digestion, muscle sections of approximately equal mass were removed from 3 to 6 animals of a particular species, (providing a total of ~10 g), placed into 50 ml glass Erlenmeyer flasks and dried for 16-20 hours at 105°C. To the dried composite in each flask were added 10 ml concentrated HNO_3. Flasks were heated slowly (70°C) on ceramic hot plates until foaming subsided and a highly viscous, organic-rich substance remained. Temperatures were increased until the samples had been charred black. They were then cooled, 2 ml concentrated HNO_3 added and charred again. This was repeated until only a fine white ash remained in the flasks, signaling complete digestion. The samples were filtered (Whatman #4) using 5% HNO_3, and the volume adjusted to 15 ml in acid-rinsed polystyrene centrifuge tubes. Reagent blanks received identical treatment. Samples prepared in this manner were analyzed immediately for silver, then for the remaining metals (Cd, Cr, Cu, Ni, Pb, Zn).

For Hg digestion, individual tissue samples of 300 to 700 mg were placed into glass culture tubes to which 10 ml of 4:1 conc. H_2SO_4: conc. HNO_3 were added. The tubes were heated (~70°C) in a water bath until a clear yellow solution was obtained. They were cooled, placed in an ice bath, and further oxidized by addition of 15 ml of 5% $KMnO_4$ (w/v in DIH_2O). Reagent blanks and calibration standards received the same treatment. Samples were analyzed using a modification of the flameless vaporization technique of Hatch and Ott (1968). Analyses were run on a Perkin-Elmer Model 50A Mercury Analyzer connected to a strip-chart recorder. A working calibration curve was used to quantify mercury concentrations in the samples.

Sediments

Core samples were taken from Smith-McIntyre bottom grabs, using 2.7 cm diameter plastic cylinders (pre-rinsed with 5% NHO_3, then DIH_2O) and frozen immediately. In the laboratory the top 5 cm portion of each was dried (16-20 hours, 60°C) and pulverized, and debris (shells, etc.) removed. Samples were then transferred to cleaned 4 oz. polyethylene containers and stored under ambient conditions.

For multi-element digestion (all metals except Hg) a modified EPA procedure was used. An aliquot of dried sediment (3 to 10 g) was weighed into a 100 ml glass beaker, 10 ml of conc. HNO_3 were added, and the samples placed on ceramic hot plates (~70°C) inside a metal free hood and evaporated to dryness. When cool, each sample received 5 ml of 8% NH_4Cl (w/v in DIH_2O), 5 ml of 0.02 m $Ca(NO_3)_2:4H_2O$, and 15 ml of an acid mixture (80 ml conc. HNO_3 plus 20 ml conc. HCL diluted to 1 L with DIH_2O). After 16 to 20 hours, the samples were again placed on hot plates (~70°C) and the volumes reduced to 10 to 15 ml. Whatman #4 paper was used to filter the leached solids from the solutions as they were transferred to glass graduates and brought to a volume of 25.0 ml using DIH_2O. Reagent blanks were run through the same digestion procedure.

For mercury analyses, the digestion procedure was: to a sample of dried sediment (0.1 to 1.0 g) 20 ml of 50% aqua regia (3:1:4, conc. HCL: conc. HNO_3DIH_2O (v/v/v)) were added. The samples were placed in a water bath (~70°C) for 15 minutes, then allowed to cool. Fifteen ml of 5% $KMnO_4$ (w/v) were added slowly and the samples were reimmersed in the water bath until a brown solution was obtained. This procedure was also followed for reagent blanks and calibration standards. A modified Hatch and Ott procedure was used for the analyses. Samples were transferred quantitatively, using 20% H_2SO_4 (v/v) into 300 ml glass BOD bottles fitted with gas sparging tubes. Mercury in the solutions was reduced using $SnSO_4$ solution, and the vaporized mercury swept through the optical cell in the analyzer (flow ~2 l/min). Concentrations of mercury were calculated from a working curve generated by analyses of calibration standards.

3.2.2 Results

Metals in Sediments

Mean concentrations of seven metals in sediments are given in Table 2. Figs. 7-13 are contour maps showing the levels of these metals and the positions of their maximum and minimum values. Breakdown into three regions facilitates interpretation of the data. Region I includes the NYB apex and HSV. These two areas are paired because sediments in each have similar characteristics (high in fines, organic carbon and contaminants), and they contrast with those from adjacent

Table 2. Mean concentrations of seven metals in sediments (ppm, dry wt.) by region, based on 5-7 replicates/station.

	Station	Cd	Cr	Cu	Hg	Ni	Pb	Zn
	21	0.45	23.67	10.95	<0.04	6.33	33.2	59.7
	1	1.18	46.67	43.67	0.35	9.88	66.7	91.2
	2	1.15	42.00	38.17	0.37	8.87	60.0	86.3
	3	0.95	39.22	34.40	0.15	7.86	52.4	78.8
	22	<0.25	8.34	4.46	<0.04	1.93	15.6	22.7
	7	0.54	11.93	14.96	0.06	2.70	30.2	34.0
	9	1.47	54.50	55.84	0.45	14.71	80.3	113.8
Region	11	0.50	18.08	14.22	0.11	5.97	26.2	37.0
I	20	<0.25	7.21	5.75	0.07	5.20	19.5	27.7
	6	3.68	65.26	120.82	-	12.52	134.9	228.9
(Apex	10	0.37	18.03	14.86	-	5.34	21.6	35.9
plus	12	<0.25	11.73	3.58	<0.04	4.63	13.8	27.5
HSV)	44	<0.25	5.16	2.15	<0.04	1.74	7.3	15.9
	19	0.30	27.10	5.24	<0.04	4.56	24.7	41.3
	43	<0.25	10.35	1.80	<0.04	1.86	7.9	16.1
	8	1.77	46.26	60.24	0.04	14.09	63.1	106.2
	18	0.72	34.08	50.61	-	10.38	53.1	72.0
	4	0.80	22.64	31.78	0.07	8.44	45.1	63.1
	40	1.20	47.72	57.93	-	17.57	88.6	125.1
	13	0.30	23.98	16.00	0.21	9.82	36.1	54.9
	16	0.50	27.43	15.11	0.18	11.20	36.2	62.8
	17	0.35	16.00	8.27	-	8.93	21.0	42.0
	15	0.30	11.81	5.22	<0.04	7.37	15.4	28.5
	14	0.25	14.27	4.74	0.04	8.90	12.8	31.0
	5	2.83	75.06	85.06	-	15.81	104.9	156.5
	41	<0.25	2.35	0.78	<0.04	0.58	4.2	6.6
	42	0.36	17.31	5.19	-	4.29	23.7	51.1
	31	<0.25	1.54	0.23	<0.04	0.51	2.3	3.1
	32	<0.25	2.40	0.76	<0.04	0.60	2.5	3.9
	33	<0.25	3.22	1.81	<0.04	1.59	6.3	6.8
	35	<0.25	7.33	2.30	<0.04	4.39	8.6	14.3
	34	<0.25	6.19	0.85	<0.04	2.31	5.2	8.8
Region	39	<0.25	4.18	1.83	<0.04	0.90	3.3	5.2
II	29	<0.25	3.14	1.50	-	0.60	3.2	4.6
	30	<0.25	5.43	1.59	<0.04	1.96	5.9	12.3
(LI and	38	<0.25	4.43	0.78	<0.04	2.02	4.7	8.4
NJ Shelf)	37	<0.25	5.60	0.55	<0.04	1.30	3.5	6.1
	36	<0.25	5.16	1.31	-	3.39	5.5	11.8
	28	<0.25	2.80	0.87	-	2.38	2.3	7.4
	23	<0.25	2.49	0.56	<0.04	0.77	3.4	7.3
	26	<0.25	3.38	0.49	<0.04	1.31	2.6	6.1
	27	<0.25	2.22	0.52	<0.04	1.32	1.9	4.8
	24	<0.25	1.66	0.67	<0.04	0.53	3.3	4.1
	25	<0.25	2.39	0.52	<0.04	0.72	2.3	4.1
	LIS 5	2.65	98.50	153.50	0.71	29.50	95.0	330.4
Region	LIS 8	1.39	63.94	78.84	0.17	18.46	59.4	193.4
III	LIS13	1.08	85.67	111.50	0.39	33.00	85.0	265.0
	LIS34	0.52	75.35	87.07	0.24	21.66	45.0	185.1
(Long	LIS35	0.68	72.43	103.14	0.24	29.43	49.6	198.8
Island	LIS36	0.81	65.79	88.04	0.29	26.41	47.7	207.8
Sound)	LIS55	0.45	68.94	66.78	0.22	27.57	43.5	172.0
	LIS69	0.33	43.73	49.69	0.18	19.95	33.4	125.2
	LIS65	0.45	56.17	64.67	0.27	23.33	38.0	135.0
	LIS88	0.45	47.67	62.14	0.19	23.92	36.1	136.2

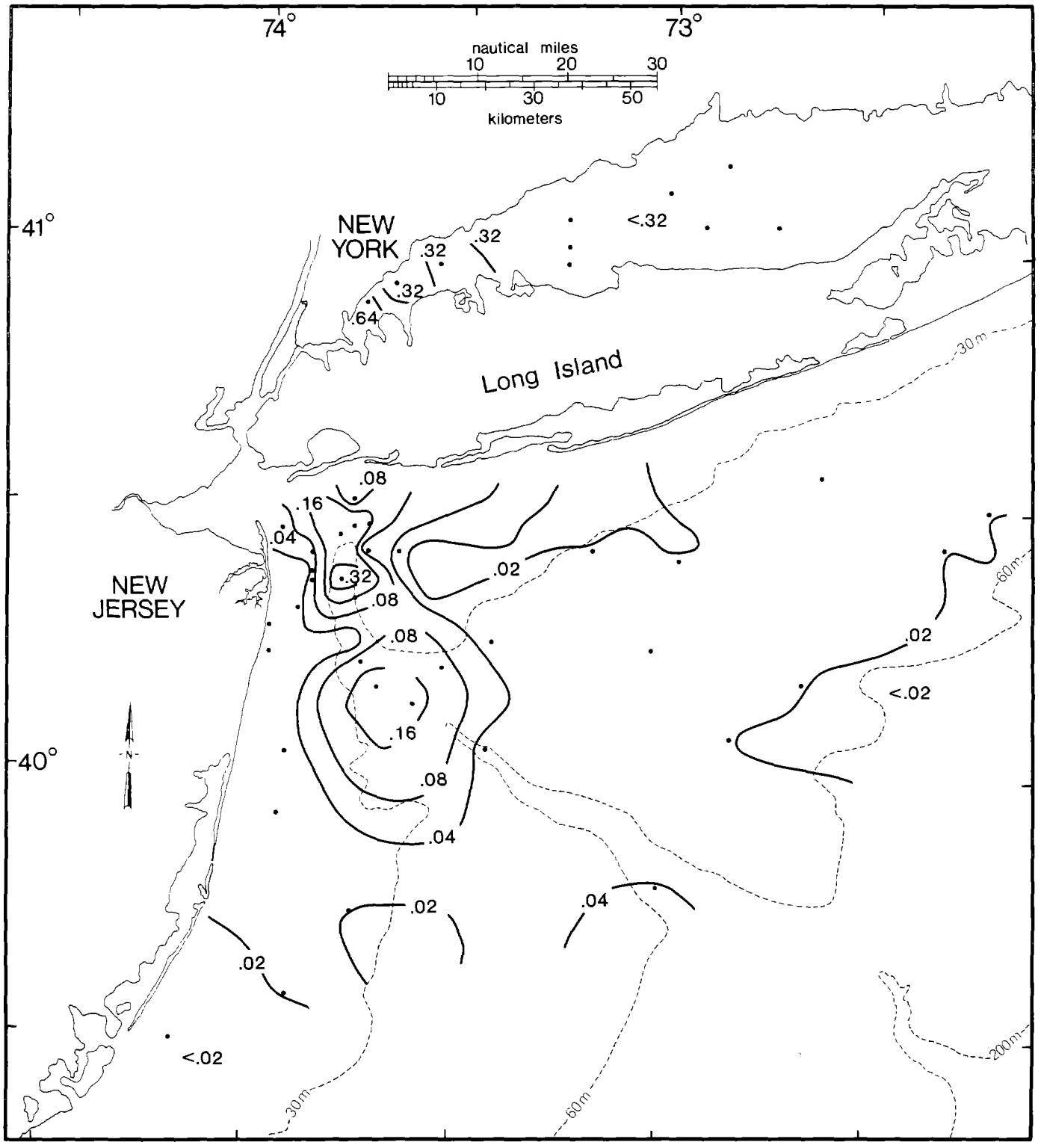


Figure 7. Distribution of Hg (ppm, dry wt.) in surface sediments.

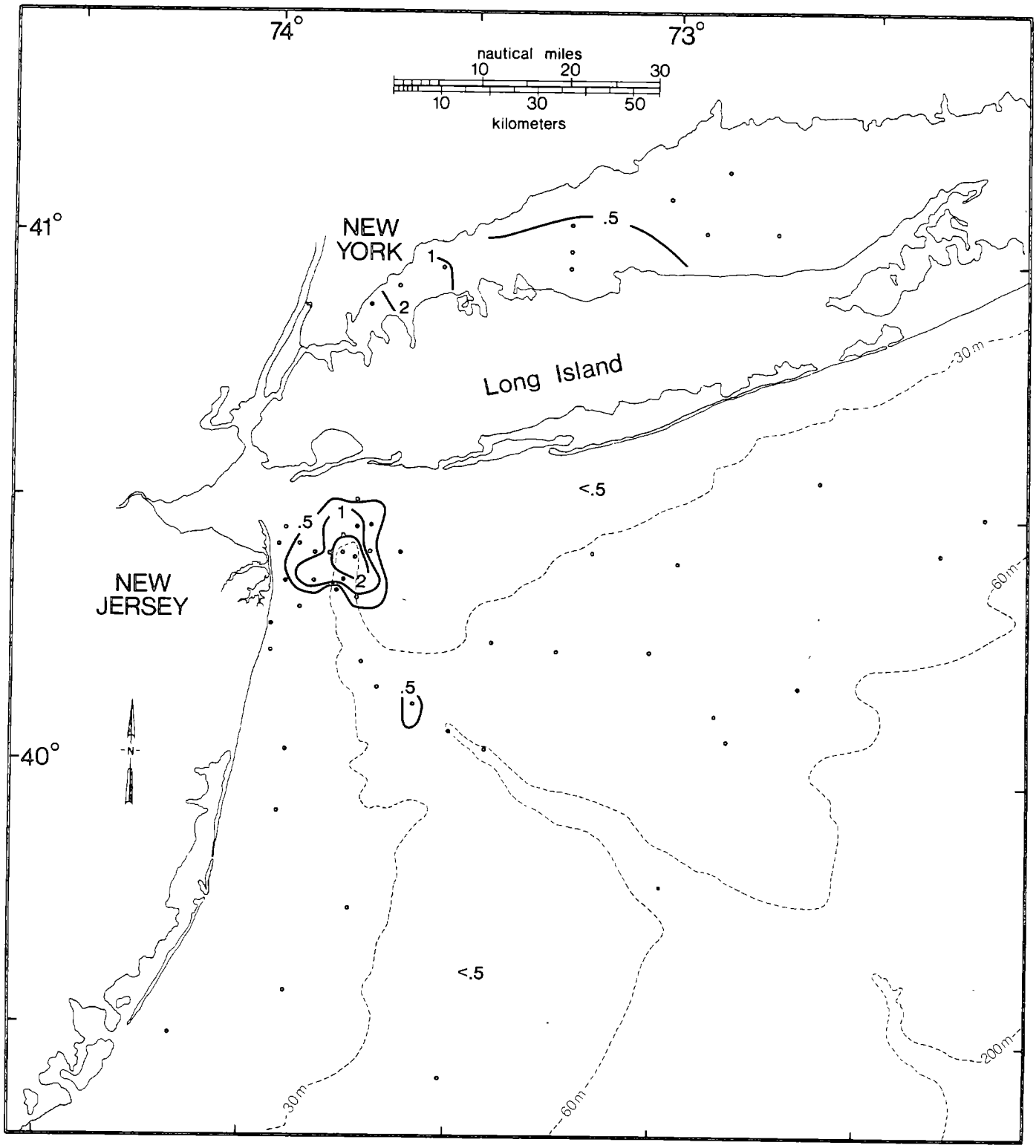


Figure 8. Distribution of Cd (ppm, dry wt.) in surface sediments.

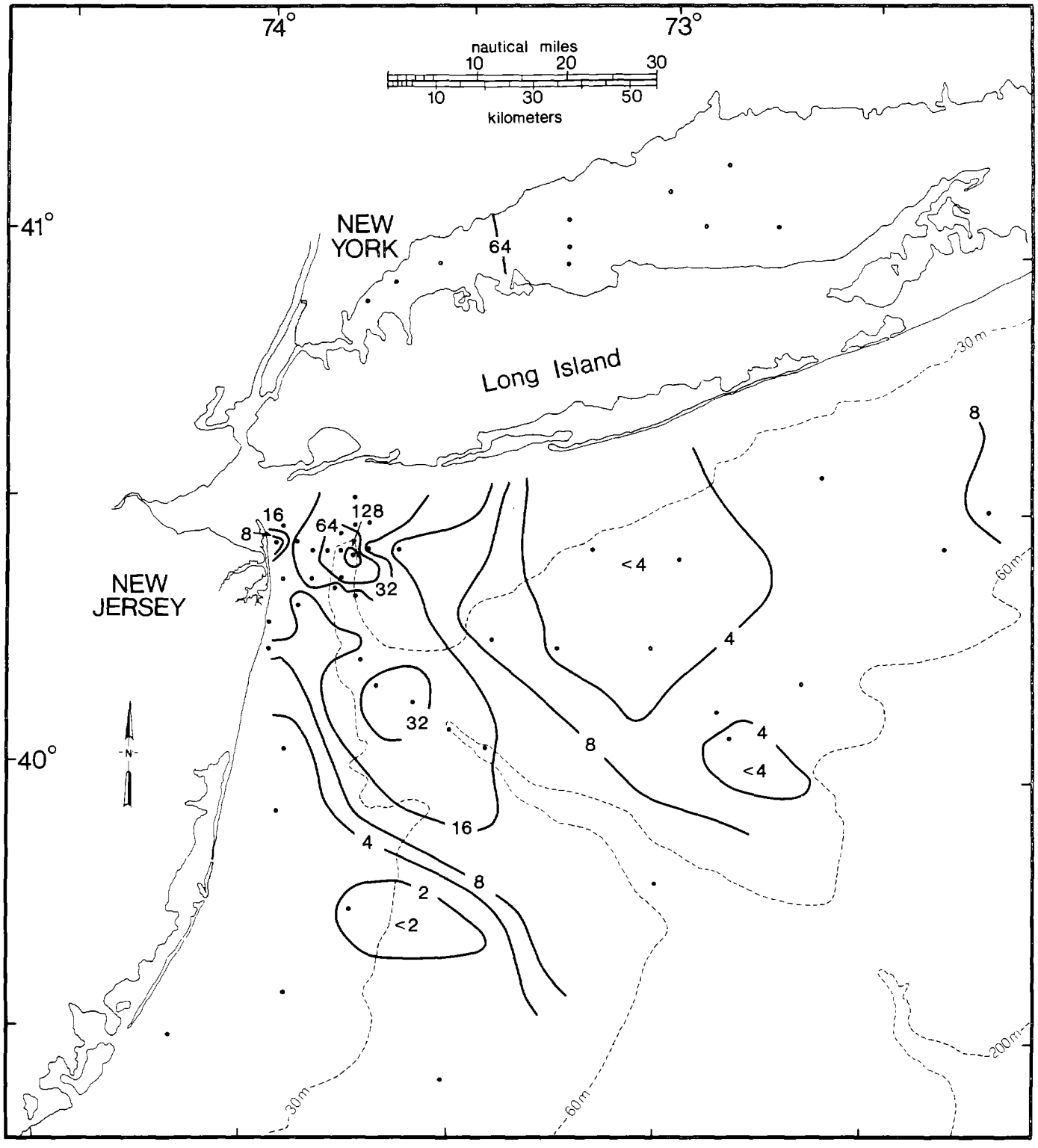


Figure 9. Distribution of Pb (ppm, dry wt.) in surface sediments.

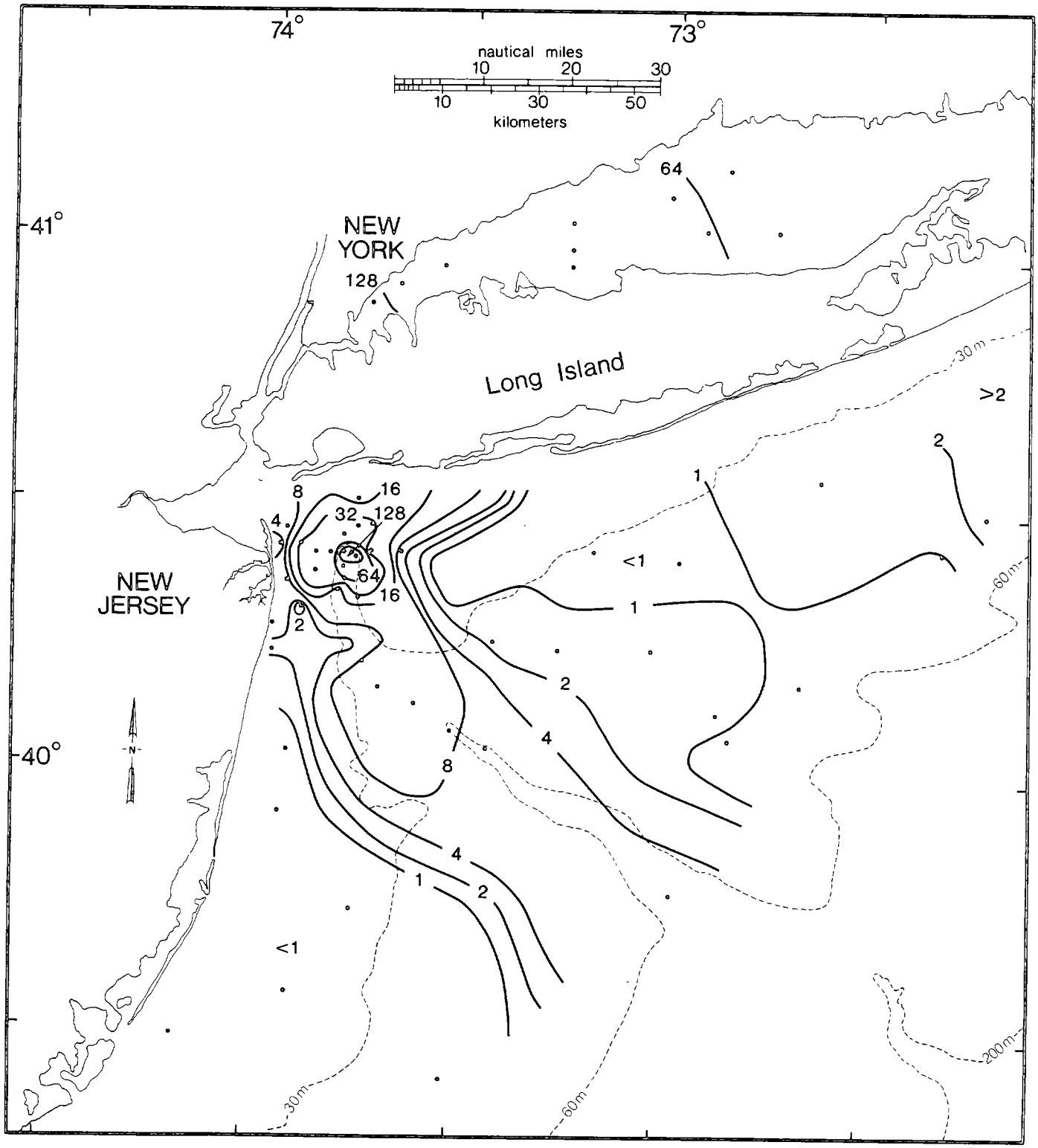


Figure 10. Distribution of Cu (ppm, dry wt.) in surface sediments.

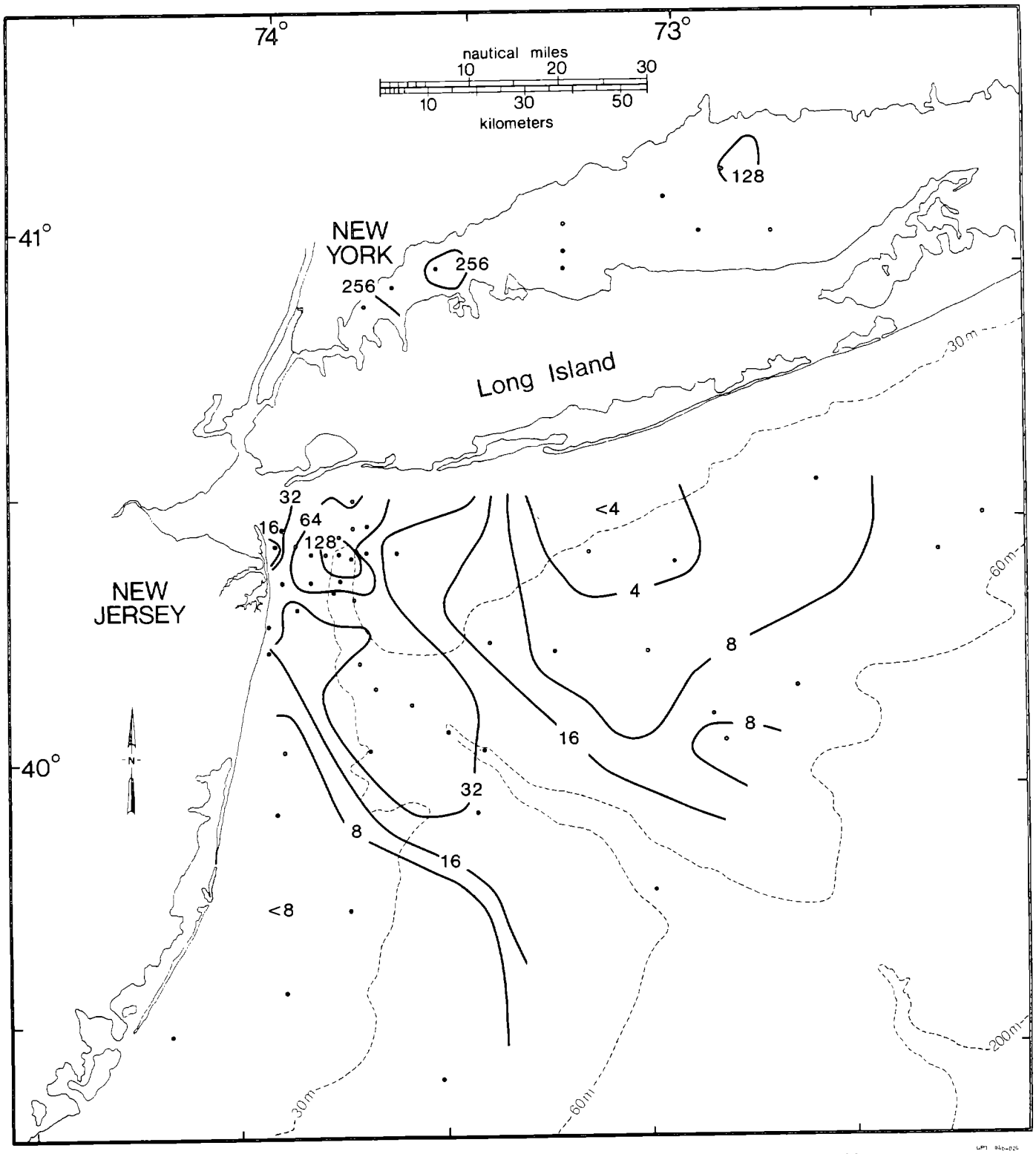


Figure 11. Distribution of Zn (ppm, dry wt.) in surface sediments.

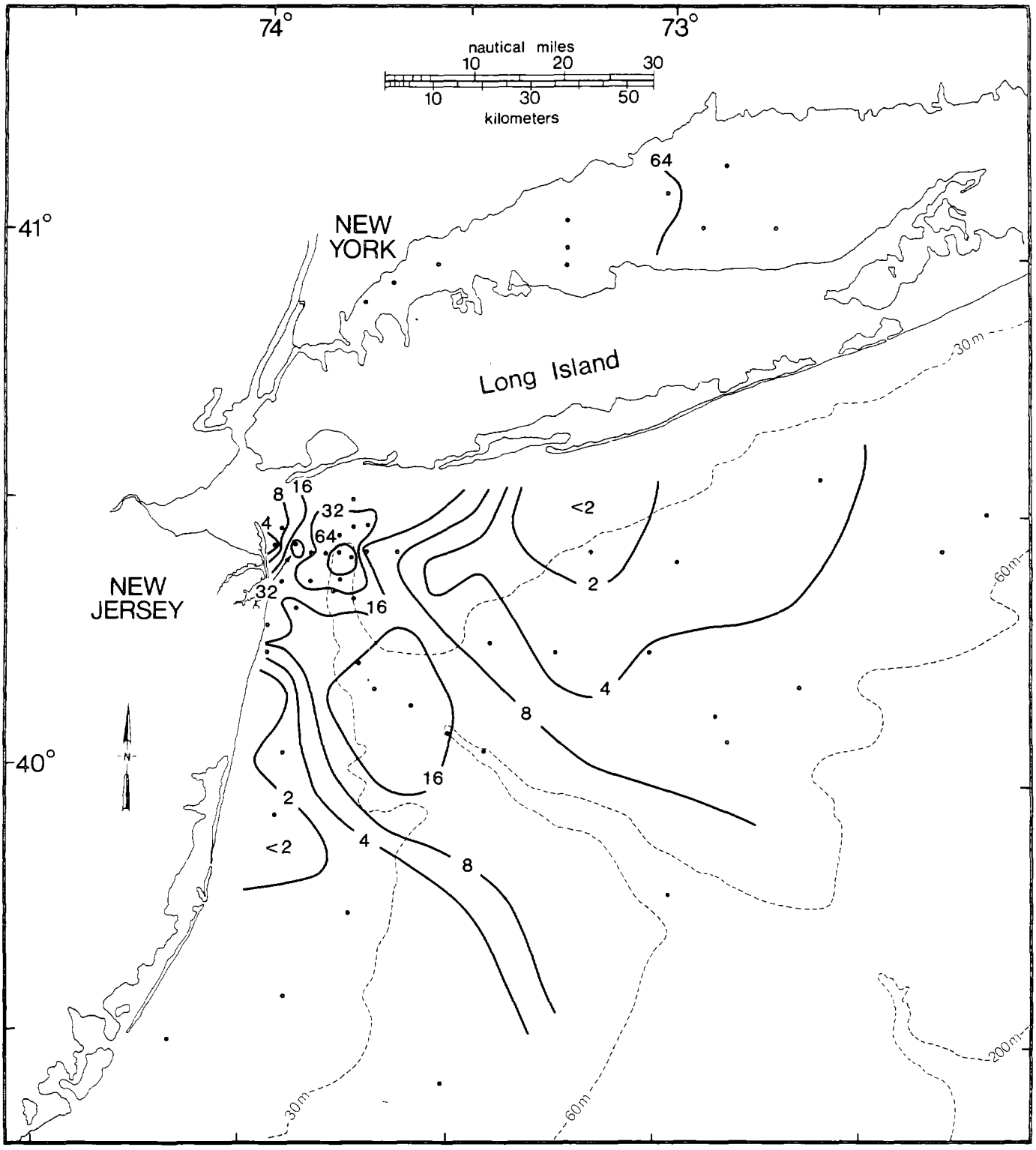


Figure 12. Distribution of Cr (ppm, dry wt.) in surface sediments.

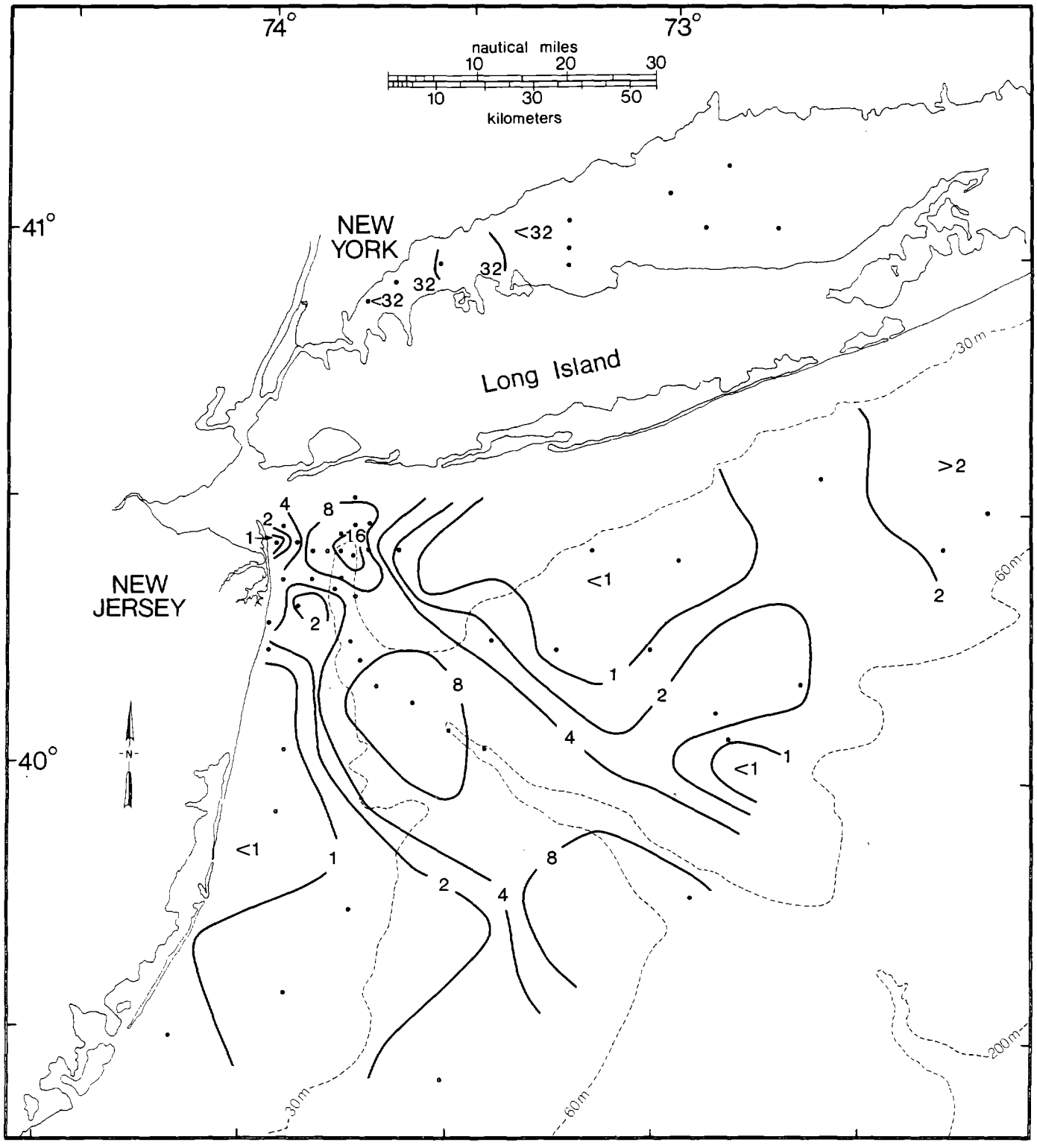


Figure 13. Distribution of Ni (ppm, dry wt.) in surface sediments.

Region II areas (LI and NJ Shelf) having coarser sediments which are not as rich in organic material. Long Island Sound (Region III) is a distinct region with sediments even higher in fines and TOC content than those of the NYB.

The highest metal levels found in the entire Bight (I and II) were centered around stations 5 and 6, in the Christiaensen Basin, just west of the sludge dumpsite. Mercury measurements at stations 5, 6, and 40 are missing, but Fig. 10 shows values increasing toward the center of the CB, with a low value ($\leq$0.04 ppm) at station 21, north of the Basin. The cadmium maximum (Fig. 7) was also centered around stations 5 and 6, generally decreasing with distance from those stations. Lead, copper, zinc, chromium and nickel maxima all lie in this area, between the sewage sludge and dredge spoils dumping sites. A second maximum (of equal or slightly lesser magnitude) for each metal was found in the "Mud Hole" (centered around stations 13 and 16). Minimum values for most metals were found at stations 41 and 43 in the apex, and in the sandy shelf sediments (Region II) bordering the apex/HSV to the east and west.

In Long Island Sound, metal concentrations were as high as those found in the Christiaensen Basin, levels generally decreasing toward the east. Copper (Fig. 9) and zinc (Fig. 13) levels at the western end of the Sound were higher than their respective levels in the Christiaensen Basin.

Discussion of these findings and comparison with other data are included in Section 4.

Metals in Biota

Tables 3 through 8 show the concentrations of eight (8) metals found in the muscle tissue of each of the six species examined by Region. Table 9 lists the overall ranges of values measured for each species, irrespective of locale.

In general, several observations can be made: 1) no muscle tissue sample contained a high level of any metal relative to highest levels found in sediments (or in the case of Hg to the "action level" of 1 ppm above which consumption may be harmful), regardless of species or catch location. 2) Apart from the Christiaensen Basin, another possible geographic "hot spot" revealed in the study is an area known locally as the "Mud Hole", a depositional area about 30 km SSE of the central basin, in the northern part of the Hudson Shelf Valley. Lobster samples from the Mud Hole had the highest lead content (0.6 ppm), and contained moderate amounts of Hg as well (0.12 and 0.15 ppm), as did a sample of windowpane flounder (0.25 ppm) from station 52. Highest Cd values were found at station 12 (0.23 ppm) and 52 (0.25 ppm) in windowpane flounder, and at station 12 (0.20 ppm)

Table 3. Metal concentrations (ppm, wet weight)[1] in muscle tissue of sea scallop.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg[2]	
I (apex-HSV)	12	5	<0.07	0.11	0.31	0.19	<0.13	<0.4	3.26	0.02	(2)
	12	5	<0.04	0.20	0.20	0.12	<0.09	0.2	1.30	0.04	(4)
II (LI-NJ Shelf)	34	4	<0.10	0.13	0.16	0.09	<0.15	<0.4	0.85	0.02	(1)
	38	3	<0.06	0.08	0.21	0.09	<0.11	<0.3	1.98	0.03	(1)
	36	3	<0.09	<0.09	0.44	0.13	<0.18	<0.5	2.56	<0.04	(2)
	14	3	<0.06	<0.07	0.25	0.08	<0.13	<0.4	1.50	0.03	(3)
III (LIS)	-	-	-	-	-	-	-	-	-	-	

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 4. Metal concentrations (ppm, wet weight)[1] in muscle tissue of lobster.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg[2]	
I (apex-HSV)	52	2	0.59	<0.07	0.24	5.37	0.27	0.3	13.45	0.15	(3)
	16	3	0.19	<0.07	0.45	4.08	0.12	<0.4	14.45	0.12	(2)
	53	3	0.61	<0.07	0.40	5.77	0.23	0.6	17.30	0.12	(3)
	57	3	0.73	0.11	0.52	9.46	0.46	0.6	18.03	0.15	(3)
	6	3	0.16	0.15	0.35	2.84	0.08	0.2	11.90	0.05	(3)
	6	2	0.10	<0.05	<0.10	2.27	0.10	0.3	5.75	0.04	(2)
III (LIS)	8	2	0.61	0.12	0.26	15.48	0.25	<0.5	19.25	0.07	(1)
	88	2	0.50	0.08	0.50	7.47	0.27	0.3	14.44	0.06	(3)

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 5. Metal concentrations (ppm, wet weight)[1] in muscle tissue of rock crab.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg^2
I (apex-HSV)	1	5	0.16	<0.06	0.54	4.99	0.26	<0.3	29.07	-
	16	3	0.24	<0.08	1.34	6.62	0.39	<0.6	44.62	-
	6	3	0.25	<0.10	1.19	6.37	<0.47	<0.6	42.86	-
	18	3	0.38	<0.17	1.13	8.89	0.53	<1.0	51.95	-
	12	5	0.27	<0.07	1.23	3.24	0.55	0.5	31.63	-
II (LI-NJ Shelf)	33	5	0.14	<0.08	0.25	3.69	0.30	<0.3	4.18	-
	34	5	0.27	0.08	0.73	8.16	0.64	0.3	30.74	-
	38	4	0.21	<0.07	1.20	6.26	0.33	0.4	45.87	-
	36	5	0.23	<0.07	0.98	6.75	0.32	0.5	36.00	-
	14	3	0.24	<0.08	1.39	4.63	0.49	0.5	38.49	-
	51	3	<0.27	<0.27	<1.29	8.89	<0.54	<1.6	57.04	-
III (LIS)	8	5	0.81	<0.20	<0.96	10.04	0.56	<1.2	59.26	0.16 (3)

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 6. Metal concentrations (ppm, wet weight)[1] in muscle tissue of winter flounder.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg[2]	
I (apex-HSV)	1	5	<0.07	<0.07	0.26	0.17	<0.14	<0.4	1.43	0.05	(4)
	1	5	<0.07	<0.07	<0.13	0.16	<0.13	<0.5	1.42	-	
	41	5	<0.05	0.18	0.37	0.16	<0.10	<0.3	1.60	0.12	(2)
	9	5	<0.08	<0.08	1.17	0.33	0.28	<0.5	5.76	-	
	6	4	<0.10	<0.10	0.94	0.30	0.23	<0.6	5.16	-	
	18	5	<0.08	<0.08	1.35	0.34	0.22	<0.5	6.44	-	
	16	3	<0.06	<0.06	0.24	0.14	<0.12	<0.4	2.97	0.03	(1)
II (LI-NJ Shelf)	30	3	<0.08	<0.08	0.12	0.15	<0.16	<0.5	1.93	<0.04	(3)
	49	3	<0.10	<0.10	0.31	0.24	<0.20	<0.6	4.05	0.04	(1)
	33	5	<0.08	<0.08	1.27	0.26	0.35	<0.5	4.45	-	
	34	4	<0.09	<0.09	1.24	0.34	0.20	<0.5	6.22	-	
III (LIS)	8	3	<0.07	<0.07	0.42	0.22	<0.16	<0.6	4.96	0.07	(2)
	88	2	<0.09	<0.09	0.56	0.17	0.14	<0.5	2.94	<0.04	(4)

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 7. Metal concentrations (ppm, wet weight)[1] in muscle tissue of windowpane flounder.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg[2]	
I (apex-HSV)	18	4	<0.09	<0.09	<0.18	0.17	<0.18	<0.5	2.71	0.04	(3)
	41	3	<0.08	<0.08	0.55	0.16	<0.15	<0.4	1.42	0.09	(1)
	46	3	<0.10	<0.10	0.18	0.23	<0.21	<0.6	5.02	0.08	(3)
	16	3	<0.08	<0.08	<0.15	0.19	<0.16	<0.5	3.01	0.02	(1)
	53	3	<0.08	<0.08	0.42	0.31	<0.16	0.3	6.80	-	
	57	3	<0.10	<0.10	0.24	0.21	<0.20	<0.6	2.52	-	
	12	3	<0.08	0.23	0.38	0.15	<0.15	<0.4	1.60	<0.08	(3)
II (LI-NJ Shelf)	52	2	<0.08	0.25	0.37	0.17	<0.15	<0.5	1.76	0.25	(2)
	49	3	<0.10	<0.10	<0.20	0.22	<0.20	<0.6	3.50	0.04	(2)
	30	3	<0.14	<0.14	0.20	0.35	<0.29	<0.9	5.55	0.10	(2)
III (LIS)	8	1	<0.08	<0.08	0.35	0.32	0.16	<0.5	6.46	0.18	(4)
	88	2	<0.08	<0.08	1.22	0.30	<0.15	<0.5	5.56	0.07	(4)

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 8. Metal concentrations (ppm, wet weight)[1] in muscle tissue of red hake.

Reference Station #		# Specimens in Composite	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg[2]	
I (apex-HSV)	53	3	<0.04	<0.04	0.10	0.15	<0.09	0.3	1.17	0.06	(2)
	46	3	<0.11	<0.11	0.14	0.31	<0.22	<0.7	2.57	0.06	(2)
	47	3	<0.07	<0.07	0.10	0.21	<0.15	<0.4	2.26	0.04	(2)
	16	3	<0.08	<0.08	0.76	0.10	<0.14	<0.4	0.77	0.09	(2)
II (LI-NJ Shelf)	30	2	<0.33	<0.33	<0.65	0.31	<0.65	<2.0	16.43	<0.05	(2)
	38	5	<0.07	<0.07	0.52	0.21	<0.14	<0.4	1.68	<0.05	(1)
III (LIS)	88	1	<0.07	<0.07	0.33	0.48	0.13	<0.4	3.69	0.03	(4)

[1]Values are means of duplicate determinations on composite samples.

[2](n) = number of individual determinations in average.

Table 9. Ranges of values found in muscle tissue -- ppm, wet weight.

Species		PPM Wet Weight							
		Ag	Cd	Cr	Cu	Ni	Pb	Zn	Hg
Sea scallop	high	<0.10	0.20	0.44	0.19	<0.18	<0.5	3.26	0.04
	low	-	<0.09	0.16	0.08	-	-	0.85	0.02
Winter flounder	high	<0.10	<0.10	1.35	0.34	0.35	<0.6	6.44	0.12
	low	-	-	0.12	0.14	<0.16	-	1.42	0.03
Windowpane flounder	high	<0.14	0.25	1.22	0.35	<0.29	<0.9	6.80	0.25
	low	-	<0.14	<0.20	0.15	-	-	1.42	0.02
Red hake	high	<0.33	<0.33	0.76	0.48	<0.65	<2.0	16.4	0.09
	low	-	-	0.10	0.10	-	-	0.77	0.03
Lobster	high	0.73	0.15	0.52	15.48	0.46	0.6	19.3	0.15
	low	0.10	<0.07	<0.10	2.27	0.08	<0.5	5.75	0.04
Red crab	high	0.81	<0.27	1.34	10.04	0.64	<1.6	59.3	0.16
	low	0.14	-	0.25	3.24	0.26	-	4.18	(1 sample)

in sea scallop. Silver was found in appreciable quantities (approaching 1.0 ppm) only in crustaceans, and moreso in lobster (from the "Mud Hole" and Long Island Sound) than in rock crab; 3) levels in flesh increased in the order scallop<fish<crab and lobster.

3.3 ORGANIC CONTAMINANTS (PCBs, POLYNUCLEAR AROMATIC HYDROCARBONS AND COPROSTANOL) IN SEDIMENTS

Dr. Paul Boehm, Energy Resources Company, Cambridge, Massachusetts, Principal Investigator.

3.3.1 Methods

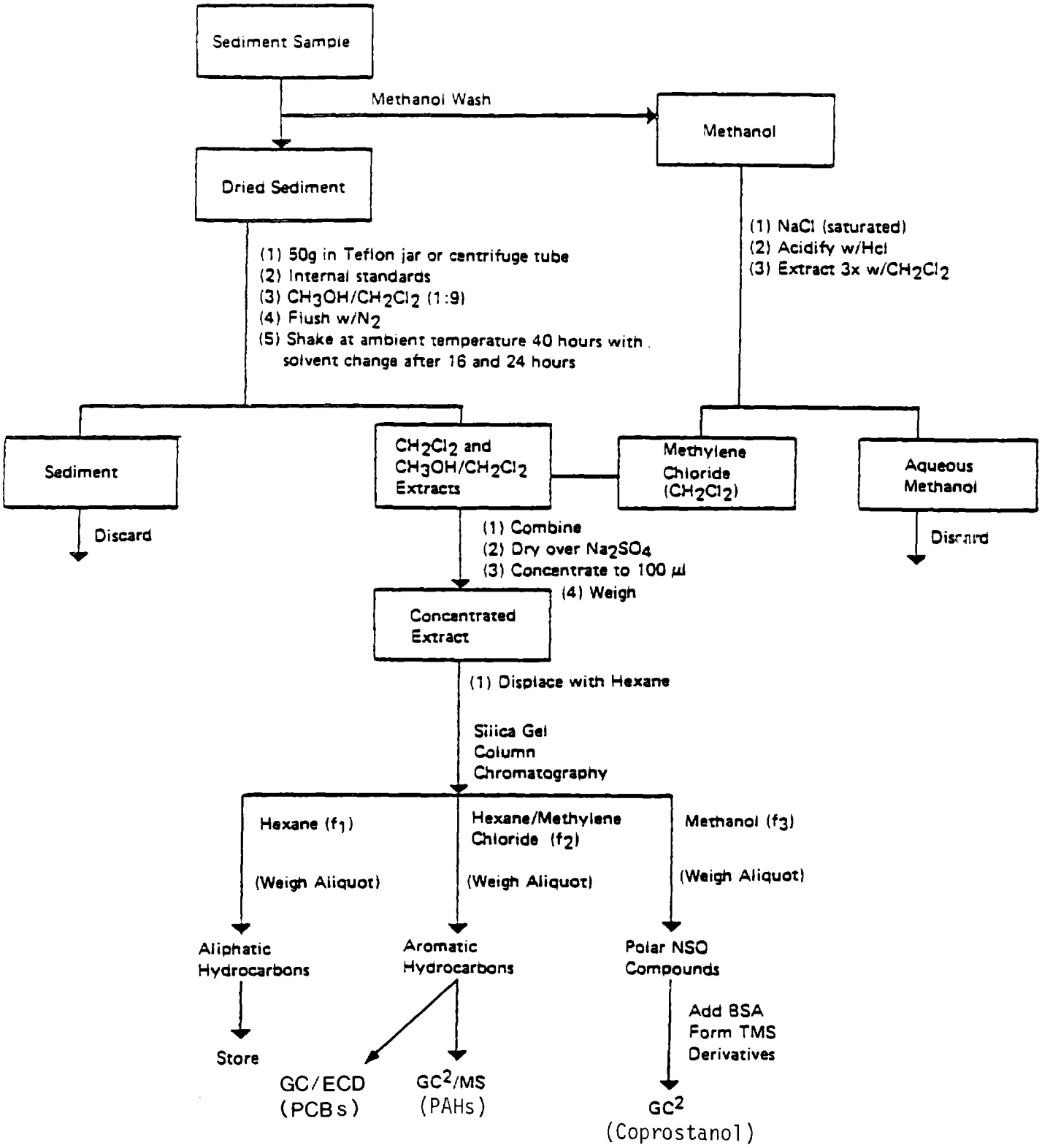
All samples were processed (i.e. extracted and fractionated) according to the ball-mill tumbler method of Brown et al. (1980) as modified for the shaking table by Boehm et al. (1980) and adapted for coprostanol analysis using the method of Hatcher and McGillivary (1979). This latter method involves isolation of the f_3, or polar, fraction from a silica gel column in a methanol eluate followed by drying and silylation using N,O-bis (trimenthyl silyl ethers of the alcoholic compounds (e.g. sterols).

The entire analytical scheme is illustrated in Fig. 14. This scheme allows for simultaneous preparation of extract fractions for PCB and PAH analysis. PCB analyses were performed by electron capture gas chromatography (EC-GC), PAH analysis by glass capillary gas chromatography/mass spectrometry (GC^2/MS), and sterol analysis by GC^2.

3.3.2 Results

Findings were presented in Boehm (1980b), and are summarized here. Both PCBs (total- Fig. 15) and coprostanol (Fig. 16) had highest concentrations in and near CB. PCB distributions indicated two main sources, sewage sludge and dredge spoils, while sludge and estuarine outflow were apparently the largest coprostanol sources. The ratio of coprostanol to total measured steroids was highest at the sewage sludge dumpsite (station 7) and accumulation area (station 6). This indicates that, as expected, the relative contribution of sewage vs. other organic inputs was highest at these stations. The PCB and coprostanol values were generally comparable to those found in NYB by West and Hatcher (1980) and Hatcher and McGillivary (1979), respectively.

PAHs (Table 10) were widely distributed but patchy, again with highest concentrations in the inner bight (except for the extremely high values found in western LIS). Peak values of many compounds were 1.5 to >10X those reported by McLeod et al. (1981) for CB.



14. Analytical scheme for PCB, PAH and coprostanol in sediment samples.

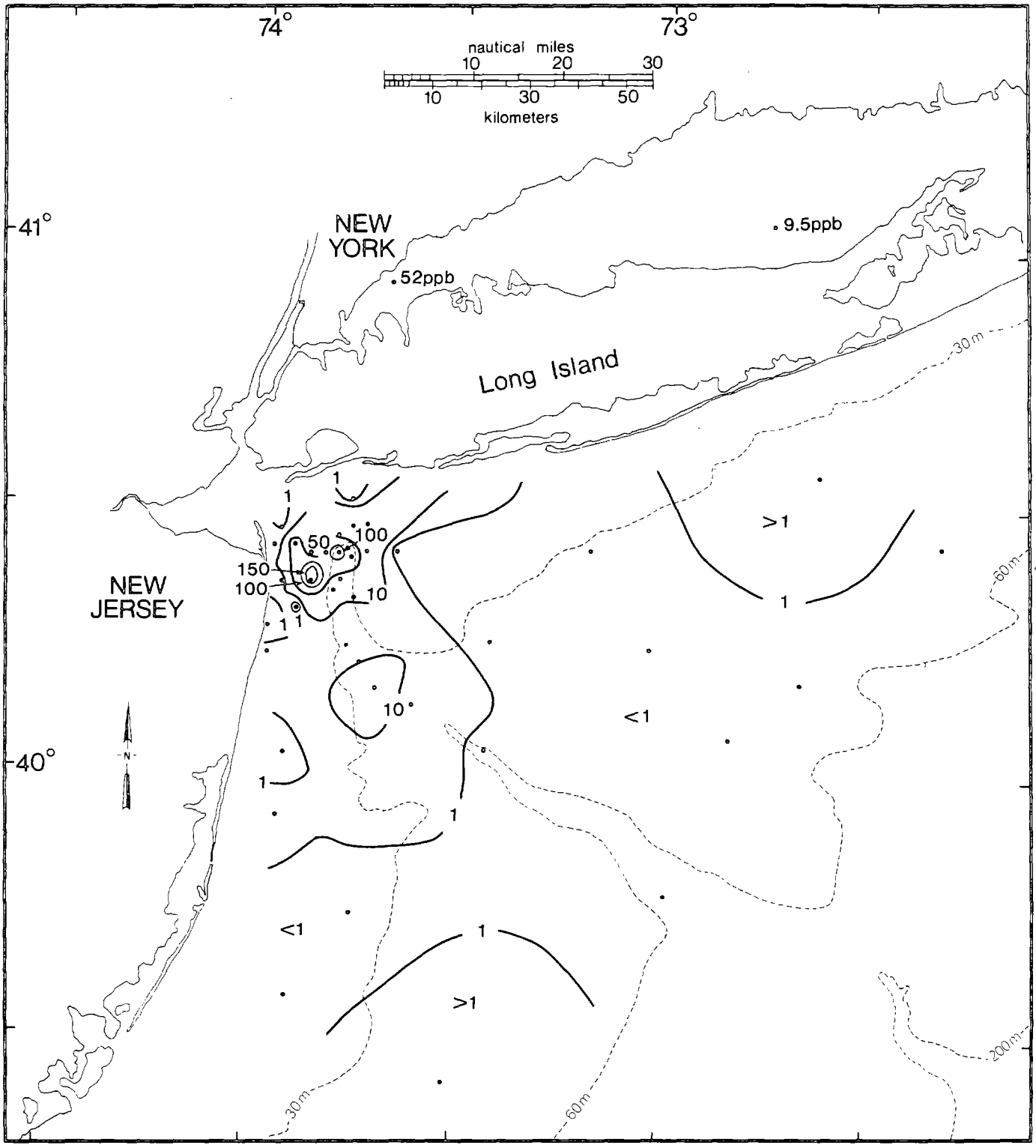


Figure 15. PCB levels (ppb) in sediments.

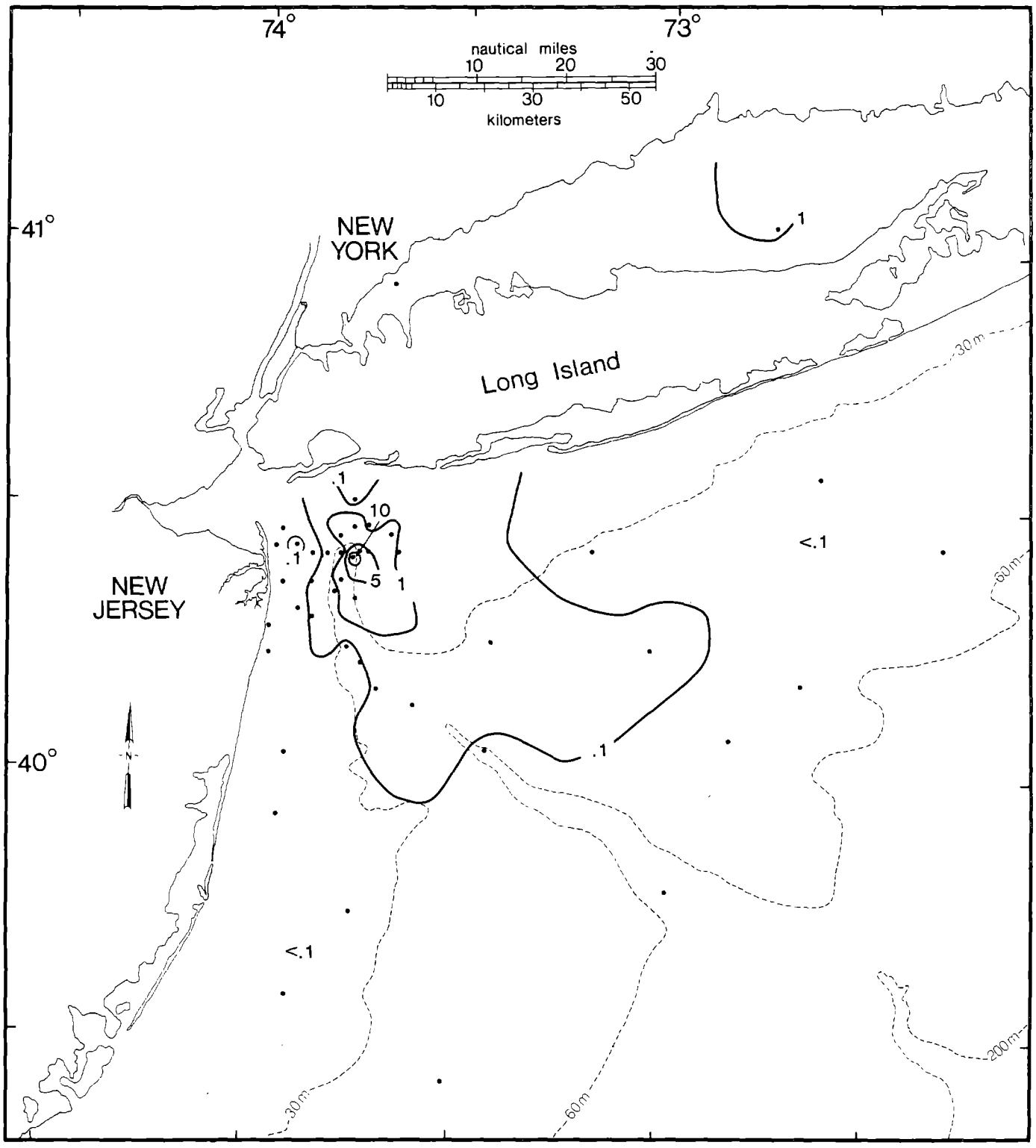


Figure 16. Coprostanol levels(ppm) in sediments.

Table 10. Polynuclear hydrocarbon content of New York Bight sediments (10^{-9} g/g = ppb)

Compound	Station 2637 NYB-4	7508 NYB-6	2466 NYB-7	2468 NYB-9	2832 NYB-14	7756 NYB-15	2874 NYB-26	2365 NYB-31	3067 LIS-8	3117 LIS-88	Lower[1] Bay	Chris.[1] Bay	Outer[1] Bight
Naphthalene (N)	26	25	17	43	<1	1.1	<1	<1	110	10	-	-	-
C_1N	120	84	87	88	1.4	2.2	<1	1.2	230	16	-	-	-
C_2N	360	220	200	190	3.9	3.6	<1	<1	510	24	5	200	-
C_3N	460	250	180	170	4.2	4.0	<1	1.1	600	35	10	100	-
C_4N	600	210	170	170	1.2	1.1	<1	<1	270	19	-	9	-
Total N	1,566	789	654	661	10.7	12.0	<5	<5	1,720	104			
Dibenzothiophene (DBT)	51	84	6	21	<1	<1	ND	ND	250	17			
C_1DBT	62	180	21	71	<1	1.4	<1	<1	440	22	1	30	-
C_2DBT	150	310	36	140	2	1.2	ND	<1	630	35	1	20	-
C_3DBT	130	260	30	360	1	12	2.2	6	800	230	1	20	-
Total DBT	393	834	93	592	4	14.6	3	8	2,120	304			
Acenaphthene	26	20	52	27	<1	<1	ND	<1	33	4	-	40	-
Biphenyl	7.1	48	4	24	<1	<1	ND	<1	210	5	-	-	-
Anthracene	200	80	4	25	1	<1	ND	<1	900	10			
Fluorene (F)	41	75	7	34	1.3	1.2	<1	1.2	420	17	-	40	<1
C_1F	86	150	18	49	1.7	<1	ND	ND	300	14	-	-	-
C_2F	320	210	53	120	2.6	1.0	ND	ND	410	21	1	-	-
C_3F	440	220	42	180	<1	ND	ND	ND	800	24	10	-	-
Total F	887	655	120	383	5.6	2.2	<1	1.2	1,930	76			
Phenanthrene (P)	510	820	53	280	15	16	4.1	10	3,500	170	-	-	<1
C_1P	740	980	150	290	14	13	3.5	8	2,460	170	1	300	-
C_2P	870	800	150	350	11	10	1.6	ND	2,000	150	2	100	-
C_3P	1,080	620	120	410	6.2	4.1	-	ND	1,400	120	2	-	-
C_4P	350	210	10	400	4.8	4.2	<1	3	1,200	110	-	20	-
Total P	3,550	3,430	483	1,730	51.0	47.3	9.2	21	10,500	720			
Fluoranthene	260	1,100	67	370	26	28	6.7	18	5,700	410			
Pyrene	300	1,200	64	410	20	25	7.2	15	6,200	370			
Benzanthracene	130	800	38	320	14	15	3.8	8	4,200	220			
Chrysene	130	600	52	290	21	20	4.4	10	3,000	337			
Benzofluoranthene	170	1,300	80	1,100	55	90	8.5	19	5,800	850			
Benzo(e)pyrene	74	590	25	270	19	22	3.0	6.6	2,200	360			
Benzo(a)pyrene	100	720	31	240	20	18	3.5	8.3	2,300	300			
Perylene	21	180	9	100	10	10	1.5	2.3	570	150			
Total PAH	7,800	19,500	1,800	9,900	300	300	60	100	62,000	4,100			

[1]From MacLeod et al., 1980; dashes = no data.

3.4 PCBs AND PAHs IN BIOTA

Mr. Don Gadbois, NMFS, Gloucester Laboratory, Principal Investigator.

3.4.1 Methods

A sample generally was comprised of tissue from five individuals. The right side of each individual was skinned, deboned and cut into small pieces. The sample was then homogenized with a Hobart silent cutter before weighing and freezing. To determine fat content, samples were blended in pet ether, introduced to a column containing sodium subate to remove moisture, concentrated to 4 ml and weighed after the solvent was removed. PCBs were isolated by the AOAC procedure. Additional cleanup of the concentrated florisil eluant was performed on deactivated silica gel chromatography to remove analogs of DDT. The final concentrated eluant was analyzed by gas liquid chromatography. The instrument used was a Perkin-Elmer Sigma-1 gas chromatograph interfaced to a Sigma-10 data station. The gas chromatograph is equipped with an AS-100 autosampler and a Ni^{63} electron capture detector. A six foot by 4 mm ID glass column consisting of 1.5 percent SP - 2250 and 1.95 percent SP - 2401 on 100/120 mesh Supelcoport was used for the analysis. The column had an efficiency of 616 plates per foot. Gas chromatographic conditions were: oven, 200°C; injector, 225°C; detector, 300°C; flow rate through column, 60 ml/minute; analytical time, 40 minutes. The autosampler injected five ml of the concentrated extract. Standard solutionsused were Aroclor 1016, 1 ppm; Aroclor 1242, 1 ppm; Aroclor 1248, 1 ppm; Aroclor 1254, 1 ppm; Aroclor 1260, 1 ppm; and various mixtures of Aroclor 1254 and 1260. Calculation was based on matching key peaks of the unknown to that of the Aroclor 1254 standard. Our quality control program consisted of spiking muscle tissue of each species with Aroclor 1254, doing duplicates, and running a blind control (carp - whole fish) and blanks.

PAH measurements focused on 16 typical compounds:

napthalene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benz (a) anthracene
chrysene
benzo (b) fluoranthene
benzo (k) fluoranthene
benzo (a) pyrene
dibenzo (a, h) anthracene
benzo (g, h, i) perylene
indeno (1, 2, 3 - c, d) pyrene

A slightly modified version of the method of Dunn and Armour (1980) was used for sample extraction. Each sample was digested at reflux in ethanolic potassium hydroxide. The extract was displaced into toluene and eluted over a column of 5 percent deactivated Florisil covered with sodium sulfate. The sample was then displaced into dimethylsulfoxide and partitioned between dimethylsulfoxide and isooctane. The isooctane layer was washed with water, dehydrated, and displaced back into 0.5 ml dimethylsulfoxide. To this, 1.5 ml acetonitrile was added and the sample was analyzed by high pressure liquid chromatography, using a Perkin-Elmer unit including a Series 3B pump module, a LC 100 column oven, and a Model 420 autosampler. A Supelco LC PAH column with internal diameter of 4.6 millimeters and length of 25 centimeters, with particle size of 5 μ was used as the analytical column. Detection was accomplished by a Perkin-Elmer Model 3000 fluorescence spectrometer. The output of the UV detector was connected to a Perkin-Elmer 023 chart recorder. The output of the fluorescence detector was connected to a Sigma 10 Data Station.

Chromatograms were obtained by the following linear solvent program. A solvent of 40 percent acetonitrile and water was used for the first 5 minutes. The acetonitrile content was increased linearly to 99.9 percent over 30 minutes and was held at 99.9 percent for another 20 minutes. The column was then brought to a 40 percent content of acetonitrile and water at a linear gradient for 5 minutes and equilibrated for 15 minutes in preparation for another run. A flow rate of 1.0 millimeter per minute and an oven temperature of 30°C were used. The UV detector was run at 254 nanometers and the fluorescence detector at 280 nanometers excitation and 389 nanometers emission. Inputs on the recorder and Sigma 10 were 10 millivolts.

3.4.2 Results

PCBs

PCB concentrations in muscle tissue (ppm, wet weight) for each of the six species are given in Figs. 17-22, along with percent fat (for which PCBs have a strong affinity) in the tissue. In general, PCB values were low relative to the recommended maximum level for human consumption (5 ppm), and were not consistently related to levels in sediments or to areas of contaminant input. Statistically significant differences (two-tailed "t" test) between concentrations found in the "contaminated" or inner New York Bight area and levels outside this area were found for rock crab ($p < 0.01$) and perhaps windowpane flounder ($p = 0.148$ for untransformed data, assuming normality; $p = 0.047$ for log-transformed). Concentrations in lobsters from the inner Bight were higher than in the single outer Bight sample, but no statistical tests could be run. The highest concentrations

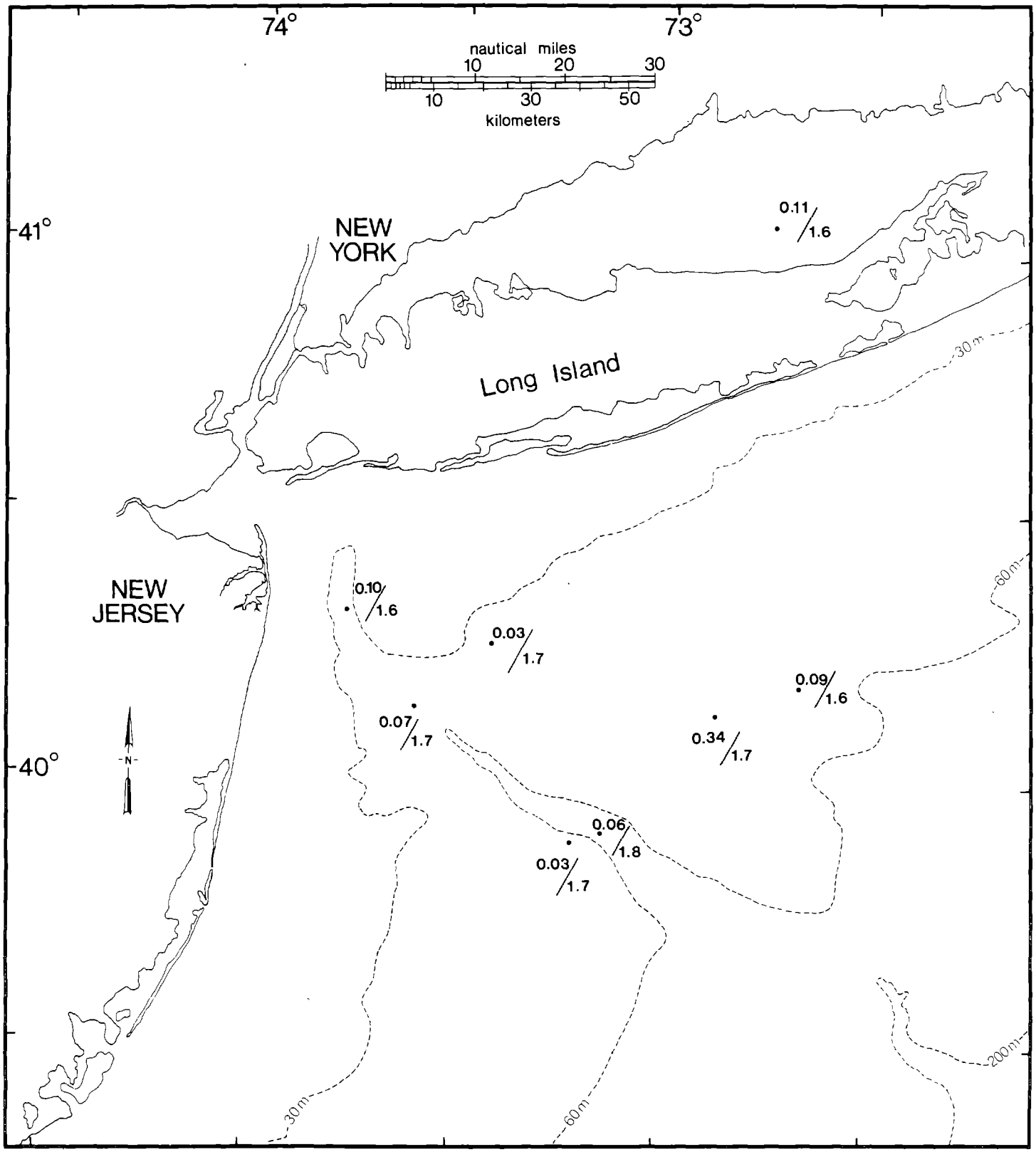


Figure 17. Wet weight values for PCBs (ppm)/% body fat in red hake.

GPO 946-025

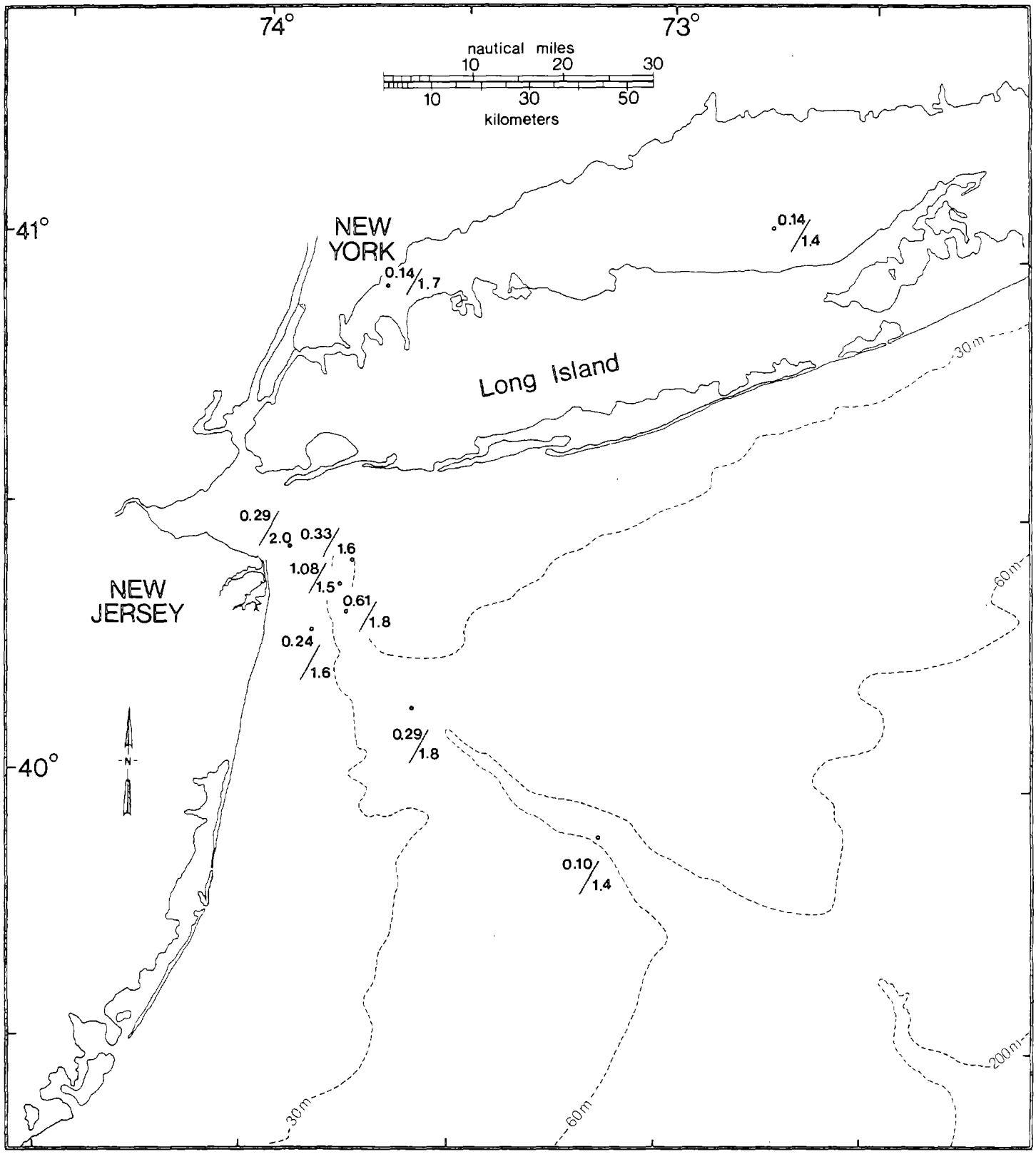


Figure 18. Wet weight values for PCBs (ppm)/% body fat in lobsters.

GPO 946-025

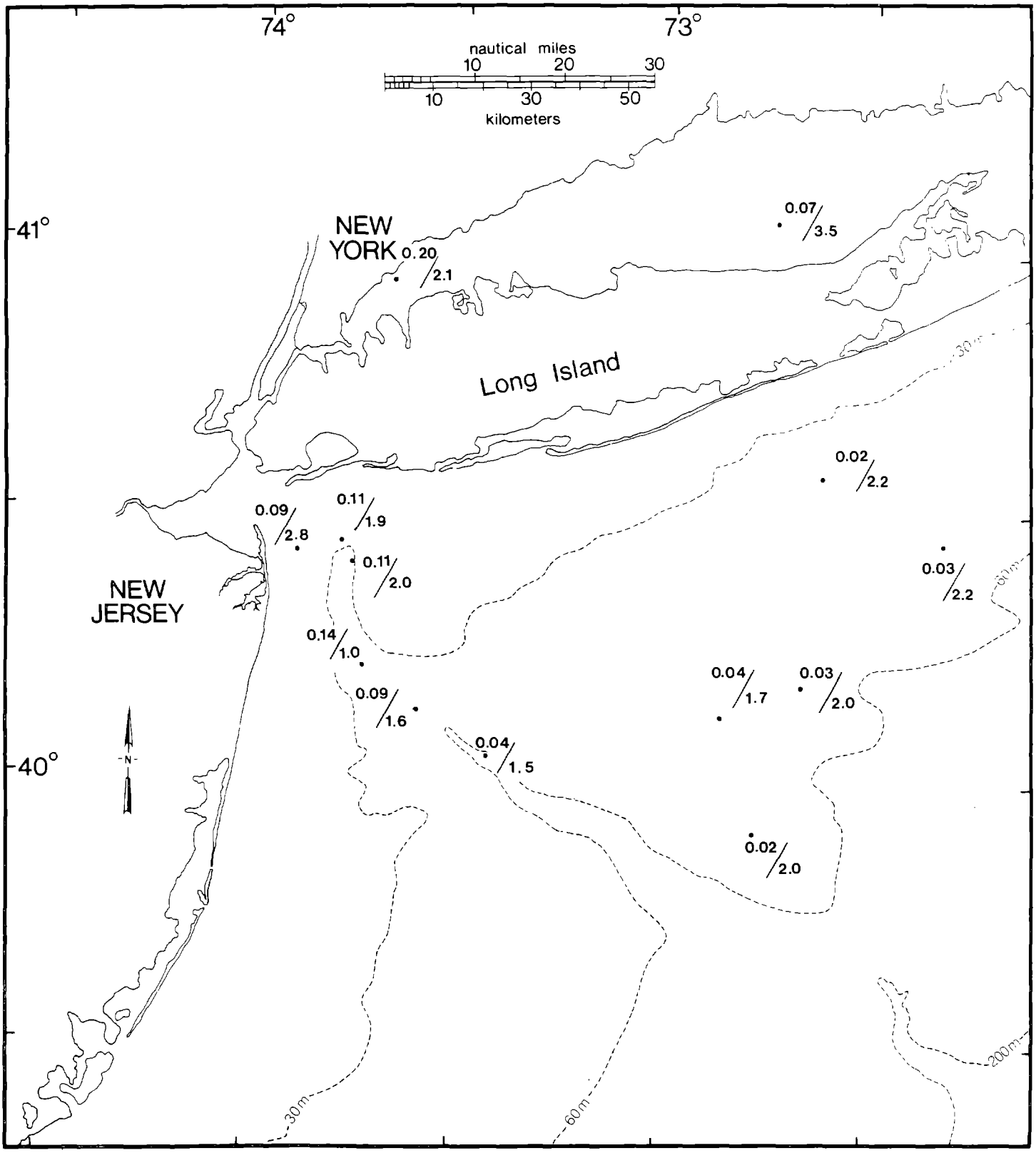


Figure 19. Wet weight values for PCBs (ppm)/% body fat in rock crab.

GPO 946-025

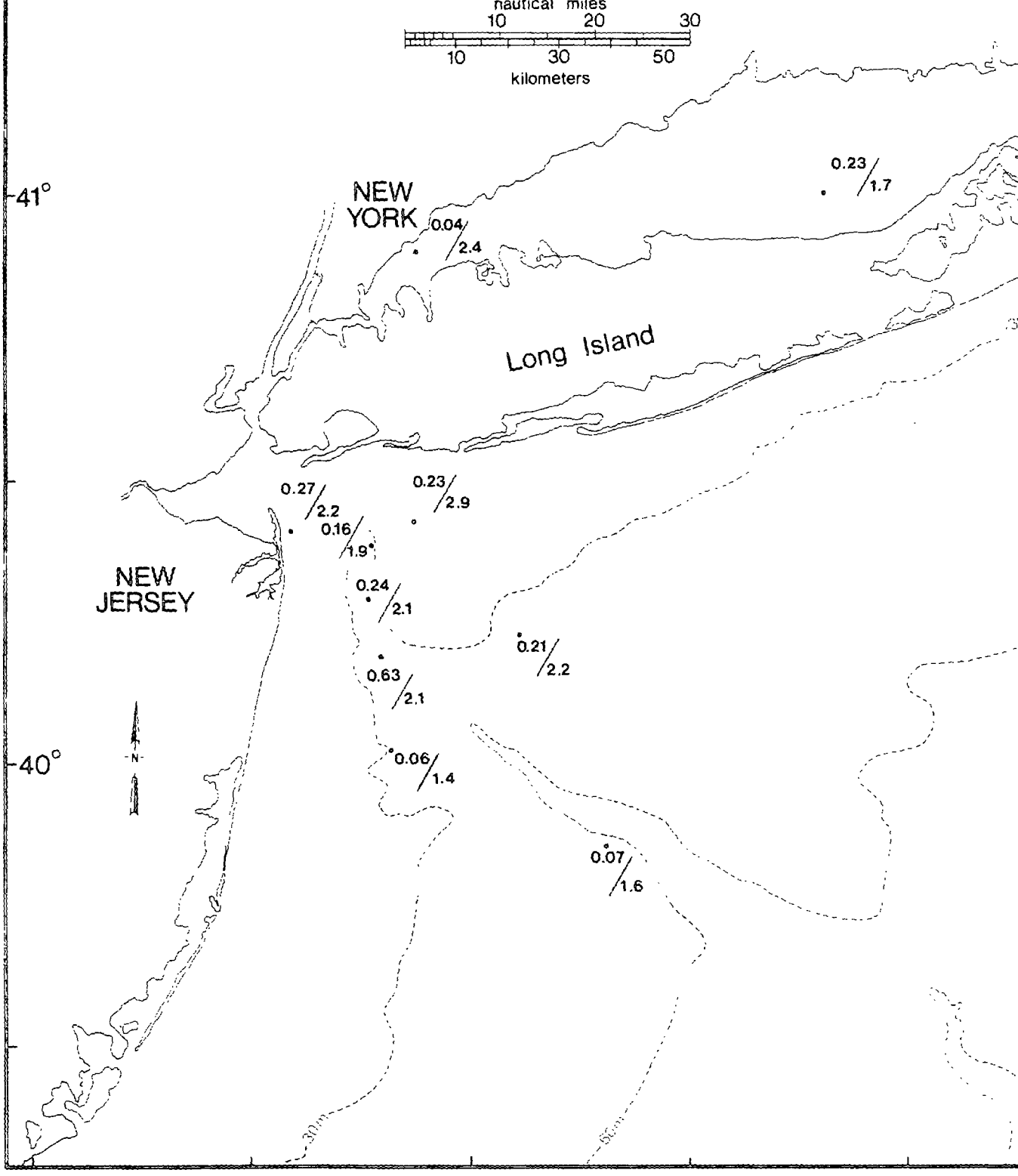


Figure 20. Wet weight values for PCBs (ppm)/% body fat in windowpane flounder.

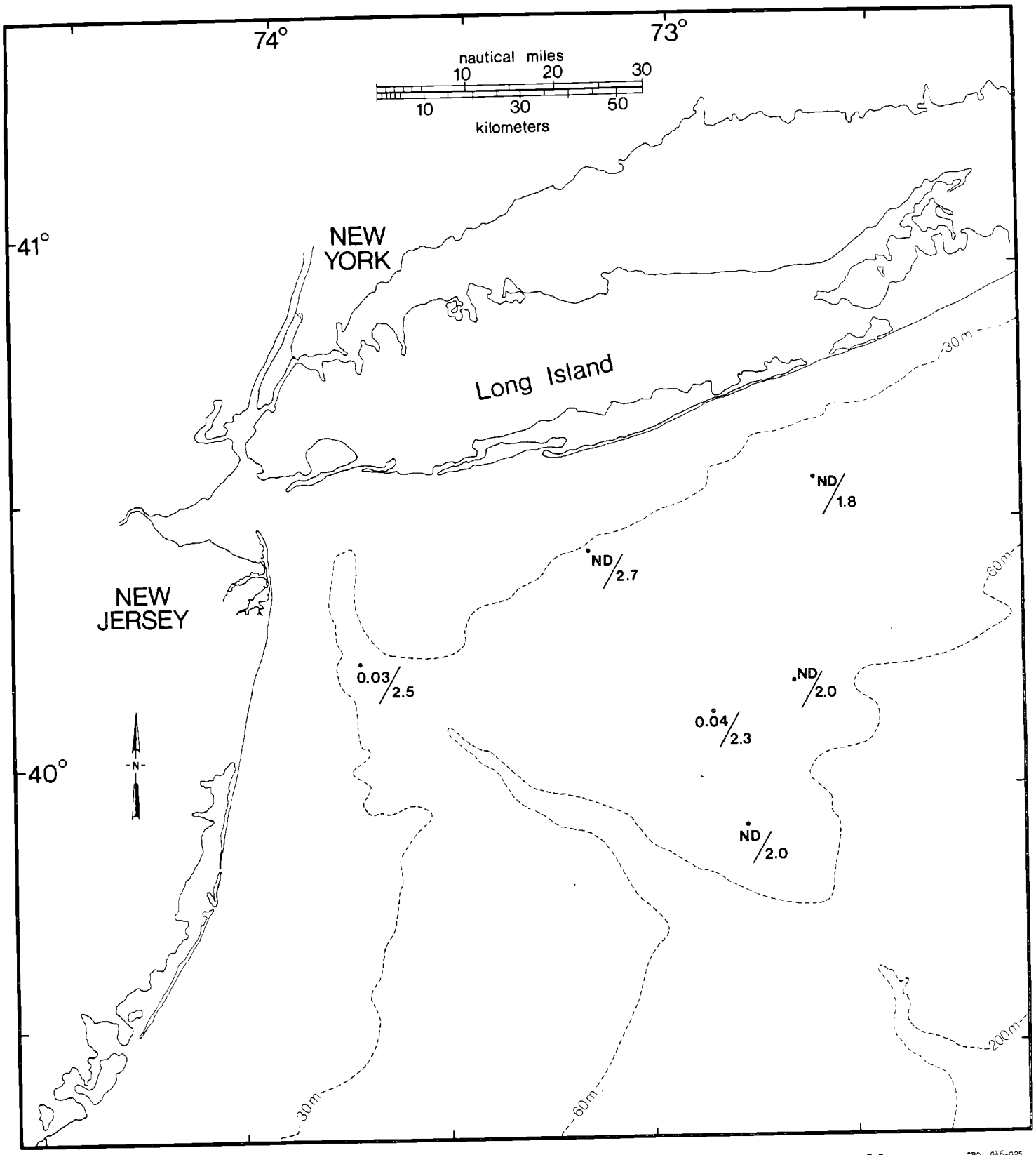


Figure 21. Wet weight values for PCBs (ppm)/% body fat in sea scallop. ND = not detected.

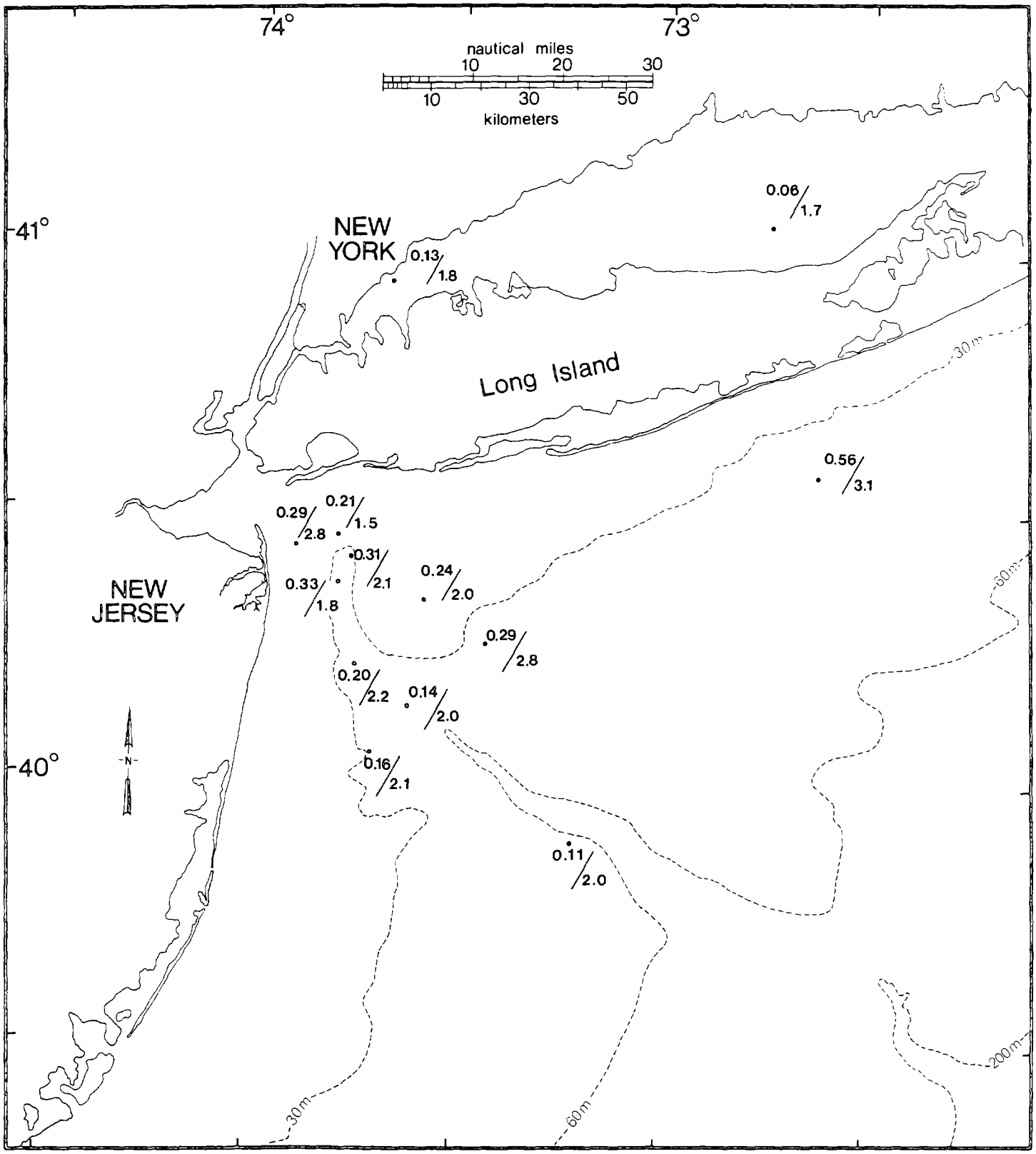


Figure 22. Wet weight values for PCBs (ppm)/% body fat in winter flounder.

GPO 946-025

measured in any species was 1.08 ppm in a lobster composite from station 9 in the lower CB (Fig. 18). All other composites of the target species contained ≤0.63 ppm PCBs. Values in winter flounder (Fig. 22) ranged from 0.11-0.56 ppm, with the highest concentration found ∿21 km off eastern Long Island. Windowpane flounder body burdens (Fig. 20) had a slightly greater range, from 0.06-0.63 ppm. All values for red hake (Fig. 17) were ≤0.1 ppm except for 0.34 ppm at a mid-shelf station off eastern Long Island. PCBs in scallops (Fig. 21) were very low or undetectable, with all values <0.04 ppm. Scallops could not be found in the inner New York Bight; they will be replaced by another species in future sampling.

The target species available in LIS also showed no consistent patterns of PCB burdens. The rock crab composite from the more contaminated western end had a higher concentration than did any of the Bight crab composites, and crabs from the mid eastern sound had a medium level (Fig. 19). On the other hand, windowpane flounder from western LIS had the lowest level recorded for that species, while a concentration more typical of those found in the Bight was measured at the eastern LIS station (Fig. 20). Lobsters (Fig. 18) and winter flounder (Fig. 22) from both eastern and western LIS had low levels. Moderate concentrations were found in red hake from eastern LIS (Fig. 17).

The lack of a consistent pattern of higher body burdens in more contaminated areas may be related to the mobility of the species sampled. It is possible, though conjectural, that a large proportion of the measured body burdens is acquired in the inner NYB or other contaminated areas, but that the migratory nature of most megafauna (and/or of their prey) yields the observed pattern of low body burdens across large areas of the shelf. Boehm (1980a), reporting results of a broader-scale survey of PCBs and petroleum hydrocarbons in shelf biota off the northeastern United States, similarly noted low-level contamination throughout the region, and the absence of high values, in contaminated areas or elsewhere. (Murray [1979] has also documented widespread presence of PCBs in areas remote from point-source contamination, in England and Wales.) Concentrations measured in the present survey were, however, generally at least an order of magnitude higher than Boehm's (1980a) reported values, if the latter are converted from dry to approximate wet weight by dividing by 5.

Our values are in better agreement with those of MacLeod et al. (1981), which included more samples from the apex than did Boehm's (1980a) Bight analyses. Both the MacLeod et al. survey and ours reported similar low concentrations of PCBs in scallops (≤0.04 ppm). Our values for rock crabs and windowpane flounder were about 1-2 times, winter flounder 1-5 times, and lobster 2-10 times levels found by MacLeod et al. (1981).

A condition factor could also be obscuring any tendency of biota from contaminated areas to show higher PCB body burdens. As mentioned above, PCBs have an affinity for fats, so composites with a greater fat content might be expected to accumulate more PCBs. Murray (1979) found highest PCB values in organs of fish with the highest lipid levels. In our study, fat and PCB contents were correlated at the 0.01 significance level for the combined data on red hake, windowpane and winter flounder (no correlation was found for the shellfish species). If fat content of the species examined is somehow inversely related to environmental stress, this will tend to confound any direct relation between environmental contamination and PCB body burdens, and could contribute to the observed absence of dramatically elevated burdens in the inner Bight.

PAHs

Data are available on concentrations of all 16 PAHs analyzed. For the sake of brevity, we report (Table 11) only summed values for all PAHs (with and without phenathrene, since the relatively high concentrations of this compound often obscured trends in other PAHs). Values for indeno (- 1, 2, 3, - c, d) pyrene are not included in Table 11 because peaks were often off the stripchart scale and because the values are suspect without mass spectral confirmation.

Highest overall PAH values were found in rock crabs, with a peak of 2.51 ppm wet weight (almost all phenanthrene) in mid-eastern LIS. Lobster had next highest residues, ranging from 0.14-0.53 ppm, followed by red hake. The only geographical trend noticed was a slight tendency for the total PAH (minus phenanthrene) for all species combined to be highest in and near CB.

3.5 MICROBIOLOGY OF SEDIMENTS AND BIOTA

Dr. John Graikoski, NMFS, Milford Laboratory, Principal Investogator.

3.5.1 Methods

All sediments and animals were analysed shortly after collection. For sediments, the top 1-2 cm of sediment from a grab sample were removed with a sterile tongue depressor, placed in a sterile bottle, and kept at 5-7°C until analysis. Procedures for fecal coliform determination were essentially as described earlier (Babinchak et al. 1977a, b).

The three-tube most probable numbers (MPN) techniques was used, in EC broth which was incubated at 44.5°C in a circulating water bath. All dilutions were made volume-to-volume with 0.5% sterile peptone saline as the diluent. The EC (+) cultures were streaked on Levine

Table 11. Concentrations of total PAHs measured (left of oblique lines) and totals without phenanthrene (right) in target species. Values are in parts per billion, wet weight. * = "contaminated" area in Figure 1.

Station	Winter flounder	Windowpane flounder	Red hake	Lobster	Rock crab	Scallop
1*	119/23				250/126	
6*	28/3	163/84		434/280	95/14	
9*	225/117			530/363	530/363	
12*	214/118	164/9			697/463	174/118
14					523/157	97/23
15					285/68	
16*	150/62		273/26	243/99	305/78	
18*				510/350	475/207	
30	155/29	217/46	376/60			
31						194/75
33	246/157				69/17	136/41
34					529/165	
36			501/124		252/54	141/36
38			323/109		1989/1510	44/38
41*		35/9				
46	142/27	213/83	270/60			
47			317/70	229/78		
50	233/23	361/83				
51*	171/106					
53*		153/45	389/131	311/161		
57*		494/175				
58*	126/23					
59*		260/66				
LIS 8	200/21	139/88		494/322	842/216	
LIS 88	123/27	189/38	241/18	137/34	2510/165	

eosin methylene blue plates (EMB), and incubated 24 hours at 35°C. Isolated colonies were picked onto slants for identification at the laboratory. In addition to the MPN determination, we also evaluated direct enrichment of approximately 3 grams of sediment in 30 ml of lauryl sulfate tryptose broth (LST) medium with incubation at 35°C for 24 hours, followed by subculturing into EC medium. The purpose was to detect fecal coliforms not detected by the MPN technique and to evaluate the direct MPN-EC procedure. Direct platings of sediment dilutions were also done on Violet Red (VR) agar, another medium used to detect fecal coliforms.

Additional collections for biota were made in September. Animals were analyzed as follows:

Total and Fecal Coliforms - Total coliform concentrations were determined in lauryl sulfate tryptose (LST) broth at 35°C with confirmation for fecal coliforms in EC broth incubated at 45.5°C. Gills and guts of crabs and lobsters, and whole scallops, were analyzed. Initial animal homogenates were made on a weight-to-weight (1:1) basis with peptone saline. To obtain enough material for analysis, it was necessary in most cases to pool tissues from several animals from each trawl or drag. As with the sediment, isolates were taken from the positive tubes for identification.

E. coli - Positive EC broth cultures were streaked onto EMB plates. Isolated colonies were pciked onto agar slants for future identification by API (Analytical Products, Inc.) speciation.

Fecal Streptococci - Aliquots of the animal homogenates were incubated in FC broth and streaked onto FC agar medium with incubation at 35°C. Typical isolated colonies were picked onto slants for later confirmation. Confirmation of isolates was by gram size stain and cell morphology.

Klebsiella - Homogenates of animals were streaked directly on the klebsiellae medium (3). Typical blue colonies were picked for identification by the API system. Other isolates were obtained from the coliform tests.

Clostridium perfringens - Homogenates were streaked onto egg yolk agar containing the antibiotic cycloserine. This was done either directly or after enrichment in cooked medium or the thioglycolate broth containing the antibiotic, with incubation at 35°C for 24 hours. Confirmation of isolates was done biochemically.

Salmonella - Homogenates were inoculated in sodium tetrathionate enrichment medium containing brilliant green and incubated at 35°C for 24 hours. After incubation, brilliant green bismuth sulfite agar plates were streaked. Typical colonies were picked further for identification.

Vibrio spp. - Enrichments were in alkaline peptone broth with incubation at 37°C for 8-18 hours. Cultures were streaked onto TCBS agar to obtain isolated colonies for identification.

Speciation of all isolates was done by the API system.

3.5.2 Results

Sediments

Fecal Coliforms - Results of the fecal coliform analysis are shown in Fig. 23 and listed in Table 12. Fecal coliforms were detected in the top sediments from 9 of the 43 stations. Counts in the sediments ranged from less than 15 per 100 ml sediment, the lowest number detectable by our MPN procedure, to 23,000, the latter obtained from the sewage sludge dump area (station 7). The numbers and pattern of distribution were similar at those stations which were sampled in our previous studies in 1971-1975 (Babinchak et al. 1977a).

The detection of fecal coliform in sediments by direct enrichment paralleled that obtained by the MPN procedure, with two exceptions. At station 3 the sediments were positive by the MPN procedure but negative by direct enrichment. At station 43 the reverse was true. These results would support the validity of directly inoculating EC broth with sediment dilutions and incubating at 44.5°C for the detection of fecal coliforms.

E. coli - approximately 80 cultures were obtained for speciation. Of the 80 isolates, 41 of the 47 colonies showing morphology characteristics of E. coli on EMB agar plates were identified as E. coli (Table 12) by the API procedure. Isolates from 15 purple colonies yielded 6 E. coli. The other isolates tested were Klebsiella spp. or not identified in the API profile index. All positive EC tubes yielded E. coli. Incubation of sediments in EC medium at 44.5°C would appear to be highly specific for the detection of E. coli, the positive indicator of fecal pollution.

Clostridium perfringens - The enrichment of sediments from all stations for C. perfringens yielded colonies on egg yolk agar which could be presumptively identified as C. perfringens. Final confirmation was not done on all isolates, so some of the sediments may be questionable for the organism. However, more sediments yielded C. perfringens (Figure 24, Table 12) than fecal coliforms as determined in the EC medium. This would indicate that C. perfringens is a more effective indicator of sewage contamination than are the fecal coliforms. The higher plate counts for C. perfringens obtained in the sediments also had higher fecal coliforms as determined by the MPN procedure. Not enough comparisons were made, however, to establish these comparisons definitely.

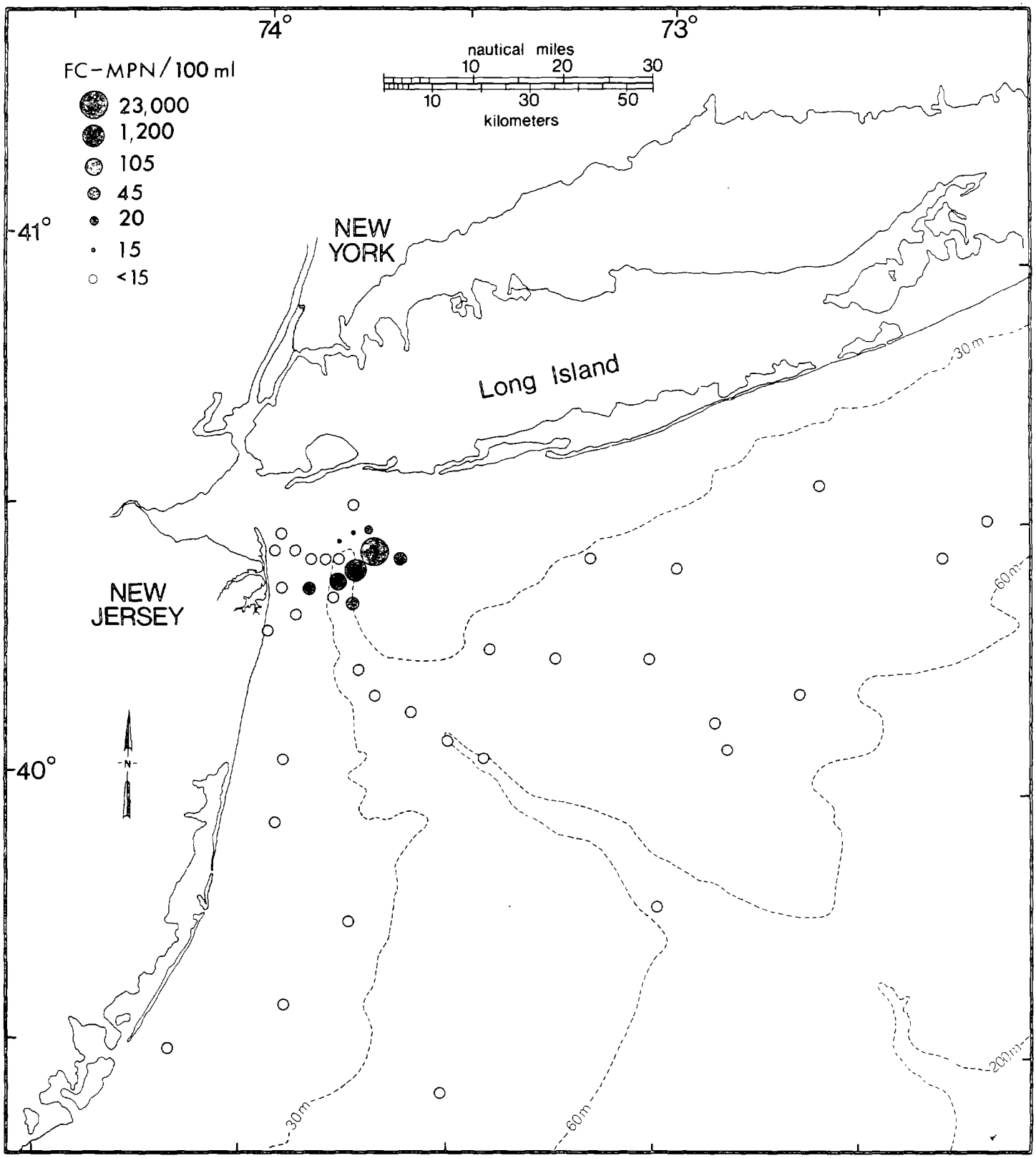


Figure 23. Fecal coliforms in top layer of sediments.

Table 12. Fecal coliforms in top layer of bottom sediments - New York Bight.

Station number	FC/100 ml sediment	Sediments Enrichments LST[1]	EC[1]	*E. coli*[2]	*C. perfringens* Enrichment	No./gram
1	15	+	+	+	+	NA[4]
2	15	+	+	+	+	NA
3	20	+	0	NA	+	NA
4,5	<15	+	0	NA	+	$6x10^2$-$5x10^3$
6	1,200	+	+	+	+	$1.1x10^6$
7	23,000	+	+	+	+	$1.1x10^5$
8	45	NA	NA	NA	+	$1.3x10^5$
9	105	+	+	+	+	$3.7x10^4$
10	<15	+	0	NA	+	NA
11	45	NA	NA	NA	NA	$1.8x10^3$
12-21	<15	+	0	NA	+	NA
22	45	NA	NA	NA	+	$>3.6x10^4$
23-40	<15	+	0	NA	Q[5]	NA
41	<15	+	0	+[3]	Q	NA
43	<15	+	+	NA	+	$9.3x10^2$
44	NA	+	+	+	+	NA

[1]LST Broth 35°C 48 hours
EC broth 44.5°C 24-28 hours

[2]EMB isolates by API speciation - Total number tested 80 - EMB positive 47, *E. coli* speciation 41

[3]From LST Broth

[4]NA = Not analysed

[5]Q = Questionable

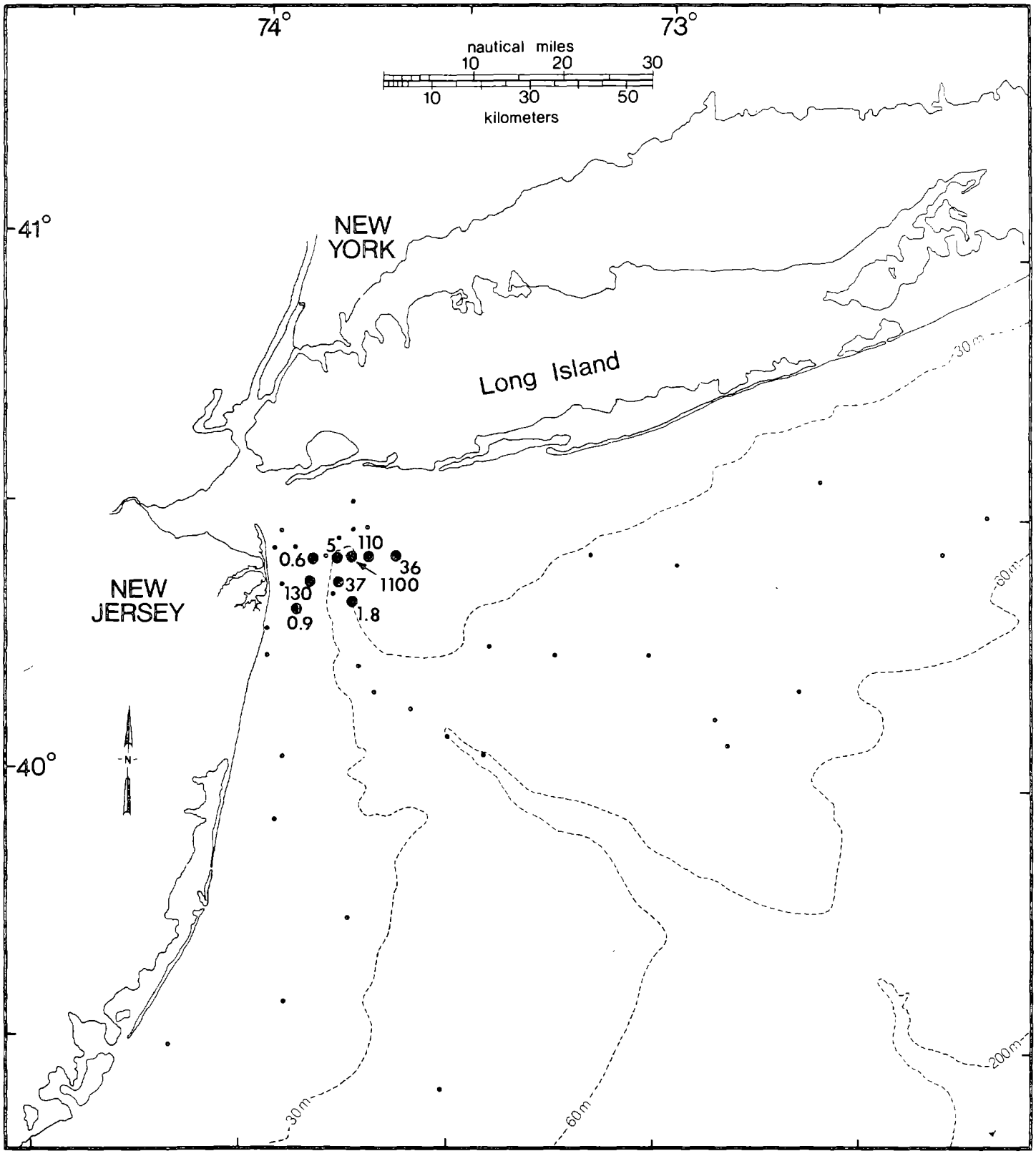


Figure 24. Clostridium perfringens in top layer of sediments. Actual values are values shown x 10^3. Dots without values indicate stations where no C. perfringens were found.

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Animals

The animals analyzed for the target group of bacteria included 12 lobsters, 8 crabs, and 12 scallops obtained from 9 stations. The tissues examined included the gills and guts of crabs and lobsters and the whole scallop. The amount of material needed to inject the various bacteriological media required that several animals, because of their size, be pooled for analysis. The number of animals from some of the desired stations was also limited. Results of all tissue analyses are given in Table 13.

Total Coliforms-Fecal Coliforms - The total coliform MPN count per gram of tissue examined varied from greater than 12,000 to 70. Counts had a tendency to be higher in animals from inshore stations, although high counts were also found at offshore station 35.

Fecal coliforms were demonstrated in animals from 5 of the 9 stations sampled. Positive readings were from the inner Bight, again with the exception of station 35. The fecal coliform MPN count per gram varied from 1200 to <15 per gram of animal tissue. No explanation for the presence of fecal coliforms at station 35 can be given at this time.

E. coli - EC tubes yielded 41 cultures positive for E. coli on speciation. All EC-positive tubes from the animals yielded E. coli, demonstrating sewage contamination in these tissues.

Fecal Streptococci - Except for material from station 49, all cultures analyzed contained gram (+) cocci. The presence of fecal streptococci did not correlate with the fecal coliform count; more animals were positive for this organism than for fecal coliforms.

Clostridium perfringens - All cultures produced from animal enrichments were presumptive positive for C. perfringens. Not all isolates are confirmed as C. perfringens because difficulties in outgrowth occurred in one of our biochemical tests, but at least one culture obtained from each animal was positive for C. perfringens. This is an indication of sewage contamination, although the fecal coliform test did not confirm such contamination. Also, other clostridial types were noted on the plates but have not been identified further.

Potential Pathogens

Salmonella: Three isolates, one from brilliant green and two from sulfate agar, speciated by the API system to be Salmonella spp. These isolates came from scallops that were harvested from station 40, near the sludge and dredge spoil dumpsites. It is interesting to note that fecal coliforms were not detected at this station, either in the animals or in the bottom sediments.

Table 13. Bacteriological analyses on animals from the New York Bight.

Station	Animal	Total Coliform (MPN/g)	Fecal Coliform (MPN/g)	*E. coli* (No. isolates)	Fecal streptococcus	*Clostridium perfringens* P	*Clostridium perfringens* C
1	Crab	2,300	45	+ 3	+	NA	NA
9	Lobster 1	1,200	NA	NA NA	+	+	+
"	" 2	1,200	NA	NA NA	+	+	0
"	" 3	1,200	NA	NA NA	+	+	+
"	" 4	>12,000	NA	+ 1	+	+	0
"	Crab	1,200	NA	NA NA	+	+	0
10	Lobster 1	+	+	Citrobacter	+	+	+
"	" 2	+	+	+ NA	+	+	+
"	" 3	+	+	No ID	+	+	+
"	" 4	+	+	+ 1	+	+	0
"	" 5	+	+	NA NA	+	NA	NA
35	Crab 1	>12,000	NA	NA NA	+	+	0
"	" 2	215	<15	NA NA	+	+	+
"	" 3	12,000	1,200	+ 2	+	+	+
36	Scallop 1	1,200	<15	NA NA	+	+	+
"	" 2	1,200	<15	NA NA	0	+	+
"	" 3	2,300	<15	NA NA	0	+	+
38	Crab 1	5,500	<15	NA NA	+	+	+
"	" 2	70	<15	NA NA	+	+	+
"	" 3	120	<15	NA NA	+	+	+
40	Scallop 1	465	<15	NA NA	+	+	+
"	" 2	5,500	<15	NA NA	+	+	+
"	" 3	5,500	<15	NA NA	+	+	+
"	" 4	>12,000	<15	NA NA	+	+	0
"	" 5	1,200	Q	*C. freydii* NA	+	+	+
"	" 6	1,200	<15	NA NA	+	NA	NA
49	Scallop 1	115	NA	NA NA	0	+	+
"	" 2	115	NA	NA NA	0	+	+
"	" 3	465	NA	NA NA	0	+	+
S. Ambrose	Crab 1	>12,000	<15	NA NA	+	+	+
"	" 2	>12,000	45	+ 2	+	+	+
"	" 3	>12,000	45	+ 3	+	+	+
"	Lobster 1	2,300	<15	NA NA	+	+	+
"	" 2	1,200	20	NA NA	+	+	+
"	" 3	5,500	0	NA NA	+	0	0
"	" 4	1,200	20	+ 1	+	+	+

[1]P = presumptive; C = confirmed; NA = not analysed; Q = questionable.

Klebsiella: Seven blue colony isolates that were oxidase negative were identified but only one, from a lobster from station 10, was Klebsiella oxytoca. It would appear that in our hands the medium was not selective for this organism, although the medium can detect the presence of the organism. Klebsiella pneumoniae was identified from our fecal coliform analysis of the animals, in a lobster from station 9 and a crab from near station. Klebsiella oxytoca was also demonstrated in a crab from station 10.

Vibrio spp.: Table 14 lists the speciation of the isolates obtained from the animals. The presence of the various isolates did not correlate with stations from which the animals were harvested. V. alginolyticus was the most common species encountered. This species is considered, but has not been established as, pathogenic. Of significance is the demonstration of the pathogens, V. parahaemolyticus and V. cholerae. The latter organism is not the classical cholera type usually found in Asia, but has been involved in food poisoning outbreaks in the United States.

3.6 VIRUSES IN SEDIMENTS AND ROCK CRABS

Dr. Sagar Goyal, Baylor College of Medicine, Houston, Texas, Principal Investigator.

3.6.1 Methods

Sediments from thirty stations and rock crabs from eight stations (usually 20-30 crabs per station) were analysed. Viruses were recovered from 250 to 500-gram samples of sediment following a procedure developed in our laboratory (Goyal et al. in prep.). The method (Fig. 25) consists of eluting the viruses from sediment by suspending the sediment in three volumes of 39% beef extract solution (pH 10.5). After vigorously shaking the mixture for five minutes it is centrifuged at 500 x g for 10 minutes. The supernatant is adjusted to pH 3.5 with the use of 1 M glucine, pH 1.5, which results in the formation of an organic floc. The floc is obtained by centrifugation of the sample at 500 x g for 5 minutes. Most of the viruses are present in this floc and are eluted by mixing the floc with 5-10 ml of 0.05 M glucine, pH 11.0. After another centrifugation at 900 x g for 20 minutes, the supernatant is obtained, passed through an 05S filter to reduce cytotoxicity, and assayed. The overall recovery efficiency of this method is greater than 50%.

3.6.2 Results

Viruses were isolated from sediments from five of the 30 stations analyzed (Fig. 26). Presence of an unidentified virus at station 5, between the dredge spoil and sewage sludge dumpsites, is presumably due to dumping activities; the unidentified virus 6.3 km off the Long Island coast, and echovirus type 1 4.7 km from Sandy Hook and the mouth of Lower Bay could have other sources. Occurrence of echovirus type 7 well to the east of the NYB apex (station 30) and type 1 on the mid-shelf off eastern Long Island (station 34) is more surprising. Station 34 is, however, in the area where we unexpectedly found total and fecal coliform bacteria in rock crabs. No viruses were found in the crabs analyzed.

Table 14. Vibrio and related species in animals - New York Bight.[1]

Species	No. of animals	Isolates
Lobster	12	27 - *Vibrio alginolyticus*
		4 - *Vibrio cholerae* (NA)
Crab	8	9 - *Vibrio parahaemolyticus*
		5 - *Vibrio alginolyticus* or *V. cholerae* (NA)
Scallop	12	2 - Lactose (+) hydrophilic
		3 - *Aeromonas hydrophilia*
		7 - *Pseudomonas* spp.
		1 - *Chromobacter*
		12 - Non-identified
	Total	70

[1]Animals were from stations 1, 9, 10, 35, 36, 38, 40, 49, and a station added just west of station 28.

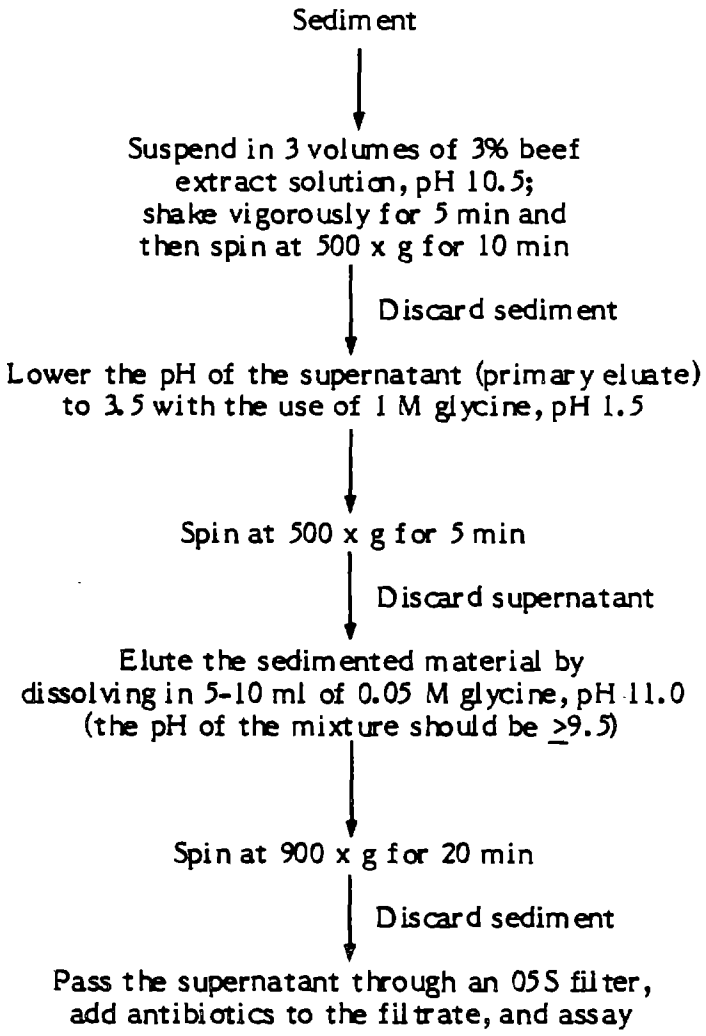

Figure 25. Methodology for determination of viruses in sediments.

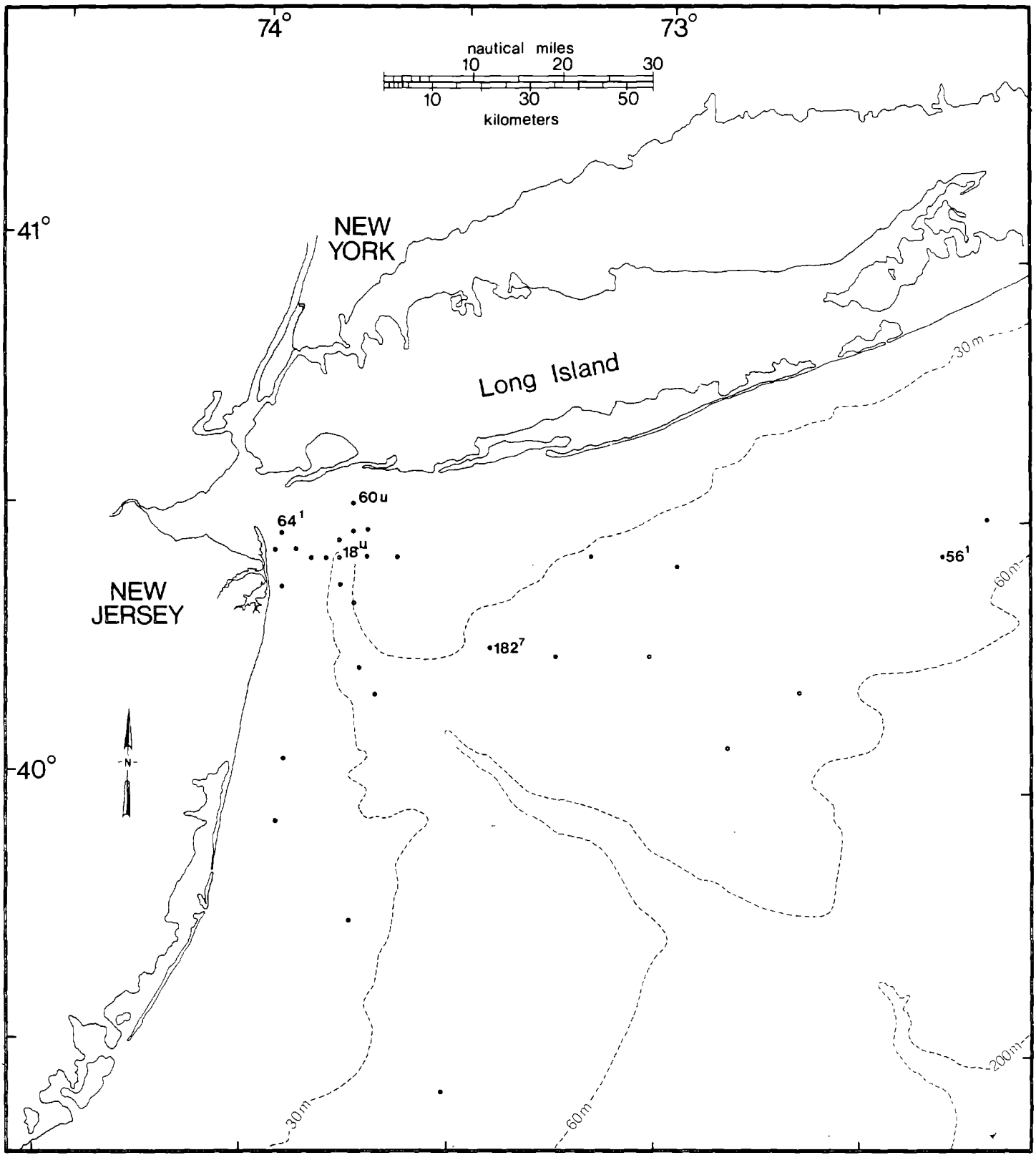

Figure 26. Numbers of human enteroviral isolates per kg of sediment. 1 = echovirus type 1; 7 = echovirus type 7; u = unidentified virus; dot without data = no virus isolated

The survival and presistence of viruses in the marine environment is of interest because viruses appear to survive longer than coliform bacteria, which are presently used to monitor the quality of water. Also, the hazard posed by viruses is considered to be more than that posed by bacterial pathogens because as little as one plaque-forming unit (PFU) of virus is capable of causing an infection in a susceptible host. Our recent studies have indicated that marine sediments may play a major role in the distribution, survival, and transport of bacterial and viral pathogens in the marine environment (Goyal et al. in prep.).

3.7 GILL FOULING IN ROCK CRABS

Dr. T. K. Sawyer, Mr. M. A. Galasso, and Mr. E. J. Lewis, NMFS, Oxford Laboratory; Mr. J. Ziskowski, NMFS, Sandy Hook Laboratory, Principal Investigators.

3.7.1 Methods

Rock crabs, Cancer irroratus, collected in trawls were measured (carapace width in cm), sexed, and opened to permit visual observations of gill color. Color was recorded as clean (white-yellow), discolored (tan-brown), less than 50% black, or more than 50% black. Gills from subsamples of the total number examined (41/338) were preserved in Davidson's fixative and processed for routine histological examination. Gross observations for evidence of stress or disease included examinations for blackening of the carapace, perforation in the shell or appendages, and small localized black areas in the gill indicative of tissue damage and melanin formation. A total of 337 Cancer irroratus were examined for evidence of black gill disease (Table 15): Gill color was recorded for 126 specimens captured in the "contaminated" area (see Fig. 1) and for 211 captured in the "control" area.

3.7.2 Results

The ratio of male to female crabs was approximately 1.4:1 (203 males, 134 females). Ninety-four percent (317/337) of the specimens had clean gills and only 2.5% (7/337) had gills that were partially blackened. There were no apparent differences between crabs from "control" and "contaminated" stations. The remarkably low incidence of black gill disease at most contaminated stations may have been an artifact of small sample size; the number of animals available for examination ranged from only 3 to 25 per station, whereas previous surveys showed that 50-100 specimens per station should be collected for each determination.

More than 50 specimens were available for examination at two of the "control" stations (36 and 46 - see Fig. 1); two animals with more than 50% of their gill tissue blackened were caught at 36, and two with less than 50% blackening at 46 (Table 15). The low incidence of black

Table 15. Summary of rock crab, Cancer irroratus, collections and gill fouling incidence in the New York Bight, July 1980.

Station No.	Type	No. Males	No. Females	Total Examined
1[1]	Contamin.	12	3	15
2	"	1	2	3
3	"	0	3	3
4	"	0	10	10
5	"	14	11	25
6	"	5	5	10
52	"	26	5	31
57	"	14	3	17
58	"	4	8	12
26	Control	7	5	12
32	"	1	5	6
34[1]	"	4	11	15
36[2]	"	58	17	75
38	"	17	12	29
46[1]	"	40	34	74
		203	134	337

[1]Stations with 1 crab with <50% gill blackening, except for station 46 which had 2.

[2]Station with 2 crabs with <50% of gills blackened.

gill disease at stations not in proximity to disposal sites, but within the confines of the New York Bight apex, was within the range previously observed in surveys of C. irroratus and reported by Sawyer et al. (1979). Black discoloration of the carapace or black perforations in the carapace or appendages was observed in 8% of the specimens (26/337). The two conditions were observed in both male and female crabs, and the incidence of both was approximately the same at "control" and "contaminated" collection strata. Black foci of melanization in otherwise clean gills were noted in 5 specimens (3 males, 2 females) and the condition was observed in both collection strata. Stations sampled and the number of crabs from each are summarized in Table 15.

Forty-one of the 126 crabs from "contaminated" stations were examined for histological evidence of disease or stress (Table 16). Unidentified copepods, probably ectoparasitic, were found between the gill lamellae of approximately 50% of the crabs examined from nearshore stations in the Bight apex. This represents a noteworthy increase over previous data.

Conversely, incidence of sessile ciliate protozoa attached to the gill cuticle was lower than in past studies. Previous studies (Sawyer et al. 1979) conducted at nearshore stations with a depth of 30 m or less showed that approximately 25-50% of the rock crabs had ciliated epibionts. Only 3 of the 41 crab gills (7%) examined in the present survey had similar fouling organisms and only one ciliate per tissue section was observed. Factors which influence the incidence and abundance of ciliates and copepods on the gill lamellae have not been determined. The incidence of epiphytic bacteria which often coat gill surfaces (Bodammer and Sawyer 1981) was approximately the same as recorded from previous surveys (50%). Although bacteria have not been identified to genus or species, ultrastructural studies (Bodammer and Sawyer 1981) have shown that nine different morphological types may be recognized in photomicrographs.

Analyses of all data on gills from C. irroratus collected since 1973 showed that the incidence of the fouling entities, except ciliates and copepods, was approximately the same as observed in the present survey. Again, the remarkably low incidence of black gill noted here may have been partly due to the small numbers of crabs captured at most of the selected stations. Our eight years of data indicate that a value of 0-2% reflects the background incidence of black gill disease in the Bight, and that a value of up to 10% may be characteristic of those areas impacted by the deposition of barge-delivered wastes (Sawyer et al. 1979).

Table 16. Percent incidence of gill-fouling entities on 41 Cancer irroratus from the New York Bight collected in July 1980 (upper row of figures) vs. entities on 472 Bight specimens examined since 1973 (Sawyer et al. 1979).

	Debris	Bacteria	Diatoms	Ciliates	Amoebae	Copepods
1980	61	50	17	7	25	50
Earlier	61	51	22	13	20	16

3.8 BENTHIC MACROFAUNA COMMUNITY STRUCTURE

Mr. Robert Reid, NMFS, Sandy Hook Laboratory, Principal Investigator.

3.8.1 Methods

Sediments were washed through 0.5 mm mesh sieves except for in LIS, where 1.0 mm sieves were used to remain consistent with our past sampling there. Retained materials were fixed in 10% formalin and later transferred to 70% ethanol with 5% glycerin. Dissecting microscopes were used for all sorting. Identifications were to species level when possible, except for rhynchocoels. Oligochaetes, archiannelids and colonial forms were not enumerated due to uncertainty of identification and/or difficulty of quantification. The resulting data set thus is consistent with those from most other NYB macrofauna studies.

Species diversities were calculated using the Shannon and Weaver (1963), index, $H' = -\sum_{i}^{S} p_i \ln p_i$, where p_i is the proportion of individuals in the i^{th} species. Q-mode cluster analysis (clustering stations according to species they have in common) was performed using all samples. To facilitate computation, the number of species was reduced to 150 by eliminating all species occurring at ≤ 5 stations and having a maximum density of ≤ 6 individuals at any station. The Bray-Curtis (1957) coefficient, $C_z = 2w/a+b$ was used to measure faunal similarities between stations. Here "a" is the sum of abundances of all species found in a given sample, "b" is the sum of species abundances for another sample, and "w" is the sum of the lower of the abundance values for each species common to both samples. Abundances were transformed by natural logarithms. Clustering was performed using flexible sorting with $\beta = -0.25$.

3.8.2 Results

Species Richness

A total of 408 species were collected at the 44 benthic stations. Number of species (S) at a given station is a relatively clear indicator of environmental stress (Green 1977). It is generally lower in areas of natural or man-made stresses, whereas variables such as faunal density and diversity may show increases or decreases depending on the nature or severity of the stress.

Numbers of species found at each station are shown in Fig. 27. Several species-poor areas are indicated. Lowest S (15/0.1 m^2) in the NYB was found in the sewage sludge deposition area (station 6) which is well documented for its impoverished fauna (NMFS 1972; Pearce 1972; Walker et al. 1979; Boesch in press; Caracciolo and Steimle in press). Two stations (23 and 26) near the southern NJ coast also had S<20. Physical stresses (primarily the dynamic nature of the sediments, and perhaps wide annual temperature fluctuations) must be partly responsible for the low S in these inshore areas. S values of 22-27 were found at four other coarse-sediment stations in waters of ≤ 21 m along the NJ coast. S was higher as a rule along the northern than southern NJ coast. This implies a lack of distinguishable adverse effects of the Hudson plume (or other waste sources) along the northern coast.

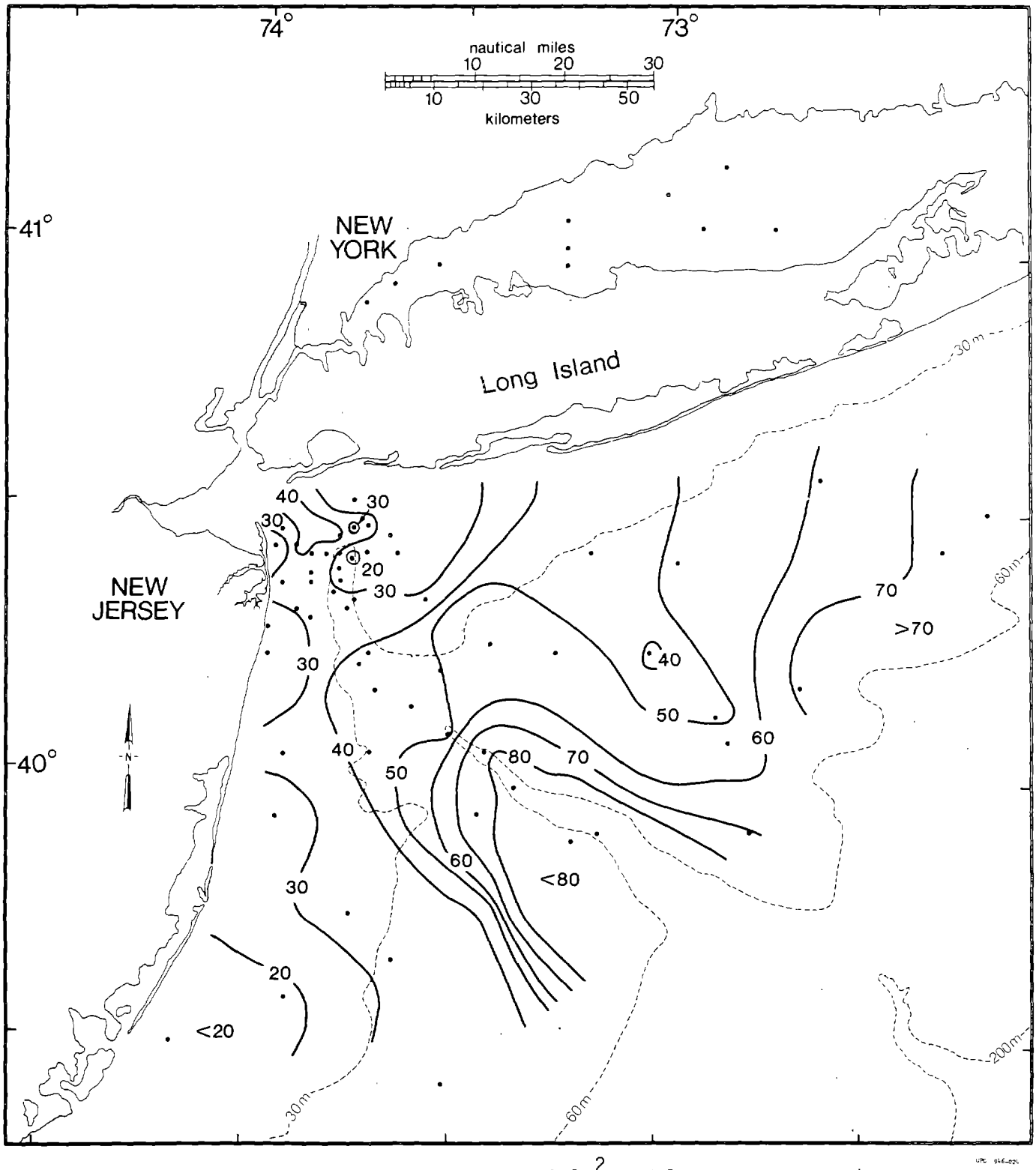

Figure 27. Numbers of species per $0.1m^2$. Values are means where replicate grabs were processed (see Figure 1). NYB data are based on 0.5 mm sieves, and LIS values on 1.0 mm.

The sewage sludge disposal site (station 7) and six other stations with 21 km of the disposal site had S values between 20 and 30. This is well below values found in similar sediments further down the HSV (see below), and is presumed to be partly a contaminant effect. The dredge spoil dumpsite (station 4) and vicinity had slightly higher S, between 30 and 40, as did the remainder of the "contaminated area" stations. There was a fairly steady increase in S moving down the HSV, from 40-50 at the northern end to 80 at station 15 -- this is the point in the HSV where large populations of Ampelisca agassizi and other sensitive amphipod species first appear, coincident with a marked decrease in levels of trace metals [and presumably other contaminants] (Boesch in press). Highest S was found at station 14, the outermost HSV station. Long Island offshore (>30 m deep) stations also had high species richness (41-79). As in the HSV, the highest values were found furthest offshore. The single NJ offshore station had a lower S (35) than did any LI counterpart. It is not known whether this represents a real difference between the areas. Some "noise" in the S values should be expected, especially where data are based on single grabs -- witness the values of 47, 57 and 72 at three neighboring LI offshore stations with similar depths and substrates.

S values for all LIS stations were lower than any recorded for the NYB. (This is partly because the 1 mm sieves used in LIS collect fewer of the small species; the LIS and NYB data therefore cannot be directly compared.) Low S in LIS may also be due to some combination of the fine and often resuspended sediments present, other typical estuarine stresses (such as large annual temperature fluctuations), and contamination. There is no clear indication of further reduction in S, however, in the more contaminated western end of LIS.

Species Diversity

Although species diversity (H') may not bear a single or direct relationship to environmental health (Goodman 1975), distribution of H' diversity values (Fig. 28) did parallel other evidence concerning the degree of stress present in certain areas of the Bight. Trends in H' generally agreed with those for species richness (this is expected, since S is a component of H'). Lowest H' (0.7) was found in the sludge deposition area. Several nearby stations also had H's of less than 2.0. Values were higher in the upper HSV, and increased moving down the valley to a maximum of 3.3 at the outermost valley station. Long Island and New Jersey offshore stations also typically had high diversities (2.2-3.3). Inshore stations 21 and 23, which had very low S values, had low H' as well (1.0).

The principal area of disagreement between S and H' was in the NJ inshore sector, where H's were relatively high although species richnesses were low. This was because of high evenness of distribution

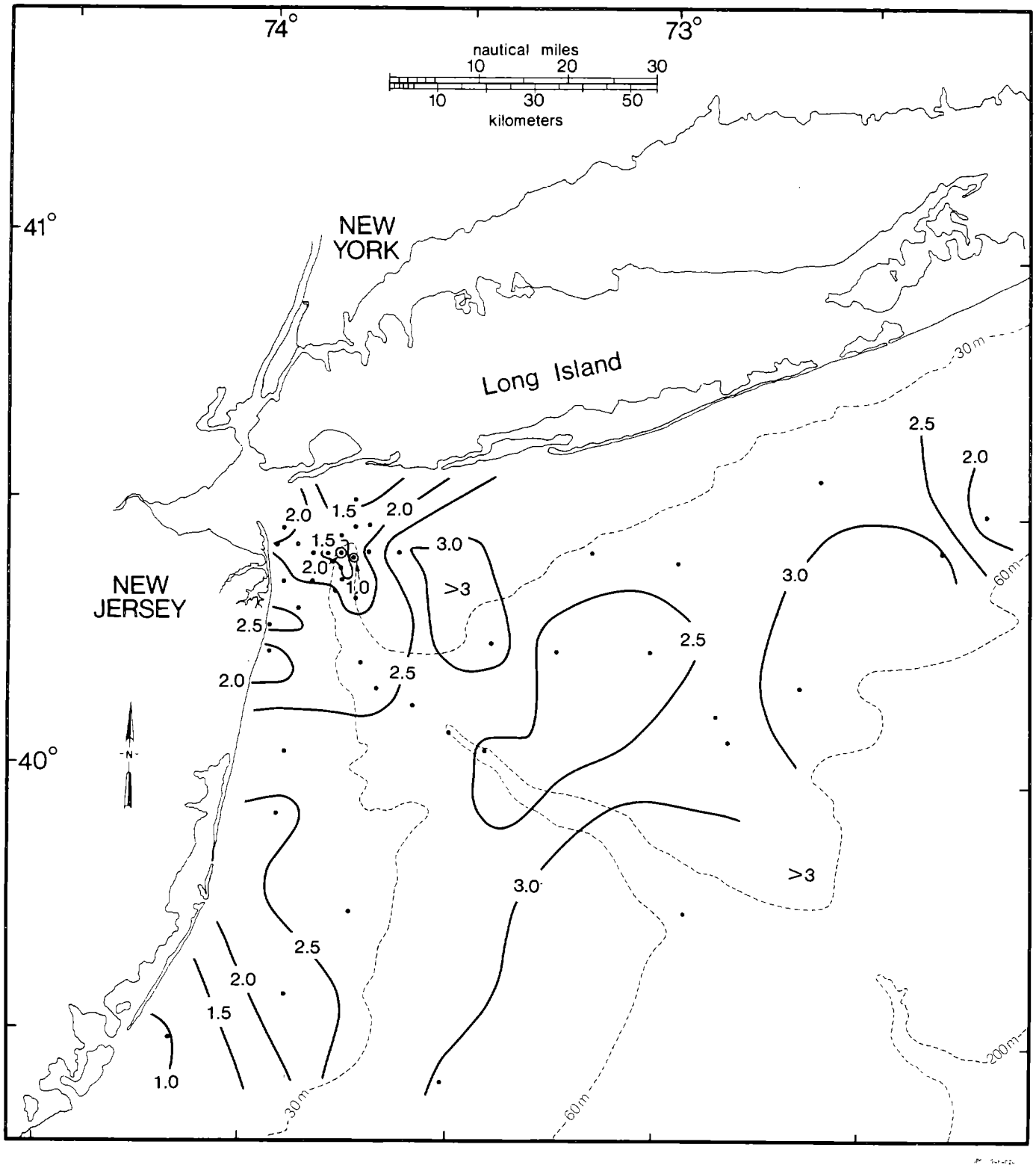

Figure 28. Shannon-Weaver species diversities per 0.1 m^2.

of individuals among species (the other component of H'); few species had high densities at any of these stations, which perhaps reflects the rigors of living in coarse shifting sand or in areas of low carbon content. Diversities in LIS were quite low (0.7-2.0) and comparable to CB values. Again, the low values may be partly due to use of a larger mesh sieve. No trends were obvious from east to west in LIS.

Community Structure (Cluster Analysis)

Classification of stations according to similarity of species compositions yielded nine station groups at the 30% similarity level (Fig. 29). The groups were: A - three stations in southern CB and three in the adjacent northern HSV; B - eight stations in and near CB; C - the two stations furthest south in the HSV and a Long Island offshore station; D - the single NJ offshore and a LI offshore station; E - nine LI offshore stations; F and H - each two NJ inshore stations; G - the dumpsites and nearby NJ inshore and CB stations (two of each); and I - five of the six southernmost NJ inshore stations.

Distribution of these groups is shown in Fig. 30. Not surprisingly, most groups consisted of stations which were physically close together as well as having similar depths and sediment types. Some noteworthy observations are:

1) Group G contained the most contaminant-altered stations. Assemblages at the sewage sludge dumpsite and sludge deposition area were sparse and dominated by pollution-tolerant species such as the polychaetes, Capitella spp., and isopod, Edotea triloba. The dredge spoil dumpsite had a denser and more diverse fauna, but here also many of the dominants were species often found in contaminated sediments (i.e., polychaetes, Amastigos caperatus and Polydora ligni, and bivalve, Tellina agilis). Of the other stations in this group, the fauna at 21 and 42 graded toward the "periphery" assemblage discussed below, having moderate numbers of several species which reach high densities in the periphery assemblage. The similarity of station 22 and 43 assemblages to dumpsite and periphery faunas was less obvious.

2) All Group B stations were 4-8 km from one or both dumpsites, and were characterized by very high densities of ceriantharian anthozoans and the deposit-feeding bivalve, Nucula proxima, and polychaetes, Nephtys incisa and Pherusa affinis. Such "enriched" assemblages have often been found on the peripheries of areas of high organic loading (Pearson and Rosenberg 1978). Walker et al. (1979) and Boesch (in press) noted the occurrence of this assemblage in CB; the large populations of several tolerant species are apparently in response to high concentrations of labile carbon in areas where sediment consistency or toxicity is less limiting than in the sludge deposition area. The deposit-feeding

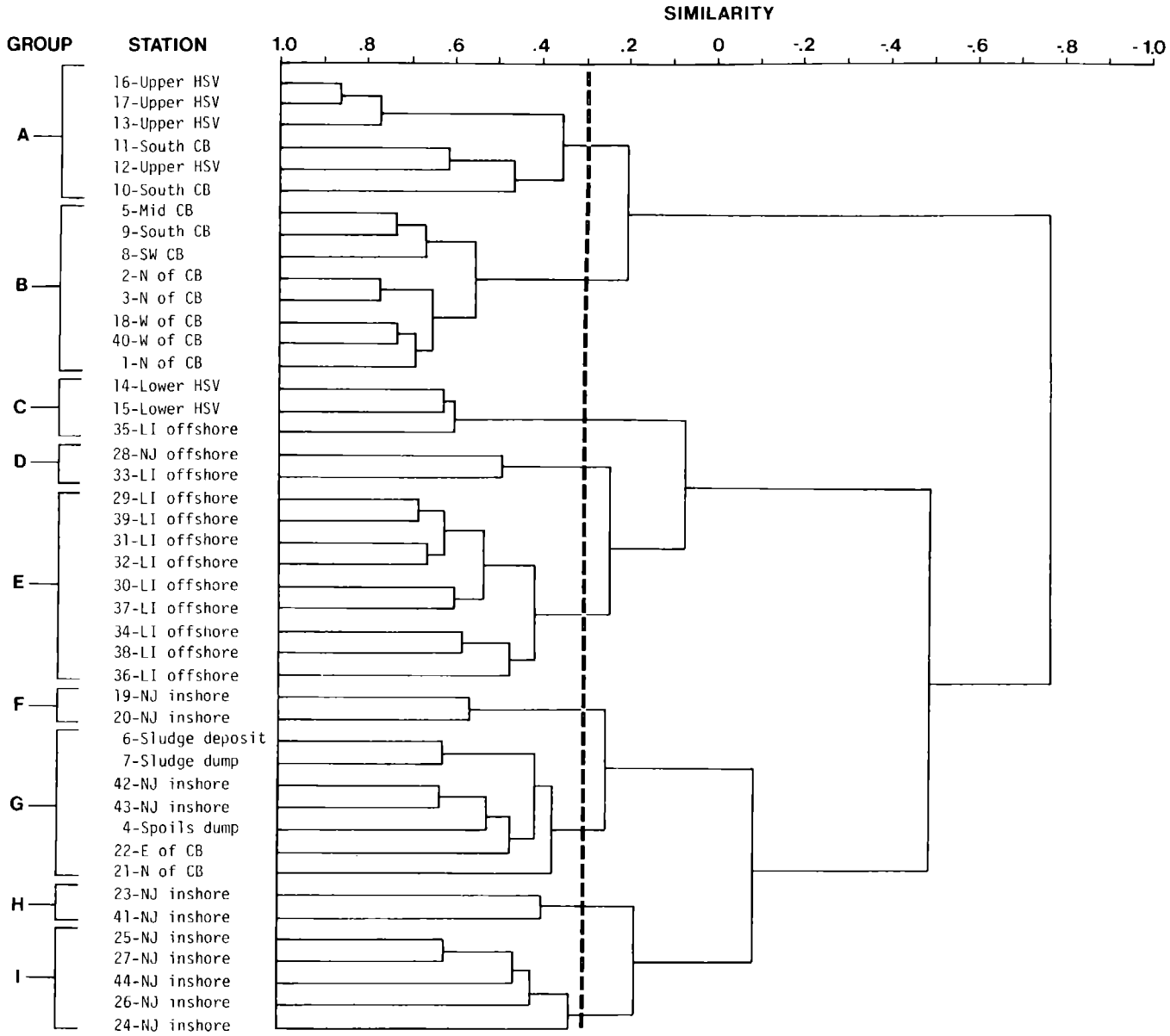

Figure 29. Dendrogram showing similarity of species compositions at New York Bight stations, with groups formed at 30% similarity level.

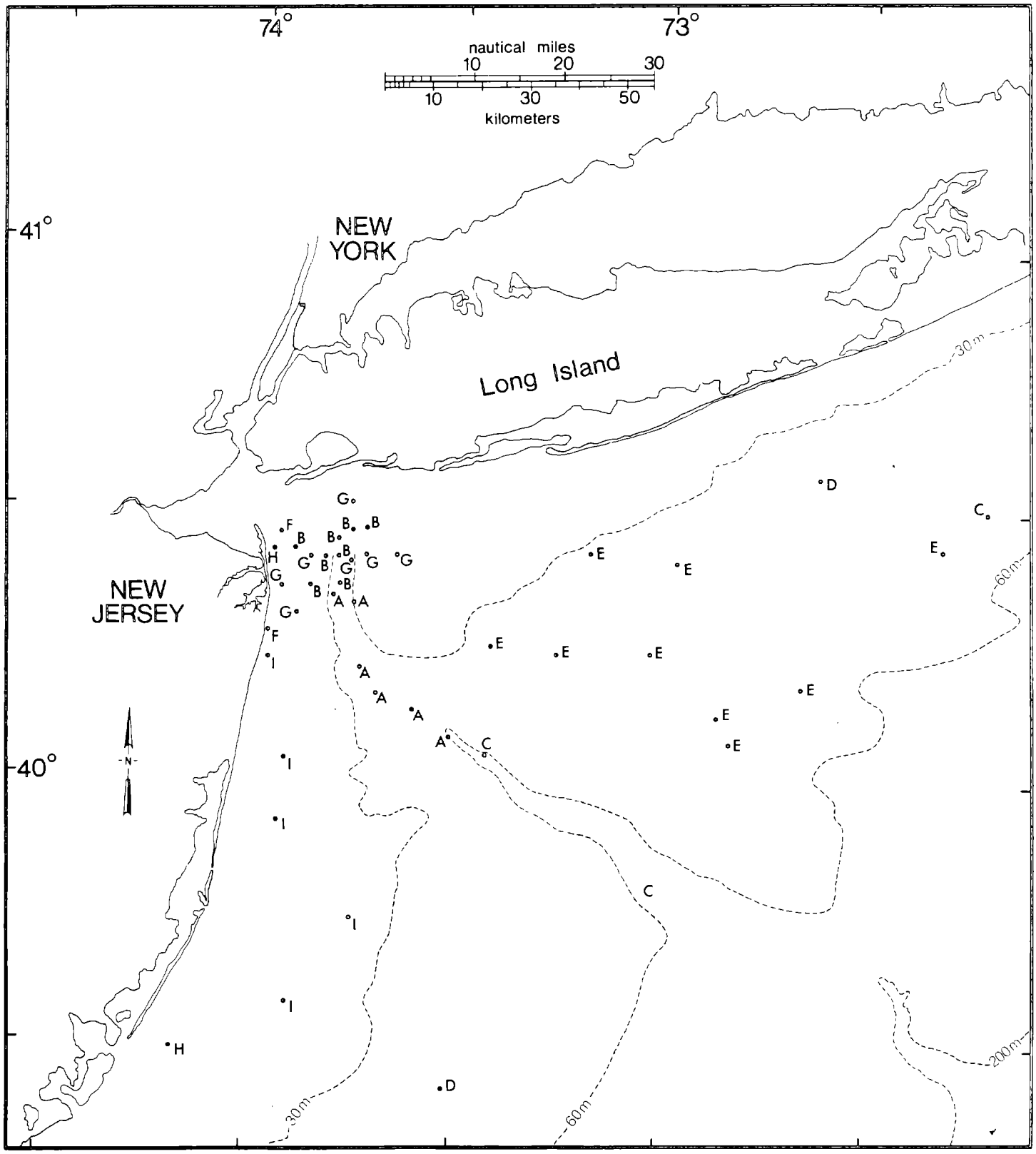

Figure 30. Distribution of cluster-derived species groups.

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polychaetes, Cossura longocirrata and Tharyx spp., and the phoronid worm, Phoronis architecta, were also abundant at most Group B stations.

3) Group A consisted of southernmost CB - northern HSV stations with less dominance by "periphery" species than in the case of Group B, and with a more abundant and diverse crustacean fauna. This area may represent a gradation between the obviously contaminant-affected faunas of groups G and B and a "natural" or pre-pollution NY Bight fine-sediment assemblage.

4) Group C (lower HSV) is in turn quite dissimilar from Group A to the north. This difference could also be contaminant-related. As discussed above, the innermost HSV station in Group C is the location where Boesch (in press) noted a sharp drop in concentrations of metals coinciding with large increased in populations of several sensitive amphipod species, especially Ampelisca agassizi. Station 35 is located in a swale (valley) on the shelf, rather than in the HSV. Its similarity to the HSV sites in Group C is largely based on dominance by A. agassizi and other amphipods. Factors besides lack of contamination undoubtedly contribute to the uniqueness of Group C. For instance, this is the only area sampled where deep, cold-water species such as the echinoderms, Astropecten americanus and Axiognathus squamatus, appeared.

Faunal Density (N)

Number of individuals ($\times 10^{-2}$) of all species combined are shown for all stations in Fig. 31. Lowest numbers, as a rule, were found in the relatively coarse sediments along the NJ coast, followed by the LI midshelf stations, which also had coarse sediments. Densities were higher on the outer shelf, and were consistently high in samples from the HSV and from the "periphery assemblage" areas described above. This pattern follows that for total organic carbon in sediments (Section 3.1). The greater food supply in the more depositional, fine-sediment areas must be largely responsible for the observed increases in N. The sewage sludge deposition site was unusual in having a high carbon content accompanied by relatively low N. This is another indication of physical and/or chemical inhibition of the fauna by sediment constituents at this site.

LIS densities were lower than almost all NYB values, perhaps due to a similar inhibition in combination with the larger sieve size used in LIS.

"Indicator" Taxa

As with species diversity, the concept that distributions of certain pollution-tolerant or sensitive species can be used to delineate areas of stress has recently been losing favor. There are problems with the uncritical application of this concept. For instance,

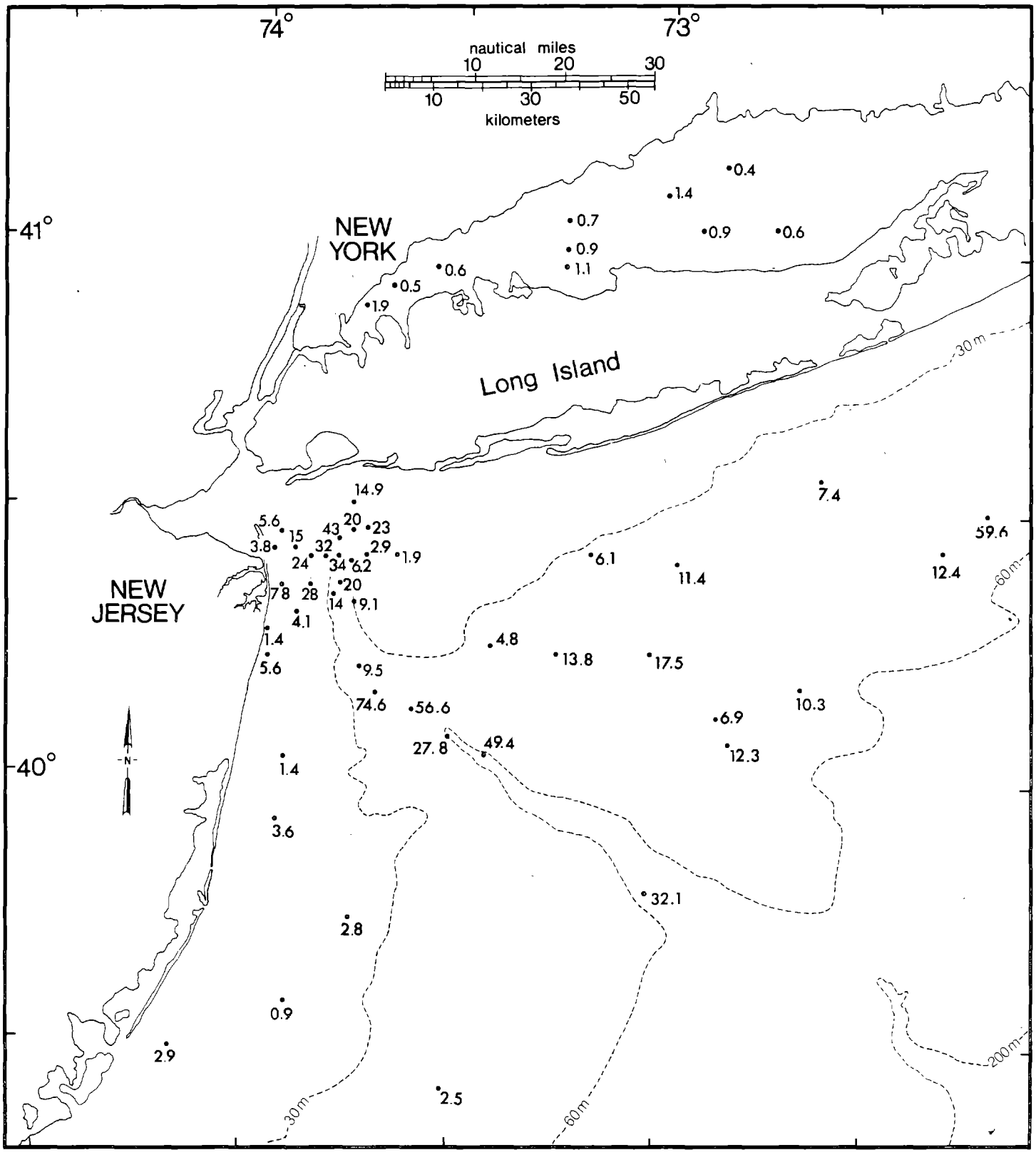

Figure 31. Numbers of individuals (x 10^{-2}) per 0.1 m^2 at New York Bight stations.

Capitella spp., often used as indicators of organic pollution, may also attain high densities in areas where only physical disturbance has taken place (Eagle and Rees 1973), and many other pollution-tolerant forms are also found in uncontaminated areas. Nevertheless, distributions of Capitella and other species may still be useful supplements to the variables treated above (species richness, diversity, density and community structure) in determining biological effects of contamination.

To the extent that large populations of Capitella do signal gross organic enrichment in the NYB apex, our collections indicate this condition is confined to a rather small area where appreciable deposition of sewage sludge occurs. Station 6, in this deposition area, had a mean of 546 Capitella/0.1 m^2. Densities at Station 7, the sludge dumpsite 2.8 km E of Station 6, did not indicate gross enrichment (43 Capitella/grab); however, this could be partly due to the Station 7 sediments being coarser than those preferred by Capitella. Stations 2.8 km W, 5.6-5.9 km NW to NE, and 6.8 km SSW of our sludge deposition station had few or no Capitella, although 72 specimens were found in the single grab from a station 10.0 km SSW of Station 7. Capitella was not abundant at any other station.

As discussed under community structure, there is also a fauna, characteristic of the periphery of the sludge deposition area, which apparently signals moderate organic enrichment in sediments more physically or chemically tolerable than in the central sludge accumulation area. Among the species having high densities in this zone, the polychaete, Nephtys incisa, gives perhaps the clearest indication of the zone's extent (Fig. 32). Nephtys is a relatively large worm with typical densities of 5 to 30 individuals/0.1 m^2 in muddy sediments such as those of the HSV axis. In summer 1980, densities of up to 140-180/grab were found in and near the northern CB. Numbers decreased again to means of 17 at the sludge dumpsite and three at the sludge deposition station. Assuming that densities of >100 Capitella/0.1 m^2 represent gross organic pollution, and >100 Nephtys imply moderate enrichment, then the former zone (as determined by planimeter) covered approximately 15 km^2 and the enriched zone, about 200 km^2. Since the area is very heterogeneous, the periphery assemblage is undoubtedly not uniformly distributed within the "enriched" zone in Fig. 32, and may occur in places outside that zone. O'Connor (1981) cites an estimate of >240 km^2 for the enriched zone which is not based solely on numbers of Nephtys, and may be more accurate.

Finally, total numbers of species of the relatively sensitive Amphipoda have been mapped (Fig. 33) to provide another indicator of distribution of "healthy" vs. "stressed" environments. Again, the approach is somewhat simplistic; other factors besides stress contribute to amphipod species richness. Bearing this in mind, we might define a relatively pristine area as one with ≥10 amphipod

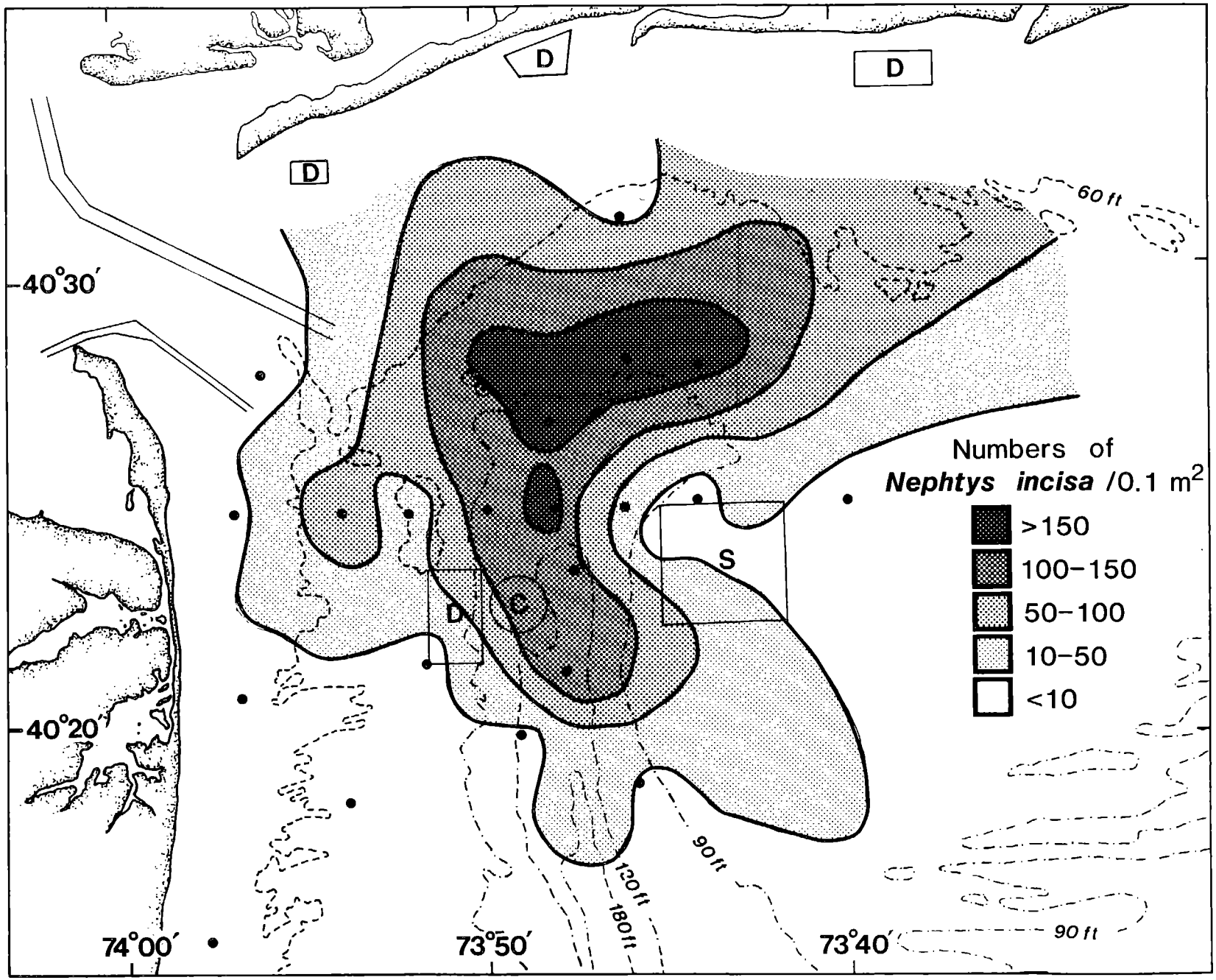

Figure 32. Abundances of Nephtys incisa in the inner New York Bight.

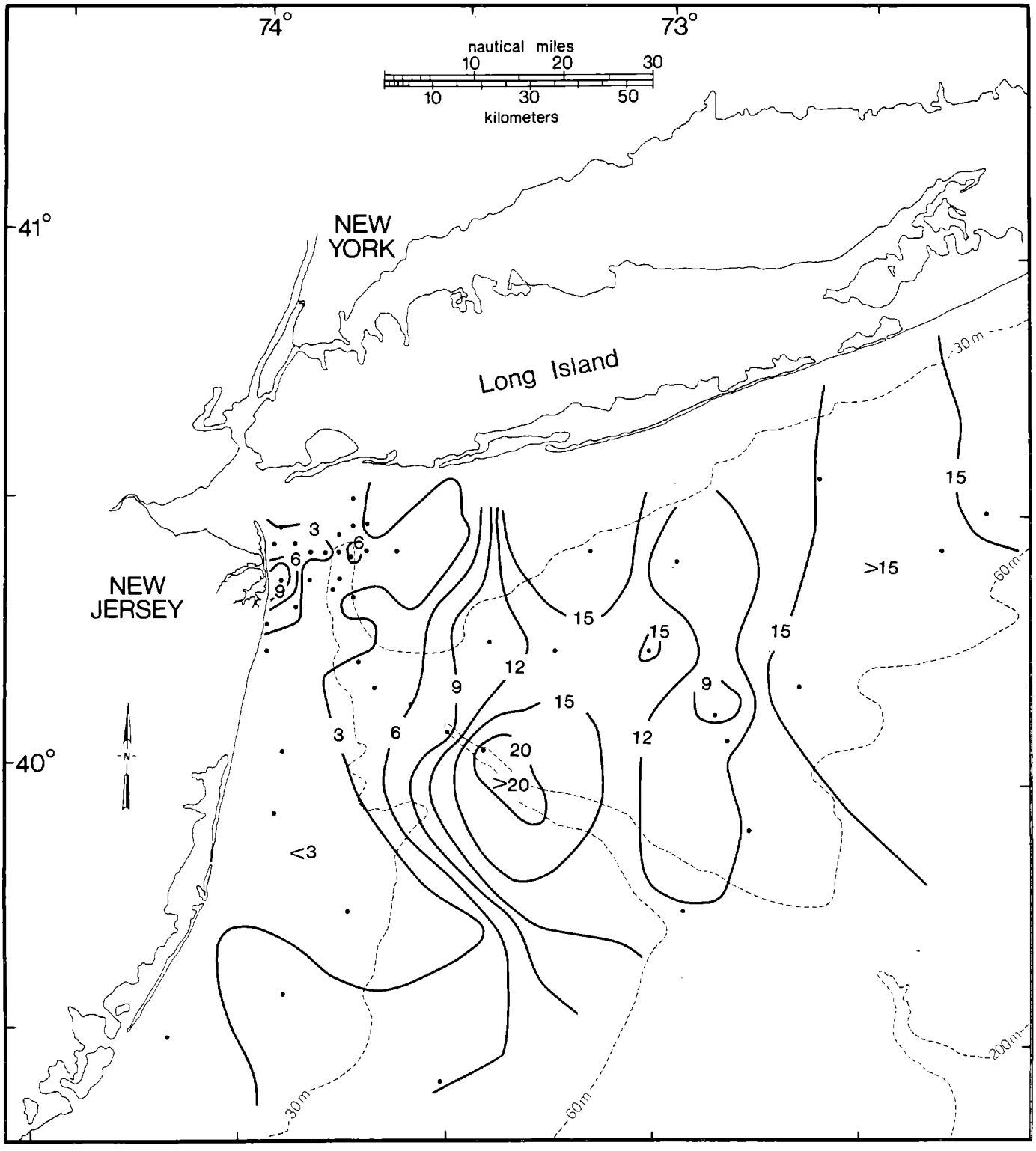

Figure 33. Numbers of species of amphipod crustaceans per 0.1 m^2.

species in Fig. 33 - this included the HSV from the first "uncontaminated" station (15) seaward, and much of the middle and outer shelf. Amphipods gradually decreased moving toward the New Jersey coast (presumably largely because of physical stresses) and CB.

Most CB and other inner apex stations had only 1-2 amphipod species per grab. This agrees with the observations of Boesch (in press) and earlier studies that peracarid crustaceans are conspicuously rare throughout this area. Poor environmental quality must be partly responsible for the scarcity of the peracarids.

3.9 ARTIFACTS

Mr. Robert Reid, NMFS, Sandy Hook Laboratory, Principal Investigator.

3.9.1 Methods

Artifacts were removed from the grab samples along with the benthic macrofauna. Only tomato and melon seeds were enumerated. Amounts of Spartina-type detritus were also noted. Total weights of artifacts in each sample were determined to the nearest 0.01 g after blotting dry for five minutes.

3.9.2 Results

Highest total weight of artifacts was at station 18 (about midway between Sandy Hook and the dredge spoil dumpsite) where the single sample analyzed contained several large pieces of glass and metal. Next greatest weights were found at the sewage sludge accumulation and release areas, respectively, followed by the dredge spoil dumpsite. Spartina-type detritus was the predominant "artifact" at this latter station. Smaller quantities of detritus were also recorded from areas immediately east (station 4) and northeast (station 1) of this dumpsite. Spartina detritus may therefore be a qualitative tag for some types of dredge material, although there must also be input of this detritus from the estuary.

Tomato seeds were considered by Pearce (1971) to be excellent indicators of sewage sludge. Their distribution in our samples (Fig. 34) is consistent with this. Numbers of seeds were highest at the sludge dumpsite and accumulation area, and at station 1 in the "enriched" faunal zone in the northern CB. Lower seed densities were found at the dredged material dumpsite and at several stations toward the estuary mouth. This pattern augments those for such variables as coprostanol and Nephtys in defining the extent of spread of dumped sludge, although again, the estuary (and dumping of dredged materials) could add smaller quantities of seeds.

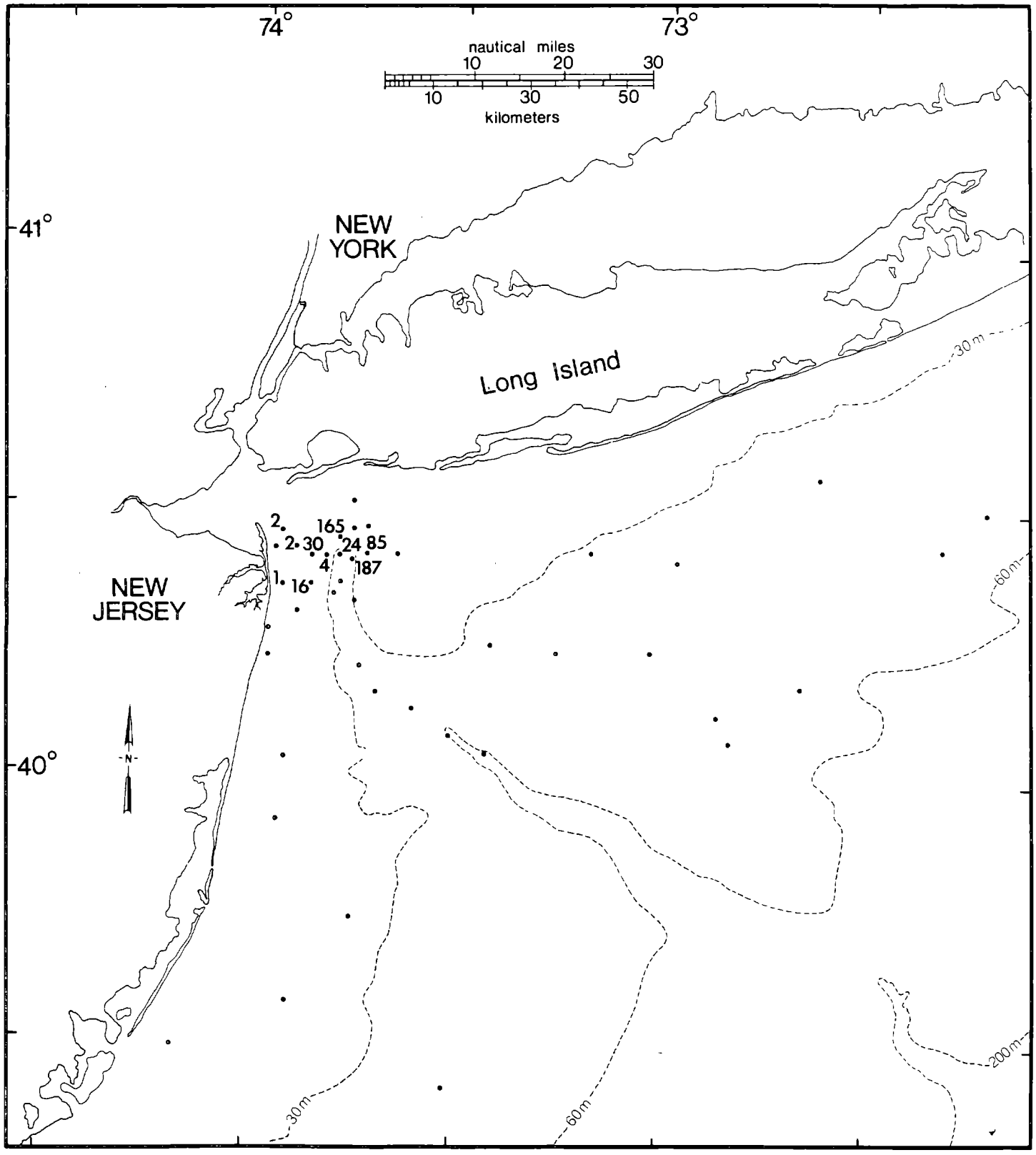

Figure 34. Numbers of tomato seeds per 0.1 m^2.

4.0 INTERDISCIPLINARY FINDINGS

To explore relationships between data sets, a correlation matrix was established using 29 variables pertaining to station location, benthic macrofauna, sediment composition and contaminants. Those variables having correlations which were significant at the 95% or higher level, using all LIS and NYB data, are shown in Table 17. (The faunal data are for NYB only, since a different sieve size was used in LIS.)

Sediment-benthic macrofauna correlations were generally weaker than those discussed below between sediments and contaminants. This was not unexpected; although sediment characteristics are known to strongly influence distribution and abundance of most benthic species (see review by Gray 1974) biological responses are complex, and many other physical and chemical factors, including contaminants, can be important. Overall faunal densities had fairly high correlations with fine sediments, TOC and TKN ($r = .51$ to $.73$, $p \leq .01$). This must be partly due to the greater food supplies found in fine sediments generally, and especially in the enriched zone in the upper CB. The correlation of densities of Nucula proxima, and to a lesser extent Nephtys incisa, to the same sediment variables reflects the association of these species with the enriched zone. The anthozoan Ceriantheopsis americanus also had elevated densities in this zone, but was common in coarser sediments throughout NYB as well, and so was not strongly correlated with fine sediments, carbon or nitrogen. Numbers of amphipod and crustacean species had moderate negative correlations with these variables, which may indicate both sediment preferences and contaminant effects (see below).

Species diversity showed weak but significant negative correlations with coarse silt, TOC and TKN. Equitability, or evenness of distribution of individuals among species (a component of diversity), correlated with these plus fine silt and clay. Species richness, being low in clean coarse sediments and in muddy enriched areas, was not linked to any of the sediment variables.

There were some interesting relationships between contaminants and biota. Diversity and equitability had highly significant ($p \leq .01$) negative correlations to all contaminants except Hg (where $p = .05$). Some of this is due to the association of contaminants with fine sediments, but the fact that correlations to contaminants were higher than to sediments indicates a separate contaminant effect. A direct contaminant effect on species richness is also evident, since S had significant negative correlations with five metals but not with fine sediments. Amphipod and crustacean species richness behaved like diversity, with stronger negative correlations to contaminants than to fine sediments. Overall faunal densities were weakly but positively related to contaminants; again, high densities in the enriched zone contributed to this. Correlations of Hg to fauna differed from those for other metals; mercury was not significantly related to species richness (overall, amphipod or crustacean), and weakly related to density, diversity and equitability. It was, however, the only contaminant highly correlated ($p \leq .01$) to densities of Nucula and Nephtys.

Table 17. Significant correlation coefficients among fauna sediment composition and sediment contaminant variables for all New York Bight and Long Island Sound samples. n=number of stations at which observations were made. +=significant at .01 level; remaining values are significant at .05 level.

	n	No. species	No individuals	Diversity	Equitability	No N. incisa	No N. proxima	No C. americanus	No A. agassizi	No amphipods	Amphipods species	No. crustacea	Crustacea species	No U. irrorata	Mean grain size	% 16-64 μ	% 4-16 μ	% <4 μ	Organic C	Kjeldahl N	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury	PCB	PNA	Coprostanol
# species	44																													
# individuals	44	.43+																												
Diversity	44	.55+																												
Equitability	44	-	- 37	.92+																										
# N. incisa	44	-	.36	-																										
# N. proxima	44	-	.54+	-		.86+																								
# C. americanus	44	-	.32	-		.79+	71+																							
# A. agassizi	44	-	-	-		-	-																							
# amphipods	44	.40+	-	.37		-	-	.94+																						
Amphipod species	44	.47+	-	.46+	.33	-	-	.47+	.64+																					
# crustacea	44	.41+	-	.38	-	-	-	.93+	.99+	.66+																				
Crustacea species	44	.51+	-	.49+	.34	-	-	.51+	.63+	.94+	.66+																			
# U. irrorata	44	-	-	.32	-	-	-	.70+	.77+	.60+	.76+	.56+																		
Mean grain size	55		.63+	-	-.33	.38	.41+	-	-	-	-	-																		
% 16-64 μm	55	-	.53+	-.43+	-.48+	-	-	-	-	-.32	-	-	.83+																	
% 4-16 μm	55	-	.73+	-	-.36	-	.33	-	-	-.35	-	-.34	.86+	.85+																
% <4 μm	55	-	.68+	-	-.35	-	.33	-	-	-	-	-	.83+	.64+	.73+															
Organic C	55	-	.51+	-.47+	-.51+	-	-	-	-	-.37	-	-.34	.80+	.75+	.80+	.73+														
Kjeldahl N	55	-	.73+	-.41+	-.50+	-	.39	-	-	-.39	-	-.33	.87+	.78+	.85+	.76+	.95+													
Cd	52	-.35	-	-.62+	-.60+	-	-	-	-	-.38	-	-.41+	.38+	-	.31	-	.59+	.48+												
Cr	52	-.31	.37	-.61+	-.60+	-	-	-	-	-.46	-	-.45+	.80+	.36+	.78+	.64+	.87+	.85+	.75+											
Cu	52	-.33	-	-.65+	-.64+	-	-	-	-	-.38+	-	-.38	.74+	.81+	.76+	.62+	.85+	.82+	.80+	.96+										
Ni	52	-	.57+	-.50+	-.57+	-	-	-	-	-.44+	-	-.37	.87+	.74+	.89+	.72+	.87+	.89+	.54+	.93+	.89+									
Pb	52	-.34	.31	-.67+	-.65+	-	-	-	-	-.45+	-	-.44+	.55+	.92+	.42+	.33	.66+	.60+	.94+	.86+	.85+	.69+								
Zn	52	-.34	.30	-.66+	-.65+	-	-	-	-	-.45+	-	-.45+	.78+	.56+	.81+	.63+	.87+	.86+	.75+	.97+	.98+	.93+	.84+							
Hg	42	-	.40	-.38	-.40	.50+	.46+	-	-	-	-	-	.68+	.78+	.64+	.48+	.67+	.71+	.81+	.85+	.85+	.77+	.87+	.85+						
PCB	38	-	-	-.53+	-.51+	-	-	-	-	-	-	-	-	.64+	-	.32	.69+	.38	.76+	.73+	.74+	.61+	.73+	.66+						
PAH	10	-	-	-.92+	-.92+	-	-	-	-	-	-	-	-	.49+	-	.80+	.69	.72+	-	.72+	.62	-	-	.72+	.61					
Coprostanol	38	-	-	-.45+	-.41+	-	-	-	-	-	-	-	.70	-	.65	-	-	-	.63+	.38	.55+	-	.56+	.51+	.37					

Sediment contaminant loads correlated strongly with physical characteristics of the sediments. This was expected, given the affinity of contaminants for fine particles with large surface:volume ratios and high TOC contents. Mean grain size (on the phi scale, so correlations are actually inverse) and amounts of coarse (16-64 μm) and fine (4-16 μm) silt correlated at the 0.01 significance level with all metals. The clay (<4 μm) fraction correlated with all metals except Cd. PAHs were highly correlated (r = .80) with clay and significantly (p = .05) with fine silt and mean grain size. PCBs showed a different pattern, correlating at the .01 level with coarse silt and at .05 with clay, but not significantly with fine silt or mean grain size. TOC and TKN were strongly interrelated (r = .95). They had moderate to high correlations ($r \geq .59$) with all contaminants except for lower but still significant values for TKN with Cd and PCB. Coprostanol did not correlate significantly with any of the grain size variables. The unanticipated stronger relationship of most contaminants to coarse silt than to clay may be explained by the higher correlation of TOC to coarse silt than to clay in our samples.

For a closer inspection of effects of various sediment types and TOC levels on contaminant correlations, we also constructed correlation matrices (Tables 18-21) for the same four subareas discussed in Section 3, Metals in Sediments: (overall NYB; apex and HSV; Long Island and New Jersey shelf; LIS). This permitted evaluation of effects of differing sediment types and TOC levels on correlations with contaminants. Correlations for individual subareas were generally lower and less significant statistically than those in the overall matrix. The lower significance is partly due to the smaller number of samples taken in each subarea.

Lowest correlations were found in the very silty LIS sediments (Table 18). There the only significant coefficients were for mean grain size: TOC and TKN, and for intercorrelations between metals. No significant correlations existed between sediment sizes and contaminants; between coarse silt, fine silt or clay fractions of sediments and TOC or TKN; or between metals and organic contaminants. The low correlations reflect the fact that all sediments sampled in LIS had similar amounts of silt/clay (81-97%), but wider ranges of contaminant concentrations. Also, due to the small number of samples available (<10), correlations would have to be quite high to be statistically significant.

For the NYB subarea (Table 19), most correlations were only slightly lower and/or less significant than for the entire NYB plus LIS data set. Exceptions were the higher correlation of PCBs and Cd with fine sediment, Cd with other metals, and PAHs with metals, in NYB than in the overall data.

The apex/HSV subarea (Table 20), characterized by silty sand sediments with the highest contaminant concentrations in NYB, had lower correlations among variables except for stronger links between PCBs and fine sediments, and PAHs and metals. Finally, correlations for the sandy sediments of the LI-NJ shelf subarea (Table 21) were also weaker than for the overall study area except for stronger relationships among amounts of coarse silt, fine silt and clay.

Table 18. Significant correlation coefficients among sediment composition and contaminant variables. Area: Long Island Sound.
n = number of stations at which observations were made. All values significant at .01 level except * =significant at .05 level.

n		Mean Grain Size	% Silt 16-64μ	4-16 μ	% Clay < 4 μ	TOC mg/g	TKN mg/g	Cd	Cr	Cu	Ni	Pb	P	Zn	Hg	PCB	M	PAH	COP
10	Mean Grain Size	-																	
10	% 16-64 μ	.73	-																
10	% 4-16 μ	-	-	-															
10	% < 4 μ	.91+	-	-	-														
10	Total Organic Carbon	-	-	-	-	-													
10	Kjeldahl Nitrogen	-	-	-	-	.97+	-												
10	Cadmium	-	-	-	-	.66	-	-											
10	Chromium	-	-	-	-	.72	-	.75	-										
10	Copper	-	-	-	-	.70	.63	.86+	.93+	-									
10	Nickel	-	-	-	-	-	-	-	.67	.65	-								
10	Lead	-	-	-	-	.66	-	.88+	.88+	.90+	-	-							
10	Zinc	-	-	-	-	.70	-	.88+	.94+	.97+	.65	.96+	-						
10	Mercury	-	-	-	-	-	-	.85+	.80+	.89+	-	.85+	.88+	-					
2	PCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
2	PAH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
2	Coprostanol	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
	(Low)	-	46		8	20	2.6	0.33	43	50	18	33	125	0.17	-	-	-		
	(High)		88		38	37	4.8	2.65	98	150	33	95	330	0.71					
			Total Silt/Clay 82-97%																

Table 19. Significant correlation coefficients among sediment composition and contaminant variables.
Area: New York Bight.
n = number of stations at which observations were made. All values significant at .01 level except * =significant at .05 level.

n		Mean Grain Size	% Silt 16-64μ	4-16 μ	% Clay <4 μ	TOC mg/g	TKN mg/g	Cd	Cr	Cu	Ni	P	Pb	Zn	P	Hg	PCB	M	COP
42	Mean Grain Size	-																	
42	% 16-64 μ	.64+	-																
42	% 4-16 μ	.71+	.71+	-															
42	% <4 μ	.65+	.50+	.63+	-														
42	Total Organic Carbon	.59+	.75+	.76+	.78+	-													
42	Kjeldahl Nitrogen	.83+	.79+	.86+	.79+	.84+	-												
44	Cadmium	.42+	.57+	.44+	.36	.67+	.59+	-											
44	Chromium	.56+	.73+	.62+	.44+	.74+	.74+	.92+	-										
44	Copper	.43+	.64+	.48+	.34	.69+	.60+	.98+	.93+	-									
44	Nickel	.68+	.88+	.74+	.63+	.83+	.87+	.77+	.89+	.81+	-								
44	Lead	.54+	.70+	.55+	.37	.69+	.69+	.95+	.97+	.97+	.87+	-							
44	Zinc	.51+	.66+	.53+	.40+	.70+	.69+	.97+	.96+	.97+	.86+	.99+	-						
34	Mercury	.58+	.67+	.49+	-	.39	.61+	.71+	.81+	.75+	.70+	.83+	.78+	-					
38	PCB	-	.63+	.52+	.49+	.83+	.54+	.75+	.76+	.77+	.73+	.73+	.71+	-	-				
8	PAH	-	-	-	-	-	-	.98+	.96+	.99+	.73+	.98+	.98+	-	-	-			
36	Coprostanol	-	-	-	-	-	-	.64+	.42	.61+	-	.57+	.59+	.31	-	.71+	-		
	(Low)	-	0.04		0.3	0.3	0.05	<0.25	1	0.23	0.5	2	3	<0.02	0.0001	0.3	0.01		
	(High)		29		10	34	2.2	3.7	75	120	17	135	228	0.21	0.160	19.5	11.0		
			Total Silt/Clay 0.4-37%																

Table 20. Significant correlation coefficients among sediment composition and contaminant variables. Area: New York Bight Apex/Hudson Shelf Valley.
n = number of stations at which observations were made. All values significant at .01 level except * =significant at .05 level.

n		Mean Grain Size	% Silt 16-64μ	4-16 μ	% Clay <4 μ	TOC mg/g	TKN mg/g	Cd	Cr	Cu	Ni	Pb	Zn	Hg	PCB	PAH	COP
26	Mean Grain Size	-															
26	% 16-64 μ	.55+	-														
26	% 4-16 μ	.66+	.61+	-													
26	% <4 μ	.54+	-	.53+	-												
26	Total Organic Carbon	.46	.67+	.67+	.73+	-											
26	Kjeldahl Nitrogen	.79+	.73+	.81+	.69+	.75+	-										
26	Cadmium	-	.44	-	-	.56+	.45	-									
26	Chromium	.41+	.63+	.46	-	.60+	.57+	.91+	-								
26	Copper	-	.52+	-	-	.58+	.45	.97+	.92+	-							
26	Nickel	.56+	.87+	.64+	.47+	.75+	.78+	.71+	.84+	.76+	-						
26	Lead	-	.59+	-	-	.54+	.51+	.95+	.95+	.96+	.81+	-					
26	Zinc	-	.52+	-	-	.56+	.50+	.97+	.93+	.97+	.79+	.99+	-				
20	Mercury	.49	.59+	-	-	-	.49	.64+	.78+	.68+	.64+	.81+	.74+	-			
26	PCB	-	.56+	.42	-	.79+	.43	.70+	.73+	.73+	.69+	.67+	.66+	-	-		
6	PAH	-	-	-	-	-	-	.97+	.96+	.99+	-	.98+	.97+	-	-	-	
26	Coprostanol	-	-	-	-	-	-	.62+	-	.58+	-	.55+	.59+	-	-	.67+	-
	(Low)	-	0.1		0.5	0.3	0.05	0.25	5	1	0.5	2	7	0.02	0.0001	0.3	0.01
	(High)		29		10	34	2.2	3.7	75	120	17	135	228	0.21	0.160	19.5	11.0

Total Silt/Clay 0.6-37%

Table 21. Significant correlation coefficients among sediment composition and contaminant variables.
Area: Long Island/New Jersey Shelf.
n = number of stations at which observations were made. All values significant at .01 level except * =significant at .05 level.

n		Mean Grain Size	% Silt														
16	Mean Grain Size	-	16-64μ														
16	% 16-64 μ	.51	-	4-16 μ	% Clay												
16	% 4-16 μ	.49	.99+	-	< 4 μ	TOC mg/g											
16	% < 4 μ	.57	.99+	.99+	-		TKN mg/g										
16	Total Organic Carbon	-	.89+	.91+	.92+	-		Cd									
16	Kjeldahl Nitrogen	.66+	.96+	.97+	.98+	.89+	-		Cr								
17	Cadmium	-	-	-	-	-	-	-		Cu							
17	Chromium	.50	.76+	.76+	.78+	.69+	.80+	-	-		Ni						
17	Copper	.50	.62	.55	.61	.52	.62+	-	.58	-		Pb					
17	Nickel	.58	.75+	.72+	.75+	.65+	.76+	-	.78+	.54	-		Zn				
17	Lead	-	.84+	.79+	.83+	.79+	.85+	-	.78+	.76+	.77+	-		Hg			
17	Zinc	.51	.75+	.72+	.74+	.64+	.75+	-	.82+	.60	.90+	.85+	-		PCB		
14	Mercury	-	-	-	-	-	-	-	-	-	-	-	-	-		PAH	
12	PCB	-	-	-	-	-	-	-	-	-	-	-	-	-	-		COP
2	PAH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
12	Coprostanol	-	-	-	-	-	-	-	-	-	-	-	-	.61	-	-	-
	(Low)	-	0.4		0.3	0.46	0.08	<0.25	1	0.23	0.5	2	3	<0.03	0.0001	-	0.01
	(High)		10.3		6 0	3.9	0.69		7	2.80	5.0	6	14		0.004	-	0.29
			Total Silt/Clay 0.4-10.3%														

Principal components analysis (Orloci et al. 1979) was performed using untransformed data to generate a reduced number of new variates which would efficiently describe the multivariate data set and identify station groups or data clusters. We used trace metal, TOC, TKN, and sediment size data from the NYB and LIS areas (54 stations). PCB, PAH and coprostanol data were not used because only two stations in LIS were sampled for these variables. Separation on the X-axis (factor 1 in Fig. 35) was based heavily on % silt, TKN, Ni and TOC, and moderately on contributions from Zn, Cr and Cu. Factor 1, essentially a "sediment component", represented 80.4% of the variance of the input. Separation along the Y-axis (factor 2, 13.5% of input variability) was based mostly on Cd and Pb and may be called a "pollutant component".

Canonical correlation analysis (Orloci et al. 1979) was subsequently performed after running principal components analysis on 37 NYB stations having a complete suite of sediment and contaminant measurements (station 8 was omitted to enhance separation of groups). This treatment relates the grouping information derived from the principal components analysis to the sediment and contaminant data, and tests the strength of separation of the principal components groups. Results (Fig. 36) indicated that stations fell into four distinct groups: 1) the sludge dumpsite and accumulation area; 2) the dredge spoil disposal area and upper HSV; 3) north and west CB; and 4) all other stations. No strong statements can be made on the statistical significance of these groupings, since the groups contain highly unequal numbers of stations. This will be corrected in future sampling by occupying more stations near the dumpsites.

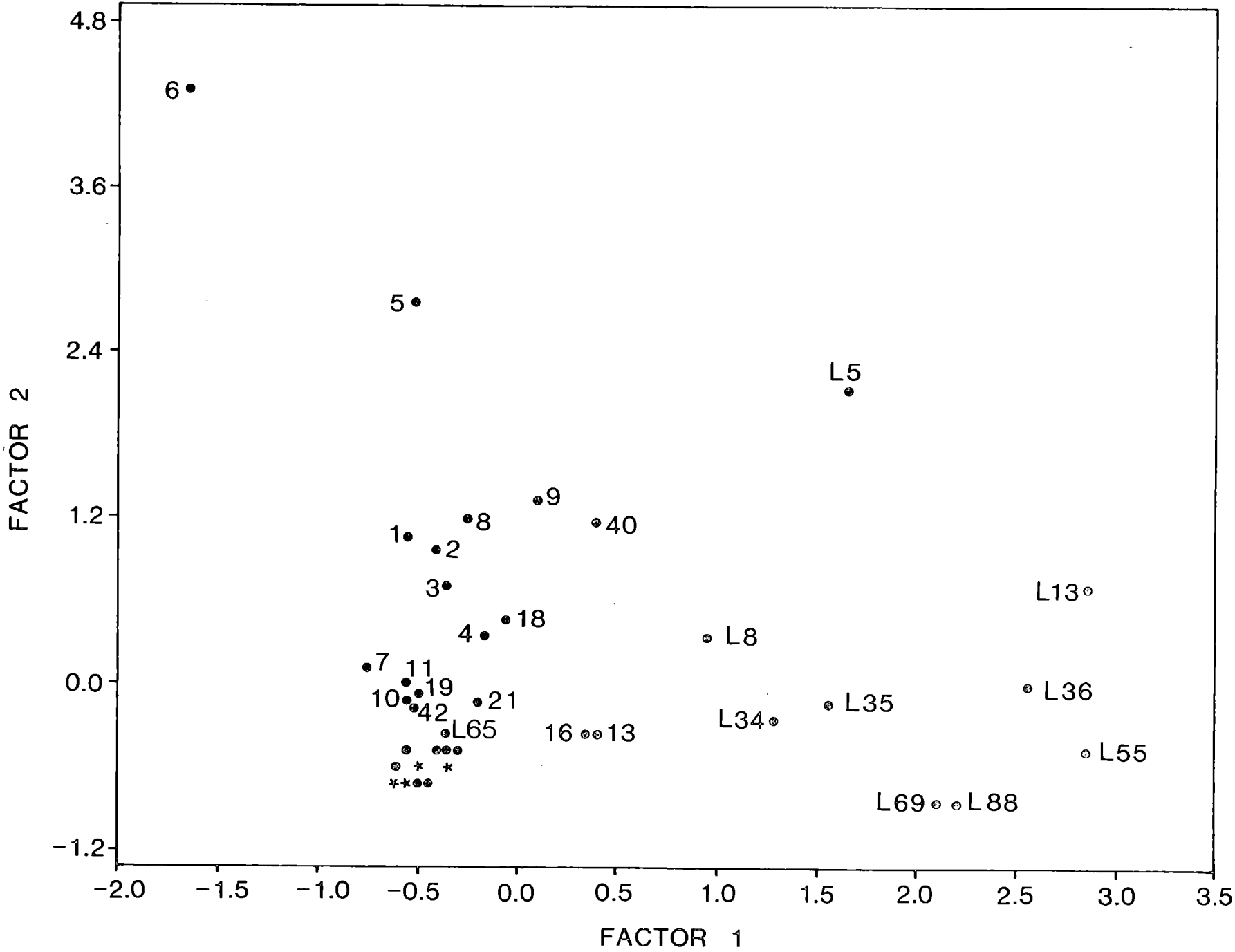

Figure 35. Results of principal components analysis of 54 MYB and LIS stations (those with L prefix), based on sediment and contaminant variables. * indicates two to nine stations located at those coordinates.

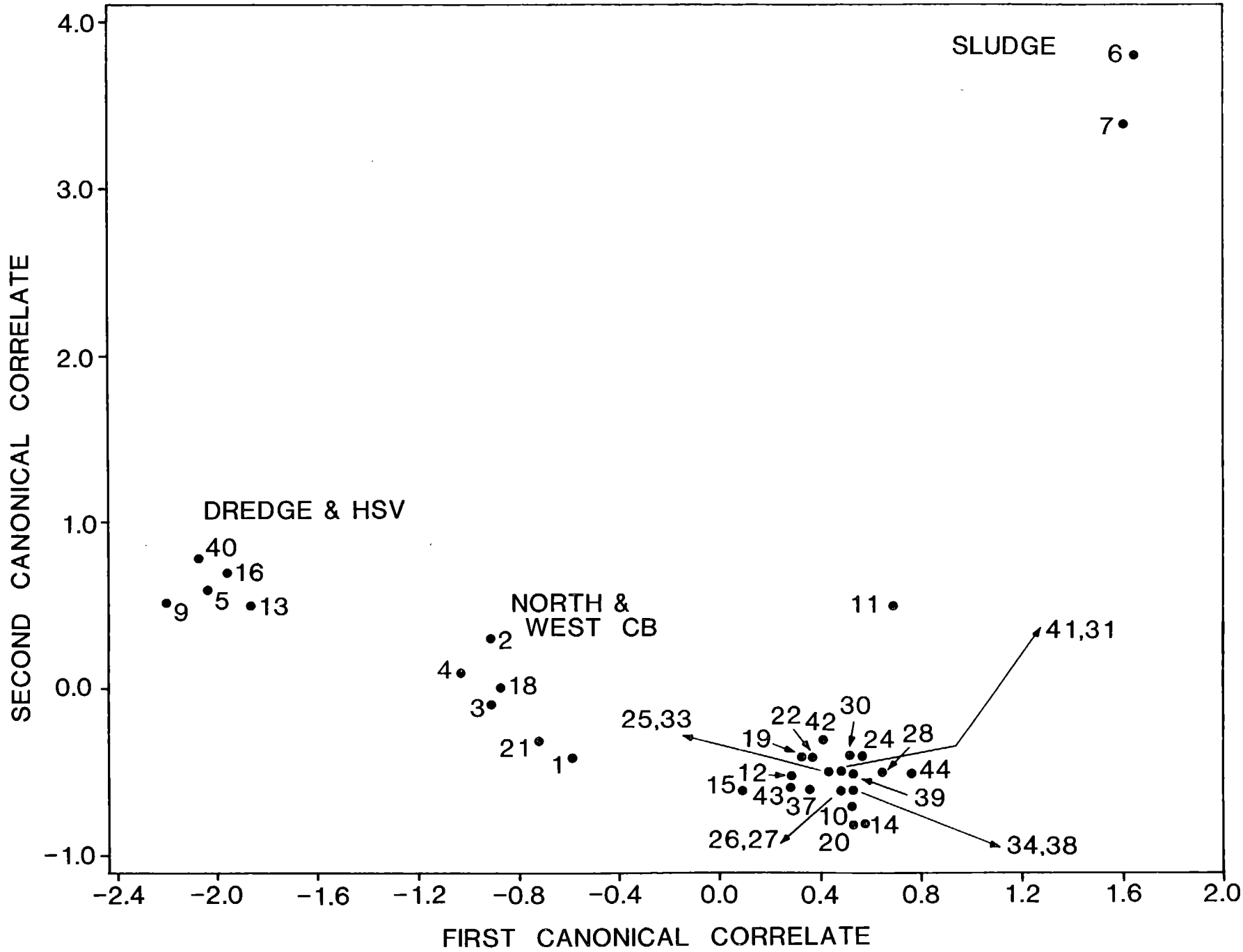

Figure 36. Results of canonical correlation analysis of 37 NYB stations (station 8 omitted to enhance separation of groups).

5.0 DISCUSSION AND CONCLUSIONS

5.1 SYNTHESIS OF 1980 RESULTS

The several measures of contaminant fates and effects explored above give a fairly consistent picture of the "health" of various portions of the NYB. Concentrations of organic carbon, metals, PCBs, PAHs and coprostanol in sediments were all at or near maximum values in the area of sewage sludge accumulation just west of the sludge dumpsite. Fecal coliform bacteria and Clostridium perfringens were also elevated here, and all macrofauna indices pointed to a highly impacted condition in eastern Christiaensen Basin. In the western basin, the dredged material dumpsite showed maximum TOC and PCBs. We agree with Boesch (in press) that it is at best difficult to separate impacts of the two dumpsites and the Hudson plume, based on present data, but that the greatest alterations appear most closely associated with sewage sludge disposal.

Most of the remaining CB contained elevated carbon and contaminant levels. Outside of the zone of highly altered fauna, the high carbon content appeared to have an "enriching" effect on the benthos, which was characterized by a paucity of crustaceans, and high densities and biomass of several polychaetes, an anthozoan and a bivalve. Secondary maxima were found or most contaminants in the "Mud Hole", toward the inshore end of the HSV, but these peaks were not accompanied by such distinct alterations of the benthic fauna. In the seaward part of the HSV, 50 km or more southeast of the dumpsites, and in coarser-sediment areas outside the CB, concentrations of contaminants and indicator microbes were generally low, and the benthic macrofauna was altered little if at all.

There were some midshelf areas where contamination was unexpectedly detected. Echovirus was found in sediments 120 km E of CB and 45 km off the Long Island coast, and fecal coliform bacteria were detected in rock crabs at a nearby station. Preliminary inspection of our summer 1981 data does not reveal continued contamination at these sites, so they should not be considered chronic problem areas. Both viruses and fecal coliforms were again detected well outside of the "contaminated" stratum in 1981, however, demonstrating that low-level sediment contamination exists over much of the NYB.

Demersal fish and shellfish from all areas sampled had low to moderate body burdens of both metals and organic contaminants. Tissue concentrations did not appear strongly related to sediment levels, presumably due to mobility of the target species and other factors noted above. Where Federal "action levels" have been established for deleterious materials in edible flesh (1.0 ppm for Hg, 5.0 ppm for PCBs), none of the concentrations measured approached these levels. (Toxicant concentrations are often higher in accumulative organs than in edible flesh, so effects on the populations themselves cannot be ruled out.) Lobsters and rock crabs generally had hignest concentrations of both metals and organic contaminants.

Total and fecal coliform bacteria did tend to have higher counts in animals from the inner Bight. There was no apparent difference in amount of gill fouling between rock crabs from "contaminated" and "control" areas, but this may be explained by the small sample sizes available.

5.2 COMPARISONS WITH EARLIER DATA

Data on sediment carbon and heavy metals, and distribution and abundance of benthic microbes and macrofauna, can be compared to findings of the 1973-74 MESA surveys and earlier work to search for temporal changes in severity or extent of habitat alterations. Comparisons of total organic carbon concentrations measured in 1980 with those reported for 1971 have already been made (Northeast Monitoring Program 1981). To summarize: maximum concentrations found in each survey were just over 5% (after correcting for methodological differences). Distribution of "elevated" concentrations was also similar, with levels higher than 1% found through most of CB and the upper HSV during both periods. No major expansion or contraction of this 1% contour was evident. The Hudson River plume, which typically hugs the New Jersey coast (Fedosh and Munday 1982) had no apparent influence on sediment TOC with the possible exception of higher values off the tip of Sandy Hook in the 1971 survey. (Due to the combination of sediment patchiness and inexact station relocation, only major changes in carbon loading would be detectable.) Analysis of dated long cores may be a better means of examining temporality of TOC concentrations.

As a rule, concentrations of heavy metals measured in 1980 were higher than 1973 values but lower than 1974 levels. As with carbon, a good deal of variability is seen in the data. Some of this is presumably due to imprecise station relocation, but some must be real small-scale patchiness (coefficients of variation of up to 47% have been found among triplicate cores from a single grab, with highest coefficients generally found in more contaminated areas). It thus appears that no changes in metal concentrations, separable from the inter-station and inter-year variability characteristic of the inner NYB, occurred between 1973-74 and 1980.

A similar conclusion can be drawn from the fecal coliform data. NMFS and MESA had previously determined fecal coliform counts in sediments in 1971-75. At those inner Bight stations which were resampled in 1980, patterns of fecal coliform distributions showed little change from the earlier work.

Comparisons of benthic macrofauna distribution/abundance between 1973-74 and 1980 indicate a possible spread in the area covered by the dense Nephtys-Nucula assemblage. In 1980, the northern "fringe" of this assemblage, with densities slightly above background levels (taken as 10/0.1 m^2), appeared to be in the vicinity of our station 21, about 13 km NNW of the sludge dumpsite (see Fig. 1). A dense assemblage was present at station 3, ~7 km N of the dumpsite. In 1973-74 there had been no evidence of enrichment at station 21, and station 3 appeared to be near the fringe of the zone. There was also

evidence of some expansion to the west. The 1980 data showed an enriched macrobenthos at station 8, ~4 km SW of the dredge spoil dumpsite, and a fringe assemblage at 4, 3 km NW of that dumpsite. Neither of these stations had had elevated numbers of Nephtys in 1973-74. The changes must be interpreted with caution; as mentioned in Section 3.8, this assemblage may be patchily distributed. Also, temporal variability may be higher than anticipated; preliminary analysis of 1981 Nephtys data indicates lower densities than in 1980 over most of CB.

No other major faunal trends were detected. Dimensions of the highly impacted Capitella-dominated zone appeared unchanged. In 1980 as in the MESA surveys, no sites sampled were so contaminated as to be devoid of macrofauna. On limited evidence, the shoreward limit of the HSV amphipod-dominated assemblage did not move appreciably toward or away from the CB. Densities of >100 amphipods/0.1 m^2 first appeared near station 12, ~22 km southeast of the dumpsites, in the 1980 collections as in the earlier data.

The lack of detectable differences in contaminant fates and effects in the NYB between the early 1970s and 1980 (except for the possible expansion of the "enriched" zone) is not surprising. The variability of measurements made in the inner NYB makes detection of subtle effects difficult; only larger-scale changes can be identified with confidence. Also, overall contaminant inputs have not changed greatly over the period in question. Sludge dumping has increased (Anderson pers. comm.), but disposal of dredge spoil (U.S. EPA 1978) and acid waste (Anderson pers. comm.) has declined. Given this, it might be expected that the system would approach a steady state, and large changes in contaminant concentrations and effects would not be expected.

For the remaining measurements made on the summer 1980 survey, no adequate historical baselines exist against which to examine spatial-temporal trends. Concerning sediment PAHs, only a few recently-collected data, mostly from contaminated inner apex sites, had existed for the NYB prior to our sampling, and few samples from outside the Bight have been analyzed. That our peak values for many compounds were higher than those McLeod et al. (1981) measured in CB is undoubtedly more a result of sampling in more and/or different locations, than of real increases over the short time period between the surveys. PAHs and pathogenic bacteria in demersal biota had also been analysed from only a small number of sites, mostly inshore.

PCBs in biota, and sediment PCBs, coprostanol, viruses and Clostridium perfringens, had been more intensively studied, but, again, only recently and with concentration on the Bight apex. Our values for PCB concentrations in biota, like those for sediment PAHs, were higher than other reported data, but this too was presumably a function of our analyzing more samples from different areas. Our sediment data agree with those of Hatcher and McGillivary (1979) and West and Hatcher (1980) in documenting high levels of coprostanol and PCB in CB sediments.

Using ratios of coprostanol/total steroids, both Hatcher and McGillivary (1979) and the present study found that extent of sewage contamination decreased rapidly from the center of CB to sites 10 n mi away; 50 n mi from the center of the basin, sediments were free from sewage contamination as indicated by coprostanol values below detection. In our data, the high coprostanol/total steroid ratios at the sewage sludge dumpsite (station 7) and accumulation area (station 6) indicate the organic carbon at these sites is almost entirely sewage derived.

5.3 FUTURE SAMPLING

Inputs of some or all of the contaminants discussed above may change substantially with such factors as adoption of the accommodative capacity concept, or capping or moving dumpsites. The present monitoring program has established benchmarks against which future changes in contaminant distributions and concentrations can be measured. Ecological effects of present contaminant levels on benthic macrofauna have been documented, so trends in contaminant effects can also be examined.

Contaminant and pathogen concentrations in fish and shellfish do not presently appear to represent a hazard to human health; we will continue to monitor these concentrations to provide warning of any changes from this condition. There is more uncertainty over the ecological effects of the contaminants on the species in question. Toward that end, our summer 1981 monitoring survey included analysis of organs such as kidney and liver, where contaminants may accumulate and endanger the well-being of individuals or populations. Time permitting, our summer 1982 survey will measure contaminants in selected benthic macrofauna species, to examine 1) relationships between burdens and observed ecological effects on the macrobenthos, and 2) movement of contaminants up food webs, from the benthos to species of direct interest to man.

Monitoring to date has not permitted a clear-cut separation of contributions of the various waste sources to observed contaminant distributions and effects. Such knowledge is needed for effective management of waste inputs, including decisions on whether specific inputs should be continued, relocated, increased or decreased. Our 1982 survey will therefore include very intensive sampling in and near the Christiaensen Basin, in an attempt to define better the relative influences of sludge and dredged material dumping vs. Hudson-Raritan and other inputs. More effort will be devoted to exploring ratios and correlations among sediments and contaminants, with the objective of establishing chemical signatures to track fates and effects of different waste inputs. This information, combined with data from the 1980-81 surveys and compared to the early '70s data, will permit stronger statements on trends in the system and means of managing it more effectively.

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