ENVIRONMENTAL BASELINES IN LONG ISLAND SOUND, 1972-1973
Final Report

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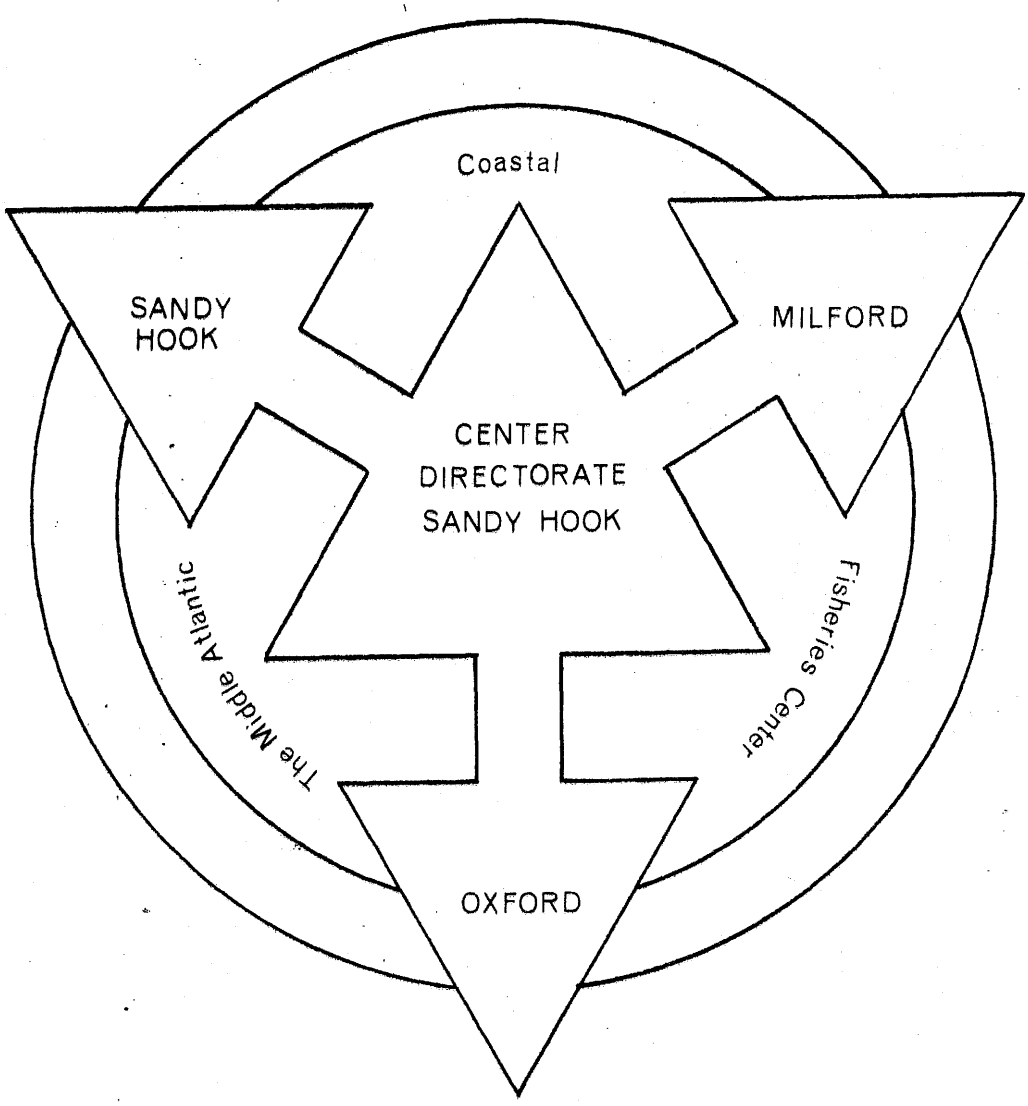

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ABSTRACT

A baseline survey of environmental quality in Long Island Sound (LIS) was carried out in 1972 and 1973. Three cruises were conducted to sample a maximum of 142 stations throughout LIS. Parameters examined were water column temperature, salinity, dissolved oxygen, nitrate, nitrite, ammonia, urea, iron, orthophosphorus and microorganisms; sediment types, organic matter, calcium carbonate, heavy metals and microorganisms; and benthic meiofauna and macrofauna.

By a number of indices (dissolved oxygen, nutrients, sediment organics, heavy metals and fecal coliform bacteria), westernmost LIS was shown to bear a considerable contaminant load. Next in degree of waste burdens were waters associated with several Connecticut urban areas. All of western and central LIS exhibited somewhat degraded water quality compared to that of the well-flushed eastern basin.

Densities, diversities, and assemblages are described for both meiofauna and macrofauna. Characteristics of both groups were found to be more closely correlated to sediment type than to the above water quality indices. Contaminant loads did appear to have some effect on macrofauna, but this was as a rule restricted to shifts in species composition; density, species richness and diversity in the most polluted areas were generally comparable to those in less perturbed regions.

The report's foremost conlusion is that environmental degradation in parts of LIS, especially the western end, was comparable to that found in other highly stressed local areas (Raritan Bay and the New York Bight sewage sludge and dredge spoil disposal areas); but that this deterioration had not affected the benthic fauna to as great an extent as in these other systems. Several recommendations are listed for retaining or improving present environmental quality in the various areas of LIS, and for other possible uses of the baseline data.

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APPENDIX A

I. INTRODUCTION

The Middle Atlantic Coastal Fisheries Center (MACFC) of the National Marine Fisheries Service (NMFS) began a baseline survey of the water column and benthos throughout Long Island Sound (LIS) in the summer of 1972. This study was necessary for several reasons. 1) Despite the heavy and often conflicting demands placed on LIS, there exists little synoptic data on water quality for the entire Sound, and no such data for benthic parameters. This baseline information is essential to document future changes in LIS' water quality. 2) Our data can also be compared to what historical information does exist to give some idea of changes that have already taken place. 3) A large body of baseline knowledge will serve as a managerial guide in judging which areas may best accept further impact of man's activities, what locations cannot tolerate any further stresses, and which areas appear already overstressed, in need of remedial action. 4) Baseline data will also be instructive as to the nature of acceptable new activities and perhaps engineering designs and precautions to minimize impacts of these activities.

The survey's primary focus is on a detailed description of the benthic environment of LIS. Due to their relative immobility, benthic macrofauna (defined here as invertebrates retained on a 1.0 mm mesh sieve) are considered among the most sensitive indicators of environmental conditions (Boesch, 1972; Gage, 1972;

Reish, 1972; Wilhm, 1967). Synoptic data on benthic faunal abundance, diversity and community structure for the entire Sound will thus go far toward establishing a yardstick for water quality changes. Distributions of sediment heavy metals, organics, fecal coliform bacteria and benthic meiofauna will provide additional indices of present water quality and future changes. These data, as well as sediment size characteristics, are also necessary for a definitive analysis of the observed faunal patterns.

As stated above, a comprehensive benthic survey throughout LIS has not previously been attempted. Existing studies have all been intensive investigations of smaller areas. Sanders (1956) studied the benthic ecology of eight stations off New Haven in central LIS, from 1952 through 1954. His results are the only historical data available for comparison with the present survey. Other benthic studies include power plant-related surveys by the New York Ocean Science Laboratory (NYOSL) in western LIS (Alexander and D'Agostino, 1972), and on the Long Island coast of central LIS at Northport (D'Agostino and Colgate, 1973), Shoreham and Jamesport (reports pending). The Shoreham area is also the site of an earlier ecological survey (Perlmutter, 1971). Studies on effects of spoil disposal have been conducted off New Haven (Rhoads, 1972, 1973a-d, 1974; Rhoads and Michael, 1974); Guilford Harbor (Rhoads, 1973c) and New London (Naval Oceanographic

Office, 1973). A benthic study in Niantic Bay was recently carried out to determine impacts of an oil spill (U. S. Environmental Protection Agency, 1973). The University of Connecticut is presently undertaking a comprehensive survey of the benthos of Fishers Island Sound; this area is considered part of LIS in the Long Island Sound Study, and will be so considered in this report.

Water column studies in LIS have been somewhat more extensive, both spatially and temporally. Riley et al. (1952, 1955, 1956, 1959, 1967) conducted synoptic surveys on current patterns, transport and mixing, water chemistry and plankton throughout LIS, in what is, again, the only historical study available for comparison with present findings. Since 1969, the State University of New York (SUNY) at Stony Brook has been measuring baseline hydrology throughout LIS. Parameters have included temperature, salinity, dissolved oxygen, nitrates, nitrites, phosphates and chlorophyll A (Hardy, 1970). Investigation of ammonia levels was added in 1970 (Hardy and Weyl, 1970; Hardy, 1972a), and urea determinations were begun in 1971 (Hardy, 1972b).

The hydrology of eastern LIS has been thoroughly studied in recent years. NYOSL has charted temperature, salinity, dissolved oxygen, nutrients and pigments in this area for the past three years. They have also carried out studies of plankton

and circulation patterns. The University of Connecticut has initiated studies on circulation and the transport of suspended material in eastern LIS, with the overall goal of determining budgets of heavy metal wastes for the eastern Sound (Dehlinger et al., 1973).

Water column measurements in the present survey were designed to complement those of the above studies. Given the need to concurrently sample the benthos, our water sampling was often less synoptic than in these other investigations. Also, our sampling frequency was generally lower than theirs. However, the previous studies have focused mainly on one to two transects along the east-west axis of LIS, and thus are less able to pinpoint areas of deteriorating water quality. Besides providing an overall picture of water quality throughout LIS, our water column data will also be examined for possible correlations with benthic faunal patterns.

II. MATERIALS AND METHODS

The sampling pattern for this survey consists of 142 stations, the majority spaced 2-3 miles apart along consecutive 5-minute longitude lines throughout LIS (Figure 1). This basic pattern was augmented by adding stations inside the 20' (6.1 m) isobath along each shoreline. Specific stations were also occupied within the New Haven, Connecticut River and New London

dredge spoil disposal grounds (stations 69, 123, 136); at locations also studied by NYOSL in conjunction with power plant operations at Shoreham, L.I. (stations 67 and 71); and at Sanders' (1956) eight stations in central LIS (corresponding to our 46, 50, 51, 55, 57, 70, 72 and 81). The latter stations were sampled for comparison with Sanders' earlier findings. Latitudes, longitudes and depths are provided for all stations in Table 1. Loran coordinates for these stations are available on request.

The first sampling, which included all 142 stations as well as 16 in adjacent Gardiners Bay, L.I. ("G" stations-Fig. 1) took place in July and August 1972 (Cruise 1). Sixty-nine of the LIS stations were resampled in April 1973 (Cruise 2), at which time three stations were also established within the Connecticut River ("C" stations). In September 1973 we resampled 103 of the original LIS stations (Cruise 3).

On Cruise 1, temperature and salinity were measured at 5 meter depth intervals using a Beckman RS-5 induction salinometer. On Cruise 2 and 3, we used reversing thermometers to measure temperature, and a Beckman RS-7B induction salinometer for salinity, in surface and bottom waters. Samples for water chemistry were taken 1 meter from surface and bottom, using Van Dorn water bottles on Cruise 1 and Niskin bottles on Cruises 2 and 3. Additional water samples were taken at 25 m depth

intervals at 15 deep water stations along the Sound's east-west axis. Dissolved oxygen was determined using the azide modification of the Winkler technique (American Public Health Association, 1965), with standard 0.25N phenylarsene oxide (Hach Chemical Co., Ames, Iowa) substituted for the less stable sodium thiosulfate.

Water samples were frozen and returned to Sandy Hook Laboratory for colorimetric determination of nitrate, nitrite, ammonia, urea, iron and orthophosphorus using a Technicon Auto Analyser.

Benthic samples (0.1 m^2) were collected with a Smith-McIntyre quantitative bottom grab. On Cruise 1, two grabs were taken at each station. One grab was washed through a series of standard geological sieves with 4 mm - 2 mm - 1 mm apertures for benthic macrofauna analyses. Surficial materials were removed from the second grab and refrigerated for microbiological study. The second grab sample was then subsampled to a depth of 5 cm for meiofauna using a plastic coring tube of 2.5 cm inner diameter. Two other sediment samples were frozen in larger coring tubes (3.7 cm I.D., with sediment ca. 15 cm deep); one was used for analysis of sediment sizes, organics and carbonate, and the other for heavy metal burdens. This same sampling scheme was followed for Cruise 2, except

that two to five replicate grab samples were taken for macrofauna at some stations. On Cruise 3, two grabs were always taken for macrofauna. No microbiology samples were taken on Cruises 2 and 3.

Sediments were analyzed for heavy metals and microorganisms at the Milford (Connecticut) Laboratory, NMFS, and meiofauna investigations were carried out under contract by Dr. John Tietjen, City College of New York. These three portions of the baseline study are subjects of separate reports. The meiofauna study is included as Appendix A to this report. Heavy metals and microbiology studies will appear as MACFC Informal Report Nos. 48 and 43, respectively. Their methodologies and detailed results are dealt with separately in the respective reports. Only highlights of these studies and correlations with other aspects of the overall survey will be considered in this central report.

Sediment analyses for grain size and other geological parameters were undertaken through a contract with Dr. James Parks, Marine Science Center, Lehigh University. A portion of each core sample was wet-sieved through a 62-micron screen. Retained material was dried and weighed, then sieved through a series of 12 screens ranging from 4 mm to 62 μ mesh (at ½ ϕ intervals) on a vibratory shaker for 5 minutes. The portion remaining on each sieve was weighed to 0.1 milligram to determine the fractions of sands and larger material.

Material passing through the 62-micron screen was placed in a 1000 ml sedimentation cylinder and stirred. Twenty-ml aliquots were pipetted off at precisely-timed intervals and depths in the cylinder to obtain coarse and fine silt and clay fractions, which were dried at 105°C and weighed to 0.1 mg.

Raw data were reduced by computer to weight percent of 10 sediment size fractions. Five other sediment characteristics were also calculated according to formulae given by Folk and Ward (1957): mean and median grain diameter in millimeters, sorting index, graphic skewness and graphic kurtosis. The first two of these terms are self-explanatory. Sorting index is a measure of sediment homogeneity: a sorting index of less than 0.35 indicates very well sorted sediments, with a large percentage falling within a narrow range of sizes; 1.00 represents moderately sorted sediments, and greater than 2.00, very poorly sorted, having good quantities of sediments of widely different sizes.

Skewness is a measure of deviation in shape from a normal (Gaussian) curve. Positive values indicate more large size material than expected, and negative skewness more fine material. Kurtosis measures peakedness, or amplitude, of the size distribution curve. A normal distribution gives a kurtosis of approximately 1.00. Values larger than this indicate an excessively peaked distribution curve. Lower values denote a flatter than normal curve.

Cruise 1 values for the above sediment parameters are averages of two replicate analyses of single core samples. Only single analyses have been performed to date on Cruise 2 and 3 samples. Two additional portions of the original sample were saved for chemical analyses. Both were dried and weighed; one was treated with dilute hydrochloric acid, washed, dried and weighed, and the loss of calcium carbonate (shell material) was computed by difference. The second portion was treated with a 10% solution of hydrogen peroxide, which oxidizes organic material; after washing, drying and weighing, the loss of organic matter was computed by difference. The chemical and physical nature of the organic matter is not determined using this procedure.

Benthic macrofauna samples were initially relaxed in a magnesium chloride-seawater solution and preserved in approximately 10% formalin in seawater. They were later transferred to 70% ethanol with glycerin. Samples were sorted using microscopes, and all organisms were identified to species whenever possible. For nomenclature we consulted Pettibone (1957, 1963) for polychaetes; Abbott (1954, 1968) for molluscs; Schultz (1969) for isopods; McCain (1968) and Bousfield (1965, 1973) for amphipods; Williams (1965) for decapods and Gosner (1971) for other taxa. Drs. Ruth Turner and Austin Williams have aided in identification of troublesome molluscs and decapods, respectively. Errors in identification or nomenclature remain our responsibility, however.

Macrofaunal analysis will concentrate on the higher groups, Polychaeta, Mollusca and Arthropoda. These three taxa comprised the great majority of the species and individuals collected. Other groups encountered included Protozoa (Foraminifera and shelled ciliates), Porifera, Cnidaria, Rhynchocoela, Nematoda, Archiannelida, Oligochaeta, Entoprocta, Sipunculida, Phoronida, Ectoprocta, Echinodermata, Chaetognatha and Tunicata. These taxa will not be considered at the present time due to their infrequency of occurrence, uncertainty of identification and/or difficulty in quantification. An exception is the anthozoan Ceriantheopsis americanus, which often represented sizable biomass and has been correlated in other studies with distributions of organics.

We have also not considered planktonic forms (chaetognaths, copepods, mysids, larval decapods, etc.), which are for the most part accidentally introduced into the benthic samples.

Species diversities were calculated using an approximation of the Shannon and Weaver (1963) index: $H' \cong - \frac{n_i}{N} \ln \frac{n_i}{N}$, where N is the total number of individuals in the sample, and n_i is the number in the ith species. This index was chosen because it has been commonly used in published benthic studies (Boesch, 1972), thus facilitating comparisons with the present study.

H' has two components: number of species or species richness (S) and equitability (J', = H'/H'max = H'/ln S). Equitability is a measure of the evenness of distribution of individuals among species.

Note that macrofauna analysis considered organisms retained on 1 mm or larger sieves, and meiofauna studies on those passing through a 0.5 mm sieve. Dr. Tietjen has examined and recorded those "intermediate" organisms retained on the 0.5 mm sieve. He reports that these forms consist principally of polychaete fragments, and also bivalves which would in most cases have been retained on the 1 mm sieve. These organisms will not be further considered with either meio- or macrofauna.

On the first cruise, 44 stations were sampled for holo- and meroplankton using oblique tows of a #0 (0.569 mm) Nitex half-meter net equipped with TSK flowmeter, and a #00 (0.760 mm) Nitex net mounted on a floating rectangular Glastronics fiberglass frame for neustonic fish eggs and larvae. Tows were of 15 minutes duration at 2-3 knots. All plankton samples are presently in storage at the Sandy Hook Museum with no immediate plans for processing them.

III. RESULTS

A substantial portion of the Cruise 1 information, especially that concerned with water chemistry, was presented in an interim report submitted to the New England River Basins Commission in December 1972, and is resummarized here.

A. Temperature, Salinity

Temperature and salinity (Table 2) followed expected patterns, as described by Riley et al. (1952, 1955, 1956), Hardy (1970, 1972a, 1972b), and Hardy and Weyl (1970). Temperatures were quite uniform both vertically and horizontally in April 1973, with all values between 4 and 9°C. In late September 1973 temperatures ranged from 14 to 22°, and generally increased from east to west, with the exception of colder water near the Connecticut River. Again, no pronounced vertical stratification was observed. The vertical uniformity of temperatures (and increasing bottom DOs, as mentioned below), indicate that mixing of the water column was already well underway by late September.

Hardy (1972b) notes that a thermocline does develop in midsummer, especially in the central basin; thermal layering is also seen in our measurements for July and August 1972 (Figures 2-3). These Cruise 1 data will not be used in examining horizontal patterns, since the sampling period covered six weeks, and effects of Hurricane Agnes may have obscured the typical distributions. Reflecting the storm's freshwater input, salinity (Figures 4-5) was below 22°/oo for most surface waters in central LIS, and down to 17.8 °/oo a mile seaward of the Saugatuck River.

Salinities on Cruises 2 and 3 increased gradually moving west to east (from 23°/oo to 29.6 in April and 25.0 to 30.6 in September). There were only small increases in salinity with depth during this sampling period.

B. Nutrients

Distributions of all nutrients measured in summer 1972 exhibit a pattern which is by now well documented: very large inputs from the East River dominate nutrient distributions and water quality throughout western LIS. Surface ammonia, for instance, approaches 30 microgram-atoms/liter (µgat/l) at Throgs Neck (Figure 6). These high levels agree with those reported for August of the previous year by Hardy (1972b), who also found ammonia continuing to increase in the East River. A tenfold decrease in surface ammonia is evident as one moves east of Hempstead Harbor. Open surface waters of the central basin (as defined by Hardy, 1972b) had moderate ammonia levels (generally 0.5 - 1.0 µgat/l). The Long Island coast east of Stony Brook showed similar concentrations. The eastern end of the Sound was characterized by ammonia values of less than 0.5 µgat/l, again in agreement with Hardy (1972b). There appear to be significant ammonia additions in the areas off New Haven-West Haven, Oyster Bay-Northport and the Nissequogue River, and perhaps off New London and Bridgeport. Ammonia is also presumably being added in the densely-populated western end, but this cannot be distinguished from the East River input.

Bottom ammonia (Figure 7) was also most elevated in the western end, with values higher than in surface waters except at Throgs Neck. In this case the "plume" of East River water extended east to the Oyster Bay-Stamford transect.

Surface nitrate (Figure 8) showed much the same pattern as ammonia, with most conspicuous inputs from the East River, Bridgeport, New Haven and New London. Bottom concentrations (Figure 9) were greatest from Hempstead Harbor west and off New Haven; other areas with high surface nitrates did not show comparable levels in bottom waters. Nitrite (Figures 10-11) and orthophosphorus (Figures 12-13) distributions also had as their most significant feature elevated values in western LIS. As a rule, noticeably elevated concentrations were confined to the Lloyd Neck area and westward. Values in µgat/l for these three nutrients ranged from undetectable to: surface nitrate, 2.76; bottom nitrate, 2.64; surface nitrite, 3.53; bottom nitrite, 3.55; surface orthophosphate, 6.90; bottom orthophosphate, 6.14.

In April 1973, ammonia concentrations were much lower at Throgs Neck than during the previous summer, and the decrease moving eastward was much less marked, with values at the eastern end slightly higher than for Cruise 1. Nitrate levels were somewhat above those measured on Cruise 1, with extremely high concentrations (up to 41.6 µgat/l) at the mouth of the Connecticut River during this period of high runoff.

Orthophosphorus was low and uniform, varying between 0.4 and 1.0 µgat/l except for values of 1.0 to 2.7 from Hempstead Harbor west. Nitrite was lower than the previous summer; large portions of central and eastern LIS contained less than 0.1 µgat/l.

On Cruise 2 we added urea determinations to our nutrient measurements, in an effort to better determine the effects of sewage additions on LIS's nutrient patterns. Urea concentrations were found to be less than 1 µgat/l for most of LIS. The higher values expected in the western end were observed, again most noticeably from Stamford and Hempstead Harbor west. The maximum concentration was 3.24 µgat/l at Throgs Neck. This was somewhat higher than that measured by Hardy (1972b) in this area in April 1971. Hardy found that urea concentrations continued to increase in the East River, with a maximum of more than 6 µgat/l in the lower river.

The Connecticut River and its plume into LIS had elevated urea concentrations, which were perhaps also detectable in a large area roughly bordered by Bridgeport, New Haven and Port Jefferson.

Values for all Cruise 1 and 2 nutrient measurements are given in Table 2. More rigorous examination of the nutrient distributions must wait until data from Cruise 2 are contoured and analysis is completed on Cruise 3 samples.

C. Dissolved Oxygen

Dissolved oxygen levels showed a strong inverse relationship to nutrient concentrations in summer 1972. Surface DOs were depressed, and bottom concentrations markedly so, in extreme western LIS (Figure 14). Surface values were greater than 7 milligrams/liter (mg/l) through most of eastern and central LIS. There was a sharply declining gradient from approximately Hempstead Harbor west, the DO falling from 8 to less than 3 mg/l within 7 nautical miles. Lesser DO depressions were evident off the Saugatuck River and in the areas of Bridgeport, New Haven, New London and Huntington Bay. A significant feature of surface DO distributions was the appearance of supersaturated areas off Hempstead Harbor, Stamford and between Bridgeport and Port Jefferson. Hardy and Weyl (1971) report similar findings for August 1970. They attribute the observed pattern to phytoplankton blooming in response to the high nutrient levels in this area. West of the DO maxima, phytoplankton standing crops may be reduced by inhibition from East River sewage effluents (Hardy, 1972b).

Bottom DOs (Figure 15) were above 5 mg/l for most of the central basin, and greater than 7 in the eastern sector. They fell below 5 mg/l in deep waters west of New Haven, less than 4 mg/l west of Stamford and under 3 mg/l past Port Chester.

There were scattered areas of still greater depletion, with 1.7 and 1.8 mg/l at two stations in the Hempstead Harbor area, and 1.7 near the mouth of the Saugatuck River. The poor oxygenation in western LIS bottom waters during summer is by now well-documented (Hardy and Weyl, 1971). An earlier survey of this area by Sandy Hook Laboratory (National Marine Fisheries Service, 1972a) revealed the entire western end to have lowest bottom DO (1.0 mg/l at Throgs Neck; 0.7 at Hempstead Harbor's mouth) coincident with highest summer temperatures. In the present survey, the Connecticut shoreline in the Bridgeport-New Haven region also showed somewhat depressed bottom dissolved oxygen.

The low DOs described above are of course a seasonal phenomenon. By the time of our April 1973 survey, colder waters and more wind-generated mixing had resulted in near-saturated conditions throughout LIS. DOs were above 10 mg/l for the entire Sound during this period (Table 2).

The relationship between wind conditions and oxygen levels is even more critical during summer. Cruise 3 samples taken on September 12 and 13, 1973, again revealed the characteristically low values associated with western LIS during this period (Table 2). Two weeks later, however, bottom DOs had increased to greater than 5 mg/l at Throgs Neck and above 6 everywhere else. This

dramatic improvement was again probably related to wind-generated mixing. Hardy and Weyl (1971) note that winds can have a controlling effect on DO concentrations in western LIS.

D. Sediment Heavy Metals, Microorganisms

As mentioned earlier, sediment heavy metals (MACFC Informal Report No. 48) and fecal coliform bacteria (MACFC Informal Report No. 43) will be treated in detail elsewhere in separate reports. To summarize their findings, heavy metal and fecal coliform distributions were closely correlated to the distributions of nutrients and dissolved oxygen described above. Concentrations in the extreme western end of LIS were invariably orders of magnitude higher than those in the well-flushed eastern basin. Most of the Long Island shoreline was also low in regard to sediment heavy metal burdens and fecal coliforms. Deep waters in central LIS showed intermediate values, while areas near population and industrial centers on the Connecticut coastline had levels almost as high as the western end.

E. Sediment Organic Matter

Distribution of sediment organic matter for Cruise 1 (Figure 16)* showed a pattern similar to that for the above water and sediment constituents. Much of LIS, especially along the Long Island coast and in the eastern basin, had less than 1% organic matter in sediments. The highest values, as usual,

*Note that due to the computer program used, all map values are 0.01% lower than actual values.

were found from Hempstead Harbor west. The Eastchester Bay, Davids Island and Mamaroneck areas all had between 9 and 10% organics in sediment. Highly organic sediments were also found in a band between Bridgeport and Crane Neck, in several other patches of mostly deep water in the central basin, and to a lesser extent off Stamford, New Haven and New London.

The high values at the west end and near other cities obviously bear a relation to nutrient and sewage additions in these areas. There are several possible explanations for raised organics elsewhere. One large patch begins just east of the New Haven dumping ground, and may represent an increased organic load due to release of organic spoils dredged from New Haven Harbor. The patches nearest the Long Island shore are located in the general area where very large chlorophyll-A values have been observed (Hardy, 1972b), perhaps due to upwelling. Elevated sediment organics may be linked to heightened plankton productivity in this region.

Sediment organic content can also be expected to show a relationship to sediment size parameters. Areas with high percentages of fine sediments can be assumed to have a current regime favorable to the deposition and retention of organic material and fine inorganics. Where sediments consist mostly of coarser materials, stronger currents have probably caused winnowing out of most organics along with the fines, and prevent settling of new material.

Organics were indeed found to be closely associated with areas of fine sediment in the present study. Mean sediment diameters throughout LIS are contoured in Figure 17, and percent silt-clay in Figure 18. The former parameter is a standard feature of sediment size analysis. The latter gives another measure of amount of fine material, but is included principally because it often dictates faunal distributions. The ten contouring levels for silt-clay content are defined by the terms of the exponential series $1.6^{(x)}$. Thus level 1 consists of sediments with 0-1.6% silt-clay; level 2 = 1.6-2.56% silt-clay;..level 5 is 6.6-10.5% silt-clay...and level 10, 68.7-100% silt-clay. We chose this series because we felt it important to examine small changes in silt-clay at the coarse end of the sediment scale; and because 1.6 is the smallest number whose 10th power covers 100% of the silt-clay range. A graphical treatment of sediment size distributions by station is given in Figure 19.

A comparison of the contour maps for organic materials and percent silt-clay shows that organic loads above 1% are strongly associated with silt-clay fractions of greater than 43%. Just three exceptions were found among the 34 stations with this much organic material. Station 57, with 2% organics, still had a considerable silt-clay fraction (35%). Only at

stations 94 (3% organic, 16% silt-clay) and 112 (4% organic, 9% silt-clay) were appreciable amounts of organic material associated with predominantly coarse sediments. This finding remains unexplained.

Also puzzling is the seasonal change in organics at many of our stations. Data for Cruises 2 and 3 have not yet been mapped, but are presented in Table 3.

F. Sediment Carbonate

Sediment chemistry also included examination of calcium carbonate content. This is perhaps of interest from a biological viewpoint, as large amounts of $CaCO_3$ (usually as shell material from dead molluscs) could possibly affect fauna by preventing contact with the sediment surface (Sanders, 1956), or by increasing niche diversity. Table 4 gives data for $CaCO_3$ in sediments on all cruises. Values showed no apparent relation to depth, geographical area or sediment type, except perhaps for more $CaCO_3$ near the Connecticut coast than near Long Island. Concentrations were often quite high, and exceeded 30% at stations 3 and 91. As with organics, there were often large seasonal fluctuations in carbonate at a given station.

G. Sediment Sizes

The contour maps for sediment size parameters, discussed above in relation to distribution of organics, further reveal

that most of the deep or offshore waters in central and western LIS were characterized by fine sediments, with a mean grain diameter (Figure 17) of less than 0.0625 mm (coarse silt) and a silt-clay content (Figure 18) greater than 68%. Inshore stations along Long Island, east of Hempstead Harbor, as a rule contained less than 2.6% silt-clay and had mean grain diameters greater than 0.5 mm (medium sand). Connecticut coastal sediments were on the whole much finer, often falling in the same categories as for the offshore stations described above. This shoreline's sediment was less homogeneous, and had several stations with large amounts of sand, gravel and/or coarse shell material.

The sediment maps illustrate several interesting features of LIS's bottom topography. A bar of coarse sediments extending out from Eatons Neck corresponds to a shoal area projecting out from this peninsula. Sediments also become coarser in the vicinity of Stratford Shoals. The large submarine ridge separating the central and eastern basins of LIS (Mattituck Sill - Hardy, 1972b) is clearly shown as the beginning of a zone of coarse sediments which continues to the eastern end of the Sound. Coarser sediments are expected here, since currents are appreciably stronger than in the central basin. More surprising is the existence of an area of fairly coarse material off New Haven.

H. Meiofauna

The benthic meiofauna investigation is another portion of the study carried out under contract and discussed in a separate report (Appendix A). Several of its major conclusions will be repeated here. Most significantly, no trends in abundance or diversity could be attributed specifically to geographical location or contaminant load. Overall meiofauna densities were greatest in the western end of LIS, and were higher along the Connecticut coast than further south. Differences between adjacent areas were not significant, however. All densities (and diversities) were within published ranges for subtidal temperate areas. Nematodes were by far the dominant meiofauna taxon. Their abundance was significantly correlated with organic matter ($p < .01$), as well as with percent silt-clay ($p < .05$). This is of course expected, since these two sediment parameters were shown above to be highly correlated. Species diversities increased with median grain size, but bore no significant relation to geographical area or total heavy metal content, the latter used as an index of pollution. Stations with mud sediments showed some within-habitat species affinities, or recurrences of the same species at other mud stations. Distinct meiofauna assemblages were lacking, though. The strongest impression was that the complexity of

LIS's meiobenthic environment, the number of possibly influential variables, and the great changes in these variables between stations, precluded any facile conclusions on cause and effect relationships between environment and meiofauna.

I. Macrofauna

The benthos of LIS was found to support generally high macrofauna standing crops. Overall species richness was also good; we encountered over 250 species of polychaetes, molluscs and arthropods alone. Table 5 lists numbers of each species for the 142 stations. Our collections revealed several distinct faunal assemblages, related primarily to depth, sediment type and/or geographical position in LIS.

1. Fine Deep Water Sediments: A large region of high silt-clay sediments offshore in central LIS corresponds to Sanders' (1956) level soft-bottom community. Sanders describes a *Nephtys incisa*-*Yoldia limatula* community according to the dominant polychaete and mollusc, after the manner of Petersen (1913) as modified by Thorson (1957). The polychaete *Pectinaria* (Cistenoides) *gouldii* and bivalve *Nucula proxima* were also numerous, but *Pectinaria* was less abundant than *Nephtys*, and *Nucula* was considered too small to be a good characterizing species (comparisons with Sanders' study will be treated in more detail below).

Using this system, the macrofauna of fine sediments in 15-40 meters of water in central LIS could presently best be termed a Nephtys incisa - Mulinia lateralis assemblage. Nephtys was present at all 17 of our stations containing greater than 68% silt-clay in these waters. We rarely found more than ten Nephtys per 0.1 m^2 grab, but these numbers represent appreciable biomass. Pherusa affinis and Melinna cristata were co-dominant with Nephtys among polychaetes; they were collected at 16 and 15 of these stations respectively. In several instances they were more abundant than Nephtys.

The coot clam, Mulinia lateralis, was by far the overall dominant of the assemblage. Densities were greater than 100 per grab at fourteen of the seventeen stations, and $>$1000/grab at five. The bivalve, Pitar morrhuana, and gastropod, Retusa canaliculata, were always present, with more than ten per grab at 16 (Pitar) and 15 (Retusa) of the stations. Yoldia limatula was also found at 16 stations - usually in low numbers, but of value in characterizing the assemblage due to its large size. The consistency of occurrence and abundance of these forms indicates that our one grab per station was adequate to define the main components of this assemblage.

Other polychaetes occuring at eight or more of the stations were (species found at the most stations listed first): Maldanopsis elongata, Euclymene collaris, Ampharete arctica,

Polydora ligni, Sigambra tentaculata, Streblospio benedicti. These species were present in low diversities, never as many as 10 per grab except for one station with 22 Maldanopsis elongata.

Additional molluscs present at more than half the stations were (in approximate order of both densities and number of station-occurrences): Nassarius trivittatus, Nucula proxima, Pandora gouldiana, Cylichna oryza, Lyonsia hyalina and Tellina agilis. Several other organisms were found at many of the 17 stations - the anthozoan, Ceriantheopsis americanus (14 stations), cumacean, Oxyurostylis smithi (11), amphipod, Ampelisca abdita, (16), sand shrimp, Crangon septemspinosa (11) and rock crab, Cancer irroratus (12). None of these species reached a density of ten per grab except for Ampelisca abdita at a single station.

A number of the above forms appear nearly ubiquitous in LIS (Ampharete, Nassarius, Crangon and Cancer among others), and thus should not be included with the more stenotopic species used to characterize this deep soft-bottom environment.

Species diversities (H') at these stations were as a rule extremely low in comparison with other habitats in LIS and with published figures for estuarine benthos. H' values

for all stations are given in Table 6 and Figure 20, along with equitabilities (J') and numbers of individuals and species. Diversities are also presented in computer-contoured form in Figure 21. Note that, as with sediment values, the computer program we used printed diversities which are lower than the actual values in Table 6 by 0.01. Mean diversities for various areas and sediment types are reported in the text as $\bar{x} \pm t.05 S_{\bar{x}}$, or mean ± the interval within which diversity of a given sample from that area will fall with 95% probability (Steel and Torrey, 1960, p. 21-23).

Thus the 17 softest-bottom stations in deep waters of central LIS showed H' values of 1.18 ± 0.34, and a median diversity of 0.94. This is appreciably lower than the median benthic diversities for a number of areas studied or reviewed by Boesch (1972). (Boesch calculated his diversities using a $\log_2$ form of the Shannon-Weaver index; his values have been adjusted for comparison to the natural log form of our study.) The Chesapeake - York estuary, a polyhaline system as is LIS, was reported to have a median of approximately 2.8. Virginia's outer continental shelf exhibited median H's approaching 3.0, and shallow shelf areas, 2.3. Mud-bottom stations in the Hampton Roads region displayed median diversities over 2.3.

Median diversities exceeded 2.0 even in mildly polluted sectors of Hampton Roads. Boesch reviewed several other studies on benthic macrofauna, and found H' almost invariably higher than we report for central LIS. Charleston Pond, R. I., Buzzards Bay and the Pocasset River, Mass., the areas geographically closest to LIS in Boesch's review, all had median H' values between 1.8 and 2.0 - in fact Sanders' (1956) samples from central LIS also fell in this range. (As will be discussed below, our study found median diversity at Sanders' stations to be a good deal higher than that encountered in much of central LIS.) Boesch also cites papers on areas known to be stressed in terms of salinity, temperature or contaminants. These areas again had higher median diversities than our central LIS stations - the sole exception being polluted portions of Los Angeles and Long Beach harbors.

Species diversity is often held to be a measure of environmental health. The H' values taken alone would then indicate the fauna of soft central LIS sediments to be highly stressed. It may be more instructive to also analyse the two components of H', species richness and equitability. Table 6 and Figure 20 show that numbers of species at these stations are on the whole comparable to

those of other habitat types described below for central and western LIS. It is the unusually low equitabilities which are principally responsible for the low diversities observed.

Low values of J' are in turn due to the high numbers of several species, especially Mulinia. Their large populations could as easily be considered evidence for the area's productivity as for any stressed condition. Stations closer to the urbanized Connecticut coast display higher diversities but no lower levels of the contaminants measured in this study. These inshore stations merely do not support such high standing crops of any species. It is probable that during winter the soft-bottom stations would show only slightly lower species richness but a large reduction in populations of short-lived dominant species. H' would then increase, but again this would not imply that environmental quality had improved. Thus while species diversity may be somehow linked to water quality in LIS, the relationship is neither simple nor consistent.

Another substantial area of find sediments (> 68% silt-clay) in deeper waters (17-31m) is found in west-central

LIS, roughly within a triangle between Port Jefferson, Bridgeport and Northport (Figure 18). Eight of our stations are included in this region. Diversity here (0.99 ± 0.44, median 0.83) was lower than that of the deep silt-clays discussed above, but not significantly at the $p < .05$ level. Species richness was generally lower; most of the abundant species were common to the two areas, but fewer rare species were represented here. Nephtys incisa and Pherusa affinis were still the dominant polychaetes, though Melinna cristata, very common to the east, was absent. Euclymene collaris and Sigambra tentaculata were less common further west, while Maldanopsis elongata, Ampharete arctica and Streblospio benedicti were found in comparable numbers. Only Polydora ligni increased in abundance in this region.

Mulinia lateralis was found in great numbers, as above - more than 750 per grab at six of the eight stations. Among other molluscs, Pitar morrhuana, Yoldia limatula, Nassarius trivittatus and Retusa canaliculata were again very common, and Nucula proxima, Pandora gouldiana, Cylichna oryza and Lyonsia hyalina fairly so. Tellina agilis was less abundant than further east, as were the crustaceans Ampelisca abdita and Cancer irroratus, while Oxyurostylis smithi and Crangon septemspinosa were still frequently encountered.

Thus this area, which began to show an increased load of nutrients, organics, and heavy metal contaminants, still supported an assemblage at most only marginally changed from that of the less impacted sediments further east.

A third area of comparably fine sediments in deep water appears as a mostly mid-Sound strip extending from east of Stamford to Execution Rocks in western LIS (Figure 18). The trend toward decreasing species richness continued, with numbers of species in the eastern part of the region comparable to those off Bridgeport-Northport, but fewer species in the western portion. Shannon-Weaver diversity was the lowest of any area we have examined, (0.81 ± 0.28, median 0.69). This still was not significantly ($p < .05$) lower than in the silt-clay areas described above. Only four stations west of Stamford fit the criteria of greater than 15 meters depth and 68% silt-clay, so statistical comparisions to similar environments further east must be viewed with caution.

Characterizing forms were those of the silt-clay assemblage to the east. Nephtys and Pherusa remained conspicuous among the polychaetes in this area, with Polydora ligni again increasing somewhat. Mulinia was

once more the overall dominant, and Pitar, Yoldia, Nucula, Lyonsia, Retusa, Cylichna and Nassarius were well represented. Crustaceans, particularly Ampelisca abdita, appeared further reduced moving to the west. Only Oxyurostylis and Crangon among crustaceans were encountered in abundance at these stations.

On the whole, the fauna of fine sediments in central and western LIS did not appear to exhibit the "trophic group amensalism" observed in other level-bottom areas (Rhoads and Young, 1970; Bloom, Simon and Hunter, 1972; Aller and Dodge, 1974). That is, populations of suspension feeders like Mulinia and Pitar were not limited by sediment-reworking activities of deposit feeders such as Nephtys, Nucula, Tellina and Yoldia. Some or all of these deposit feeders were abundant at many stations where Mulinia and Pitar reached great densities. This indicates that either 1) the typical energy level of the deep silt-clay environment is too low to resuspend reworked sediments (Rhoads and Young (1970) suggest this possibility where the two feeding types exist), or 2) Mulinia and Pitar are tolerant of suspended material loads in bottom waters.

There were other deep water stations scattered through central and western LIS with sediments only slightly coarser

than above. An additional five stations had 43 - 68% silt-clay, and another nine contained 27 - 43%. A first inspection showed these stations to retain many of the characteristics of the soft-bottom community. Some changes were apparent, such as less dominance by Mulinia (still very abundant at several stations) and often greater numbers of Nucula, Ensis, and Tellina. Nephtys and Pherusa were slightly less common, and Ampharete, Scalibregma and Owenia more abundant. Numbers of crustaceans, especially amphipods, increased. These changes probably reflect an intergradation with the fauna of coarser and/or shallower bottoms described below.

Only five stations in the eastern basin had correspondingly fine sediments (28 - 70% silt-clay). Diversity here (2.26 ± 1.05, median 2.25) was significantly ($p < .05$) higher only than in the westernmost group of fine sediments discussed above. Differences were due largely to lowered dominance. The progressive increase in crustaceans from west to east continued. The small number of samples from this environment, and the paucity of dominant species, make it difficult to detect any recurring faunal community which might be present.

2. Coarse Shallow Water Sediments (Long Island coast): Another distinct faunal assemblage is found in the coarse sediments of shallow waters along the northern shore of Long Island. Coarse sands (mean diameter $\geq$ 0.5 mm) with less than 3% silt-clay were found at nearly all of our inshore stations (2 - 6 m depth) from Manhasset Neck in the west to Greenport in eastern LIS. This physical consistency of environment provides a good opportunity to measure effects of different contaminant loads on the Sound's benthic macrofauna.

The shallow sandy sediments of the eastern half of Long Island's coastline (east of Northport) contained a more diverse fauna ($H' = 1.66 \pm 0.37$, median 1.86) than did the finer substrates offshore, though the difference was significant ($p < .05$) only in relation to the westernmost silt-clays. The increase was due less to change in species richness than to reduction of dominance. However, the fauna can still be thought of as a distinct assemblage, with characteristic polychaetes and molluscs. *Nephtys picta* replaces *N. incisa* as the polychaete best indicative of these harder sediments, occurring at ten of the thirteen stations. As with *N. incisa*, the densities were not high (> 10/grab at only three stations, but represented

considerable biomass. Other polychaetes which appeared confined to these coarse, shallow substrates (occurring at five or more stations) were Aricidea jeffreysii, Spiophanes bombyx and Travisia carnea. Sabellaria vulgaris, Lumbrineris fragilis, Sigalion arenicola and Sthenelais boa were less frequently encountered.

Several polychaetes with wider-ranging distributions were found here as well as in the deep soft-bottom areas. Ampharete arctica was noteworthy among these "cosmopolitan" forms. Polydora ligni, Streblospio benedicti, Maldanopsis elongata, Owenia fusiformis, Tharyx acutus, Scalibregma inflatum and Spiochaetopterus oculatus were occasionally found here.

Most conspicuous among molluscs were juvenile surf clams, Spisula solidissima. Grabs at ten of the thirteen stations contained ten or more Spisula, with more than 100 at four stations. Their peak densities appeared to represent the highest biomasses we encountered in any LIS samples. Crepidula fornicata was another mollusc common only in coarse sediments. Ensis directus and Tellina agilis were much more abundant here than in the fine deep water sediments, while Mulinia lateralis and Pitar morrhuana, the soft-bottom dominants, were rare inshore. Species with

similar frequencies in both habitats were Nassarius trivittatus, Pandora gouldiana and Lyonsia hyalina.

Several amphipod species (Acanthohaustorius millsi, Protohaustorius wigleyi, Trichophoxus epistomus) were abundant only in this environment. Unciola irrorata was much more prevalent than in soft sediments, and Crangon septemspinosa and Cancer irroratus less common. Ampelisca abdita was for the most part replaced by A. vadorum in the coarser substrates. Oxyurostylis smithi and Pagurus longicarpus were abundant in both regions.

Coarse shallow areas west of Northport showed diversity very similar to stations further east (1.65 ± 0.61, median 1.73). There were, however, faunal changes which may be meaningful. No Spisula were found west of station 31 (off Northport). Ensis directus increased to a position of dominance, and large numbers of small Mytilus edulis appeared. Of the polychaetes, Polydora ligni rose dramatically in density west of Northport, with over 240 per grab at five of the six stations in this region. Streblospio benedicti, Tharyx acutus, Heteromastus filiformis, Mediomastus ambiseta and Phyllodoce spp. also increased to the west. Nephtys incisa and Ampharete arctica remained high in terms of biomass. Spiophanes bombyx and Aricidea jeffreysii were found in the

same proportions as further east, while Travisia carnea was absent from samples at the six westernmost stations. The amphipods Acanthohaustorius millsi and Protohaustorius wigleyi were also not found here. Leptocheirus pinguis, Erichthonius brasiliensis and Corophium tuberculatum increased, however, as did the isopod Edotea triloba.

Thus faunal shifts, such as the disappearance of Spisula (which may of course have an alternate explanation), the increase in Ensis and in spionid, cirratulid and capitellid polychaetes, were evident between eastern and western portions of Long Island's north shore. The changes occurred in an environment that appears quite uniform physically. We consider this evidence of an impact on benthic communities by the heavier contaminant load to the west.

3. Coarse Deep Water Sediments: The medium to coarse sandy sediments found on the Long Island coastline also extend into deeper waters (20 - 40 m) in the Mattituck Sill region and eastward. These regions were typically poorer in numbers of species and individuals than were the coarse shallow stations treated above. Evenness of the faunal distributions accounted for diversities (2.11 ± 0.48, median 2.14) which were significantly ($p < .05$) higher than those in the deep

soft sediments to the west. Differences were not significant in relation to coarse inshore sediments or Eastern basin silt-clays, however. Species which did occur were more often those frequenting the shallow sandy sediments than those of the deep silt-clay milieu: polychaetes Nephtys picta, Aricidea jeffreysii, Spiophanes bombyx, Travisia carnea, Sabellaria vulgaris, Lumbrineris fragilis and Sigalion arenicola; gastropod Crepidula fornicata; bivalves Spisula solidissima, Tellina agilis (much more abundant offshore than Spisula, and Ensis directus; amphipods Acanthohaustorius millsi, Protohaustorius wigleyi and Trichophoxus epistomus. This is an indication that sediment type is more important than depth-related parameters in determining distributions of stenotopic species of the sand and silt-clay assemblages.

Many forms inhabiting both the shallow sandy and deep silt-clay environments were, not surprisingly, also present here. Among these were Ampharete arctica, Polydora ligni, Tharyx acutus, Owenia fusiformis, Spiochaetopterus oculatus, Nassarius trivittatus, Crangon septemspinosa, Cancer irroratus and Pagurus longicarpus.

A number of species were present or abundant only east of Mattituck Sill, including several terebellid polychaetes;

the molluscs Astarte spp., Anachis sp., Venericardia borealis, Hiatella arctica, Cerastoderma pinnulatum, Crenella glandula, and Solemya velum; pycnogonids (sea spiders); amphipods Byblis serrata and Phoxocephalus holbolli; and rock crab Cancer borealis. The Mattituck Sill area may thus represent a limit of sorts to distribution of more boreal or oceanic forms. The higher species richness and diversity in eastern LIS perhaps reflect, among other things, this overlapping of several geographical faunas. No highly consistent faunal assemblages were apparent in this environment.

4. Transitional Shallow Water Sediments (Connecticut-New York coast): Another major habitat type consisted of sediments intermediate in mean size and silt-clay content along the northern coast of the Sound. This zone also appeared to have a fauna intermediate between those of the deep mid-Sound stations and inshore Long Island areas. Diversities (1.55 ± 0.22, median 1.66) were closer to those of the latter region. H' levels showed no obvious changes moving west to east along the northern shore. Many species characteristic of the deep soft sediments were found here, though usually in lower frequency and at a smaller percentage of stations: Nephtys incisa, Pherusa affinis, Euclymene

collaris, Cylichna oryza, Retusa canaliculata, Pitar morrhuana, Yoldia limatula, Nucula proxima and Ampelisca abdita. A number of species common to the shallow coarse substrates also occurred here with low to fair regularity: Nephtys picta, Aricidea jeffreysii, Spiophanes bombyx, Sabellaria vulgaris, Lumbrineris fragilis, Sthenelais boa, Crepidula fornicata, Ensis directus, Tellina agilis, Unciola irrorata and Ampelisca vadorum. As expected, those species which showed similar abundances in the deep silts and shallow sands were also well represented here. These included Ampharete arctica, Polydora ligni, Streblospio benedicti, Spiochaetopterus oculatus, Nassarius trivittatus, Pandora gouldiana, Lyonsia hyalina, Oxyurostylis smithi, Cancer irroratus and Pagurus longicarpus. The fauna of Connecticut coastal stations, then, represented a continuum between the assemblages of medium sand and silt-clay described above. This is undoubtedly due in part to the sediment heterogeneity along this coast. Coarse and fine sediments were found mixed together to a much greater extent than on the north shore of Long Island. This was true both for the entire coastline and at a given station, as shown by the high sorting index values (Figure 19). Several species were

more abundant in these sediments than elsewhere, especially Glycera americana, Scoloplos armiger, Eumida sanguinea, Spio filicornis, Mya arenaria and Yoldia limatula.

The Connecticut coastal fauna had (in common with that of Long Island) a shift in species composition moving from east to west. The most conspicuous trend was a relative increase in polychaete species and individuals toward the west end. Polydora ligni became the numerically dominant organism from Bridgeport to Throgs Neck. Its maximum of 6100 off Stamford was the greatest number of any species taken in a single grab. Densities decreased east of Bridgeport, and P. ligni was rarely found east of station 81 along the Connecticut coast. Another spionid, Streblospio benedicti, had a similar pattern and was second in abundance to P. ligni for most of the western Connecticut coast. The cirratulid, Tharyx acutus, capitellids, Heteromastus filiformis and Mediomastus ambiseta, mussel, Mytilus edulis, isopod, Edotea triloba, and amphipod, Corophium tuberculatum, increased toward the western end as they had on the Long Island coast.

Several of these species have been discussed elsewhere in relation to stressed or "new" environments. Polydora ligni was found to be the second most opportunistic polychaete (after Capitella capitata) in recolonizing areas affected by the West Falmouth, Mass., oil spill. Streblospio benedicti was fifth and M. ambiseta sixth most opportunistic species (Grassle and Grassle, 1974). Sanders et al. (1972) had reported M. ambiseta along with C. capitata as the most successful recolonizers after this spill. Streblospio benedicti also appeared early in a benthic recolonization experiment in central LIS (Fisher and McCall, 1973), and was considered an indicator of highly variable or stressed environments.

The faunal changes in shallow waters toward New York City, and to a lesser extend in the deep silt-clay assemblage, show that these regions were not unaffected by their contaminant burdens. Yet species richness was still fair and densities high in the most contaminated areas. Diversities were somewhat lower than in the cleaner eastern basin, but differences between areas were rarely significant at the $p < .05$ level. It appears that for LIS diversity has a lower correlation to environmental health than to other variables, especially sediment type.

The only highly significant ($p < 0.02$) differences in H' we found were in central and western LIS and were between all deep silt-clays and all shallow coarser sediments along either coastline. Within any of these habitats, changes with decrease in contaminant load were nil.

The overall conclusion is that the benthic macrofauna of LIS had as of summer 1972 been only marginally affected by water quality deterioration. This may no longer be the case; subsequent work by Rhoads (1973d) indicates widespread decline in densities and diversities following their high levels of summer 1972. These findings are considered in the following section.

5. Comparison with Other LIS Surveys: Alexander and D'Agostino (1972) conducted an intensive benthic survey of western LIS, with transects through Hempstead Harbor and across LIS in the Execution Rocks - Davids Island area, in March and April 1972. Their findings agree with ours on the relative health of this area. They state that "in no case...did there seem to be a depleted bottom devoid of life". Species richness was moderate, with a high of 57 and never less than 16 species at a station. They did note that amphipods were less common than in NYOSL studies of southeastern LIS (Shoreham), but comparable to

the numbers found at stations in the Northport area. Molluscs, with the exception of several large populations of Mulinia lateralis, were less numerous than elsewhere in LIS. Their samples in this region were clearly dominated by polychaetes, as were ours. Both surveys showed Streblospio benedicti to be very abundant in western LIS sediments. Mediomastus ambiseta (referred to as Heteromastus filiformus in the earlier survey - K. Serafy, pers. comm.) and Scoloplos spp. were common in both studies. We encountered larger numbers of Polydora ligni than did Alexander and D'Agostino. Capitella capitata was more abundant in their survey, as were nematodes and the archiannelid Polygordius triestinus (formerly identified as Chaetogordius canaliculatus - Serafy, pers. comm.). The latter two were listed among their dominants. Lower frequencies of these small forms in the present survey can be attributed to different sieve mesh sizes (1.0 vs 0.5 mm). Tietjen's meiofauna investigation (Appendix C) did report highest densities in its "New York City" region.

To summarize, both surveys found the faunal composition of western LIS to differ somewhat from stations further east. This was seen chiefly in the relatively greater dominance of polychaetes, notably species identified above

as opportunistic or stress-tolerant, at the expense of molluscs and amphipods. The surveys agree that numbers of species and individuals have not been drastically reduced by environmental degradation in this area.

Comparisons with other surveys around LIS show general agreement on the characterizing fauna of various areas. At Northport, D'Agostino and Colgate (1973) described a sand substrate fauna with many of the same constituents we found for the northern Long Island coastline - especially Tellina agilis, Ensis directus, Aricidea jeffreysii and Acanthohaustorius millsi. The archianellid Polygordius triestinus (referred to as Chaetogordius canaliculatus) was reported as the overall dominant organism on sandy bottoms at Northport. As noted above, the larger sieve size used in the present survey may have prevented us from sampling this small form effectively.

Deeper water mud bottom stations in the Northport survey contained several of the species characteristic of our deep silt-clay stations, including Mulinia lateralis, Nucula proxima and Nephtys incisa; and also forms identified in both surveys as occurring in a variety of substrates: Mediomastus ambiseta, Polydora ligni, Streblospio benedicti and Tellina agilis. On the average, these stations actually

had somewhat shallower depths and coarser substrates than those designated the deep silt-clay stations in the present survey. Reflecting this, their fauna appears to interdigitate with that of the shallow coarse environments of our survey.

NYOSL has also conducted benthic studies further east on the Long Island coastline, at Shoreham and Jamesport (Serafy, 1973). Species reported to be abundant there included Polygordius triestinus, Tellina agilis and Ensis directus in sands, and Nucula proxima, Clymenella torquata, Nephtys incisa, Sigambra tentaculata, Mediomastus ambiseta and Hutchinsoniella macracantha in muddy substrates. Other species commonly found in sandy sediments were Spisula solidissima, Nephtys picta, Acanthohaustorius millsi, Trichophoxus epistomus, Aricidea jeffreysii and Spiophanes bombyx, with the latter two also occurring in muds (Serafy, pers. comm.). These species were well represented in our samplings of corresponding substrates, with the following exceptions: we never found Hutchinsoniella and rarely Polygordius, almost certainly due to our larger sieve size; Clymenella torquata was less abundant at our soft-bottom stations than were two other maldanids, Euclymene collaris and Maldanopsis elongata; and Mediomastus ambiseta was more common in intermediate sediments in our survey. Overall, the benthos of the northern coastline of Long Island was fairly

consistent between these several surveys and over the three years since the first such survey (D'Agostino and Colgate, 1974) was begun at Northport in September 1971.

A benthic survey of Niantic Bay was conducted from April to July 1972 to evaluate effects of an oil spill in this area (U.S. Environmental Protection Agency, 1973). Several stations showed constituents of the classical *Nephtys*-*Nucula*-*Yoldia* community, as well as large numbers of amphipods. The lower density of these amphipods in a mid-bay station was considered evidence that oil had accumulated in the mid-bay sediments and affected this sensitive group of animals.

Our inshore stations in the Niantic Bay area were also dominated by amphipods, chiefly the ampeliscids *A. verrilli* and *A. vadorum*. These species were much rarer offshore, though whether their populations were limited by oil contamination is questionable. The *Nephtys*-*Nucula*-*Yoldia* grouping was also evident in our collections. *Clymenella torquata* and *Pagurus longicarpus* were common to both surveys. Chief discrepancies were our finding more *Tellina agilis* and fewer of the small gastropod *Bittium alternatum*.

The U. S. Naval Oceanographic Office (1973) recently completed a survey of the effects of spoil disposal (92,500 cubic yards from the Thames River) on the benthos of the New London, Ct., dumping ground. They reported the predisposal (June 1972) fauna to be dominated by amphipods, with polychaetes and bivalves also abundant. Numbers of taxa and individuals (especially amphipods and polychaetes) were reduced in samples taken in November 1972, just after completion of dumping. Six months later, however, there had been a marked recovery of the benthic fauna. Ampeliscid amphipods especially had reestablished themselves, often in greater numbers than in the predump survey a year earlier. That the new substrate was suitable for ampeliscids was taken as evidence that benthic recovery would not be inhibited by the nature of the spoil material.

Our samples from a single station within this dumping ground showed the same dominance of ampeliscids in August 1972 and April and September 1973. Densities of *Ampelisca abdita* and *A. vadorum* here were among the highest we encountered anywhere in LIS. Polychaetes and bivalves were well represented, so diversity was fair (2.25 in August 1972) despite the large numbers of amphipods. We are currently undertaking a much more intensive suvey of this dumping ground in

conjunction with a larger dredge-disposal operation (2.8 million cubic yards from the Thames). Thirty-eight stations within a two nautical mile radius of the designated dumping point have been occupied to date. Preliminary analysis of predisposal samples shows that an extensive area still supports dense Ampelisca colonies, and species richness is very high relative to most of LIS. There is a good deal of environmental and faunal heterogeneity within the two-mile radius, however. Some areas which appear suitable for Ampelisca do not contain appreciable numbers of these organisms. In other portions, dense sets of juvenile mussels or typical rock-associated fauna are found. This variability underlines the need to augment baseline data with more intensive collecting if effects of new impacts are to be comprehensively documented.

One of the most intensive benthic research programs currently underway in LIS is that of Rhoads and co-workers of Yale University. Yale has been investigating effects of dredging and spoil disposal in the central Sound. Data have been collected from New Haven Harbor, the New Haven dumping ground, and control sites to the south and northwest, before and since the onset of dredging activities. The possible alternate dumping grounds off Milford, Branford and Guilford

have also been sampled. An experiment in benthic recolonization is underway in inshore waters near Guilford.

Again, differences in survey methods preclude exact comparisons of Rhoads' findings with ours. The Yale investigators made their benthic macrofauna collections with Van Veen grabs, initially using a grab sampling 0.147 m^2 and later changing to replicates of a 0.0413 m^2 Van Veen to better define the small-scale patchiness encountered. Brillouin's diversity index (Hb) was used to analyze faunal patterns rather than the Shannon-Weaver formula of the present study. To date, Rhoads has concentrated on the molluscan component of the fauna, so our densites and diversities for total fauna are not directly comparable.

Data for molluscs have been compared, however, and they reveal agreement between the two surveys on some important features of molluscan populations in central LIS. Mollusc diversity (as in our silt-clay areas) was found to be quite variable in the areas sampled off New Haven, but even the highest values (at the N. W. control site) were very low in absolute terms (Rhoads, 1973d).

The low diversities in both surveys were in large measure due to dominance of a few bivalve species, especially

the opportunists Mulinia lateralis and Pitar morrhuana. The highest densities reported by Rhoads (1972, 1973a) for these species were similar to numbers we found in soft-bottom sediments throughout central and western LIS. Rhoads and Michael (1974) agreed that Nucula annulata,* which had had high densities in the central Sound twenty years ago (Sanders, 1956), was much less widespread in 1972-73, and was abundant only at their northwest control site. As will be discussed below, our re-examination of Sanders' stations confirmed that in most cases Mulinia dominated where Nucula formerly had. Further evidence for this change was found in gravity cores samples (Rhoads and Michael, 1974) which indicated densities of Mulinia had increased in the top 20 cm of sediment (equivalent to about 44 years). The upper 20 cm also contained increased organic carbon and trace metals. Rhoads and Michael (1974) thus considered the increase in Mulinia to be a reflection of recently changing environmental conditions in central LIS.

Rhoads (1973b) sampled three other areas as possible alternatives to the New Haven disposal site. The designated dumping grounds off Branford and Guilford were dominated by Nucula, with only small populations of Mulinia and Pitar. This may be in part a seasonal phenomenon - sampling of both sites was done in January 1973. At this time Mulinia and Pitar also had low densities at the dump and south

*This is apparently the correct name for the bivalve referred to as Nucula proxima in our survey, Sanders (1956) and other studies cited in this report.

control sites (Rhoads, 1973c), where they had been abundant the previous summer. Our own survey contains five stations (74, 75, 84, 85, 93) more or less bracketing the Branford and Guilford disposal areas. All but the easternmost of these stations (93) had appreciable standing crops of Mulinia and Pitar in our summer 1972 sampling. On the whole these stations did, however, contain greater densities of Nucula than did the typical Mulinia-dominated assemblage at our deep silt-clay stations.

Rhoads (1973b) found the Milford dumping ground to be impoverished of macrofauna in January 1973. For this reason he considered Milford preferable to Branford or Guilford if an alternative to the New Haven disposal site were necessary. Again, seasonality of sampling must be taken into account. Our July 1972 sample collection at station 55, 0.7 nautical miles east of this dumping ground, revealed a typical Mulinia-Pitar assemblage with the high standing crop characteristic of this grouping.

Continued sampling by Yale personnel has revealed a dramatic decline in the macrofauna standing crops of central LIS from the summer of 1972 to summer 1973 (Rhoads, 1973d). Brillouin diversities dropped still further from their already low values during this period. The few summer

1973 samples processed to date in our survey show varying degrees of this same trend. Greatest population decreases occurred at offshore stations, again in agreement with Rhoads (1973d). This was especially true in the very fine sediments where a single species such as Mulinia had had large standing crops the summer before. The decline is evidence for the inherent instability of these high dominance-low diversity assemblages.

Rhoads (1973d) in fact reports that he has "never seen a more spatially patchy or temporally unstable subtidal benthic system". He attributes the "population crash" to a widespread recruitment failure in 1973, with the causative agent(s) still a matter of speculation. Subsequent sampling by Rhoads revealed the decline to continue through summer 1974 (Rhoads, 1974), though some recovery now appears to be underway (Rhoads, pers. comm.). The area affected appears to include a considerable portion of central LIS, at least from Guilford in the east to Milford in the west. Our own analyses of replicate grab samples from two stations still further west, off Eatons Neck, show a similar decrease in numbers of individuals and species between 1972 and 1973. The decline was not apparent in our collections taken far to the east, near New London.

Finally, a primary objective of our macrofauna survey has been a re-examination of the eight stations studied by Sanders (1956) in central LIS. Stations correspond as follows:

Sanders (1956)	Present Survey
Charles Island	50
1	51
2	70
3	55
4	46
5	57
7	72
8	81

Sanders' station designations will be used in the following discussions.

Several differences between the surveys must be mentioned. Sanders sampled more intensively, occupying these stations every two to six months from summer 1953 until fall 1954. Our comparisons will rely most heavily on samples taken in July and August 1972, although preliminary results from April and September 1973 will also be considered. Sanders' study was conducted with an anchor dredge, which actually takes a "grab"-type sample, but probably with a different sampling bias than the Smith-McIntyre grab. Sanders washed most of his sediment through a 2 mm sieve, but he also sieved an aliquot down to 0.3 mm, so his data will include some species and many individuals that would escape our 1 mm sieve.

Despite these differences, it is still instructive to make qualitative and some quantitative comparisons of the data. Numbers of individuals and species recorded in our survey are compared with Sanders' findings in Table 7.

It is evident that Sanders' collections are most closely comparable to our summer 1972 samples. Note that Sanders still found greater densities at six of the eight stations. Species occurring in greatest numbers in his samples were generally small polychaetes, tanaidaceans, amphipods and gastropods, many of which could easily have passed through our 1 mm sieve. Sanders did report over $1000/m^2$ of several species which attain larger sizes: *Nephtys incisa*, *Macoma tenta*, *Astarte undata*, *Mulinia lateralis* and *Nucula proxima*. The latter two were found in comparable numbers in the present survey, as were three other bivalves: *Tellina agilis*, *Pitar morrhuana* and *Yoldia limatula*.

Numbers of species were generally similar between 1953-4 and 1972; there was certainly no discernable trend toward changing species richness. Diversities also showed no clear patterns, although two of our samples had values much lower than any of Sanders' collections, due to single-species dominance. Our mean diversity for these eight

stations was considerably higher than the very low values discussed above for much of central and western LIS. This is largely because the eight stations include proportionally more shallow and/or coarse areas and fewer of the high-dominance deep silt-clays than does the survey in general.

The benthos appeared to undergo greater quantitative changes between 1972 and 1973 than between our early samples and those of Sanders. Numbers of species and individuals were greatly reduced in April 1973. Part of this decrease may be a seasonal effect. Densities had not recovered by September 1973, however; they ranged from slightly lower than the previous summer to only 1/40 as great. Species richness also showed a decline in all collections but at Station 1. These findings agree with Rhoads' (1973d) description of a recruitment failure and subsequent "population crash" following the high standing crops of summer 1972. Also in agreement with Rhoads (pers. comm.), earliest or most extensive declines were seen at deep water stations. Diversities of our samples did not reflect the lowering of densities and species richness, largely because equitabilities often increased as populations of dominants were reduced.

As noted earlier, Sanders had described an association of species consistent enough to be termed a "community" at

his soft-bottom stations 2, 3, 7 and 8. Animals found at these stations constituted his "level soft-bottom community" for LIS. Dominant organisms were Nephtys incisa and Nucula proxima, together comprising an average 60% of total biomass at these stations. Also important were Yoldia limatula and the polychaete Pectinaria gouldii. Other species commonly associated with this community were Ceriantheopsis americanus; nemertean worms; the polychaetes, Melinna cristata, Ninoe nigripes, Lumbrineris tenuis and Praxillella praetermissa; amphipods, Leptocheirus pinguis and Siphonoecetes smithianus; bivalves, Lyonsia hyalina, Macoma tenta, Mulinia lateralis and Pitar morrhuana; and gastropods, Lunatia triseriata, Retusa canaliculata and Cylichna alba.

At the time of our sampling, Nephtys incisa was still the most abundant polychaete in these sediments. It was the only species present (in numbers from one to thirty per grab) in every sample analyzed from the four soft-bottom and one "transitional" station. Maldanids were next most numerous among polychaetes, although we found none of the Praxillella praetermissa reported by Sanders. Pectinaria gouldii and Lumbrineris tenuis were also absent from our samples.

Polychaetes common in 1972-3 but not listed in 1953-4 were Ampharete arctica, Pherusa affinis and Owenia fusiformis. Numbers of Melinna cristata and Ninoe nigripes were comparable between the surveys. The polychaetes identified earlier as currently reaching high densities in stressed areas such as westernmost LIS and along parts of the Connecticut coast, were generally rare or absent at these deep, soft central LIS stations. An exception was the numerical dominance of the capitellid, Mediomastus ambiseta, at station 7 in September 1973. On the whole, polychaete densities and species composition showed little change between our 1972 and 1973 samples.

Of the molluscs, Nucula proxima was still extremely abundant at station 8 and common at station 7 in summer 1972, but rare at stations 2 and 3. Yoldia limatula reached high densities only at station 7. Conversely, Sanders (1956) found that Mulinia lateralis made "only an insignificant contribution to the biomass" in most of the area studied. Pitar morrhuana was apparently still less common. In summer 1972, Mulinia and Pitar were abundant at stations 2 and 7, and dominant at station 3. Rhoads and Michael (1974) also found the Nucula-Nephtys assemblage to be much more restricted off New Haven than Sanders reported, and Mulinia and Pitar to have increased in numbers.

These changes may represent a tendency for Mulinia and Pitar to replace Nucula in areas with deteriorating water quality in LIS. O'Connor (1972) found that Mulinia had increased with the eutrophication of Moriches Bay over the past three decades, while Nucula, among several other species, had decreased. Mulinia was also prevalent in the polluted muds of Raritan Bay, and Nucula was not found there, in a recent survey (McGrath, 1974). Nucula had been present in this area in the late 1950s (Dean, 1974), albeit not in abundance. Nucula's sensitivity to stress is questionable, however; this species exists in great numbers at the peripheries of the New York Bight sewage sludge and dredging spoils disposal areas (Pearce, 1972).

Molluscs showing little population change between 1953-4 and 1972 were Lyonsia hyalina, Pandora gouldiana, and Retusa canaliculata. Nassarius trivittatus was much more abundant in our samples, and Tellina agilis somewhat so. Lunatia triseriata and Macoma tenta, included in Sanders' soft-bottom community, were not found in our collections.

The "population crash" of 1973 had a much greater effect on molluscs than on polychaetes. This is again consistent with the findings of Rhoads (pers. comm.).

We saw largest reductions in populations of short lived opportunists such as Mulinia and Pitar, which had reached such high densities the summer before. The decline in numbers of individuals and species was observed throughout the Mollusca, however.

The last remaining difference of note in species composition was the greater abundance of Leptocheirus pinguis in Sanders' collections, and Ampelisca abdita in ours. Crustaceans were never a major constituent of the soft-bottom community, and changes between 1972 and 1973 were not extensive.

Station 5, considered by Sanders as transitional between stations with coarse and fine sediments, showed slightly less change between surveys. Both studies found amphipods, including Ampelisca abdita, Unciola irrorata and Leptocheirus pinguis, very common here. Other abundant species in both investigations were the anthozoan Ceriantheopsis americanus; polychaetes, Nepthys incisa, flabelligerids and malanids; and bivalves, Pandora gouldiana, Lyonsia hyalina and Pitar morrhuana. Scalibregma inflatum, Owenia fusiformis and Nassarius trivittatus were more common in the present survey. Several other species not listed by Sanders were also found in 1972-3. On the other hand, Diopatra cuprea, Lumbrineris tenuis, Melinna cristata, Pectinaria gouldii, Stenothoe

cypris, Siphonoecetes smithianus and Cylichna alba were found in Sanders' samples but not in ours. The population decline between 1972 and 1973 was less evident than at the four softer-bottom stations discussed above.

Stations with coarser sediments (1, 4 and Charles Island) revealed considerable change in species composition between surveys. Sanders' "representative collections" from these stations contained large numbers of amphipods, among them Ampelisca vadorum, Stenothoe cypris, Leptocheirus pinguis, Erichthonius brasiliensis, Corophium acherusicum and C. crassicorne. Other species abundant at at least two of the stations included Nephtys incisa, Ampharete acutifrons, Glycera spp., Anadara transversa, Lyonsia hyalina, Pandora gouldiana, Macoma tenta, Crepidula plana, Nassarius trivittatus and several decapods.

We found offshore station 4 to be still amphipod-dominated, especially by A. vadorum, L. pinguis and Unciola irrorata. Most other fauna common in Sanders' samples were also present in ours. There had been an increase in several of the forms linked above to deteriorating water quality, specifically Polydora and Streblospio and the possible indicators Mulinia and Pitar. The polychaete, Scalibregma

inflatum, and bivalve, *Tellina agilis*, were also abundant in our samples; we again found none of the *Macoma tenta* reported by Sanders.

Reductions in density and species richness were substantial at this station between 1972 and 1973. The decline was much less noticeable at Charles Island and station 1. On the other hand, these inshore areas had experienced greater changes in species composition as compared to Sanders' earlier results. Amphipod numbers were much lower, and stress-resistant taxa more in evidence, in our collections. In addition to *Streblospio*, *Polydora* and *Tellina*, we found significant numbers of the polychaetes, *Tharyx acutus* and *Mediomastus ambiseta*, both also common in westernmost LIS.

To summarize: quantitative data for densities, species richness and diversity did not reveal gross changes in the benthic fauna of Sanders' study area between 1953-4 and 1972. Decreases in densities and richness were at least as great between 1972 and 1973 (though diversities showed no proportional decline over this period). A more obvious alteration over the past two decades was that in species composition, which is thus held to be a more sensitive measure of change in the area's benthic environment.

The shift toward stress-tolerant polychaetes at the inshore stations and opportunistic bivalves offshore is evidence of deteriorating environmental quality in the central Sound.

IV. CONCLUSIONS

Our data point to 1) several areas of LIS as showing significant effects of man's activities, 2) other broad regions with less severe impacts and 3) some portions in which perturbations were negligible or undetectable.

The western end of LIS, from the Hempstead Harbor transect to Throgs Neck, was by far the most stressed in terms of amounts of various contaminants present. All nutrients measured reached their highest levels here (with specific exceptions, such as the Connecticut River's massive input of nitrates in April 1973). Orthophosphorus was higher and nitrate only slightly lower than their maximum concentrations in the sewage sludge and dredge spoil disposal areas of the New York Bight (National Marine Fisheries Service, 1972b). The ammonia maximum of 28.4 μgat/l was as much as three orders of magnitude above the values recorded in the eastern basin. Evidence of waste input was also clearly seen in the levels of sediment organics, fecal coliform bacteria and heavy metals. At several western end stations, chromium, copper, nickel, lead and zinc exceeded mean values found near dredging spoil and sludge disposal centers in the New York Bight (Carmody, Pearce and Yasso, 1973).

Perhaps most critical is the reduction of dissolved oxygen levels by contaminant loading in the western Sound. In summer, bottom DOs here often fall well below the Interstate Sanitation Commission's criterion of 3 ppm for fish survival and passage of anadromous fish. The condition is aggravated by the low amount of wind-generated mixing during this period, and perhaps also be reduction of phytoplankton standing crops toward the East River (Hardy and Weyl, 1971). The DO minimum occurs at a time when highest temperatures may be adding to the stresses presented by high contaminant concentrations. Fish kills are commonplace in western LIS; the U. S. Fish and Wildlife Service (Anon., 1973) reports "periodic kills resultant from a combination of factors in this area", giving as an example a die-off of an estimated 35,000 commercially valuable fish (mostly menhaden) in early August 1970. The feeling is widespread that an extended period of calm, hot weather could affect the biota of western LIS to a far greater extent than has yet been observed.

Given the stresses present, the relative health of the area's benthic meio- and macrofauna was somewhat surprising. Densities of both meio- and macrofauna were high. Species richness was not significantly lower than in similar sediments from much less perturbed areas of LIS. Sensitive stress

indicators such as some amphipod species were still present, though perhaps in reduced numbers. The trend toward dominance by pollution-tolerant polychaetes and bivalves was not far advanced at the time of our survey. The benthos of westernmost LIS was thus much less impoverished or altered than that of other local systems which appear to be under similar stresses - Raritan Bay (McGrath, 1974) and portions of the New York Bight (Pearce, 1972).

We can find no obvious explanations for this discrepancy. Perhaps western LIS is lower in some contaminants not measured in this survey, such as oils or pesticides. Presence of ampeliscid amphipods, thought to be sensitive to oil in low concentrations (Sanders, Grassle and Hampson, 1972), may be evidence that this pollutant is still at tolerable levels in western LIS.

Next in magnitude of observed perturbations were waters associated with urban centers on the Connecticut coast. Bridgeport and New Haven, and to a slightly lesser extent New London and Stamford, had elevated levels of most or all of the contaminants discussed above for western LIS. Again, effects on the biota appeared limited to a slight shift toward more tolerant taxa. The stresses present produced no obvious changes in density, richness or diversity.

Some areas showed changes from surrounding waters for single parameters, such as Oyster Bay and Smithtown Bay (increased ammonia) and Huntington Bay (decreased dissolved oxygen) on the Long Island coast; and of course the Connecticut River vicinity had elevated levels of several nutrients during high flow periods. Almost all of remaining central and western LIS showed values for nutrients, dissolved oxygen and expecially heavy metals somewhat removed from "background" levels found in the eastern basin. This well-scoured eastern region, with the exception of the Thames River environs, was still relatively pristine in terms of these contaminants.

Our data thus showed all of central and western LIS to contain varying but definite contaminant burdens, as measured by water column nutrient and dissolved oxygen levels, and sediment heavy metal, organic and fecal coliform values. Impacts on benthic fauna, however, were for the most part minor and limited to changes in species composition. Quantitative differences in density, species richness and diversity were more closely related to naturally varying parameters, especially sediment texture, than to water quality in LIS.

V. RECOMMENDATIONS

The baseline data indicate that LIS may be divisible into three areas for management purposes:

1. The western end - This region (defined perhaps arbitrarily by our sampling pattern as the area from Hempstead Harbor west to Throgs Neck) contains the highest concentrations of a number of contaminants. Yet at the present time, westernmost LIS still appears to be ecologically viable. It thus becomes all the more essential that no new stresses be added in this area, and that efforts be made to reduce existing contaminant burdens. Lowering inputs of oxygen-demanding wastes, to relieve the seasonal dissolved oxygen shortages, should be given high priority. The attendant problem of nutrient additions and potential eutrophication should be dealt with concurrently. Any new sewage plants providing less than tertiary treatment would only increase total concentrations of nutrients, chemical- or biological-oxygen-demanding substances, heavy metals and/or other toxins in these waters, and thus aggravate present conditions. Inputs due to storm runoff will of course have similar effects.

Other planned activities, such as thermal additions and dredge spoil disposal operations, which would add to the stresses already present, should be relocated or deferred if at all

possible. The present limiting of spoil disposal to Eatons Neck and eastward is sound policy, and should be continued.

2. Remaining western and central LIS - As a rule, contaminant loads are somewhat lower than in the western end, but still far above background levels. The "population crash" recently seen in the benthos of this region is evidence that stresses are indeed present, and that the faunal balance here is at best precarious. New impacts proposed for this area should be examined carefully, and rejected if they would add significantly to the cumulative stresses now affecting the western and central basins.

Within central LIS, waters adjacent to Long Island show less deterioration than do those near Connecticut. Long Island coastal waters could presumably assimilate new impacts more easily than could the northern coast. The advisability of spreading such impacts throughout LIS, rather than clustering in areas which are presently approaching or even beyond carrying capacities, should be considered.

3. Eastern basin - East of Mattituck Sill and the Connecticut River, environmental quality is much improved over the rest of LIS, with contaminant levels generally close to background. The higher flushing rates here would tend to minimize impacts

of new activities. The eastern basin should thus be chosen for most of those activities whose siting need not be restricted to waters further west.

The baseline data have a number of other possible applications. Below are a few suggestions, presented more as examples of possible uses than as a comprehensive list.

1. Should it become necessary to relocate or add to the present four disposal areas in LIS, the maps of sediment sizes, heavy metal and organic content may aid in site-selection. For instance, to minimize effects on biota, sediment at a disposal area should ideally have size characteristics similar to the spoils. If spoils are high in organic matter but not otherwise contaminated, disposing of them in an area presently low in organics might keep total concentrations within acceptable limits and perhaps even enhance productivity. If the spoil has high levels of heavy metals, oils, pesticides or other toxins, it is best disposed of in a location already showing similar contamination (contrary to the above suggestion that spreading impacts might be less harmful as a rule). Benthic communities should also be considered: if all other things were equal, it could be preferable to dump spoils where small polychaetes dominate, and avoid

areas abundant in amphipods, sand shrimp or other organisms of known importance in marine food webs. The decisions to be made are obviously complex, but consideration of the baseline data will enable sounder choices than are possible without it.

2. Sediment size data can also be of value if LIS sediments are to be utilized as a source of sand and gravel. As with spoil disposal, the contaminants and benthic communities present must be considered. If medium to coarse sands are needed, it is perhaps not too far-fetched an idea to mine portions of Mattituck Sill, with a possible bonus being the creation of channels to increase flushing in the central basin. Any detrimental effects of such channels must of course be considered.

3. It may not always be possible to conduct more intensive baseline studies in areas where new point-source impacts are anticipated. In such cases our baseline data, in combination with suitable postsurveys, can provide an indication of local responses to specific activities.

4. Finally, the baseline data establish a standard against which future environmental change throughout LIS can be measured. It is recommended that some or all of the baseline stations be monitored periodically (perhaps every three, five or ten years)

for the same parameters as examined in the present study. This will provide a dual function: a) it will insure that the baseline data are current and accurate; and b) more significantly, it will indicate whether measures to manage the Sound's resources and preserve or improve its water quality are having an effect, or whether deterioration is continuing. Impacts of new types or in new areas can also be detected and thus treated.

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Before citing or reproducing any of these unpublished data, a written request must be made to the Director, Ecosystems Investigations, Sandy Hook Laboratory, MACFC, Highlands, New Jersey 07732.

VII. LITERATURE CITED

Abbott, R. T.

1954. American Seashells. D. Van Nostrand Co., Princeton, N. J. 541 p.

1968. A Guide to Field Identification. Seashells of North America. Golden Press, N. Y. 280 p.

Alexander, J. and A. D'Agostino.

1972. Biological and chemical characteristics of sediments along the aquatic sections of the Dunwoodie-Glenwood interconnection. Final Report, Contract No. SR 71-24, NYOSL, N. Y. 18 p.

Aller, R. C. and R. E. Dodge.

1974. Animal - sediment relations in a tropical lagoon - Discovery Bay, Jamaica. J. Mar. Res. 32(2):209-232.

American Public Health Association.

1965. Standard Methods for the examination of water and waste water including bottom sediments and sludges. 12th ed. Amer. Public Health Assoc., N. Y. 769 p.

Anon.

1973. Connecticut and New York Fish Kills, 1962 to 1972. LISS Supplementary Report, U. S. Department of the Interior, Fish and Wildlife Service, Division of River Basin Studies, Patchogue, N.Y. 5 p.

Bloom, S. A., J. L. Simon and V. D. Hunter.

1972. Animal-sediment relations and community analysis of a Florida estuary. Mar. Biol. 13(1):43-56.

Boesch, D. F.

1972. Species diversity of marine macrobenthos in the Virginia area. Ches. Sci. 13:206-211.

Bousefield, E. L.

1965. Haustoriidae of New England (Crustacea: Amphipoda). Proc. U. S. Nat'l. Mus. 117(3512):159-239.

1973. Shallow-Water Gammaridean Amphipoda of New England. Cornell Univ. Press, Ithaca, N. Y. 312 p.

Carmody, D. J., J. B. Pearce and W. E. Yasso.

1973. Trace metals in sediments of New York Bight. Mar. Poll. Bull. 4(9):132-135.

D'Agostino, A. and W. A. Colgate.

1973. Infaunal invertebrates in the near shore waters of Long Island Sound. Benthos of Northport. Final Report Contract SR 72-22 with Long Island Lighting Company. 28 p.

Dean, D.

1974. Raritan Bay macrobenthos survey, 1957-1960. NMFS Technical Rpt. (in press). 9 p.

Dehlinger, P., W. F. Fitzgerald, S. Y. Feng, D. F. Paskausky, R. W. Garvine and W. F. Bohlen.

1973. A determination of budgets of heavy metal wastes in Long Island Sound. Univ. of Conn. Mar. Sciences Inst. First Annual Rept. Submitted to Office of Sea Grant Programs, NOAA.

Folk, R. L. and W. C. Ward.

1957. Brazos River Bar: A study in the significance of grain size parameters. J. Sediment Petrol. 27(1):3-26.

Fisher, J. B. and P. L. McCall.

1973. The environmental consequences of dredge spoil disposal in central Long Island Sound: IV. The effect of environmental perturbations on benthic communities: An experiment in benthic recolonization and succession in Long Island Sound. Yale Univ. Unpubl. manuscript.

Gage, J.

1972. Community structure of the benthos in Scottish sea-lochs. I. Introduction and species diversity. Marine Biol. 14:281-297.

Gosner, K. L.

1971. Guide to Identification of Marine and Estuarine Invertebrates. Wiley-Interscience, New York. 693 p.

Grassle, J. F. and J. P. Grassle.

1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res. 32(2):253-284.

Hardy, C. D.

1970. Hydrographic data report: Long Island Sound - 1969. Marine Sci. Research Center, State Univ. of New York, Stony Brook, New York. Tech. Rep. No. 4. 129 p.

1972a. Hydrographic data report: Long Island Sound - 1970. Part II. Marine Sci. Research Center, State Univ. of New York, Stony Brook, New York. Tech. Rep. No. 13.

1972b. Movement and quality of Long Island Sound waters, 1971. Marine Sci. Research Center, State Univ. of New York, Stony Brook, New York. Tech. Rep. No. 17. 66 p.

Hardy, C. D. and P. K. Weyl.

1970. Hydrographic data report: Long Island Sound - 1970. Part I. Marine Sci. Research Center, State Univ. of New York, Stony Brook, New York. Tech. Rep. No. 6. 96 p.

1971. Distribution of dissolved oxygen in the waters of western Long Island Sound. Marine Sci. Research Center, State Univ. of New York, Stony Brook, New York. Tech. Rep. No. 11. 37 pp.

McCain, J. C.

1968. The Caprellidae (Crustacea: Amphipoda) of the Western North Atlantic. U. S. Nat'l. Mus. Bull. 278. 147 p.

McGrath, R. A.

1974. Benthic macrofaunal census of Raritan Bay - preliminary results. Pap. No. 24; Proc. 3rd Symp. Hudson R. Ecol.; Mar. 22-23, 1973. Bear Mt., N. Y.; Hudson R. Environ. Soc.

National Marine Fisheries Service.

1972a. Davids Island Phase I: A Short-Term Ecological Survey of Western Long Island Sound. Middle Atlantic Coastal Fisheries Center, Informal Report No. 7. 29 p.

1972b. The Effects of Waste Disposal in the New York Bight. Final Report. Submitted to U. S. Army Corps of Engineers, Coastal Engineering Research Center. 9 sections. Sandy Hook Laboratory, Middle Atlantic Coastal Fisheries Center.

O'Connor, J. S.

1972. The benthic macrofauna of Moriches Bay, New York. Biol. Bull. 142(1):84-102.

Pearce, J. B.

1972. The effects of solid waste disposal on benthic communities in the New York Bight. In: M. Ruivo, Ed., Marine Pollution and Sea Life. Fishing News, Ltd., Surrey, England. p. 404-411.

Perlmutter, A.

1971. Ecological study of the aquatic environs of the proposed nuclear power station of the Long Island Lighting Company at Shoreham: 1970-1971 and Summary, 1968-1971.

Petersen, C. G. J.

1913. The valuation of the sea. Part II. The animal communities of the sea bottom and their importance for marine zoogeography. Rep. Danish Biol. Sta., 21: 110 p.

Pettibone, M. H.

1957. Check-List of Polychaeta of New England Region. (mimeographed). Univ. of New Hampshire, Durham, N. H.

1963. Marine polychaete worms of the New England region. I. Aphroditidae through Trochochaetidae. U. S. Nat'l. Mus. Bull. 227. Part I. 356 p.

Reish, D. J.

1972. The use of marine invertebrates as indicators of varying degrees of marine pollution. In: M. Ruivo, Ed., Marine Pollution and Sea Life. Fishing News, Ltd., Surrey, England.

Rhoads, D. C.

1972. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. I. Benthic biology of the New Haven dump site. Yale Univ. Unpubl. manuscript. 4 p.

1973a. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. III. Benthic biology of the south control site. 1972. Yale Univ. Unpubl. manuscript. 5 p.

1973b. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. V. Benthic biology of the Milford, Branford and Guilford dump grounds. Yale Univ. Unpubl. manuscript. 19 p.

1973c. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. VI. Benthic biology of the New Haven dump site, south control, and northwest control sites, January 1973. Yale Univ. Unpubl. manuscript. 20 p.

1973d. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. VII. Benthic biology of the New Haven ship channel, dump site, south and northwest control sites. Summer 1973. Yale Univ. Unpubl. manuscript. 17 p.

1974. Report to U. S. Corps of Engineers on the environmental consequences of dredge spoil disposal in central Long Island Sound. IX. Benthic biology of the New Haven harbor channel, New Haven dump site, new south control and northwest control sites. February-March 1974 (during dredging and dumping operations). Yale Univ. Unpubl. manuscript.

Rhoads, D. C. and A. Michael.

1974. Summary of benthic biologic sampling in central Long Island Sound and New Haven harbor (prior to dredging and dumping), July 1972-August 1973. Report to U. S. Corps of Engineers. V. Yale Univ. Unpubl. manuscript. 15 p.

Rhoads, D. C. and D. K. Young.

1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28(2):150-178.

Riley, G. A.

1955. Review of the oceanography of Long Island Sound. Deep Sea Res., Suppl. to Vol. 3:224-238.

Riley, G. A., S. M. Conover, G. B. Deevey, R. J. Conover, S. B. Wheatland, E. Harris and H. L. Sanders.

1956. Oceanography of Long Island Sound, 1953-1954. Bull. Bingham Oceanogr. Coll. 15.

Riley, G. A., S. M. Conover, R. R. Larkin, S. J. Altshuler, S. W. Richards and A. G. Carey, Jr.

1967. Aspects of oceanography of Long Island Sound. Bull. Bingham Oceanogr. Coll. 19(2).

Riley, G. A., G. B. Deevey, D. Merriman, R. Sclar and H. L. Sanders.

1952. Hydrographic and biological studies of Block Island Sound. Bull. Bingham Oceanogr. Coll. 13(3).

Riley, G. A., E. Harris, H. M. Schurr, P. J. Wangersky, S. W. Richards and R. W. Covill.

1959. Oceanography of Long Island Sound. Bull. Bingham Oceanogr. Coll. 17(1):1-153.

Sanders, H. L.

1956. Oceanography of Long Island Sound, 1952-1954. X. Biology of marine bottom communities. Bull. Bingham Oceanogr. Coll. 15:345-414.

Sanders, H. L., J. F. Grassle and G. R. Hampson.

1972. The West Falmouth oil spill. I. Biology. WHOI. Tech. Rept. 72-20.

Schultz, G. A.

1969. How to Know the Marine Isopod Crustaceans. Wm. C. Brown, Co., Dubuque, Iowa. 359 p.

Serafy, D. K.

1973. NYOSL benthic invertebrate studies: Past and present. Paper presented at 6th Long Island Sound Conference, Montauk, N. Y., 1 December 1973.

Shannon, C. E. and W. Weaver.

1963. The Mathematical Theory of Communication. Univ. of Illinois Press, Urbana, Illinois. 117 p.

Steel, R. G. D. and J. H. Torrie.

1960. Principles and Procedures of Statistics. McGraw-Hill, Inc. New York. 481 p.

Thorson, G.

1957. Bottom communities, Chapter 17. In: Treatise on marine ecology and paleoecology. Vol. I. Ecology. pp. 461-534. J. W. Hedgpeth, Ed., Mem. Geol. Soc. Am. 67:461-534.

U. S. Environmental Protection Agency.

1973. Oil spill, Long Island Sound. March 21, 1972. Environmental effects. Final Report. Contract No. 68-01-0044. 136 p.

U. S. Naval Oceanographic Office.

1973. Preliminary Report. Environmental investigation of a dredge spoil disposal site near New London, Connecticut. NAVOCEANO Technical Note No. 7300-3-73. 87pp.

Wilhm, J. L.

1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. J. Water Poll. Con. Fted. 39(10):1673-1683.

Williams, A. B.

1965. Marine decapod crustaceans of the Carolinas. Fishery Bull. 65(1). 298 p.

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APPENDIX A

SUBLITTORAL MEIOBENTHOS OF LONG ISLAND SOUND

A Report to: National Marine Fisheries Service
Middle Atlantic Coastal Fisheries Center
Sandy Hook Marine Laboratory
Highlands, New Jersey 07732

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INTRODUCTION

The basic objectives of this study will be to ascertain the qualitative and quantitative distribution of meiofauna in Long Island Sound, to study seasonal fluctuations in the populations of the Sound, and to relate the spatial and temporal distribution of the meiofauna to the sedimentary environment. It forms part of a larger study being conducted under the direction of the National Marine Fisheries Service at Sandy Hook, New Jersey which will attempt to provide ecological baseline information for the whole of Long Island Sound.

The early phase of the research will essentially be a survey of the meiofauna present in the Sound, a survey aimed at obtaining some information about the gross distribution of meiofauna in the area. No previous information on meiofauna distribution in Long Island Sound is extant save that of Gross et al. (1971). In this study, however, only those organisms retained on sieves larger than 149 μ were examined; this, unfortunately, excludes such a large percentage of the meiofauna that their study cannot be used for comparative purposes.

This report will include information on the distribution of total meiofauna in Long Island Sound in April and September 1973. In addition, the species composition of the most dominant taxon encountered, the free-living nematodes, will be detailed for April, along with comments on the relationships of species composition and species diversity with sediment granulometry, geographical position and total heavy metal concentration.

METHODS

Meiofauna samples were obtained from the NMFS laboratory at Sandy Hook. The samples had been taken in the field by inserting plastic core liners into bottom samples which had been taken with a Smith-McIntyre bottom grab. The

sediment was sampled to a depth of 5 cm. To facilitate enumeration of the meiofauna, the samples were preserved in a 1:500 Neutral Red:5 % buffered formalin mixture. It was found that Neutral Red did not function as an adequate stain; thus Rose Bengal was added to the samples.

In the laboratory, the volume of the samples was noted. The samples were then washed through a set of two sieves, the larger one with a mesh opening of 0.500 mm and the smaller one with a mesh opening of 0.074 mm. Animals which passed through the larger sieve but which were retained on the smaller sieve were regarded as meiofauna.

The stations selected for examination are given in Figure 1. It was decided to divide the Sound into four basic regions: a "New York City" region (Stations 2, 4, 5, 6, 7, 8, 9, 10), a Western region, thought to be somewhat potentially removed from the influences of New York City (Stations 11, 12, 13, 14, 15, 16, 17, 18, 23, 25, 26), a Central region (Stations 32, 35, 37, 44, 45, 47, 49, 61, 63, 67, 82, 86, 90) and an Eastern region (Stations 100, 103, 105, 114, 117, 120, 126, 128, 130). In addition, the Sound was divided latitudinally into a Northern region (Stations 7, 11, 15, 23, 32, 44, 61, 82, 100, 114, 126), a Center region (Stations 8, 9, 12, 13, 16, 17, 25, 35, 45, 63, 86, 103, 117, 128) and a Southern region (Stations 10, 14, 18, 26, 37, 49, 67, 90, 105, 120, 130). The samples were taken on NOAA Long Island Sound Cruises II (April 1973) and III (September 1973).

For the analysis of nematode species composition, 26 of the above 41 stations were selected on the basis of geographic position, sediment granulometry and heavy metal concentration. These were Stations 2, 5, 7, 8 and 10 in the New York City region; Stations 11, 13, 14, 23, 25 and 26 in the Western region; Stations

32, 35, 37, 61, 63, 67, 82, 86 and 90 in the Central region, and Stations 100, 103, 105, 126, 128 and 130 in the Eastern region. The median grain sizes and percent silt clay (data obtained from Lehigh University, J.M. Parks, personal communication) of the sediments, and the total heavy metal concentrations (data obtained from NMFS, Sandy Hook) in the sediments are given in Table 1.

RESULTS

Spatial Distribution of Total Meiofauna. The numbers of toal meiofauna per 100 cm^3 of sediment in April and September 1973 are given in Tables 2 and 3. Excluding nauplii, a total of 18 major meiofauna groups were found at the 41 stations. Nematodes were the dominant taxon, comprising more than 90 % of the total meiofauna at the stations examined. Nematodes were found in all samples analyzed. Harpacticoid copepods and polychaetes were the next-most encountered groups; these were followed by varying numbers of the remaining groups. Ciliates are included in the enumeration of the total fauna, but since the method of extraction of the fauna loses most of the ciliates, no reliance should be placed on these numbers. They are included for gross comparison purposes only.

If the data for April and September are combined (Table 4), the following observations may be made on the spatial distribution of total meiofauna:

(1) The Eastern region of the Sound had the lowest mean population densities of meiofauna (1291 and 1732 /100 cm^3 of sediment for April and September, respectively), and the New York City region the highest mean population densities (3490 and 3624 per 100 cm^3 of sediment for April and September, respectively),

(2) The difference in population densities between the New York City and Eastern regions was significant in both April and September,

(3) On a latitudinal basis, the Northern portion of the Sound had the highest

mean population densities (1874 and 4392 individuals per 100 cm^3 of sediment in April and September, respectively); the Southern portion had the next highest mean population density, and the Center region the lowest mean population density.

Temporal Distribution of Total Meiofauna. A comparison of the April and September population densities yielded the following:

(1) On a longitudinal basis, the abundance of meiofauna in September was significantly higher than in April in the Western and Central regions of the Sound; in the New York City and Eastern regions the numbers in September were higher than in April but not significantly so,

(2) On a latitudinal basis, the abundance of meiofauna in September was significantly higher than in April in the Northern and Southern regions of the Sound; in the Center region the numbers in September were higher than in April but not significantly so,

(3) In April, the New York City region had significantly higher population densities than the Western, Central and Eastern regions; in September, the New York City, Western and Central regions did not differ significantly among themselves, but all three had significantly higher population densities than the Eastern region and

(4) In April, no statistically significant latitudinal differences existed among the Northern, Center and Southern portions of the Sound, but in September both the Northern and Southern portions had significantly higher population densities than did the Center region.

In summary, it appears that major differences do exist in meiofauna population

densities in different geographic sections of Long Island Sound, and that there might also be seasonal differences in the abundance of meiofauna in the Sound. However, more data are needed to see if the latter observation is correct.

Nematodes. A total of 205 species were found at the 26 stations selected for the study of nematode species composition; their relative abundances are given in Table 5. Most of the species were quite restricted in their distribution; 98 species were found at only one station, 43 species at two stations, 12 at three stations and eight at four stations. Thus only 44 species were encountered at five or more stations; of these, the most frequently encountered were: Microlaimus dimorphus Chitwood (20 stations), Sabatieria pulchra Scheider (17 stations), Desmodora tenuispiculum Allgen (14 stations), Dorylaimopsis metatypicus Chitwood, (13 stations), Terschellingia longicaudata de Man and Theristus normandicus de Man (12 stations) and Odontophora armata Ditlevsen and Microlaimus sp 1 (11 stations).

The 26 stations were divided into five major sedimentary habitats, based on the sediment granulometry data for April 1973 provided by Lehigh University. These habitats were: mud (Stations 2, 5, 7, 8, 13, 35, 61, 63 and 82); muddy sand (Stations 32, 86 and 100); fine sand (Stations 90, 105, 126 and 130); medium sand (Stations 10, 11, 14, 25, 37, 67 and 103) and coarse sand (Stations 23, 26 and 128).

The affinity among the nematode species occurring in these sediments is given in Figure 2. Figure 2, a trellis diagram, is a semi-quantitative method of indicating relationships among communities from different areas. Details of the method are given by Sanders (1960) and Wieser (1960). Within the five habitats, the highest degree of affinity was observed among the species inhabiting muddy sediments. Within the remaining habitats, only the medium sands tended to show any degree of high faunal affinity, and this was largely due to the overwhelming

dominance of the fauna by Theristus problematica at three of these stations (Stations 10, 67 and 103). The other three habitats displayed little within habitat faunal affinity.

There was no high degree of affinity among species inhabiting different sediments. In other words, the fauna of one habitat showed little affinity with the fauna of another habitat. The species inhabiting muds and medium sands showed higher degrees of affinity with other habitats than did the species occurring in muddy sands, fine sands and coarse sands, but there was little consistency in the data. It appears, therefore, that there might be a distinct mud fauna, which is identifiable by its high within-habitat species affinity. The other habitats exhibited a high degree of within habitat variation (that is, a high degree of station to station species variation within the habitat).

If the stations are arranged by geographic location (New York City, Western, Central, Eastern regions, etc.), there is little either within or between habitat similarity in species composition.

Outside of muddy sediments, therefore, the high individual station to station variation in species composition makes impossible the detection of certain faunas associated with certain sediments (medium sand, fine sand, etc.).

Nematode Feeding Types. The nematodes were divided into four basic feeding types, based on the structure of the buccal cavity, according to the method outlined by Wieser (1953). These groups are:

Group designation	Characteristics
1A	Without oral cavity (selective deposit feeder)
1B	With large, unarmed oral cavity (non-selective deposit feeder)
2A	With weak oral armament (epigrowth feeder)
2B	With heavy oral armament (predator/omnivore)

For ease of comparison, Groups 1A and 1B were combined into one group, deposit feeders. The distribution of feeding types in the five major sediment types is shown in Figure 3. Deposit feeders were the overwhelmingly dominant feeding type encountered in muddy sediments. An increase in epigrowth feeders was observed in sandy sediments, but deposit feeders were still the dominant feeding type encountered. The group 2B, predators/omnivores, were consistently the least abundant feeding type observed in all sediments.

Nematode Species Diversity. Nematode species diversity was calculated using the familiar Shannon formula,

$$H' = - \quad p_i \log_2 p_i,$$

where p_i is the proportion of individuals belonging to the ith species. Species diversity has a "species richness" component and an "evenness" component (Lloyd and Ghelardi 1964). Species richness was estimated by $SR = (s - 1)/ \ln N$, where s is the number of species and N the number of individuals in a sample (Margalef 1958). Evenness, a measure of the allocation of individuals among species, was calculated as $J = H'/\log_2 s$ (Pielou 1966).

The median and ranges of species diversity, species richness and evenness are given in Figure 4. Median diversity was highest in muddy sands and fine sands, where the range of diversity was also lowest. Diversity was lowest in muds and coarse sands. In muds, medium sands and coarse sands the range in diversity was quite large; this high range in H' was due to a great range in both the richness and evenness component of species diversity (Fig. 4).

Total Numbers of Nematodes. The median and range of the total numbers of nematodes observed in April 1973 in the five sediment types is given in Figure 4. A great range in the population densities was observed in all but the coarsest sediments, which had a significantly lower median population density than did the other

four sediment types. The highest population densities were usually found in muddy sediments, but no significant differences in total population density existed among the muddy, muddy sand, fine sand and medium sandy sediments.

DISCUSSION

Spatial and Temporal Distribution of Total Meiofauna. There have been few studies of meiofauna in what might be regarded as "polluted" areas. In the only other study in which the population densities of total meiofauna in polluted areas were considered, Marcotte and Coull (1974) used a 0.125 mm mesh sieve as the smallest sieve, thereby making comparisons with the present study nearly impossible. They report that, in general, there is a decrease in the total numbers of meiofauna away from the pollution source (waste effluent pipe) in the Bay of Piran, Yugoslavia. This decrease is not significant, however.

The population densities observed during the course of the present study agreed well with those reported in similar subtidal areas (McIntyre 1964; Wieser 1960; Tietjen 1969; Coull 1970; McIntyre and Murison 1973; and others, summarized in McIntyre 1969). Finer sediments have been reported as generally having higher population densities than coarser sediments, and the results of the present study are in agreement with this general trend.

Taken as a whole, Long Island Sound is not depauperate either in total meiofauna density or in the diversity of major taxa. However, ostracods normally constitute a major taxon in most meiofauna assemblages. In Long Island Sound, the number of ostracods, both in terms of toal density and spatial distribution, is disproportionately low. This was unexpected, particularly in the finer sediments where the numbers of ostracods normally is in the range of $10^4 - 10^5\ m^{-2}$. (Smidt 1951; Tietjen 1969). No reason can be given at this time for the apparent reduction in ostracod numbers in Long Island Sound.

As for comparisons in the numbers of total meiofauna between April and September, the apparent increase in total numbers in September was primarily due to increased numbers of nematodes and polychaetes. The latter were especially abundant in September in the form of recently settled juveniles. Similar increases in the numbers of meiofaunal polychaetes in late summer have been noticed by Tietjen (1969) in two nearby estuaries in New England (the Niantic River in Connecticut and the Pettaquamscutt River in Rhode Island).

Tietjen also observed maximum abundances in nematode densities in the same two estuaries tended to occur in the summer. During the present study, the increased abundances of nematodes observed in September were most pronounced at those stations closest to shore (in the Northern and Southern regions of the Sound; Figure 5). In contrast, the stations in the Center region generally showed but a slight increase in the numbers of nematodes from April to September. The significant increase in the numbers of nematodes observed at the stations closest to shore may well have been due to seasonal changes in temperature and food composition similar to those observed by Tietjen (1969) in the Niantic and Pettaquamscutt Rivers. It is not unexpected that the variations in abundance might have been less in the Center region of the Sound, an area which is deeper and more removed from the annual disturbances in the environment which are more likely to occur in the more shallow Northern and Southern regions of the Sound. No data are available at this time on seasonal variations in the species composition of nematodes; the September 1973 samples are just beginning to be analyzed for nematode species composition.

Nematodes. In general, the samples richest in silts and clays contained the highest numbers of nematodes, independent of geographic location. However, the highest number of nematodes observed at all stations was at Station 14, a medium sand (8,100 and 11,300 per 100 cm^3 of sediment in April and September, respectively). A review of the literature shows that, while the highest population densities of

of nematodes are usually found in fine sediments (Wieser 1960, for Buzzards Bay; Rees 1940, for an intertidal mud flat; Teal and Wieser 1966, for a salt marsh), there are occasions (Tietjen 1969; Warwick and Buchanan 1970) on which sandy sediments may contain higher population densities than finer sediments. The factors which regulate the abundance of nematodes (and other meiofauna) in shallow subtidal regions like Long Island Sound are obviously too complex and interrelated to seek a single causative agent which might explain something as gross as spatial and temporal abundances. Nevertheless, it does appear that the total numbers of nematodes in Long Island Sound might be well-correlated with the amount of silt-clay present in the sediments. A step-wise regression analysis using an IBM 370 computer showed that, with total numbers as the dependent variable, a correlation with percent silt - clay was significant at the 95 % level of confidence ($r = +0.419$). The correlation of total numbers with organic carbon was even higher ($r = +0.529$, $p < .01$).

Nematode Species Composition and Diversity. More than half (141) of the 205 species of nematodes identified in April occurred at but one or two of the 26 stations chosen for the analysis of species composition. It has been suggested (Wieser 1960; Hopper and Meyers 1967; Tietjen 1969) that more species of nematodes will be found in a habitat which has a large number of ecological niches; all three authors have concluded, therefore, that the heterogeneity of the nematode fauna should increase with a decrease in the silt-clay fraction. Coarser sediments might be expected, therefore, to have a higher species diversity and lower incidence of dominance by one or a few species than sediments rich in silt-clay. Heip and Decraemer (1974) recently observed a remarkably clear correlation between nematode species diversity (H ') and sediment size (median grain size) in agreement with the expected results in the North Sea.

Results of the present study are not as clear. In the present study, diversity was lowest in sediments rich in silt-clay and increased, as expected, in medium and fine sands. However, in sediments coarser than 0.25 mm diversity decreased and, except for two unusually high values at Stations 14 and 128, diversity displayed a tendency to decrease as median grain size rose above 0.30 mm. Since the study conducted by Heip and Decraemer was in sediments finer than 0.32 mm, the results of the two studies are not directly comparable. However, it does appear that the two are in basic agreement as to the relationship between diversity and sediment size, at least up to a medium grain size of about 0.30 mm.

In the present study the diversity of nematodes was somewhat correlated with percent silt-clay ($r = -0.25$); this correlation was not significant, however, and other factors must be sought which might explain diversity. Since the environmental factors operating in the Sound may be so different from station to station (even among stations with the same sediment characteristics), it is hopeless at this time to attempt to explain the diversity as being a function of something simple like median grain size or precent silt-clay. More will be said later on this subject.

Wieser (1960) observed that, in Buzzards Bay, sandy sediments were characterized by a large number of stenotopic species, species which did not occur in finer sediments. Conversely, nearly all the species occurring in fine sediments also occurred in coarse sediments, although usually in smaller numbers. Such a faunal distribution could easily be attributed to sediment distribution, where the presence of some silt-clay in sandy sediments could provide sufficient interstitial space to permit the existence of a silt fauna, while the high amount of silt and clay in finer sediments would exclude or nearly exclude animals dependent on a sandy substratum (Wieser 1960).

The distribution of nematodes in the present study is in good agreement with the observations of Wieser in Buzzards Bay. Of the 141 species restricted in distribution to one or two stations, only 24 were restricted to muds; 45 were restricted to fine sands and 53 were found only in medium and coarse sands. Thus the coarser sediments contained many more stenotopic species than did those sediments rich in silt-clay. This was also seen in Figure 2, which illustrates that a high degree of species affinity both within habitat and between habitat was in evidence only at the stations rich in silt-clay. The high degree of affinity among the stations rich in silt-clay most probably is a result of the smaller number of niches present in finer sediments. As mentioned above, the high degree of species affinity shown among Stations 10, 26, 67 and 103 was due to the overwhelming dominance of the fauna at these stations by Thersistus problematica. It will be interesting to see if the fauna at these four stations continues to be dominated by the same or another species in September 1973.

The more common species (those occurring in at least ten of the 26 samples analyzed) were examined for distributional trends. The distributional trends of the 25 commonest species are given in Table 6. Of the 25, only nine may be taken to be indicative of certain sediment conditions in Long Island Sound. Microlaimus dimorphus, Theristus problematica and Paracanthonchus caecus displayed an affinity for sand, while Sabatieria pulchra, Terschellingia longicaudata , Theristus normandicus, Sprinia parasitifera, Neotonchus punctatus and Halichoanolaimus raritanensis preferred finer sediments. The remaining 16 species were eurytopic in their distribution.

The distributional trends of the 25 commonest species in Long Island Sound were mostly in agreement with their distributional trends in other areas where they have been found. Wieser (1960) found Terschellingia longicaudata and Sabatieria pulchra were much more abundant at the siltiest stations in Buzzards

Bay; Tietjen (1969) observed the same distributional trends for both species in the Niantic and Pettaquamscutt Rivers. Spirinia parasitifera and Halichoanolaimus raritanensis occurred in greater abundance in the finer sediments of both Long Island Sound and the estuaries studied by Tietjen; these species were not reported by Wieser as occurring in Buzzards Bay. Among the species found to be eurytopic in Long Island Sound, Tripyloidesgracilis and Dorylaimopsis metatypicus were also eurytopic in Buzzards Bay and the Niantic and Pettaquamscutt Rivers. Desmodora tenuispiculum, Neochromadora poecilosoma and Sabatieria hilarula were also eurytopic in Buzzards Bay; these species were not found by Tietjen in the Niantic and Pettaquamscutt Rivers.

Some of the species common to Long Island Sound, Buzzards Bay and the Niantic and Pettaquamscutt Rivers were also found by Warwick and Buchanan (1970) off the Northumberland coast. There the distributional trends differed somewhat from those in New England. Sabatieria celtica, eurytopic in the Niantic and Pettaquamscutt Rivers and Long Island Sound, was found in silt in Northumberland, and Sabatieria hilarula, eurytopic in New England and Long Island Sound, displayed an affinity for sand in Northumberland. There were differences noted among other species also.

It thus appears that it may be somewhat premature to consider the use of nematodes as faunal indicators, at least of sediment type. While relationships between certain species and sediment type may exist, these relationships may not be the same in all areas. Even in Long Island Sound, more data are needed to see if the distributional trends noted in April 1973 still exist.

Nematode Feeding Types. The observed distribution of feeding types in Long Island Sound conformed very well to the expected distribution. Deposit feeders were the dominant form, especially in fine sediments, whereas epigrowth feeders tended to

attain their maximum abundances in coarser sediments. The results of the present study agreed well those of Wieser (1959, 1960), Tietjen (1969), Coull (1970), Warwick and Buchanan (1970) and others; nothing more need be said.

SUMMARY

In summary, it can be said that the meiofauna of Long Island Sound appears to be quite typical of that occurring in subtidal areas both nearby (Buzzards Bay) and quite distant (North Sea). The population densities and spatial distributions of most of the taxa found conformed very well to what was expected.

Nematodes were the dominat taxon, and their species composition and diversity were studied in detail. Of particular interest was the relationship, if any between species composition, diversity and "pollution," an index of the latter being the heavy metal concentration in the sediments. On the basis of this study, it appears that nematode species diversity is not indicative of pollution, at least of heavy metal pollution. Step-wise regression analyses showed that there no significant differences in diversity (H ') which could be attributed either to heavy metal concentration or geographic position in the Sound. Median diversity was lowest in fine sediments; it was higher in muddy sands and fine sands and then decreased again in sediments coarser than 0.30 mm. Within each sediment type, there were no differences in diversity between those sediments having high heavy metal concentrations and those with low heavy metal concentrations. The range in diversity, both within a given sedimentary habitat and among different habitats makes its use as an indicator of pollution, at least for the present, impossible in Long Island Sound. It appears that sediment size, rather than heavy metal concentration or organic carbon content may play the dominant role in the regulation of nematode species diversity in Long Island Sound. In finer sediments,

the restricted number of niches available to the nematodes will keep diversity low. Diversity may then increase in muddy sands and fine sands as a function of increased habitat heterogeneity in these sediments, as long as these sediments (which tend to be somewhat more unstable than the finer sediments) are not too difficult for most species to colonize. As the sediments become coarser, diversity may again decrease because fewer species can survive in these high energy environments. This is the pattern of diversity observed among the nematodes in Long Island Sound, and it is not inconsistent with the Stability-Time Hypothesis of Sanders (1969).

In Long Island Sound, particular attention must be paid to local environmental conditions, however, since the factors controlling the distribution and abundance of nematodes (and other meiofauna also) are so variable from place to place.

REFERENCES

Coull, B.C. 1970. Shallow water meiobenthos of the Bermuda Platform. Oecologia, 4: 325-357.

Gross, M.G., Black, J.A., Kalin, R.J., Schramel, J.R. and R.N. Smith. 1971. Survey of marine waste deposits, New York Metropolitan Region. Tech. Rep. No. 8, Mar. Sci. Res. Ctr., State Univ. of New York, Stony Brook. 71 pp.

Heip, C. and W. Decraemer. 1974. The diversity of nematode communities in the southern North Sea. J. mar. biol. Ass. U.K., 54: 251-255.

Hopper, B.E. and S.P. Meyers. 1967. Population studies on benthic nematodes within a subtropical seagrass community. Mar. Biol., 1: 85-96.

Lloyd, M. and R.J. Ghelardi. 1964. A table for calculating the "equitability" component of species diversity. J. Anim. Ecol., 33: 217-225.

Marcotte, B.M. and B.C. Coull. 1974. Pollution, diversity and meiobenthic communities in the North Adriatic (Bay of Piran, Yugoslavia). Vie et Milieu. (In Press).

Margalef, R. 1958. Information theory in ecology. Gen. Syst., 3: 36-71.

McIntyre, A.D. 1964. Meiobenthos of sub-littoral muds. J. mar. biol. Ass. U.K., 44: 665-674.

McIntyre, A.D. 1969. Ecology of marine meiobenthos. Biol. Rev., 44: 245-290.

McIntyre, A.D. and D.J. Murison. 1973. The meiofauna of a flatfish nursery ground. J. mar. biol. Ass. U.K., 53: 93-118.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. J. theor. Biol., 13: 131-144.

Rees, C.B. 1940. A preliminary study of the ecology of a mud flat. J. mar. biol. Ass. U.K., 24: 185-199.

Sanders, H.L. 1960. Benthic studies in Buzzards Bay. III. The structure of the soft bottom community. Limnol. Oceanogr., 5: 138-153.

Sanders, H.L. 1969. Benthic marine diversity and the stability-time hypothesis. Brookhaven Symp. Biol., 22: 71-81.

Smidt, E.L.B. 1951. Animal production in the Danish Waddensea. Medd. Komm. Dann. Fiskeri-og. Havunders., 11 (6). 151 pp.

Teal, J.M. and W. Wieser. 1966. The distribution and ecology of nematodes in a Georgia salt marsh. Limnol. Oceanogr., 11: 217-222.

Tietjen, J.H. 1969. The ecology of shallow water meiofauna in two New England estuaries. Oecologia, 2: 251-291.

Warwick, R.M. and J.B. Buchanan. 1970. The meiofauna off the coast of Northumberland. I. The structure of the nematode population. J. mar. biol. Ass. U.K., 50: 129-146.

Wieser, W. 1953. Die Beziehung zwischen Mundhohlengestalt, Ernahrungsweise und Verkommen bei freilebende marinen Nematoden. Ark. Zool., 4: 439-484.

Wieser, W. 1959. Free-living marine nematodes. IV. General Part. Chile Reports 34. Lunds Univ. Arsskr., N.F. Avd. 55 (5). 109 pp.

Wieser, W. 1960. Benthic studies in Buzzards Bay. II. The meiofauna. Limnol. Oceanogr., 5: 121-137.

Table 1. Median grain size, percent silt-clay (by weight) and total heavy metal* concentration (ppm, dry weight basis) for the stations in Long Island Sound at which nematode species composition was analyzed

Station	Median grain size (mm)	Percent silt-clay	Metal Concentration
2	0.007	86.5	736.84
5	0.024	67.9	1074.96
7	0.026	67.4	744.40
8	0.011	83.2	1184.10
10	0.335	2.1	1166.47
11	0.355	2.1	447.30
13	0.015	78.3	778.70
23	0.708	1.1	188.10
25	0.391	9.5	604.60
26	0.609	0.4	469.60
32	0.089	42.1	99.40
35	0.014	90.3	1104.10
37	0.373	0.6	23.50
61	0.018	87.9	143.70
63	0.020	85.1	550.50
67	0.359	4.9	20.15
82	0.024	83.2	471.00
86	0.077	40.3	253.30
90	0.166	4.1	107.90
100	0.103	21.2	580.70
103	0.253	2.0	67.00
105	0.137	12.7	137.60
126	0.138	8.7	137.60
128	0.542	6.0	216.70
130	0.241	0.4	90.20

* Includes Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn

Table 2. Numbers of meiofauna per 100 cm^3 of sediment at 41 stations in Long Island Sound, April 1973.

Meiofauna Group	STATION 2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	23	25	26
Foraminifera	8		2	21			36			1					13		11		
Ciliata		13	6	10		15			7	1		5	2						2
Nemertinea		4			3			3				3		5	2	3		96	
Nematoda	6755	3318	4188	2980	1500	3354	646	3110	740	575	1048	8100	246	1700	414	126	382	423	53
Kinorhyncha			7			11				1				1	4				
Gastrotricha				7													3		6
Turbellaria																			
Polychaeta	64	680	149	11		67		58	10	2		10	5	9	17		8	10	
Harpacticoida	585	13	172			15	3	6	3			50	22	15	18	41	97	4	765
Ostracoda			27			2						5	3		7				
Amphipoda	4																		
Other Crustacea*																			
Nauplii	59	4	26	3	8	7		3			6	25		3		3	2	2	775
Halicarids													1						
Lamellibranchiata	5		3						3										
Gastropoda																			
Tardigrada																			
Total Meiofauna	7480	4032	4580	3032	1511	3471	685	3180	753	580	1054	8298	279	1733	475	182	503	525	1601

* Cumacea and Tanaidia

32	35	37	44	45	47	49	61	63	67	82	86	90	100	103	105	114	117	120	126	128	130
	2		760									11						6			6
		91																		9	
			21	2	2							60			5	11				118	
2961	960	332	2600	1410	1110	117	3942	3670	654	2000	1300	2278	2153	538	1011	2015	212	823	2970	589	418
7	2						6	7		5											
2									5	4											22
				1	10		44	2		6		27			4			7			
20		4			11			11	19	20		9	13		2	54	15	26		17	
37	52	23	17		7	23	46	47	13	490	5		2	162		119	50	55	10	50	57
13	5	9	26		2		7	8							2						
		3					1														
37	52	22	17			14	32			18		2		10	1						
	1	2																			
	4		5				13			7					7	14				6	
																				1	
		1																			
3042	1028	468	3457	1413	1142	154	4089	3745	691	2550	1305	2367	2168	710	1032	2213	277	917	2980	790	503

Table 3. Numbers of meiofauna per 100 cm^3 of sediment at 40 stations in Long Island Sound, Sept. 1973

Meiofauna Group	2	4	5	6	7	8	9	10	11	12	13	14	15	17	18	23	25	26
Foraminifera		4	36		2	670		31		24			3	10		6	27	
Ciliata	19		8	99			2	209				133	56		57	31		62
Nemertinea	24		4	53				3	32									
Nematodes	3640	5015	4128	2218	539	6500	1568	2620	2763	840	576	11300	2571	485	3418	3978	905	3000
Kinorhyncha		3	7			9			13			15	15					
Gastrotricha								14							84			78
Turbellaria															12			
Polychaeta	225	82	24	80		371		43	604	28		241	96	5	60	48		19
Harpacticoidea				612				2	194			18	326	8	48	36		37
Ostracoda												7	4	3		5		
Amphipoda		9		13					9			13						
Nauplii				27							3		4			1		
Halicarids			4	3	1	3							26					
Lamellibranchiata				2								6	41		1		15	31
Gastropoda																		
Hydromoa																		
Cumacea																		
Total Meiofauna	3908	5113	4211	3107	542	7553	1570	2927	3615	892	579	11733	3242	511	3680	4105	949	3227

32	35	37	44	45	47	49	61	63	67	82	86	90	100	103	105	114	117	120	126	128	130
		3	37	22	1		9	9			3				10		2	33	2		21
37		42	1				39	3	67			55		15							5
		1	3	2	9	1		40				5		1	8	32			1	218	47
7754	836	1686	9638	2609	2134	200	1141	2436	1727	3080	1160	1858	2000	1210	1334	3461	202	1110	3650	277	383
17	1	2			16	2		26	3	7						1					
		4																27		11	32
																				1	
1910	43	104	2310	835	196	3	32	66	6	525	90	28	191		50	59	12	37		18	11
184	47	1892	23	41	61	4	13	63	37	100		51	204	37	34	177	353	47	10	4	96
100		35				7		5	6							3				1	
		1			1					21			11								
2		43			3		1		1								15				
3					13		2	1				3									2
8	1	73		45	35		8	29	14	2		50				20	1	14			
					1																
								3													
															1						
10015	928	3886	12012	3554	2470	217	1245	2681	1921	3735	1253	2000	2406	1263	1437	3753	585	1269	3663	630	597

Table 4. Mean population densities of total meiofauna (number of individuals per 100 cm^3 of sediment) in various regions of Long Island Sound, April and September 1973

Region (see text)	April	September
New York	3490	3624
Western	1881	2961
Central	1963	3532
Eastern	1291	1732
Northern	1874	4392
Center	1271	1761
Southern	1703	2992

Table 5. Relative abundance of nematode species in L I S in April, 1973

Species	Feeding Type	Station 2	5	7	8	10	11	13	14	23	25	26	32
Sabatieria pulchra G. Scheider	1B	46.2	19.9	60.0	59.0	2.1		4.1	2.0		1.3		3.2
Theristus setosus Butschli	1B	2.8	3.3										
Terschellingia longicaudata De Man	1A	7.6	9.2	8.5	16.5			40.3					5.2
Tripyloides gracilis Ditlevsen	1B	15.9	4.0		0.8	5.0	0.7		5.4	4.5			
Oncholaimus paralangrunensis Allgen	2B	1.4	0.7				2.2			9.1			
Anticoma litoris Chitwood	1A	4.1				1.4							
Euchromadora gaulica Inglis	2A	0.7				1.4				3.6	1.3		
Halichoanolaimus raritanensis Hasbrouck	2B	1.4											
Odontophora armata Ditlevsen	1B	1.4					35.2	40.3	18.5		14.7		9.7
Sabatieria hilarula De Man	1B	6.9				1.4	0.7		1.4				5.2
Chromadorina cervix Wieser	2A	1.4											
Spirinia parasitifera Cobb	2A	2.8		11.4	0.8	5.7			13.7				0.6
Desmodorella cephalata Cobb	2A	0.7	1.3			1.4				2.7			6.5
Anonolaimus arcuatus Stekhoven	1B	1.4	14.6			1.4							
Dorylaimopsis metatypicus Chitwood	2A	1.4	1.3			3.5			1.4		16.0		
Latronema sp.	2B	0.7											
Metalinhomoeus typicus De Man	2A	0.7											

35	37	61	63	67	82	86	90	100	103	105	126	128	130
6.4		26.8	4.3	2.2	64.0		0.7	17.2		1.3			
	14.6	7.0			1.9					1.9			
45.8		3.0	26.6			3.1		0.7		1.3			
	2.7												
			2.2										2.3
0.6					0.6						0.7		
								0.7			1.4		1.1
		1.0	0.7		0.6			5.0		1.3			
		14.6	10.0				1.5	0.7		1.3			
1.1		10.6	7.2				3.0	0.7					
		3.5			3.2	1.0		4.3					
		1.5	1.4	0.7			6.7	2.1		2.5	0.7		
		1.0	2.9			1.0	2.2	18.6		11.5	1.4	4.0	
											0.8		
			6.5		0.6			1.4					

Species	Feeding Type	Station 2	5	7	8	10	11	13	14	23	25	26	32
Leptolaimus setiger DeConinck & Stekhoven	1B	0.7											
Monhystera filicaudata Allgen	1B	0.7									8.0		0.6
Unidentified Monhysteridae A	1B	0.7											
Cervonema tenuicauda Stekhoven	1B		3.3			0.7			7.5		1.3		1.9
Desmoscolex americanus Chitwood	1B		1.3	17.1									
Odontophora setosoides Timm	1B		4.0				3.0		0.7			5.8	
Hypodontolaimus setosus Butschli	2A		0.7								1.3		
Paracanthonchus caecus Bastian	2A		4.6			0.7	0.7		3.4	0.9			
Theristus problematica Allgen	1B		2.6			41.9				1.8		70.5	
Mononcholaimus conicaudatus Allgen	2B		0.7										
Odontophora setosa Allgen	1B		11.9		5.8					8.2			
Theristus normandicus De Man	1B		8.6		12.4			1.0	2.0		8.0		0.6
Monhystera sp.	1B		0.7										
Neochromadora poecilosoma De Man	2A		1.4				1.5		1.4		1.3		
Chromadorina epidemos Wieser & Hopper	2A		2.0								5.8		0.6
Halalaimus caroliniensis Chitwood	1A		0.7						0.8				
Eleutherolaimus stenosoma De Man	1B		1.3										
Odontophora variabilis Wieser & Hopper	1B		1.3		1.6						11.1		

35	37	61	63	67	82	86	90	100	103	105	126	128	130
			1.4										
2.1								2.1		1.9			
2													
4.2											0.7		
		0.5			0.6			2.1		0.6		0.8	1.1
									2.2	0.6			
			2.2						1.0			1.5	
				38.9		3.1			48.4			5.5	6.9
										2.6	0.7		
2.1			2.9		6.4		1.5	0.7		1.3			1.1
	1.3	0.5		4.3								1.5	1.1
		2.0			0.6			2.1			0.7		
										0.6			
							1.5						
2.1			0.7								2.1	0.8	

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Microlaimus dimorphus Chitwood	2A				1.6	4.3	3.0		6.8	3.6	1.3	5.8	12.6
Monoposthia mirabilis Schultz	2A				0.8	4.2							
Microlaimus sp. 1	1B				0.8	1.4	2.2		2.0		2.7		23.8
Theristus horridus Steiner	1B					3.5			0.7				
Prochromadorella neapolitana De Man	2A					7.1	0.7		7.3	1.8			
Viscosia carnlayensis Ditlevsen	2B					1.4				1.8	4.0		
Oncholaimus dujardinii De Man	2B					1.4				3.6			
Marilynia quadriseta Wieser	2A					1.4							
Canacolaimus prytherci Chitwood	2A			2.8		2.1	1.5						
Halalaimus striatus Gerlach	1A					0.7							
Parodontophora brevamphidia Timm	1B					2.6							
Polygastrophora hexabulba Filipjev	2B					0.7			1.4				
Axonolaimus hexapilus Wieser & Hopper	1B						5.2		0.8		1.3		
Sabatieria celtica Southern	1B						0.7				1.3		0.6
Promonhystera proteus Wieser	1B						17.9	1.0	6.2				
Halalaimus meyersi Wieser & Hopper	1A						0.7						
Campylaimus inequalis Cobb	1B						2.2						
Theristus bütschli Bresslau & Stekhoven	1B						2.2						

35	37	61	63	67	82	86	90	100	103	105	126	128	130
2.1	19.3		2.9		1.3	6.2	3.7	2.1	1.0	1.9	2.9	1.5	3.4
	2.7			0.7							0.7		1.1
3.2	9.3	18.2	1.4							1.9			
							0.7	2.1					
1.1										1.9	1.4		
	2.7												
					0.6					0.6			
						1.0		1.4		1.3			
		0.5											
5.3		1.5			0.6					3.8	4.3		
						3.1	36.6						
			2.2			3.1		0.7		0.6			

Species	Feeding Type	Station 2	5	7	8	10	11	13	14	23	25	26	32
Desmodora quadripapillata Daday	2A						3.0						0.6
Eumorpholaimus chesapeakensis Timm	1B						0.7						
Comesoma minimum Chitwood	1B						1.5			1.8			3.2
Metachromadora onyxoides Chitwood	2A						0.7						
Metonyx horridus Chitwood	2A						0.7				1.3		
Chromaspirina pontica Filipjev	1B						1.5		2.7		2.7		
Paracomesoma hexasetosum Chitwood	1B						1.5						0.6
Neotonchus punctatus Cobb	2A							13.4		0.9	4.0		
Theristus rusticus Kreis	1B								2.0				
Sabatieria sp.	1B								1.4				
Microlaimus texianus Chitwood	2A								6.8				
Mononcholaimus labiatus Kreis	2B								1.4				
Chromadora sp.											2.7		
Paralinhomoeus lepturus De Man	1B												
Metalinhomoeus effilatus Stekhoven	2A										1.3		
Paralinhomoeus strigosus Wieser											5.3		
Monhystera parva Bastian	1B										1.3		
Terschellingia paxi Schneider	1A										2.7		

35	37	61	63	67	82	86	90	100	103	105	126	128	130
4.3	4.0			2.2	1.3		11.2				1.4		
							1.5				1.4		
		0.5			5.8			4.3			21.5	1.1	
		0.5	5.8							0.6	1.4		
1.1							2.2	0.7		1.3			
3.2		0.5	1.4		2.6	1.0		5.0					
3.2						4.1				14.1	1.4	4.8	
													0.8
			1.4		2.6						0.7	3.1	2.3
1.1													
											0.7		
			0.7								0.7		
			0.7										

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Paralongicyatholaimus zosterae Allgen	2A										1.3		
Linhomoeus sp. 1	1B										1.3		
Unidentified Linhomoeidae A	1B												
Odontophora angustilaimus Filipjev	1B												13.5
Theristus (Cylindrotheristus) sp. 1	1B												3.2
*Proonchola*imus *aransas* Chitwood	2B												1.3
Gonpionema fellator Wieser & Hopper	2B												2.6
Sphaerolaimus balticus G. Scheider	2B												0.6
Metalinhomoeus retrosetosus Wieser	2A												0.6
Unidentified I	1B												0.6
Axonolaimus steineri Timm	1B												3.2
Microlaimus kaurli Wieser	2A												1.3
Microlaimus sp. 2	2A												
Microlaimus gerlachi Wieser	2A												
Diplopelta incisus Southern													
Leptolaimus elegans Stekhoven & DeConinck	1B												
Oxystomatina alpha Chitwood	1A												
Halanonchus sp.	1B												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
2.1								2.2					
							0.7						
1.1		0.5	1.4	1.4	2.6	1.0		1.4	1.4	1.3		0.8	
1.1	6.6					1.0							
							3.0					1.5	
2.1													
1.1	1.3												
1.1											0.7		
1.1													
						2.1							
							3.7						

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Enoplolaimus sp.	1B												
Rhips ornata Cobb	2A												
Didelta sp.	1B												
Chromadorella filiformis Bastian	2A												
Ptycholaimellus ponticus Filipjev	2A												
Eurystomina sp.	2B												
Choniolaimus sp.	2A												
Monhystera sp. 2	1B												
Hypodontolaimus schuurmans-stekhoveni Gerlach	2A												
Phanoderma sp.	1A												
Sabatieria effilata Stekhoven	1B									3.6			
Gammanema sp.	2B												
Unidentified II	1B												
Aegialolaimus elegans De Man	1B												
Theristus acrilibiatus DeConinck & Stekhoven	1B									5.5			
Theristus (*Daptonema*) sp.	1B												
Halalaimus scleratus Timm	1A												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
							0.7						
							2.2						
							0.7						
							0.7					0.8	
											4.3	1.1	
							0.7						
							0.7						
							0.7						
							0.7		1.0				
							1.5				10.0		
							0.7				1.4		
							0.7						
								0.7					
								4.3					
								2.1		6.4	1.4		
								0.7					
								2.1		3.2	2.1	0.8	

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Pomponema tautraense Allgen	2A												
Sabatieria longiseta Kreis	1B												
Diplopeltula striata Gerlach	1B												
Oxystomatina elongata Cobb	1A												
Desmodora sp.	2A												
Linhomoeus sp. 2	1B												
Theristus galeatus Wieser & Hopper	1B												
Metoncholaimus scissus Wieser & Hopper	2B												
Halalaimus parvus Chitwood	1A												
Metacyatholaimus spatiosus Wieser	2A												
Amphimonhystera sp. 2	1B												
Monhystera chesapeakensis Timm	1B												
Rhynchonema cinctum Cobb	1B												
Richtersia beauforti Chitwood	2A												
Chromadorita leukarti De Man	2A												
Rhadinema flexile Cobb	2A												
Oncholaimoides rugosum Chitwood	2B												
Mononcholaimus separabilis Wieser	2B												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
								2.1					8.1
								4.3		2.6			
								0.7					
								0.7					
								0.7					
								0.7	1.0			0.8	
									2.1		0.7		
									5.2				
									3.1				
									3.1			4.0	
									1.0				
									1.0				
									9.3				3.4
										0.6		0.8	
										0.6			
										0.6			
										1.9			
										3.2	2.9		

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Tarvaia sp. 1	1B												
Oxystomatina oxycaudata Ditlevsen	1A												
Oncholaimoides striatum Chitwood	2B									1.8			
Comesoma sp.	1B												
Paralinhomoeus brevicaudatus Stekhoven	1B												
Cyatholaimus sp.	2A												
Ceramonema reticulatum Chitwood	1B												
Gonionchus sp.	2A												
Cobbia trefusiaeformis De Man	2A												
Axonolaimus sp. 1	1B												
Sabatieria anucaudiana Wieser	1B												
Cylindrotheristus sp. 2	1B												
Bathylaimus capacosus Hopper	1B									43.6			
Metachromadora obesa Chitwood	2A											5.8	
Penzanica sp.	1B												
Paramicrolaimus sp.	1B												
Disconema sp.	1B												
Euchromadora pectinata Wieser & Hopper	2A												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
										0.6			
										1.3	0.7		
										1.3			
										1.9			
										1.9			
										0.6			
										0.6			
										0.6			
	1.3												
	1.3						0.7						
	1.3										14.3		
	1.3												
	1.3										0.7		
	9.3												
	8.0												
	2.7												
	1.3												
	1.3												

Species	Feeding Type	Station											
		4	5	7	8	10	11	13	14	23	25	26	32
Metoncholaimus simplex Wieser & Hopper	2B												
Monhystera parelegantula DeConinck	1B												
Xyala striata Cobb	2A											5.8	
Carcharodorita guidoschneiderei Filipjev	2A												
Pelagonemella sp.	1B												
Oncholaimus viridis Bastian	2B												
Mesacanthion sp. 1	2B												
Unidentified Monhysteridae B	1B												
Paralinhomoeus sp. 1	1B												
Mononcholaimus papillatus Kreis	2B												
Mesacanthion conicus Filipjev	2B												
Pselionema heralatum Chitwood	1B												
Amphimonhystera sp. 1	1B												
Tricoma adelpha Greef	1B												
Axonolaimus demani DeConinck & Stekhoven	1B												
Diploeltula sp. 1	1B												
Paratripyloides longicaudata Stekhoven	1B												
Laimella longicauda Cobb	2A												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
	2.7												
	2.7												
	1.3			0.7		1.0			13.4			3.1	19.6
	1.3				0.6							4.8	
	1.3	5.0					1.5	3.6			2.9		
		1.0											
		0.5											
		0.5				21.7			2.1	2.6	1.4	7.1	1.1
		0.5											
		0.5											
			5.0										
			1.4			1.0						7.9	1.1
			0.7										
			1.4			1.0							
			1.4				2.2						
			0.7										
			1.4									1.5	

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Unidentified Linhomoeidae B	1B												
Paramicrolaimus lunatus Wieser & Hopper	2A												
Axonolaimus interrogativus Wieser	1B												
Terschellingia communis De Man	1A												
Symonema obtusicaudatus De Man	1B												
Eurystomina minutisculae Chitwood	2B												
Microlaimus sp. 3	2A												
Metalinhomoeus filicaudatus Allgen	2A												
Halalaimus alatus Timm	1A												
Trefusia sp.	1A												
Theristus sp. 1	1B												
Paralinhomoeus buculentus Wieser	1B												
Monhystera microphthalma De Man	1B									0.9			
Halalaimus supercirrhatus Gerlach	1A												
Campylaimus mirus Gerlach	1B												
Axonolaimus typicus De Man	1B												
Leptolaimus sp.	1B												
Halalaimus longicollis Allgen	1B												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
			0.7										
				49.6									
				0.7									
					1.3								
					0.6								
					0.6					1.3			
						1.0							
						3.1							
						5.2						4.8	
						5.2	0.7						
						4.1							
						6.2				1.9			
						1.0		1.4		9.0		1.5	
						1.0	0.7						
						2.1					1.4		
											2.2		
											2.1		
											2.9	1.5	

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Thalassoalaimus sp.	1A												
Leptolaimus papilliger De Man	1B												
Microlaimus sp. 4	2A												
Tricoma sp.	1B												
Barbonema horridum Gerlach	2B												
Diplopetula nuda Gerlach	1B												
Diplopetula longiceps Gerlach	1B												
Wieseria pica Gerlach	1A												
Tarvaia donsi Allgen	1B												
Pselionema rigidum Chitwood	1B												
Mesacanthion sp. 2	2B												
Tarvaia sp. 2	1B												
Microlaimus sp. 5	2A												
Campylaimus sp.	1B												
Tricoma cylindricauda Chitwood	1B												
Dasynemella phalangida Chitwood	2A												
Prochromadorella sp.	2A												
Leptolaimus sp.	1B												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
											1.4		1.1
											1.4		
											1.4		
												0.8	
												2.3	
												3.1	
												0.8	
												2.3	
												2.3	
												0.8	
												0.8	10.3
												0.8	
												6.3	
												0.8	
												0.8	
												0.8	1.1
												4.8	
												3.2	

Species	Feeding Type	Station											
		2	5	7	8	10	11	13	14	23	25	26	32
Diplopeltula sp. 2	1B												
Oxystomatina sp.	1A												
Theristus (Cylindrotheristus) sp. 3	1B												
Paramicrolaimus sp.	2A												
Amphimonhystera anechma Southern	1B												
Stephenolaimus sp.	2A												
Odontophora axonolaimoides Timm	1B												
Neotonchus sp.	2A												
Tricoma absidata Timm	1B												

35	37	61	63	67	82	86	90	100	103	105	126	128	130
												0.8	
													4.6
													1.1
													11.5
													4.6
													3.4
													3.4
													1.1
													1.1

Table 6. Distributional trends exhibited by the 25 commonest species of nematodes in Long Island Sound, April 1973

Eurytopic	Affinity for sand	Affinity for mud
Odontophora armata	Paracanthonchus caecus	Halichoanolaimus raritanensis
Tripyloides gracilis	Microlaimus dimorphus	Sabatieria pulchra
Microlaimus sp 1	Theristus problematica	Terschellingia longicaudata
Sphaerolaimus balticus		Theristus normandicus
Prochromadorella neapolitina		Spirinia parasitifera
Desmoscolex americanus		Neotonchus punctatus
Sabatieria celtica		
Euchromadora gaulica		
Cervonema tenuicauda		
Desmodora tenuispiculum		
Dorylaimopsis metatypicus		
Neochromadora poecilosoma		
Desmodora quadripapillata		
Xyala striata		
Monoposthia mirabilis		
Sabatieria hilarula		

FIGURE LEGENDS

Figure 1. Map of Long Island Sound, showing the station locations and division of the Sound into New York City, Western, Central and Eastern Regions

Figure 2. Trellis diagram for the 26 stations selected for analysis of nematode species composition, April 1973, showing the degree of faunal affinity among the nematodes

Figure 3. Distribution of nematode feeding types in the five major sedimentary habitats, April 1973

Figure 4. Ranges and medians of nematode population density (numbers of individuals per 100 cm^3 of sediment), species diversity (H '), species richness (SR), and evenness (J) in the five major sedimentary habitats, April 1973

Figure 5. Population densities of nematodes (number of individuals per 100 cm^3 of sediment) in April (first bar) and September (second bar) 1973 at the 41 stations in Long Island Sound selected for meiofauna analysis

FIGURE 1

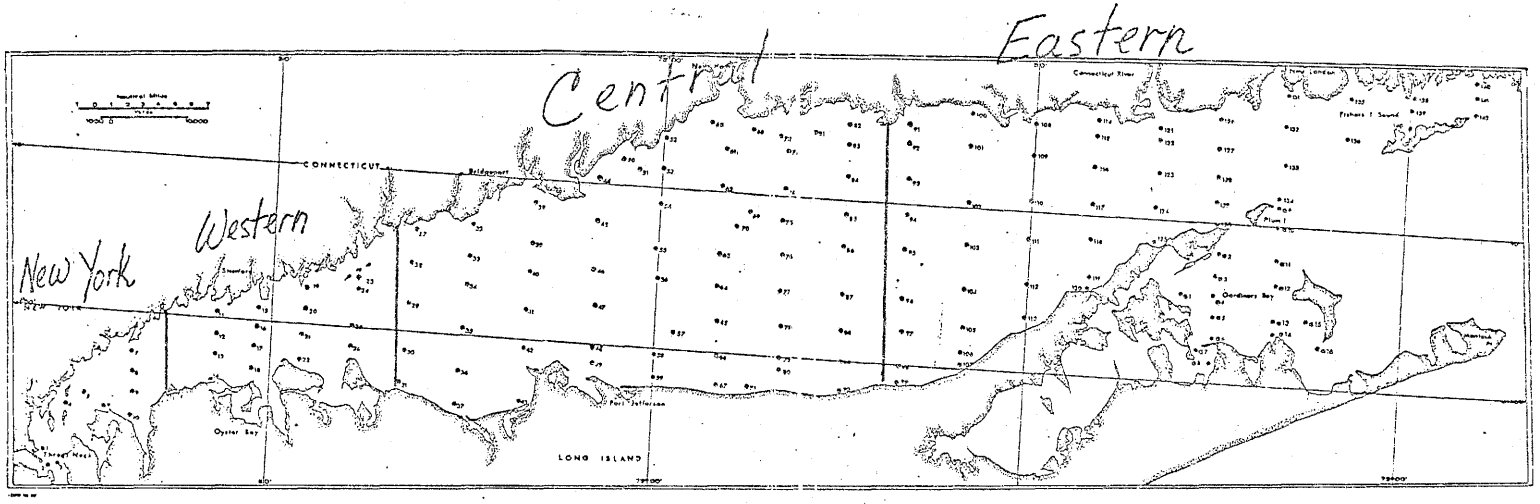

Eastern
Central
Western
New York
CONNECTICUT
LONG ISLAND
Oyster Bay
Port Jefferson
Connecticut River
Fishers I. Sound
Gardiners Bay

FIGURE 2

		2	5	7	8	13	35	61	63	82	32	86	00	90	105	126	130	10	11	14	25	37	67	103	23	26	128
Mud	2	X	38	57	55	13	16	46	26	53	17	5	27	7	10	4	2	17	5	17	6	6	3	10	7	0	2
	5		X	30	46	14	22	31	23	30	13	7	24	7	13	6	7	14	8	22	15	7	7	4	17	6	8
	7			X	68	11	15	34	13	64	9	5	21	1	4	0	1	10	2	14	1	0	3	0	0	0	1
	8				X	22	29	31	27	68	12	6	21	4	9	5	5	7	3	9	13	4	3	1	8	2	2
	13					X	49	22	43	8	19	5	11	4	5	0	1	15	36	26	21	0	2	11	1	0	0
	35						X	16	41	16	24	11	18	13	11	13	2	9	10	19	17	12	5	1	4	2	6
	61							X	30	35	43	6	35	9	15	8	2	11	21	28	22	17	4	1	2	2	3
	63								X	14	30	13	19	15	16	8	9	13	23	30	26	4	4	1	8	3	12
	82									X	8	4	26	5	11	10	2	8	4	12	8	5	5	1	2	2	7
Muddy Sand	32										X	12	13	21	13	6	4	12	25	29	18	26	4	1	5	6	4
	86											X	10	9	16	8	10	10	9	14	3	8	5	7	7	10	25
	100												X	12	35	11	4	18	9	15	27	2	4	2	8	4	11
Fine Sand	90													X	11	12	4	10	34	18	7	8	5	2	4	4	6
	105														X	20	5	13	13	16	23	6	3	4	18	2	17
	126															X	8	10	9	11	12	7	3	3	9	4	12
	130																X	12	6	8	5	6	9	26	9	16	18
Medium Sand	10																	X	10	33	11	12	42	44	18	46	12
	11																		X	44	24	10	4	10	24	6	4
	14																			X	30	14	4	2	12	7	12
	25																				X	8	3	2	5	1	5
	37																					X	3	2	7	7	5
	67																						X	40	2	40	8
	103																							X	4	49	17
Coarse Sand	23																								X	5	5
	26																									X	10
	128																										X

< 10 % 10 - 25 % 26 - 40 % > 40 %

FIGURE 3

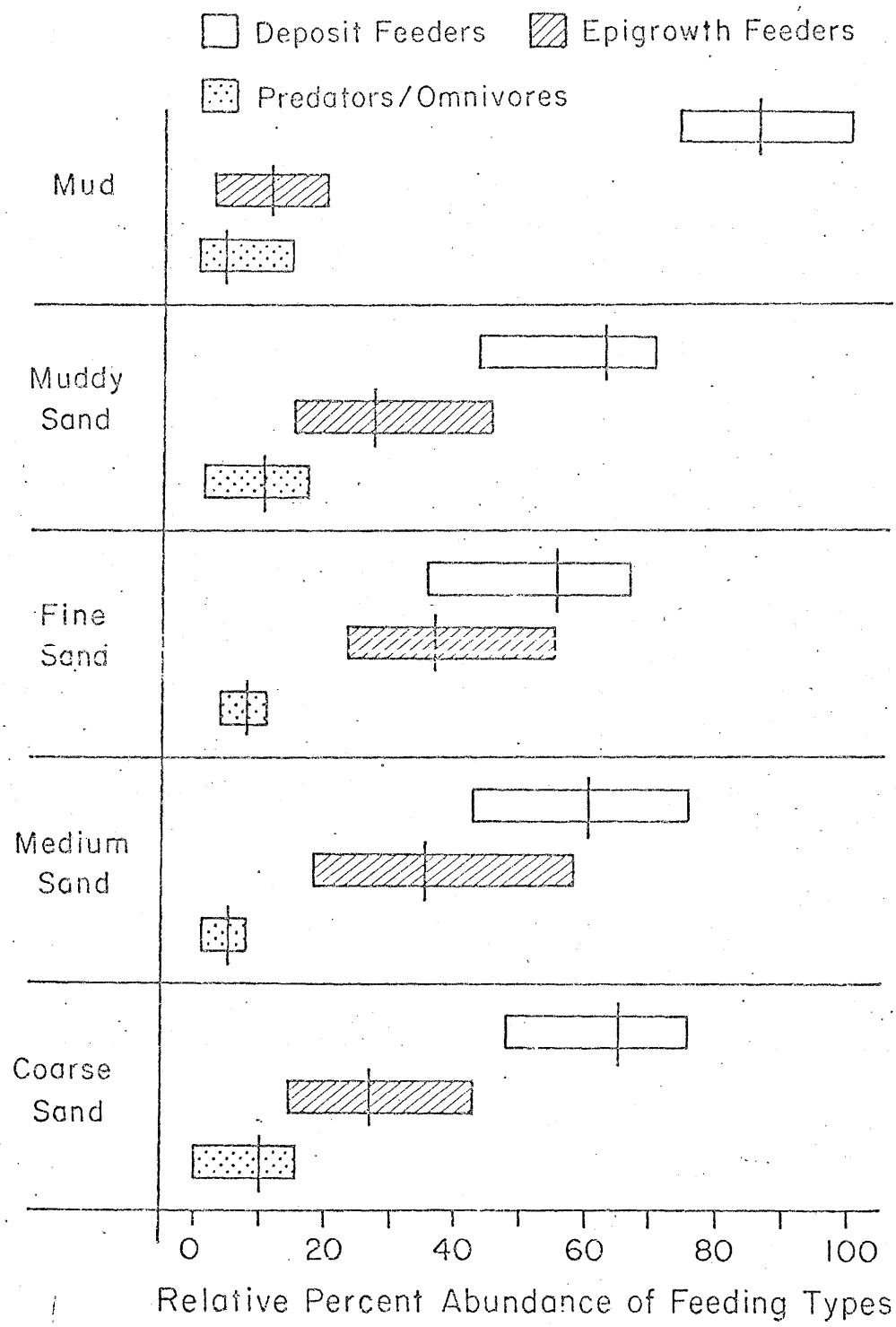

Deposit Feeders
Epigrowth Feeders
Predators/Omnivores
Mud
Muddy Sand
Fine Sand
Medium Sand
Coarse Sand
0
20
40
60
80
100
Relative Percent Abundance of Feeding Types

FIGURE 4

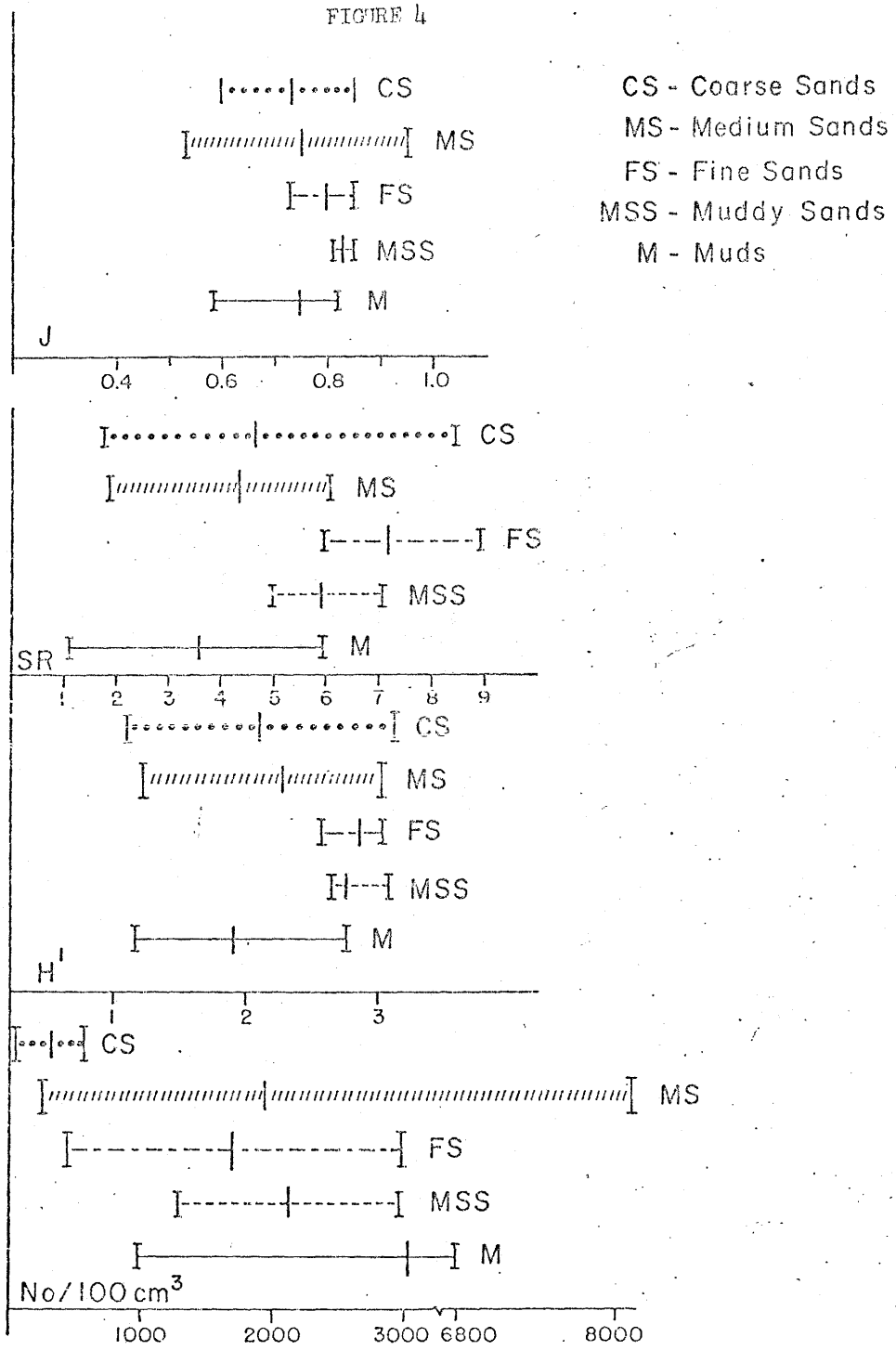
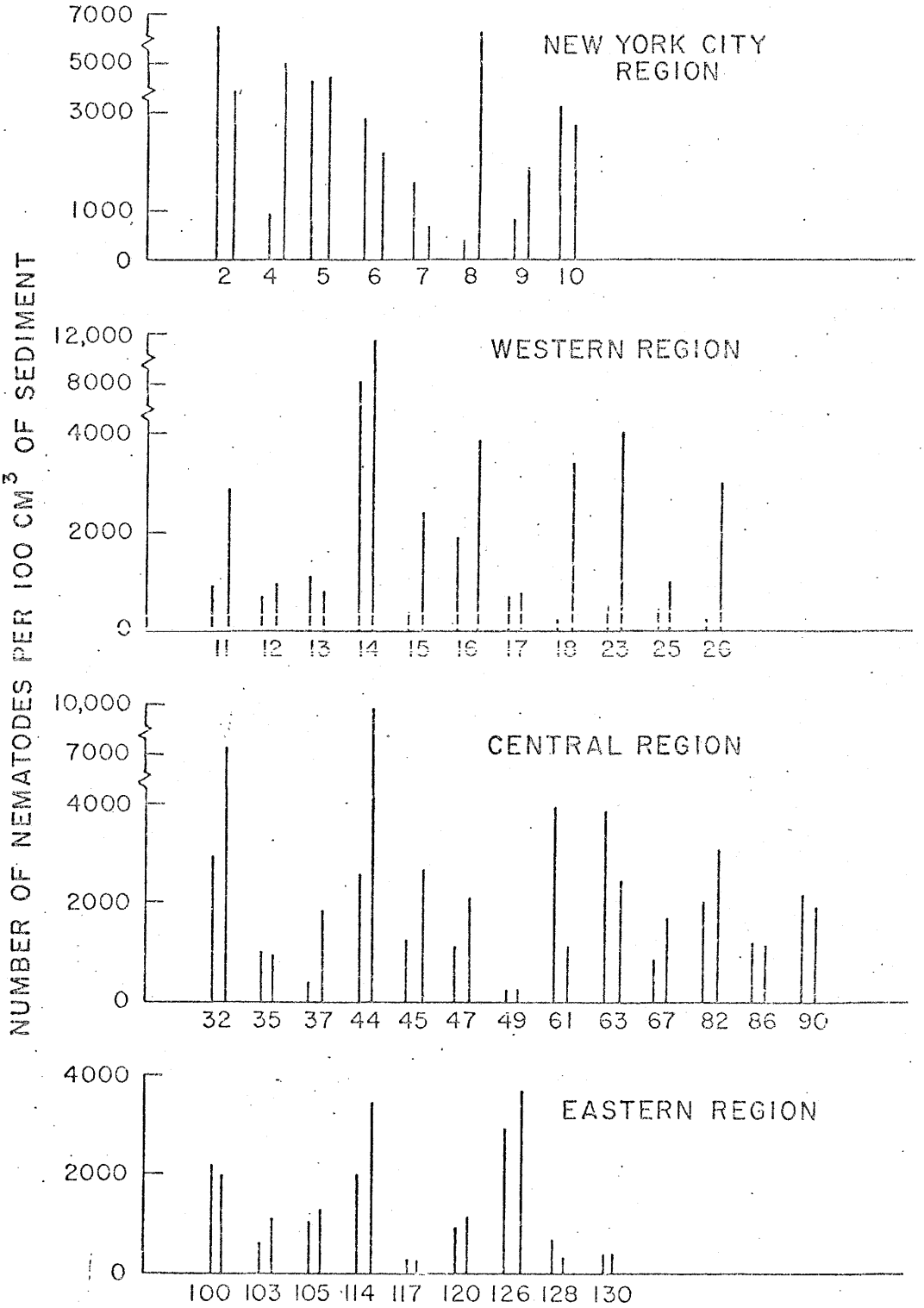

CS - Coarse Sands
MS - Medium Sands
FS - Fine Sands
MSS - Muddy Sands
M - Muds
CS
MS
FS
MSS
M
J
0.4
0.6
0.8
1.0
CS
MS
FS
MSS
M
SR
1
2
3
4
5
6
7
8
9
CS
MS
FS
MSS
M
H'
1
2
3
CS
MS
FS
MSS
M
No/100 cm3
1000
2000
3000
6800
8000

FIGURE 5


NUMBER OF NEMATODES PER 100 CM³ OF SEDIMENT
NEW YORK CITY REGION
7000
5000
3000
1000
0
2 4 5 6 7 8 9 10
WESTERN REGION
12,000
8000
4000
2000
0
11 12 13 14 15 16 17 18 23 25 26
CENTRAL REGION
10,000
7000
4000
2000
0
32 35 37 44 45 47 49 61 63 67 82 86 90
EASTERN REGION
4000
2000
0
100 103 105 114 117 120 126 128 130