SURFICIAL SEDIMENT AND SEAGRASSES OF EASTERN GREAT SOUTH BAY, N.Y.

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SPECIAL REPORT 12

REFERENCE 77-9

MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY OF NEW YORK
STONY BROOK, NEW YORK 11794

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and D. S. Becker

January 15, 1978

Sponsored by the Lerner Fund for Marine Research, of the American Museum of Natural History; the Nassau-Suffolk Regional Planning Board; the Jessie Smith Noyes Foundation; and the New York Sea Grant Institute

Special Report 12

Reference 77-9

Approved for Distribution

J.R. Schubel

J. R. Schubel, Director

ACKNOWLEDGEMENTS

We wish to thank Dr. J. R. Schubel, Dr. J. L. McHugh, Dr. B. Brinkhuis, and Dr. R. Dayal, of the Marine Sciences Research Center for contributing advice and comments on the project and report; Jim Allen of the National Weather Service for providing weather data; Carol Cassidy and Marie Eisel for preparing the figures; and Hirlsa White for typing the final manuscript.

Support for this project was provided by the Lerner Fund for Marine Research, of the American Museum of Natural History; the Nassau-Suffolk Regional Planning Board; the Jessie Smith Noyes Foundation; and the New York Sea Grant Institute.

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ABSTRACT

During the spring of 1977 a study was conducted of the sediments in eastern Great South Bay from Homans Creek east to Smith Point. A total of 186 stations were sampled in the open bay and in channels, creeks and rivers. Sediments were characterized according to two variables - particle size and organic content. During the summer of 1977 a survey was made of the distribution and density of seagrasses present in the study area.

Most Bay bottom consists of sandy sediments with low organic content. High organic muds were found in the deeper areas of the Bay off Bayport and in Patchogue and Bellport Bays. Distribution of mud and organic content was closely correlated with depth. Gravel content of sediments was usually very low. Some areas, however, contained high percentages of shell material. Creek sediments were extremely high in mud and organic content. Approximately 1/3 of the Bay sediments were covered with rooted seagrasses, almost exclusively *Zostera marina*. Estimation of the total biomass of seagrasses in the study area suggested they may play an important role in the nutrient balance of the Bay.

The character of sediments in the Bay probably has a large effect on growth, survival and abundance of the commercially important hard clam, *Mercenaria mercenaria*, and these relationships are discussed.

INTRODUCTION

Great South Bay is a shallow, bar-built lagoon on the south shore of Long Island, New York (Fig. 1). The Bay is approximately 40 km long and is bordered on the east and west by Moriches Bay and South Oyster Bay, respectively. An extensive system of barrier beaches encloses the Bay, and water is exchanged with the Atlantic Ocean through Fire Island Inlet and, to a lesser extent, through Moriches Inlet. A large number of streams and creeks empty into the Bay from the mainland, the largest of which are the Connetquot, Carlls, Carmans, and Patchogue Rivers (Hair and Buckner, 1973). The north shore of the Bay is well developed, mainly with private residences and small commercial establishments such as marinas and restaurants. Developments on Fire Island, a popular recreational area, are mainly summer residences and support services.

Great South Bay is presently most noted for its natural populations of hard clams (*Mercenaria mercenaria*) and the fishery they support. The fishery has an estimated annual retail value of over 100 million dollars, directly employs thousands of baymen and shippers, and indirectly contributes to a variety of supporting businesses (Nassau-Suffolk Regional Planning Board, 1974). The resource also supports substantial unrecorded recreational and subsistence clam fisheries (McHugh, 1977). Besides the clam industry, the Bay is used for various other purposes. It serves as a spawning, nursery and feeding ground for a wide variety of finfishes, including bluefish (*Pomatomus saltatrix*) and weakfish (*Cynoscion regalis*), that support recreational and commercial fisheries. The Bay also serves

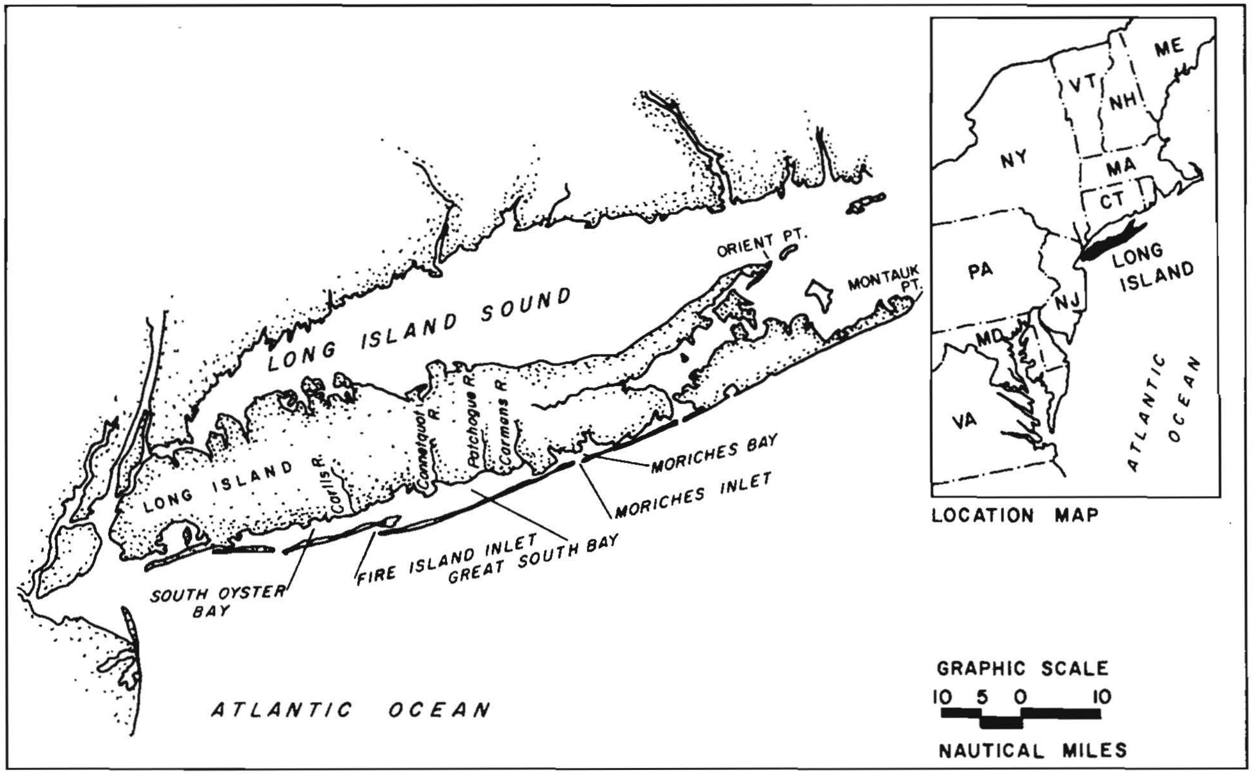

Fig. 1. Location of Great South Bay.

important transportational functions, mainly for ferries, cargo barges and small oil tankers, which require maintenance dredging of inlets, channels and creeks. Summer recreational activities, including boating, are intensive. The coastal zone adjacent to the Bay has extensive residential and commercial developments which directly affect the amount of runoff and pollutants reaching the Bay. These uses are bringing about changes in the sedimentary marine environment. Alterations in stream flows have changed the amounts and nature of sediments carried to the Bay. Increased loads of nutrients and organic materials are increasing productivity of Bay waters and increasing the amount of organic material available for sedimentation. Dredging has altered circulation patterns, provided unnatural settling basins and created dredge spoil sites.

The character of bottom sediments, particularly in relation to particle size and organic content, has a major effect on hard clam distribution, growth and survival (Pratt, 1953; Pratt and Campbell, 1956; Saila et al., 1967). Consequently, basic knowledge of the sediments is needed to understand why clam populations show certain setting, growth and survival patterns, and why some areas are productive and others are not. Knowledge of the sediments can be helpful in identifying areas of the Bay that might be optimal for clam seeding and transplant projects and, in general, for identifying particular benthic environments. It has recently become apparent that some type of clam management program, based on reliable knowledge of the physical characteristics of the Bay and of hard clam biology, must be implemented to maintain the productivity of the clam resources. Increased closings of areas to shellfishing because the waters are polluted and increases in the number of men relying on the clam beds for employment have subjected the resource to intense harvesting. It is now generally accepted that the resource is being seriously overfished, although published scientific confirmation is not yet available. Present management programs are in the early stages of development and are largely limited by the lack of scientific information on the Bay environment and the living resource.

This report presents the results of a study of sediment and seagrass distributions in eastern Great South Bay conducted during the spring and summer of 1977. The only other major study of the sediments in Great South Bay was done by Rockwell (1974), who completed a less detailed survey of the Bay sediments based on mean particle diameter in 1968 (Rockwell, 1974; Jones and Schubel, 1977). The objectives of this study were to determine and map the distributions of surficial sediments according to particle size and organic content and to determine and map the distribution and density of eelgrass. The eastern portion of the Bay was chosen as the study area because it has well defined physical and political boundaries and contains many important clam harvesting areas.

The overall purpose of the study was to provide basic information on sediment distribution for scientific management and planning of the hard clam industry. The present study provides baseline data for measuring long term changes in sediment quality that might result from man-induced or natural alterations of the environment. The study also identifies areas that may be serving as sinks for various trace contaminants such as heavy metals, petroleum hydrocarbons and chlorinated hydrocarbons. The nature of the material that must be periodically dredged out of channels and disposed of is also identified. Baseline information for detecting long-term changes in eelgrass abundance and for assessing the role of eelgrass in the nutrient balance of the Bay is provided.

METHODS

An area of approximately 80 km^2 (31 mi^2) in eastern Great South Bay from Homans Creek, Bayport, east to Smith Point was studied from April to August, 1977 (Fig. 2). Samples were taken on 17 north-south transects spaced approximately 800 m (0.5 mi) apart. Samples were taken approximately 100 m from shore at each end of the transects and at approximately 800 m intervals along each transect. After the initial sampling, additional stations were taken to define sediment transition zones more clearly. Samples were also taken from most of the channels and creeks in the study area. A total of 186 stations were sampled. Stations 1-158 and 184-186 were Bay stations, 159-182 were creek and channel stations, and Station 183 was a dredge spoil site. Station locations are shown on Fig. 3.

Station locations were determined with horizontal sextants. Using two Davis sextants, simultaneous sitings were made and averaged to improve accuracy in positioning. At each station a sediment sample was taken and the following observations were recorded: 1) date and time of day, 2) depth to the nearest 0.25 m, 3) position, 4) color and texture of sediments, 5) presence or absence of seagrasses.

Sediment samples were taken using a cylindrical metal scoop fastened at 90 degrees to the end of a telescoping aluminum pole. The scoop had a diameter of 10 cm and was 15 cm long. Sediment samples could be taken at all depths and in all sediment types encountered in the study. At the beginning of the study, several small conventional bottom grabs were tested in the range of sediments found in the Bay. They could not penetrate hard-packed sand and could not close tightly enough to prevent the sample from washing out in shelly and gravelly areas. In muddy areas, fine materials were washed out of the grabs as they were lifted from the water. The scoop used in this study penetrated 5 to 8 cm depending on sediment firmness. Since the sediment was packed into the scoop before it was raised to the surface, material was not washed out. The scoop worked well even in the most shelly and most muddy sediments. Depth was measured with the calibrated aluminum pole of the scoop. Sediment samples were placed in plastic bags, transported from the field in a cooler and refrigerated until analyzed.

In the laboratory, each sediment sample was thoroughly mixed in its plastic bag and two subsamples were taken for particle size and loss on ignition analyses. Particle size distribution was determined by wet sieving and pipette analysis according to methods similar to those described by Folk (1968). Subsamples were dispersed with 1% calgon solution and mechanically shaken for 2 hours. The dispersed mixture was wet sieved through 2 mm and 63 μ sieves to remove gravel and sand, respectively. Two pipette withdrawals were made to determine the amount of silt and clay in the sample. All 4 fractions were dried at 65-75°C and weighed, and the weight percentages of each were calculated. Salt content of a range of sediments was determined to see if a correction for the weight of salt was required in calculating the weight percentages of silt and clay in the pipette analysis. The salt content was not large enough to have a significant effect on the weight percent calculations.

Organic particles were not removed by oxidation with H_2O_2 and were considered part of the sediment. As shown by loss on ignition data, organic content was usually low and was not observed to cause flocculation or otherwise interfere with settling in the columns. The gravel fraction initially contained mineral as well as shell material. Gravel fractions containing shell were weighed before and

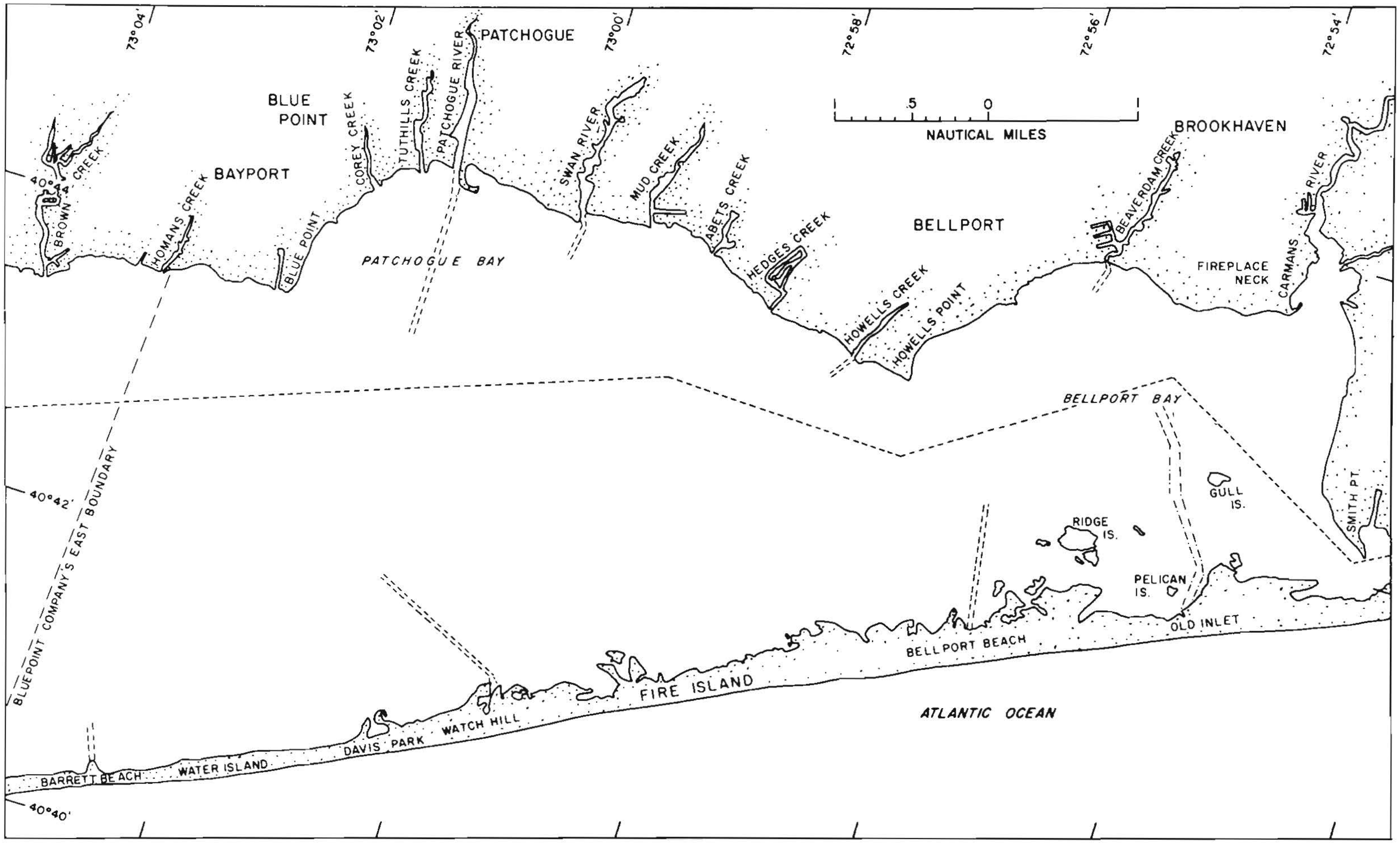

Fig. 2. Location of Study Area. Major channels are shown by dotted lines.

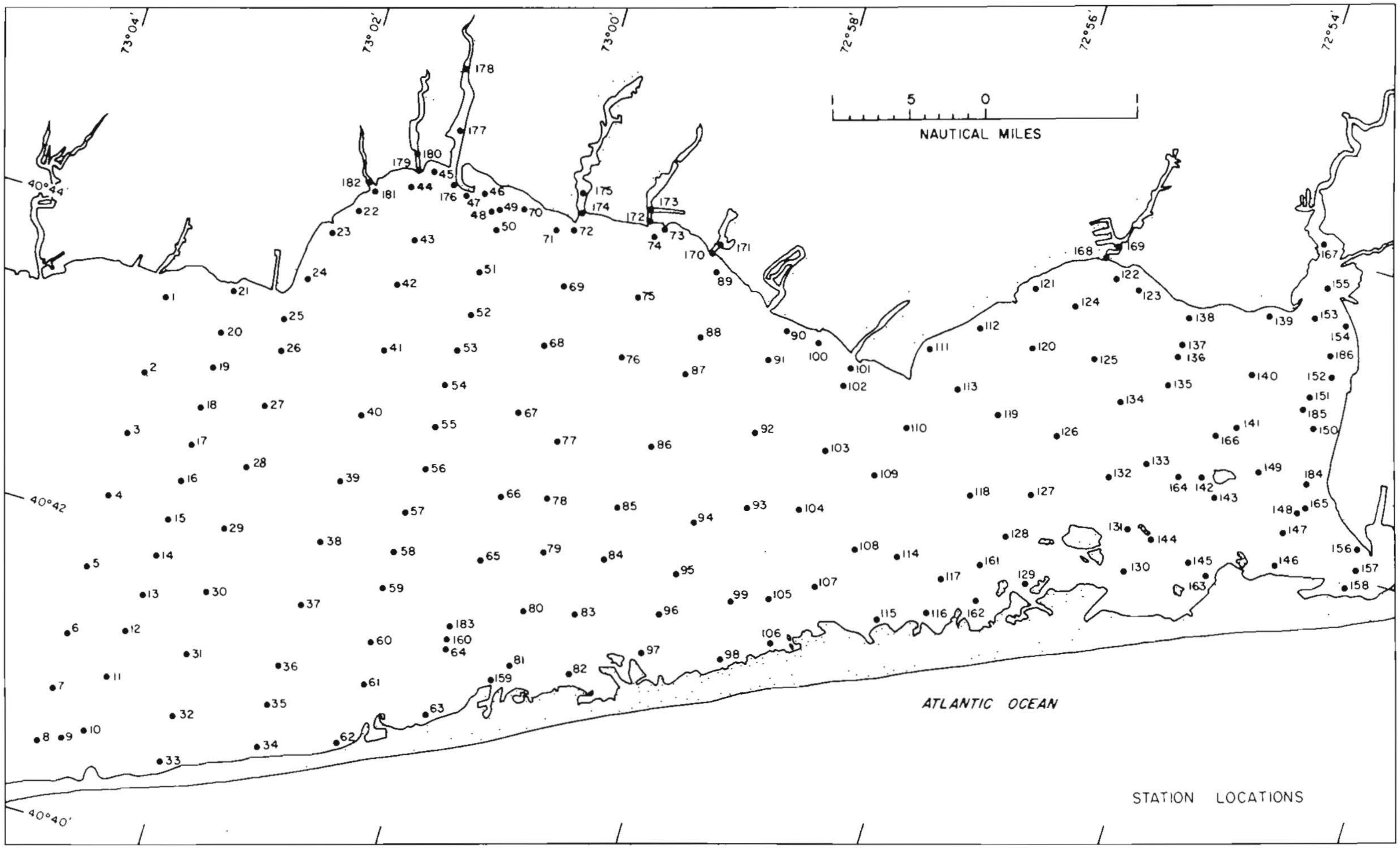

Fig. 3. Location of Stations

after removal of shell material. Weight percentages of the four particle-size categories were calculated with and without shell material in the gravel fraction. Shell material from each sample was studied under magnification to identify species contributing the bulk of shell material.

Percent loss on ignition was used as an index of organic content and was determined using methods similar to those described by Gross (1972). Each subsample was dried at 65°C, lightly disaggregated in a mortar and pestle and dry sieved through a 2.0 mm sieve. Approximately 25 grams of each sieved subsample was combusted at 550°C for 5 hours, cooled in a dessicator at room temperature and weighed. Percent weight loss was then calculated.

A survey of seagrass was made on August 3, 1977, based on preliminary observations regarding the presence or absence of grass made while taking the sediment samples. Two boats were used to survey the distribution and density of the seagrass beds. Visual observations from the boats were supplemented with underwater observations and bottom grabs. Visual estimates of seagrass density were quantified by sampling square meter quadrats of thick, medium and thin seagrass cover, including roots. Seagrass roots and blades within a meter quadrat were dug up with a spade, washed in a sieve, and brought back to the laboratory. Samples were then rewashed, dried in an oven at 65°C, and weighed. Estimates of coverage were divided into quartiles of 100%. Estimates of average dry weight per meter for seagrass areas were derived by combining density and percent coverage data. Total biomass of seagrass in the study area was estimated by multiplying percent cover by area and summing. Amounts of nitrogen and phosphorous stored in the total seagrass biomass were estimated to assess the role of seagrasses in the nutrient balance of the Bay.

RESULTS AND DISCUSSION

Sediment Particle Sizes

Weight percentages of gravel (excluding shell material), sand, silt and clay, and percent loss on ignition for each sample are tabulated in Appendix 1. Figure 4 is a contour map of percent silt + clay for all stations except river, creek and channel stations. A contour interval of 20% silt + clay was used, and percent intervals of 0-20, 20-80 and 80-100 are shaded differentially to indicate more clearly the main types of sediments in the Bay. Sediments are also classified according to the categories defined by Folk (1968) and are presented in Table 1. Fig. 5 shows the categories of sediments found in the study area using this classification scheme.

As Figs. 4 and 5 show, sediments in Great South Bay are predominantly sandy. Approximately 66% of the Bay bottom studied consists of sediments of less than 20% silt + clay, and only 11% consists of sediments with a silt + clay fraction greater than 80%. Transitional sediments with a silt + clay content of 20-80% cover only 25% of the Bay bottom. Silt content of some of the samples was high, but the clay fraction seldom exceeded 30% and was typically only 15-20% in the most muddy sediments. Extensive areas of sandy sediments (over 90% sand) are on the Fire Island side of the Bay. The bottom immediately adjacent to the north shore of the Bay is also sandy. The high silt + clay areas are found in basically three basins; west of Blue Point, Patchogue Bay and Bellport Bay. Samples with highest silt + clay content were found in Patchogue Bay where values as high as 94.9% (Station 42) occurred.

The correlation between silt + clay content and depth is high (Table 2). Fig. 10 is a contour map of water depths in the study area which allows visual comparison

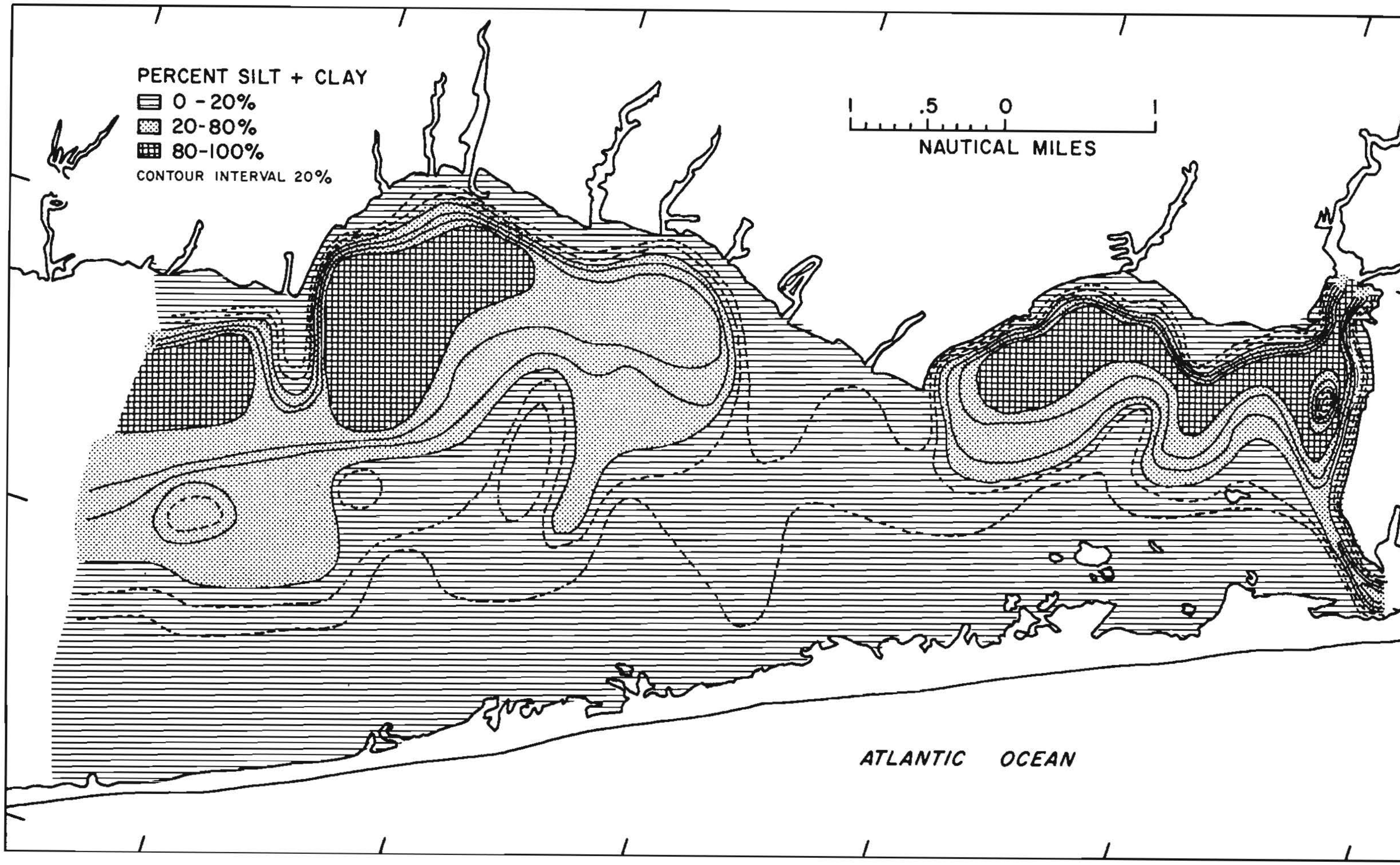

Fig. 4. Contour Map of Percent Silt + Clay

TABLE 1. SEDIMENT CLASSIFICATION (Folk , 1968)

Gravel	80% or more pebbles, etc. (+ 2.0 mm in dia.)
Sand	90% or more sand (2.0 - 1/16 mm in dia.)
Silt	67% or more silt (1/16 - 1/256 mm in dia.)
Clay	67% or more clay (1/256 - 1/4096 mm in dia.)
Mud	less than 10% sand; no more than 63% of either silt or clay
Sandy Gravel	30 - 80% gravel; remainder sand
Gravelly Sand	sand with up to 30% gravel
Muddy Sand	50 - 90% sand; remainder silt and clay
Sandy Mud	10 - 50% sand; remainder silt and clay

TABLE 2. CORRELATIONS OF SEDIMENT VARIABLES

Variables[1]	n[2]	r	s_r[3]	t_s[4]	L_1[5]	L_2[5]
Silt + clay, depth	162	0.5275	0.0672	7.8540	0.4064	0.6305
LOI, depth	162	0.4881	0.0690	7.0739	0.3611	0.5972
LOI, silt + clay	162	0.8466	0.0420	20.1205	0.7965	0.8852

[1]arcsine transformations performed on LOI (loss on ignition) and "silt + clay" values prior to correlations.

[2]channel stations were not included in the correlation because channels are unrepresentative of typical bay sediments.

[3]the standard error of the correlation coefficient for a sample from a bivariate normal distribution with $\rho = 0$ is $s_r = ((1-r^2)/(n-2))^{\frac{1}{2}}$

[4]t-test statistic with n-2 degrees of freedom, compared with the critical value $t_{.001}(160) = 3.291$.

[5]lower and upper 95% confidence limits around r, using the z-transformation.

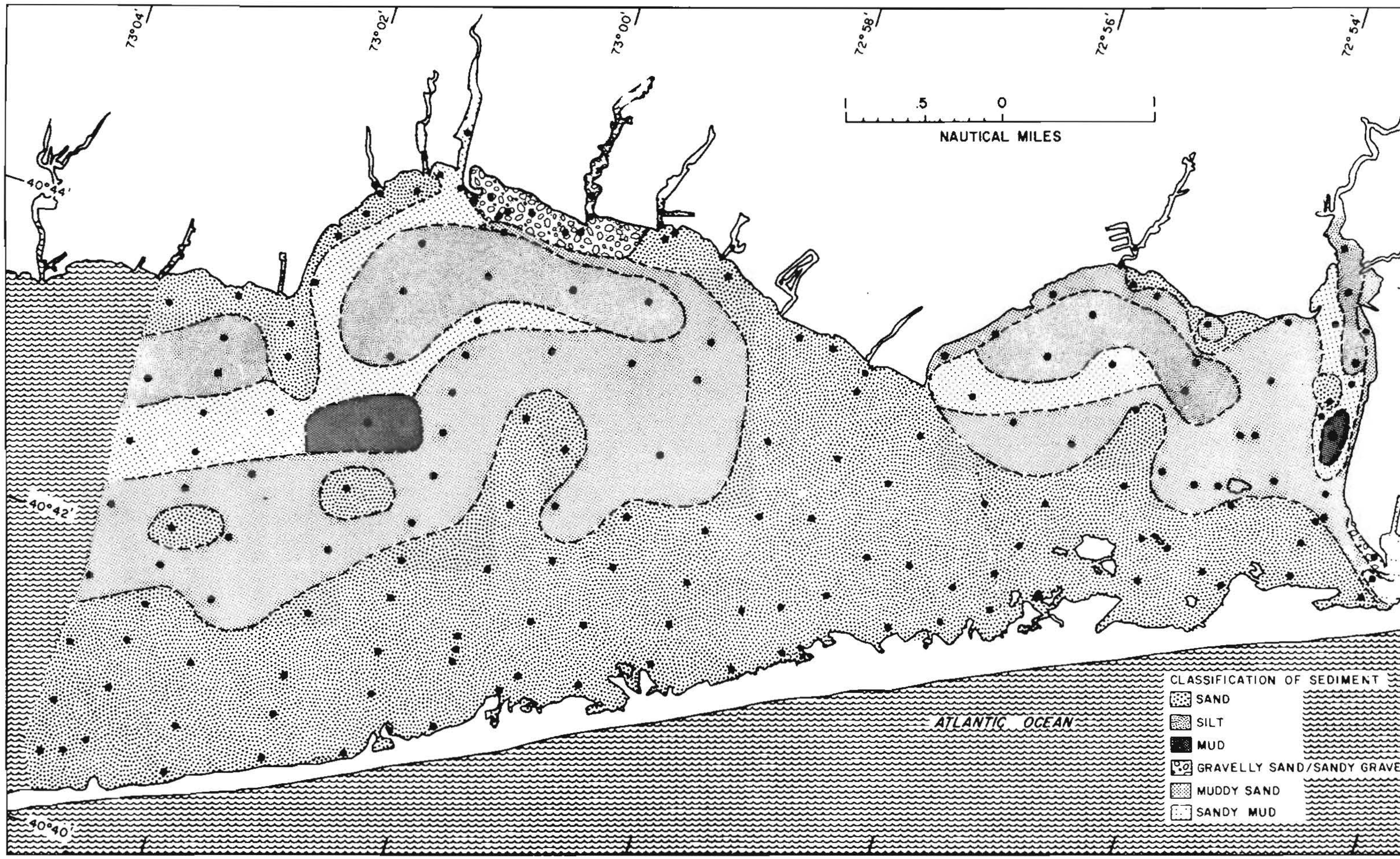

Fig. 5. Classification of Sediments

of depth and silt + clay content. The transitions between sediment types largely reflect changes in depth. Sharp transitions from high sand to high silt + clay sediments along the north shore of the Bay correspond to sudden increases in depth along the shore. Along the north shore this transition is consistently near the 2 m depth contour. The gradual transition from sand to muddy sand along the south side of the Bay reflects the very gradual increase in depth there. The close relation between sediment type and depth probably reflects the nature of bottom water currents, which in Great South Bay are primarily tidally induced. Bottom current velocities are reduced in many of the deeper parts of the Bay, permitting settling of fine materials.

Samples were usually very low in gravel content, excluding the shell material. Only 31 stations contained gravel and only 4 stations (49, 70, 72, 154) contained substantial amounts. Most of the sediments containing gravel are from very low silt + clay areas adjacent to the north shore of the Bay. Sands at these stations usually appeared much more coarse than those from other stations. The nature of these nearshore sediments is probably the result of wave action and erosion of the mainland which consists of unconsolidated glacial deposits (Koppelman et al., 1976; Smith, 1973).

Although low in gravel, many samples contained substantial amounts of gravel-sized shell material. Shell material was excluded in mapping percent silt + clay, but percentages of gravel + shell material were calculated separately and contoured (Fig. 6). Stations 4, 30, 38 and 110 had weight percentages of shell of 49.9, 23.4, 55.3 and 52.8, respectively. The samples from these stations contained large amounts of fragmented *Crassostrea virginica* and *Crepidula fornicata* shells and were apparently from areas of old oyster beds. In total, the shells of 26 mollusk and 1 worm species were identified in the shell fraction. The species are listed in Appendix 2 in order of their frequency of occurrence in the samples. Numerically, the most abundant shells in sediment are from live and dead duck clams (*Mulinia lateralis*) and razor clams (*Ensis directus*). Figures 7 and 8 indicate where high concentrations of the shells of these species are found. *Mulinia* is found exclusively in areas greater than 20% silt + clay, and the highest densities are in samples containing more than 80% silt + clay. *Ensis* shells, 2-5 cm long, are abundant in mud and sand. The area off Blue Point is a center of high density for both species. Live gem clams (*Gemma gemma*) are very abundant in several sandy areas, particularly in shallow waters along Fire Island.

Samples from 11 stations contained shells of *Mercenaria mercenaria*. Six of the 11 stations contained the shells of dead, young *Mercenaria* ranging from 4-16 mm long. The remaining stations contained fragments of much larger hard clams. It is interesting that 3 other species of clams (*Mulinia lateralis, Ensis directus* and *Gemma gemma*) are apparently numerically more abundant than hard clams in the Bay

Loss on Ignition

Loss on ignition values of sediments for each Bay station are tabulated in Appendix I and contoured in Fig. 9. A contour interval of 2% is used and areas of 0-2%, 2-6% and greater than 6% loss on ignition are differentially shaded. Highest organic levels in open Bay sediments are found off Bayport, in Patchogue Bay, and in Bellport Bay, particularly at the mouth of Carmans River and off Smith Point. The high organic, fine muds at the mouth of the Carmans River may be remnant sludge deposits from duck farms that previously discharged wastes into the Carmans River. Sandy sediments immediately

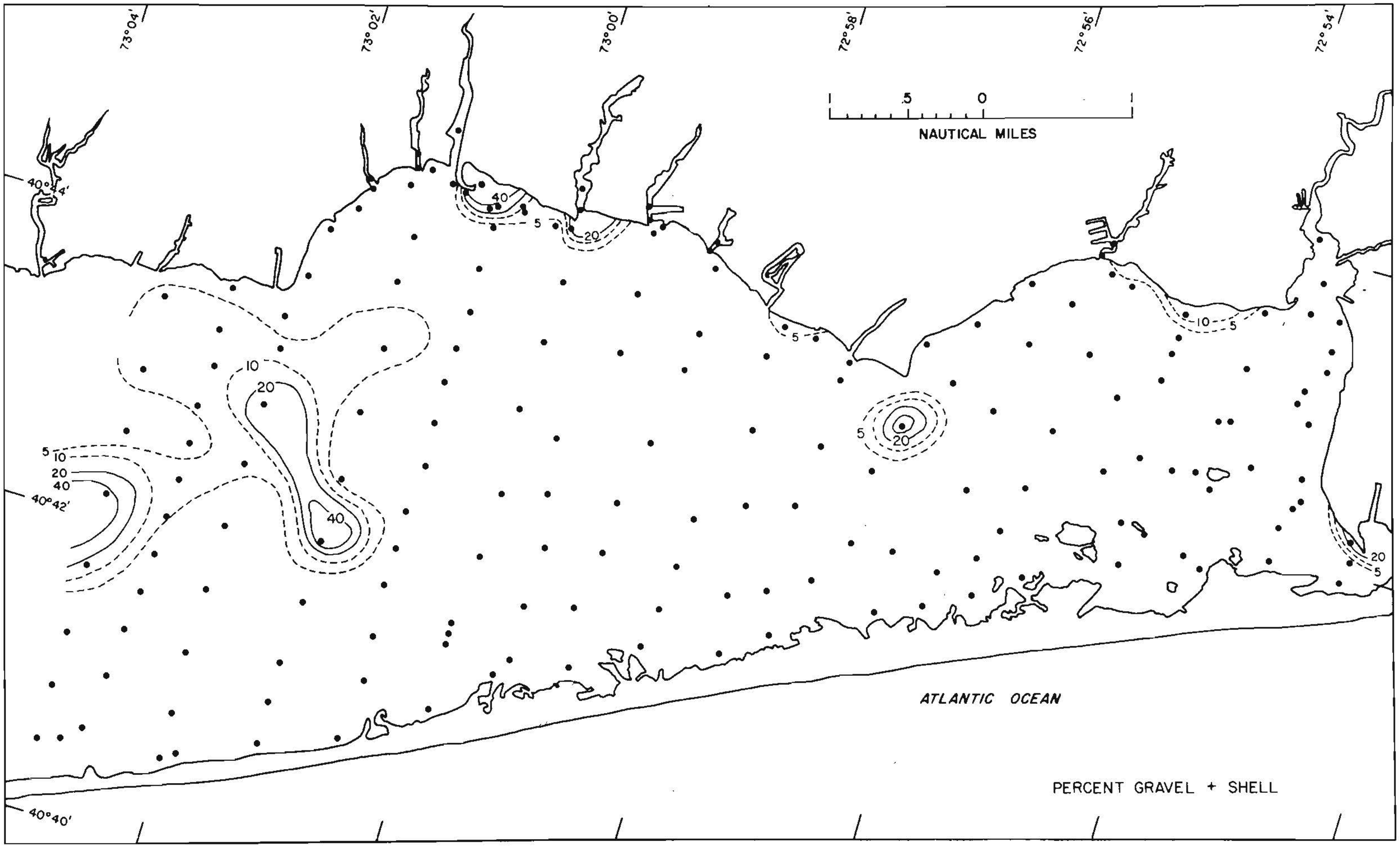

Fig. 6. Contour Map of Percent Gravel + Shell

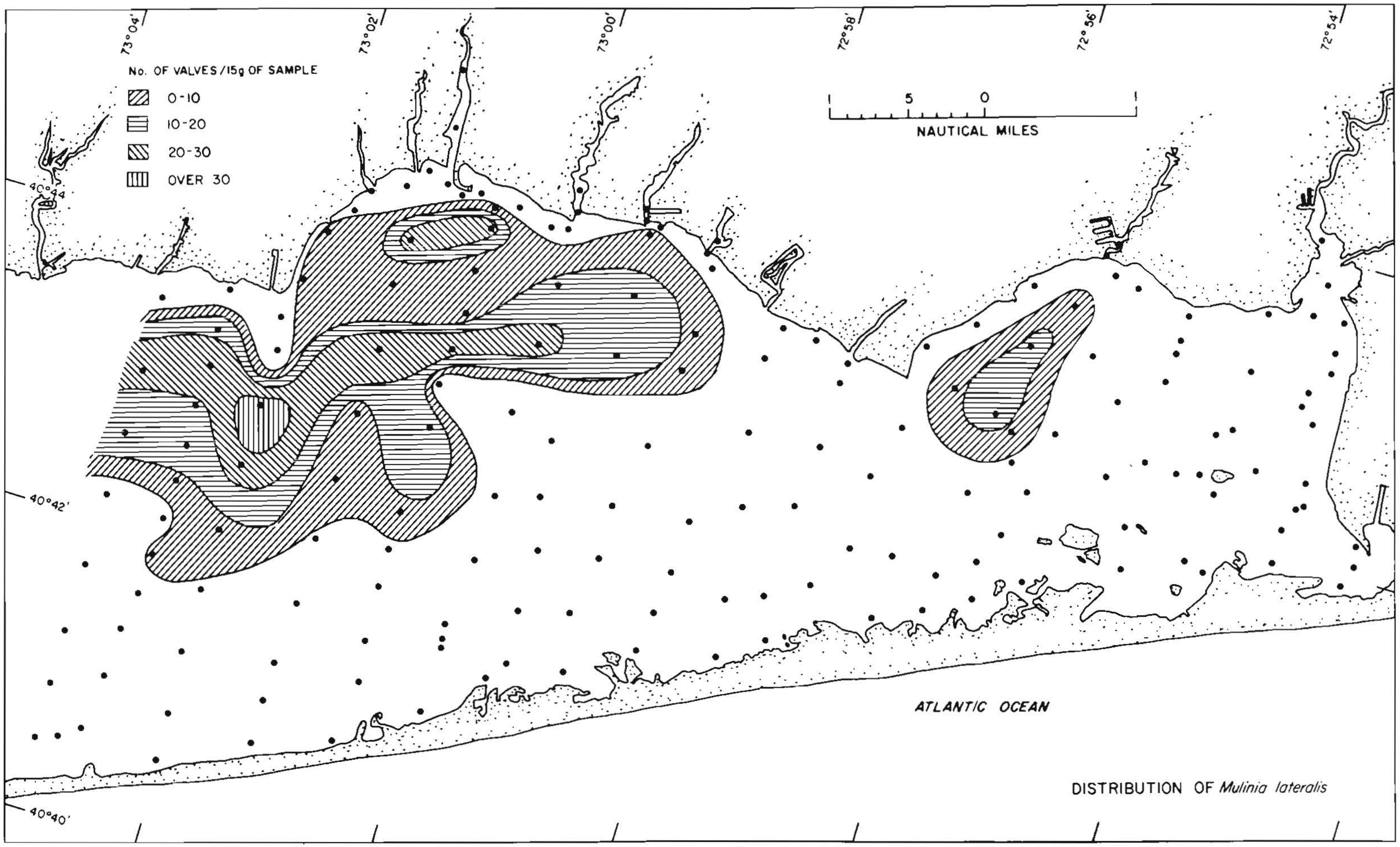

Fig. 7. Distribution of *Mulinia lateralis*

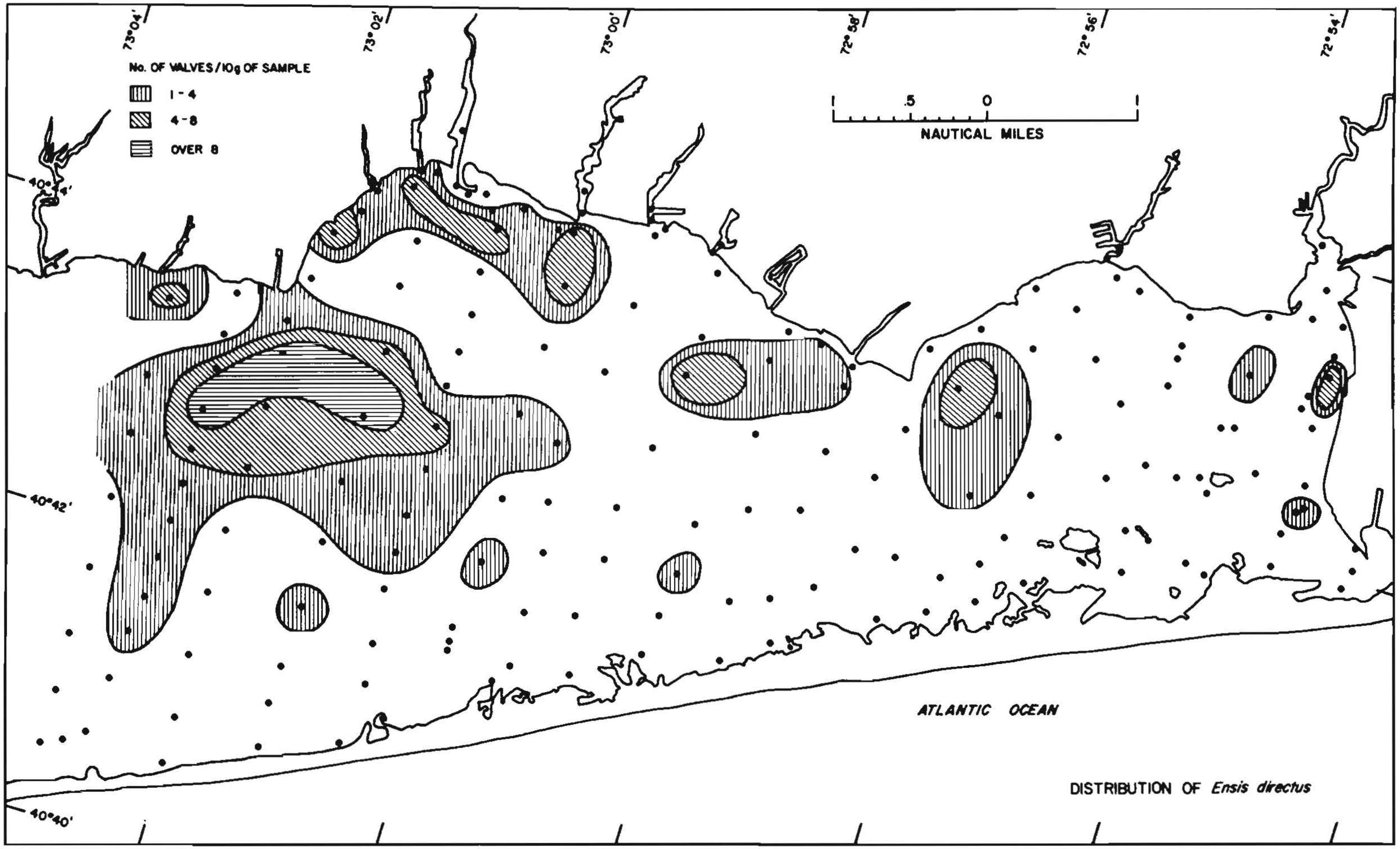

Fig. 8. Distribution of *Ensis directus*

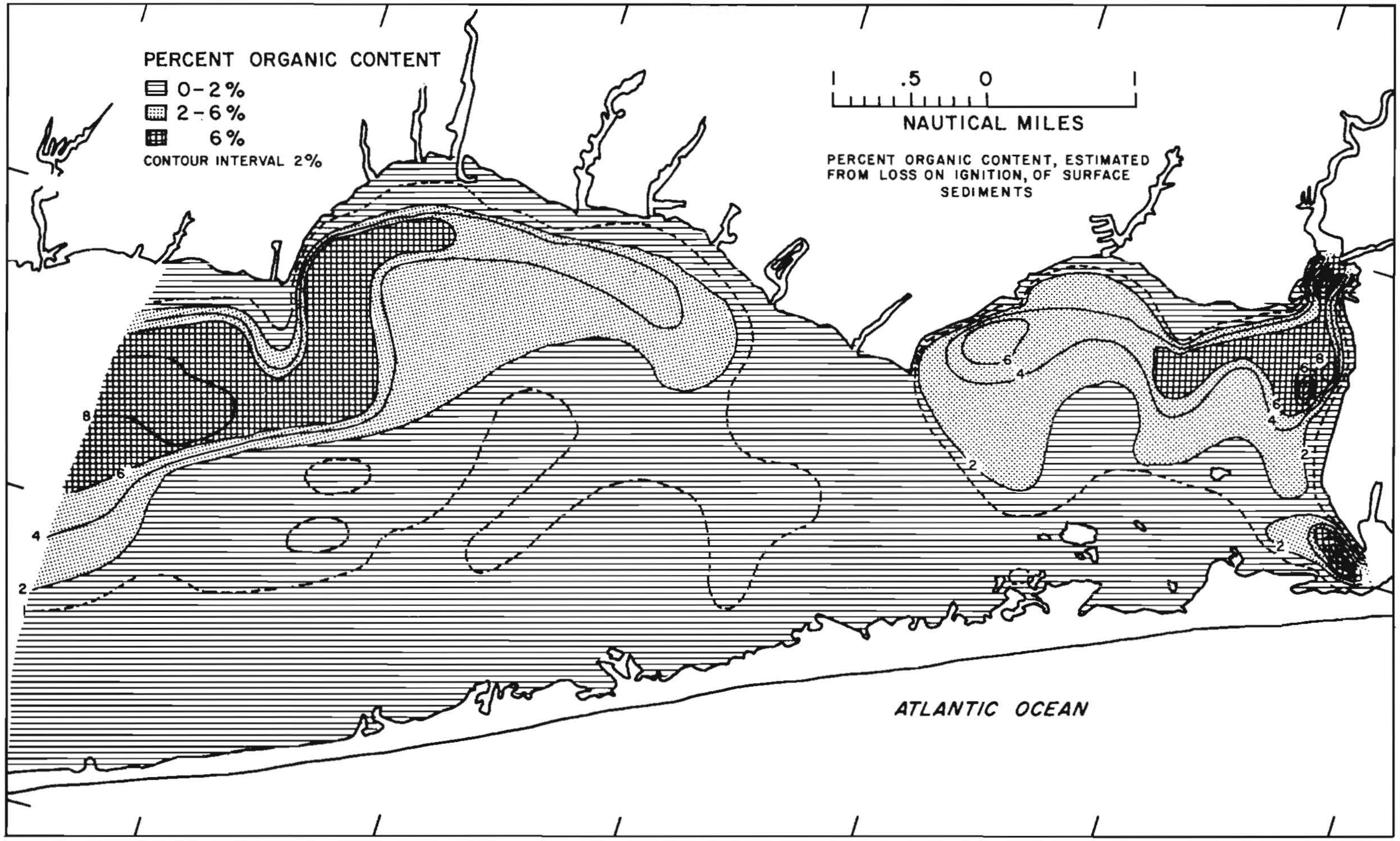

Fig. 9. Contour Map of Percent Loss on Ignition

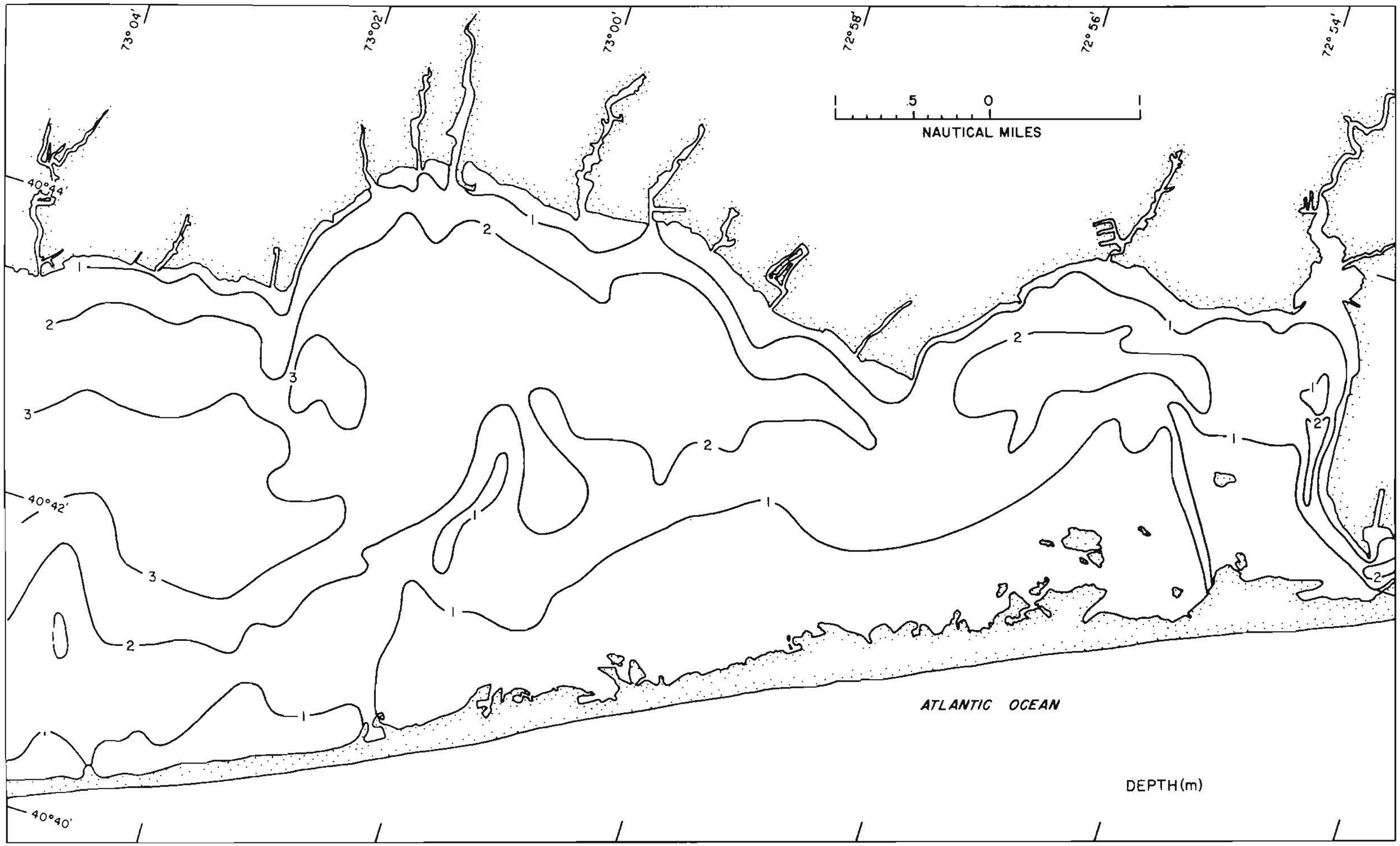

Fig. 10. Contour Map of Depth

adjacent to the north shore of the Bay and the extensive sand flats along the barrier beach are very low in organic content, consistently less than 1%. Comparison of Figs. 4 and 10 makes it apparent that areas of high silt + clay content correspond closely with areas of high loss on ignition. This is substantiated by the high statistical correlation found between silt + clay content and percent loss on ignition (Table 2). The gradual increase in organic levels northward from the barrier beach and the rapid transition along the north shore from low to high loss on ignition values coincide with increases in silt + clay content and depth. A large amount of organic material apparently is contained in the silt + clay fractions of the sediments.

Distribution and Abundance of Seagrass

The spatial distribution and density, expressed as dry weight per m^2 of bottom, of seagrasses are illustrated in Fig. 11. At the time of the survey, eelgrass (*Zostera marina*) was the dominant seagrass in terms of distribution and biomass in the study area, and it comprised at least 98% of total seagrass biomass. Small beds of wigeon grass (*Ruppia maritima*) existed in several areas of the Bay, particularly in shallow waters adjacent to islands and the barrier beach in Bellport Bay. *Ruppia* had a relatively small biomass per unit area and was apparently limited in distribution to areas where *Zostera* could not grow well. Figure 11 shows that seagrass beds, mainly *Zostera*, existed on the entire barrier beach side of the study area. Eelgrass apparently thrives in these protected shallow waters where the sediments are exclusively sand.

On the south side of the Bay, *Zostera* extended to a depth of approximately 1.8 m. On the north shore, eelgrass seldom grew at depths greater than 0.5 m and the beds were generally much thinner. Prevailing winds in summer are from the southwest and, consequently, waters on the north shore of the Bay are usually rougher and much more turbid than waters on the south shore. High turbidity along the north shore probably limits light penetration to such an extent that eelgrass growth below 0.5 m may not be possible. McRoy (1966) has shown that light limitation is the most important factor governing the lower limit of colonization for *Zostera*.

The thickest and most extensive eelgrass beds in the study area were found in Bellport Bay. Biomass in the thickest beds was approximately 0.5 kg dry weight/m^2. Typical values for thick eelgrass beds on the east and west coasts of the United States and in Europe range from 0.5 to 1.0 kg dry weight/m^2 and are as high as 1.5 kg dry weight/m^2 (McRoy, 1966; McRoy, 1970; McRoy and McMillan, 1977). Baymen have reported that the extent and density of eelgrass beds in Great South Bay were less during the summer of 1977 than in preceding years. Blades were shorter within the beds and some beds disappeared entirely.

There are several possible causes for the recent decline in eelgrass abundance. Rasmussen (1977) has found that eelgrass declines in the past have corresponded with increases in water temperature associated with exceptionally hot summers. High temperatures may lead to the destruction of eelgrass either directly by disrupting metabolism or indirectly by making the grass more susceptible to attacks by bacteria, slime molds and fungi. A record-breaking heat wave occurred in the New York City area from July 13 to July 21, 1977 (J. Allen, National Weather Service, personal communication). Daily temperatures averaged above 90°F (32.2°C) for 9 consecutive days, and three days had daily high temperatures over 100°F (38.8°C). The daily high temperature on July 21 was 104°F (40°C), making it the hottest day

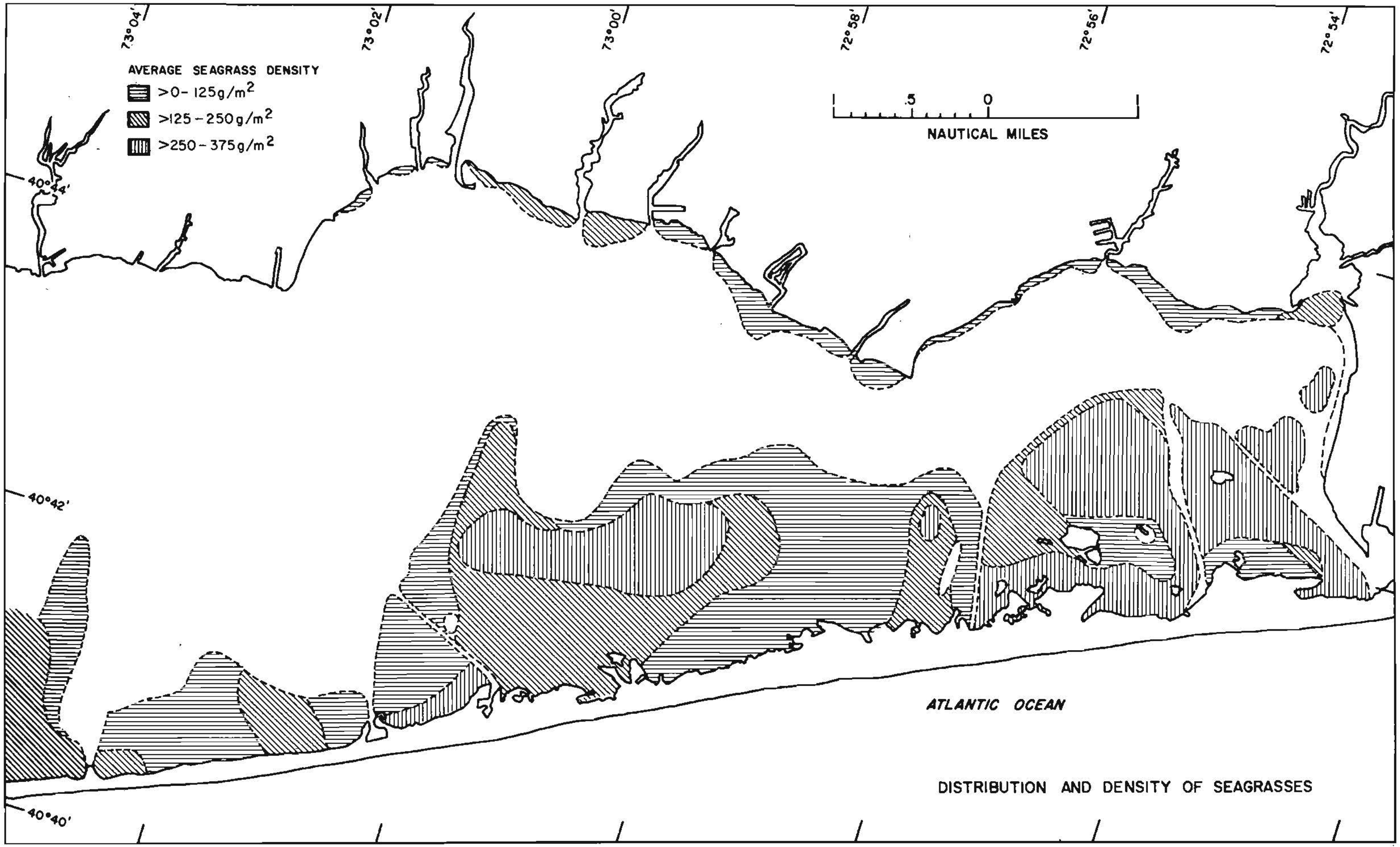

Fig. 11. Distribution and Density of Seagrasses

in the New York City area in 41 years. Persistent high temperatures may have heated shallow waters to unusually high temperatures and caused deterioration of eelgrass beds. In addition to the hot summer, the preceding winter was the coldest in 41 years and the tenth coldest on record (J. Allen, National Weather Service, personal communication). Because unusually low temperatures were persistent ice up to 0.6 m thick covered most parts of Great South Bay for approximately 1½ months, from late December to mid-February. Mechanical action of ice in the shallow waters may have scoured eelgrass beds, also causing a reduction in eelgrass abundance.

By determining the total areas inhabited by various categories of seagrass density and percent cover, total biomass in the study area was estimated to be 4.9×10^6 kg dry weight. Dry weight percentages of nitrogen and phosphorus in eelgrass are approximately 3.045% and 0.286%, respectively (Burkholder and Doheny, 1968). Therefore, approximately 1.49×10^5 kg of nitrogen and 1.40×10^4 kg of phosphorus were stored in the standing stock of *Zostera* in the study area. Total inputs of nitrogen and phosphorus from stream flow, subsurface flow and rainfall into Great South Bay have been estimated to be 1.945×10^4 and 1.456×10^3 kg-at/year, respectively (Hair and Buckner, 1973). Total loads of nitrogen and phosphorus into Great South Bay each year are therefore 2.72×10^5 and 4.51×10^4 kg/year, respectively. It is apparent that substantial amounts of nutrients are bound in the standing crop of seagrass, especially when compared to the total amounts entering the Bay. The distribution and abundance of seagrass probably have a strong influence on the nutrient balance of the Bay.

Channel, Creek and River Sediments

Twenth-three stations were located in channels, creeks and rivers throughout the study area. Samples taken from creeks and channels were very different from those taken in the open Bay. The sediments, especially those in creeks entering the Bay from the mainland, have very high silt + clay contents, usually greater than 95%. Patchogue River, Swan River and Abets Creek have silt + clay values of 97.5%, 97.6% and 97.6%, respectively. These are the highest silt + clay values observed in the study. Loss on ignition values are correspondingly high with a maximum value of 30.2% observed at Station 173 in Mud Creek.

Dredged channels and creeks apparently serve as settling basins for large amounts of fine-grained and organic materials, much of which probably originates from land runoff. Another source of sediment in the creeks is floating seagrass and algae that are pushed into the creeks by winds. Rapid accumulation of partially rotted seagrass has been a problem for many of the smaller creeks that do not have stream flows sufficient to prevent the buildup of floating seagrass. Channels along the Fire Island side of the Bay, which cut through shallow seagrass beds, also contain large amounts of partially decayed seagrass fragments. Anaerobic conditions exist at the bottom of many of these channels and creeks and inhibit decomposition of accumulating organic materials (Smith, 1973).

The high organic and fine-grained nature of the sediments in the creeks and their close proximity to potential sources of pollution suggest that they serve as traps for heavy metals, oils and greases, chlorinated hydrocarbons and other contaminants. To what extent these high-organic, fine-grained sediments and contaminants possibly associated with them are resuspended from the creek beds and flushed into the Bay during periods of storms and increased runoff and stream flows is not known, but this could be a significant factor affecting the quality of open Bay waters and sediments. Some of the rivers and larger creeks in the study area, such as Patchogue River, are periodically dredged for navigational purposes. The dredge spoils are usually disposed of at specified sites, commonly former wetlands adjacent to the creeks.

Sediment Quality in Relation to Hard Clams

The character of bottom sediments has been shown to be significantly related to clam abundance, growth and survival. Surveys of clam populations have shown that hard clams are often most abundant in particular sediment types. In Narragansett Bay, Pratt (1953) found hard clams most abundant where dominant sediments are fine, but clam abundance in fine sediments was strongly related to the presence of large particles such as shell material and gravel as minor constituents. Allen (1954) found that the hard clam was abundant only in sandy bottoms in the Little Annemessix River of the Chesapeake Bay area. Wells (1957), in a study of Chincoteague Bay, Maryland, found the densest populations of hard clams in sediments containing shell material and thinnest populations in sediments containing mud alone. Saila et al., (1967) found that organic carbon content and particle size greater than 2 mm diameter were the only variables that contributed effectively to discrimination of abundance between 2 study areas in the Providence River, Rhode Island.

Zuraw et al., (1969) reported that hard clams in some Connecticut waters survived best in sand but were found in a wide range of sediments. Taylor and Saloman (1970) found that southern quahogs apparently preferred firm sand sediments with a mean grain size of 0.125-0.165 mm in diameter and less than 9% organic content. In Delaware Bay, *Mercenaria* was found in substrates of silt-clay to sand containing shell material (Maurer et al., 1974). Cole (1977) found that sandy mud substrates containing shell material in Rehoboth and Indian River Bays, Delaware, contained significantly higher clam densities than other substrates. Bader (1954) found that organic content and its decomposition in sediments were the major factors controlling pelecypod densities in the Mount Desert area of Maine.

A relation between clam abundance and a substrate variable, however, does not necessarily indicate a cause-effect relationship. Factors that lead to formation of a particular type of substrate, such as water circulation, may be the critical factors affecting clam densities. Abundance of clams in many areas is substantially affected by harvesting, so that a more productive clam area could actually have lower clam densities than other areas that are harvested less. Areas of high shell content could have higher clam densities because the difficulty of working shelly substrates discourages clammers from harvesting such areas.

There is some evidence, however, that substrate type may have a direct effect on setting, growth and survival of clams and, consequently, on abundance. Keck et al., (1974) found that clam setting was higher in sand than in mud. Apparently clam larvae show a preference for sandy sediments in selection of a setting site. Zuraw et al., (1969) also reported that clams more frequently colonize sand than mud. Pratt (1953) reported that clams living in sand grew 24% faster than clams living in an adjacent plot of sandy mud containing high amounts of organic material. Pratt and Campbell (1956) reported that growth rates of hard clams were consistently greater in coarse-grained sand than muds with high silt content. Using boxes filled with different sediment types, they found that clams grew 24% faster in sand than in mud at the same location in Narragansett Bay. Rhoads and Pannella (1970) found that growth rates of clams in sand were significantly greater than growth rates of clams in mud in Milford Harbor, Connecticut and in Buzzards Bay, Massachusetts. Greene (1975) found that clams growing in sand in Great South Bay grew 58% faster than clams growing in mud. The slow growth of clams in mud was due to numerous breaks in growth, apparently caused by environmental disturbances, as well as generally slower growth throughout the year.

Several explanations have been given to account for the slow growth of clams growing in mud. According to Pratt and Campbell (1956), a clam often siphons water through a layer of sediment because its burrow to the surface tends to become clogged with sediment. Because mud has a lower permeability than sand, clams in mud can not maintain efficient siphonal water exchange. Consequently, nutrition, respiration and excretion are hindered. Pratt and Campbell (1956) also found that clams living in mud tended to live nearer the sediment surface compared to clams living in sand, perhaps to compensate for the difficulties of maintaining a functional connection with the water. Rhoads and Young (1970) found that mud bottoms are often covered by a thin layer of loose, low-density sediment formed by workings of deposit feeders and settlement of detritus. Such a loose layer is easily stirred up and suspended above the mud surface. Quahogs living in mud inadvertently take up considerable amounts of these suspended particles. Sorting mud from food and cleaning clogged filters requires additional expenditures of energy and reduces feeding time and efficiency (Pratt, 1953; Pratt and Campbell, 1956). Loosanoff and Tomers (1948) showed that silt at a concentration as low as 0.1 gm/l decreased pumping and feeding of oysters, *Crassostrea virginica*, by 57%. Mud may be especially detrimental to young clams, whose small siphons and gill surfaces are easily clogged by suspended silt (Levinton and Bambach, 1970). In general, clams living in mud have added energy expenditures, the effect of which is reduced growth and increased susceptibility to other environmental stresses. Clams tend to sink in very soft muds, making it difficult to maintain a position suitable for feeding and respiration. Clams are unable to live in many channels, river mouths and creeks because sediments are too soft.

Particular types of sediments may have a direct effect on survival of clams. Maurer and Watling (1973) found in Delaware Bay that high concentrations of clams were often associated with old, non-cultivated oyster beds. As mentioned above, Pratt (1953), Wells (1957), Saila et al., (1967), Maurer et al., (1974) and MacKenzie (1977) have reported higher densities of clams in areas containing shelly sediments. Andrews (1969) reported that shelly oyster beds provide the best habitats for survival of young clams and that most of the commercial catch of hard clams in Cheasapeake Bay comes from such areas. Shell fragments, gravel and stones may effectively hinder predation especially bv crabs (MacKenzie, 1977). Buried shells and gravel make it difficult for predators to locate clams and force additional expenditures of energy and time searching for prey. Surfaces of shells and rocks often contain barnacles, slipper shells and other buffer prey, thus relieving clams from some degree of predator pressure.

Presence of seagrasses could also affect clam growth and survival. Kerswill (1949) showed that clams growing in areas of heavy eelgrass cover grew much more slowly than clams on a clear bottom. He attributed low growth rates to highly reduced water circulation in eelgrass beds and its effects on the availability of food and oxygen. Heavy seagrass cover may also reduce predation because predators such as whelks, snails and crabs probably have a more difficult time finding and dislodging clams growing in sediments firmly matted with seagrass roots.

Thorough knowledge of the relationships between sediment type and hard clam biology could provide a way of categorizing the Bay into favorable and unfavorable clam production areas. Studies are needed to determine if clam setting, growth rates, survival and other biological variables are fairly uniform in areas of similar sediment type. Such a categorization would be useful to clam management programs. It would be helpful, for example, in determining which areas of the Bay could provide maximum survival and growth of hatchery raised seed clams.

CONCLUSION

Great South Bay has acquired great commercial and recreational value in the last decade. Conflicting with this growing economic importance has been intense development of the coastal zone and resulting deterioration of coastal waters from pollution and other adverse alterations of the natural system. In view of these growing conflicts, a thorough understanding of the present physical environment of the Bay is required if the Bay is to be maintained in a healthy state. Knowledge of the sediments is basic to understanding the physical and biological environment.

The present study provides a detailed description of the sediment environment for approximately 1/3 of the Bay in terms of several important variables - particle size, organic content and seagrass coverage. The general conclusions are:

1. Most Bay bottom consists of low organic, sandy sediments. High organic muds are found in roughly 3 areas; off Bayport, in Patchogue Bay and in Bellport Bay.

2. Distribution of muds and organic content is closely related to depth. High positive correlations exist between percent silt + clay and percent organic content, percent silt + clay and depth, and percent loss on ignition and depth.

3. Except for a few specific locations, Bay sediments are very low in gravel. Certain areas, especially old oyster beds, contain large amounts of shell material in their sediments.

4. Creek sediments are very high in silt + clay and organic content, suggesting that they may serve as traps for various contaminants entering the Bay from the mainland.

5. *Zostera marina* is the dominant seagrass in the eastern part of the Bay. A substantial amount of nutrients are locked into the standing stock of eelgrass, suggesting that eelgrass has an important role in the nutrient balance of the Bay.

6. Other studies have shown that a close relationship exists between clam growth, survival and abundance, and sediment type. A specific study of these relationships in Great South Bay could provide a practical approach to categorizing the Bay into favorable and unfavorable clam production areas for management and planning purposes.

7. This study has supplied baseline data that can be used to detect long-term changes in the sedimentary environment of the Bay.

APPENDIX I

DATA FOR SURFICIAL SEDIMENTS OF EASTERN GREAT SOUTH BAY

Station Number	Depth (meters)	% Loss on Ignition	% Gravel	% Sand	% Silt	% Clay
1	1.4	0.5	5.8	92.4	0.6	1.2
2	3.0	8.0	0.0	9.7	75.7	14.6
3	3.5	6.3	0.0	26.8	58.0	15.2
4	3.0	5.6	0.0	57.7	24.4	17.9
5	2.9	3.9	0.0	81.9	12.0	6.1
6	1.4	0.5	0.0	98.1	0.7	1.2
7	1.8	0.3	0.0	98.6	0.5	0.9
8	1.5	0.4	0.0	98.7	0.3	1.0
9	1.2	0.4	0.0	97.4	0.9	1.7
10	0.8	0.3	0.0	98.8	0.0	1.2
11	1.8	0.6	0.0	96.3	1.8	1.9
12	2.4	0.5	0.0	96.8	1.9	1.3
13	2.9	0.9	0.0	94.6	2.9	2.5
14	3.5	1.8	0.0	72.9	22.4	4.7
15	3.2	1.0	0.0	90.7	7.7	1.6
16	3.2	1.4	0.0	88.9	7.3	3.8
17	3.7	8.2	0.0	34.1	35.2	30.7
18	3.2	8.3	0.0	17.6	65.1	17.3
19	3.0	6.4	0.0	15.5	72.3	12.2
20	2.6	7.0	0.0	12.6	71.4	16.0
21	1.4	0.4	0.8	98.1	0.0	1.1
22	1.5	0.4	1.7	95.4	0.8	2.1
23	1.6	1.4	0.0	90.9	6.3	2.8
24	1.8	6.5	0.0	17.6	68.0	14.4
25	1.5	0.3	2.9	93.9	0.7	2.5
26	1.8	1.2	0.0	95.8	1.2	3.0
27	3.0	7.2	0.0	28.6	56.4	15.0
28	3.0	1.7	0.0	78.8	17.3	3.9
29	3.2	1.4	0.0	78.4	19.4	2.2
30	3.2	1.1	0.0	87.1	11.1	1.8
31	1.8	0.3	0.0	98.6	0.2	1.2
32	1.5	0.4	0.0	98.7	0.2	1.1
33	0.5	0.2	0.0	99.2	0.0	0.8
34	0.8	0.4	0.0	98.0	0.5	1.4
35	1.2	0.4	0.0	98.5	0.0	1.5
36	1.2	0.4	0.0	98.5	0.1	1.4
37	2.6	0.8	0.0	93.2	0.2	6.6
38	3.0	3.1	0.0	62.0	22.7	15.3
39	2.7	1.0	0.0	92.2	5.2	2.6
40	3.0	6.5	0.0	7.7	60.4	31.9
41	2.7	4.5	0.0	19.8	72.2	8.0
42	2.1	3.1	0.0	5.1	88.3	6.6

DATA FOR SURFICIAL SEDIMENTS (cont.)

Station Number	Depth (meters)	% Loss on Ignition	% Gravel	% Sand	% Silt	% Clay
43	2.1	6.5	0.0	8.5	79.2	12.3
44	1.8	0.6	0.3	94.4	1.9	3.4
45	1.7	10.1	0.0	23.3	58.8	17.9
46	1.2	0.5	1.8	95.5	0.7	2.0
47	1.5	1.4	50.0	43.1	4.0	2.9
48	1.8	0.8	2.5	86.8	5.1	5.6
49	1.7	0.6	27.2	68.8	0.6	3.4
50	2.4	4.3	5.1	9.4	78.4	7.1
51	2.4	2.9	0.0	12.8	78.3	8.9
52	2.7	2.8	0.0	26.3	54.0	19.7
53	3.0	3.5	0.0	51.9	47.5	0.6
54	3.4	2.8	0.0	50.0	43.7	6.3
55	3.4	1.6	0.0	67.0	29.4	5.6
56	3.4	1.3	0.0	82.9	14.0	3.1
57	3.4	1.6	0.0	81.9	14.6	3.5
58	2.3	0.4	0.0	98.3	0.4	1.3
59	2.3	0.6	0.0	95.3	1.1	3.6
60	3.1	0.4	0.0	96.7	0.0	3.3
61	1.8	0.4	0.0	97.7	0.9	1.4
62	0.9	0.2	0.0	99.0	0.0	1.0
63	0.9	0.7	0.0	96.3	1.4	2.3
64	1.2	0.7	0.0	95.4	2.1	2.5
65	1.5	1.2	0.0	93.2	3.5	3.3
66	0.5	0.6	0.0	95.4	0.0	4.6
67	2.4	0.8	0.0	97.0	1.2	1.8
68	2.9	2.4	0.0	59.2	35.5	5.3
69	2.3	3.8	0.0	20.8	71.4	7.8
70	1.2	0.4	10.0	88.6	0.1	1.3
71	0.8	0.5	0.1	97.8	0.7	1.4
72	0.9	0.8	33.7	63.2	0.0	3.1
73	0.6	0.7	1.5	96.1	0.6	1.8
74	0.8	1.7	1.6	89.1	1.8	7.5
75	2.3	4.7	0.0	12.4	78.2	9.4
76	2.7	1.7	0.0	64.4	32.1	3.5
77	2.4	0.6	0.0	90.2	3.9	5.9
78	2.7	1.8	0.0	77.8	17.0	5.2
79	2.0	0.8	0.0	92.2	1.6	6.2
80	1.5	0.7	0.1	96.1	1.6	2.2
81	0.8	0.7	0.0	97.9	0.0	2.1
82	0.9	0.4	0.0	98.5	0.3	1.2
83	0.9	0.4	0.0	98.6	0.5	0.9
84	1.2	0.9	0.0	96.5	1.2	2.3
85	1.8	0.5	0.0	97.3	0.9	1.8
86	2.6	1.4	0.0	84.4	12.5	3.1

DATA FOR SURFICIAL SEDIMENTS (cont.)

Station Number	Depth (meters)	% Loss on Ignition	% Gravel	% Sand	% Silt	% Clay
87	2.6	2.7	0.0	52.3	32.6	15.1
88	2.3	2.9	0.1	35.9	61.4	2.6
89	0.9	0.7	2.0	96.5	0.1	1.4
90	0.9	0.5	0.0	98.5	0.9	0.6
91	1.5	0.4	0.0	98.8	0.0	1.2
92	2.0	0.5	0.1	99.0	0.1	0.8
93	1.2	1.5	0.0	93.5	3.7	2.8
94	1.4	0.8	0.0	93.4	4.5	2.1
95	1.2	0.6	0.0	96.1	2.2	1.7
96	1.2	0.4	0.0	97.6	1.2	1.2
97	1.2	0.4	0.1	98.3	0.4	1.2
98	0.6	0.3	0.0	98.8	0.0	1.2
99	1.1	1.3	0.0	94.4	3.6	2.0
100	1.1	0.5	1.7	96.2	0.7	1.4
101	0.9	0.7	1.5	96.1	0.7	1.7
102	1.8	0.9	1.2	90.8	5.4	2.6
103	2.0	0.9	0.0	94.4	3.0	2.6
104	1.2	1.6	0.0	95.3	0.0	4.7
105	0.6	0.4	0.0	98.4	0.8	0.8
106	0.6	0.4	0.0	99.6	0.4	0.0
107	0.8	0.4	0.0	99.2	0.0	0.8
108	0.8	0.4	0.0	98.2	0.6	1.2
109	2.1	0.6	0.0	94.7	4.8	0.5
110	1.7	0.6	0.6	97.9	0.8	0.7
111	1.5	2.4	0.5	80.2	9.7	9.6
112	2.1	6.2	0.0	13.9	70.8	15.3
113	2.4	3.2	0.0	32.9	58.4	8.7
114	0.8	0.5	0.0	97.9	0.6	1.5
115	0.6	0.5	0.9	97.3	0.5	1.3
116	0.5	0.4	0.0	98.6	0.5	0.9
117	1.4	0.4	0.1	97.9	0.4	1.6
118	1.8	1.0	0.0	91.4	5.4	3.2
119	2.0	3.2	0.0	46.7	44.0	9.3
120	2.0	4.8	0.0	12.9	71.8	15.3
121	1.4	2.7	0.3	76.9	12.6	10.2
122	1.2	1.0	3.4	93.2	1.8	1.6
123	1.2	1.3	0.4	89.9	4.6	5.1
124	2.1	6.2	0.0	18.4	71.1	10.5
125	1.8	3.7	0.0	38.5	53.1	8.4
126	2.0	2.0	0.0	71.0	19.8	9.2
127	0.6	0.3	0.0	97.4	1.0	1.6
128	0.5	0.5	0.0	96.8	1.6	1.6
129	0.6	1.6	0.0	93.3	3.5	3.2
130	0.9	0.8	0.0	90.7	7.5	1.8

DATA FOR SURFICIAL SEDIMENTS (cont.)

Station Number	Depth (meters)	% Loss on Ignition	% Gravel	% Sand	% Silt	% Clay
131	0.5	0.7	0.0	97.3	0.9	1.8
132	0.9	1.0	0.0	92.0	4.9	3.1
133	1.4	2.6	0.0	76.7	19.0	4.3
134	1.5	1.4	0.0	93.4	3.5	3.1
135	2.3	7.4	0.0	6.4	72.9	20.7
136	2.3	6.8	0.0	12.7	72.7	14.6
137	1.5	0.6	0.0	96.8	1.0	2.2
138	1.2	4.6	13.4	55.5	16.2	14.9
139	0.9	1.1	3.3	89.2	5.5	2.0
140	1.5	3.1	0.0	35.1	56.5	8.4
141	1.5	2.2	0.0	80.7	16.2	3.1
142	1.2	1.4	0.0	87.1	9.0	3.9
143	0.3	0.8	0.0	95.3	3.5	1.2
144	0.5	0.4	0.0	98.7	0.0	1.3
145	0.6	0.9	0.0	93.0	4.4	2.6
146	0.3	0.4	0.3	97.1	0.4	2.2
147	0.6	2.0	0.2	93.5	2.1	4.1
148	1.2	0.3	0.0	98.9	0.3	0.8
149	1.2	1.1	0.3	87.5	8.1	4.1
150	1.5	0.7	0.0	5.5	63.9	30.6
151	0.5	1.0	0.4	91.2	5.3	3.1
152	1.2	8.9	0.0	19.1	63.1	17.8
153	1.2	4.0	0.2	33.6	55.9	10.3
154	0.8	1.0	8.3	88.3	1.8	1.6
155	1.2	12.0	0.0	5.4	71.0	23.6
156	1.2	10.7	23.3	74.4	1.1	1.2
157	2.4	14.8	0.6	22.4	54.7	22.3
158	0.9	1.7	0.0	94.9	4.0	1.1
159	2.4	10.2	1.8	78.3	10.2	9.7
160	2.3	4.9	0.0	63.5	25.5	11.0
161	2.4	31.4	0.0	12.9	52.7	34.4
162	2.4	34.4	0.0	8.0	49.3	42.7
163	2.3	12.4	0.0	22.0	51.6	26.4
164	2.0	4.3	0.0	31.6	59.4	9.0
165	2.4	0.4	0.4	98.8	0.0	0.8
166	2.4	7.6	0.0	32.7	59.7	7.6
167	0.6	18.0	0.0	1.6	74.1	24.3
168	1.8	22.9	0.0	12.8	51.1	36.1
169	2.0	21.6	0.0	1.2	65.0	33.8
170	1.5	21.6	0.0	27.1	39.3	33.6
171	1.4	21.4	0.0	2.4	59.5	38.1
172	2.4	18.3	0.0	3.1	52.5	44.4
173	2.4	30.2	0.0	5.6	41.5	52.9
174	2.7	22.6	0.0	2.4	41.9	55.7

DATA FOR SURFICIAL SEDIMENTS (cont.)

Station Number	Depth (meters)	% Loss on Ignition	% Gravel	% Sand	% Silt	% Clay
175	2.7	21.6	0.0	2.8	43.6	53.6
176	3.4	14.4	0.0	2.5	68.3	29.2
177	2.4	11.0	0.0	41.1	29.8	29.1
178	3.7	16.6	0.0	17.4	42.2	40.4
179	1.7	13.1	0.0	7.1	73.6	19.3
180	1.5	16.6	0.0	5.1	54.2	40.7
181	1.8	13.7	0.0	3.4	71.5	25.1
182	1.5	15.7	0.0	3.4	61.1	35.5
183	0.8	0.3	0.5	98.6	0.3	0.6
184	2.0	2.3	5.2	74.5	10.8	9.5
185	2.0	7.3	0.0	27.5	54.5	18.0
186	2.0	6.9	0.0	12.6	67.7	19.7

APPENDIX 2

SPECIES CONTRIBUTING TO THE SHELL FRACTION OF SEDIMENTS

	Species	Common Name	No. of Sta. Present
1.	*Ensis directus*	Atlantic jacknife clam	42
2.	*Mulinia lateralis*	Duck clam	40
3.	*Crepidula fornicata*	Atlantic slipper shell	18
4.	*Gemma gemma*	Amethyst gem clam	16
5.	*Mercenaria mercenaria*	Hard clam	11
6.	*Hydroides hexagonus*	Worm shell	9
7.	*Nucula proxima*	Atlantic nut clam	8
8.	*Ilyanassa obsoleta*	Eastern mud nassa	6
9.	*Tellina agilis*	Northern dwarf tellin	6
10.	*Crassostrea virginica*	Eastern oyster	5
11.	*Nassarius yibex*	Common eastern nassa	5
12.	*Anomia simplex*	Atlantic jingle	4
13.	*Bittium alternatum*	Alternate bittium	4
14.	*Lyonsia hyalina*	Glassy lyonsia	4
15.	*Urosalpinx cinera*	Atlantic oyster drill	3
16.	*Mya arenaria*	Soft clam	3
17.	*Crepidula plana*	White slipper shell	3
18.	*Eupleura candata*	Sharp ribbed drill	3
19.	*Laevicardium mortoni*	Morton's egg cockle	2
20.	*Aequipecten irradians*	Atlantic bay scallop	2
21.	*Nassarius trivittatus*	New England nassa	2
22.	*Marginella borealis*	Margin shell	2
23.	*Petrocola pholadiformis*	False angel wing	1
24.	*Crepidula convexa*	Convex slipper shell	1
25.	*Turbonilla interrupta*	Interrupted turbonille	1
26.	*Mytilus edulis*	Blue mussel	1
27.	*Mitrella lunata*	Lunar dove shell	1

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