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**Estuarine Resources of the Fire Island
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New York Sea Grant

Cornell University • State University of New York • NOAA

**ESTUARINE RESOURCES OF THE
FIRE ISLAND NATIONAL SEASHORE AND VICINITY**

A FINAL REPORT

**Prepared by the
New York Sea Grant Institute**

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from the National Park Service.**

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EXECUTIVE SUMMARY

The goal of this project was to assemble and synthesize information on the estuarine natural resources of the Fire Island National Seashore (FINS) to assist the National Park Service in the development of an estuarine habitat monitoring and research program for the FINS. A team of technical experts reviewed available information in each of five subject areas: the physical environment/coastal processes, water column productivity/ecology, aquatic vegetation, shellfish/benthic invertebrates, and finfishes. Experts were asked to identify the ecologically and economically important estuarine resources and to present information and data for each subject area in a habitat context. This format was used in order to assist the National Park Service in formulating technically-sound, habitat-specific monitoring and management plans. In addition to reviewing all pertinent information, the technical experts attempted to identify data gaps and monitoring needs, research opportunities, and potential critical resource habitat issues and impacts. Their findings were reviewed and presented at a workshop attended by other local experts and local, state, and federal agency and government representatives. This report was revised based on discussions at the workshop and additional written comments provided by participants and others.

That estuarine portion of the FINS in Great South Bay (GSB) contains plankton, aquatic vegetation, benthic organisms, and finfish distributed among a range of estuarine habitats including the shoreline, marshland, eelgrass beds, and shoals. The distribution and status of these resources are generally known for GSB as a whole, but most of the available data has been collected from outside the FINS area or extrapolated from similar environments elsewhere. The following represent selected highlights regarding these resources and their habitats.

- The phytoplankton species composition is similar to other lagoon estuaries, with small forms ($<5\ \mu\text{m}$) usually predominant.
- Although the bay has been classed as potentially highly susceptible to eutrophication and chronic algal blooms, dramatic and unusual blooms are the exception rather than the rule in the bay.
- The important submerged aquatic vegetation found in the bay consists primarily of the macroalgal species *Enteromorpha* spp., *Ulva lactuca*, *Cladophora gracilis*, and *Codium fragile* and the eelgrass *Zostera marina*.
- There have been great fluctuations in eelgrass populations within the bay. It is not clear whether a decline between the late 1960's-70's and 1985-86 was due to brown tide blooms or to a more gradual, ongoing loss. Despite the decline, extensive populations were found more recently in the shallow southern portion of the bay.
- The sediments within the FINS are primarily sandy, and two distinguishable benthic species assemblages are present: high salinity fauna (e.g., blue mussel, hermit and lady crab, starfish) associated with the inlets, and a lower salinity fauna (e.g., hard clam, whelk, gem shell, mysid and sand shrimp, blue crab) found elsewhere. Densities of legal size hard clams were generally <2 per m^2 within the FINS boundaries.

- While there is no evidence of drastic differences in benthic species composition between 1938 and the 1980's, landings information in GSB show major declines for oyster and hard clam, but increases for conch, blue crab, and mussel. It is not clear whether the increased landings for the latter three species reflect abundance changes or simply represent changes in harvesting patterns.
- In terms of economic value, the bay does not by itself represent a major portion of New York's commercial finfish landings. Data on the recreational fishery suggest that fluke, winter flounder, and bluefish remain among the top species landed. GSB has had historically high catches of flatfishes. Presently, flounders in the bay are more likely to be limited by overexploitation than by habitat. There are no endangered fish species that rely on the bay as a principal habitat.
- The overwhelming environmental factor affecting fishes in the bay is temperature. Variations in salinity probably have little influence on the major fishes of the bay. Because the bay is so shallow, dissolved oxygen levels are unlikely to drop so low as to negatively affect fishes to a measurable degree.

The general level of understanding of the distribution and status of these resources, however, is probably not sufficient for many management decisions. Site-specific information on all aspects of the estuarine resources are needed within the boundaries of the FINS, and the expression of local processes influencing these resources need to be quantified. The following specific information needs were identified.

A comprehensive inventory is needed of shoreline environments on a small scale. The north shore of Fire Island is a mosaic of beaches, coves, marshlands, dredged basins, and armored shorelines. To assess impacts and trends, site-specific studies of the local hydrography are required in sufficient detail to resolve these various shoreline classes. High resolution data on sediment types, sediment transport, shoreline changes, and physical forcings are needed as is detailed information on the groundwater hydrography and pollutant inputs along the bay shore. Measurements of turbidity, quantifying the relative contribution of natural and human sources, can be used to assess the significance of these sources on the bay's ecology.

The effect of inlets and the impacts associated with new inlets are important topics for the preservation and management of the FINS aquatic resources. Studies are urgently needed to assess the potential for breaches in the barrier island and to understand the behavior of new inlets. Models predicting impacts of inlet formation and inlet longevity would provide information needed to properly manage these features. Inlets serve as pathways for a significant portion of the sediment supply to the bay. The processes associated with these features can also result in the alteration of habitats. Inlets also reduce the sand supply to downdrift beaches, increase the bay tidal range and salinity, and increase the flushing of bay waters. Inlets in the FINS area would, therefore, have important impacts not only on FINS resources but also on the entire region. These impacts need to be quantified with assessment of relative environmental costs and benefits.

On-going water quality monitoring programs conducted elsewhere in GSB should be expanded to include sites within the FINS and assess additional measures of eutrophication including chlorophyll, light attenuation, nutrients, and groundwater seepage. In conjunction with an expanded monitoring program, inventories of important phytoplankton and zooplankton species (including *Aureococcus anophagefferens*, the brown tide organism) should also be assessed at selected sites on a seasonal basis. Seaweeds need to be described both qualitatively (i.e., species present and distribution) and quantitatively (i.e., abundances and seasonal variation) for their importance as habitat and as indicators of eutrophication. Annual surveys of the extent of seagrass beds, as well as monthly surveys of bottom irradiance, would document long-term changes in water quality and the health of this important habitat. Other research opportunities identified include: the role of micronutrients in bloom formation; understanding the nutritional status of seaweeds and their response to light limitation; and the response of opportunistic green algae to increased nutrients and light.

Populations of benthic resources, including shellfish, need to be assessed in each of the major habitats within the FINS. Information on benthic populations is particularly lacking from salt marshes and intertidal beaches. In addition to characterizing the resource, assessment of benthic populations in relation to water quality monitoring could indicate whether or not changes in water quality were affecting the living resources of the FINS. Surveys of commercial and recreational fisheries conducted by Briggs in the late 1950's need to be updated. The role of eelgrass beds and other vegetated and non-vegetated bottom habitats in supporting the recruitment of fish also needs to be quantified.

The work described above would significantly improve the understanding the estuarine resources of the FINS and help guide future management decisions. In addition, the presence of relatively undisturbed and protected habitat within the FINS makes it an ideal location as a reference site for the investigation of animal-habitat relationships and the effects of human activities on estuarine resources.

I. INTRODUCTION

The National Park Service (NPS) is in the process of developing a long-term estuarine habitat inventory, research, and monitoring program for the estuarine natural resources within the boundaries of the Fire Island National Seashore (FINS). The Park boundaries extend up to 4,000 feet into Great South Bay (GSB) from the north shore of Fire Island (Figure 1). The purpose of this project is to identify and describe the important species and habitats in this area and to identify potential impacts to these resources due to both natural processes and human activity.

The first step in this process was to assemble the existing technical and scientific information on estuarine resources in this area, and to identify the data gaps that need to be filled to better understand and manage these resources. This document provides a review of the information on the estuarine resources in the vicinity of the FINS according to resource type and habitat. First, previous and on-going studies concerning the living marine resources and coastal processes are briefly summarized. Ecologically and economically important species are identified. Next, the various marine habitats are characterized in terms of their physical environment, living marine resources found in the habitat, and the critical environmental parameters controlling the abundance and distribution of these resources. Finally, data gaps and monitoring needs, opportunities for research, and potential impacts are identified. Appendix I contains all figures and tables referenced in the text. The question of jurisdiction over resources in the FINS and activities which may affect FINS resources are beyond the scope of this project, and are not discussed. These issues will need to be resolved, however, before a comprehensive management plan for the FINS can be adopted.

The following people provided the information presented in this report: D. Conover, finfish; R. Cerrato, shellfish and benthic invertebrates; V. Gerard, aquatic vegetation; E. Cosper, water column productivity and ecology; and H. Bokuniewicz and J. Tanski, coastal processes. The manuscript was compiled and edited by H. Bokuniewicz, A. McElroy, C. Schlenk, and J. Tanski. A draft of this report was distributed for review by local, state, and federal agency and government representatives as well as local scientists, most of whom participated in a workshop held on January 28, 1993 (see Appendix II). This final report has been revised based on written comments received and discussion at the workshop.

II. MAJOR STUDIES OF FINS ESTUARINE RESOURCES

A. PREVIOUS STUDIES

Many excellent studies have been conducted in or near the FINS. Even though each study had its own specific objectives, covered its own particular area of interest which often was not within the boundaries of the FINS, and, in some cases, was conducted decades ago, the results in aggregate provide the best possible characterization of the area. This section summarizes the major original works and technical syntheses.

1. Physical Environment/Coastal Processes

Articles and reports, including studies concerning the coastal processes, are summarized in the "History of Scientific Research for Fire Island National Seashore, Volumes I and II" (Renwick 1992). Most of the data and information on coastal processes available for the Fire Island area are the result of studies done by or for the U.S. Army Corps of Engineers (USACE) as part of their hurricane protection, beach erosion, and navigation projects, especially those done in conjunction with the development and reformulation of the USACE's Fire Island Inlet to Montauk Point beach erosion control and hurricane protection project. As the name implies, however, the focus of that effort was the ocean shoreline rather than the bay shoreline and submerged bay bottom that is of concern to this report. The regional coastal processes discussed in the earlier reports are processes that also influence the bay shore. However, the bay shore is geomorphically diverse so that waves and tidal action provoke differing shoreline responses over relatively short distances. Presently, there is a shortage of information concerning site-specific coastal dynamics from place to place along the bay shore.

Two reports prepared in association with the USACE projects provide relatively comprehensive information regarding coastal erosion processes and encompass earlier studies on this topic. These are: "Geomorphic Analysis, Fire Island Inlet to Montauk Point, Long Island, New York" (Leatherman and Allen 1985) and "Sediment Budget Analysis Summary, Fire Island Inlet to Montauk Point, NY" (Research Planning Institute, Inc. 1985). Both studies focus on the Atlantic Ocean nearshore system but also include incidental information on historical shoreline changes and sedimentation on the bay shore. The latter study included beach and shoreface profiles in addition to shoreline changes to calculate various elements of the sand budget. More recent analyses are not available, but it is reasonable to assume that the general processes proceed at rates that only change very slowly. Unfortunately, updating the studies of shoreline change would be hampered because the original data has apparently been lost (J. Allen, NPS, personal communication). A comprehensive overview and assessment of the coastal processes data and information available for the south shore of Long Island is contained in Tanski et al. (1990).

The hydrology, geology, and oceanography of the GSB is summarized in "The Great South Bay" (Schubel et al. 1991). This book does not contain new data but relies on the aggregation of earlier studies. Notable among these data sources are the studies of surficial sediments by Jones and Schubel (1980), the bay's response to meteorological tides by Wong and Wilson (1985), the results of finite element numerical models looking at potential changes in hydrodynamics and salinity in the bay in response to inlet configuration changes by Pritchard and Gomez-Reyes (1986) and Zarillo et al. (undated), and the groundwater hydrography by Bokuniewicz and Zeitlin (1980) and Bokuniewicz and Pavlik (1990). These studies not only present new results but summarize the relevant findings of previous investigators. Hollman and Thatcher (1979) also conducted studies using a spatially integrated numerical model of tidal hydraulics to assess potential changes in salinity in GSB related to sewerage of Long Island. The information provided by these studies, however, does not differentiate between the various subenvironments along the bay shore.

2. Water Column Productivity/Ecology

The plankton of GSB have been investigated since the beginning of the century (Whipple 1912), and important published studies describe the major aspects of the plankton ecology of GSB during this century. No studies have been conducted specifically within the FINS. In many instances, studies have resulted in unpublished reports to government agencies or unpublished Master's theses which must be obtained from the source (the agency or university library). However, the citations are extensively listed in the bibliography compiled for the FINS (Claxon 1992).

In the 1950's, researchers from the Woods Hole Oceanographic Institution were enlisted by the Townships of Islip and Brookhaven to investigate plankton and nutrients in GSB and Moriches Bay because of intense microalgal blooms called "green tides" (Ryther et al. 1956, 1957, 1958; Guillard et al. 1960). Ryther (1954, 1989) detailed research concerning the causes of these green tides. During the 1960's and 1970's several studies investigated the plankton dynamics, primary productivity and nutrient characteristics of GSB, the most notable of which are: Mandelli et al. (1970), Hair and Buckner (1973), Weaver and Hirschfield (1976), Cassin (1978), Lively et al. (1983), and Kaufman et al. (1984). Extensive species lists and enumeration on a seasonal basis at sites throughout the bay are to be found in Lively et al. (1983) for phytoplankton and at Fire Island Inlet for phytoplankton and zooplankton in Weaver (1974).

Dense algal blooms called "brown tides" were observed in GSB from 1985 to 1987, and resulted in numerous investigations continuing to the present time. Much of the research was compiled and summarized by Cosper et al. (1989a, 1990). Reviews of the literature on water quality and on primary production and nutrients have been prepared by Dennison et al. (1991) and Carpenter et al. (1991), respectively. The first extensive and comprehensive studies of zooplankton and ichthyoplankton in GSB were also conducted at this time by

Monteleone (1988, 1992), Duguay et al. (1989), and Caron et al. (1989), who were the first to establish the importance of microzooplankton in consuming the dominant small microalgal forms in these bays.

3. Aquatic Vegetation

Macroalgae. GSB has a limited amount of hard substratum and, therefore, limited habitat for seaweeds. There have been few studies of GSB specifically focused on seaweeds, most of which occur as free-floating mats or epiphytes on eelgrass. Early floristic studies of Long Island included very limited collections in GSB, and none along the southeastern shore of GSB (Pike 1886, Taylor 1940). The most comprehensive study of seaweeds in GSB was done by Koetzner (1963), who surveyed the entire bay during June through August 1963. Koetzner found 25 species, primarily green (Chlorophyta) and red (Rhodophyta) algae, five of which occurred within a mile of the Fire Island shore (*Enteromorpha* spp., *Ulva lactuca*, *Sphacelaria cirrosa*, and *Champia parvula*). Burkholder and Doheny (1963) reported six species of green and red macroalgae growing epiphytically on eelgrass in western GSB (*Ulva lactuca*, *Cladophora gracilis*, *Chaetomorpha linum*, *Agardhiella tenera*, *Champia parvula*, and *Polysiphonia harveyi*). Briggs and O'Connor (1971) recorded macroalgae associated with eelgrass and unvegetated areas of southwestern GSB. In addition to *Ulva* and *Cladophora*, they reported seasonally high abundances of the brown alga *Punctaria latifolia*. Also, it is likely that the brown algae *Fucus vesiculosus* and *Ascophyllum nodosum* occur in the salt marshes at the FINS, although their presence has not been reported in the literature.

Seagrasses. The southeastern portion of GSB adjacent to the FINS consists primarily of shallow (<2 m deep), sand-bottom habitat (Jones and Schubel 1980) which supports extensive areas of seagrass. Eelgrass, *Zostera marina*, is the dominant species, while widgeongrass, *Ruppia maritima*, occurs only in small patches at very shallow sites. Numerous investigators, including Wilson and Brenowitz (1966, cited in Henrickson and Eisel 1973), Greene et al. (1977), Elder (1976, cited in Jones and Schubel 1978), Jones and Schubel (1980), and Carpenter et al. (1991), published surveys of eelgrass distribution in various locations of GSB over the period 1966-1978.

The New York State Department of Environmental Conservation (NYSDEC) used aerial photography to survey eelgrass meadows in 1967, but the results were not published (Dennison et al. 1989; K. Koetzner, NYSDEC, personal communication). During 1980-1981, A.C. Churchill of Adelphi University and B.H. Brinkhuis of SUNY Stony Brook attempted to survey eelgrass meadows in GSB using aerial photography and ground verification. The method was successful in delineating eelgrass meadows, but did not provide accurate estimates of grass density. Analysis of the aerial photographs was never completed, and the photographs have since disappeared (A.C. Churchill, Adelphi University, personal communication). In addition, several of Churchill's students studied seed production and dispersal by eelgrass at Smith Point (Gates 1984, Churchill et al. 1985).

Salt Marshes. O'Connor and Terry (1972) mapped the marine wetlands of Nassau and Suffolk Counties in 1972, including those of Fire Island. McCormick and Associates, Inc. (1975) classified wetlands at the FINS from 1973 maps into types, including low tidal marsh, high tidal marsh, and upland fringe (summarized by National Park Service 1992). In 1974, the NYSDEC took aerial photos of all of the coastal wetlands on Long Island, collected ground-truth information, and made maps delineating low and high marsh areas. These maps are available for use at the NYSDEC offices in Stony Brook. The FINS area marshes are covered in more than a dozen maps which were too large to include in this report. The NYSDEC took a new set of aerial photos for wetland delineation in 1989. These photos are currently being analyzed and ground-truthed. Unfortunately, photos of the FINS marshes will probably not be analyzed until at least 1994 (D. Fallon, NYSDEC, personal communication). New aerial photos are scheduled to be taken in 1994 and annually thereafter. Another set of aerial photos was taken around 1985, as part of the U.S. Fish and Wildlife Service's National Wetlands Inventory and are available as maps. Additional maps can be found in the Final Environmental Statement for FINS (National Park Service 1977a) and the environmental report for Nassau/Suffolk Water Quality Management (Beck et al. 1978).

4. Shellfish and Benthic Invertebrates

With only three exceptions, no major benthic or shellfish studies have been carried out within the boundaries of the FINS. The exceptions are WAPORA, Inc. (1982), a survey of hard clams and hard clam predators throughout GSB, and two benthic studies of Moriches Bay (O'Connor 1972, Cerrato 1986). A number of major studies have been conducted outside of the boundaries of the FINS and are important in characterizing the benthic fauna and shellfish resources of GSB. These include Marine Sciences Research Center (1973), Wiggins (1986), Buckner (1984), and Kassner et al. (1991). The latter two citations describe annual hard clam surveys conducted by the Towns of Islip and Brookhaven, respectively. In reviewing these studies, it is important to take into account the sampling approach and the type of sampling gear utilized, as this affects the precision of the population analysis and type and size of organisms collected.

WAPORA, Inc. (1982) collected shellfish samples throughout a 214 km² area of bay bottom between the Meadowbrook Parkway in Merrick and Smith Point in Shirley. The primary goals of the study were to assess hard clam abundance and shellfish predators in GSB and to identify factors controlling the distribution of clams in the bay. Shellfish were sampled with both modified commercial clamming tongs and a suction dredge. Commercial clamming tongs were modified to catch shellfish over 15 mm in width. Tong samples covered an area of approximately 3.4 m², and four replicates were taken at each survey station. Suction-dredge samples were collected by SCUBA divers and were used to obtain macrobenthic animals greater than 1 mm in size. Three dredged samples were taken at each station. Each sample was 0.16 m² in area. A total of 392 stations were sampled from June

to November 1978. Of these, 72 stations were located within the boundaries of the FINS (Figure 2). Additionally, 17 detailed plot stations distributed throughout GSB were sampled by WAPORA, Inc. (1982). Six of these stations were within the boundaries of the FINS (Figure 3). Detailed plots were sampled in May-June and November 1978. A total of 20 tong and 5 dredged samples were collected at each station during each sampling date.

O'Connor (1972) conducted a quantitative study of the benthic fauna of Moriches Bay. In his study, bottom samples were collected between April 1969 and June 1970 using a 0.05 m² Ponar grab. Two replicate samples were taken at each of 72 stations (Figure 4). Samples were washed through a 1 mm mesh screen. Station locations were distributed for the most part randomly throughout the bay. Sixteen of the sampling stations fall within the boundaries of the FINS.

Cerrato (1986) collected quantitative benthic samples seasonally at 11 stations in Moriches Bay (Figure 5). Samples were obtained in May, August, and November 1981 and in May 1982. Winter sampling was not possible because of ice. Benthic samples were taken with a 0.04 m² Shipek grab. Three replicates per station were collected on each sampling date, and each sample was wet-sieved through a 1 mm diameter Nitex screen. Three of the sampling stations were located within the boundaries of the FINS.

Other major studies in GSB, while important in characterizing the benthos and shellfish of the bay, have not been conducted within the FINS's boundaries. One of these, carried out by the Marine Sciences Research Center (1973), sampled the benthic fauna in western GSB between May and October 1972. Twenty-two grab sample stations were located in western GSB; all of these locations were west of Fire Island Inlet. Sampling was carried out by collecting unreplicated 0.05 m² weighted Ponar grabs. Samples were washed through a 1 mm screen. Open bay stations were primarily fine-grained and not similar to the subtidal sand flats near the FINS. Sampling was also conducted in eelgrass beds, and these stations were more comparable to the habitat found near the FINS.

Wiggins (1986) characterized the benthic fauna in Patchogue Bay in a nearshore region ranging from east of the Patchogue River to Hedges Creek (Figure 6). Sampling was carried out in October and December 1984 and June 1985. Three replicate bottom samples were collected using a 0.04 m² Ponar grab, and samples were sieved through a 1 mm mesh screen. Although Wiggins' study area is relatively far from the FINS, and based on its nearshore location the benthic fauna has been no doubt heavily influenced by development, it is nonetheless important because it contains the only seasonal data for the benthos in GSB.

Buckner (1984) carried out a major study of the population dynamics of hard clams in the Town of Islip waters during 1978 and 1979. The 6,000 hectare (ha) study area was divided into 400 m by 400 m grid units, and sampling stations were located randomly within each unit (Figure 7). Duplicate samples using a 1 m² clamshell bucket were collected at each

station. Samples were washed through a 6.4 mm screen, and the number and sizes of all live clams and articulated valves recorded. A subsample of clams was collected for microgrowth analysis. During 1978, a total of 349 stations were sampled, and samples were collected at 354 stations in 1979. All sampling stations were to the north of the FINS's boundary.

Kassner et al. (1991) reported the results of a hard clam census that has been undertaken annually from 1986 within an approximately 4000 ha area located in the Town of Brookhaven and lying between Blue Point and Howell's Point in the north and extending southward almost to Fire Island (Figure 8). A grid array and stratified random sampling scheme was adapted from the method first described by Buckner (1984). The study area (Figure 8) was divided into a fixed grid of 232 units measuring approximately 400 m on a side (17 ha). Because of shallow depths, sampling was not carried out in this study within the boundary of the FINS. During each annual census, sampling stations were chosen randomly within a unit. At each station, two replicate bottom grabs were taken using a 1 m² commercial clamshell bucket. For the 1986 and part of the 1987 censuses, each grab was washed through a 12 mm screen; but, since 1987, a 6 mm screen has been used. Shell length and width were measured on all clams collected. A random subsample of clams was retained for later cross-sectional analysis of age and growth. Associated shell microgrowth studies and additional analyses of the census data have been presented by Cerrato and Wallace (1989) and Wallace (1991).

A number of studies which are not of major significance in characterizing the benthos and shellfish of the FINS should be mentioned briefly for completeness. The earliest study of the benthos in Long Island waters was probably that of Townes (1939). This study is of very limited value, however, since Townes pooled his results from all of the marine waters of Long Island, used a variety of sampling devices (grabs, trawls, and seines), and did not report sampling locations. Only 33 of the 169 taxa listed by Townes were explicitly reported as being found in GSB. A number of species were listed as being common "in the bays" or widespread in Long Island waters, and so it is likely that many of these were collected in GSB. Unfortunately, which of these species were actually present cannot be determined.

In other studies, Neville and Bevelander (1941) describe the shrimp bait fishery in the region near Fire Island Inlet and report the catch in a shrimp trawl survey conducted from May to September 1940. Briggs (1975a) lists invertebrates caught in pots at the artificial reef off Kismet. Beck et al. (1978) report three benthic species lists in an appendix to their water quality environmental report. One list is reprinted from Townes (1939). The other two species lists, one of GSB and the other listing species from East and West Fire Islands along with other south shore areas, were compiled by M. Hair of Adelphi University. No further information on sampling methods was provided by Beck et al. (1978). Hanlon (1983) collected benthic invertebrates in GSB by "drag" and Ponar grab sampler. No station locations were reported. Results are listed as the total number of individuals collected in sand and sandy-mud substrates.

Croker (1970) sampled the intertidal beach fauna at 17 localities distributed primarily along Long Island's south shore and Peconic Bay. His study included both bay and ocean sampling sites. Three to five replicate 0.1 m² sand samples were collected in each of three tidal levels (high, mid, and low) at each site. Samples were washed through a 1.5 mm screen. Of Croker's sampling sites, only four are located near the FINS: two in Fire Island Inlet, one in South Oyster Bay, and one in Narrow Bay. This reference is of very limited value since it does not readily distinguish between ocean and bay habitats, nor does it report the raw data by stations. However, it represents the only local characterization of intertidal beach fauna.

The NYSDEC has sampled hard clam populations in GSB by hydraulic dredge (Fox 1979, 1982). In these two studies only two sampling locations were within the boundaries of the FINS. These stations were sampled in spring and fall during 1979-1981 (Fox 1982). Data consist of the number and size distribution of collected individuals.

Finally, a number studies of hard clam ecology have been carried out in GSB. These have detailed predation by ctenophores on larvae (Quaglietta 1987), quantified fecundity and the reproductive cycle (Bricelj 1979, Kassner 1982), assessed heavy metal depuration (Behrens 1978), and measured age structure, growth, and mortality (Greene 1978).

5. Finfishes

Very few studies of fishes have been focused specifically within the boundaries of the FINS. Most fish investigations in GSB have been conducted either to the west of the park in the region of Fire Island Inlet or have sampled areas throughout the bay, but some do include sampling locations within the park (Table 1). Hanlon (1983) states that the majority of GSB sites in his study were on the Fire Island shore, but he does not provide the specific locations where sampling was conducted. For this reason, we describe the finfish resources of the FINS based upon the much larger set of studies that have been conducted in various regions of GSB beginning in 1938. Given the highly migratory and transient nature of most marine fishes in the mid-Atlantic region, these studies are likely to provide a fairly accurate representation of the fishes found in various habitats within the FINS.

The major sources of information on the distribution and abundance of fishes by habitat are Briggs and O'Connor (1971), on shore-zone fishes from naturally vegetated vs. sand-filled areas, and Hanlon (1983), who provides extensive tables on the combined catches from otter trawls and beach seines in GSB, Moriches Bay, and Shinnecock for nine different types of habitats (Table 2). Little is known of the present abundance of major species by habitat in GSB. The last major inventory of GSB fishes was completed over a decade ago (Hanlon 1983).

Ichthyoplankton Survey. Temporal and spatial surveys of fish eggs and larvae in the plankton are an especially valuable source of information because they indicate not only the presence or absence of various species, but also their spawning times and locations. The first comprehensive survey of the ichthyoplankton of Long Island waters, including GSB, was that of Perlmutter (1939, Table 1). Later surveys of GSB encompassing at least part of each season of the year were conducted by Miller (1977) and Monteleone (1988, 1992). Shima and Cowen (1989) described the summer ichthyoplankton of the bay.

Juvenile/Adult Surveys. The primary surveys of juvenile and adult fishes in GSB (see Table 1) are those of Gaw (1972), Briggs and O'Connor (1971), Schreiber (1973), Briggs (1975b), and Hanlon (1983). The most comprehensive studies of the shore zone were those of Briggs (1975b), who collected 57 fish species in Fire Island Inlet, and Briggs and O'Connor (1971), who recorded 40 fish species from the vicinity of Captree Island. Hanlon (1983) provides the most complete coverage of GSB as a whole, including fishes collected by beach seining (772 seine hauls), trawling (561 tows), and gillnetting (67 sets) during March through November 1981 (includes sampling effort in Moriches Bay and Shinnecock Bay).

B. ONGOING WORK

1. Physical Environment/Coastal Processes

Presently there are no large-scale investigations concerning coastal processes being conducted in the study area. No data sets have been produced on a regional level that would substantially add to the information summarized in the above mentioned reports. The NPS is in the process of conducting several intensive, site-specific, but isolated, investigations of sediment transport processes and bayside erosion related to storms and boat wakes (Jackson et al. 1993, Sherman et al. in review). These investigations include a 22-day time series of bayside beach processes conducted in the spring of 1992. Measurements were taken of beach form change, wind field, water levels, wave characteristics, and currents at a site west of Sailor's Haven. Sediment tracer studies were also conducted. However, the results of these efforts will not be published until later this year and are not generally available at this time. Although the USACE monitors conditions (primarily bathymetry) around their project sites, these areas are outside of the FINS's boundaries.

2. Water Column Productivity/Ecology

Since 1985 when the first brown tide blooms occurred, Suffolk County has been conducting a monitoring program both in the Peconic Bay system as well as GSB, Moriches Bay, and Shinnecock Bay (Nuzzi and Waters 1989). This program has now developed into the Brown Tide Comprehensive Assessment and Management Program conducted by the Suffolk County Department of Health Services which monitors not only brown tide cell

densities, but also standard water quality variables including concentrations of major nutrients, coliforms, and certain pesticides.

A recently completed study by E. Cosper and D. Lonsdale at SUNY Stony Brook investigated the coupling between phytoplankton productivity and zooplankton dynamics in GSB. Additionally, another project by Cosper, Lonsdale, and E. Carpenter has recently begun, looking at how various environmental factors may enhance brown tide blooms in GSB.

3. Aquatic Vegetation

Discussions with K. Koetzner (NYSDEC) and local phycologists, L. Liddle (Southampton College) and H. Moeller (Dowling College), indicated that no studies are currently being undertaken of seaweeds in GSB.

Discussions with V.M. Bricelj (SUNY Stony Brook), A.C. Churchill (Adelphi University), and S. Tettelbach (Southampton College) indicated that no studies are currently being carried out on the seagrass meadows along the southeastern shore of GSB.

Although the FINS general management plan included a long-term program of tidal marsh research (National Park Service 1977b), and the workshop on salt marsh restoration made extensive research recommendations (Roman 1988), there is no evidence in the published or available gray literature that either plan was carried out. Discussions with C. Hamilton, D. Ninivaggi, D. Fallon, and K. Chytalo, all of the NYSDEC, failed to disclose any current studies of the salt marshes at the FINS.

4. Shellfish and Benthic Invertebrates

The Towns of Islip and Brookhaven continue to conduct annual census surveys of hard clams in GSB. Islip has carried out its survey since 1978 (S. Buckner, Town of Islip, personal communication). Brookhaven initiated its survey in 1986 (J. Kassner, Town of Brookhaven, personal communication). Data from these annual surveys are used by the Towns to manage the hard clam resource. These data are, in general, not published.

5. Finfishes

Most of the ongoing studies of GSB fishes concern monitoring of the recreational and commercial catches. The NYSDEC monitors the use of an artificial reef off Kismet and also conducts creel surveys at this site (S. Heins, NYSDEC, personal communication). The NYSDEC also conducts creel surveys of the Captree party boat fishery for winter flounder and summer flounder (A. Weber, NYSDEC, personal communication). For information, contact NYSDEC Finfish and Crustacean Division, Building 40, SUNY, Stony Brook, NY,

11790. The National Marine Fisheries Service (NMFS) reports commercial landings of finfish from GSB (F. Blossom, NMFS, personal communication) and also estimates recreational catch and effort through telephone interviews and creel surveys. For information, contact National Marine Fisheries Service, Fisheries Statistics Division, 1335 East-West Highway, Silver Spring, MD, 20910.

The Marine Sciences Research Center (MSRC) of SUNY Stony Brook has conducted a number of recent studies in GSB focusing on recruitment of and predation by bluefish (Nyman and Conover 1988, McBride and Conover 1991, Juanes 1992), effects of brown tide on fishes (Shima and Cowen 1989, Castro and Cowen 1989, Duguay et al. 1989), the early life history of bay anchovy (Monteleone and Duguay 1988, Monteleone 1988, Castro and Cowen 1991), and the general ichthyoplankton community (Monteleone 1988, 1992). At present, however, D. Conover and E. Schultz have the only ongoing MSRC project concerning GSB fishes, examining mechanisms of winter survival in GSB Atlantic silversides. On a broader geographic scale, they are also examining physiological adaptation among silversides from different latitudes, using GSB as one of their key study sites.

III. ECOLOGICALLY/ECONOMICALLY IMPORTANT FINS LIVING ESTUARINE RESOURCES

A. PLANKTON

The relative importance of different plankton species in GSB has varied over time. Studies conducted by investigators from the Woods Hole Oceanographic Institution (Ryther et al. 1956, 1957, 1958; Ryther 1989; Guillard et al. 1960) documented changing phytoplankton populations in the 1950's. Chlorophyte species, *Nannochloris atomus* and *Stichococcus* sp., bloomed suddenly in 1952 and 1953 due to reduced salinities in the bays and enhanced nutrients from duck farm effluents, which were high in phosphorus (relative to nitrogen) as well as other organic nutrient forms. The closing of Moriches Inlet at the beginning of the decade reduced exchange between ocean and bay waters, leading to dramatically lower salinities: down to 13 ppt from previous levels of 23 ppt. The duck farms located on the tributaries entering into the bays discharged effluents high in nutrients which then accumulated in the enclosed bays, fueling the growth of only two very competitive species of phytoplankton. These species were particularly small, only 2-4 μm in diameter, and were not suitable food for the oyster populations, *Crassostrea virginica*, which were abundant in the bays (Foehrenbach 1969). The subsequent demise of the oyster populations and the fishery were attributed, at least in part, to this extreme shift in phytoplankton species composition and the extensive green tide blooms. These species were not new to these bays and had been noted many times in past analyses as detailed in the above reports. Even the presence of very small microalgae was considered normal for these bays (Ryther 1954).

The re-opening of Moriches Inlet by dredging during the latter part of the decade increased the flushing rate and salinity. The green tides subsided and to this date have not returned, although these species are still present. Subsequent studies over several decades have documented that the small forms of microalgae previously noted during earlier decades were the dominant group of phytoplankton on a biomass basis throughout all seasons. The phytoplankton species composition is similar to other lagoon estuaries, but the seeding of the bay waters through the Fire Island Inlet with coastal species is a significant factor. Particularly along the southern shores of the bay and western Fire Island, this has led to two distinct populations.

Within the phytoplankton community the importance of any single species, except during bloom periods as described above, is not what is critical. When the dominant small microalgae, <5 μm in diameter, are very diverse, as described in Lively et al. (1983), then trophic coupling appears to be well balanced between grazing and primary production. Except for the work by Caron et al. (1989), the microzooplankton which graze on these small primary producers have not been described. It is a diverse group of species including

many loricate and aloricate ciliates and heterotrophic dinoflagellates, and the importance of any particular species is not significant. The larger mesozooplankton of GSB are dominated by copepods, particularly *Acartia tonsa* and *Acartia hudsonica*, with large populations developing during the summer and spring months, respectively, typical of neritic coastal waters (Duguay et al. 1989). Numerous other groups of larval forms of bivalves, polychaetes, decapods, and others are also found with no particular species dominating (Duguay et al. 1989). Among the ichthyoplankton, bay anchovy eggs and larvae (*Anchoa mitchilli*) are dominant (Duguay et al. 1989; Monteleone 1988, 1992). The growth rates of the bay anchovy have been found to be high in GSB compared to other bay systems (Shima and Cowen 1989, Castro and Cowen 1989), suggesting a high degree of trophic transfer of plankton productivity.

B. AQUATIC VEGETATION

1. Macroalgae

Three species of green algae, *Enteromorpha* spp., *Ulva lactuca*, and *Cladophora gracilis*, are repeatedly mentioned in past reports as particularly abundant in GSB. Henrickson and Eisel (1973) estimated the standing crop of *Ulva* and *Cladophora* in southwestern GSB to be 2.2 and 1.3 dry metric tons per hectare, respectively. During summers in the 1950's and 1960's, *Cladophora* sometimes formed extensive floating mats (Koetzner 1966, Briggs and O'Connor 1971). *Cladophora* "blooms" may have been stimulated by high nutrient concentrations related to the duck industry, similar to blooms of green microalgae (Ryther 1954). Koetzner (1970) determined the geographic distribution of *Cladophora* propagules overwintering in the southwestern portion of GSB.

Another green alga, *Codium fragile*, which was introduced to Long Island from Europe around 1957 (Carlton and Scanlon 1985), was reported to have high population densities in eastern GSB (Fox 1973). Large, free-floating populations of *Codium* and the red alga *Gracilaria* were observed in areas of GSB where eelgrass died off during the 1985-1986 brown tide blooms (Dennison et al. 1989). *Codium* attaches to shells, including those of living oysters and scallops, and often causes them to be carried onto beaches or into areas which are not suitable for growth (Wassman and Ramus 1973). *Codium* may also prevent scallops from swimming and, therefore, limit their ability to escape from predators. Dense populations of *Codium* established after eelgrass die-off possibly could prevent reestablishment of eelgrass in deeper portions of GSB.

2. Eelgrass

Eelgrass meadows reduce effects of currents and wave action, stabilize sediments, have high rates of primary production, and provide food and shelter for a diverse community

of plants and animals (see review by Thayer and Fonseca 1984). This valuable resource and habitat has fluctuated greatly in GSB within recent history.

The disappearance of eelgrass from GSB during 1931 along with populations throughout the North Atlantic, as suggested by Jones and Schubel (1978) and Carpenter et al. (1991), is controversial. It is possible that eelgrass did not occur in GSB from 1835 to 1931 due to low salinity, and that submerged aquatic vegetation was dominated during that period by widgeongrass (*Ruppia*) and pondweed (*Potamogeton* spp.), which tolerate brackish water (Dennison et al. 1989). In the coastal ponds of Rhode Island, eelgrass dominated lagoons with high salinities (15-31 ppt), but *Ruppia* and *Potamogeton* dominated more brackish lagoons (4-15 ppt, Thorne-Miller et al. 1983). Pollen analysis of cores from Long Cove, however, indicated that *Potamogeton* invaded Moriches and Shinnecock Bays, but not GSB (Clark 1986). Whether due to low salinity or wasting disease, eelgrass was probably absent from GSB during the 1930's, but eventually recolonized following the opening of Moriches Inlet and the recovery of North Atlantic populations from wasting disease. In 1966, eelgrass standing crops were estimated to be as high as 4.5 wet kg/m² (Carpenter et al. 1991). Wilson and Brenowitz (1966, cited in Henrickson and Eisel 1973) estimated the average eelgrass standing crop along a transect from Hecksher Park to Ocean Beach to be 1.9 wet kg/m².

The NYSDEC used aerial photography to survey eelgrass meadows which covered 88.2 km² or 37.6 percent of GSB in 1967, but the results were not published (Dennison et al. 1989; K. Koetzner, NYSDEC, personal communication). Elder (1976, cited in Jones and Schubel 1978) used preexisting data to map the 1969-1972 distribution of eelgrass in GSB (Figure 9). Greene et al. (1977) surveyed the southeastern portion of GSB during August 1977 and found eelgrass meadows extending from Smith Point to Barrett Beach, the western end of their study area, with standing crops up to 375 dry kg/m² (Figure 10). Jones and Schubel (1980) extended the eelgrass survey to the west during July 1978. They found meadows extending from the Fire Island shore approximately 500 m into GSB from Pines to Saltaire, and extensive meadows to the east and north of East Fire, West Fire, Sexton, and Captree Islands (Figure 11).

Brown tide blooms during 1985-1986 killed off eelgrass growing below 2 m depth in GSB (Cosper et al. 1987). Dennison et al. (1989) used aerial photography and ground-truth data collected during 1988 to estimate the areal extent of eelgrass meadows in GSB (Figure 12). They concluded that eelgrass area was reduced by 40-50 percent compared to 1967 and 1977-1978, and that the remaining populations also had reduced density. It was not clear, however, whether the decline in density was due to the brown tide or to a more gradual, ongoing loss. Despite the decline, extensive populations were found in 1988 in the shallow southern portion of GSB along the Fire Island shore (Dennison et al. 1989).

3. Salt Marshes

Approximately 250 ha of salt marshes exist within the FINS which exhibit the typical species composition of northeastern U.S. salt marshes. O'Connor and Terry (1972) found 10 ha of salt marsh on Sexton Island, 50 ha on East Fire Island, 165 ha from Davis Park to Old Inlet, 8 ha on Ridge Island, and about 30 ha to the east of Smith Point County Park (Figure 13). These marshes were dominated by *Spartina alterniflora* and *S. patens*.

McCormick and Associates, Inc. (1975) classified wetlands at the FINS as low tidal marsh dominated by *S. alterniflora*, high tidal marsh dominated by *S. patens*, *Distichlis spicata*, *Juncus gerardi*, and *Scirpus americanus*, and upland fringe dominated by *Iva frutescens* and *Baccharis halimifolia* (summarized by National Park Service 1992). *Phragmites australis* was found mainly in elevated areas and on dredged sediment deposits.

The NYSDEC 1974 aerial survey of all of the coastal wetlands on Long Island produced maps delineating intertidal and high marsh areas, dominated by *S. alterniflora* and *S. patens*, respectively. The aerial photos taken around 1985 as part of the U.S. Fish and Wildlife Service's National Wetlands Inventory classified the upland fringe (*Iva frutescens* and *Baccharis halimifolia*) as wetland areas.

The Final Environmental Statement (FES) for FINS (National Park Service 1977a) contains detailed maps showing marsh along most of the bayside from Davis Park to Smith Point County Park (Figure 14). It is not clear whether these maps are based on ground or aerial surveys. The salt marsh areas coincide closely with those shown on the maps by O'Connor and Terry. The major difference is that the FES maps show Sexton, East Fire, and Ridge Islands as relict flood tidal deltas rather than as salt marsh. A similar, but less detailed, wetlands map (Figure 15) was included in the environmental report for Nassau/Suffolk Water Quality Management (Beck et al. 1978).

Clark (1986) analyzed pollen data from cores taken at Watch Hill, Long Cove, and East Long Cove. Although salt marsh species were represented in all samples from pre-1640 to 1980, the extent of tidal marshes was probably reduced during 1835 to 1931 due to inlet closures which reduced the tidal range and left former marshes above the tidal zone.

Salt marshes are among the most productive communities known. Much of that production is exported, mostly as *Spartina* wrack and detritus, to the adjacent estuary. Coastal marshes are also important in stabilizing shorelines and as wildlife habitat. The ecological value of salt marshes is well known and will not be discussed further here. Private and town-owned wetlands on the bayside of the FINS were zoned as critical environmental areas to prevent damage by development or erosion control (National Park Service 1977b).

C. SHELLFISH AND BENTHIC INVERTEBRATES

Tables 3 through 6 list the major species in the four benthic habitats of the study area. With few exceptions, a species was considered for these lists only if an explicit reference existed citing it as ecologically or commercially important in GSB or Moriches Bay. These lists are by no means exhaustive nor are they particularly up to date. The seagrass and subtidal shoals and flats lists are based on at least some limited sampling within the boundary of the FINS, but no data within the boundary of the FINS were available to identify species in the intertidal and marsh habitats.

Also given in these tables is an assignment of each species to a functional group or guild on the basis of several life history characteristics. Criteria for assigning each species to a guild are given in Table 7. These criteria represent an operational compromise between two prior attempts at classifying the marine benthos in terms of similar lifestyles. The first, due to Woodin and Jackson (1979), classified species into categories according to similar substratum exploitation and their effects on sediment properties. The second, proposed by Fauchild and Jumars (1979), placed polychaetes with similar food sources, feeding mechanisms, and motility patterns into groups which they defined as feeding guilds. Examination of guild assignments can provide information on community structure and biotic-environmental relationships.

D. FINFISHES

In terms of economic value, GSB does not by itself represent a major portion of New York's commercial finfish landings, but it does support a modest fishery with annual landings of 116 to 278 thousand pounds over the past decade, 1981-1991 (Table 8). Chief species in the commercial fishery are bluefish, eels, winter flounder, weakfish, and menhaden. The primary gears used are gill nets and, to a lesser extent, fish traps such as pound nets and pots (F. Blossom, NMFS, personal communication). State law prohibits trawling in GSB.

The recreational fisheries of GSB have been described thoroughly by Briggs (1962). The fishery includes charter boats, most of which sail from Captree State Park, bank and pier fishermen, surf fishermen, and private boaters. During the period 1956-1960, 90 percent of the annual catch of all species combined were flatfishes, namely fluke and winter flounder. These two species support the bulk of the sport fishing activity in the bay. The only exception was among surf fishermen who landed primarily striped bass, bluefish, and northern kingfish (Briggs 1962, 1965a). Overall, bluefish ranked highest among the species taken.

Although the overall sport fisheries of GSB have not been described in detail since Briggs (1962), total recreational landings for New York as a whole suggest that fluke, winter flounder, and bluefish remain among the top species landed (Van Voorhees et al. 1992). In 1991, New York anglers landed an estimated 4.3 million flounders, about evenly divided among fluke and winter flounder. About 4.4 million bluefish were landed. The only other species with higher overall 1991 NY landings was scup, which is caught primarily in eastern Long Island waters rather than in GSB. Landings of reef fishes (primarily tautog, but also including cunner and black sea bass) from GSB by the sport fishery are probably also higher now than described by Briggs (1962) due to the construction of an artificial reef in GSB during the 1960's.

1. Atlantic Silverside (*Menidia menidia*)

This species is the dominant member of the ichthyofauna of GSB throughout much of the year (Tables 9 and 10). Hanlon (1983) found that 79 percent of fish captured by all methods in his survey were *M. menidia*. Silversides in GSB spawn from April to June. The eggs are deposited on intertidal algae where they are protected from aquatic predators (Tewksbury and Conover 1987). Larvae and young juveniles are found in the neuston close to shore and hence are undersampled by plankton tows taken in mid-bay such as those of Miller (1977) and Monteleone (1988). They are extremely abundant in the shore zone virtually everywhere in the bay.

M. menidia of GSB and other areas have been studied extensively by D. Conover of MSRC. The species completes its entire life cycle in one year. Young-of-the-year reach adult size by the end of autumn, migrate offshore with the onset of winter (Conover and Murawski 1982), and return to the shore zone in the spring (Conover and Ross 1982). Conover and Heins (1987a,b) show that Atlantic silversides from GSB have temperature-dependent sex determination. Low temperatures during larval development produce mostly female offspring while high temperatures produce mostly male offspring. The inherent capacity for growth increases with latitude in *M. menidia* (Conover and Present 1990). Silversides from GSB grow at rates that are intermediate between those from higher (e.g., Nova Scotia) and lower (e.g., South Carolina) latitudes.

Grover (1982) reported that Atlantic silversides in GSB fed primarily on copepods during all seasons of the year. In the spring and early summer, however, up to 40 percent of the diet consisted of fish eggs and larvae. The Atlantic silverside is an important forage species for piscivorous fishes. Juanes (1992) reported that *M. menidia* is a major portion of the diet of young-of-the-year bluefish in GSB. In addition, the Atlantic silverside is consumed by several other piscivores in the bay including striped bass (Schaefer 1970, Briggs and O'Connor 1971), weakfish, and summer flounder (Poole 1964).

M. menidia is one of the main species used as bait in the recreational fishery, primarily for catching summer flounder and young (snapper) bluefish (Briggs and O'Connor 1971). Reported commercial landings of silversides from GSB have increased in the last few years, from negligible catches prior to 1985 to 49,000 lbs landed in 1991 (NMFS unpublished landings records for GSB).

2. Bay Anchovy (*Anchoa mitchilli*)

Although the bay anchovy does not appear to be a major species based on beach seine or trawl surveys (Tables 9 and 10), its dominance in the summer ichthyoplankton suggests it to be a major component of the water column fauna in the mid-bay. Monteleone (1992) showed that over 96 percent of the eggs and over 69 percent of the larvae of all fishes collected from March through December were bay anchovy. Castro and Cowen (1991) found that the peak in spawning of bay anchovy in GSB was in late June and July, and coincided with the summer peak in microzooplankton abundance. They found no difference between eelgrass and unvegetated areas of GSB in egg or larval densities (but see Shima and Cowen 1989), larval growth rates, or egg and yolk-sac larvae mortality rates of bay anchovy. Mortality of older bay anchovy larvae was higher over eelgrass beds than over unvegetated bottom, perhaps because of greater exposure to predators inhabiting the eelgrass beds.

The bay anchovy is a major food source for piscivorous fishes in GSB. They constitute a large majority of the diet of young bluefish in GSB during late summer and fall (Juanes 1992) and are also consumed by virtually every piscivore in the bay including striped bass (Schaefer 1970), summer flounder (Poole 1964), and weakfish (Merriner 1975). With the onset of winter, bay anchovies migrate offshore over the continental shelf (Voughlitois et al. 1987), returning as adults in the spring.

3. The Killifishes: Mummichog (*Fundulus heteroclitus*), Striped Killifish (*F. majalis*), Sheepshead Minnow (*Cyprinodon variegatus*)

Members of the family *Cyprinodontidae* are generally very abundant in the shore zone of Atlantic coast estuaries. The mummichog predominates in high and low salt marsh habitats, especially salt marsh creeks, ditches, rivulets, or beaches where the sediment is soft, and/or where vegetation is present. The striped killifish prefers sandy bottom habitats. These differences in habitat preference are evident in Briggs and O'Connor's (1971) study in GSB (Table 10). Hanlon (1983) generally collected about twice as many striped killifish as mummichog (Table 9). The habitat types where he found mummichogs to outnumber striped killifish were subtidal mud and gravel (Table 2). *C. variegatus* may be found in either habitat, but both Briggs and O'Connor (1971) and Hanlon (1983) collected more over sandy bottoms than over naturally vegetated or mud habitats.

Killifishes feed on a variety of invertebrate marsh organisms, including insect larvae (Kneib 1986). Because they rarely stray further than a few meters from the shoreline, they are not usually a large component of the diet of piscivorous fishes. On the other hand, they represent a major food source for crabs and wading birds (Kneib 1986). *F. heteroclitus* is used extensively as bait in the summer flounder fishery (Briggs and O'Connor 1971).

4. Sticklebacks: Fourspine Stickleback (*Apeltes quadracus*), Threespine Stickleback (*Gasterosteus aculeatus*)

The fourspine stickleback, *A. quadracus*, was the second most abundant fish overall in Briggs and O'Connor's (1971) study of shore zone fishes, and it ranked first in abundance in naturally vegetated habitats (Table 4). In Hanlon's (1983) study, however, the relative abundance of fourspine stickleback was far less (overall rank=6) than found by Briggs and O'Connor (1971, see Tables 3 and 5). Threespine sticklebacks, *G. aculeatus*, were also common in both studies but much less so than *Apeltes*. Sticklebacks spawn in the spring and summer and are nest-building species that use vegetation for nest concealment and protection from predators. Young of *G. aculeatus* migrate offshore in the late spring and summer, but young of *Apeltes* appear to remain in estuaries throughout much of the year.

Due probably to their close association with cover and their armor of lateral plates and/or spines, sticklebacks do not represent a major fraction of the diet of most piscivores, but they have been found in the stomachs of striped bass (Schaefer 1970) and summer flounder (Briggs and O'Connor 1971).

5. Northern Pipefish (*Syngnathus fuscus*)

Pipefish are abundant both as larvae in the summer plankton (Miller 1977) and as juveniles and adults in vegetated areas (Briggs and O'Connor 1971, Hanlon 1983). They feed on zooplankton in the water column and are themselves consumed by summer flounder (Poole 1964) and striped bass (Schaefer 1970). Pipefish represent a substantial fraction (~ 10 percent) of the diet of summer flounder in GSB (Poole 1964).

6. American Sand Lance (*Ammodytes americanus*)

A major component of the winter fish assemblage in GSB is probably the sand lance. Although this species does not appear to be abundant in GSB based on catches reported by Hanlon (1983), Briggs and O'Connor (1971), or other studies of GSB, this may be largely because of lack of sampling with appropriate gear in winter. Miller (1977) found that the sand lance was overall the most numerous larval fish collected in GSB. Larvae were collected from January to May with a peak production in late January through the end of February.

American sand lance are found almost exclusively over sandy bottoms and are one of the most abundant fishes over the inner half of the continental shelf along the U.S. East Coast (Grosslein and Azarovitz 1982). They have the unique habit of burrowing in the sand in dense aggregations. They feed at all levels in the water column, primarily on copepods, crustacean larvae, chaetognaths, and various invertebrate and fish eggs (Grover 1982, Grosslein and Azarovitz 1982). The sand lance is itself preyed upon by numerous piscivores, and its biomass is responsible for sustaining many of the commercially important stocks in the northeast region of U.S. (e.g., cod, haddock, and white hake), as well as finback whales and porpoises (Grosslein and Azarovitz 1982). In GSB the main predators on sand lance are likely to be adult bluefish, striped bass, weakfish, summer flounder, and birds.

7. Bluefish (*Pomatomus saltatrix*)

Annual commercial landings of bluefish in GSB have fluctuated between zero and 62,000 lbs since 1962. Doubtless, many more are landed by recreational fishermen, for bluefish has been among the top five species landed each year since 1979 when surveys of the recreational fishery were begun by NMFS (Van Voorhees et al. 1992). There are two main components to this fishery: a "snapper" fishery involving bank and pier fishermen focusing on young-of-the-year bluefish in August and September, and an adult bluefish fishery involving surf fishermen and boaters (Briggs 1962).

Both young-of-the-year and adult bluefish are also of great ecological importance in GSB because they represent the most abundant piscivores in the system. Bluefish spawn over the continental shelf in spring and summer (Nyman and Conover 1988, McBride and Conover 1991). Young-of-the-year bluefish migrate into GSB from continental shelf waters in two waves: a May and June recruitment consisting of spring-spawned fish, and an August recruitment consisting of summer-spawned fish (Nyman and Conover 1988, McBride and Conover 1991). As they migrate from the shelf to the shore zone, the diet of young bluefish shifts from zooplankton to fish (Marks and Conover 1993, Juanes et al. in press). Juanes (1992) showed that young bluefish in GSB feed largely on young silversides in June and July and then shift their diet over to young bay anchovy in August and September. Other species consumed by young bluefish in GSB include shrimp (*Crangon septemspinosa* and *Palaemonetes vulgaris*) and winter flounder. Adult bluefish feed on a variety of species including sand lance, menhaden, bay anchovy, butterfish, and squid (Richards 1976, Safina and Burger 1989). Safina and Burger (1985) show that schools of feeding bluefish force prey fishes near the surface where they become available to surface feeding birds such as common terns.

8. Winter Flounder (*Pleuronectes americanus*)

Winter flounder in GSB support a very modest commercial fishery, on the order of 1,000 to 3,000 lbs per year. By comparison, the recreational fishery for winter flounder in GSB is several orders of magnitude larger. Briggs (1965b) showed that the average annual sport catch of winter flounder from GSB was about 1.3 million fish. Moreover, GSB has the largest sport catch of winter flounder on Long Island: roughly equal to the combined catch from Moriches Bay, Shinnecock Bay, and the Gardiners and Peconic Bays. The fishery is most active in spring and fall, although catches also occur in the summer particularly when catches of summer flounder are low.

Winter flounder are probably resident in GSB most of the year and may represent a subpopulation unique to the area. Spawning occurs in GSB from about March to May and, together with sand lance, winter flounder are a major portion of the winter ichthyoplankton (Miller 1977, Monteleone 1992). Although winter flounder are generally believed to migrate offshore as temperatures increase in summer, Olla et al. (1969) showed that some winter flounder remain in GSB throughout the summer, burying themselves in the sediment when temperatures exceed 23°C. Poole (1966) showed that winter flounder of GSB grow slower than do those from Moriches, Shinnecock, or Peconic Bays. Mortality rates for winter flounder in GSB are reported by Poole (1969). More recent data are available from the NYSDEC, Finfish and Crustacean Division, Building 40, SUNY, Stony Brook, NY, 11790.

Adult winter flounder feed primarily on a variety of benthic invertebrates including amphipods, polychaetes, the shrimp *Crangon septemspinosa*, *Mya arenaria*, and *Mytilus edulis* (Schreiber 1973, Grosslein and Azarovitz 1982). Larvae feed mainly on copepods. Winter flounder in GSB are themselves preyed upon by a variety of species, most notably bluefish (Juanes 1992) and summer flounder. Poole (1964) found that 28 percent (by weight) of the summer flounder diet in GSB was winter flounder.

9. Summer Flounder or Fluke (*Paralichthys dentatus*)

Summer flounder represent the main focus of the recreational fishery in GSB during the summer. Briggs (1962) found that the average annual catch of summer flounder from GSB during the period 1956-1969 was 1.3 million fish. Annual commercial landings of summer flounder in the bay are negligible, the most ever reported by NMFS being 1,200 lbs in 1967.

Summer flounder spawn over the continental shelf in the fall (Grosslein and Azarovitz 1982). Young fish enter estuaries along the mid-Atlantic coast in the winter and spring (Able et al. 1989). Poole (1961) found that young summer flounder in GSB grow rapidly during their first summer reaching a size of about 23 cm by autumn. Similar high rates of growth have been reported by Szedlmayer et al. (1992) in New Jersey estuaries.

Adult summer flounder migrate into GSB in May. Poole (1961) showed that the majority of fluke caught by the sport fishery in GSB are one- and two-year-old fish and that they were heavily exploited. Some young-of-the-year fish probably also enter the fishery toward the end of summer. Hence, the sport fishery is highly dependent on the success of reproduction in the previous year. Weber (1984a) compared data on size distributions and mortality rates of summer flounder in 1981-1983 with that described by Poole (1961, 1962). Weber (1984a) found that range and mode of fluke sizes entering the bay in early summer had not changed much but the number of large fish (>36 cm) had declined. Survival rates had also declined: Poole's (1962) estimate of survival rate in GSB averaged 0.32 during the period 1956-1959, whereas Weber (1984b) found a survival rate of 0.13 in 1981-1982.

Summer flounder feed mainly on shrimp and fish. Poole (1964) found that sand shrimp (*Crangon* spp.), winter flounder, and blue crabs (*Callinectes sapidus*) respectively contributed 28.5, 27.8, and 12.1 percent of the total weight of food content of summer flounder in GSB.

10. Reef Species: Tautog (*Tautoga onitis*), Cunner (*Tautogolabrus adspersus*), Black Sea Bass (*Centropristis striata*)

Just offshore from Kismet, at the western border of the FINS, is an artificial reef in GSB that supports a substantial recreational fishery for several reef species (Briggs 1975a). The Kismet reef is 457 m long, 46 m wide, and lies in about 6 m of water. It consists of two sunken barges, 20,000 concrete blocks, and 3,450 tires. Main fish species occupying the Kismet reef are tautog and cunner, which together comprised 94 percent of the fish collected in pots by Briggs (1975a). A few black sea bass were also present. Briggs (1977) estimated that about 19,000 tautog occupied the reef in 1969-1972. The Kismet reef is heavily fished in the fall when anglers focus largely on tautog.

The biology of tautog and cunner has been studied extensively in Fire Island Inlet by Olla et al. (1974, 1975, 1979) and Grover (1982). Spawning occurs in the summer, and newly-settled juveniles occupy shallow, vegetated (eelgrass or *Ulva*) habitats (Grover 1982, Sogard et al. 1992) beginning in late summer and continuing until reaching a size where they can take up residence on the reef. Olla et al. (1974, 1975, 1979) show that a portion of the cunner and tautog population are resident throughout the year in the Inlet. Cover is a critical habitat requirement for these species. Fish tend to be active by day and inactive by night. Older fish move offshore in winter but younger fish remain on inshore reefs, enduring the winter in a state of torpor.

Young cunner and tautog in eelgrass beds feed primarily on copepods and amphipods in GSB. Larger cunner and tautog in GSB feed primarily on the mussel *Mytilus edulis* in May and June (Olla et al. 1975). Later in the summer and fall, tautog continue to feed on *Mytilus* while the cunner shifts to feeding largely on the isopod *Idotea baltica*.

11. Endangered or Unique Finfish Species

There are no endangered fish species that rely on GSB as a principal habitat. There are a large number of rare fishes collected in GSB from time to time that represent expatriates of primarily southern species. These have been reported extensively in the literature by Alperin and Schaefer (1964, 1965), Briggs (1970), and Briggs et al. (1985). Briggs (1992) provides a complete review of all such reports of rare species.

IV. MAJOR ESTUARINE HABITATS OF THE FINS

A. WATER COLUMN

1. Physical Characteristics

Tides. The semidiurnal astronomical tide is the primary agent driving water circulation in GSB. The tidal range on the ocean side of Fire Island Inlet is 125 cm but decreases rapidly within the bay where the normal tide range is generally less than 40 cm (Wilson et al. 1991). Although only water levels have been measured around the bay's perimeter, other aspects of the circulation have been calculated using a numerical hydrodynamic model (Pritchard and Gomez-Reyes 1986, Zarillo et al. undated). Along GSB, the amplitude of the vertically averaged tidal current increases from about 5 cm/sec in the eastern bay to 15 cm/sec in the western bay (Figure 16). From there through Fire Island Inlet, tidal currents increase in speed to 70 cm/sec. The non-tidal residual currents rarely exceed a few cm/sec. Most of the tidal exchange of water occurs through Fire Island Inlet and the amplitude of the tidal flux was calculated to be approximately 50,000 m³/sec (Wilson et al. 1991). The average volume of the bay is 2.9×10^8 m³. Since Fire Island Inlet provides the principal tidal access into and out of the bay, the residence time of water increases to the east, away from the Inlet, from about 32 days to over 100 days (Weyl 1974).

Storm Tides. Meteorological forcing of the bay at subtidal frequencies is important, especially the response of the bay to coastal sea level changes (Wilson et al. 1991). The low frequency flux of water through the bay's open boundaries (Robert Moses Causeway, Fire Island Inlet, and Smith Point) is about 5,000 m³/sec, and the subtidal variations typically have a period of about seven days or longer. This corresponds with the time it takes substances in the water to be dispersed across the bay; dye studies reveal this time to be about 10 days (Wilson et al. 1991). Tidal and storm flushing is important to the vertical mixing of the water column allowing for distribution of nutrients and particles throughout and preventing vertical stratification. This may be important for benthic-pelagic coupling, although this is only speculation due to the lack of any studies and the absence of hypoxia problems in the bay.

Salinity and Freshwater Inflow. Based on observations prior to 1991, the salinity of the bay generally decreased from about 26 ppt in the western bay to 23 ppt in the east (Wilson et al. 1991). This dilution is due to the influx of fresh water at a rate of about 14 m³/sec (12×10^8 L/day) supplied from the bay's north shore; about 15 percent of this influx is supplied directly across the bay floor, probably within a few hundred meters of the shoreline (Bokuniewicz and Zeitlin 1980). The contribution of fresh water from Fire Island is only about 0.14 percent of the total freshwater supply. However, this flow may be locally important in suppressing salinity in the shoreline sediments.

About one-quarter of the rainfall on Fire Island can be expected to seep into the bay within about 100 m of the shoreline. (About one-half of the total precipitation might be expected to be lost due to evapotranspiration, and one-half of that remaining probably flows to the south, seeping into the ocean.) Given a total annual rainfall of 118 cm and assuming that the island is 54 km long and averages 400 m in width, fresh water is supplied to the bay by the island at a rate of about $0.2 \text{ m}^3/\text{sec}$. To this quantity must be added the potable water pumped for human consumption. Rainwater falling on the barrier island cycles through the freshwater lens which is entirely in the Upper Glacial Aquifer, but potable water is taken from the Magothy Aquifer and returned to the Upper Glacial Aquifer after its use primarily through the septic systems on the island. Only in Ocean Beach is this water discharged directly into the bay through a sewage treatment system. The communities on Fire Island may be drawing about 4.5 million gallons per day during the summer period. If half of this reaches the bay (the other half flowing to the ocean), the contribution over a five-month summer would be $0.5 \text{ m}^3/\text{sec}$, which corresponds to an average of about $0.02 \text{ m}^3/\text{sec}$ annually.

Based on direct measurements of the seepage, Bokuniewicz and Zeitlin (1980) estimated the total flow across the bay floor from Fire Island to be equivalent to $1.1 \text{ m}^3/\text{sec}$. As much as 40 percent of this flux may be recirculated sea water rather than new, freshwater input (Bokuniewicz and Pavlik 1990). These measurements were made in August and compare favorably to the expected summer value, but differences between this value and the above estimates may represent the degree of uncertainty in both estimates.

Inlets. One of the most important processes affecting the water column habitat would be changes in salinity in either the open bay or the sediment pore waters due to a change in the ratio of the rates of supply of fresh water to sea water. One of the effects of opening (or closing) an inlet channel would be an increase (or decrease) in baywide salinity as indicated by the modeling studies of Pritchard and Gomez-Reyes (1986). The salinity might also increase (or decrease) by decreasing (or increasing) the supply of fresh water to the bay. While the long-term average supply could only be affected by severe droughts or exceptionally wet years, local conditions can be altered by development which changes the distribution of freshwater supply. Additional inlets would also increase the flushing rate for the bay, decreasing the residence time of pollutants. (During the winter of 1992-1993, a new inlet was opened through Westhampton Beach into Moriches Bay. Anecdotal evidence suggests that conditions have changed even in eastern GSB as a result, but no measurements have been made to date to confirm this assertion).

No one has calculated the probability of new inlets forming, but Leatherman and Allen (1985) have indicated the positions and temporal extent of existing and former inlets since about 1735 (Figure 17) in the area east of Fire Island Inlet. If we assume that general conditions have remained the same, the probability of new inlets might be estimated by the occurrence of past inlets. Four inlets formed approximately at the same time between

Moriches Inlet and Fire Island Inlet and persisted for about 50 years. No other inlets had appeared in the area now considered Fire Island during the 250-year record, suggesting that the probability of a new inlet is about 0.4 percent per year and, if one appears, its natural lifetime might be expected to be about 50 years.

The historical evidence suggests that the formation of new inlets on Fire Island has been confined to the eastern end of the island, so it might be reasonable to expect any new inlets to be more likely to form there also. A rudimentary, preliminary analysis of the vulnerability of the ocean shoreline to erosion damage based solely on dune height and beach volume done by Zarillo (in Tanski et al. 1990) showed a good deal of variability in erosion risk based on these criteria for the length of Fire Island. Although no clear trends are discernable, the risks may be slightly higher in the eastern half (Figure 18). This analysis, however, does not take into account a number of other important factors such as the width of the island, the severity of bayside erosion, the presence of deep channels near the bay shore that might enhance the probability of new inlet formation, the extent of salt marshes on the bay side, or shoreface processes that could cause erosion on the oceanside beaches. A much more detailed analysis is needed to adequately assess the potential for breaches and new inlets.

2. Plankton

Controlling Factors. The plankton species found in GSB were described in section III.A of this report. Pelagic production in this bay is temperature driven, so the peak abundances and productivities generally occur during the warmer, summer months (Cosper et al. 1989a, Duguay et al. 1989, Lonsdale et al. in review). Species succession is an ongoing process throughout the year with diversity being high throughout most of the year. Even when temperatures are extremely low, just above freezing, primary producers and grazers are found to be quite active with no indication of the typical coastal, winter-spring bloom phenomenon (Lonsdale et al. in review). The trophic coupling and structure in this bay develops complexity early during the year and well-balanced trophic linkages are maintained generally over most of the year. The unusual algal blooms previously described are the anomalies.

North to south distributions of planktonic species and biomass reflect the new inputs of nutrients from the north shore tributaries with higher levels being found in more northern waters (Hair and Buckner 1973; Lively et al. 1983; Cosper et al. 1989a,b; Dennison et al. 1991). East to west gradients reflect the longer residence time of waters in the eastern portion of the bays, up to hundreds of days (Vieira 1989), so that potentially greater biomass can accumulate in eastern portions, however, this is not necessarily the case. The inflowing coastal waters through Fire Island Inlet can affect the distribution of species in the southwestern portions of the bay (Weaver and Hirschfield 1976).

Great South Bay is one of the most productive estuaries known, with a net primary production of $\sim 450 \text{ g C/m}^2/\text{year}$ (Mandelli et al. 1970, Hair and Buckner 1973, Weaver and Hirschfield 1976, Cassin 1978, Lively et al. 1983, Kaufman et al. 1984). These studies have established that nutrients are abundant and primary production is light and temperature limited. Light availability, as indicated by Secchi disc readings and calculation of light attenuation coefficients, has been found to vary seasonally, becoming minimal and severely attenuated during the summer months (Lively et al. 1983, Duguay et al. 1989). New nutrients are supplied through freshwater inputs either from the numerous tributaries on the north shore or groundwater flows into the bay, but account for less than one percent of that needed for primary production (Lively et al. 1983). Recycling of nutrients within the bay system itself is high and rapid: on the order of hours during the warmer months. Nutrient concentrations show spatial distributions that reflect these sources and the dilution from oceanic waters through Fire Island Inlet, resulting in higher concentrations near the northern shores and eastern areas of the bay. Chlorophyll *a* levels were highest during the summer months, reaching concentrations of $\sim 25\text{-}30 \text{ }\mu\text{g/l}$ and reflecting the spatial distributions of nutrients.

During the brown tides starting in 1985, the shift to a new, single-cell species of microalga $2\text{-}3 \text{ }\mu\text{m}$ in diameter, *Aureococcus anophagefferens*, over extensive bay areas throughout much of the summer months over several years seemed to relate to many rather than a single environmental factor (Casper et al. 1989a,c). Importantly, the levels of phytoplankton biomass, the dominance of a small alga, primary production levels, and lack of correlation with major nutrients during these brown tide blooms were similar to findings in previously detailed studies for this bay. The species shift and dominance of a single species was the key factor. This species could always have been present, although a new introduction from oceanic waters cannot be ruled out. The growth physiology of this species indicated that a drought, elevating salinities in the bay, and the presence of high organic nutrients, as well as micro-nutrients such as iron, were conducive to the blooms (Dzurica et al. 1989).

The green tides of the 1950's and the brown tides of the 1980's have been described above. It should also be noted that a macroalga, *Cladophora gracilis*, bloomed during the 1960's (Koetzner 1965, 1971). Although this macroalga is attached to sand grains for a short period of time, it spends much time free floating or drifting in the water column. The causes of these blooms were never elucidated, although this macroalga was quite a nuisance to boaters and fishermen (it fouled baits so fish would not or could not "bite") on the bay. Chang and Carpenter (1985) reported a bloom of the red tide species *Gyrodinium aureolum* during the summers of 1982 and 1983 in the Carmens River estuary, a tributary of GSB, but the blooms were very localized in distribution. Another red tide species, *Gonyaulax tamarensis*, has been found in Moriches Bay and as resting cysts in the sediments of most Long Island embayments. Blooms of these organisms have so far not been found in GSB (Schrey et al. 1984).

A comparative study of northeast estuaries in terms of physical and hydrological characteristics and their susceptibility to nutrient inputs has classed GSB as potentially highly susceptible to eutrophication and chronic algal blooms (NOAA/EPA 1989). However, dramatic, unusual algal blooms are actually the exception rather than the rule in GSB, occurring on a bay-wide basis during only about six of the last forty years. This strongly suggests that equally powerful stabilizing processes act to prevent blooms in most years.

A number of parameters related to the physical and chemical characteristics of the water column may exert a controlling influence on phytoplankton populations and production in GSB. Salinity has a strong influence on species shifts, particularly sudden increases or decreases in salinity, and the resultant blooming of only one or two species (Ryther 1954, Cosper 1989c). This seems to be a key variable lending a competitive advantage to certain species and causing trophic imbalance. Temperature variations on a seasonal basis drive the overall production of this non-nutrient limited bay system.

Tidal flushing and local wind events are important to the vertical mixing of the water column, allowing for distribution of nutrients and particles throughout, and preventing vertical stratification. This is important for benthic-pelagic coupling (although this is only speculation due to the lack of any studies) and elimination of hypoxia problems in the bay. The bay-wide average supply of nutrients is probably as stable as the human population and the acreage of farmland around the bay, but habitats could be influenced by changes in the distribution of wastewater input or agricultural drainage. The flow and seepage of fresh water into the bay also carry along nutrients. Nutrient supply generally does not limit water column productivity, although it can affect biomass levels in localized areas of new inputs.

Trace elements have rarely been considered but are probably critical to phytoplankton species shifts. A study beginning in 1993, to be conducted by E. Cosper, D. Lonsdale, and E. Carpenter will specifically address the role of micronutrients and other trace elements, such as chelators, on phytoplankton composition and dynamics. The brown tide species and its ability to bloom appears to relate, at least in part, to high levels of iron in Long Island coastal bays (Cosper et al. 1993).

Predation and planktonic trophic transfer have recently been studied by Lonsdale and Cosper (Lonsdale et al. in review) and these processes are well-coupled in GSB, keeping biomass levels relatively stable within planktonic groups despite the high rates of turnover of lower trophic levels (on the order of hours). Ctenophores have been found to be important predators on the zooplankton community, including bivalve larvae (Quaglietta 1987). This results in tight coupling of production and consumption and subsequent nutrient regeneration at high trophic levels.

Bluefish juveniles migrate into the bay during the summer (Nyman and Conover 1988), and their diet is composed of larval fish, mainly bay anchovy (Juanes 1992). The

growth rates of these juvenile bluefish have been found to be very high compared to other species of fish (McBride and Conover 1991). The bluefish migrate back out onto the continental shelf in the autumn, exporting plankton production from GSB into the coastal ocean. This process, even during the brown tide blooms, did not appear to be disrupted, indicating a high degree of pelagic trophic resilience to the bloom effects.

On the other hand, bivalve populations, mainly clams, were severely affected, although it is not very clear why, except for a chronic toxicity associated with the brown tide species (Bricelj and Kuenstner 1989). Despite the tremendous commercial importance of hard clam production in GSB in terms of human consumption, with peak production levels representing nearly 60 percent of the total United States' landing of hard clams (Koppelman and Davies 1987), understanding of how these benthic macrofaunal suspension feeders interact with the pelagic community has not been determined (McHugh and Ginter 1978, Koppelman and Davies 1987, McHugh 1991). The lessons of the green tides from the 1950's and the brown tides from the 1980's indicate that species shifts at the lowest trophic levels are critical to the well-being of bivalve populations.

Disease has rarely been considered for plankton. However, very recent evidence from a brown tide bloom in West Neck Bay on Shelter Island (Drewes and Cosper in preparation) indicates that the bloom was curtailed by the presence of infective viruses specific for this species. This area of investigation is in its infancy, but the prevalence and activity of disease agents may be valuable in terms of control on species succession and bloom phenomena.

3. Shellfish and Benthic Invertebrates

Blooms of microalgae and perhaps the production by microalgae of an as yet unidentified toxic substance stress the feeding of bivalve populations and result in losses to the clamming industry. In addition, these and other benthic species produce planktonic larvae, and any factors affecting water quality could impact the survival of these larvae.

4. Finfishes

The main fish species dependent on the water column are silversides, herrings, and anchovies, as well as their predators, but this habitat is the least well-studied region of the bay. Bay anchovy is probably the dominant planktivore in the middle of the bay during much of the year (Monteleone 1988), but the existence of a modest commercial fishery for menhaden suggests that it, too, may be an important component of the pelagic fauna. Atlantic silversides, which dominate virtually all habitats in GSB, are probably also very important in the water column, especially close to shore. Both juvenile and adult bluefish are probably highly dependent on the abundance of silversides and anchovies in the pelagic zone, based on the dominance of these species in the diet (Juanes 1992). Friedland et al.

(1988) showed that the young-of-the-year bluefish condition was higher in years when fish rather than invertebrates predominated in the diet.

These studies indicate two seasonal peaks in the ichthyoplankton of GSB: one in winter consisting largely of eggs and/or larvae of the American sand lance (*Ammodytes americanus*) and the winter flounder (*Pleuronectes americanus*); and the other in summer consisting mainly of the bay anchovy (*Anchoa mitchilli*), but also including substantial numbers of the Atlantic silverside (*Menidia menidia*), the northern pipefish (*Syngnathus fuscus*), the northern puffer (*Sphoeroides maculatus*), and the windowpane (*Scophthalmus aquosus*). Miller (1977) identified 16 species in the ichthyoplankton, Shima and Cowen (1989) found 21, and Monteleone (1992) found 23 species. Monteleone (1992) reports that >96 percent of eggs and >69 percent of the overall larvae collected were bay anchovy.

The effects of various environmental factors on fishes found in GSB are similar for the different habitats. Consequently, the discussion of important environmental parameters below can be applied to following sections concerning other habitats.

The overwhelming environmental factor affecting fishes in GSB is temperature. The species composition of GSB's fish community, for example, is controlled largely by the annual temperature cycle. In winter, the main species in the bay are probably sand lance, Atlantic herring (*Clupea harengus*), grubby (*Myoxocephalus aeneus*), longhorn sculpin (*M. octodecemspinosus*), and winter flounder. With the return of warmer temperatures in April and May, the summer suite of species including Atlantic silversides, summer flounder, bay anchovy, and bluefish return to the bay from offshore, and species which have overwintered in a torpid state (killifishes, tautog, and cunner) become active again.

Variations in salinity probably have little influence on the major fishes of GSB. Most GSB fishes are euryhaline and can easily adapt to the relatively minor fluctuations in salinity that typically occur in GSB. Because the bay is shallow, dissolved oxygen levels are unlikely to drop so low as to negatively affect fishes to a measurable degree.

The bay's shallowness probably favors shore zone fishes such as the Atlantic silverside and limits to some degree the abundance of more open water fishes such as bay anchovy, menhaden, and sand lance. This is little direct evidence, however, of habitat limitation in pelagic fishes.

Effects of dense blooms of algae on fishes are not clear. Duguay et al. (1989) found densities of eggs and larval fishes to be higher in a year with a severe outbreak of brown tide than in a year with more moderate algal concentrations. Castro and Cowen (1989) found little difference in growth of bay anchovy among two years where turbidity caused by brown tide differed markedly. In fact, larval bay anchovy growth in GSB during years of brown tide blooms was among the highest recorded for the species (Castro and Cowen 1989).

Effects of brown tide on other fishes of GSB have not been studied. The major impact of brown tide on fishes is likely to be an indirect result of the loss of eelgrass habitat due to shading.

B. NON-VEGETATED BAY BOTTOM

1. Physical Characteristics

Bay sediments have been mapped by Jones and Schubel (1980), including earlier data collected by Rockwell (1974). Their map shows that only five percent of the bay floor is covered by fine-grained sediment (> 80 percent silt and clay) which is distributed in a few major areas (Figure 19). One of these is found near Bellport and the Carmans River, while another lies south of the Patchogue River. The third area is found south of Bayport, and a fourth patch is located at the mouth of the Connetquot River in Great Cove. Fine-grained sediment is also found in Babylon Cove offshore of Lindenhurst. There is no information concerning the thickness of these deposits or sedimentation rates in the bay.

2. Shellfish and Benthic Invertebrates

The benthic fauna of subtidal unvegetated areas is moderately well known from several major studies (O'Connor 1972, Marine Sciences Research Center 1973, WAPORA, Inc. 1982, Cerrato 1986, Wiggins 1986) detailing distribution and abundance patterns in GSB and Moriches Bay. Within the FINS, the sediments are primarily sandy, so only a sand fauna will be described for this habitat. A list of the major species occurring in this habitat is given in Table 4. All of these species are found in other habitats within the bays although some, like the suspension feeders *Mercenaria mercenaria* and *Gemma gemma*, are much more limited in muddy areas (O'Connor 1972). Since the principal sediment type is sand, few deposit feeders occur in this habitat (Table 4). No information about the present abundance of benthic species is available. No studies of the subtidal fauna have been conducted within the boundaries of the FINS since 1986.

The distribution pattern which emerges from combining the results of the major benthic studies is that there are two distinguishable species assemblages present in the study area: a discrete, high salinity fauna (≥ 28 ppt) associated with the inlets (Fire Island and Moriches) and a second, lower salinity fauna. The high salinity assemblage is dominated by the bivalves *Mytilus edulis* and *Tellina agilis*, the polychaetes *Nephtys picta* and *Nereis arenaceodonta*, the hermit crab *Pagurus longicarpus*, the lady crab *Ovalipes ocellatus*, and the starfish *Asterias forbesii*. WAPORA, Inc. (1982) found that *Tellina agilis*, *Pagurus longicarpus*, and *Ovalipes ocellatus* were abundant only in Islip waters and rare or absent in Brookhaven. *Mytilus edulis* was distributed throughout both GSB and Moriches but reached peak abundances in the vicinity of inlets (WAPORA, Inc. 1982, Cerrato 1986). A similar

distribution pattern in Moriches Bay was found for *Nephtys picta* and *Nereis arenaceodonta* by Cerrato (1986). *Asterias forbesii* appears to be the most restricted of the high salinity species. WAPORA, Inc. (1982) found this starfish limited in distribution to Fire Island Inlet and channel areas leading from the inlet. Distribution maps for *Tellina agilis* and *Ovalipes ocellatus* are available in WAPORA, Inc. (1982).

The fauna distributed in lower salinity waters in the study area is somewhat more diverse (Table 4). Detailed distribution maps from WAPORA, Inc. (1982) exist for *Mulinia lateralis*, *Busycotypus canaliculatum*, and *Mercenaria mercenaria*. Distribution maps for *Mercenaria mercenaria* are also available in Buckner (1984) and Kassner et al. (1991).

Wiggins (1986) identified six species as dominant or abundant in his study of Patchogue Bay. These were the polychaetes *Sabellaria vulgaris* and *Trichobranthus glacilis*, the snail *Retusa canaliculata*, the bivalves *Mulinia lateralis* and *Mercenaria mercenaria*, and the amphipod *Corophium tuberculatum*. WAPORA, Inc. (1982) reported that *Mulinia lateralis* was widely distributed throughout Islip and Brookhaven waters, but highest abundances were found in the north in muddy sediments. No other habitat information relative to the FINS is available on the remaining five species.

The whelk *Busycotypus canaliculatum* (commonly referred to as conch) is a significant predator of adult hard clams (WAPORA, Inc. 1982). This species was distributed at low abundances throughout Islip and Brookhaven waters (WAPORA, Inc. 1982).

The razor clam *Ensis directus* was restricted to Brookhaven waters (WAPORA, Inc. 1982). Highest densities occurred in intermediate substrates consisting of 40-60 percent silt-clay (WAPORA, Inc. 1982). This substrate type is not commonly found within the boundaries of the FINS (Jones and Schubel 1980).

WAPORA, Inc. (1982) reported that the horseshoe crab (*Limulus polyphemus*) was abundant only on the Fire Island side of Brookhaven waters. High abundances here were attributed to the proximity of this habitat to the crab's prime spawning grounds (i.e., intertidal sand flats).

Gemma gemma is an extremely abundant, suspension feeding bivalve which is widely distributed throughout GSB and Moriches Bay. In GSB, WAPORA, Inc. (1982) found especially high abundance areas in the sandy shoals within the boundaries of the FINS in Brookhaven. A second high abundance region was found along the north shore in Brookhaven. *Gemma gemma* was present but at substantially reduced abundances in Islip. O'Connor (1972) identified *Gemma gemma* as a biomass dominant in the sand habitats within Moriches Bay.

A considerable amount of information exists concerning the distribution of the hard clam (*Mercenaria mercenaria*) within Islip and Brookhaven waters of GSB. Distribution maps reported in WAPORA, Inc. (1982), Buckner (1984), and Kassner et al. (1991) agree on the general features of this distribution. Major concentrations of legal size clams (≥ 48 mm in shell length) and seed clams (15-48 mm) lay for the most part outside of the boundaries of the FINS. Densities of legal size clams within the FINS were generally less than 2 per m². The only exceptions to this trend were several small patches of legal size clams south of East and West Fire Islands. Seed clams were found in high abundances in the sand flats along Fire Island opposite Bayport in Brookhaven and in two small patches north and west of Clam Pond in Islip.

Other species likely to be important in the subtidal sandy habitat are the mysid shrimp *Neomysis americana*, the sand shrimp *Crangon septemspinosa*, and the blue crab *Callinectes sapidus*. All are cited by Poole (1964) as principal food sources for flounder. Additionally, the blue crab is of commercial and recreational value. No distributional data for these species are available for the sand flats within the FINS's boundaries.

Both Wiggins (1986) and Cerrato (1986) compared the results of their studies to prior surveys in an attempt to identify long-term changes in the benthos. Their results suggest that no striking long-term changes in species composition or abundance of major taxa has occurred. In comparing his data to the annotated list of species found in Townes (1939), Cerrato found that 61 of 75 species listed by Townes as occurring in Moriches and/or Great South Bay, common or abundant "in the bays", or widespread in Long Island waters also occurred in Moriches Bay in 1981-1982. Wiggins was more restrictive in selecting species from Townes (1939) and only used those species specifically noted as being found in GSB. Of the 33 species listed in this way, Wiggins found 18 to be present in his study. Additionally, most (11 of 15) of the dissimilar species were common only in habitats not sampled by Wiggins such as mud, on eelgrass or seaweeds, on pilings, or parasitic on fish and squid. Both Wiggins and Cerrato concluded that there did not appear to be evidence for drastic differences in species composition between 1938 and the 1980's.

Wiggins (1986) also compared the abundances of major taxonomic groups in his study to those of O'Connor (1972) and Cerrato (1986). His comparison of results for sandy sediments is given in Table II. O'Connor and Cerrato found substantially higher bivalve abundances, but no other major differences were apparent. Both O'Connor and Cerrato collected high numbers of juvenile blue mussels in late spring-early summer. O'Connor and Cerrato also report that the juvenile mussels did not survive throughout the year.

In contrast to these findings, a variety of information suggests that there have been significant changes in several shellfish populations in GSB. Commercial landings for conchs, oysters, mussels, hard clams, and blue crabs are given in Figures 20 through 24. Oyster populations have declined drastically in the subtidal areas of GSB, and no commercial

harvests have been reported since 1985. Hard clam landings peaked in the mid-1970's and declined substantially over a 10-year period (1975-1985). Commercial landings for conchs, blue crabs, and mussels have increased over the past 10-15 years but still represent minor fisheries. It is unclear whether the increased landings for these three species reflect abundance changes or simply represent changes in harvesting patterns.

None of the benthic species identified in this section are restricted to this habitat, and factors expected to be critical in controlling the distribution and abundance of the species in Table 4 include salinity, temperature, sediment type, predation, food supply, and harvesting. WAPORA, Inc. (1982) summarized the importance of these factors in controlling the distribution of hard clams, shellfish predators, and potential hard clam competitors (Table 12). Kassner et al. (1991) found that high hard clam abundances corresponded to areas of low silt-clay content and often with the location of relict oyster reefs and/or deposits of shell fragments.

3. Finfishes

Unvegetated bay bottom is the preferred habitat of several benthic fishes. Sogard (1992) found that juvenile winter flounder were more abundant and grew faster in unvegetated habitats than in eelgrass habitats. Sand lance are found almost exclusively over sandy bottoms. Briggs and O'Connor (1971) found six species in GSB that were more abundant over sand-filled than vegetated habitats, the main ones being *Menidia menidia*, *Fundulus majalis*, and *Cyprinodon variegatus*. Hanlon (1983) caught relatively more *Pleuronectes americanus* and *Paralichthys dentatus* in unvegetated than vegetated bottom habitats.

The environmental factors impacting fisheries resources in non-vegetated bay bottom areas are essentially the same as those described above in the section on the water column.

Based on the historically high catches of flatfishes from GSB compared with other bays on Long Island (Briggs 1962, 1965b), the bottom environment of GSB, which includes large areas of soft sediment and sand (Jones and Schubel 1980), probably represents excellent habitat for flounders as well as sand lance. Sogard (1992) found that young winter flounder in New Jersey grew more rapidly on unvegetated than vegetated bay bottom. Presently, flounders in GSB are probably more likely to be limited by overexploitation than by habitat.

C. SUBMERGED VEGETATION AS HABITAT

1. Submerged Vegetation

As indicated in previous sections, the important submerged aquatic vegetation found in the study area consists primarily of the macroalgal species *Cladophora gracilis*, *Ulva lactuca*, *Enteromorpha* spp., and *Codium fragile* and the seagrass *Zostera marina*. Because there are no recent or current studies of seaweeds in southeastern GSB, the present abundance and distribution are not known. The historical distribution of eelgrass in GSB is shown in Figures 9 through 12. Aerial photographs showing eelgrass distribution during 1988 provide the most recent information on distribution and abundance in southeastern GSB (Dennison et al. 1989, Figure 12).

Factors Controlling the Nature and Distribution of Submerged Vegetation. The diversity of seaweeds in GSB is probably most limited by the large seasonal range in water temperature ($< 0^{\circ}$ to $> 25^{\circ}\text{C}$), as there are relatively few seaweeds which can tolerate such a wide range. Koetznner (1963) found a correlation between species richness and salinity, suggesting that low salinity is another factor limiting diversity of seaweeds.

The environmental factor most limiting to seaweed abundance in GSB is probably availability of hard substrata for attachment. High turbidity and low irradiance may limit the survival and growth of seaweeds in deeper subtidal areas ($> 3\text{--}4\text{ m}$) of GSB. Secchi disc depth averages about 1.5 m (Koetznner 1963, Dennison et al. 1989), indicating that the photosynthetic compensation depth (1 percent light-level) is only 4 m. During microalgal blooms, the compensation depth is decreased to less than 2 m (Cosper et al. 1987, Dennison et al. 1989). However, most of the area adjacent to the FINS is less than 2 m deep (Jones and Schubel 1980), so the distribution of seaweeds in this area is probably not light-limited.

Light, however, is probably the most limiting environmental factor affecting eelgrass distribution in GSB. Eelgrass requires 12 hours per day of irradiance above photosynthetic compensation to survive. The average Secchi disc depth over the course of a year approximates the compensation depth (Dennison 1987). Although eelgrass is limited to shallow areas of GSB, most of the southeastern portion along the FINS is $< 2\text{ m}$ deep and supports eelgrass growth. If the frequency or density of phytoplankton blooms is enhanced by eutrophication or other causes, increased turbidity and reduced irradiance will further limit eelgrass growth and distribution, as evidenced by the impact of the brown tide blooms on eelgrass populations in GSB. The greater extent of eelgrass meadows along the southern shore compared to northern portions of GSB has been attributed to lower phytoplankton biomass in southern areas due to greater proportions of oceanic water entering via Fire Island Inlet (Carpenter et al. 1991).

Although eelgrass can withstand a wide range of salinities, it is replaced by other species under low salinity conditions (Thorne-Miller et al. 1983). Changes in inlet configuration which result in reduced salinity in GSB could potentially affect eelgrass distribution. High turbidity and reduced irradiance is thought to have caused the loss of meadows below 2 m depth during the brown tide blooms (Cosper et al. 1987, Dennison et al. 1989).

Eelgrass can tolerate a wide temperature range. In GSB, it experiences a seasonal temperature range of $<0^{\circ}$ to $>25^{\circ}\text{C}$. Unusually cold winters could potentially damage perennial eelgrass in GSB through ice scour, i.e., by physically removing root/rhizome systems. Northern eelgrass populations function successfully as annuals, however, and repopulate each year by seed (Robertson and Mann 1984). Unusually warm summers and greenhouse warming are also not an immediate threat to GSB eelgrass, as more southerly populations survive exposure to temperatures $>30^{\circ}\text{C}$ (Thayer and Fonseca 1984). However, warm temperatures have been suggested as a factor in the widespread die-off of eelgrass during the 1930's (Thayer and Fonseca 1984).

Eelgrass meadows reduce currents and cause deposition of sediments, which may ultimately raise the substratum level above low tide level. Although eelgrass can withstand some exposure to air, combined effects of desiccation and high temperature was observed to cause the decline of a population in North Carolina (Thayer et al. 1975).

2. Shellfish and Benthic Invertebrates

The benthic fauna of seagrass beds is moderately well known from several major studies (O'Connor 1972, Marine Sciences Research Center 1973, WAPORA, Inc. 1982, Cerrato 1986) that assessed distribution and abundance patterns in GSB and Moriches Bay. A list of the major species documented as occurring in this habitat is given in Table 5. All of these taxa are also present on subtidal sand flats within the bays. Seagrass beds, however, represent a critical habitat for at least one species (*Argopecten irradians*) in this list. No current information about present abundance of benthic species in this habitat is available. No studies of the seagrass fauna have been conducted within the boundaries of the FINS since 1986.

The sampling methods used in the major studies were not designed to collect animals which live primarily on or among sea-grass blades. Thus, the listing in Table 5 is incomplete. In particular, several gastropods (e.g., *Bittium alternatum*, *Littorina littorea*, and *Mitrella lunata*) and the shore shrimp *Palaemonetes vulgaris* probably should be included, but there is no information documenting their actual occurrence in this habitat.

Marine Sciences Research Center (1973) characterized the benthic fauna in the dense eelgrass beds of South Oyster Bay and in the western and southern part of Western GSB.

They distinguished between two distinct bottom types within the beds: muddy sand flats in South Oyster Bay and sand flats in southwestern South Oyster Bay and Western GSB. Species which were dominant and found within both bottom types included the polychaetes *Nereis succinea* and *Haploscleros fragilis*, the bivalve *Tellina agilis*, and the amphipod *Lysianopsis alba*. Other species which were abundant in both bottom types were the polychaetes *Lumbrineris brevipes* and *L. tenuis*, the bivalve *Solemya velum*, the amphipod *Paraphoxus spinosus*, and the isopod *Idotea balthica*.

In addition to the species which occurred throughout the entire seagrass area, Marine Sciences Research Center (1973) determined that the individual bottom types were characterized by species associated with distinct macrobenthic subcommunities. Within the sand bottom type, additional dominants included the polychaete *Platynereis dumerilii* and the bivalves *Mercenaria mercenaria* and *Laevicardium mortuni*. The polychaetes *Sabella microphthalma*, *Arabella iricolor*, and *Clymenella torquata*, the slipper shell *Crepidula fornicata*, the blue mussel *Mytilus edulis*, and the mud crab *Dyspanopeus sayi* were also abundant. In muddy sand flats of South Oyster Bay, the bivalve *Gemma gemma* and two polychaetes of the genus *Harmothoe* were additional dominants. The polychaetes *Lumbrineris brevipes*, *L. tenuis*, *Nereis succinea*, and *Haploscleros fragilis*, the amphipod *Lysianopsis alba*, and the isopod *Idotea balthica* were also characteristic of the muddy sand flat subcommunity. Based on the sediment maps in Jones and Schubel (1980), the muddy sand eelgrass habitat (54 to 66 percent sand) described by Marine Sciences Research Center (1973) is probably not common within the FINS.

O'Connor (1972) identified biomass dominants in his benthic study of Moriches Bay. Those found in moderate to dense vegetation and having an average biomass of greater than 1 g/m² were the polychaetes *Clymenella torquata* and *Nereis virens*, the gastropods *Urosalpinx cinerea* and *Ilyanassa obsoleta*, the bivalves *Mytilus edulis* and *Mercenaria mercenaria*, the mud crab *Dyspanopeus sayi*, and the tunicate *Botryllus schlosseri*. Cerrato (1986) sampled the seagrass fauna in Narrow Bay and the western part of Moriches Bay during 1981-1982. He identified eight species as numerically dominant, abundant, or common at these sites throughout the study period. These were the polychaetes *Heteromastus filiformis*, *Lumbrineris tenuis*, *Nephtys picta*, *Nereis arenaceodonta*, and *Prionospio heterobranchia*, the blue mussel *Mytilus edulis*, and the amphipods *Ampelisca abdita* and *Lysianopsis alba*.

The Atlantic oyster drill *Urosalpinx cinerea* is a significant predator of clams (WAPORA, Inc. 1982). WAPORA, Inc. (1982) found this species most abundant in the eelgrass beds of Bellport Bay.

The rock crab *Cancer irroratus* was restricted in distribution to thick eelgrass areas during the study by WAPORA, Inc. (1982). Highest densities occurred in the protected, high salinity beds of Islip, South Oyster Bay, and Hempstead (WAPORA, Inc. 1982).

WAPORA, Inc. (1982) reported that the mud crab (*Dyspanopeus sayi*) was widely distributed in Brookhaven and Islip waters. Highest abundances within the boundaries of the FINS occurred in eelgrass beds near Clam Pond in Islip waters. WAPORA, Inc. (1982) attributed the distribution of this species to the availability of adequate bottom cover (e.g., shell, eelgrass, etc.).

Gemma gemma is an extremely abundant, suspension feeding bivalve which is widely distributed throughout GSB and Moriches Bay. In GSB, WAPORA, Inc. (1982) found especially high abundance areas in the eelgrass regions within the boundaries of the FINS in Brookhaven. *Gemma gemma* was present, but at substantially reduced abundances in Islip.

WAPORA, Inc. (1982) found bay scallops (*Argopecten irradians*) on eelgrass flats in Islip and in eastern Brookhaven waters. They noted, however, that scallops were not abundant during the time of their survey (1978). Some harvesting of bay scallops occurred in Islip and Brookhaven waters during the 1960's (Figure 25). Based on landings data, however, there has been no sustained fishery for this species for the past 20 years.

Factors likely to be critical in controlling the distribution and abundance of benthic species associated with eelgrass in Table 3 include eelgrass density, salinity, temperature, sediment type, predation, food supply, and harvesting. WAPORA, Inc. (1982), for example, suggested that the mud crab (*Dyspanopeus sayi*) was particularly dependent on eelgrass for protection from predators, and that the rock crab (*Cancer irroratus*) distribution was controlled by the availability of both eelgrass cover and high salinity water.

3. Finfishes

The importance of eelgrass (*Zostera marina*) as a habitat for the juvenile and adult stages of numerous marine fishes has been frequently documented. Many studies have shown that eelgrass beds support significantly higher faunal densities than other habitats (reviewed by Orth et al. 1984), but the reasons for eelgrass habitat dependence are not always clear and probably vary greatly among species. Some studies have demonstrated that eelgrass habitats represent a refuge from predation while others emphasize the role of eelgrass habitat as nurseries (Heck and Thoman 1984, Heck et al. 1989). Sogard and Able (1991) showed that eelgrass meadows in New Jersey supported higher densities of fish and crustaceans than did *Ulva*-dominated or unvegetated habitats, but less than marsh creeks. On the other hand, Sogard (1992) showed that the growth rates of young fishes in vegetated vs. non-vegetated habitats differ greatly among species. Using caging experiments, Sogard showed that the presence of vegetation increased the growth rate of tautog but not of winter flounder. Castro and Cowen (1991) found that bay anchovy larvae had higher mortality rates over eelgrass bottom than in the middle of GSB where the bottom was unvegetated.

Based on the work of Briggs and O'Connor (1971) in GSB (Table 10), Hanlon (1983) in GSB, Moriches and Shinnecock Bays (Table 2), and of Sogard and Able (1991) in New Jersey, those species in GSB that are probably most dependent on eelgrass or other vegetated habitats include *Apeltes quadracus*, *Gasterosteus aculeatus*, *Syngnatus fuscus*, and juvenile *Tautoga onitis* and *Tautoglabrus adspersus*. Other major species frequently captured over eelgrass beds, but also caught frequently elsewhere, include *Menidia menidia*, *Fundulus heteroclitus*, *Pleuronectes americanus*, and *Cyprinodon variegatus*.

The availability of eelgrass probably has a direct influence on the total number of pipefish, sticklebacks, and juvenile tautog and cunner because these species depend strongly on eelgrass habitat as a shelter and/or nursery. For the other major species that are found throughout the bay, such as the Atlantic silverside, winter flounder, summer flounder, or bay anchovy, the effect of eelgrass habitat availability on overall abundance is unknown.

Several animals which are important as commercial or sport species are abundant in GSB eelgrass meadows and depend on eelgrass as a nursery and adult habitat. Larvae of the bay scallop (*Argopecten irradians*) settle on eelgrass blades, and juvenile scallops depend on dense eelgrass for protection from predators (Thayer and Stuart 1974, Pohle 1990). Hard clams (*Mercenaria mercenaria*) also use eelgrass beds for protection from predators (Peterson 1982). Winter flounder and white hake appear to use eelgrass meadows as nursery areas (Heck et al. 1989); both species occur in GSB eelgrass areas (Briggs and O'Connor 1971). The distribution of major waterfowl feeding and nesting areas in GSB (Beck et al. 1978, Figure 26) closely corresponds to the distribution of eelgrass meadows.

The critical environmental factors affecting finfish populations in the eelgrass habitat are the same as those described above for the water column habitat.

D. SALT MARSHES AS HABITAT

1. Distribution

The distribution of salt marshes within the FINS was discussed previously and is shown in Figures 13 through 15.

2. Coastal Processes and Environmental Factors

Because of their location at the land-sea interface, both marshes and intertidal beaches are influenced heavily by the physical coastal processes operating in the area. These processes include overwash and sedimentation processes, inlet formation and associated hydrographic changes, and shoreline erosion. In many cases these processes control the location, distribution, and abundance of the marsh and beach habitats. For example, as

emergent, high-intertidal plants, marsh grass productivity is limited by habitat area, which is probably most limited by tidal range. Changes in inlet configuration which affect that tidal range will affect the extent of salt marshes, as shown by Clark (1986). Breaches in the barrier are also important to salt marsh distribution. Much of the present salt marsh exists where flood tidal deltas were created by breaches. Although a breach might cause local erosion, the deposition of sediment on the north shore of the barrier island is associated with inlets or washovers. Washovers and the formation of new inlets with the subsequent deposition of flood tidal deltas are rare events, but they can substantially alter the distribution of habitats by converting shallow shoals to intertidal marshland (or marshland to subaerial beach, or deeper-water habitat to shoal areas). A more complete understanding of the intertidal marsh and beach habitats requires a better understanding of the coastal processes shaping them. These processes are summarized below.

Leatherman and Allen (1985) examined the frequency and extent of washovers, noting that overwash could only be evaluated since 1938 when good aerial photographs were first available. From aerial photographs in 1938, 1954, 1960, and 1962, they estimated the areas of overwash and the percentage of island area covered by overwash and provided an estimate of the total volume of overwash sand based on assumed thicknesses:

<u>Year</u>	<u>Area</u> <u>(km²)</u>	<u>%</u>	<u>Volume</u> <u>(million m³)</u>
1938	6.7	26	5.0
1954	3.0	11	1.4
1960	0.4	2	0.2
1962	1.1	4	0.5

The Research Planning Institute, Inc. (1985) also estimated the overwashed sand volume between 1955 and 1979 and found the changes were equivalent to an average rate of less than 35,000 cubic yards per year for the entire shoreline east of Fire Island Inlet. Within the FINS boundaries the volume of overwash sand was on the order of 5,000 yd³/year for the same period. This is very small compared to the volumetric changes on the ocean beach and shoreface. The overwash process, however, appears to be one of the few natural mechanisms for providing sand to the bayside beaches, but it (as distinct from inlet formation) probably has a very minor impact on the growth of marshland.

Leatherman and Allen (1985) found that marsh creation relied primarily on the formation of inlets, a process that, of course, has impacts on other habitats and resources. In addition to eliminating some subaerial barrier island habitat, new inlets should increase the bay salinity, bring stronger tidal currents and wave activity to a formerly quiescent environment, and consequently alter the existing habitats perhaps by eliminating shoal areas and eelgrass beds through shoaling and/or scouring. A new inlet might also increase the tidal range, thus altering the intensity of ocean shore, bay shore, and marsh erosion, as well

as the danger of additional breaches. We know of only one study that attempted to quantify this effect on Long Island's south shore. For Moriches Bay, modeling studies by Pritchard and DiLorenzo (1985) showed that a large breach could increase the normal tidal ranges by 60 percent and some storm-tides by 35-40 percent for certain storms. Translating these hydrographic changes into changes in shoreline erosion, however, remains problematic.

Shoreline erosion is usually thought of as the erosion of the north shore beach, but could also include the erosion of marshland or the narrowing of the barrier island by a combination of north shore and south shore erosion. Erosion of the north shore of the barrier island can be caused by locally generated wind waves, perhaps aggravated by wind set-up, high tides, or storm tides. The sediment supply to the north shore is primarily via overwashes from the ocean side of the barrier or, near inlets, by the growth of flood tidal deltas. The supply of new sediment depends on very energetic storm events which can breach the ocean front barrier beach or dune, while smaller storms can raise erosive waves in the bay more frequently. Smaller storms would, therefore, usually produce erosion usually at a low but more persistent rate. Rare but potentially large overwashes would generally result in localized accretion on the bay side. The net effect could be erosion or accretion over the long term, but the conventional wisdom is that barrier islands tend to migrate landward over geological time scales, so the net result should be accretion on the bay shore if the island is migrating landward.

The shoreline analysis of Leatherman and Allen (1985) shows the net change in the bay shoreline position between essentially instantaneous shoreline positions between 1834 or 1838 and 1873 or 1892; 1873 or 1892 and 1933; 1933 and 1979; and between 1834 or 1838 and 1979 (Figure 27). In the FINS, away from the inlets, the differences in shoreline positions are small and irregular, but tending towards erosion corresponding to an average recession of about one foot/year. Such recession would not in itself be a threat to habitats since the shoreline habitat still exists but at a slightly different location. In some areas, however, the erosion could be converting marshland to shallow shoal habitats.

The rates of shoreline changes and overwashing were calculated from a few essentially instantaneous snapshots of the conditions existing many years apart. From such data alone, it is impossible to determine if differences are due to long-term trends or merely are within the range of intra-annual or supra-annual variations. The inlets are stabilized so the rate of exchange of sea water with the bay should be relatively stable; the freshwater supply should also be fairly stable. There is no evidence that the bay salinity has changed over the long term, although interannual variations of 2 to 3 ppt have been measured.

Shoreline and marsh erosion might be expected to be controlled almost entirely by storm conditions, that is, the intensity, duration, and direction of the waves and the winds, and the height of the storm tides. Wong and Wilson (1985) examined the low frequency, sea-level response (i.e., storm tides) using short-term tide-gage records. They found the

maximum range of fluctuations in coastal sea level due to low frequency (2 to 20 day) weather events was 75 cm. These fluctuations are relatively undampened as they enter GSB. Butler and Prater (1983) calculated combined hurricane and northeaster stage frequency flood elevation curves for a number of locations on the south shore, including the bay side of Davis Park and Saltaire on Fire Island. These curves indicate maximum water level elevations for return periods of up to 1,000 years based on numerical model predictions. Although this work is still considered preliminary, initial results show that the maximum water levels due to surge, tide, set-up, and wave crests associated with a 100-year return period are about 7.2 and 8.0 feet above National Geodetic Vertical Datum (NGVD) of 1929 for Saltaire and Davis Park, respectively. Maximum elevations due to surge and tide alone associated with a 100-year return period are approximately 5.5 feet NGVD of 1929 for the two locations.

The only measurements of wave climate available for GSB consist of a 22-day record collected during the spring of 1992 (Jackson et al. 1993). No long-term measurements have been made. PRC Harris (1985) estimated wave conditions on the bay side of Fire Island Inlet using shallow water forecasting curves and effective fetch calculation methods given in the Shore Protection Manual (USACE 1984). Using sustained 50- and 100-year wind speeds, significant wave heights of 3.4 ft. and 3.6 ft. respectively were projected for this area. Offshore eelgrass beds may to some extent protect low tidal marsh areas from erosion by reducing onshore wave action and nearshore current flow (Thayer and Fonseca 1984). In principle, the beds of eelgrass could help to attenuate wave energy approaching the shore and therefore reduce the threat of erosion. Harlin et al. (1982) and Christiansen et al. (1981) indicated that *Zostera marina* might effectively trap sediments and enhance shoalings in moderate- to low-energy environments. However, the former investigators noted that the initiation and demise of the major portion of the eelgrass population in a Rhode Island embayment was controlled by sediment dynamics, which in turn is regulated by water velocity associated with tidal and wind-generated currents. In areas of strong currents and sedimentation caused by wind stress, plants eventually died from being buried. Given the range of variation of wave attack and water level elevation, it seems likely that any effect of eelgrass on shoreline erosion would be immeasurably small.

The occurrence of overwashes and the formation of new inlets would also depend in a basic way on the storm intensity and character. The absolute elevation of the storm tide is probably of more importance than wave height. Large waves are expected in any storm, but it is during times of exceptionally high water levels that the dunes are threatened with breaching. The dune height, width, and volume all play a role in controlling overwash. If the dune altitude is above the storm tide level, breaching can only occur if the volume of the dune is substantially eroded, so the volume of the dune as well as the duration of the erosive event are critical. Based on empirical data, Hallermeier and Rhodes (1988) postulated that for a 100-year event, a dune would not erode through if it contained 50 m³/m or more of sand in the area above the 100-year still water flood level and seaward of the crest. If the

storm tides rise above the elevation of the dune, overwash occurs regardless of the dune volume. A dune of large volume is greater protection against overwash during the more frequent, lower elevation storm tides, but a high dune elevation would be beneficial during the very extreme events. It must be realized, however, that these benefits are qualitative. The processes are very non-linear and ill-defined. If one dune is twice the height (or volume) of another dune, it does not necessarily mean that it offers twice the degree of protection. It may be only marginally more resistant to overwash, or, alternatively, it may be many times more resistant. Presently, there is not enough information to quantify the level of protection provided by various dune configurations in the face of storm-induced erosion.

McCluskey et al. (1983) calculated the volume of sediment transported by eolian processes for the entire shoreline east of Fire Island Inlet was on the order of 250,000 yd³/year with over 90 percent of this transport occurring seaward of the dune crest and in an easterly direction. Sand-trap data indicated the amount of sand transported across the dune from the seaward direction to be 0.08 yd³/ft/year. This seaward source has been supported by grain-size analysis (Williams et al. 1985). Massa (1981), however, has shown that ridges near Fire Island Inlet were primarily produced by water-borne sand, and at East Hampton the analysis of grain sizes by Zimmer (1991) show both air-borne and water-borne sands contribute about equally to the dune formation. The supply of sand to the dune does not seem to be limited by the amount of sand on the beach but rather by the occurrence of suitable wind (and wave) events (Zimmer 1991). Rhodes Fairbridge (Columbia University, personal communication) has suggested that the rates are not sufficient today to explain the large dunes and that these dunes may be relict features dating from a time of lower sea level.

The dune height and volume also contribute to controlling the process of inlet formation. For this process, however, the width of the barrier and the back bay bathymetry also are important. Inlets are often created from the bay side. The dune area may be weakened by overwash, but the bay water must break through the barrier to form an inlet. The chances of this are enhanced if there is a relatively deep bayside channel near the shore to reduce the friction of any shoreward flow and if the island itself is relatively narrow. Once again, however, these conditions are merely qualitative ones. All other things being equal, a section of the barrier that is narrower and near a deep bayside channel may have an only insignificantly greater risk of new inlet formation, or it may be many times more at risk. Again, the data needed to quantitatively assess this risk is not presently available.

3. Shellfish and Benthic Invertebrates

Key benthic species in salt marshes include the mud snail *Ilyanassa obsoleta*, the salt-marsh snail *Melampus bidentatus*, the ribbed mussel *Geukensia demissa*, the marsh crab *Sesarma reticulatum*, and the fiddler crabs *Uca pugnator* and *U. pugnax* (Table 6). In addition, a large assemblage of epifaunal and infaunal species common in subtidal sand and

mud habitats should be present in the marsh, but no information about present abundance is available. No studies of the salt marsh fauna have been conducted within the boundaries of the FINS. Therefore, it is not known which of these species occur within the study area. Marsh animals, like other intertidal organisms, must possess morphological, physiological, and behavioral adaptations to resist heat stress, desiccation, and limited submergence time (Levinton 1982).

4. Finfishes

Salt marshes have long been recognized as nurseries for a wide variety of fishes (Nixon and Oviatt 1973, Weinstein 1979, Rountree and Able 1992). The primary finfish inhabitants of polyhaline mid-Atlantic salt marshes are *Menidia menidia* and *Fundulus heteroclitus* (Rountree and Able 1992). *Cyprinodon variegatus* and *Anchoa mitchilli* are also abundant, but less so than the above species. In a comparison of marsh creek, sea lettuce, and eelgrass habitats, Sogard and Able (1991) found that salt marsh creeks supported the highest overall densities of fish, but only for a few species (listed above) that are also abundant in other estuarine habitats. Hanlon (1983) collected primarily striped killifish, Atlantic silversides, mummichogs, and bluefish (in descending order of abundance) from the salt marsh habitats of the south shore bays he sampled.

The relatively low abundance in GSB of *F. heteroclitus*, which usually dominate mid-Atlantic salt marshes, is probably a reflection of the lack of salt marsh habitat. Whether lack of salt marsh habitat affects the abundance of other species, such as winter flounder or summer flounder, is unknown. *Menidia* tend to be more abundant in salt marshes than along beaches or in open water (Conover and Ross 1982, Rountree and Able 1992, Sogard and Able 1991), but their dominance of the overall fish community in GSB suggests they may be near maximum abundances.

E. INTERTIDAL BEACHES AS HABITAT

1. Distribution/Physical Characteristics

The estuarine intertidal beaches are the least studied marine habitat in the FINS area. This is probably due to the relative scarcity of flora and fauna in this area compared to the other habitats. Consequently, little information is available regarding the physical or biological characteristics of the intertidal beaches. In terms of distribution, intertidal beaches generally comprise the portion of the bay shoreline not inhabited by salt marsh vegetation. As a result, Figures 13 through 15, which depict the locations of salt marshes, can be used to infer the extent and distribution of intertidal beach habitat within the FINS.

Like the salt marshes, intertidal beaches are by definition at the interface of the land and the sea and would be subject to the same physical processes described in the previous section on salt marshes.

2. Shellfish and Benthic Invertebrates

The only reference of any consequence describing the intertidal beach macrofauna is Croker (1970). As cited earlier, this study has very limited value in characterizing the intertidal beach fauna. Of the twelve species reported, only eight clearly were collected in a bay habitat. These are reported in Table 3. Five of these taxa (*Nephtys bucera*, *Nereis arenaceodonta*, *Haploscleros fragilis*, *Scolecopsis squamata*, and *Acanthohaustorius millsi*) were also collected in subtidal habitats by either Cerrato (1986) or Wiggins (1986). The isopod *Chiridotea nigrescens* also has a distribution that includes shallow water, subtidal areas (Gosner 1971). Of the remaining species cited by Croker, only the isopod *Chiridotea caeca* (Gosner 1971) and the amphipod *Neohaustorius biarticulatus* (Bousfield 1973) appear to be intertidal. Intertidal sand flats are the prime spawning grounds for the horseshoe crab (*Limulus polyphemus*). The hard clam *Mercenaria mercenaria* and soft-shell clam *Mya arenaria* probably also occur in this habitat, but no data are available to confirm this.

No information about the present abundance of intertidal macrofauna is available. No studies of the intertidal beach fauna have been conducted within the boundaries of the FINS. Therefore, it is not known whether these species occur within the study area. In general, most species found on intertidal beaches will also be distributed subtidally. Possible exceptions in the present case include the isopod *Chiridotea caeca* (Gosner 1971) and the amphipod *Neohaustorius biarticulatus* (Bousfield 1973). The two apparently intertidal species, the isopod *Chiridotea caeca* (Gosner 1971) and the amphipod *Neohaustorius biarticulatus* (Bousfield 1973), may be limited by the availability of this habitat. Intertidal organisms on sandy beaches must possess morphological, physiological, and behavioral adaptations to resist heat stress, desiccation, and limited submergence time (Levinton 1982).

Some regular commercial harvesting of soft-shell clams (Figure 28) occurred in Brookhaven waters during the 1960's to mid-1970's. Very little commercial harvesting has been reported in either Islip or Brookhaven from 1975 to the present. Declines have been attributed by McHugh (1972) to pollution, over-harvesting, and predation.

3. Finfishes

Intertidal beaches are used by several fish species as a spawning site. The Atlantic silverside deposits its eggs in filamentous algae (*Enteromorpha* sp.) or other vegetative material in the upper intertidal zone of salt marshes and open beaches (Conover and Kynard 1984) where they are protected from predation by aquatic predators (Tewksbury and Conover 1987). The mummichog also deposits eggs in the upper intertidal zone either on stems of

Spartina, within empty mussel shells, or amongst filamentous algae (Taylor et al. 1977, Able and Castagna 1975, Conover and Kynard 1984). Both of these species spawn on a semilunar schedule that corresponds with the occurrence of new and full moons.

There is insufficient knowledge of the use of intertidal habitats for spawning by GSB fishes (silversides and mummichogs) to decide whether or not habitat availability limits abundance.

V. DISCUSSION

A. DATA GAPS AND MONITORING NEEDS

1. Physical Environment/Coastal Processes

In general, higher resolution data and information on coastal processes and sediment transport are needed within the FINS. Previous studies provide baywide descriptions of the physical environment, general circulation, and hydrography. However, these studies do not contain sufficient detail to adequately address coastal processes management issues associated with Fire Island's north shore which is composed of a mosaic of many, relatively small subenvironments (beaches, marshes, coves, bays, etc.) that can be very different in terms of physical properties. Data collection and monitoring programs should be established to describe these environments on an appropriate scale. Several types of measurements are needed.

The measurements of the change in the shoreline position is one of these types of data. Unlike observations on a straight, open-ocean shoreline, measurements of shoreline changes at one location on the north shore of Fire Island are unlikely to be applicable even a short distance away. The shoreline orientation and character changes too quickly. To understand and forecast shoreline changes and identify any critically eroding areas, changes in shoreline position need to be measured on a fine spatial scale.

An inventory of coastal environments is also needed on a small scale, including artificial settings. Along the bay shoreline, pocket beaches, small coves, marshes, dredged channels, and bulkheaded sections of shoreline alternate over small distances. There is no comprehensive inventory of these classes of shoreline, but such information is needed to assess site-specific impacts and trends in changing shoreline types. Information on the location and types of structures found along the shoreline can probably be found in state or NPS permit records and in detailed maps produced by Topometrics, Inc. in 1980 as part of the USACE shoreline study.

Quantitative knowledge of the local groundwater hydrology is needed at a variety of sites along the north shore of Fire Island. The freshwater lens under the barrier island is contained in the Upper Glacial aquifer which is separated from the Magothy Aquifer by the Gardiners Clay. Most of the potable water used on the island is drawn from the Magothy Aquifer and wastewater is discharged into the freshwater lens. While the total amount of water (and pollutants) contributed from the island is a negligibly small fraction of the total supply to the bay, it can have local impacts. To determine whether or not this is the case, site-specific studies are needed to quantify the local hydrography.

Among the different environments along the north shore, the expression of important coastal processes must also be described. There is little information, for example, about the turbidity generated at the bay shoreline by usual wave action, storms, boat wakes, dredging activity, clamming, or the local effects of algal blooms. Measurements need to be made to quantify the relative contribution of each of these sources, to determine whether they have a significant impact on the bay's ecology.

In general, there is a need to improve our understanding of sediment transport (longshore drift rates and directions, shoaling rates, storm effects) in the bay. Particular attention is needed to describe how these processes vary along the bay shoreline. Boundary layer flow studies also deserve attention in order to better quantify the physical stress on eelgrass beds, clam beds, and other habitats.

2. Plankton/Water Quality

There is little or no information concerning plankton and water quality within the FINS's waters on the bay side, although many of the above referenced research findings and issues, which have been identified for GSB as a whole, would be expected to be important in considering FINS's bay waters. There is an ongoing monitoring program, conducted by park personnel in conjunction with the Suffolk County Health Department, along transects north to south across Fire Island, which includes water samples for total and fecal coliform bacteria counts along the beach areas on the bay side. This program could be enlarged to include some key measurements for plankton productivity and water quality assessment.

Additional measurements suggested would be: temperature, salinity, Secchi disc (for light penetration), chlorophyll *a* (preferably whole and $>20\ \mu\text{m}$ fraction), and dissolved inorganic nutrients such as nitrogen and phosphorus. These observations should be made so as to delineate periods when the island and park have large influxes of people on a seasonal basis, particularly summer periods, as well as areas which are inhabited versus wilderness areas. The transects which exist already will encompass areas along the island where the residence time of the water varies, increasing up to hundreds of days in the easterly direction. The area around the single sewage treatment plant should be included in the transects, if it is not already being sampled. Measurements of groundwater seepage into the bay and nutrient levels are also suggested, since these can contribute to nutrient loading from septic tank drainage.

This expansion of the existing monitoring program will be very useful for evaluating the state of eutrophication of park waters and the effects of summer, visitor communities versus winter resident communities, on nutrient loading and the potential for algal blooms. The more local assessment of park waters can then be compared to the more extensive findings for GSB, in general. This will provide information necessary for evaluating the water quality in park waters and the need, if any, for corrective measures.

In conjunction with this monitoring program, an effort to do an inventory of plankton, both phytoplankton and zooplankton, within park waters is suggested. This does not have to be a very extensive or expensive effort if it is focused on identifying the key, important species in the plankton at selected times (seasonally) and at selected sites (particularly west to east, reflecting the effects of oceanic waters moving in through Fire Island Inlet). This inventory can be compared to the plankton already defined for GSB as a whole and the extent to which there are differences between park waters and the open bay waters. One species of interest whose populations should be assessed is the brown tide microalga *Aureococcus anophagefferens*, and the Brown Tide Monitoring Program of the Suffolk County Health Department could help in this regard. Brown tide blooms continue to periodically plague Long Island bays, and the presence of this alga in park waters is of interest for predicting the potential for blooms. Noting the presence of other bloom type species is also suggested.

3. Seaweeds

The seaweed resources of the FINS should be described both qualitatively (species present and distribution) and quantitatively (abundance and seasonal variation). This information does not currently exist. The potential importance of seaweed beds as habitats for invertebrates and fishes, as indicators of eutrophication, or as nuisance blooms, justifies creation of an inventory.

Specific monitoring of *Codium fragile* populations within the FINS is recommended, if part of a comprehensive macroalgae monitoring effort. The abundance of this introduced species may be increasing in GSB, and high abundances could have significant impacts on eelgrass and shellfish.

4. Seagrasses

Annual surveys of the eelgrass meadows within the FINS would provide an indicator of the health and status of eelgrass in GSB. The eelgrass meadows of GSB are an important resource and habitat, have suffered large fluctuations in area and density during historic times, and are not well described or monitored presently.

Light is the limiting factor to eelgrass distribution, abundance, and productivity and may also be a factor in major population changes (e.g., during the brown tide blooms). Periodic (e.g., weekly) measurements of bottom irradiance, either by Secchi disc or quantum meter, would provide information about seasonal variation in light availability, as well as long-term changes due to changes in water quality, etc.

5. Salt Marshes

The NYSDEC is presently analyzing and groundtruthing 1989 aerial photos of GSB salt marshes, including those within the FINS. Beginning in 1994, the NYSDEC plans to take and analyze aerial photos on an annual basis, with groundtruthing information taken at longer intervals.

6. Benthic Resources

An inventory of the benthos in each of the major habitat types within the FINS is required in order to identify the resources. No comprehensive studies of the benthic fauna within the boundaries of the FINS have been attempted. Of the four habitats, no information was available on the species present in salt marshes and intertidal beaches, and very limited information was available on the fauna of vegetated and unvegetated bay bottoms. Species growing on eelgrass blades, living among the plants, or utilizing this habitat for protection from predators were not assessed in any study. Only a few dated studies, characterized by either limited scope (i.e., restricted to shellfish and their predators as in WAPORA, Inc. 1982) or limited geographic range (i.e., restricted to Moriches Bay as in O'Connor 1972 and Cerrato 1986), actually sampled within the FINS boundaries. Much of the information presented on the benthos was extrapolated from other studies conducted outside of the FINS boundaries. Data gaps are large enough, therefore, to state that an accurate, reliable characterization of the benthos in any of the four habitats cannot be made at this time.

Since the FINS extends the length of GSB and includes a wide variety of habitats, the NPS is in an ideal position to implement a monitoring program which could track and assess the health of the bay. Such a monitoring program, if implemented, should not be limited to water quality sampling but should contain a benthic faunal component for several reasons, including the fact that benthic fauna are generally regarded as sensitive indicators of disturbance because they are year-round and relatively sessile residents, and they include organisms with a wide range of life histories, trophic groups, and tolerances to environmental conditions. Since the activities of benthic organisms in shallow water systems can have a major impact on both the bottom and the water column, any impact on the benthos will be directly reflected as a change in water quality. Finally, the highest concentrations of most toxicants are generally found in sediments, so it is reasonable to have a benthic component included in a monitoring program.

7. Finfishes

There is little doubt that a major influence on the abundance of fishes in GSB is harvesting by recreational and commercial fishing. Fortunately, the finfisheries of GSB in the late 1950's were thoroughly described by Briggs (1962), but we have insufficient knowledge of how the overall commercial and recreational fisheries of GSB have changed

since then. The NYSDEC currently monitors catches of weakfish and flounders by the Captree head-boat fishery, and usage of the Kismet artificial reef is also monitored. But a broader characterization of the commercial and recreational finfishery of GSB as a whole would be valuable.

Use of habitats within the FINS as a nursery for young fishes or for adult fishes needs to be better established. The boundaries of the FINS encompasses a large fraction of the eelgrass and other vegetated habitats within GSB. Based on maps of eelgrass distribution provided by Jones and Schubel (1980), the eelgrass meadows off the eastern end of the FINS are the largest in GSB. These vegetated habitats may represent a critical habitat for the early juvenile stages of the wrasses (cunner and tautog) that occupy the reef and other hard bottom habitats near Fire Island Inlet. There are several channels dug directly through the major eelgrass meadows of the FINS that lead to communities on Fire Island and these receive frequent boat traffic. The effect of these channels and the boat traffic they bring, as well as the effect of re-dredging of such channels were this necessary, on the fauna inhabiting the eelgrass community should be examined. Moreover, the importance of eelgrass meadows as opposed to other vegetated (macroalgal) habitats and/or non-vegetated bottom habitats to the recruitment of reef species and flatfishes needs to be evaluated.

There is a lack of knowledge concerning utilization of GSB by fishes in winter. Few studies include the winter months, hence, we can only speculate on the composition of the winter community. Winter mortality may represent a recruitment bottleneck for some species and, therefore, should not be overlooked.

Winter flounder spawn within local bays and estuaries, and evidence from tagging data suggests that estuaries along the mid-Atlantic coast may each harbor a unique stock of inshore fish. This needs to be evaluated with respect to GSB. Are the winter flounder of GSB a unique subpopulation, or are they part of a much larger population found along the mid-Atlantic coast? Poole (1966) found that winter flounder from GSB grow more slowly than in east end bays of Long Island. Is this still true today when densities of winter flounder are at historically low levels? How does current growth compare with the past?

B. RESEARCH OPPORTUNITIES

1. Physical Environment/Coastal Processes

Data gaps and monitoring needs discussed above should also be the topics of research to understand the patterns documented by a data collection program. Research topics include (a) understanding local shoreline changes along the bayside and their aggregate effects, (b) quantifying potential impacts of bulkheads and other shore protection devices, and (c)

quantifying the processes controlling the local groundwater hydrography and the impacts of groundwater seepage on the local ecology.

In addition, a major research effort needs to be focused on understanding the formation and behavior of new inlets. Methods need to be developed to predict where new breaches are likely to occur as well as the fate and impacts of new inlets. This research would include studies of the shoreface dynamics that control spot erosion on the ocean shore. Historically, inlets seem to have occurred in the same places repeatedly. This may be found to be related to the offshore morphology or bar geometry. The role of the dunes in preventing breaches needs to be more firmly established and quantified so that the relative degree of protection along the length of the island can be assessed. In the bay itself, the dynamics of bayside flooding and storm erosion need to be investigated, including the role of marshes, eelgrass beds, and channels in the process of inlet formation.

If a new inlet does form, decision makers will need to know the effects of the inlet on the bay's salinity, tidal range, residence time of the bay water, and mainland flooding frequency. They will also need to know whether or not the breach will close naturally and, if so, how long it will take. Quantitative models of the bay oceanography and of inlet dynamics are needed to decide these issues. These models must be calibrated and verified by a program of well-focused measurements in the bay as well as on the ocean shore. They may indicate whether or not new inlets need to be artificially closed or, perhaps, if new inlets need to be artificially opened to relieve pressure on critical areas or to enhance the bay environment.

2. Plankton/Water Quality

The plankton and water quality monitoring and inventory programs outlined in the previous section should be given top priority. However, a research opportunity which perhaps should be considered in light of the continuing brown tide blooms in GSB during summer months is the role of micronutrients, particularly iron, in fueling these blooms. Iron has long been invoked as a micronutrient promoting nuisance blooms, particularly red tides caused by dinoflagellates, and recent results (Casper et al. 1993) implicate it in the chronic brown tides. Long Island freshwater inputs are very high in iron but vary spatially and temporally due to storm activity. How these high iron loadings to Long Island bay waters, and in particular FINS waters, might affect the potential for nuisance blooms is of interest and might further an understanding of the factors contributing to these blooms. How these loadings might change between periods when human populations and uses of freshwater are high on Fire Island, as during the summer months, will be informative relative to the potential for impacts on local bay waters. Determining the species of iron and its availability to specific algae is important. How the chemical speciation of dissolved iron and changes in chelation affect the growth of the brown tide species is currently under investigation by E. Casper.

3. Seaweeds

The cause of extensive *Cladophora* blooms in GSB during the 1950's and 1960's has been hypothesized to be nutrient enrichment, but this hypothesis has not been tested. Information about the nutritional status of seaweeds in the FINS, specifically the growth response of opportunistic green algae to fertilizing with nitrogen and/or phosphorus, would be helpful in understanding and predicting future blooms. Studies of light-limitation of growth would also provide useful information. If seaweeds in GSB are limited by light rather than nutrients, changes in phytoplankton abundance might be a threat to the resource or an influential factor in causing blooms.

4. Seagrasses

Epiphytic organisms growing on eelgrass in GSB are not well known. Epiphytic algae, in particular, may have positive (reduction of grazing pressure) or negative (competition for light and nutrients) effects on the eelgrass. Enhancement of algal biomass due to eutrophication may result in reduced productivity and abundance of eelgrass. Identification and biomass measurements of epiphytes, particularly epiphytic algae, during surveys of eelgrass populations would provide baseline data and information about long-term changes.

5. Salt Marshes

The extensive marshes within the FINS seem to be characteristic of Long Island marshes, but may be relatively undisturbed by human activities. Research using those marshes as experimental sites should be encouraged.

6. Benthic Resources

The diversity of available benthic habitats (i.e., intertidal and subtidal sand flats, salt marshes, and seagrass beds) makes the FINS a natural laboratory for detailed investigations of animal-substrate relationships. Research should be directed toward understanding benthic processes within the various habitats, identifying functions key or unique to each habitat, and determining how various substrates and changes in substrate type affect the benthic resources. Such studies would have both basic and applied value.

As an example, an examination of the literature suggests that the relationship between seagrasses, hard clams, and hard clam predators is well known. Extensive research by C.H. Peterson and co-workers (e.g., Peterson 1982, 1986; Peterson et al. 1984; Irlandi and Peterson 1991) in North Carolina has led to the conclusion that seagrasses are beneficial to hard clams, providing a refuge from predators and conditions supporting higher individual growth and higher population densities than found in unvegetated bottoms. In contrast, data

from WAPORA, Inc. (1982) for GSB show lower hard clam abundances in eelgrass, and additionally, eelgrass beds serving as a refuge for hard clam predators such as the mud crab *Dyspanopeus sayi*. Thus, some processes in and functions of eelgrass beds within the FINS may be quite different than currently presumed. Additionally, these observations have direct management consequences, suggesting that seagrasses within the FINS may not be an appropriate area for planting seed clams if one were interested in enhancing hard clam populations in the bay.

7. Finfishes

The FINS can play an important role in management of GSB fishes by the identification and protection of critical habitats for various species that occur within the FINS, especially if those habitats are rare outside park boundaries. The opportunity to investigate the relationship between habitat and fish production within the FINS should be seized. Moreover, it would be extremely valuable to begin and maintain an annual seine and/or trawl survey of finfish abundance within the FINS. No agency currently monitors fishes of GSB. Such data would provide a fisheries-independent source of information on year class strength of various species, as well as providing baseline information that could be used to evaluate the effects of perturbations to the system such as algal blooms, breaches, or oil spills.

C. POTENTIAL RESOURCE HABITAT ISSUES AND IMPACTS

The interrelationships among both living and non-living resources in GSB are complex and substantial. Conditions in the bay impact the FINS just as conditions in the FINS can affect the bay and its resources. To be successful, resource and habitat management efforts in the FINS must recognize this interdependency. Management programs should be coordinated with and sensitive to the programmatic goals of those agencies responsible for other areas in the bay. The following section provides an overview of the technical issues and potential threats that were considered most significant in terms of maintaining, protecting and enhancing the natural resources and habitats of the GSB and the FINS.

1. Physical Environment/Coastal Processes

The most important coastal processes issue, with consequences extending far beyond the FINS area, is the opening of new inlets in the barrier island during storms. Inlet formation in a natural barrier island system is a major event that can cause substantial alterations to the bay's environment. Potential impacts associated with these features include the possibility for increased erosion and flooding on the mainland, changes in the tidal range, salinity, and flushing characteristics of the bay which may destroy some habitats and create others, increased shoaling at presently stabilized inlets, and disruptions to the longshore

transport of sand along the ocean coast. Over time periods of hundreds to thousands of years, new inlet formation is important in maintaining the barrier system. The relative short- and long-term costs and benefits associated with efforts related to managing new inlets must be evaluated.

The potential for human activity to significantly affect the coastal processes which influence the various habitats depends to a large extent on the level or intensity of the activity and its location. Leatherman and Allen (1985), for example, cite the development of Fire Island between 1938 and 1965 as one of the principal causes of reductions of marshlands during that period. Obviously, increases in population density and human use of the bay environment could affect water quality and local habitats. However, there is little quantitative data available that would permit an accurate assessment of the relative impact of most human activities compared to the effect of natural processes. As a result, there is not enough information to accurately characterize the carrying capacity of GSB and the FINS resources and habitats at this time. Ideally, this type of information could be used in conjunction with future population projections to develop sound management plans and strategies.

Several important local coastal processes issues that need to be quantitatively assessed in a regional, environmental context were identified. These are as follows:

(1) Use of shore hardening structures to control erosion and flooding. Although there is no up-to-date inventory of shore protection devices in the area, bulkheads and revetments are the most common erosion control structures found along the north shore of Fire Island. Quantitative field data on the potential impacts of these structures is scarce. However, it has been noted by Dean (1986) that coastal armoring can cause adverse impacts by reducing sediment supply to the beach, if the upland is a significant source; by blocking longshore transport of sand, if the structure projects into the surf zone; and by preventing the landward migration of the shore form, if the area is experiencing long-term chronic recession. If the barrier island is migrating landward over the long term, one would expect the bay shoreline to be moving north or accreting, and some of the impacts associated with these structures would be insignificant over time periods of hundreds to thousands of years. However, they may have local short-term impacts in eroding areas.

(2) The effect these structures may have in terms of preventing the landward migration of wetlands in response to rising sea level. In most cases these structures were built in response to erosion stresses. Thus, the structures are commonly found in high energy areas that have sandy beaches and scarps typical of an eroding shoreline rather than the fringe marshes typical of a stable coast. In these cases, the structures may result in the loss of the beach, but would have minimal impacts in terms of wetlands loss. However, structures placed landward of existing marshes probably would prevent the possible landward migration of wetlands in the face of rising sea level. Whether this will have an impact on

the extent of this habitat depends to a large extent on whether the marshes will be able to keep pace with rising sea level. Greatly increased rates of sea level rise could outpace sedimentation rates and result in the loss of the wetlands even in areas without structures.

Other coastal process issues that should be quantified for their regional environmental impact are:

- a. the desirability of creating, enhancing, or preserving particular habitats;
- b. the impact associated with the construction of docks;
- c. the desirability of removing offshore debris (e.g. sunken vessels, timber, etc.); and
- d. the possible need to manage overwash sand. (Is it best left in place? Should it be returned to the beach as an erosion control measure or delivered to the bay?)

Notably, the effects of boat wakes and Off-Road Vehicles (ORV's) were not considered to be issues in this area; the available data, technical information, and experience suggest that these impacts are minor except perhaps at special very localized sites as discussed below.

Boat wakes generated very near the shore could contribute to erosion in certain, protected areas. However, studies of the effect of boat wake on shore erosion (Zambawa and Ostrem 1980) showed that adverse impacts associated with boating activity were in most cases insignificant compared to erosion caused by storm events and wind-generated waves, even in fetch-limited areas. It was determined that for boating to have an impact on erosion in an area the shore line has to have a combination of the following factors:

- a. an exposed point of land in a narrow channel or cove,
- b. fastland composed of easily erodible material,
- c. steep nearshore profile gradient, and
- d. high rate of boating with passes within about 100 yards of the shoreline.

Because most of the north shore of Fire Island is exposed to considerable fetches, it is unlikely that boating is a significant contributor to shoreline erosion problems on a regional basis. Similarly, one would expect that potential turbidity and sediment resuspension resulting from boating activities would be very small compared to that caused by natural processes.

Studies (Leatherman and Anders 1981) done on the impact of ORV's on erosion on the ocean beach indicate that while ORV's can cause a downslope movement of sand on an active beach profile (i.e., seaward of the dune), the sand is only moved a few tens of centimeters away from the tire track and the total sand flux produced by this activity is

several orders of magnitude less than the daily natural variations in beach volume. Profile measurements could distinguish no significant difference between heavily-traveled beaches and relatively undisturbed beaches. However, these studies did show vehicles traveling near or on dune vegetation could significantly impact the integrity of the dunes. Traffic on the dune is, of course, prohibited and this does not appear to be a problem as long as compliance levels continue to be high. Gaps in the dunes that are maintained for vehicle access to the beach, however, provide "weak-links" in the dune line and may increase the chances of overwash and flooding. In addition, vehicle traffic may limit the nesting activity of the piping plover. All of the above mentioned studies focused on the ocean beaches. While ORV traffic could impact vegetation on the bay shoreline, this activity does not appear widespread in this area and, thus, does not exert significant influence on coastal processes in this area. Pedestrian traffic is probably more widespread than ORV traffic in this area.

2. Plankton/Water Quality

The deterioration of water quality and increased eutrophication problems through nutrient loadings and the promotion of algal blooms will have two major effects on the FINS bay habitat. Light availability is crucial for the maintenance of eelgrass habitat areas and this can be gravely attenuated during algal blooms or just by increased particulate loads due to unbalanced (i.e., unconsumed) algal growth. Eelgrass habitat within the park area should be preserved and promoted as a valuable resource, as detailed in other sections. Also, if nuisance algal blooms occur, this could affect higher trophic levels such as bivalve populations (particularly clams) or possibly fish and fish larvae dependent on the normal, diverse community of plankton species for growth and survival. The ongoing chronic brown tides are only one example of how the ecosystem can be affected. If toxic algal blooms occur, such as some red tides, even top predators, including humans, can be affected by the toxins. So far, this is not a problem in GSB or the park waters, however, a further evaluation of existing conditions and inventories is desirable for future assessment of impacts. Also, the continued standard water quality monitoring conducted by the Suffolk County Health Department as well as the fecal and total coliform bacteria counts used as pathogen indicators by the NYSDEC will be useful to determine any threats to the beaches and shellfish resources and habitats within the Fire Island park area and waters.

3. Seaweeds

Eutrophication could affect seaweeds directly by enhancing nutrient-limited growth or indirectly by causing phytoplankton blooms and reducing benthic irradiance. These effects are dealt with in the water column section.

4. Seagrasses

Physical damage to vegetation associated with boating and fishing activities (propeller and anchor damage) and clamming (rake damage) may have deleterious effects on eelgrass populations within the FINS. The magnitude of these effects could be determined by comparing eelgrass density in restricted and control areas. A preliminary study which controls boating and clamming within small monitored plots could provide data to determine impacts of these activities on eelgrass habitat.

5. Salt Marshes

Accretion rate and the ability of tidal marshes to keep up with sea level rise depends on sedimentation as well as peat accumulation. Changes in sediment flux could affect accretion rates of marshes. Enhanced rates of sea level rise due to global warming could potentially drown salt marshes globally.

Salt marshes are particularly susceptible to damage by oil spills. Although major spills within GSB are unlikely, spills on the Atlantic side of the FINS are possible and could impact GSB marshes via the inlets. It is recommended that the local spill response plan be examined for its ability to prevent or reduce damage to FINS marshes and other intertidal habitats.

A permanent breach could affect GSB salt marshes by changing tidal range. Salt marsh impact should be a consideration in setting breach management policy. The construction of new bulkheading, piers, and floats within FIN's boundaries should be monitored by the NPS. The NPS should request to be notified of all such projects occurring within the FINS's boundaries by being included on the U.S. Army Corps of Engineers Public Notice recipient list. In this manner, the NPS could begin to assess the individual and cumulative effects of such structures on FINS salt marshes.

6. Benthic Resources

Oyster populations in GSB have undergone a dramatic decline since the turn of the century. Factors contributing to this decline include eutrophication and associated small-form phytoplankton blooms (McHugh 1991), salinity changes (due to opening of Moriches Inlet) allowing increased predation by oyster drills (McHugh 1991), and MSX (National Park Service 1977b).

Harvesting has been intense on hard clams in GSB during the past decade. Reflecting this, Wallace (1991) found a shift in hard clam size- and age-structure to smaller, younger individuals. For example, during 1978 in Brookhaven waters, over 75 percent of the hard

clam population was comprised of legal sized clams (WAPORA, Inc. 1982). Only 31 percent of the clams in that same area were legal size in 1986-1989 (Wallace 1991).

At present, hard clams support the only economically important commercial shellfishery occurring in GSB. WAPORA, Inc. (1982) and the census surveys by the Towns of Islip (Buckner 1984) and Brookhaven (Kassner et al. 1991) show that the major hard clam resources lay to the north outside of the boundaries of the FINS.

None of the other commercial shellfish species (i.e., soft-shell clams, oysters, bay scallops, mussels, whelks, and blue crabs) support more than very modest commercial landings. None of these species are presently limited by overharvesting in GSB.

The brown tide cannot be excluded as having an important influence on shellfish populations and eelgrass fauna in the bay. Brown tide blooms have been a persistent problem in Long Island's bays since 1985. The devastating impact of these blooms on scallop populations and noted reductions in eelgrass cover have been well documented (Cosper and Wise 1990). Less well known, however, are the effects on other shellfish species and, in particular, their potential impact on hard clams. The effect of eelgrass loss on animals living on or among the eelgrass has also not been assessed.

Changes in salinity, temperature, and phytoplankton composition associated with the creation of new inlets could have a major impact on the benthic fauna. As discussed earlier, there are distinct benthic assemblages associated with salinity regimes in the bay. The magnitude of faunal change would depend on the location, but a high salinity assemblage would be expected to become dominant in the region near a new inlet. WAPORA, Inc. (1982) suggested that increased salinities would adversely affect hard clam populations primarily through an increase in the distribution and abundance of potential hard clam predators such as whelks, moon snails, oyster drills, and hermit crabs.

Any substantial changes in substrate type would also have an impact on benthic community structure. As discussed earlier, distinct communities or subcommunities are associated with specific sediment grain size, organic content, and vegetation characteristics.

A large proportion of the existing eelgrass habitat within Islip and Brookhaven is found within the boundaries of the FINS. Loss of this habitat in the FINS could be expected to limit the productivity of some species and could adversely affect living resources in the rest of the bay. Species growing on eelgrass blades, living among the plants, or utilizing this habitat for protection from predators would be especially impacted. Stauffer (1937), comparing the benthic fauna before and after the disappearance of eelgrass around Woods Hole in 1931, noted that one-third of the characteristic eelgrass-associated species were eliminated. Almost all of the animals found living on or among the eelgrass disappeared

with it. Benthic epifaunal and infaunal species were least affected, although the number of these species also declined slightly.

7. Finfishes

Major changes in the finfish resources of GSB are probably those relating to over-exploitation by the recreational fishery. The modest commercial fishing that is carried out in the bay is minor compared to the magnitude of the recreational harvest. However, with the possible exception of winter flounder, stocks of fishes harvested from GSB must be managed on a geographic scale much larger than that of GSB to be effective. It would probably not be productive for the FINS to get involved directly in the fishery management arena. But an important fishery enhancement activity that can be implemented at the local level is protection of natural habitat.

The potential impact of severe algal blooms on fishes needs further study. Although past studies on bay anchovy suggest little adverse impact on survival and growth, the algal concentrations during these studies were not as high as has been recorded in other years. Moreover, the impact of algal blooms on other species (e.g., *Menidia* spp.) needs to be investigated.

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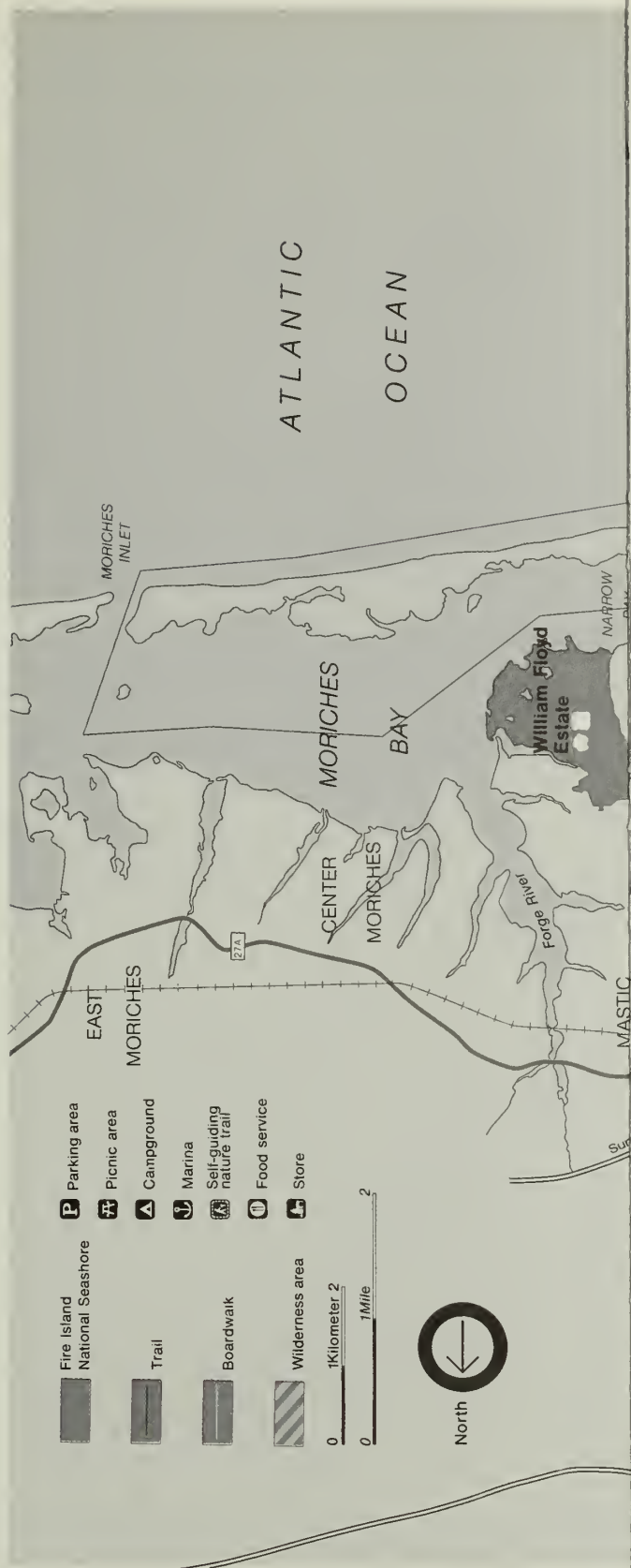
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APPENDIX I
Figures and Tables

Figure 1: Map of Fire Island National Seashore. Courtesy of the National Park Service.



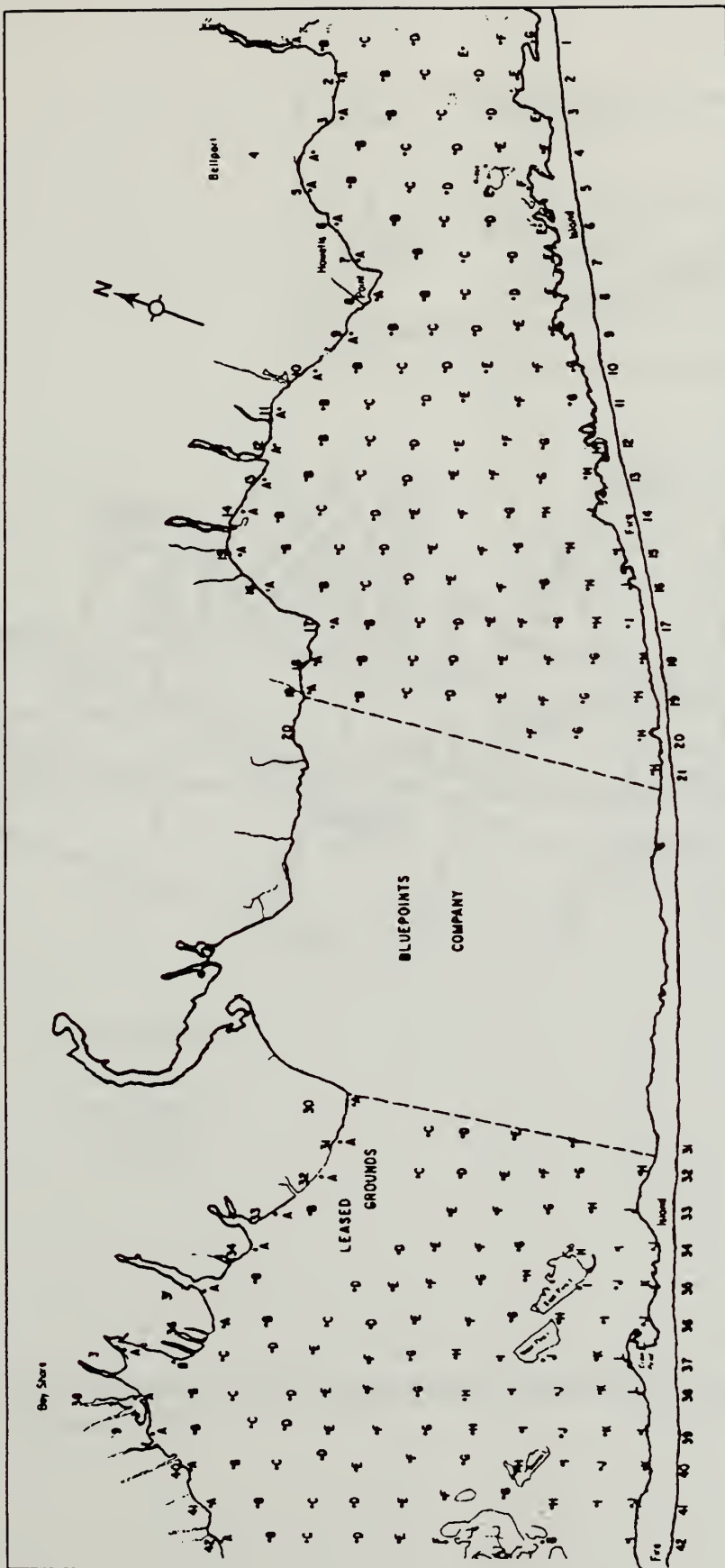


Figure 2: Tong and dredge station locations. Adapted from WAPORA, Inc. (1982).

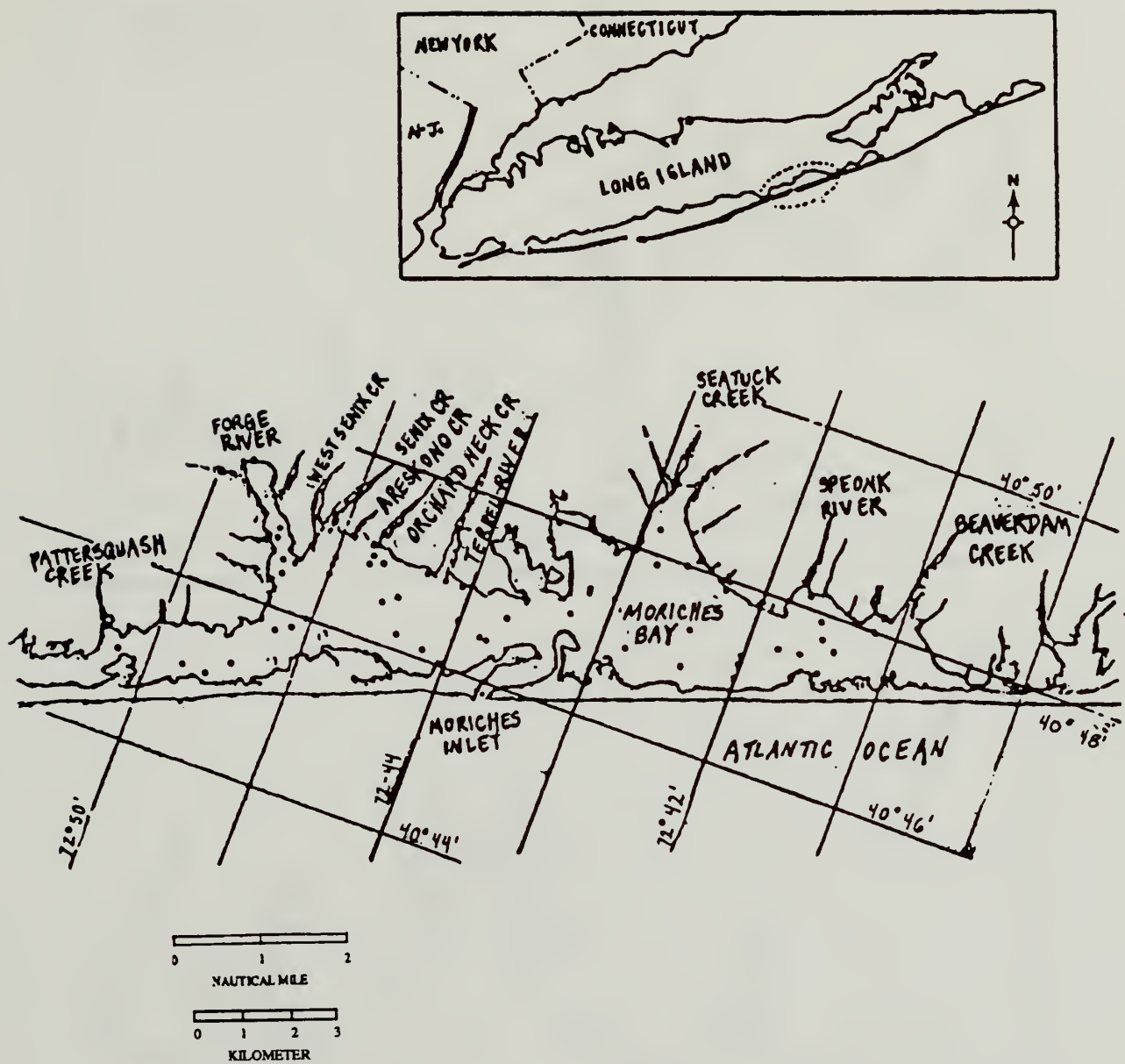


Figure 4: Station locations of benthic samples taken in Moriches Bay, New York. Adapted from O'Connor (1972).

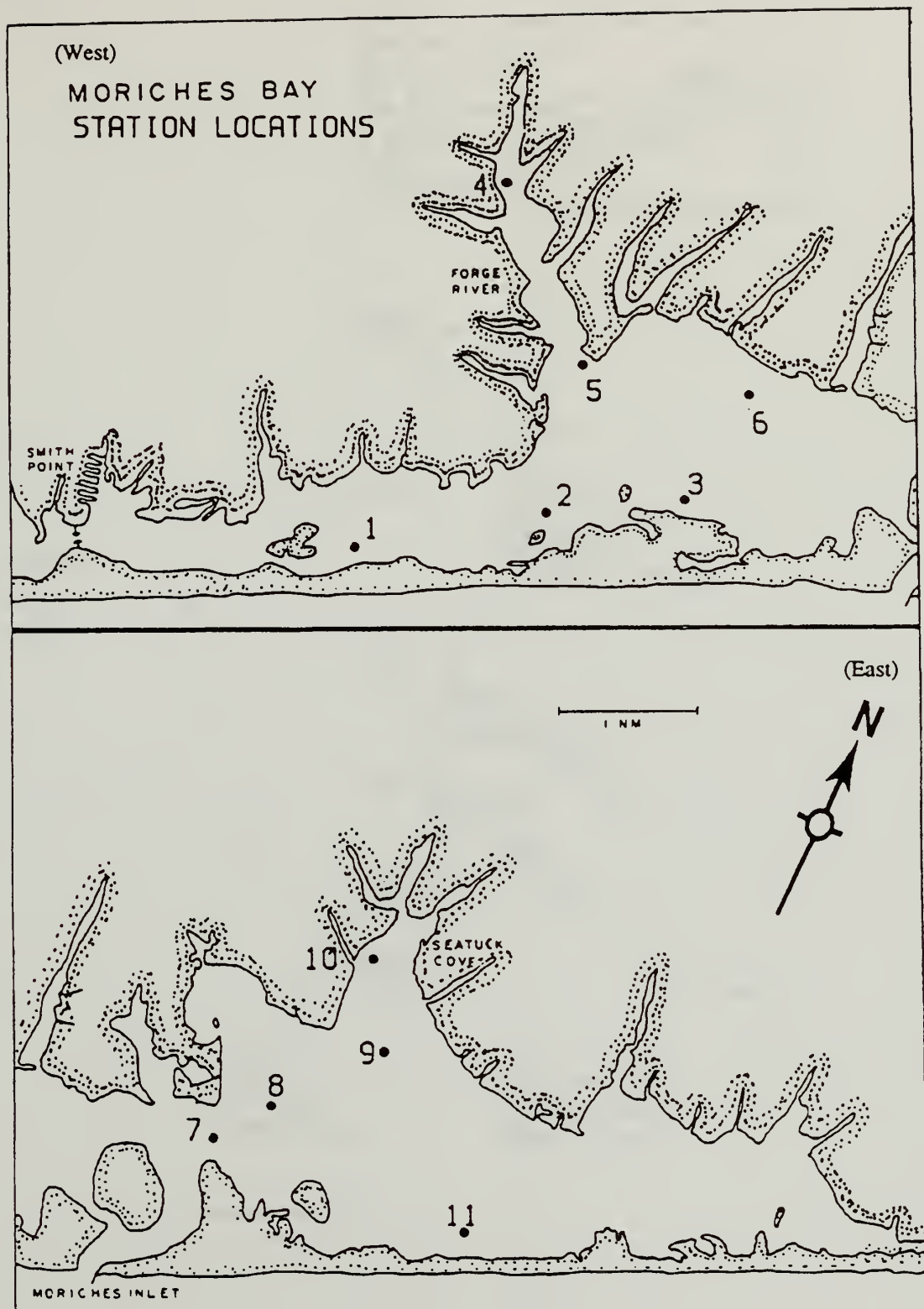


Figure 5: Benthic sampling locations. Adapted from Cerrato (1986).

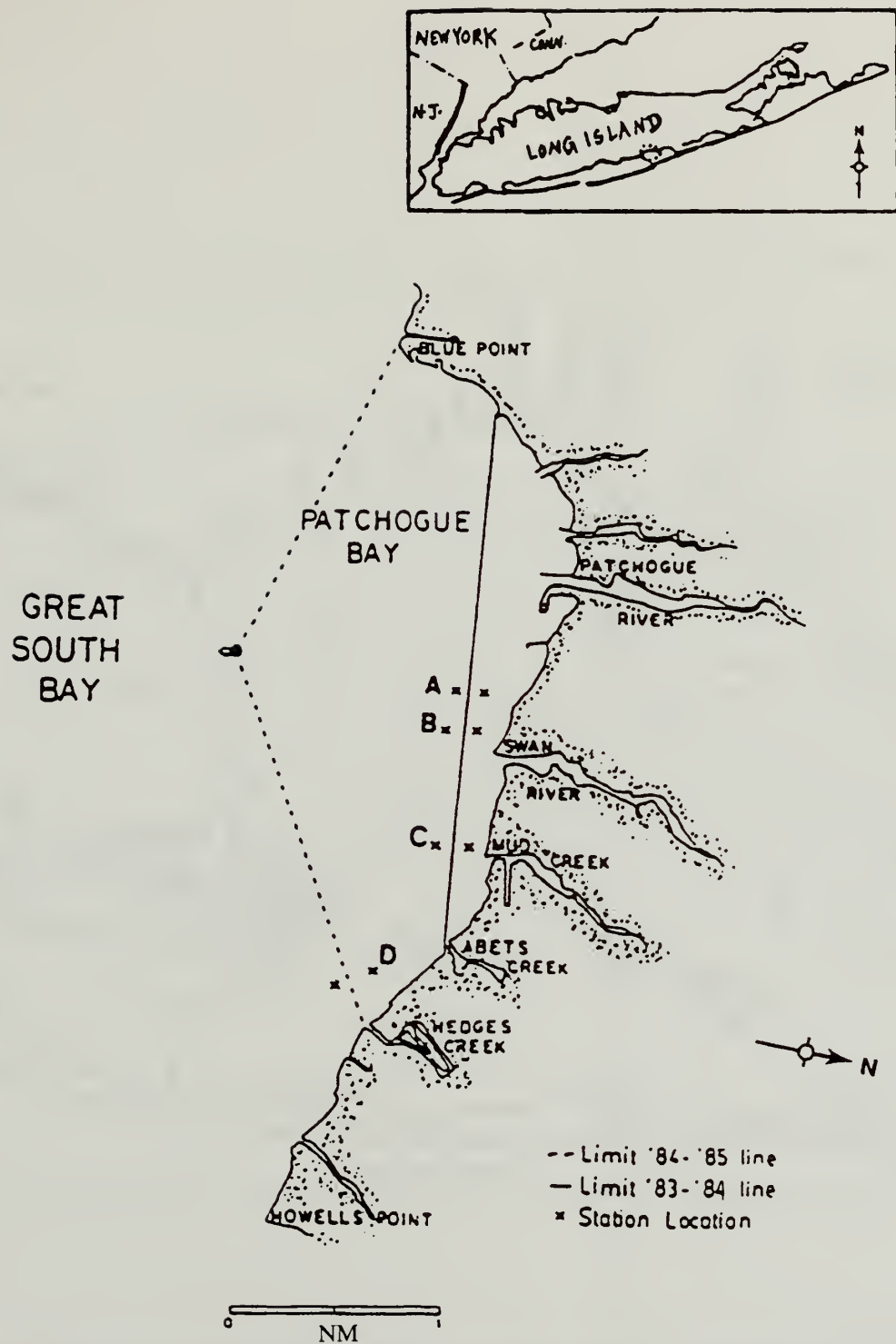


Figure 6: Benthic sampling locations in Patchogue Bay. Adapted from Wiggins (1986).

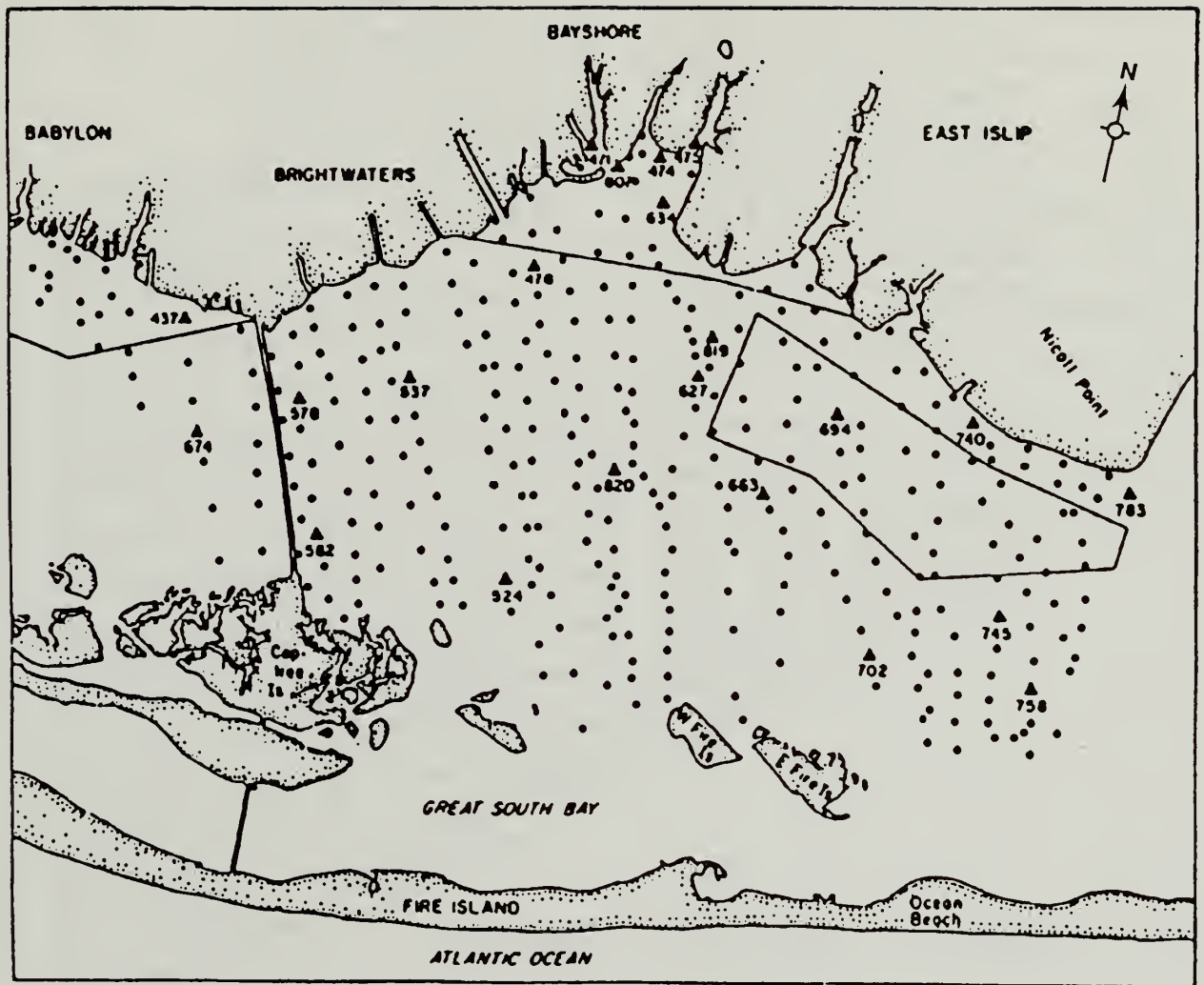


Figure 7: Hard clam sampling stations in Islip during 1979. Adapted from Buckner (1984).

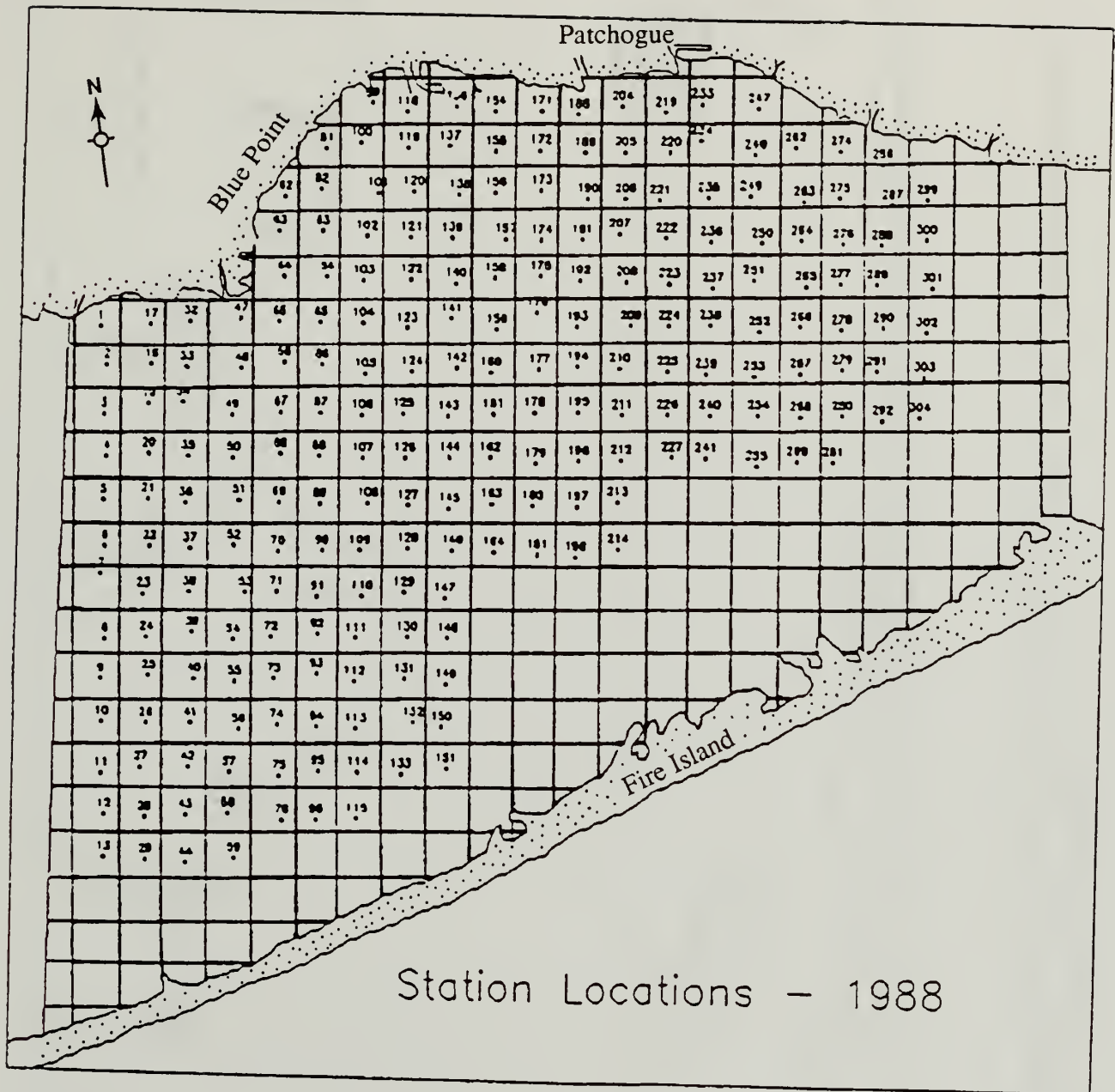


Figure 8: Hard clam sampling locations in Brookhaven during 1988. Each station is randomly located within a 400 m X 400 m quadrat. Adapted from Wallace (1991).

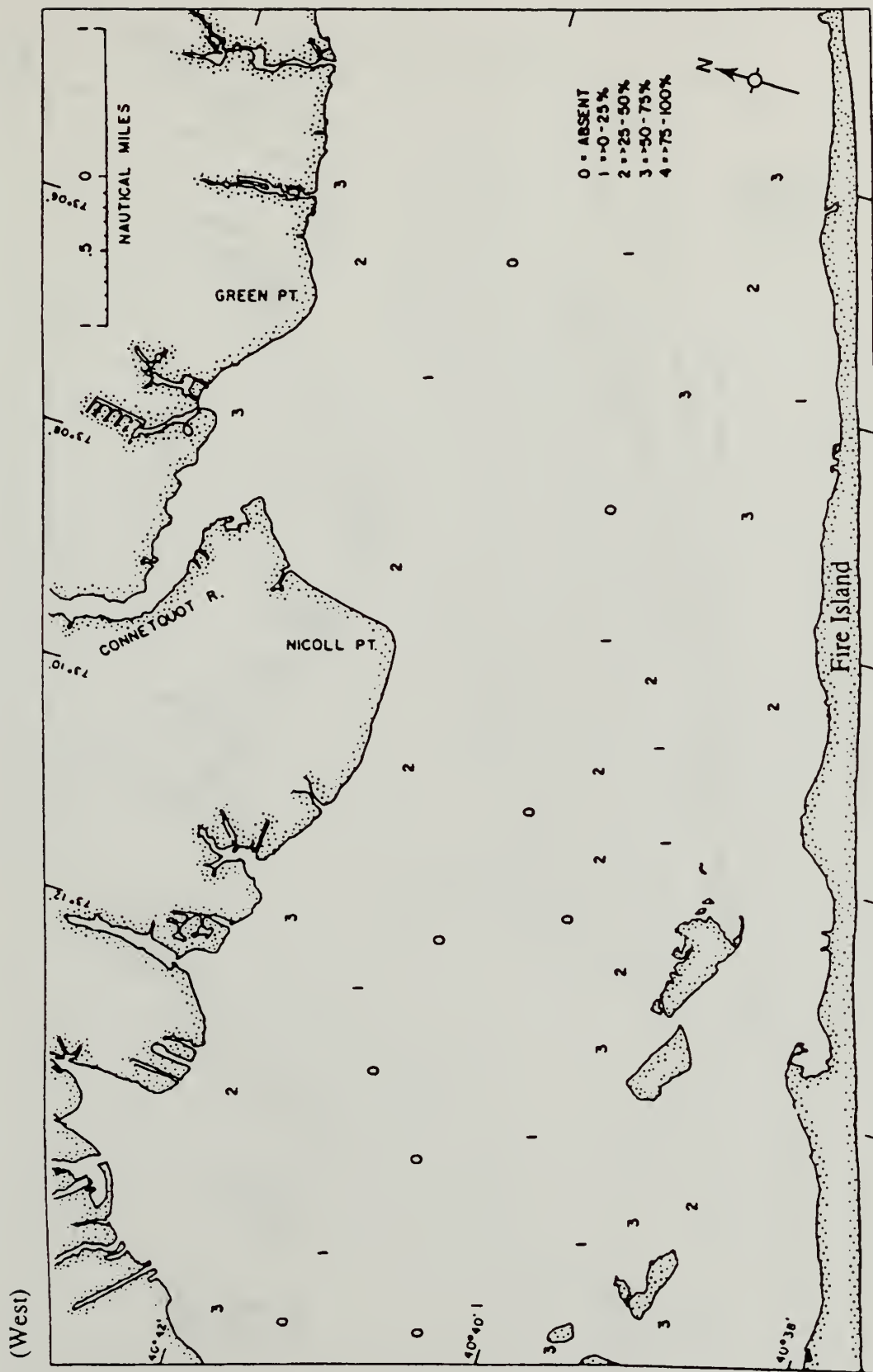


Figure 9: Eelgrass distribution (percent cover by area) in central Great South Bay, 1969-1972. Adapted from Jones and Schubel (1978). (Continued on next page).

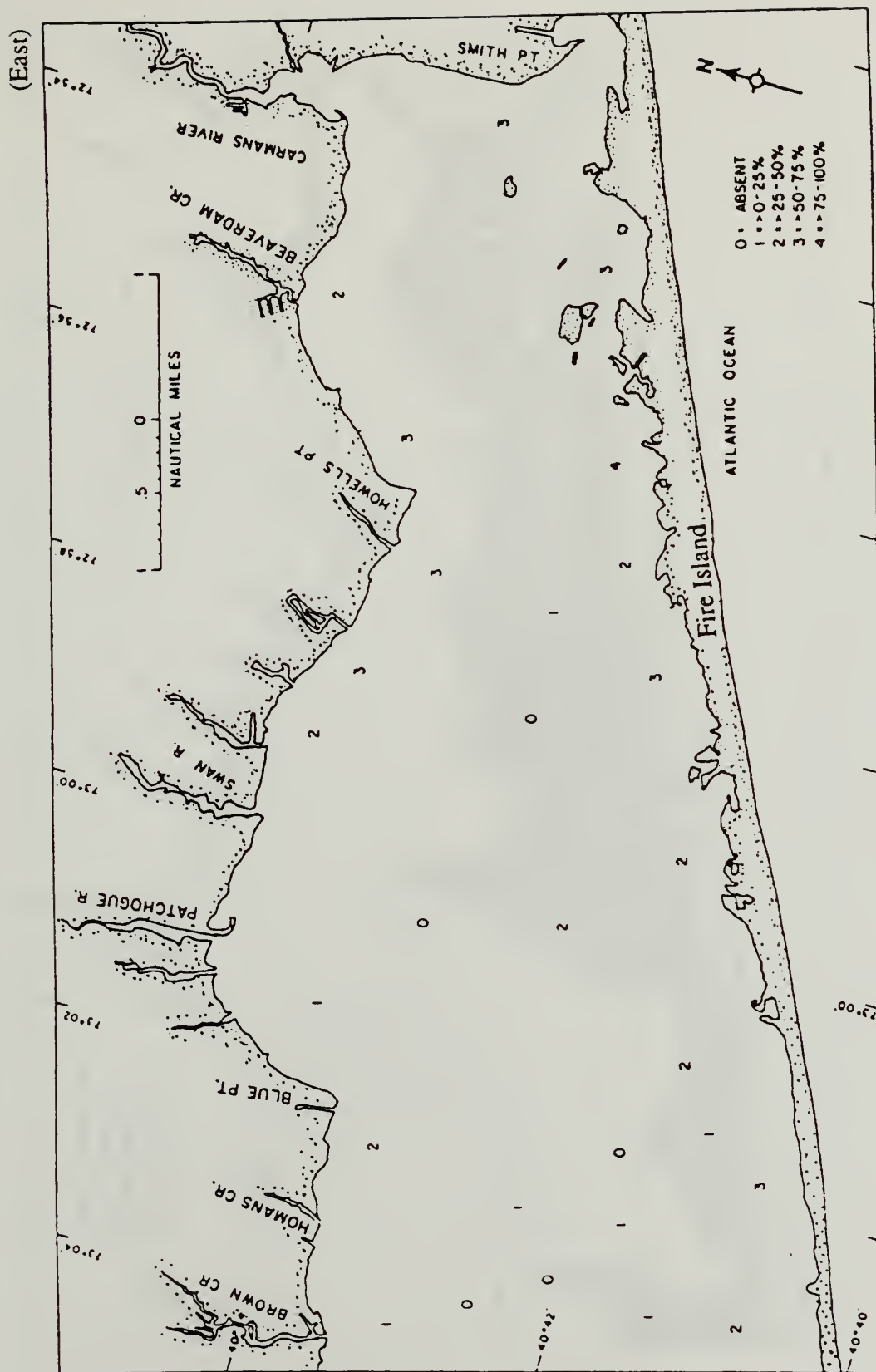


Figure 9: Eelgrass distribution (percent cover by area) in central Great South Bay, 1969-1972. Adapted from Jones and Schubel (1978). (Continued from previous page).

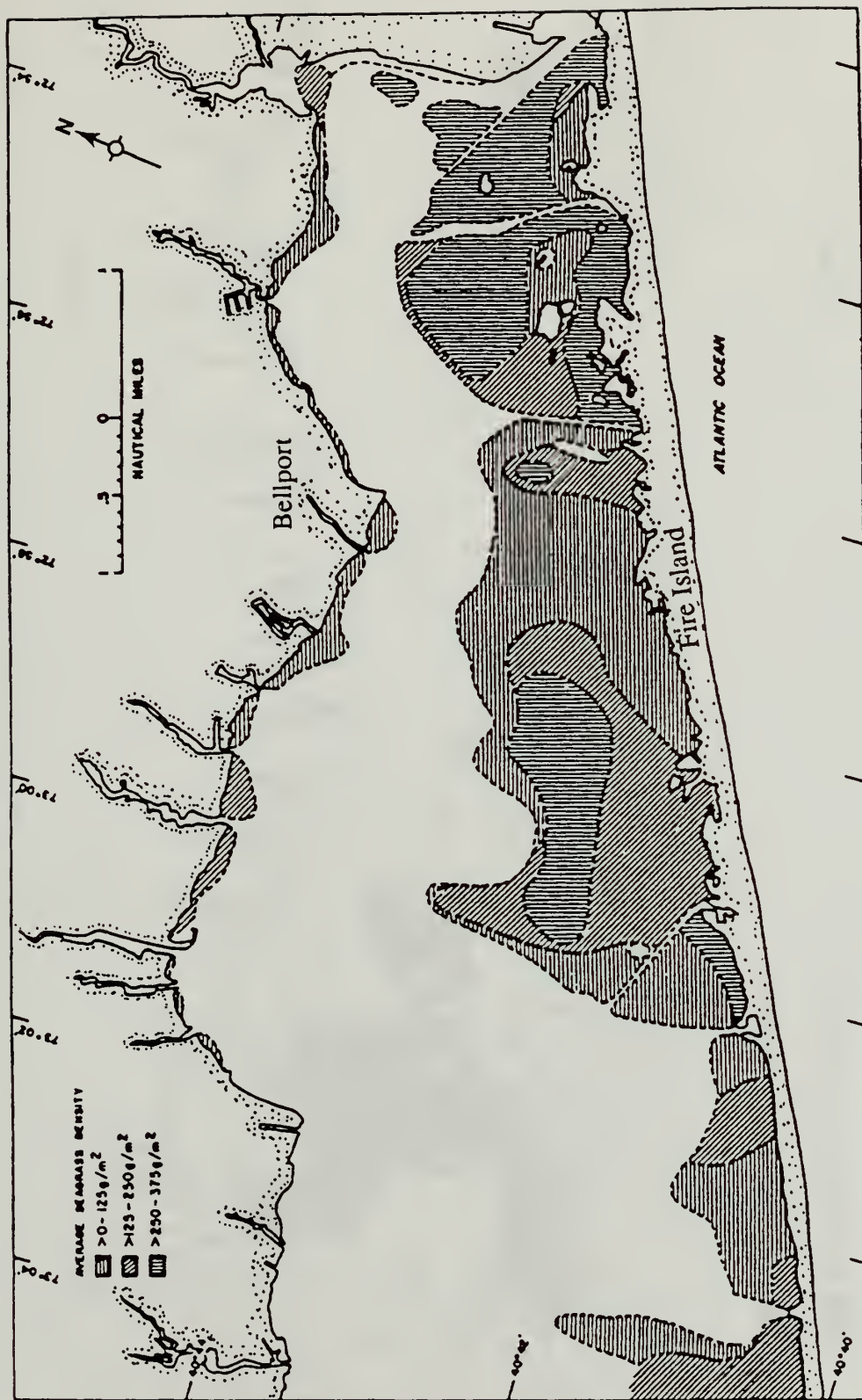


Figure 10: Distribution and density of seagrasses during August 1977. Adapted from Greene et al. (1977).

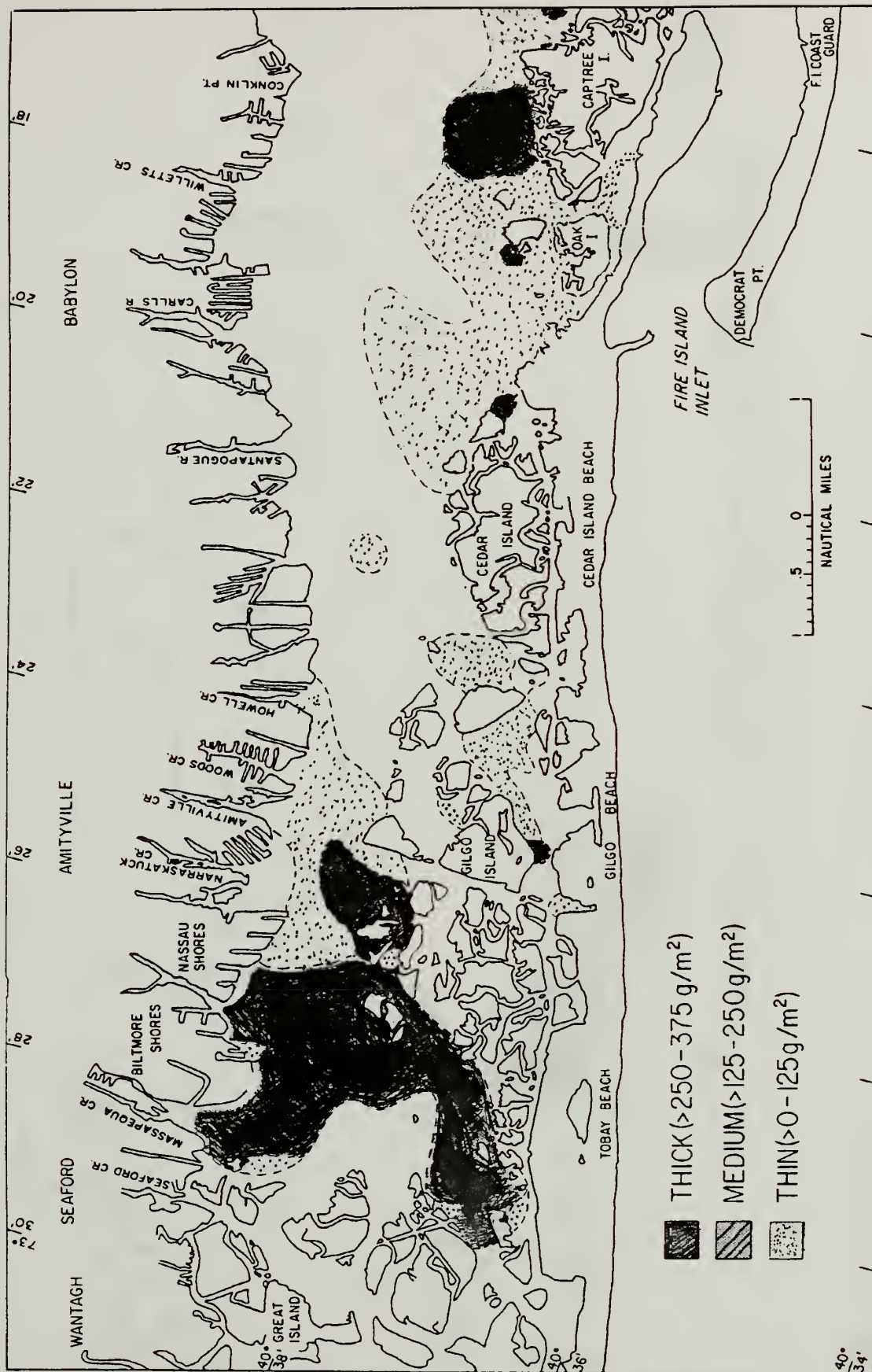


Figure 11: Distribution and density of seagrasses, 1977-1978. Modified from Jones and Schubel (1980). (Page 1 of 3 running west to east).

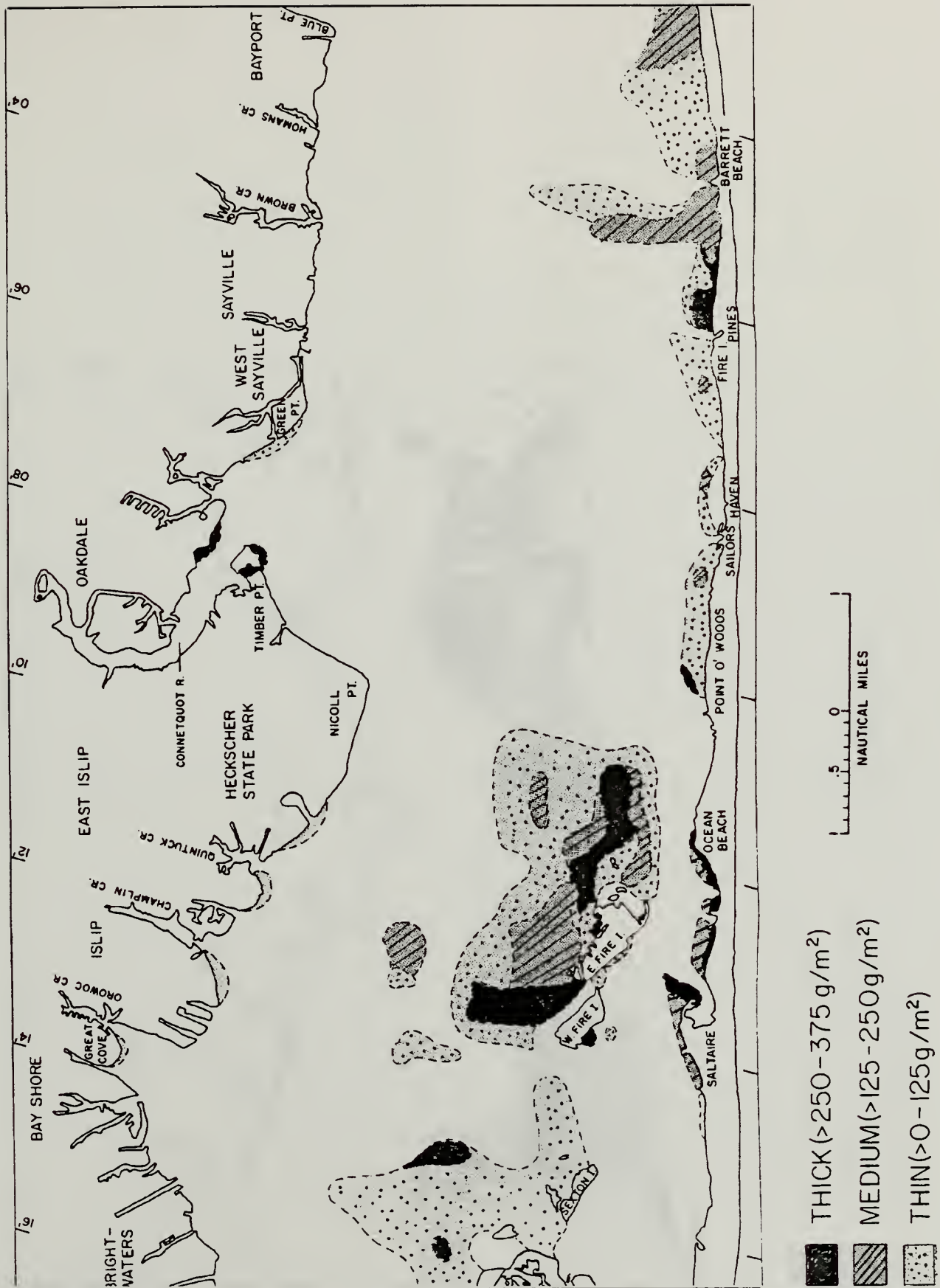


Figure 11: Distribution and density of seagrasses, 1977-1978. Modified from Jones and Schubel (1980). (Page 2 of 3 running west to east).

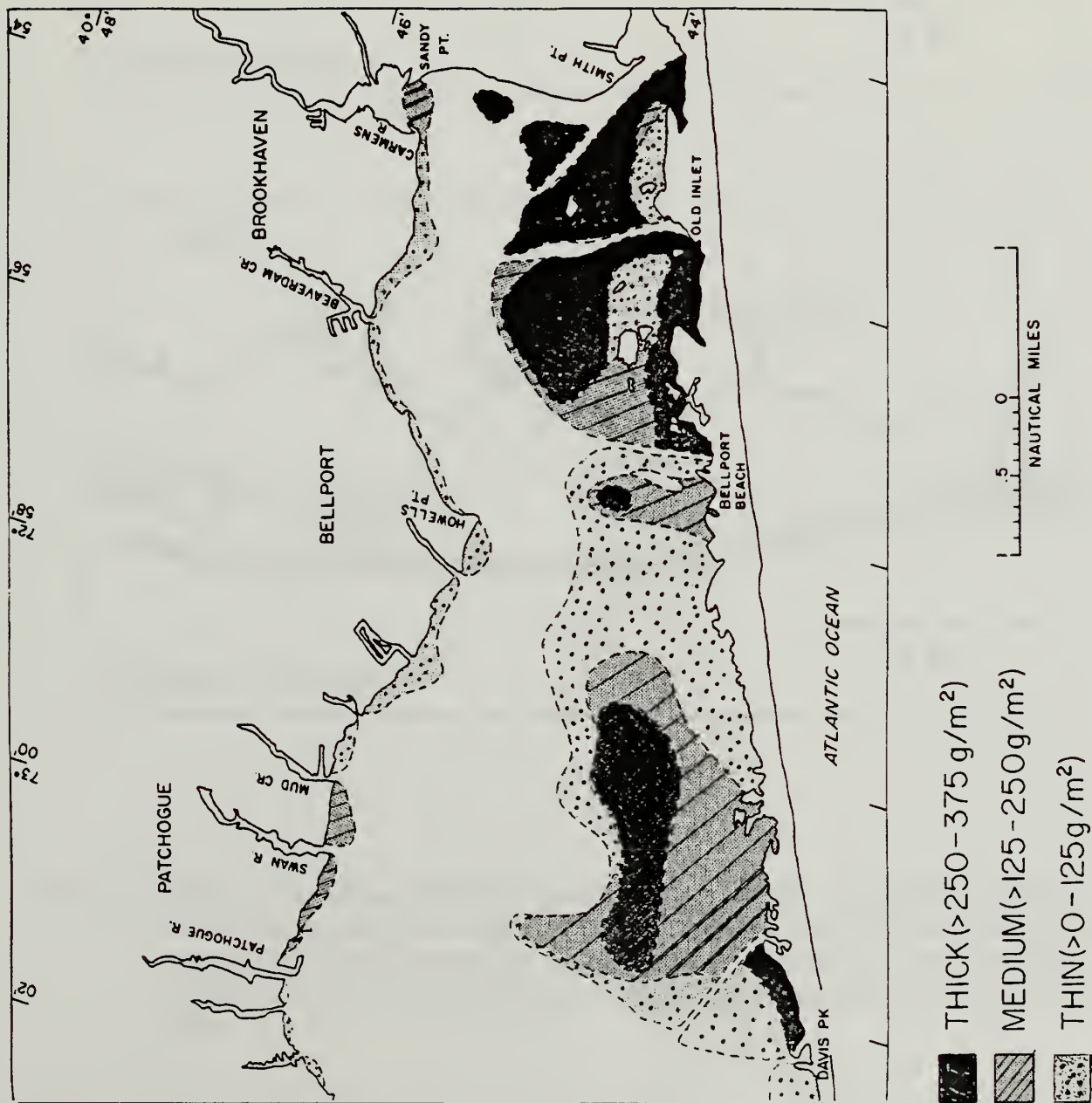


Figure 11: Distribution and density of seagrasses, 1977-1978. Modified from Jones and Schubel (1980). (Page 3 of 3 running west to east).

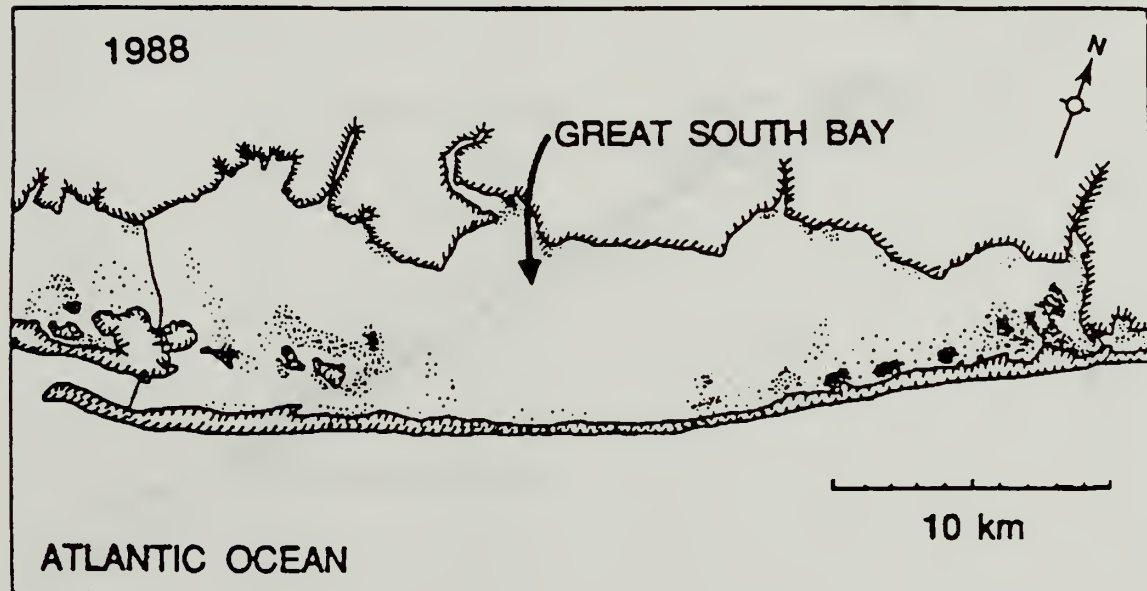
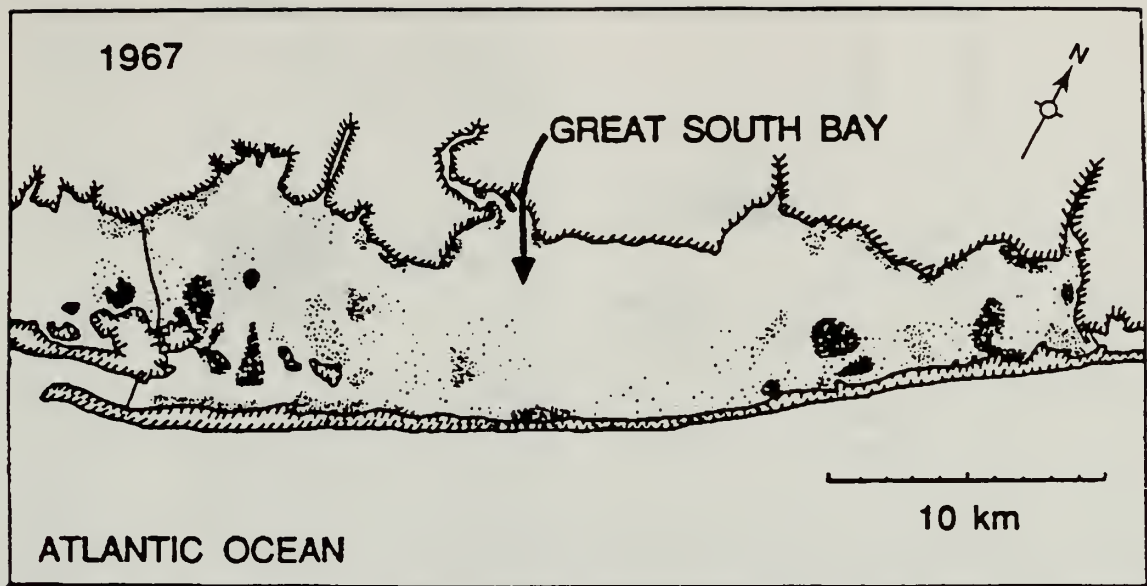
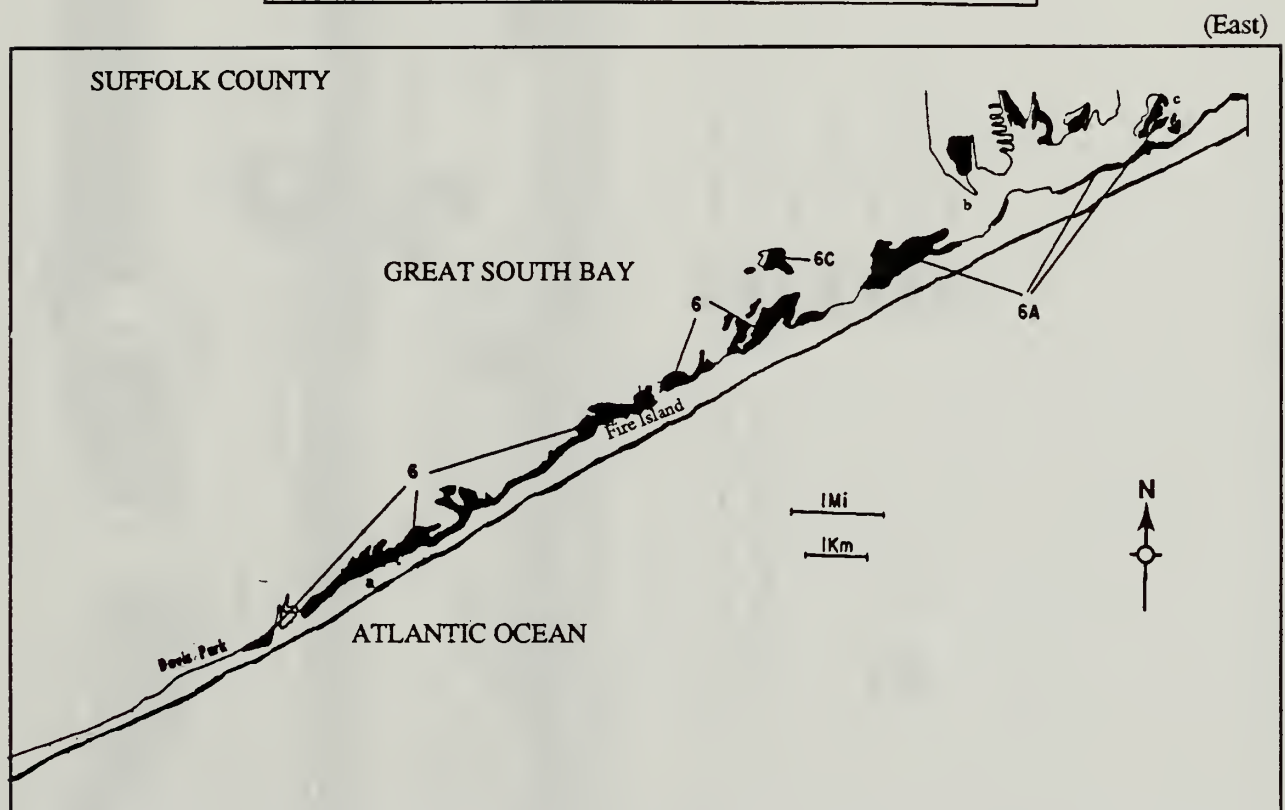
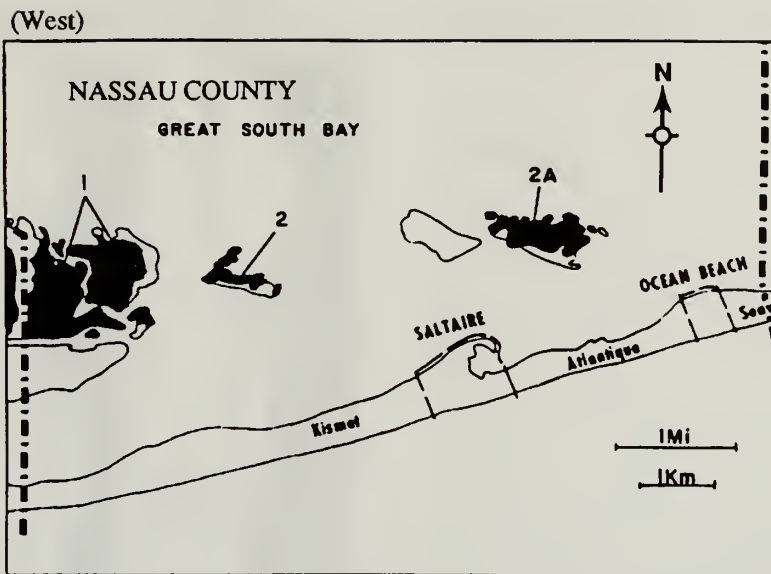


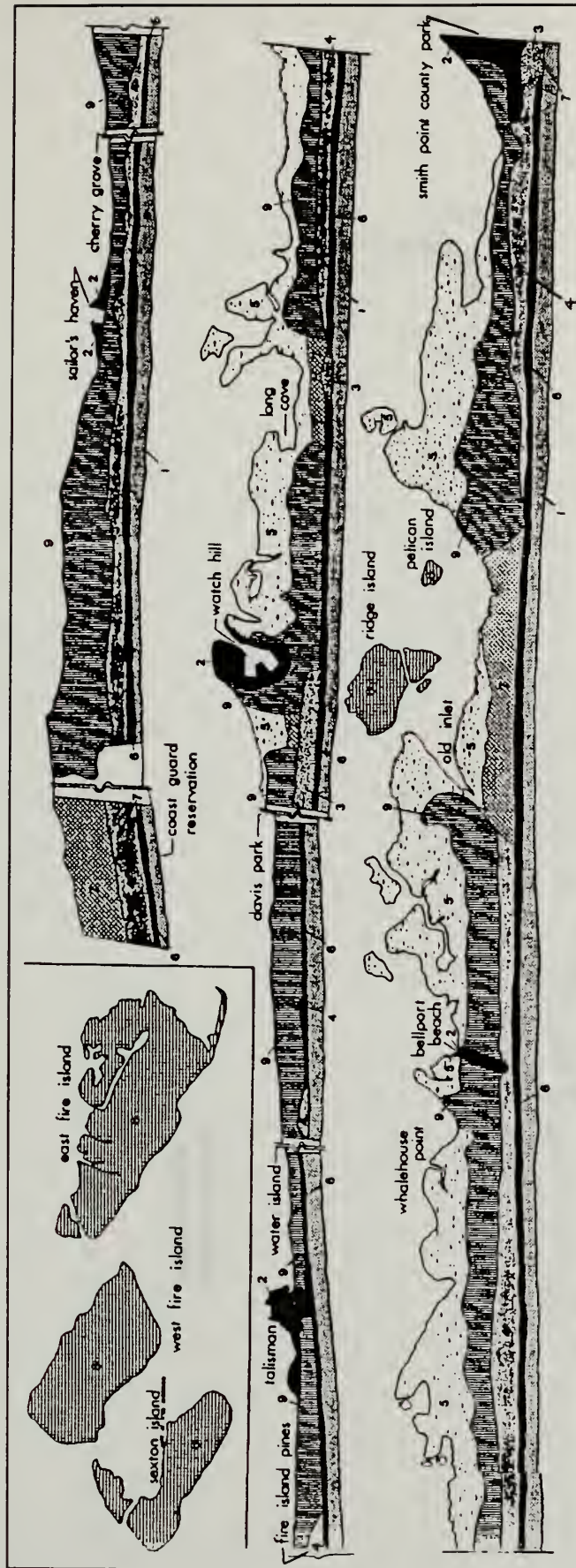
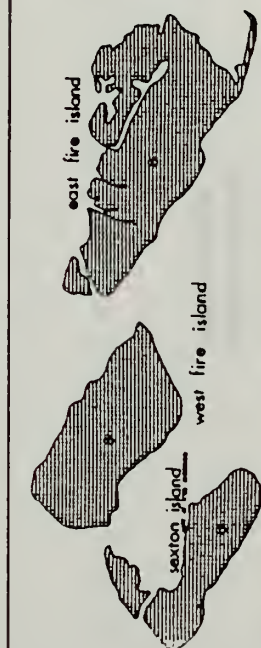
Figure 12: Eelgrass (*Zostera marina*) distribution in Great South Bay, Long Island. Stippling indicates dense, patchy and sparse eelgrass determined from 1967 aerial photographs (top) and 1988 aerial photographs and ground-truthing (bottom). Great South Bay extends from Gilgo Island/Amityville to Smith Point. Adapted from Dennison et al. (1989).



- | | | |
|---------------------|--|-----------------------|
| 1 Captree Island | 6 Fire Island National Seashore | a Atlantic Beach |
| 2 Sexton Island | 6A Moriches Inlet & Smith Point Cnty Parks | b Smith Point |
| 2A East Fire Island | 6C Ridge Island | c Pattersquash Island |

Figure 13: Maps of the marine wetlands of Nassau and Suffolk Counties, including those of Fire Island. Adapted from O'Connor and Terry (1972).

(West)



(East)

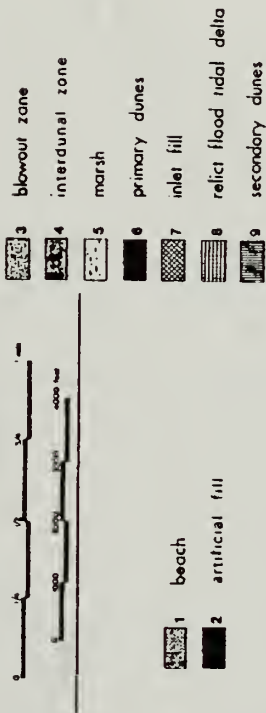


Figure 14: Terrain features of the Fire Island National Seashore. Adapted from National Park Service (1977a).

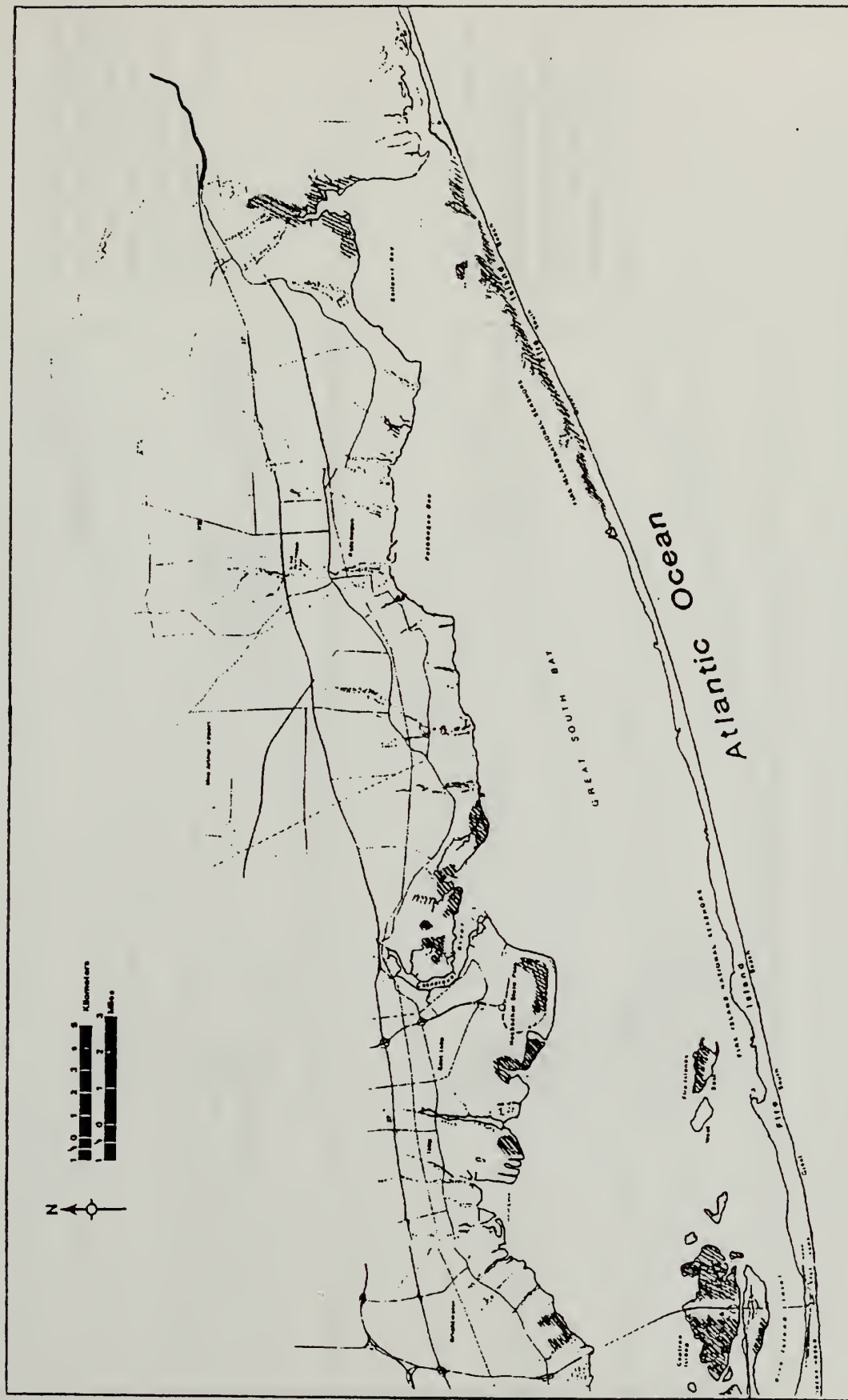


Figure 15: Location of remaining wetland areas in Great South Bay, August 1977. Adapted from Beck et al. (1978).



16a. Amplitude in cm/s (a) and relative phase in degrees (b) of component of semidiurnal tidal current along 070°T from numerical simulations by Wong (1981). Phase lag of 29° corresponds to a true lag of 1 hour.

16b. Amplitude in cm/s (a) and relative phase in degrees (b) of component of semidiurnal tidal current along 340°T from numerical simulations by Wong (1981). Phase lag of 29° corresponds to a true lag of 1 hour.

Figure 16: Amplitude and phase lag of semidiurnal tidal currents in Great South Bay. Adapted from Wilson et al. (1991).

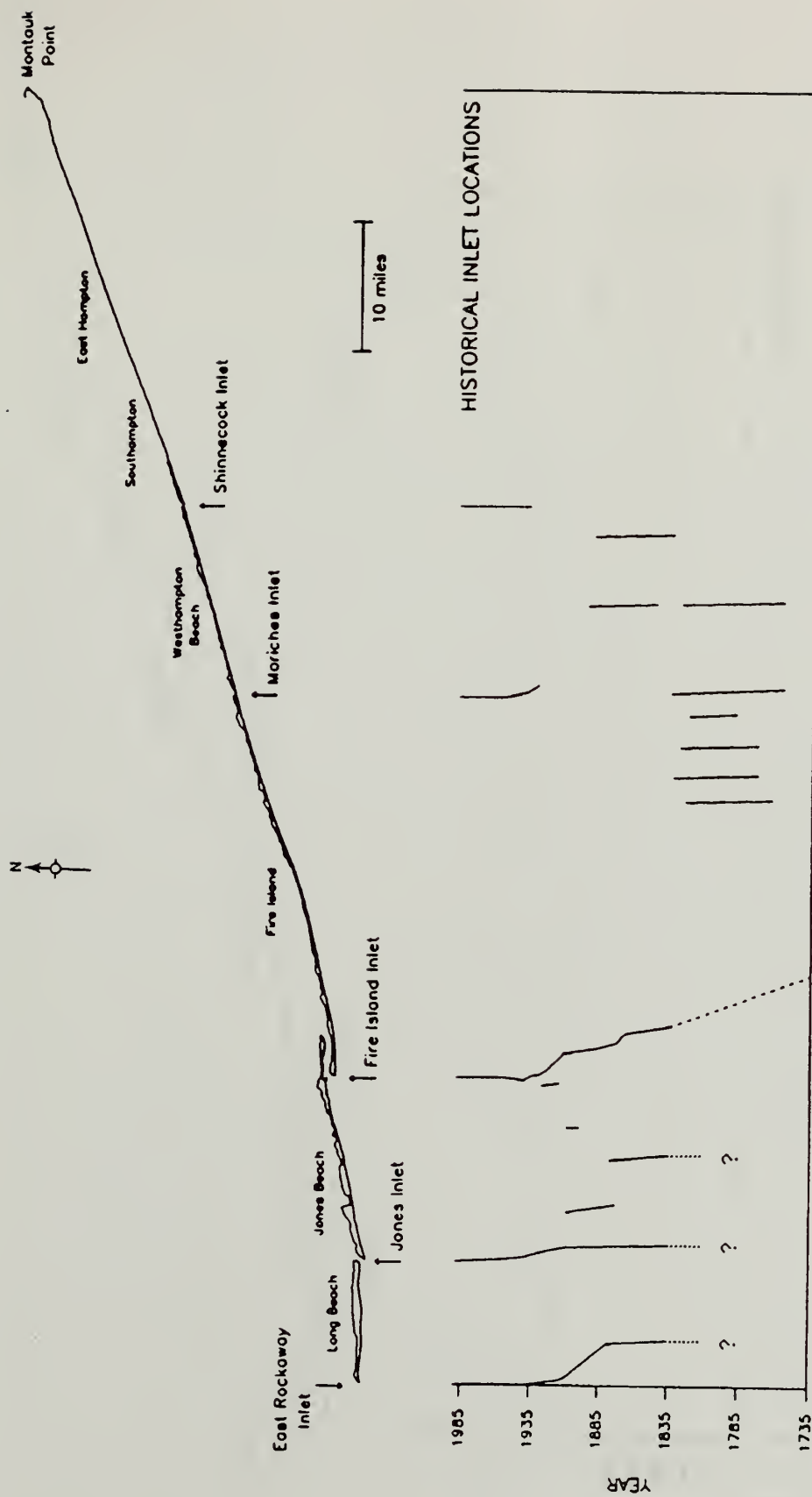


Figure 17: Locations of historical inlets based on data from Leatherman and Allen (1985) for the area east of Fire Island Inlet and from Taney (1961) for the area west of Fire Island. Adapted from Tanski et al. (1990).

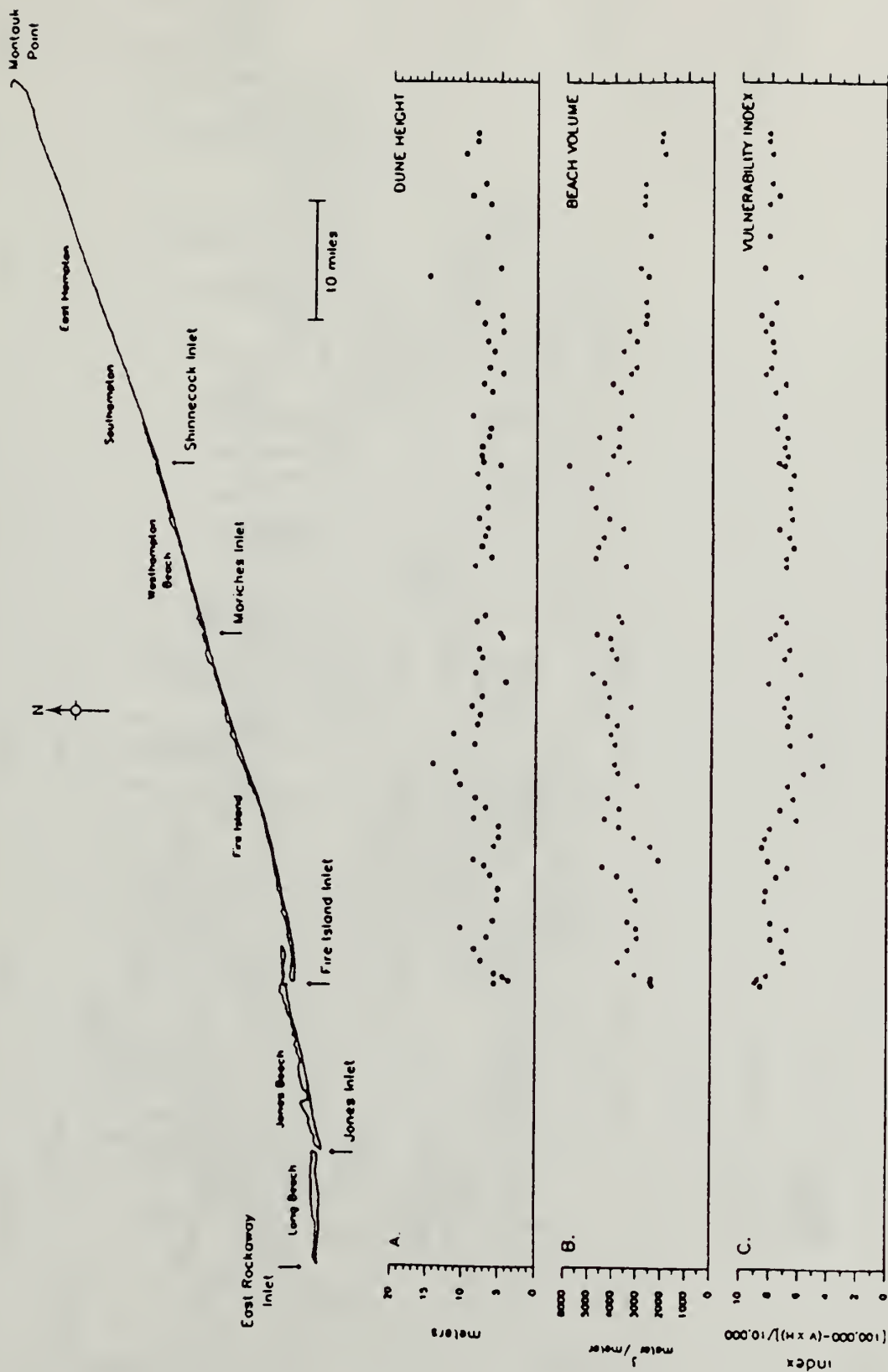


Figure 18: Preliminary vulnerability index for south shore based on dune height (A) and beach volume (B). The actual value of the index for seventy discrete points along the shore is shown in C. V = beach volume and H = dune height. Adapted from Tanski et al. (1990).

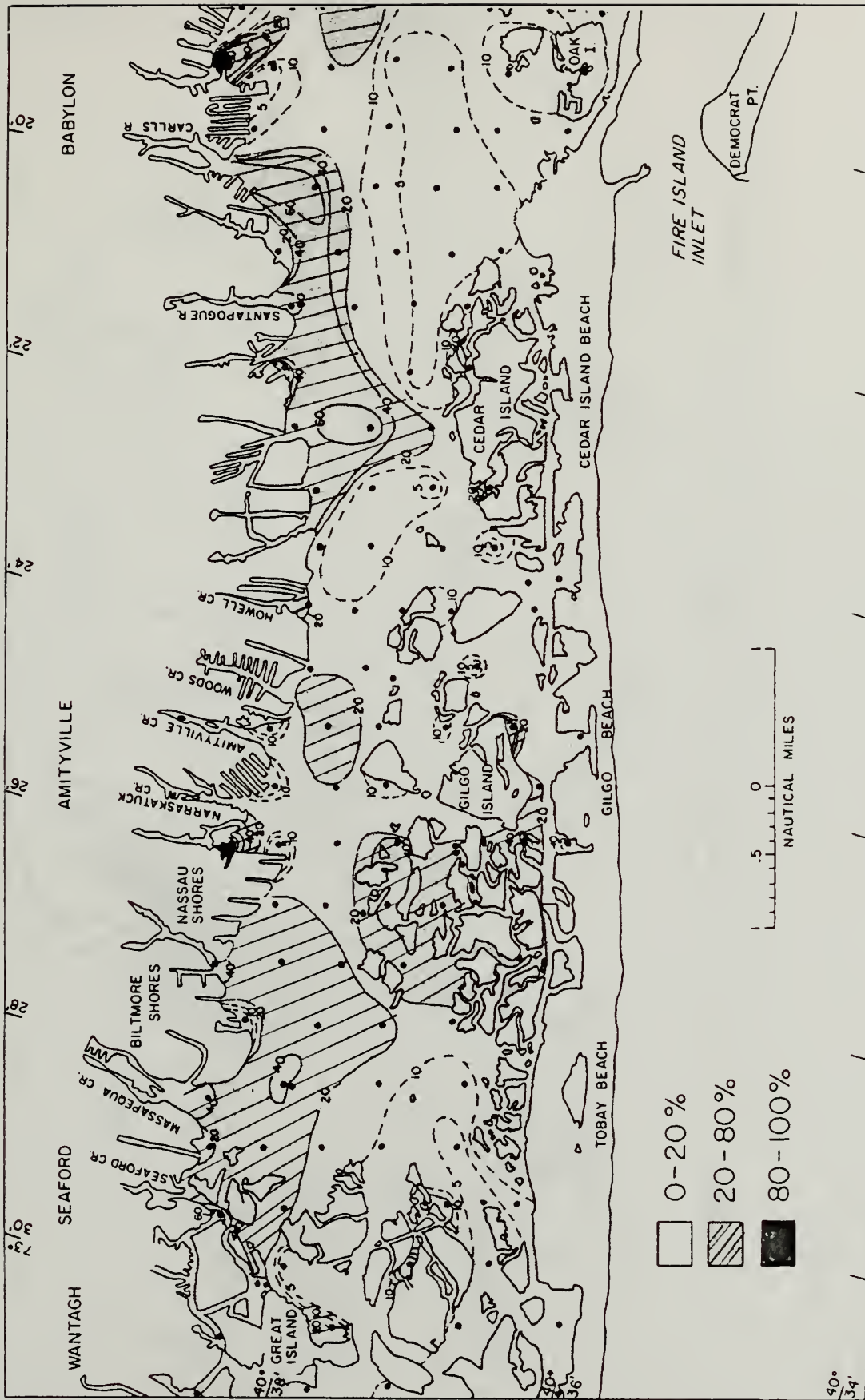


Figure 19: Percent (by mass) silt + clay in the surficial sediments. Adapted from Jones and Schubel (1980). (Page 1 of 3 running west to east).



Figure 19: Percent (by mass) silt + clay in the surficial sediments. Adapted from Jones and Schubel (1980). (Page 2 of 3 running west to east).

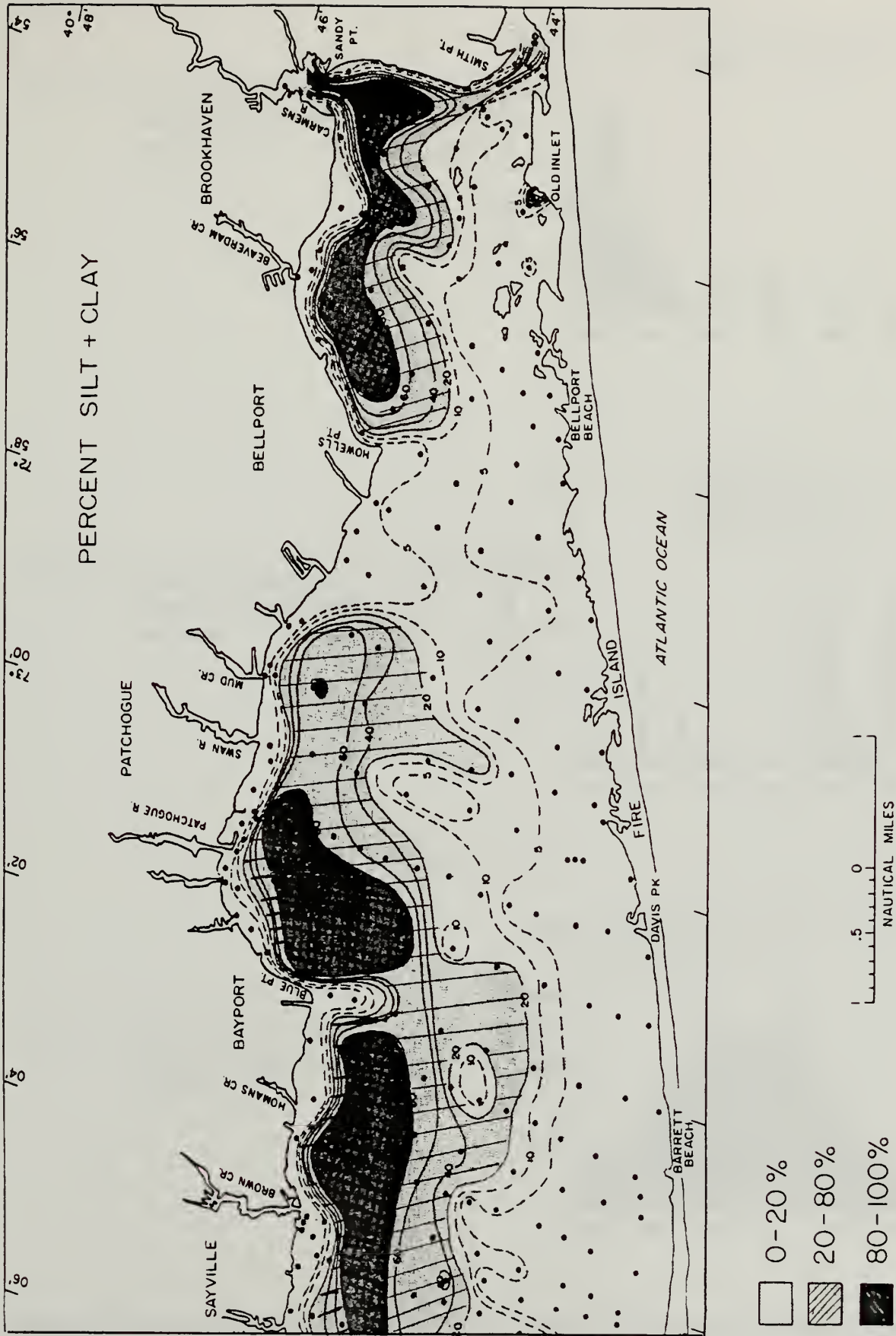


Figure 19: Percent (by mass) silt + clay in the surficial sediments. Adapted from Jones and Schubel (1980). (Page 3 of 3 running west to east).

Figure 20: Oyster landings in Towns of Brookhaven and Islip.

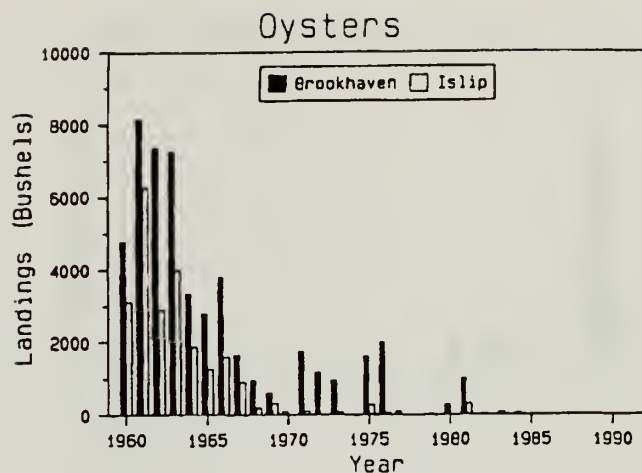


Figure 21: Mussel landings in Towns of Brookhaven and Islip.

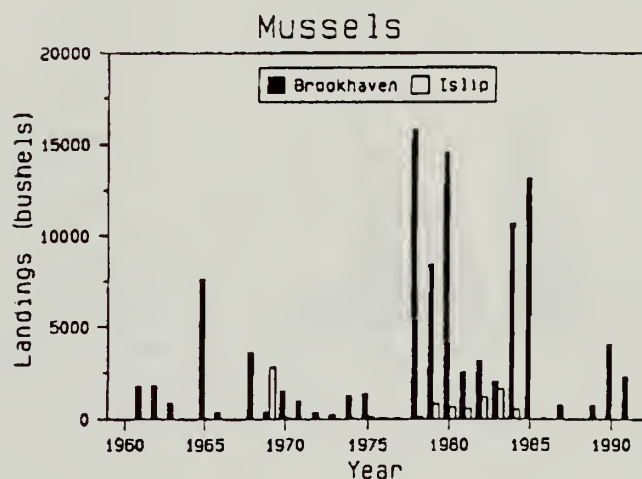
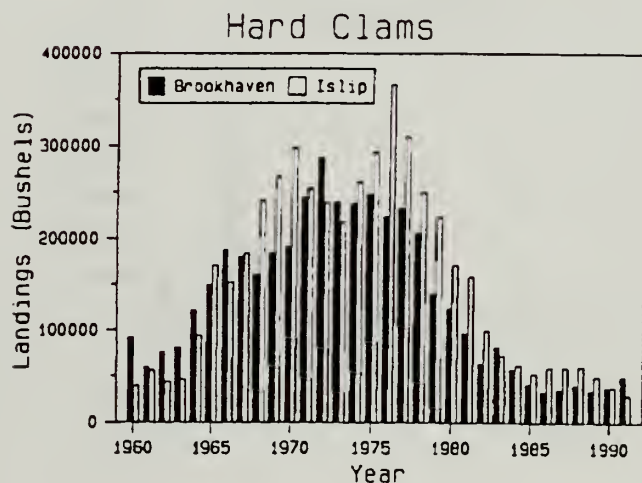


Figure 22: Hard clam landings in Towns of Brookhaven and Islip.



From NYS Department of Environmental Conservation and National Marine Fisheries Service.

Figure 23: Blue crab landings in Great South Bay.

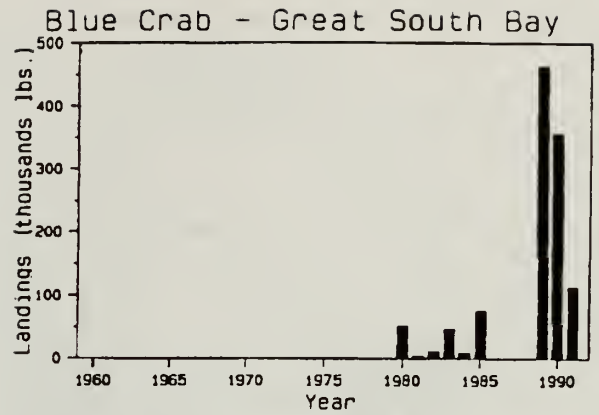


Figure 24: Conch landings in Towns of Brookhaven and Islip.

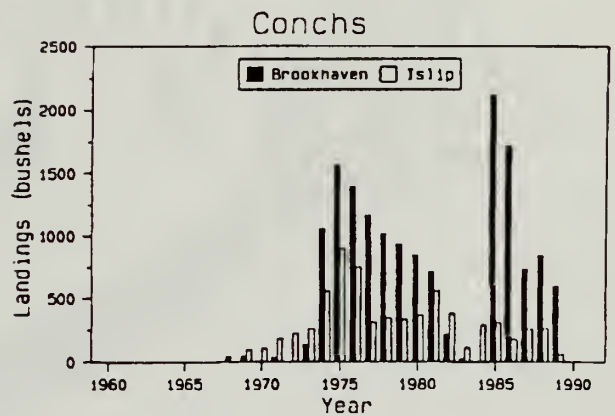
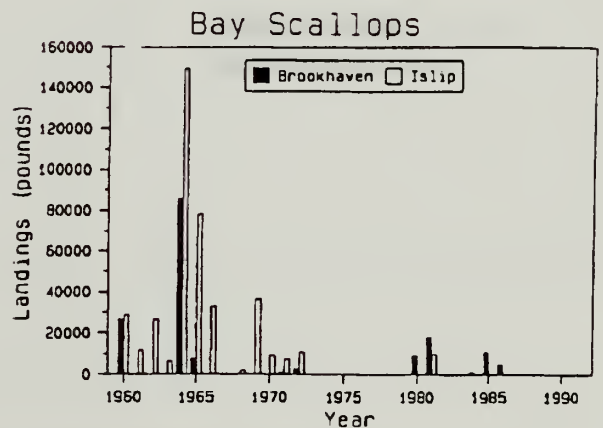


Figure 25: Bay scallop landings in Towns of Brookhaven and Islip.



From NYS Department of Environmental Conservation and National Marine Fisheries Service.

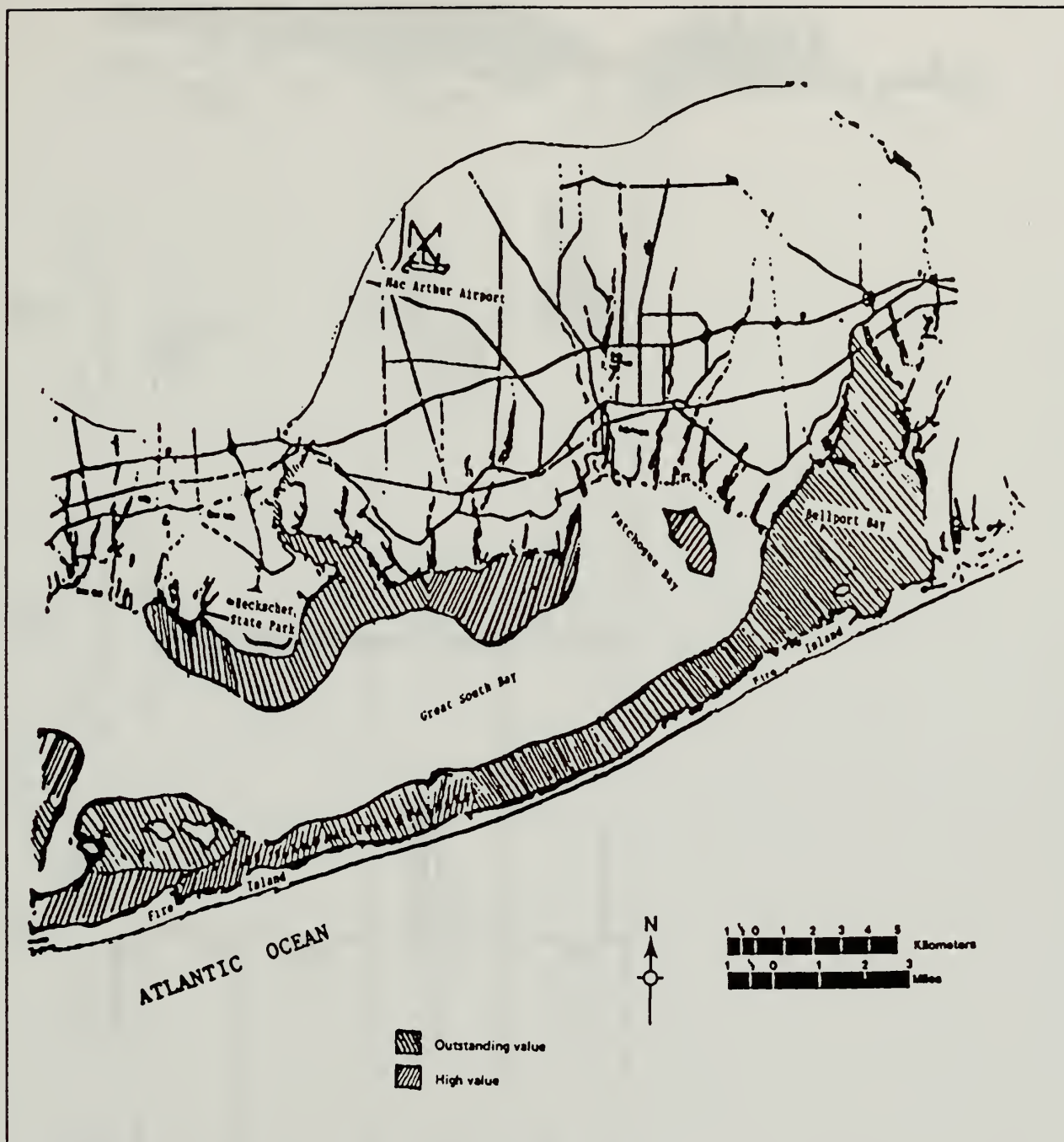


Figure 26: Location of major waterfowl feeding and nesting areas in Great South Bay, 1977. Adapted from Beck et al. (1978).

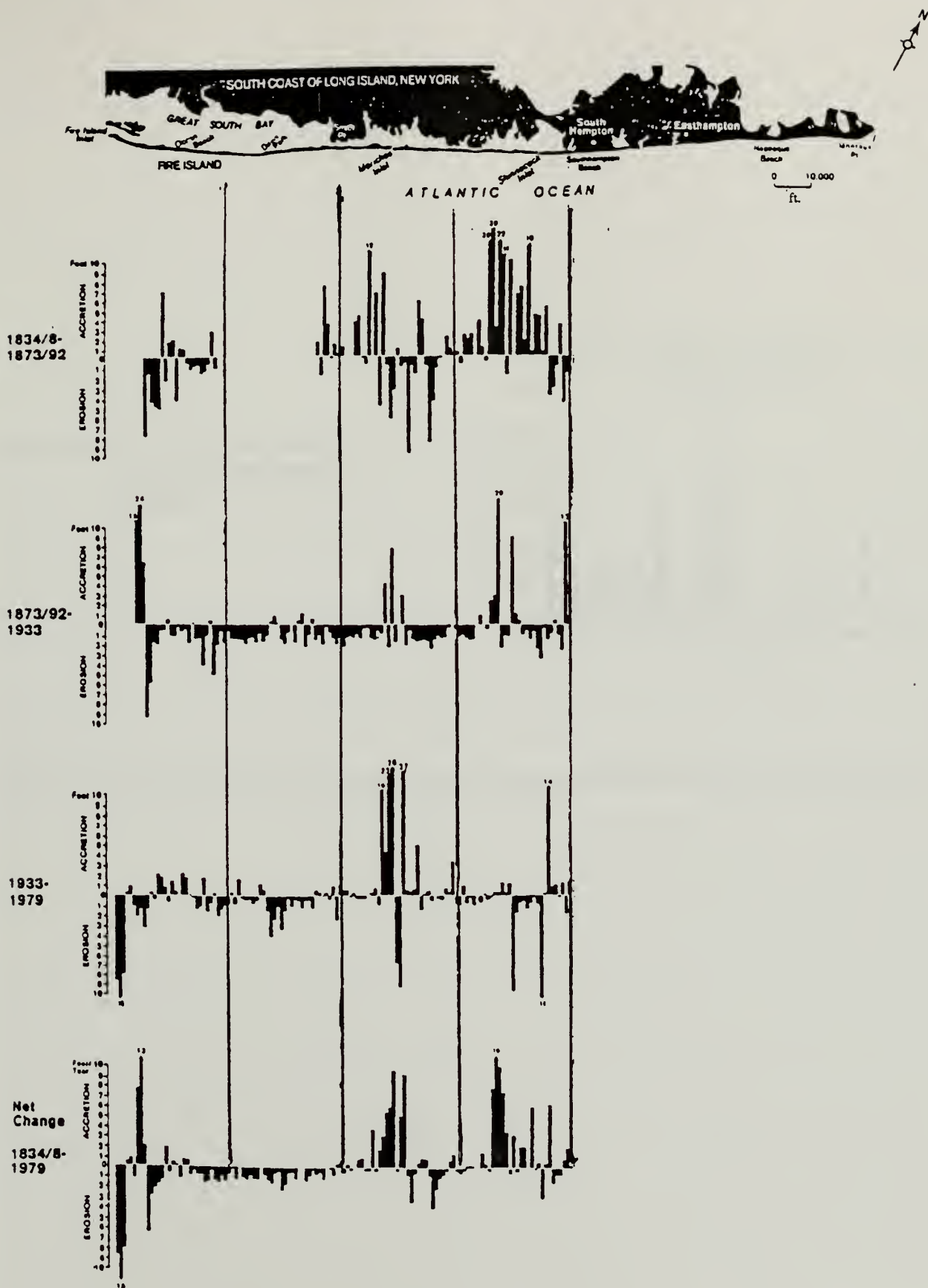
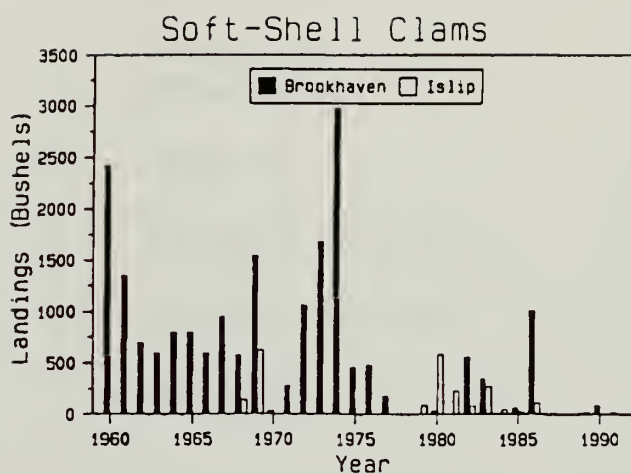


Figure 27: Bayside shoreline changes, 1834-1979. Adapted from Leatherman and Allen (1985).

Figure 28: Soft-shell clam landings in Towns of Brookhaven and Islip.



From NYS Department of Environmental Conservation and National Marine Fisheries Service.

Table 1: Major faunal surveys of the fish assemblages of Great South Bay (GSB).
 An * indicates the study appears to include at least one sampling station within the boundaries of FINS.

Life stages/habitat sampled	Location	Reference
Ichthyoplankton/ young juveniles	throughout LI	Greeley 1939 Perlmutter 1939
Ichthyoplankton	throughout GSB*	Miller 1977
Ichthyoplankton	throughout GSB*	Monteleone 1988, 1992
Ichthyoplankton	throughout GSB*	Shima and Cowen 1989
Shore-zone and bottom fishes	Connetquot R. & GSB	Gaw 1972
Fishes from vegetated vs. unvegetated shore zones	islands inside Fire Island Inlet	Briggs and O'Connor 1971
Shore-zone fishes	Fire Island Inlet	Briggs 1975
Pelagic, bottom, shore-zone fishes	Fire Island Inlet*	Schreiber 1973
Pelagic, bottom, shore-zone fishes	throughout GSB*	Hanlon 1983
Fish by-catch in shrimp trawl fishery	throughout GSB	Neville and Bevelander 1941
Shore-zone fishes	Mercer's Island	Alperin and Schaefer 1964

Table 2: Summary of fish distribution by habitat captured by otter trawl and beach seine during March through November 1981. Habitats: 1 = Intertidal saltmarsh-sand; 2 = Intertidal saltmarsh-mud; 3 = Unvegetated intertidal flat-sand; 4 = Unvegetated intertidal flat-mud; 5 = Vegetated subtidal zone-sand; 6 = Vegetated subtidal zone-mud; 7 = Unvegetated subtidal zone-sand; 8 = Unvegetated subtidal zone-mud; 9 = Unvegetated subtidal zone-gravel. From Hanlon (1983).

SPECIES	MARCH - NOVEMBER									TOTALS
	1	2	3	4	5	6	7	8	9	
Smooth dogfish	-	-	-	-	1	-	1	1	-	3
Little skate	-	-	-	-	-	-	1	-	1	2
Winter skate	-	-	-	-	-	-	2	-	-	2
American eel	-	-	-	-	17	25	9	5	-	56
Conger eel	-	-	-	-	1	1	1	-	1	4
Blueback herring	-	-	-	-	30	-	16	1	1	48
Atlantic menhaden	-	-	-	-	21	-	-	-	-	21
Bay anchovy	1	-	-	-	175	134	13	54	-	377
Inshore lizardfish	-	-	-	-	10	3	5	-	-	18
Oyster toadfish	-	-	-	-	419	590	144	460	-	1613
Atlantic cod	-	-	-	-	8	-	-	-	-	8
Silver hake	-	-	-	-	2	34	2	10	-	48
Atlantic tomcod	-	-	-	-	16	4	5	-	-	25
Pollock	-	-	-	-	-	-	1	-	-	1
Red hake	-	-	-	-	-	1	-	1	-	2
Spotted hake	-	-	-	-	3	1	1	1	-	6
White hake	-	-	-	-	2	4	3	-	-	9
Atlantic needlefish	-	-	-	-	353	-	79	1	-	433
Sheepshead minnow	5	-	-	2	903	3	279	5	-	1197
Banded killifish	-	-	1	-	-	-	-	-	-	1
Mummichog	23	52	14	5	6393	1105	1588	596	17	9793
Striped killifish	1139	163	25	17	9823	5	8784	213	1	20170
Atlantic silverside	390	64	1	1	97360	1395	51540	3318	311	154380
Fourspine stickleback	1	-	1	7	1629	516	226	158	7	2545
Threespine stickleback	-	-	-	-	8	11	10	-	1	30
Blackspotted stickleback	-	-	-	-	3	2	7	-	-	12
Lined seahorse	-	-	-	-	37	32	31	59	1	160
Northern pipefish	2	-	-	-	1146	369	104	110	5	1736
White perch	-	-	-	-	-	-	1	-	-	1
Striped bass	-	-	-	-	3	-	2	-	-	5
Black sea bass	-	-	-	-	2	1	1	17	2	23
Bluefish	46	-	-	-	165	9	87	16	2	325
Blue runner	-	-	-	-	-	-	1	-	-	1
Crevalle jack	-	-	-	-	1	1	-	-	1	3
Lookdown	-	-	-	-	-	1	-	-	-	1

(more)

Table 2: Continued.

MARCH - NOVEMBER										
SPECIES	1	2	3	4	5	6	7	8	9	TOTALS
Permit	-	-	-	-	2	-	2	-	-	4
Scup	-	-	-	-	61	34	68	117	5	285
Weakfish	-	-	-	-	3	20	8	55	-	86
Northern kingfish	-	-	-	-	8	11	6	3	-	28
Foureye butterflyfish	-	-	-	-	-	2	1	-	-	3
Tautog	-	-	-	-	139	129	117	173	37	595
Cunner	-	-	-	-	59	77	52	149	4	341
White mullet	29	-	-	-	73	-	37	92	-	231
Northern sennet	-	-	-	-	1	-	-	-	-	1
Rock gunnel	-	-	-	-	-	10	1	5	-	16
American sand lance	-	-	1	-	16	1	158	-	2	178
Seaboard goby	-	-	-	-	-	12	12	3	-	27
Butterfish	-	-	-	-	-	1	-	2	-	3
Northern searobin	-	-	-	-	5	4	16	15	8	48
Striped searobin	-	-	-	-	8	12	11	15	4	50
Sea raven	-	-	-	-	-	-	1	1	1	3
Grubby	-	-	-	-	21	32	44	34	-	131
Shorthorn sculpin	-	-	-	-	-	1	-	-	-	1
Smallmouth flounder	-	-	-	-	22	14	20	26	6	88
Summer flounder	-	-	-	-	93	135	134	146	23	531
Fourspot flounder	-	-	-	-	-	1	2	7	3	13
Windowpane	-	-	-	-	265	285	247	263	151	1211
Winter flounder	-	-	-	-	1479	3801	2852	3444	555	12131
Hogchoker	-	-	-	-	46	93	15	40	-	194
Orange filefish	-	-	-	-	-	-	1	-	-	1
Planehead filefish	-	-	-	-	-	-	-	1	-	1
Honeycomb cowfish	-	-	-	-	1	-	-	-	-	1
Scrawled cowfish	-	-	-	-	1	-	-	-	-	1
Northern puffer	-	-	-	-	202	22	32	32	9	297
Striped burrfish	-	-	-	-	5	2	-	1	-	8
TOTAL FISH	1636	279	43	32	121041	8946	66781	9650	1159	209567
Number of samples	9	1	2	1	487	186	463	148	36	1333
Number of species	9	3	6	5	48	45	52	40	26	65
Catch per effort	181.8	279.0	21.5	32.0	248.5	48.1	144.2	65.2	32.2	157.2

Table 3: Benthic species in the intertidal.

Taxa	Func. Group	Distr./Abundance	Source
Annelida			
Polychaeta			
Nephtyidae			
Nephtys bucera	INMC	Found near FI Inlet	Croker (1970)
Nereidae			
Nereis arenaceodonta	INMO	Found near FI Inlet	Croker (1970)
Orbiniidae			
Haploscoloplos fragilis	INMDi	Found near FI Inlet	Croker (1970)
Spionidae			
Scolecopsis squamata	INMDi	Found near FI Inlet	Croker (1970)
Mollusca			
Myidae			
Mya arenaria	INSS		NONE
Veneridae			
Mercenaria mercenaria	INSS		NONE
Arthropoda			
Amphipoda			
Haustoriidae			
Acanthohaustorius millsii	INDMi	Found near FI Inlet	Croker (1970)
Neohaustorius biarticulatus	INMDi	Found near FI Inlet	Croker (1970)
Isopoda			
Idoteidae			
Chiridotea caeca	ENMO	Found near Jones Inlet	Croker (1970)
Chiridotea nigrescens	ENMO	Found near Jones Inlet	Croker (1970)

Table 4: Benthic species in subtidal shoals and flats.

Taxa	Func. Group	Distr./Abundance	Source
Annelida			
Polychaeta			
Nephtyidae			
Nephtys picta	INMC	Common near Moriches Inlet	Cerrato (1986)
Nereidae			
Nereis arenaceodonta	INMO	Common near Moriches Inlet	Cerrato (1986)
Sabellaridae			
Sabellaria vulgaris	ETSS	Abundant in Patchogue Bay	Wiggins (1986)
Terebellidae			
Trichobranthus glacilis	ETSDs	Abundant in Patchogue Bay	Wiggins (1986)
Mollusca			
Gastropoda			
Calyptraeidae			
Crepidula fornicata	ENSS	Abundant near inlet?	NONE
Retusidae			
Retusa canaliculata (Acteocina)	ENMC	Dominant in Patchogue Bay	Wiggins (1986)
Melongenidae			
Busycon canaliculatum	ENMC	Significant predator of large clams	WAPORA (1982)
Bivalvia			
Mactridae			
Mulinia lateralis	INSS	Dominant in Patchogue Bay	Wiggins (1986)
Mytilidae			
Mytilus edulis	ENSS	Dominant near inlet Biomass dominant Very abundant near inlet Abundant Common food organism of GSB fishes	Cerrato (1986) O'Connor (1972) WAPORA (1982) MSRC (1973) MSRC (1973)
Ostreidae			
Crassostrea virginica	ENSS	Commercial species	NONE
Solenidae			
Ensis directus	INMS	Commercial species	NONE
Tellinidae			
Tellina agilis	INSDs	Abundant near inlet Biomass dominant Abundant in Islip only	Cerrato (1986) O'Connor (1972) WAPORA (1982)
Veneridae			
Gemma gemma	INSS	Biomass dominant Dominant in Brookhaven	O'Connor (1972) WAPORA (1982)
Mercenaria mercenaria	INSS	Abundant in Patchogue Bay Biomass dominant	Wiggins (1986) O'Connor (1972)
Arthropoda			
Amphipoda			
Corophiidae			
Corophium tuberculatum	ETMS	Abundant in Patchogue Bay	Wiggins (1986)
Merostomata			
Limulidae			
Limulus polyphemus	ENMC	Abundant in Brookhaven	WAPORA (1982)

(more)

Table 4: Continued.

Taxa	Func. Group	Distr./Abundance	Source
Mysidacea			
Mysidae			
<i>Neomysis americana</i>	ENMO	Principal food source for summer flounder	Poole (1964)
Decapoda			
Crangonidae			
<i>Crangon septemspinosa</i>	ENMO	Principal food source for summer flounder	Poole (1964)
Paguridae			
<i>Pagurus longicarpus</i>	ENMO	Abundant only near inlet	WAPORA (1982)
Portunidae			
<i>Callinectes sapidus</i>	ENMO	NOT abundant in 1978 Principal food source for summer flounder Common food organism of GSB fishes	WAPORA (1982) Poole (1964) MSRC (1973)
<i>Ovalipes ocellatus</i>	ENMO	Abundant only near inlet Common food organism of GSB fishes	WAPORA (1982) MSRC (1973)
Echinodermata			
Asteriidae			
<i>Asterias forbesii</i>	ENMC	Restricted to inlet	WAPORA (1982)

Table 5: Benthic species in seagrass beds.

Taxa	Func. Group	Distr./Abundance	Source
Annelida			
Polychaeta			
Arabellidae			
<i>Arabella iricolor</i>	INMO	Abundant	MSRC (1973)
Capitellidae			
<i>Heteromastus filiformis</i>	INMDi	Abundant in Moriches	Cerrato (1986)
Lumbrinereidae			
<i>Lumbrineris brevipes</i>	INMO	Abundant	MSRC (1973)
<i>Lumbrineris tenuis</i>	INMO	Abundant	Cerrato (1986)
		Abundant	MSRC (1973)
Maldanidae			
<i>Clymenella torquata</i>	ITMDi	Biomass dominant	O'Connor (1972)
		Abundant	MSRC (1973)
Nephtyidae			
<i>Nephtys picta</i>	INMC	Common	Cerrato (1986)
Nereidae			
<i>Nereis arenaceodonta</i>	INMO	Common	Cerrato (1986)
<i>Nereis virens</i>	INMO	Biomass dominant	O'Connor (1972)
<i>Nereis succinea</i>	ITMDs	Dominant	MSRC (1973)
<i>Platynereis dumerilii</i>	INMO	Dominant	MSRC (1973)
Orbiniidae			
<i>Haploscleros fragilis</i>	INMDi	Dominant	MSRC (1973)
Sabellidae			
<i>Sabella microphthalma</i>	ETSS	Abundant	MSRC (1973)
Spionidae			
<i>Prionospio heterobranchia</i>	ITMDs	Abundant throughout year	Cerrato (1986)
Mollusca			
Gastropoda			
Calyptraeidae			
<i>Crepidula fornicata</i>	ENSS	Abundant	MSRC (1973)
<i>Crepidula convexa</i>	ENSS	Abundant	MSRC (1973)
Muricidae			
<i>Urosalpinx cinerea</i>	ENMC	Biomass dominant	O'Connor (1972)
		Abundant in Bellport Bay	WAPORA (1972)
Nassariidae			
<i>Ilyanassa obsoleta</i>	ENMO	Biomass dominant	O'Connor (1972)
Bivalvia			
Cardiidae			
<i>Laevicardium mortuni</i>	INSS	Dominant	MSRC (1973)

(more)

Table 5: Continued.

Taxa	Func. Group	Distr./Abundance	Source
Mytilidae			
<i>Mytilus edulis</i>	ENSS	Abundant Biomass dominant Abundant Common food organism of GSB fishes	Cerrato (1986) O'Connor (1972) MSRC (1973) MSRC (1973)
Pectenidae			
<i>Aequipecten irradians</i>	ENMS	NOT abundant in 1978	WAPORA (1982)
Solemyacidae			
<i>Solemya velum</i>	INMDi	Abundant	MSRC (1973)
Tellinidae			
<i>Tellina agilis</i>	INSDs	Dominant	MSRC (1973)
Veneridae			
<i>Gemma gemma</i>	INSS	Dominant in Brookhaven Abundant	WAPORA (1982) MSRC (1973)
<i>Mercenaria mercenaria</i>	INSS	Biomass dominant Dominant	O'Connor (1972) MSRC (1973)
Arthropoda			
Amphipoda			
Ampeliscidae			
<i>Ampelisca abdita</i>	ITSDs	Dominant	Cerrato (1986)
Lysianassidae			
<i>Lysianopsis alba</i>	INMDs	Abundant throughout year Dominant	Cerrato (1986) MSRC (1973)
Phoxocephalidae			
<i>Paraphoxus spinosus</i>	INMDi	Abundant	MSRC (1973)
Decapoda			
Cancridae			
<i>Cancer irroratus</i>	ENMO	Present in Islip	WAPORA (1982)
Xanthidae			
<i>Neopanope texana sayi</i>	ENMO	Biomass dominant Abundant near Clam Pond Abundant	O'Connor (1972) WAPORA (1982) MSRC (1973)
<i>Panopeus herbstii</i>	ENMO	Abundant near Clam Pond	WAPORA (1982)
Isopoda			
Idoteidae			
<i>Idotea balthica</i>	ENMO	Abundant	MSRC (1973)
Chordata			
Styelidae			
<i>Botryllus schlosseri</i>	ENSS	Biomass dominant	O'Connor (1972)

Table 6: Benthic species in salt marshes.

Taxa	Func. Group	Distr./Abundance	Source
Mollusca			
Gastropoda			
Littorinidae			
<i>Littorina littorea</i>	ENMO		NONE
Nassariidae			
<i>Ilyanassa obsoleta</i>	ENMO		NONE
Bivalvia			
Mytilidae			
<i>Modiolus demissus</i>	INSS		NONE
Arthropoda			
Decapoda			
Ocypodidae			
<i>Uca pugilator</i>	ENMDs		NONE
<i>Uca pugnax</i>	ENMDs		NONE

Table 7: Functional group assignment chart.

	Infaunal (I)				Epifaunal (E)			
	Tubicolous (T)		Non-Tubicolous (N)		Tubicolous (T)		Non-Tubicolous (N)	
	Motile (M)	Sessile (S)	Motile (M)	Sessile (S)	Motile (M)	Sessile (S)	Motile (M)	Sessile (S)
Suspension Feeder (S)	ITMS	ITSS	INMS	INSS	ETMS	ETSS	ENMS	ENSS
Surface Deposit Feeder (Ds)	ITMS	ITSDs	INMDs	INSDs	ETMDs	ETSDs	ENMDs	ENSDs
Infaunal Deposit Feeder (Di)	ITMDi	ITSDi	INMDi	INSDi	ETMDi	ETSDi	ENMDi	ENSDi
Carnivore (C)	ITMC	ITSC	INMC	INSC	ETMC	ETSC	ENMC	ENSC
Omnivore (O)	ITMO	ITSO	INMO	INSO	ETMO	ETSO	ENMO	ENSO

Table 8: Commercial landings of the major species from Great South Bay. Other less-frequently landed species included in the total finfish category are white perch, striped bass, puffers, silversides, sea bass, sturgeons, sand lance, scup, butterfish, bonito, anglerfish, tautog, shad, sharks, searobins, king whiting, mackerel, skates, yellowtail flounder, and sea herring. From National Marine Fisheries Service statistics.

Year	Landings (in 1,000 lbs.)					total finfish
	bluefish	eels	flounder	weakfish	menhaden	
1962	18.0	48.0	6.5			82.2
1963	25.0	49.5	3.5			90.0
1964	15.9	39.0	3.0			70.2
1965	38.0	93.0	1.5	0.1	0.2	144.7
1966		44.0	8.5			53.5
1967	7.2	24.4	2.5			41.0
1968		10.6	2.6			44.0
1969		32.3	5.8			39.6
1970	3.3	55.6	3.5	8.4		81.6
1971	22.6	51.1	3.3	41.8		143.5
1972	25.5	34.7	11.8	75.2	10.0	188.1
1973						
1974						
1975		8.8				8.8
1976		7.3				7.3
1977						
1978						
1979						
1980				1.1		1.1
1981	49.3			46.5	83.5	191.5
1982	13.5	1.9		13.6	102.0	132.9
1983	29.1			11.1	76.1	116.5
1984	13.8	48.3		14.5	175.8	271.3
1985	5.9	40.3	0.1	7.0	64.6	148.7
1986						
1987						
1988						
1989	62.2	36.8	3.5	7.0	42.3	192.3
1990	6.1	14.8	6.2	0.4	186.6	240.7
1991	4.4	33.0	1.5	2.8	147.1	278.4

Table 9: Percent of total fish captured by species in Great South Bay (based on total fish captured by all methods: beach seines, trawls and gill nets). From Hanlon (1983).

Rank	Species	Percent of total catch (n = 118,116)
1.	Atlantic silverside	78.8
2.	striped killifish	5.3
3.	mummichog	3.3
4.	winter flounder	2.8
5.	oyster toadfish	1.2
6.	fourspine stickleback	1.1
7.	northern pipefish	1.0
8.	sheepshead minnow	0.8
9.	windowpane flounder	0.7
10.	tautog	0.3
11.	bluefish	0.3
12.	bay anchovy	0.3
13.	Atlantic menhaden	0.3
14.	Atlantic needlefish	0.2
15.	summer flounder	0.2
16.	northern puffer	0.2
17.	scup	0.2
18.	hogchoker	0.2
19.	white mullet	0.1
20.	weakfish	0.1
21.	cunner	0.1
22.	lined seahorse	0.1
23.	American sand lance	0.1
24.	smallmouth flounder	<0.1
25.	blueback herring	"
26.	northern kingfish	"
27.	American eel	"
28.	northern sea robin	"
29.	threespine stickleback	"
30.	striped searobin	"
31.	inshore lizardfish	"
32.	Atlantic tomcod	"
33.	grubby	"
34.	black sea bass	"
35.	striped burrfish	"
36.	blackspotted stickleback	"
37.	striped bass	"
38.	seaboard goby	"
39.	fourspot flounder	"
40.	smooth dogfish	"

(more)

Table 9: Continued.

Rank	Species	Percent of total catch (n= 118,116)
41.	spotted hake	"
42.	blue runner	"
43.	permit	"
44.	foureye butterflyfish	"
45.	rock gunnel	"
46.	butterfish	"
47.	sea raven	"
48.	silver hake	"
49.	red hake	"
50.	white hake	"
51.	white perch	"
52.	crevalle jack	"
53.	northern sennet	"
54.	Atlantic mackerel	"
55.	orange filefish	"
56.	honeycomb cowfish	"

Table 10: Species and number of fish seined over natural and sand-filled bottoms of Great South Bay in 1967 and 1968. From Briggs and O'Connor (1971).

Species	Number	
	Natural Bottom	Sand-filled bottom
Atlantic silverside	241,026	406,501
Fourspine stickleback	269,770	18,710
Striped killifish	1,734	87,339
Mummichog	49,134	7,540
Sheepshead minnow	2,480	14,991
Northern puffer	4,067	3,904
Northern pipefish	4,226	658
Atlantic needlefish	1,568	1,063
White mullet	166	2,411
Striped mullet	5	1,791
Threespine stickleback	1,960	9
Winter flounder	509	332
Silver perch	486	0
American eel	435	35
Northern kingfish	25	319
Rainwater killifish	324	16
Tautog	191	3
Oyster toadfish	168	26
Cunner	141	2
Atlantic herring	93	34
Tidewater silverside	59	66
Bluefish	63	46
Bay anchovy	31	9
Atlantic menhaden	26	14
Pollock	20	0
Blueback herring	19	0
Atlantic tomcod	17	0
Permit	2	5
Northern sennet	4	0
American sand lance	2	1
Windowpane	1	2
Spotted hake	3	0
Alewife	0	2
Gray snapper	2	0
Grubby	1	1
Black sea bass	0	1
Smooth trunkfish	1	0
Northern searobin	1	0
Scup	1	0
White hake	1	0
Total	578,762	545,831

Table 11: Abundances of the major taxonomic groups in Wiggins (1986) compared to the results from sandy sediments in Cerrato (1986) and O'Connor (1972). From Wiggins (1986).

Taxa	Abundance (#/m ²)		
	Wiggins (1986)	Cerrato (1986)	O'Connor (1972)
Polychaeta	883	1,908	557
Bivalvia	284	13,901	4,136
Gastropoda	723	19	462
Amphipoda	423	1,065	189
Decapoda	2	26	22
Other Crustacea	49	97	24
Total	2,363	17,016	5,390

Table 12: Summary of factors affecting the distribution and abundance of major species in the study area. From WAPORA (1982).

Species	Larval Dispersal	Harvesting Intensity	Predation	Competition	Salinity	Temperature	Food Supply	Oxygen	Substrate Characteristics
Hard Clam	H	H	M	S	S	N	S	N	H
Shellfish Predators									
Oyster Drills	S	N	S	S	H	U	M	N	H
Mud Crabs	M	N	M	U	S	N	U	N	H
Whelks	S	S	M	U	H	S	H	N	S
* Calico Crab	S	S	U	U	H	S	M	N	M
Starfish	S	N	N	N	H	M	H	N	N
Moonsnails	S	N	M	U	H	M	H	N	S
Hermit Crabs	S	N	S	U	H	S	M	N	S
Blue Crabs	S	M	S	U	S	M	M	N	N
Rock Crabs	S	N	S	U	H	M	M	N	N
Horseshoe Crab	S	S	U	U	S	N	M	N	N
Competitors, Other Bivalves									
Gem Clam	H	N	H	N	S	N	S	N	H
Little Surf Clam	U	N	M	N	S	N	S	N	M
Razor Clam	U	S	M	U	S	N	S	N	S
Dwarf Tellin	U	N	M	U	H	N	S	N	S
Soft Clam	S	S	H	U	S	N	S	N	N
Blue Mussel	M	S	M	N	M	H	S	N	M
Bay Scallop	M	H	H	N	M	N	S	N	S
False Quahog	M	S	M	U	H	N	S	N	M
Slipper Shells	S	N	M	N	N	N	S	N	M
Common Thyone	N	N	M	N	N	N	S	N	M

NOTES: H = Highly important. M = Moderately important. S = Slightly important. N = Not significant. U = Effect unknown.

* AKA Lady Crab

APPENDIX II
Workshop Agenda and Participants

MARINE RESOURCES OF THE FIRE ISLAND NATIONAL SEASHORE WORKSHOP AGENDA

January 28, 1993
Holiday Inn Express Stony Brook

- | | |
|-----------------|---|
| 8:15 - 8:30 AM | Coffee |
| 8:30 - 8:45 | Introduction and Background <ul style="list-style-type: none">- Dr. Anne McElroy, Director, New York Sea Grant- Dr. Charles Roman, Director, National Park Service Coastal Research Center- Mr. James Ebert, Resource Management Specialist, Fire Island National Seashore |
| 8:45 - 12:00 | Status, Critical Factors, and Major Threats to the Marine Resources of the Bayside FINS, presented by Resource Experts |
| 8:45 - 9:15 | Finfish <ul style="list-style-type: none">- Dr. David Conover, Marine Sciences Research Center (MSRC), SUNY at Stony Brook |
| 9:15 - 9:45 | Shellfish and Benthic Invertebrates <ul style="list-style-type: none">- Dr. Robert Cerrato, MSRC, SUNY at Stony Brook |
| 9:45 - 10:00 | BREAK |
| 10:00 - 10:30 | Coastal Processes <ul style="list-style-type: none">- Dr. Henry Bokuniewicz, MSRC, SUNY at Stony Brook |
| 10:30 - 11:00 | Macroalgae, Seagrasses, and Marsh Plants <ul style="list-style-type: none">- Dr. Valrie Gerard, MSRC, SUNY at Stony Brook |
| 11:30 - 11:30 | Water Column Productivity (Plankton and Nutrients) <ul style="list-style-type: none">- Dr. Elizabeth Coper, MSRC, SUNY at Stony Brook |
| 11:30 - 12:00 | Additional Discussion |
| 12:00 - 1:00 PM | LUNCH BUFFET |
| 1:00 - 2:30 | Identification and Prioritization of Management Issues <ul style="list-style-type: none">- Participants' comments moderated by Mr. Jay Tanski, New York Sea Grant |
| 2:30 - 3:30 | Discussion of Management Issues and Identification of Data Gaps <ul style="list-style-type: none">- Break-out sessions led by Resource Experts |
| 3:30 - 4:45 | Review of Management Issues and Discussion of Technical Information Needs <ul style="list-style-type: none">- Panel of resource experts and group discussion moderated by Dr. Anne McElroy |
| 4:45 - 5:00 | Next Steps and Adjourn <ul style="list-style-type: none">- Dr. Charles Roman- Dr. Anne McElroy |

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