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May 1994

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US Army Corps of Engineers
Waterways Experiment Station

New York Bight Study

Report 5
NY Bight Biological Review Program

by Pace Wilber

Robert Will
U.S. Army Engineer District, New York

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Prepared for U.S. Army Engineer District, New York

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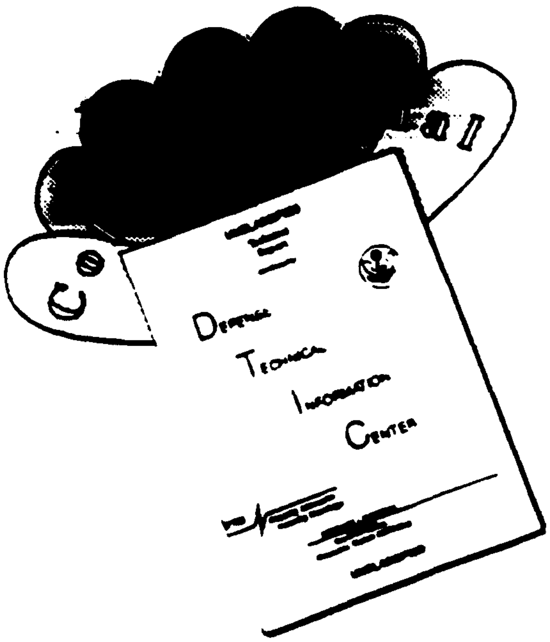

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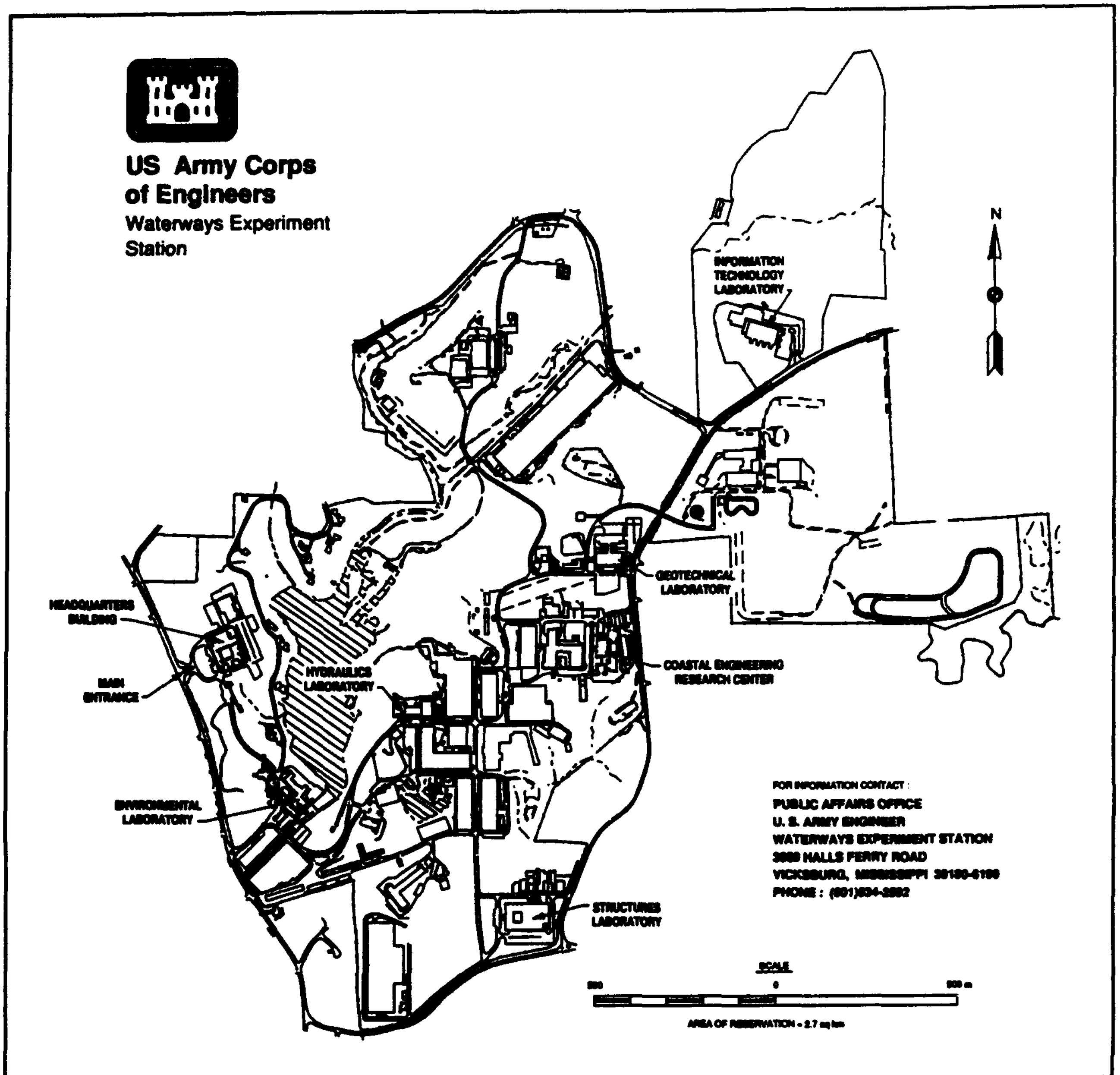

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Preface

The New York Bight Biological Review Program (BBRP) was one portion of a larger effort to determine the feasibility of various modeling and monitoring strategies for measuring the effects of pollution in the NY Bight. The specific goal of the BBRP was to identify information gaps that need to be filled in order to efficiently examine impacts to marine biological resources from large-scale projects within the NY Bight. Other portions of the NY Bight study included demonstrations of the feasibility of hydrodynamic and water quality modeling, development of a field monitoring plan, and generation of a database/geographical information system that would support modeling efforts. Together, these studies provide the U.S. Army Engineer District, New York, (CENAN) with a systematic approach to estimating future responses of the NY Bight to various environmental conditions.

The U.S. Army Engineer Waterways Experiment Station (WES) gratefully acknowledges the direction and assistance of Mr. John Tavolaro, Ms. Patricia Barnwell-Pechko, Mr. Bryce Wisemiller, Mr. Leonard Houston, and Mr. Brian May (CENAN).

General supervision was provided by Dr. John Harrison, Director of the WES Environmental Laboratory (EL). Direct supervision was provided by Mr. H. Lee Butler, Chief, Research Division, Coastal Engineering Research Center, WES, who also served as the overall project manager. Additional supervision was provide by Dr. C. J. Kirby, Chief, Ecological Research Division, EL, and Mr. E. J. Pullen, Chief, Coastal Ecology Branch (EL).

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
fathoms	1.8288	meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412	cubic decimeters
miles	1.609347	kilometers
nautical miles	1.852	kilometers
square miles (U.S. statute)	2.589998	square kilometers
square nautical miles	3.4299	square kilometers
tons (2,000 pounds, mass)	907.1847	kilograms

Executive Summary

The New York Bight Biological Review Program (BBRP) was authorized by Section 728 of the Water Resources and Development Act of 1986 (PL99-662). Its objective was to identify the types of databases and models that are needed, but currently unavailable, for examining impacts to marine biological resources from large-scale projects within the NY Bight. Other studies authorized by the Section 728 study included demonstration of the feasibility of hydrodynamic, eutrophication, and general water quality modeling for the NY Bight and development of a Geographic Information System (GIS) for cataloging model input and displaying model results.

The BBRP used five hypothetical projects to accomplish this objective. In doing so, it was expected that impacts examined via these hypothetical projects would be representative of impacts that would result from whatever future projects actually are pursued in the NY Bight. In this manner, the adequacy of existing information for examining the more important biological impacts from future projects will have already been reviewed and plans outlined for obtaining critical missing information with sufficient lead time to allow the gaps to be filled in a scientifically reliable manner. The BBRP's work was periodically reviewed by an independent group of scientists from academia, the Biological Review and Assessment Group (BRAG), to ensure assessments were scientifically reasonable.

The hypothetical projects chosen to guide the BBRP were: (1) use of offshore containment islands for disposal of dredged material, (2) expansion of the Mud Dump Site to accommodate more dredged material, (3) use of a new offshore dredged material disposal site, (4) use of offshore borrow pits as disposal sites for dredged material, and (5) lengthening and deepening Ambrose Channel (the main entrance to NY/NJ Harbor). For simplicity, the types of organisms considered were limited to macroinfauna, epifauna (which was defined to be amphipods, crangonid shrimp, and mysid shrimp), fish (including ichthyoplankton), and macrocrustaceans (crabs, shrimps, and lobsters).

Information gaps identified by examining these hypothetical projects were synthesized into a set of recommendations that are not likely to be addressed by the site-specific surveys that would accompany planning of a particular project. Instead, these recommendations focus upon system-wide studies that are crucial to correctly interpreting site-specific studies. These information gaps include:

a. Synthesizing past studies into a process-oriented view of the NY Bight ecosystem and quantitatively testing conceptual models of how that ecosystem functions. Most of the effort monitoring biological resources in the NY Bight has been spent describing the abundance of species rather than examining processes that result in these abundances. Experiences in many coastal areas clearly show that a process-oriented approach, which elucidates the cause-and-effect relationships between species and between species and the physical and geochemical environments, is necessary to characterize long-term and cumulative impacts from anthropogenic activities. An essential component in developing a process-oriented view of the NY Bight ecosystem is the testing of conceptual models of how this ecosystem functions; e.g., the hypoxia model for coastal New Jersey. Many of these hypotheses can be tested using hydrodynamic and water quality models developed under the Section 728 study. Tests of these hypothesized mechanisms are essential to improving understanding of the NY Bight ecosystem and should be done before additional descriptive surveys or broad-scale model development are undertaken.

b. Determining the importance of the Hudson River plume in plankton dynamics, fishery recruitment, and material exchanges between Hudson/Raritan estuary and the Atlantic Ocean. The Hudson River plume is one of the few features in the NY Bight whose potential significance to the ecosystem is much greater than implied by its area. In other coastal areas, river plumes have been shown to be important components of coastal ecosystems and variations in plume characteristics often are correlated with variations in fisheries, water quality, and sediment transport. Given the large potential importance of the Hudson River plume, its use as a conduit for transporting anthropogenic discharges to the ocean, and the fact that disposal activities occur within the plume, clearly understanding the role of the plume in the NY Bight ecosystem seems essential.

c. Examination of bioaccumulation of contaminants by fish from an east coast perspective. Contaminant concentrations within fish and other organisms represent a summation of ingestion, absorption, biochemical transformation, and excretion. Most fishes from the NY Bight are only seasonal residents of the ecosystem, migrating from as far away as Florida and Canada. These migrations bring fish into contact with many potential point-sources and non-point-sources of contamination. Therefore, it is reasonable to hypothesize that a portion of the contaminants measured in the bodies of organisms from the NY Bight are acquired outside the New York/New Jersey area. This hypothesis requires rigorous examination because, if true, it would strongly imply that current efforts to prioritize regulatory and potential cleanup efforts are too narrow in scope. Tests of this hypothesis would require examining bioaccumulation of contaminants within the contexts of normal migrations and geographic ranges of the species sampled.

Additional information that would facilitate the planning of particular projects could be addressed inexpensively with existing data and include:

a. Generic modeling of the general water-flow patterns around and above subaqueous pits. Both quantitative and qualitative examinations of potential impacts from disposing dredged material in borrow pits require knowledge of how water flows around large depressions. One specific question relevant to these examinations is what design features (*e.g.*, size, shape, pit depth, water depth, current speed, etc.) induce water to separate and flow around a depression, leaving a semi-quiescent area above the pit proper, as opposed to flowing over the depression. This knowledge would greatly improve assessments of the potential for hypoxia in existing and proposed borrow pits, the degree borrow pits and natural depressions confine fine dredged material placed in them, and the attractiveness of borrow pits and natural depressions to fishes.

b. Mapping infaunal and epifaunal abundances and value as food to bottom feeding fishes. Four of the hypothetical projects involved usurpation of some portion of the sea bottom resulting in loss of infauna and epifauna. Even if an EIS will require additional site-specific information about benthos, a synthesis of existing information about distributions and abundances would be a valuable planning tool since some general decisions about siting are necessary in the early planning stages of a project. This synthesis also would be useful in maximizing the cost-effectiveness of any site-specific sampling. Over 30 studies of infauna and infaunal habitat in the NY Bight were identified during the BBRP. If synthesized together, they would provide the most comprehensive information available about infaunal and epifaunal distributions and the value of various areas as a forage base for fish, lobsters, crabs, and shrimp.

c. Quantifying the distributions and abundances of hard-bottom benthos and fish and the food habits of hard-bottom fishes. Evaluation of an offshore containment island will include a balancing of several public-interest factors. One factor likely to be portrayed as a benefit is the potential for organisms to exploit the hard-bottom substrate offered by an island. Existing information only allows a qualitative assessment of this impact. Quantitative surveys of existing hard-bottom areas (mostly artificial reefs) would greatly improve the rigor of this assessment and thereby allow a more precise balancing of the public-interest factors. This information also would improve the rigor of any assessment of potential forage value associated with the hard-bottom substrate, if additional studies are done to better characterize the feeding habits of fishes found in this type of habitat.

1 Introduction

In response to concerns regarding effects from human activities to resources within the New York Bight, the U.S. Congress directed the Secretary of the Army to "study a hydroenvironmental monitoring and information system" for the Bight (Appendix A). The New York Bight Biological Review Program (BBRP) was a portion of this effort[1]. The program's objective was to identify the databases and models that are necessary but currently unavailable for examining impacts (positive and negative) to marine biological resources from large-scale projects within the NY Bight. To accomplish this objective, hypothetical projects were used to guide reviews of existing databases and models. It was expected that impacts examined via these hypothetical projects would be representative of impacts that would result from whatever future projects are pursued in the NY Bight. In this manner, the adequacy of existing information for examining the more important marine biological impacts from future projects will have already been reviewed and plans will have been outlined for obtaining critical missing information with sufficient lead time to allow important information gaps to be filled in a scientifically reliable manner.

The overall objective of the BBRP was accomplished in four steps:

a. Listing and prioritizing impacts likely from each hypothetical project.

b. Identifying important information gaps by determining which impacts can be adequately examined using existing databases and models.

c. Prioritizing information gaps and outlining how missing information could be obtained.

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[1] The New York Bight and New York Bight Apex are general geographic areas without explicit boundaries. For the BBRP, the NY Bight constituted all portions of the Atlantic Ocean shown on National Oceanic and Atmospheric Administration (NOAA) chart 12300 that are west of longitude 72° (Montauk Pc NY), north of latitude 39° (Cape May, NJ), landward of the 1,000-fathom contour, and seaward of the Sandy Hook/Rockaway Point transect (Figure 1). The NY Bight Apex constituted all portions of the NY Bight shown on NOAA chart 12326, which is generally the ocean area west of longitude 73° 10′ (Islip, NY) and north of latitude 40° 8′ (Spring Lake, NJ).

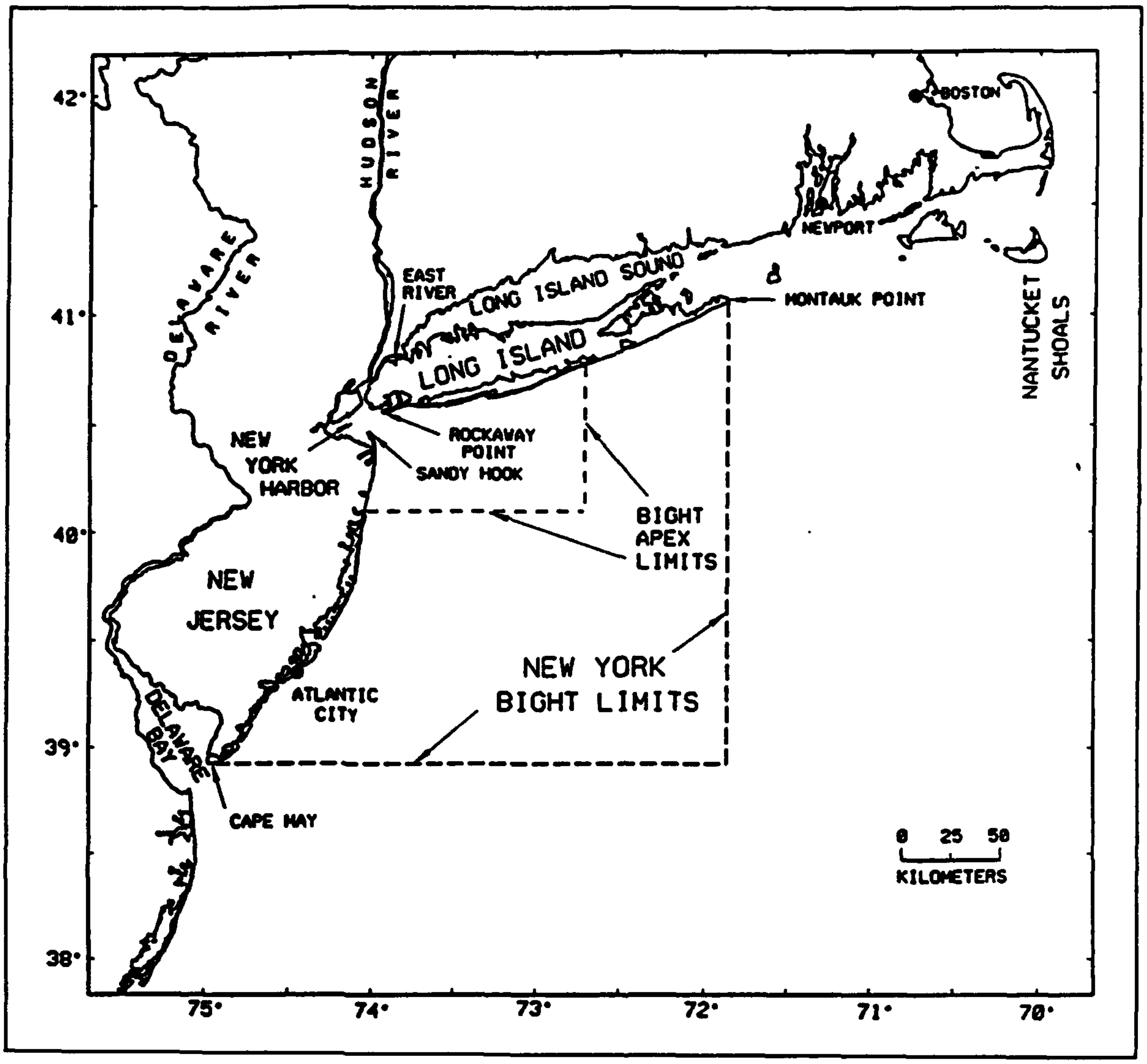

Figure 1. Map of NY Bight and Bight Apex. For the BBRP, the boundaries of the New York Bight were all portions of the Atlantic Ocean shown on NOAA chart 12300 that are west of longitude 72°, landward of the 1,000-fathom contour, and seaward of the Sandy Hook/Rockaway Point transect; the southern latitudinal boundary of this chart is in the vicinity of Cape May, NJ. The New York Bight Apex was defined to be all portions of the Bight shown on NOAA chart 12326, which is generally the ocean area north of Spring Lake, NJ, and west of Islip, NY

d. Outlining mitigation projects that might compensate for unavoidable impacts from large-scale projects.

The BBRP was conducted by the U.S. Army Engineer District, New York and the U.S. Army Engineer Waterways Experiment Station (WES). Work was periodically reviewed by an independent group of scientists, the Biological Review and Assessment Group (BRAG), to ensure assessments of existing databases and models were objective, thorough, and scientifically reasonable. The members of BRAG came from academia and had expertise in physical oceanography, marine geology, environmental monitoring, marine benthic ecology, and ichthyology. The BRAG met five times during the course of the BBRP (Appendix B), which allowed reviews of work in progress and was essential to making important mid-course corrections.

Five hypothetical projects were chosen to guide the BBRP:

a. Use of an offshore containment island for the disposal of dredged material.

b. Expansion and use of an existing offshore dredged material disposal site (*i.e.*, the Mud Dump Site) in order to increase the amount of dredged material that can be placed in it.

c. Use of a new offshore dredged material disposal site.

d. Use of offshore borrow pits for disposal of dredged material.

e. Lengthening and deepening Ambrose Channel.

The first four projects were directed towards developing a long-term management plan for dredged material from NY/NJ Harbor. Projects similar to the fifth (*e.g.*, the Coal Port project originally proposed for NY/NJ Harbor in the mid-1970s) would be undertaken by federal and/or state government(s) and/or the private sector as a civil works project if justifiable economically. These hypothetical projects were believed to represent the basic types of impacts that one might expect from any large-scale project in the NY Bight and, thus, should be applicable for projects other than those considered here. Large-scale projects previously considered for the NY Bight included sealing dredged material in containers that would then be placed on the ocean bottom and spreading dredged material in thin layers over very large areas of ocean bottom to reduce the magnitude of physical and chemical alterations at a particular site. These projects had previously been considered "not currently reasonable" (Conner et al. 1979), a conclusion supported by more recent reviews (U.S. Army Corps of Engineers (USACE) 1989), and were not reviewed by the BBRP.

When selecting these hypothetical projects, the BBRP recognized that similar projects had been previously discussed for either the NY Bight or NY/NJ Harbor, especially during development of the District's Dredged Material Disposal Management Plan (DMDMP; USACE 1989). The BBRP differed from DMDMP efforts in that the BBRP focused exclusively on the NY Bight, whereas DMDMP emphasized potential projects within NY/NJ Harbor and compared the economic and engineering feasibility of dredged material disposal alternatives. In addition, the BBRP emphasized identifying gaps in information needed to examine projects and outlined plans to fill those gaps. It was also recognized in the BBRP that any long-term solution to the management of dredged material in NY/NJ Harbor must pragmatically include provisions for contaminated dredged material (termed category II and III dredged material by the District and defined in more detail in Chapter 2). The BBRP discussed ocean disposal of category II and III material even though such disposal may have been contrary to the District's policies. However, because the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (often called the London Dumping Convention) and the Marine Protection, Research, and Sanctuaries Act of 1972 (often called the Ocean Dumping Act), permits ocean disposal of such material under certain management practices (Engler 1992), this possibility could not be excluded from discussion.

Finally, it should be emphasized that BBRP's objective was to evaluate tools available for examining project impacts, not to recommend which projects should be pursued. Only tools suited to examining impacts to marine biological resources were reviewed. Actual examination of impacts and expansion of the impact scope to include other issues (*e.g.*, air quality, economics, shoreline erosion, navigation, cultural resources, and fishing) would be done during preparation of Environmental Impact Statements (EIS) or similar documents that evaluate specific projects.

2 Step 1: Probable Impacts from Potential Bight Projects

Descriptions of Dredged Material and Hypothetical Projects

Before the BBRP could use the hypothetical projects to identify likely environmental impacts, the projects and general characteristics of dredged material from NY/NJ Harbor needed to be described to clarify the biological issues examined and ensure that assessments were relevant to the District's anticipated needs. Two alternative strategies could be used to describe the projects. First, the hypothetical projects could be described in as much detail as possible using reasonable assumptions about location, size, and management. Although such an approach would be useful in specifying potential impacts, it also would limit the range of impacts considered, potentially compromising BBRP's conclusions should actual projects differ substantially from those chosen for review. For example, if assumptions about siting led one to conclude a containment island would not be located in areas where shellfishing occurs, few impacts to shellfish would be considered. However, if such assumptions prove false, a major class of impacts would have been excluded. Second, potential projects could be described broadly, specifying details only when critical to BBRP's overall objective. Even though some obvious constraints on the projects were omitted, this strategy was used for the BBRP because it potentially included a broad range of impacts. For example, it is reasonable to assume a containment island would not be located in a navigation fairway. However, since the usefulness of existing information for predicting the marine biological impacts from an island depends on the physical, chemical, and biological environment, not on an artificial designation such as a navigation fairway, this assumption seemed unnecessary.

Because of their tendency to set limits on what was considered, assumptions were made sparingly. However, at times it was necessary to provide details about a project in order to focus discussions upon likely perturbations. These details were termed guideposts. The overall conclusions of the BBRP did not appear sensitive to the exact information chosen for the guideposts.

For example, the utility of hydrodynamic models to examine how containment islands might alter nearby currents should not be particularly sensitive to island size within the size range likely for such islands (100-5,000 acres, 0.1-6 nm^2)[1] since such islands would have a dimension less than either the external or internal Rosby radius of deformation.

General characterizations of dredged material from NY/NJ Harbor have been prepared by the District and the U.S. Environmental Protection Agency (USEPA), and additional project-specific data are collected prior to each dredging event. As is true for many ports, the general characteristics of the dredged material are quite variable. Material removed during maintenance of Ambrose Channel is primarily sand, material removed from the NY Passenger Ship Terminal and Stony Point is primarily silts and clays, and material removed from the Port Authority Terminal is generally one half sand and one half silts and clays (O'Connor 1982). Overall, about 67 percent of the material consists of silts and clays. The organic carbon content of the material can range from <1 percent to 20 percent. From 1979-1988, the typical amount of material dredged from the harbor each year was approximately 9×10^6 yd^3; approximately 89 percent of this material was placed in the Mud Dump Site (USACE 1989). Typical rates of placement were 2-4 barge loads ($8\text{-}16 \times 10^3$ yd^3) per day.

Dredged material considered for ocean disposal is tested according to criteria outlined in USEPA and USACE (1977), which were nationally updated by USEPA and USACE (1991) with implementation guidelines for the NY region set forth in December 1992. These tests typically include bioassays for toxicity and bioaccumulation if material contains a substantial amount of silt or clay. Based on test results, the District places dredged material into three categories (USACE 1989). Approximately 90-95 percent of the material removed from the harbor met the 1977 standard for unconfined open-ocean disposal (Coch et al. 1985, USACE 1988) and is termed category I material. Category II material shows evidence of deleterious effects to biota but still meets Federal standards for ocean disposal because contaminants are rapidly and sufficiently diluted during disposal. Category III material does not meet Federal standards for ocean disposal. Under current District and USEPA Region II policies, category II material can be placed in the ocean if capped (isolated from the environment) by another layer of material soon after disposal. Category III material is not placed in the ocean, it is either placed in upland disposal areas or not dredged. Category I material must be used for intermediate or long-term caps of category II material. Category II material can be capped for short time periods by other category II material in a practice called de facto capping.

Many types of organic and inorganic contaminants have been found in harbor sediments, including the navigation channels. Exact sources of

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page vii.

contaminants are often unclear, but the general mechanisms by which contaminants enter the harbor include sewage outfalls, stormwater outfalls, and accidental spills. Contaminants that have been tested and shown to accumulate in organisms during bioassays of NY/NJ Harbor sediments include petroleum hydrocarbons, PCBs, dioxin, cadmium, and mercury. Metals and organic pollutants have been measured in body tissues of animals caught in or near the Mud Dump Site (reviewed by SAIC 1991a); however, since the NY Bight receives contaminants from several sources, it was not possible to determine the source of the contaminants in the animal tissues. For example, during some bioaccumulation studies, several million tons of sewage sludge (a known source of heavy metals and petroleum hydrocarbons) were placed in the 12-Mile Dump Site annually, an area about 4 nm from the Mud Dump Site. Further, most fishes in the NY Bight undergo extensive migrations that bring them near many potential sources of contamination, which prevents clearly determining the actual source(s) of contaminants within a particular fish.

Offshore containment islands

Large, man-made containment islands have been used worldwide for disposal of dredged material for many years and are generally differentiated from containment areas in that islands are separated from uplands by open water or wetlands. Some of the larger islands include Point Mouillee, MI, (900 acres), Hart-Miller Island, MD, (1,140 acres), Gaillard Island, AL, (1,300 acres), and Craney Island, VA, (2,500 acres). All of these islands are located in inshore areas protected from severe erosive forces; hence, their designs are likely to differ substantially from any island constructed in the NY Bight. Although some of these islands contain contaminated dredged material, they were not built solely as storage areas for material with high contaminant concentrations. Two disposal islands, 72 and 640 acres, have been built in the Netherlands of sand dikes expressly for receiving moderately and severely contaminated dredged material and have a capacity of 1.17×10^6 yd^3 and 117×10^6 yd^3, respectively (Vellinga 1989). The smaller disposal island is used exclusively for severely contaminated material and is lined with high-density polyethylene sheeting.

Of 21 dredged material disposal alternatives identified by the District during a 1977 workshop, placement of material in a >1,000-acre offshore (seaward of the Sandy Hook/Rockaway Point transect) containment island was considered technically feasible but "not currently reasonable" based on legal issues and economics (Conner et al. 1979). This view did not hold for inshore islands. In a preliminary examination, Poindexter et al. (1988) and Walski and Schaefer (1988) examined the relative storage capacity and costs of several options for 500-acre islands within the harbor. They concluded islands built of prefabricated caissons have lower unit storage costs than similar-sized islands built of sand or rock dikes. However, by themselves, 500-acre containment islands in the harbor do not represent long-term (i.e., >50 years) solutions to the dredged material disposal problem, and islands larger than 500 acres may be too detrimental to biological resources.

The BBRP assumed that the primary purpose of a containment island would be a disposal site for dredged material (Figure 2). Any containment island built in the open Atlantic Ocean would reflect numerous engineering constraints. However, it seemed unnecessary to make any assumptions about the siting, size, or shape of an island for the BBRP nor were assumptions made about the categories of dredged material placed in the island. Small islands (about 100 acres at sea level) might be used for the relatively small amounts of category III sediments within NY/NJ Harbor (USACE 1989). Large islands (>500 acres, 0.6 nm^2, at sea level) might be used for all categories of dredged material. The BBRP assumed that an island would be constructed to create an impermeable barrier between the island's interior and the ocean, rather than allowing controlled discharges of solids. A major design feature of an island is how its border is protected from the outward forces exerted by the island's weight and from erosion by waves and currents. Border protection could be

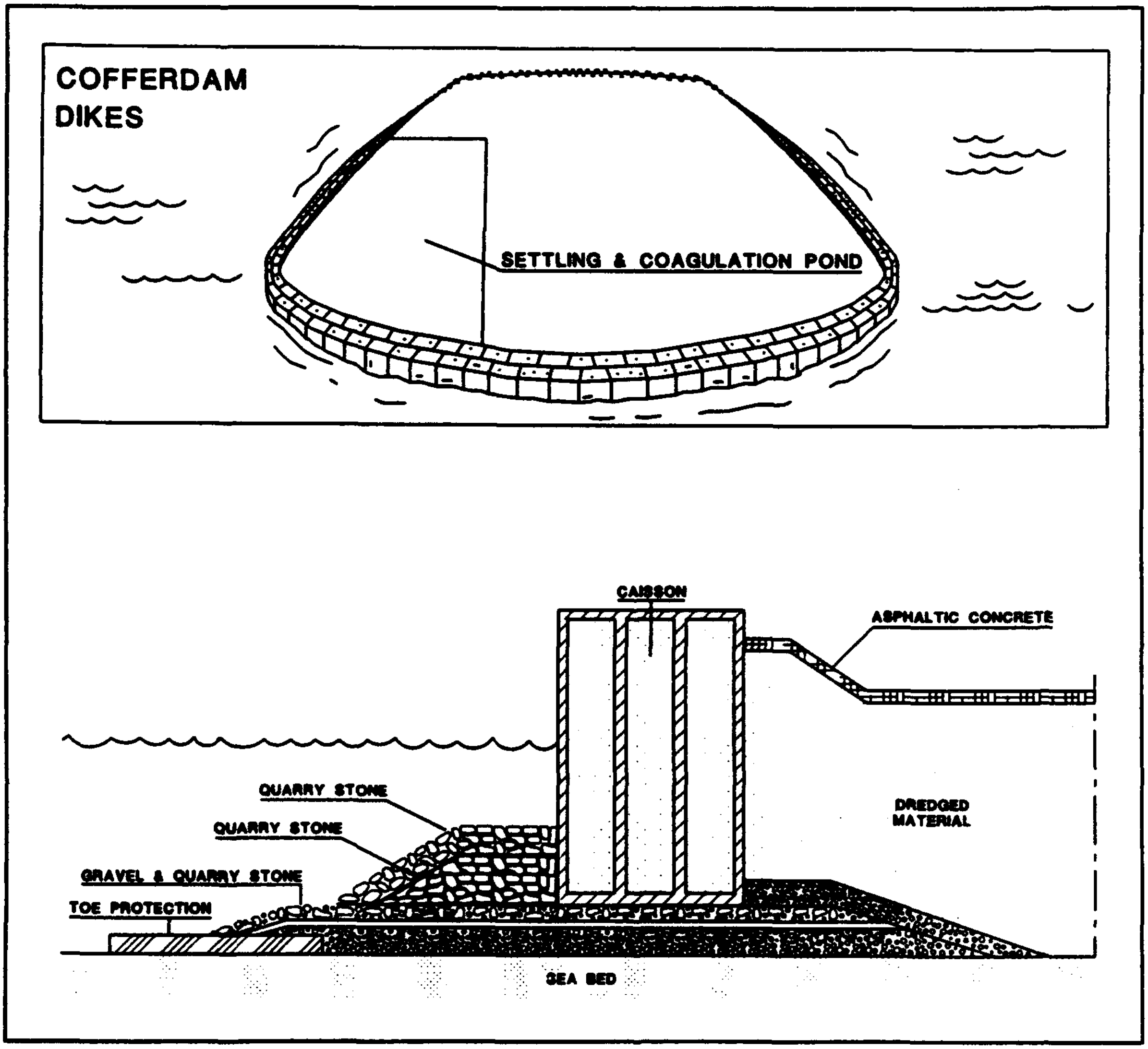

Figure 2. Conceptual representation of the offshore containment island discussed by BBRP

achieved with sacrificial beaches, earthen dikes, armor, or caissons. The BBRP assumed any island in the Bight would be constructed with caissons because other methods of border protection are either not typically feasible in waters deeper than 40-60 ft (McAleer 1975, Wang and Peters 1985) or uneconomical (Walski and Schaefer 1988). Thus, from an impact-assessment perspective, the type of island reviewed during the BBRP would probably have fewer impacts than other island types, primarily because of its smaller sea-bottom surface area and greater potential for isolating material. The BBRP assumed the freeboard of an island (*i.e.*, its height above the water surface) would be high enough to prevent overtopping by waves and surge during typical storm conditions. The purpose of this assumption was to indicate the island's contents (soil and water) would remain isolated from the environment by structural means under common weather conditions. The formal risk analysis that would accompany planning of an actual island would include quantitative examinations of more severe storms.

For stability, the caissons probably would be either trapezoidal in cross section or the outer edge of rectangular caissons would be heavily armored at the bottom with quarry stone or similar material (Ocean Industry 1973, Hotta 1989). At the surface, the caissons may include special structures or surfaces to dissipate wave energy and reduce wave overtopping (Eddie et at. 1985, Hotta 1989). It is also likely caisson bottoms would be buried 20+ ft into the seafloor, providing additional assurance that contaminants would not seep through the island's bottom and into the marine environment. Synthetic liners or layers of silt/clay dredged material at the bottom of the islands may further reduce the possibility of seepage.

No assumptions were made about how material would be transferred from barges to the island's disposal cells, although it was noted that hydraulic transfer is likely. Placing dredged material in an island would displace water within the disposal cells, and this water may require treatment before discharge. The amount and type of treatment would depend on the material placed in the island and could be as simple as coagulation and ponding to settle fine material, but also might include chlorination to kill pathogens and filtration to remove dissolved or fine-particulate contaminants (Walski and Schaefer 1988). Treatment of the discharge would be important if category II and III material were placed in an island because contaminants are often more concentrated in silty/clay material than sandy material, and silty/clay material is more likely to be suspended during disposal operations. The amount of effluent to be treated would depend upon an island's size, and likely orders of magnitude are 10^6 to 10^7 gallons per day (Walski and Schaefer 1988). Similar considerations may be necessary for the island's stormwater discharges, particularly once dredged material is emergent.

Expansion of the mud dump site

The Mud Dump Site is one of over a hundred active Ocean Dredged Material Disposal Sites (ODMDS) nationwide that has a formal designation from the USEPA. The depths of these sites range from about 30 ft to >1,000 ft, and they generally are 1-3 nm^2 in size. Dredged material has been placed in the vicinity of the Mud Dump Site for almost 100 years (USACE 1989); its current location is immediately landward of the 90-ft depth contour near the head of the Christiaensen Basin (Figure 3). The Cellar Dirt Disposal Site, which was used for construction debris, is approximately 1 nm east of the Mud Dump Site and within the Christiaensen Basin. This site has been used since the 1940s, but received only limited use during the 1980s and is no longer used. The 12-Mile Municipal Sludge Disposal Site (commonly called the 12-Mile Site) is about 4 nm east of the Mud Dump Site; the Christiaensen Basin is between the 12-Mile Site and the Mud Dump Site. Until 1987, this site received several million wet tons of sewage sludge each year. Other active or recently active ocean disposal sites in the NY Bight and their approximate distance to the Mud Dump Site are the Acid Waste Disposal Site

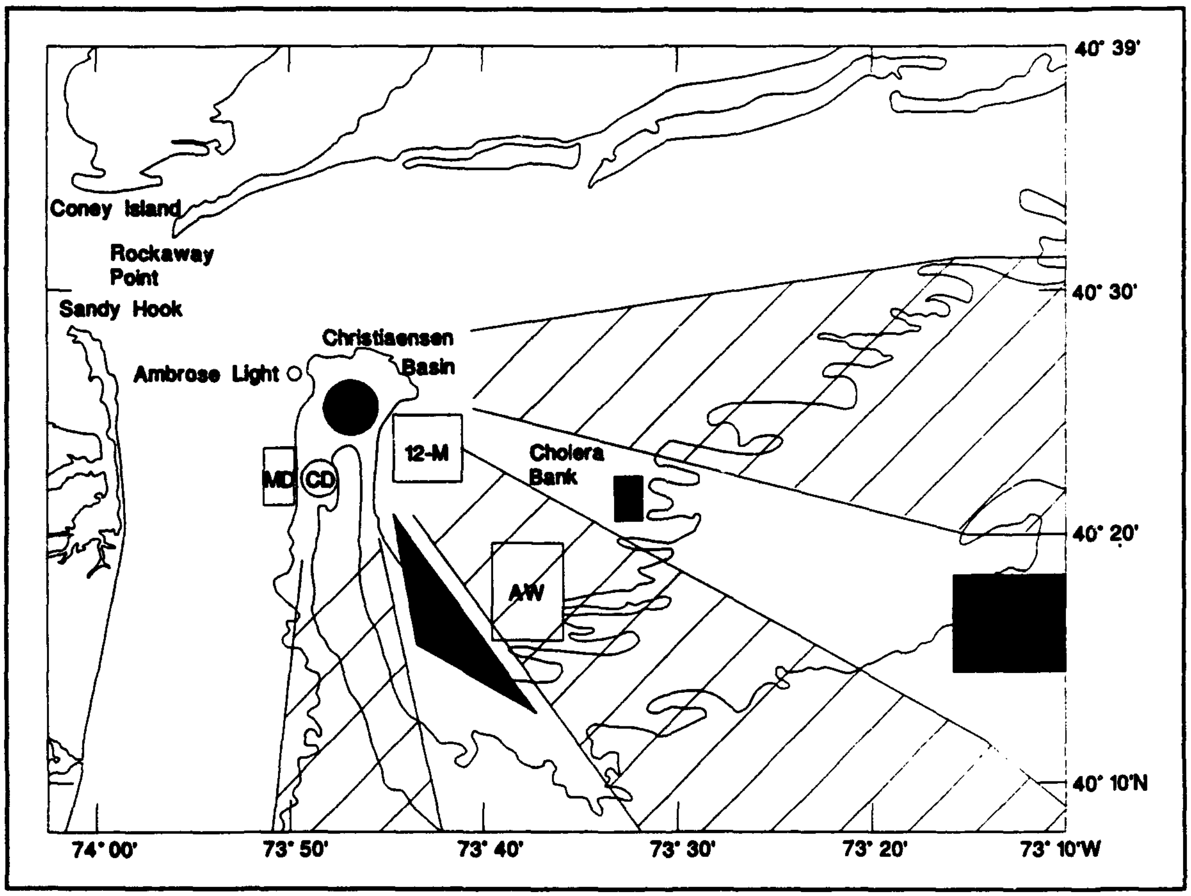

Figure 3. Location of the Mud Dump Site (MD), the currently active ocean disposal site for dredged material. Other disposal sites include the Cellar Dirt Site (CD), which was used for construction rubble, the 12-Mile Sewage Sludge Disposal Site (12-M), which was used for municipal sewage sludge, and the Acid Waste Disposal Site (AW). Blackened areas are described in Figure 4, hatched areas are the shipping lanes (including separation zones)

(11 nm), 106-Mile Deepwater Municipal Sludge Dump Site (115 nm), and 106-Mile Deepwater Industrial Waste Disposal Site (110 nm). Use of the latter was discontinued in June 1992.

Formal regulation of the Mud Dump Site was authorized by the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA), and it was designated as an interim disposal site in 1977 when USEPA promulgated regulations necessary to implement MPRSA. Subsequent studies led to the formal designation of the Mud Dump Site as an ODMDS in 1984. During the formal designation process, the estimated remaining capacity of the Mud Dump Site was defined to be 10^8 yd^3 (USEPA 1982). Current estimates indicate the Mud Dump Site could reach its capacity by 1995-1998 (USACE 1989). The height of accumulated sediments at the Mud Dump Site is limited to prevent disruptions to navigation and to reduce erosion from long-period waves; thus, expansion could only occur by moving its horizontal boundaries. No assumptions were made about the size or direction of the expansion, although an area of 2 nm^2, a height limit of 55-75 ft below the sea surface, and a placement rate of 4-8 10^6 yd^3 per year were used as guideposts, which essentially doubles the size of the current Mud Dump Site. Currently, use of the Mud Dump Site is limited to category I dredged material and category II material that can be capped (*i.e.*, material that forms a mound, rather than spreading over a large area, when ocean disposed). The BBRP assumed that the same restrictions would apply to an expansion of the Mud Dump Site.

Several studies show that capping contaminated material with clean material effectively isolates contaminants associated with the former when the cap is placed within a few weeks of disposal of the contaminated material (O'Connor and O'Connor 1983; Brannon, Hoeppel, and Gunnison 1987; Brannon and Poindexter-Rollings 1990). Palermo (1992) describes the various requirements of a capping project. Nationally, caps are generally 2-3 ft thick. An important aspect of managing dredged material via capping is precisely controlling placement location. Placement of dredged material in particular locations (called "precision dumping") can be achieved using taut-lined buoys to mark exact disposal targets; this practice has been used at the Mud Dump Site. Depending on depth, currents, material density, and movement of the vessel during a dump, precision dumping can control placement location to within a few hundred yards of a target (Bokuniewicz 1986). However, as has been demonstrated at the Mud Dump Site, the location of taut-lined buoys should be closely monitored because they can be moved by high waves and collisions with ships and can be lost when salt water and fouling organisms destroy the tether. Management practices currently employed at the Mud Dump Site were used as guideposts in evaluating the utility of existing information for predicting impacts from an expanded Mud Dump Site. No assumptions were made about the granular composition of the material used for capping other than that sound engineering judgement would be used to choose material that would form a stable cap.

Designation of a new ocean disposal site for dredged material

No assumptions were made about the location, shape, or size of a new ODMDS, although an area of 2 nm^2 and minimum depths of 100 ft were used as guideposts. Operation of a new ODMDS may afford opportunities for disposal of dredged material that were not possible for the Mud Dump Site (*e.g.*, capping of category III dredged material or low-density category II material in natural or man-made depressions). Therefore, no assumptions were made about the type of dredged material placed in a potential new ODMDS. As a guidepost, management of a new ODMDS was envisioned to be similar to that of the Mud Dump Site. In examining this hypothetical project, it was noted that alternate locations for a new ODMDS were investigated under the authority of Section 211 of the Water Resources and Development Act of 1986 (*e.g.*, Scheffner 1989) and Section 412(a) of the Water Resources and Development Act of 1990 (USACE and USEPA 1992), as well as during the formal designation of the Mud Dump Site (USEPA 1982). Figure 4 shows locations of some previously considered alternatives to the present ODMDS.

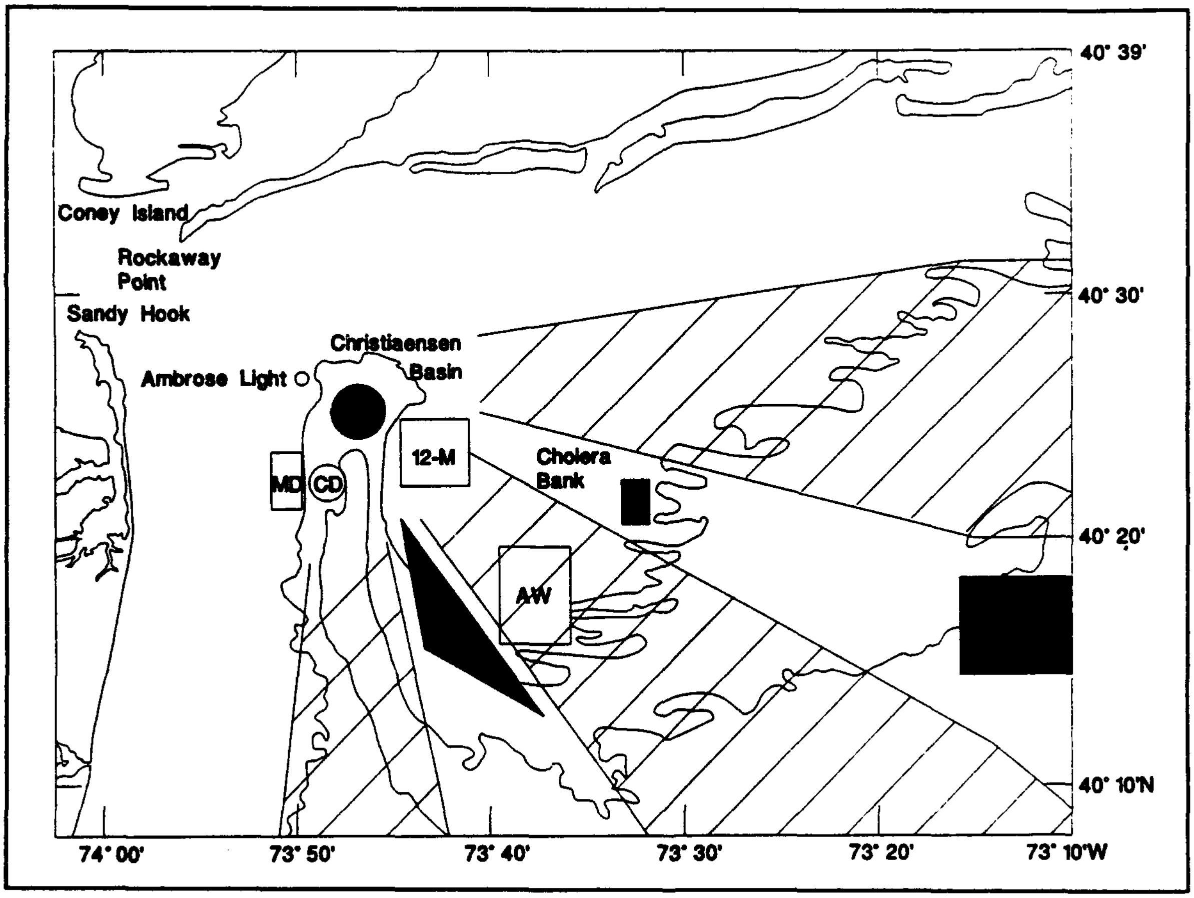

Figure 4. Alternative locations for an ocean dredged material disposal site (ODMDS) considered under previous studies, including studies that led to the formal designation of the Mud Dump Site (MD). Other sites and symbols are defined in Figure 3

Subaqueous offshore borrow pits

In many coastal areas, including NY/NJ Harbor, material has been excavated from subaqueous areas for fill or construction material. In some cases, these depressions (borrow pits) have acted as artificial reefs, attracting many fish and fishermen (Conover et al. 1983, Conover, Cerrato, and Bokuniewicz 1985). In others, poor water quality within the borrow pits has limited their fish-attraction potential (Murawski 1969, Broughton 1977). When practical, the latter borrow pits have been filled with dredged material to restore the natural bottom contours or to raise elevations sufficiently so that poor water quality is no longer a problem.[1] In some areas, particularly Chesapeake Bay, Indian River, FL, and NY/NJ Harbor, the collective volume of borrow pits exceeds 10^7 yd^3, representing a substantial amount of dredged material disposal capacity. Of the disposal alternatives identified by the District during a 1977 workshop, placement of material in large subaqueous borrow pits was considered "possible in special cases and feasible for large volumes of material" (Conner et al. 1979). Placement of dredged material in subaqueous borrow pits also was deemed the "technically preferred option" for disposal of all categories of dredged material from the harbor (USACE 1983, 1991). Candidate existing borrow pits and sites for new pits within NY/NJ Harbor for dredged material disposal have been proposed in a specific EIS (USACE 1991). However, an issue requiring consideration before disposing in these borrow pits is their frequent and historical use by fish and other resources (Conover et al. 1983, Conover, Cerrato, and Bokuniewicz 1985). This may not be an important concern in the NY Bight because pits would be dug expressly for filling them with dredged material. Construction and disposal could be phased to minimize the time a significant depression is present (Figure 5).

The BBRP made no assumptions about the location, size, shape, or depth of a borrow pit. A wall slope of 20-30 deg and minimum wall height of 4-5 ft located 650 ft from the center of the dump location, to contain the material surge (Bokuniewicz, Cerrato, and Hirschberg 1986), were used as guideposts. As was true for containment islands, a small pit (<100 acres of sea bottom) could be used for the relatively small amounts of category III harbor sediments, plus the category I material needed to cap contaminated material. Large pits (>500 acres of sea bottom) could be used for all categories of dredged material. Pits could be lined with a synthetic barrier or with clean material to provide additional assurance that contaminants would not seep from the site. In addition, the BBRP assumed all material excavated to create a pit would be used by upland construction industry or for beach nourishment; hence, disposal of the excavated material was not discussed. The following management procedures were used as guideposts: All disposal would be by precision dumping from the surface (*i.e.*, use of devices that place material directly on the bottom were not considered). *De facto* capping would be

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[1] Personal Communication, 7 July 1992, C. Truitt and J. Culter, Mote Marine Laboratory, Sarasota, Florida.

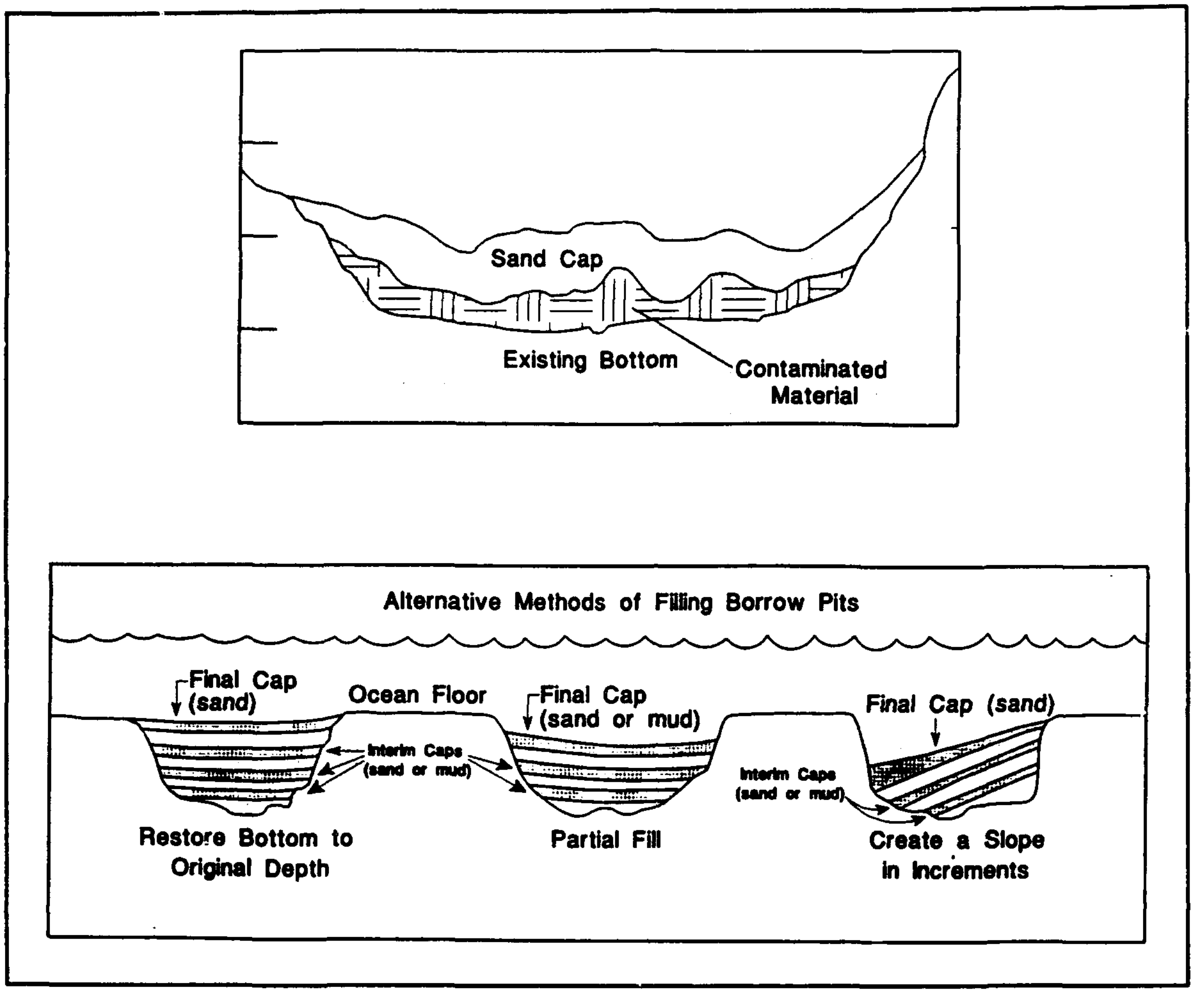

Figure 5. Conceptual representation of dredged material disposal in subaqueous offshore borrow pits

permissible. When *de facto* capping would not be feasible, it was assumed that capping with category I material would occur within 2 weeks of disposal of contaminated material and that these intermediate caps would be generally 2-3 ft thick. The final cap was assumed to be at least 5-10 ft thick and of material that maximizes stability of the cap rather than habitability by infauna, if both objectives cannot be met.

Lengthening and deepening Ambrose Channel

Construction of Ambrose Channel, the major access channel to NY/NJ Harbor for large ships, was begun in 1889. Currently, the design depth and width of the channel are 45 ft and 2,000 ft, respectively (Figure 6), although in some areas it has been deepened by private interests to greater than 45 ft. An increased dependence on deeper-draft vessels could require expansion of the channel. No assumptions were made about the depth or width of the new channel, although a depth of 90 ft and width of 2,000 ft (*i.e.*, the current

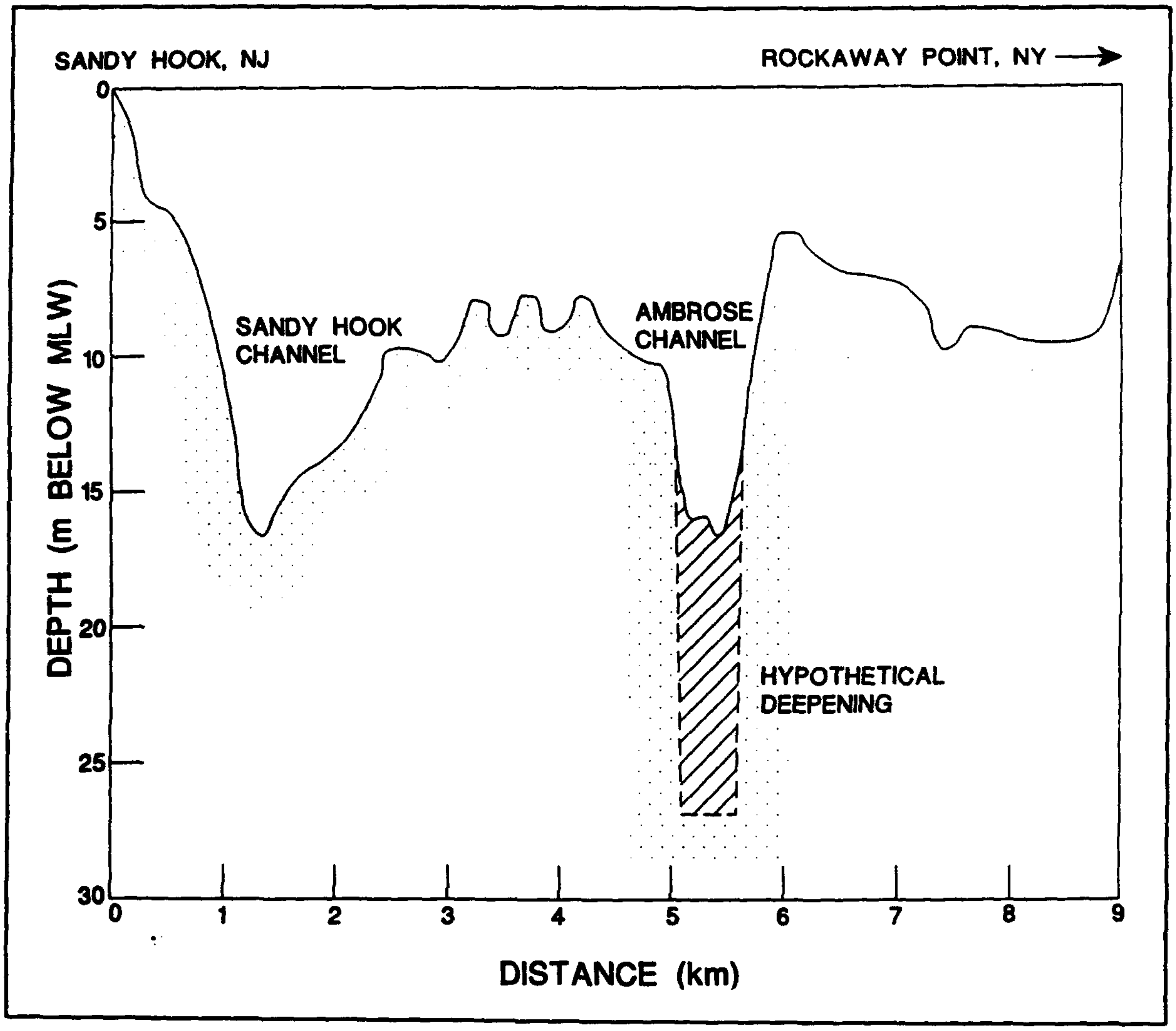

Figure 6. Cross section of the Sandy Hook/Rockaway Point transect with the current Ambrose Channel and hypothetical deepening discussed during the the BBRP

width) were used as guideposts. A corollary of these guideposts was the channel would be lengthened until it reached the natural 90-ft depth contour, which would put the seaward terminus within the Christiaensen Basin (assuming the present alignment is maintained). The landward terminus of the channel was assumed to be in the Upper Bay, in the vicinity of Bayonne or Jersey City, NJ. In making this assumption, the BBRP avoided the complex navigation and hydrodynamic issues associated with deepening the Kill Van Kull or Arthur Kill navigation channels to 90 ft. Total length of the hypothetical channel would be on the order of 19 nm and could require excavation of over 2.5×10^8 yd^3 of material. In terms of cross-sectional area, deepening the channel to 90 ft represents approximately an 8 percent increase to the cross-sectional area of the Sandy Hook/Rockaway Point transect. Even though the volume of material required to excavate such a channel is very large, the BBRP assumed all excavated material would be used for beach nourishment and upland construction. This assumption was made to focus BBRP's discussions on hydraulic impacts, not because the BBRP believed there would be no disposal-related impacts. Obviously, such a project probably could have a greater effect on NY/NJ Harbor than the NY Bight. Thus, although the principal focus of the BBRP was to examine the suitability of current databases and models for addressing impacts within the NY Bight, impacts within the harbor were also considered for this project.

Technical and Legal Aspects of Impact Characterization

Any program that identifies information gaps must recognize the importance of perspective. Under the National Environmental Policy Act (NEPA, PL 91-190) and similar laws, impact assessment is both a technical and a legal process. The BBRP tried to anticipate both technical and legal requirements when selecting impacts to examine. In general, it is easy to make a long list of biological impacts that could result from a project if "could" is interpreted in a broad sense. This list is then screened to determine which impacts are likely from a technical standpoint and which must be addressed from a legal standpoint. Impacts in the latter category may not be in the former. Relevant technical criteria are developed by professional judgement based upon information in the scientific literature. Relevant legal criteria are outlined in various laws (*e.g.*, NEPA, Migratory Marine Game-Fish Act [PL 86-359], Clean Air Act [PL 91-604], Federal Water Pollution Control Act [PL 92-5000], and Endangered Species Act [PL 93-205]), regulations (most notably the Council on Environmental Quality [CEQ] Regulations [40 CFR 1500-1508]), and formal legal opinions generated in case law.

Summary of technical aspects of impact characterization

A two-stage process is used to characterize environmental impacts from a technical perspective (National Research Council 1990a). The first stage simply identifies areas of concern (*e.g.*, potential health hazards from eating shellfish or water quality unsuitable for fish). The second stage refines areas of concern into testable (falsifiable) hypotheses (*e.g.*, the average amount of methyl mercury in whole lobsters caught within 1 mile of the Mud Dump Site is less than 1.0 ppm, or the average of the daily minimum concentration of dissolved oxygen within 10 ft of the bottom between the 30-ft and 60-ft depth contours off the coast of New Jersey during the month of August is greater than 2.0 mg/l). Pilot studies are often needed to refine an area of concern into testable hypotheses. Formulation of testable hypotheses is crucial to the technical quality and economic efficiency of any program that examines project impacts, yet this step is often omitted from assessment programs because of time and funding constraints and because agency goals are poorly defined (National Research Council 1990a). Unfortunately, a common approach is to collect as much data as economically feasible and test hypotheses in a *post hoc* fashion, an approach that is seldom efficacious. The BBRP could not complete the second stage of impact identification because the hypothetical projects were defined too generally (particularly in terms of siting), but more importantly because many of the necessary pilot studies have not been done and would require a specific research program or project-planning effort. This limitation was recognized early in the program, but it was not believed to make BBRP's primary goal of identifying important information gaps unfeasible.

Identifying areas of concern and refining them into testable hypotheses require differentiating between impacts to habitats and impacts to populations. In this context, a population is a group of individuals from a particular species in which individuals show similar patterns of growth, migration, and reproduction and whose abundance (size) does not change substantially due to emigration or immigration. This definition is similar to the concept of the unit stock used in fishery management (Hilborn and Walters 1992) and differs from the more common operational definition of a population, all individuals of a species occupying a particular space at a particular time (Krebs 1978). This difference is important because impacts under the latter definition may have little ecological significance or be uninterpretable (McArdle and Gaston 1993). Throughout this report, the former definition of population is used.

In general, it is more difficult to test for environmental impacts to populations because a population's geographic boundaries are unclear due to uncertainties about migration, emigration, and immigration and to difficulties in interpreting clinal variations in morphology, biochemistry, and behavior. When sufficient information is available to postulate boundaries, the area encompassed can be so large (*e.g.*, all continental shelf waters off the coast of four or more states for many fishes) that sampling populations with sufficient statistical resolution to distinguish between naturally caused fluctuations (*e.g.*, upwelling events, weather, and river discharges) and possible anthropogenically caused fluctuations (*e.g.*, fishing effort, pollution from municipal sewage outfalls, loss of nursery habitat, pesticide-laden stormwater runoff, and pollution from ocean disposal) is not practical. In some cases, a proxy for population abundance may be more tractable than abundance per se and can be used to examine environmental impacts efficiently. For example, catch-per-unit-effort (CPUE) has long been used as a proxy for abundance in fisheries science. Using a 100-year database, natural and anthropogenic causes of variation in CPUE were contrasted for striped bass (Polgar et al. 1985, Summers and Rose 1987), American shad (Polgar et al. 1985) and white perch (Rose et al. 1986), leading to the general conclusion that natural causes were more important than the specific effluent discharges and river/estuarine dredging examined. Abundance of eggs, larvae, and juveniles and age-frequency characterizations also have been suggested as proxies for population abundance. However, use of proxies for population abundance has limitations because the linkage to abundance may be weak and/or vary tempor:: ly due to ecological processes, such as competition or predation (Fogarty, Sissenwine, and Cohen 1991; Feller et al. 1992, Rijnsdorp and van Leeuwen 1992) that cannot be modeled adequately.

Direct examination of environmental impacts on populations also is difficult because of the many pathways by which individuals within populations can be affected. Several dichotomies are used to conceptualize these pathways, although the categories are somewhat artificial. Toxicity of contaminants can result from acute or chronic exposures, ecological effects can result directly or indirectly (*sensu* Paine 1980, Kneib 1991), and impact causes can be onsite or offsite. Pathways differ in the amount of background knowledge needed to examine them. Potential impacts that are acute, direct, and onsite are far more tractable than chronic, indirect, offsite impacts, but there is no reason to generally believe the more tractable impacts will be the most important to an ecosystem.

Impact studies often focus upon habitat rather than populations because habitat characteristics (*e.g.*, temperature, salinity, sediment grain-size distribution) are relatively easy to measure and relate to predictions generated by models of the physical environment. There are two versions to this approach. First, the amount of habitat change is assumed to be directly proportional to the potential for population change, making habitat a proxy for population impacts. However, selecting meaningful habitat parameters to follow can be difficult, especially for large mobile organisms, because habitat needs may change seasonally, ontogenetically, or geographically, limiting the utility of extrapolations from short-term, site-specific studies, which often are the only type of information available or developed for an EIS. For small, sedentary organisms (*e.g.*, infauna), the sampling process (*e.g.*, the disaggregation and sieving necessary to construct a grain-size distribution curve) destroys the micro-environment, leaving only an abstraction of the relevant habitat parameters (Watling 1991). Even if an organism's habitat requirements are clearly defined, relationships between amount of habitat and population abundance may be weak or simply unknown, limiting the utility of this approach. Second, some habitats (such as seagrass beds, mud flats, and reefs), are clearly more valuable to an ecosystem than implied by their relative geographic extent, leading scientists and regulators to give special considerations to these areas (*e.g.*, a general policy of no negative impacts in these areas). This approach also suffers from the shortcoming that the relationship between amount of habitat and population abundance is poorly known, and it is not always clear which habitats should be given special consideration.

In summary, directly assessing impacts to populations is conceptually straightforward but often not practical, whereas assessing impacts to habitat is often practical but may be of questionable relevance. This dilemma has no general resolution. For species legally listed as endangered or threatened, some efforts should be spent at population-level assessments because, by implication, these species are declared to have dangerously low population abundances and reaffirmation of this status can only be made by estimating abundance. However, for common species whose populations have broad geographic distributions and whose individuals use many habitats, it is unclear if monitoring for environmental impacts can be done effectively. When selecting ecological impacts to review, the BBRP used professional judgement and focused upon two questions: (1) the potential of a project to significantly reduce population abundance, and (2) the potential of a project to reduce the amount of a habitat that has been shown to be relatively more important than implied by its geographic extent.

Summary of legal aspects of impact characterization

The NEPA requires federal agencies to describe and evaluate environmental impacts from major actions that affect the quality of the human environment and to communicate those considerations to the public. Section 102(2)(C) of NEPA outlines the basic procedures for integrating environmental considerations into decision making. More specific steps are given in the CEQ Regulations. In general, large-scale projects similar to those reviewed by the BBRP would likely require an EIS to comply with the CEQ Regulations (Mandelker (1984) reviews the case law supporting this generalization). The CEQ Regulations require EISs to describe environmental impacts, assess the significance of those impacts, and balance those impacts against other specified public-interest factors (*e.g.*, public health and safety, archaeological value, and socioeconomics). The overall balance determines the acceptability of a project. Hence, a project may be detrimental to biological resources and still be acceptable if this detriment is outweighed by other public-interest factors. Differentiations between impacts judged to be potentially significant and those judged to be mostly descriptive were used to prioritize impacts and information gaps. The BBRP attempted to be thorough in identifying likely impacts from projects to marine biological resources. However, there was no attempt to identify all the potential impacts, since this would be the objective of the scoping process for an EIS and could not be effectively done until projects are more clearly defined (especially in terms of siting).

Potential Impacts Chosen for Examination

The BBRP used three approaches to select potential impacts to review. First, EISs for similar projects were examined to determine which impacts to marine biota were discussed. This was especially helpful for the hypothetical projects involving ODMDSs and borrow pits since relatively recent EISs existed for the general area (USEPA 1982, USACE 1991). Second, for the hypothetical projects that had similar counterparts in the DMDMP, DMDMP documents were reviewed to determine the marine biological impacts considered. Finally, impacts identified by the first two processes were reviewed to determine if any likely areas of concern were omitted. This review put special emphasis on impacts caused by:

a. Altered topography.

b. Altered sediment grain-size distribution.

c. Increased concentrations of sediment contaminants.

d. Decreased water quality.

e. Disruption of medium- and large-scale currents, such as secondary circulations associated with river plumes.

The types of organisms considered were limited to macroinfauna and epifauna that would be retained by a 0.5-mm sieve, fish (including ichthyoplankton), and macrocrustaceans (crabs, shrimps, and lobsters). Epifauna are difficult to define precisely. In a broad sense, epifauna include all organisms living at the sediment surface or in near-bottom waters, which would include fish and macrocrustaceans that have already been designated as distinct categories. Further, practical differentiations of epifauna from infauna and nekton are often difficult because of ontogenetic variations in behavior and differences in sampling gear efficiency. The intent in distinguishing epifauna from the other categories is to recognize that some common fish (*e.g.*, windowpane flounder) and macrocrustaceans often feed upon organisms not sampled quantitatively by bottom trawls or grabs. Thus, epifauna was defined to consist of amphipods (such as *Protohaustorius* spp. and *Unicola irrorata*), crangonid shrimp, and mysid shrimp.

Meiofauna, microbial communities, phytoplankton, and most zooplankton were excluded from consideration because these groups are rarely covered in an EIS. Potential impacts to sea turtles and cetaceans were not examined in detail, although it was recognized that all projects considered could affect these species. The most likely mechanism for such effects would be a project causing a permanent diversion of ship traffic or fishing vessels into the foraging grounds or migratory routes of these species, thereby increasing the potential for collisions with ships (Kraus 1990) or entanglement in fishing gear (National Research Council 1990b). Impacts to birds also were not considered in detail, although it should be noted that potential impacts to birds were mostly relevant to offshore containment islands. All impact pathways discussed in the previous section were considered, but it should be noted that limitations in the knowledge of contaminant uptake pathways, the natural history of key organisms, and characteristics of the NY Bight ecosystem, make it difficult to articulate meaningful questions about some pathways.

Guideposts were used to identify the likely extent of physical perturbations from projects in order to more sharply focus examinations of the utility of existing information. Particular species also were used as guideposts to help focus discussions. Common species were selected, as opposed to species that have a demonstrated sensitivity to a particular environmental impact (*i.e.*, indicator species). In the context of environmental impact studies, the abundance (absolute or relative) of indicator species abruptly changes when an ecosystem is stressed (the change can be an increase or a decrease). Although the concept of indicator species has existed for many years, its utility has been questioned almost since its inception (Gray 1976). The principal difficulty is a priori identification of the indicator species (reviewed in Soule (1988)). Pearson, Gray, and Johannessen (1983) proposed criteria for choosing indicator species among benthic infauna for pollution studies. These criteria are based on a log-normal distribution and can be summarized as focusing upon species with intermediate densities (16-63 m^{-2}). However, the necessary background studies to test the applicability of these criteria for the NY Bight have not been done (Young and Young 1982, Nelson 1987, Chang et al. 1992). Finally, common species were chosen as guideposts rather than communities (*e.g.*, bottom fish) because species characteristics are generally easier to describe and examine, and therefore more tractable than communities. In the words of J.H. Lawton (Pimm, Lawton, and Cohen 1991), "The irony is that we now know far more about black holes and distant galaxies than we do about communities of living resources."

Offshore containment islands

From a biological perspective, the key characteristic of islands is the topographic relief in what might otherwise be a flat landscape. In addition to the relief, many microhabitats may also be present due to gradients in substrate type, light penetration, groundwater seepage, surface runoff, etc. All of these microhabitats can attract fish and benthos and in some cases give rise to special communities. In addition, islands in the paths of currents give rise to localized flow features at which fish, ichthyoplankton, and other organisms are more abundant (Lobel and Robinson 1988, Wolanski and Hammer 1988). Designing and managing artificial islands to benefit birds has received some study (Soots and Landin 1987), but little has been done from the perspective of benthos and fish, although some information in the literature about artificial reefs and offshore drilling platforms is useful in this respect.

Although there are several EISs that discuss impacts to marine biological resources from inshore dredged material containment islands and fill islands, no EISs were found for large *offshore* containment islands. Studies done during development of the DMDMP discussed three general areas of concern (Conner et al. 1979, Poindexter et al. 1988, Walski and Schaefer 1988, and USACE 1989):

a. Loss of ocean bottom habitat within the island's footprint (bottom boundaries) and the effect of that loss on infauna abundance.

b. Deleterious effects on biota from leaked contaminants, including acute toxicity, chronic toxicity, bioaccumulation, and disease.

c. Deleterious effects on biota from poor water quality in and around an island's discharge outfalls, including the above contaminant-related effects and effects from elevated levels of total suspended solids (TSS) and lowered concentrations of dissolved oxygen (DO).

Refining these impacts into more manageable units and adding others, the BBRP identified eleven areas of concern, three of which might represent significant potential disruptions to the NY Bight ecosystem, while eight were primarily thought to address the descriptive aspect of an EIS.

Impacts with potential ecological or human health significance

1. *Decreased growth of larval and early juvenile fishes from disruptions of the Hudson River plume, if the island is located within the plume.* River plumes are generally important components of coastal ecosystems because they mediate exchanges of material (sediments, nutrients, organisms, pollutants, etc.) between estuaries and oceanic areas. Primarily because of differences in salinity and temperature, water from the Hudson River is more buoyant (*i.e.*, has a lower density) than oceanic waters of the NY Bight. When this low density water is discharged into the NY Bight, it piles up near the Sandy Hook/Rockaway Point transect because the dense NY Bight water resists being displaced by the light river water. Eventually, the piling up becomes a sufficient force to push the discharge into the Bight, generally along the path of least resistance. This path is generally controlled by the combined effects of the baroclinic pressure gradient force distribution, Coriolis force, wind stress, and steering effects of bottom topography. Averaging over a tidal cycle and in the absence of wind, the plume will turn right and head along the New Jersey shore. Moderate and strong winds, especially from the southwest, can disrupt this pattern causing the plume to head in other directions. Secondary circulations also occur due to convergence and downwelling at the boundaries between the plume and NY Bight waters. Buoyant particles, such as fish eggs, ichthyoplankton, phytoplankton, and flotsam, can aggregate at the convergence zones.

Bowman (1978) reviewed the limited research that has been done to characterize the plume. When discharges are high and winds are light, the plume usually flows along the NJ coast and is discernable 2-3 nm from shore. When discharges are low and winds to the northeast (common summer conditions) the plume can flow directly into the Apex beyond the Mud Dump Site. Han and Niedrauer (1981) indicate the plume can split along the axis of the Hudson Shelf Valley. Although the area of the plume can be on the order of 150 nm^2, which is a relatively small portion of the Bight's area, it coincides with the concentration of human activity and resource abundance.

Organisms that aggregate at the convergence zones could benefit from the high concentrations of food in these areas, as has been seen elsewhere (Govoni, Hoss, and Colby 1989; Kiorboe et al. 1988; Kingsford 1990; Grimes and Finucane 1991). Faster growth could allow animals to more rapidly escape size-limited predators and physical stresses and, hence, promote recruitment to fisheries. If an island is located near the Hudson River plume, it is possible the island could disrupt the fronts, affecting local recruitment dynamics. Although data on ichthyoplankton distribution and abundance are sparse for the NY Bight (Yentsch 1977, Grosslein and Azarovitz 1982), several common species are likely to aggregate at fronts created by the Hudson River plume, including clupeids (herrings), engraulids (anchovies), northern searobin (*Prionotus carolinus*), winter flounder (*Pleuronectes americanus*), windowpane flounder (*Scophthalmus aquosus*), and summer flounder (*Paralichthys dentatus*). Due to the large geographic range of most fish populations in the NY Bight, it would be very difficult to unequivocally show that disrupting the convergence zones associated with the plume will change the abundance of a population. However, the relative significance of the plume may be higher than implied by its area, indicating this area may warrant special protection. If it is not feasible to site an island outside the Hudson River plume, detailed and quantitative consideration of this impact may be warranted.

2. *Loss of viable benthic and pelagic habitat from discharges of material during a large-scale structural failure.* Obviously, containment islands will not be built in the NY Bight unless there is reasonable assurance that catastrophic structural failures are very unlikely to occur. Nonetheless, it is likely an EIS would have to address this issue. Examination of this impact and assessment of its potential significance require information about the footprint of the discharged material and location of the island (*i.e.*, its proximity to valuable benthic resources). If the discharged material is not contaminated, potential impacts would primarily result from burial and chronically high TSS concentrations from the actual discharge and from redistribution of sediments by currents and waves. If the discharged material is contaminated, concerns about the sediments being too toxic to allow full recolonization also are relevant. Finally, since the sediment is likely to be stored under hypoxic conditions, it may pose an excessive oxygen demand on the water column for a short time period.

3. *Bioaccumulation of contaminants by fish and benthos from discharges of contaminated material during normal operations or large-scale structural failures, if category II or III dredged material is placed in the island.* No containment island will be built in the NY Bight unless there is reasonable assurance that contaminated material will be isolated from the environment. Although most of the contaminants associated with material discharged from an island would remain adhered to particles, organisms will live among the particles and may ingest them. Complex geochemical and physiological processes may transform contaminants from an inert state into bioavailable substances that may be more toxic than the parent compounds. Once bioavailable, the contaminants could affect the organisms that uptake them or enter the food chain and affect other organisms, including humans. Bioaccumulation pathways are generally not well known nor are the factors regulating them. Nonetheless, empirical evidence shows contaminants move into the NY Bight food chain (Table 1; SAIC 1991a,b). Identifying the source of contaminants and interpreting the significance of bioaccumulation to populations and human health is generally difficult. Depending on rates of discharge and exact nature of the discharged substances, bioaccumulation of contaminants could be significant.

<u>Impacts unlikely to affect the NY Bight ecosystem or human health</u>

4. *Permanent reduction of habitat useable by soft-bottom (i.e., unconsolidated bottom) infauna from usurpation of ocean bottom by the island.* Clearly, an island will permanently eliminate infauna within its borders. Pearce et al.

Table 1
Species Listed in SAIC (1991a,b) with Heavy Metals or Organic Contaminants Found in Body Tissues[1]

Species	Metals	Organics
Rock crabs	X	X
Blue crabs		X
American lobsters	X	X
Sea scallops	X	X
Blue mussels[1]	X	
Polychaete worms	X	X
Mackerel		X
Red hake	X	X
Windowpane flounder	X	X
Winter flounder	X	X

[1] In the studies reported, blue mussels were placed near potential contaminant sources as a bioassay, these data did not come from natural populations.

(1981) and Wigley and Theroux (1981) provide the most comprehensive broad-scale view of the Bight's infaunal communities and show a general correlation between sediment characteristics and the abundance and species of infauna present (Figures 7 and 8). Because no assumptions were made about the location of an island, infaunal communities associated with the more common surface-sediment habitats in the NY Bight were considered to determine if this loss had the potential to significantly affect infaunal populations.

Freeland, Swift, and Stubblefield (1976) and Freeland and Swift (1978) provide concise reviews of surface sediment types in the NY Bight. Generally the shelf is covered by sand-sized sediment with isolated patches of gravel; most of the gravel patches are southwest of the Hudson Shelf Valley off the coast of New Jersey. Silty material is common in the Hudson Shelf Valley and in areas deeper than 200 ft. Small ephemeral patches of mud and silt also occur in nearshore areas, particularly along the coast of Long Island. Surface sediments near the Christiaensen Basin are variable because of complex topography and anthropogenic input. The sediment types present include mud, fine sand/silt, fine/medium sand, coarse sand, sandy gravel, and anthropogenic debris.

Table 2 lists the major taxonomic groups from the major sediment types. Many infaunal species are found in a variety of bottom types, particularly if sediments are poorly sorted (*i.e.*, several different size ranges of sediment are present). Aside from the bivalve populations that are commercially fished (*i.e.*,

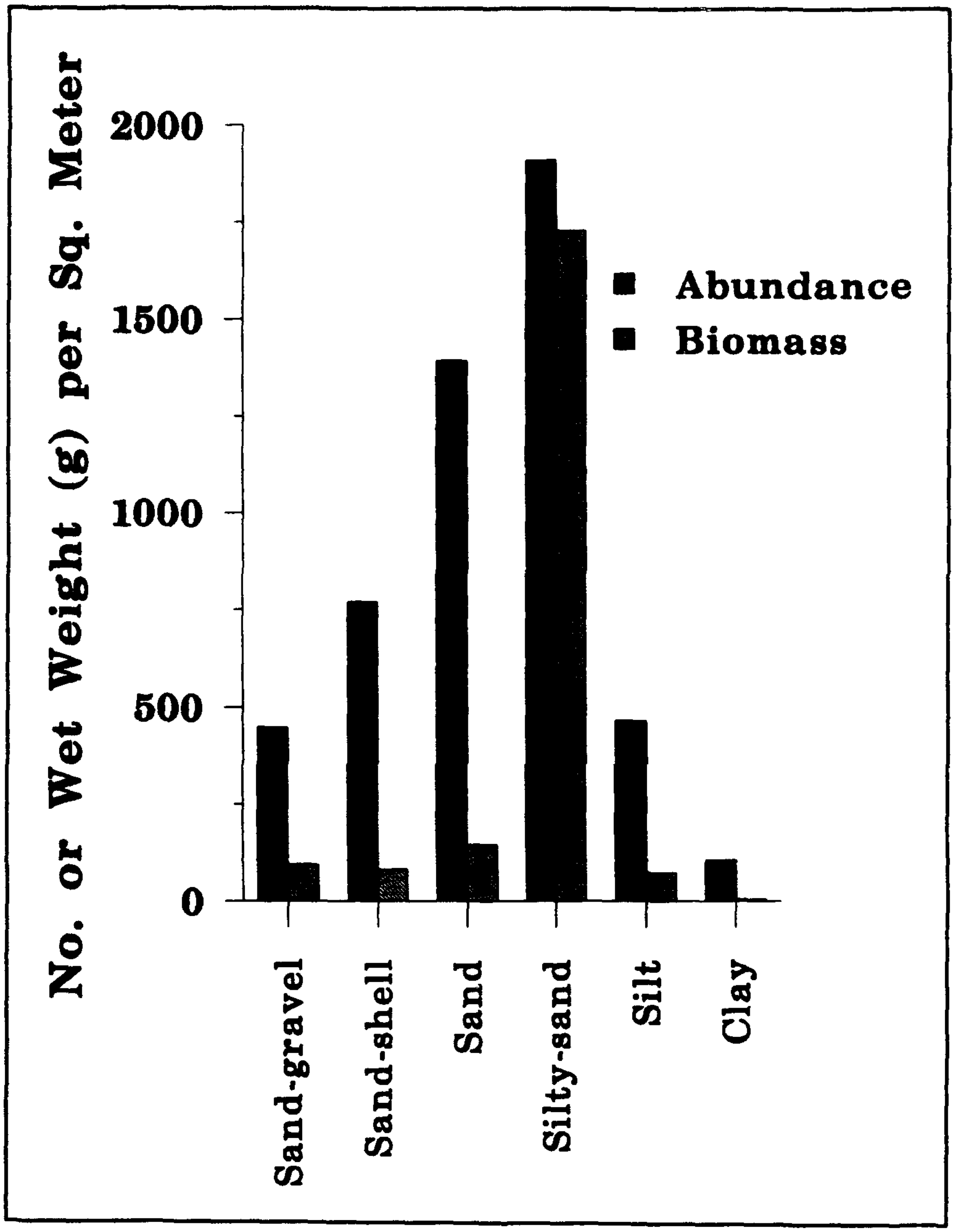

Figure 7. Mean biomass and abundance of macrobenthos for various surface sediment types in the NY Bight (from Wigley and Theroux (1981))

ocean scallops, ocean quahogs, and surf clams), none of the infaunal populations of the NY Bight are believed to have special ecological significance, limited abundance, or restricted geographic distributions, although the Christiaensen Basin and Hudson Shelf Valley may have species assemblages not commonly found elsewhere in the NY Bight. Thus, from both population

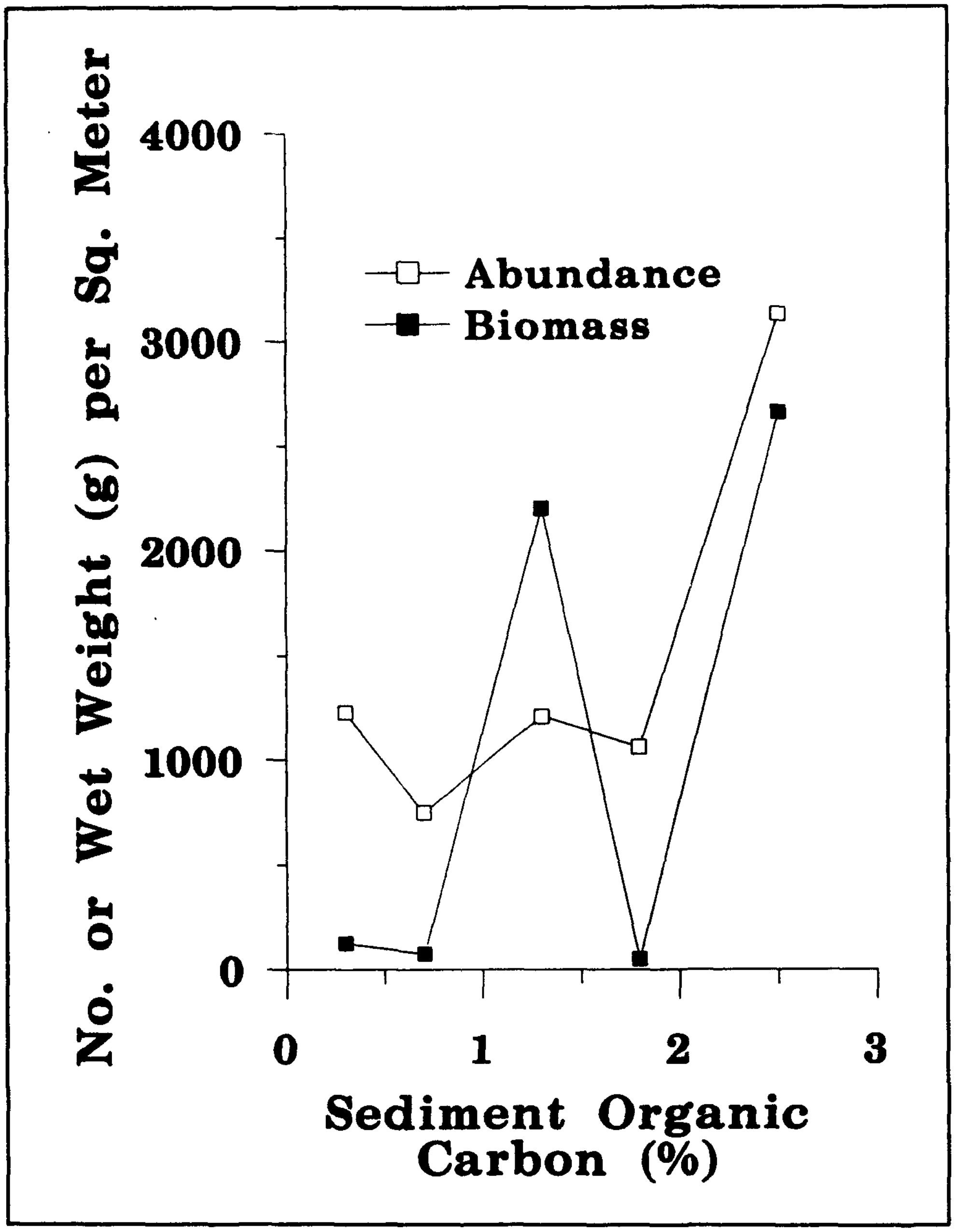

Figure 8. Abundance and biomass of macrobenthos for sediments with various amounts of organic carbon in the NY Bight (from Wigley and Theroux (1981))

and habitat perspectives, an offshore containment island is not likely to significantly affect infaunal populations, particularly if the island is outside the Christiaensen Basin or Hudson Shelf Valley. Many sandy portions of the NY Bight support bivalve fisheries (McHugh and Ginter 1978, Long and Figley 1981). Shellfishing is illegal within about 14 nm of the Sandy Hook/Rockaway Point transect, an area that includes the Mud Dump Site and Christiaensen Basin. Given the wide occurrence of these species in the NY Bight and natural fluctuations in abundance, it is unlikely that the area

Table 2
Mean Number of Infaunal Organisms (m^{-2}) for Common Surface Sediment Types in the New York Bight

Phylum-Class	Surface Sediment Type: Gravel	Sand-Gravel	Shell	Sand-Shell	Sand	Silty Sand	Silt	Clay
Porifera				4.3	0.2	0.7		
Cnidaria-Hydrozoa		2.6		8.6	2.1	23.9	0.1	
Cnidaria-Anthozoa		3.8		0.4	1.5	26.3	4.8	1.8
Platyhelminthes				0.3	0.1			
Nemertea		4.0		3.3	3.0	2.3	1.4	0.1
Nematoda					0.1	0.1	0.1	
Annelida-Polychaeta		142.4		224.3	532.8	285.4	48.7	11.3
Pogonophora						2.9	4.7	2.1
Sipunculida				0.6	2.5	1.9	1.9	0.8
Echiura						1.3	0.4	0.3
Mollusca-Gastropoda		0.4		8.3	25.7	39.2	13.4	2.4
Mollusca-Bivalvia		4.2		119.3	114.5	793.3	362.5	71.4
Mollusca-Scaphopoda					1.3	5.7	2.3	0.6
Crustacea-Ostracoda				2.5	0.1			
Crustacea-Cirripedia					43.0	440.7	2.13	
Crustacea-Copepoda					0.1			
Crustacea-Cumacea		0.4		10.3	11.8	1.7	0.4	0.6
Crustacea-Isopoda		8.6		11.0	12.3	12.3	5.7	0.1
Crustacea-Amphipoda		267.6		286.4	541.7	233.3	6.6	0.8
Crustacea-Mysidacea		0.4		3.1	1.1			
Crustacea-Decapoda		12.8		17.0	9.8	11.7	0.7	0.1
Bryozoa		0.4		18.6	3.9	9.1		
Echino.-Holothuroidea				0.6	0.5	4.4	0.4	0.4
Echino.-Echinoidea				21.4	60.8	0.2		
Echino.-Stelleroidea				1.7	11.9	4.9	1.5	3.2
Hemichordata					0.1			
Chordata		0.6		15.6	5.6	0.2	3.9	2.4
Unknown				11.7	4.5	0.9	1.9	5.5

Note:
Based upon Wigley and Theroux (1981). Effective sampling gear for surveying gravel and shell sediments has not been used. Echino. = Echinodermata

occupied by a containment island would result in a discernable decrease in population size for one of these fisheries. However, it should be noted that an EIS views impacts to fisheries from other perspectives as well (*e.g.*, economics), and these perspectives were not considered in the BBRP.

5. *Permanent reduction of habitat useable by soft-bottom epifauna from usurpation of ocean bottom by the island.* Many EISs group infaunal and epifaunal species under the more general heading of benthos when examining impacts. This grouping is done partly because sampling gear and protocols for quantitative study of epifauna are not well developed and some sampling gears for infauna secondarily collect epifauna. In many situations, much of the information about epifauna comes from surveys of infauna. When possible, examinations of impacts to epifauna and infauna should be separated because of the substantial differences in sampling efficiency and relatively higher importance of epifauna in the diets of certain fish species (Clarke et al. 1991). As was true for infaunal species, a containment island is not likely to significantly impact the abundance of epifaunal populations in the NY Bight or reduce the amount of habitat capable of supporting these species.

6. *Reduction in foraging area for organisms that feed upon soft-bottom benthos.* One reason abundance of benthos is discussed in an EIS is the general implication that benthos are frequently fed upon by fish that constitute commercial and recreational fisheries. Fish typically have varied diets that reflect their morphology and behavior. Table 3 provides some general distinctions useful for examining diets of the more common fishes from the NY Bight. Because natural diets are variable and foraging areas large, no fishes in the NY Bight are thought to be food limited. Further, because the abundances of benthos are not likely to be affected by a containment island, the reduction in foraging area for fish is not likely to be significant, especially if the island is not placed in the Christiaensen Basin or Hudson Shelf Valley.

7. *Increased habitat suitable for hard-bottom benthos from the presence of the island walls and material used to armor its base.* The walls and base of a containment island are likely to become important habitat because hard substrate is relatively uncommon in the NY Bight and because the walls will provide a depth (microhabitat) gradient. The community that will develop on walls would probably be similar to the inshore fouling communities and the epifauna that colonize artificial reefs. Mytilid mussels, arborescent hydroids and bryozoans, acorn and stalked barnacles, tunicates, and macroalgae would likely dominate in terms of percent cover or biomass. Other species likely to be abundant in terms of numbers include caprellid and gammarid amphipods, isopods, predaceous polychaetes, serpulid polychaetes, holothuroids, and small decapod crustaceans. Hardbottom species that are common south of the NY Bight but rarely seen in NY Bight waters may become common on the island walls, particularly if the island is far offshore. Seasonal and longer-period fluctuations in the community are likely. If the fouling community is viewed as beneficial, the walls could be constructed to include features that promote

Table 3
Common and Scientific Names of Some of the More Common Predatory Fish and Macrocrustaceans of the NY Bight

Species that primarily feed upon soft-bottom infauna and epifauna	
Atlantic croaker	*Micropogonias undulatus*
Longhorn sculpin	*Myoxocephalus octodecemspinosus*
Ocean pout	*Macrozoarces americanus*
Red hake	*Urophycis chuss*
Scup	*Stentitomus chrysops*
Skates	*Raja* spp.
Tilefish	*Lopholatilus chaemaeleonticeps*
Windowpane flounder	*Scophthalmus aquosus*
Winter flounder	*Pleuronectes americanus*
Yellowtail flounder	*Pleuronectes ferruginea*
American lobsters	*Homarus americanus*
Red deepsea crabs	*Geryon quinquedens*
Rock crabs	*Cancer* spp.
Sevenspine shrimp	*Crangon septemspinosa*
Species that primarily feed upon fish but also feed upon soft-bottom infauna and epifauna	
Bluefish (juvenile)	*Pomatomus saltatrix*
Cod (late juveniles and adults)	*Gadus morhua*
Fourspot flounder	*Paralichthys oblongus*
Goosefish	*Lophius americanus*
Silver hake	*Merluccius bilinearis*
Spiny dogfish	*Squalus acanthias*
Summer flounder (juvenile)	*Paralichthys dentatus*
Weakfish (juvenile)	*Cynoscion regails*
Wrasses	Family Labridae

Note:
Based mostly upon Grosslein and Azarovitz, 1982, with taxonomy according to Robins et al. (1991).

colonization by selected species (*e.g.*, tubercles, pocket depressions, and crevices).

Since hardbottom areas are uncommon in the NY Bight, the walls and base of a containment island may significantly increase the amount of this habitat type, potentially increasing the population size of some hardbottom organisms. A potential negative impact, which was discussed earlier, is the possibility of contaminants leaking from the island and becoming concentrated in the tissues of organisms living on or near the walls. Hence, examination of this impact may be an important component to examining the potential of species to bio-accumulate contaminants that may seep or spill from the island.

8. *Increased forage area for organisms that feed upon hard-bottom benthos.* Just as discussions of the abundance of soft-bottom benthos imply use of those organisms as a forage base, discussions of hard-bottom benthos have similar implications. Table 4 lists some organisms likely to feed upon the fouling community associated with the island walls. This list is relatively short because it focuses upon predators that often feed upon macroalgae, mussels, and tunicates, animals likely to dominate the new hardbottom in terms of percent cover. As indicated earlier, the island's walls are likely to be colonized by numerous subdominant invertebrate and fish species that also will serve as a forage base; thus, Table 4 should be viewed as an abbreviated list. It is unlikely that provision of this additional foraging area will increase the abundance of fishes in the NY Bight. However, the island may serve to concentrate the distribution of certain species to the benefit of commercial and recreational fishing, an effect that would be examined in an EIS but not examined by the BBRP. This impact also may be an important component to examining the potential of fishery species to bioaccumulate contaminants that may seep or spill from the island.

9. *Attraction of thigmotactic and rheotactic fish and crustaceans.* Many fish and crustaceans are attracted to structures (thigmotropism) or currents (rheotropism) for a variety of reasons (*e.g.*, protection from predators, minimized swimming effort, and reproduction) independent of foraging-related behaviors. In a sense, the net result of this potential impact and impact 8 are

Table 4
Common and Scientific Names of Some of the More Common Predatory Fish and Macrocrustaceans that Feed Upon Hard-bottom Benthos

Atlantic croaker	*Micropogonias undulatus*
Black sea bass	*Centropristis striata*
Ocean pout	*Macrozoarces americanus*
Tilefish	*Lopholatilus chamaeleonticeps*
Wrasses	Family Labridae
Rock crabs	*Cancer* spp.

Note:
Based mostly upon Grosslein and Azarovitz (1982), with taxonomy according to Robins and others (1991)

the same. However, for discussion purposes, they were separated because of the different underlying mechanisms. Table 5 lists some species with thigmotropic and rheotropic tendencies. Some of these species are likely to occupy particular patches of substrate (*e.g.*, toadfish), others are likely to just swim close to the island for long time periods (*e.g.*, jacks). As was true for impact 8, this impact is not likely to change the abundance of fish or macrocrustaceans in the NY Bight, but may have secondary effects that benefit commercial and recreational fishing. This impact also may be an important component in evaluating the potential for bioaccumulation of contaminants that seep or spill from the island.

10. *Concentration of larval and early juvenile fish at topographically-controlled frontal zones.* Fronts are boundaries between water masses and they can occur at spatial scales from <1 to >100 nm and can be caused by several processes, including current fields, internal waves, and winds. Wolanski and Hammer (1988) provide a concise review of how frontal systems associated with topographic features, such as islands, can affect ichthyoplankton, juvenile fishes, and other organisms. Eddies will potentially shed in all directions from an island depending upon the directions of currents that impinge upon it (*e.g.*, generally on-offshore for tidal currents and alongshore for wind-driven currents). Once shed, bottom topography will tend to steer eddies along isobaths.

Table 5
Common and Scientific Names of Common Species from the NY Bight that Exhibit Thigmotropic and Rheotropic Behaviors

Codfishes	Family Gadidae
Conger eels	Family Congridae
Cusk eels	Family Ophidiidae
Goosefish	*Lophius americanus*
Jacks	Family Carangidae
Sea robins	Family Triglidae
Ocean perch	*Sebastes* spp.
Ocean pout	*Macrozoarces americanus*
Sculpins	Family Cottidae
Toadfish	*Opsanus* spp.
Wrasses	Family Labridae
American lobster	*Homarus americanus*
Rock crabs	*Cancer* spp.

Secondary currents associated with these fronts create convergence zones and eddies where flotsam and organisms accumulate. Ichthyoplankton, juvenile fishes, and other organisms may accumulate in these areas because of passive transport or active behavioral mechanisms to seek such areas (Govoni, Hoss, and Colby 1989; Kiorboe et al. 1988; Kingsford 1990; Grimes and Finucane 1991). From the organism's perspective, a potential benefit to occurring in such an area is these areas have relatively high concentrations of food because the flotsam includes nutrients and plankton. Higher food concentrations typically lead to faster growth rates, which correlates with a higher probability of survival. This impact could be an important component to impact 1 if the island were located in the Hudson River plume. If the island were outside the plume, this impact could still occur, but at a smaller scale.

It is unlikely that an offshore containment island, by creating eddies and similar flow features, will change the abundance of any species in the NY Bight because of the island's relatively small size and vagueness of larval-recruit relationships. Construction of an island, however, provides opportunities for creating such flow features, which may secondarily benefit fishermen. This impact also could be an important component in examining the potential for bioaccumulation of contaminants leaked from the island.

11. *Loss of viable pelagic and benthic habitat from discharges of material during normal operations.* Clearly great care would be taken to construct and operate an island to minimize the chance of inadvertent discharges of material to the NY Bight ecosystem. Nevertheless, any EIS for such an island will be required to discuss such possibilities, especially if contaminated material would be placed in the island. There are several potential pathways for material to enter the environment during normal operation of an island, including spills during transfer, supernatant and stormwater discharges, and seepage through the island walls. To streamline discussion, these pathways will be collectively called discharges.

Pelagic habitat could be affected by elevated concentrations of TSS caused by discharges. Elevated concentrations of TSS could impact fish abrading sensitive surface membranes (*e.g.*, gills) of fish eggs, larvae, juveniles, and adults. Toxicity of these discharges also may be important, although the salinity and pH of the marine environment promote adhesion of contaminants to silt and clay particles, which makes contaminants relatively inert (reviewed by Pequegnat and Gallaway (1990)). Viable benthic habitat could be buried by discharged material. Although contaminants are likely to be strongly adhered to particles and hence not bioavailable, the toxicity of the sediment also may be important. Given the localized nature of these pelagic and benthic perturbations, these effects are not likely to cause decreases in population abundance. However, they may be important components to examining the potential for bioaccumulation of contaminants.

Several potential impacts from containment islands were discussed early in the BBRP but omitted from examination because they were generally believed to be too unlikely, inconsequential, or dependent upon island design to make further discussions fruitful. These impacts included examinations of water quality within any harbor the island may contain and localized currents around the island altering sediment types near the island.

Expanding the Mud Dump Site and designating a new ODMDS

It is a common practice to manage dredged material by placing it in a USEPA- designated and monitored ODMDS. All material placed in such sites must pass a series of tests designed to ensure its acceptability to the environment according to established criteria (USEPA and USACE 1977, 1991). Laws and regulations upon which these tests are based recognize there are information gaps in our understanding of toxicity and bioaccumulation pathways and effects upon organisms (Dillon and Lutz 1991); hence, tests are designed to be conservative. As new information is developed by government, academic, and private laboratories or field studies, it is incorporated into testing protocols. Several ongoing programs within USEPA and USACE are studying these issues exclusively.

Under the BBRP framework, likely impacts to marine biota from expanding the Mud Dump Site and designating a new ODMDS were very similar; hence, these hypothetical projects will be discussed together. More detailed differentiation of impacts between these project types cannot be done efficiently until candidate sites for a new ODMDS are identified, although one would expect sites far from the Mud Dump Site would have less contaminated sediments than sites in the immediate vicinity and, therefore, may have a more natural faunal assemblage.

USEPA (1982) identified the following areas of concern regarding marine biota when the Mud Dump Site was formally designated an ODMDS:

a. Mortality and abnormal growth of phytoplankton and zooplankton due to elevations in particulates, reduced transparency, and chemical release.

b. Gill damage to fishes from swimming through disposal plumes with a high concentration of suspended sediments.

c. Uptake of contaminants by fishes and benthos leading to acute and chronic effects.

d. Changes in sediment characteristics that lead to changes in infaunal communities or decreased productivity (described as "nutrient cycling and energy pathways" in the EIS) by benthos.

These impacts are similar to those identified in other EISs for ODMDs along the east coast of the United States. Conner et al. (1979) identified the following areas of concern during the early stages of the DMDMP:

a. Decreased abundance of benthos from burial and alterations of sediment characteristics.

b. Uptake of contaminants and pathogens by benthos and fish leading to mortality and sublethal effects and contamination of food meant for human consumption.

Refining these impacts into more manageable units and adding others, the BBRP identified six areas of concern, five of which were thought to reflect more the descriptive aspects of an EIS rather than a significant potential to disrupt the Bight ecosystem or to affect human health. The low number of potentially significant impacts is not surprising since extensive national and international study and discussion are reflected in USEPA's ODMDS program.

Impact with potential ecological or human health significance

1. *Bioaccumulation of contaminants by fish and benthos, if category II and III material are placed in the site.* The rationale for this impact is similar to that of impact 3 of the section on offshore containment islands. Any category II or III dredged material placed in an ODMDS is likely to be capped by category I material. Although caps have been shown to be stable for several years (O'Connor and O'Connor 1983; Brannon, Hoeppel, and Gunnison 1987; Brannon and Poindexter-Rollings 1990), their long-term stability is likely to be an EIS issue. Conceptually, caps could fail for several reasons, including breaches from localized erosion or bioturbation, removal of large portions from large-scale erosion, inversion of cap and contaminated material due to structural instabilities, and excessive post-placement consolidation of the cap leaving a thinner than intended barrier between contaminated material and the environment. The BBRP did not address the engineering aspects of cap design, placement, and maintenance; it focused upon effects to biota given hypothesized levels of cap failure.

Agents that could potentially breach a cap include scouring by currents or storm waves; burrowing by large polychaetes (*e.g., Nereis virens*), sea anemones (*Ceriantheopsis americanus*), and hemichordates; and digging by animals that feed by making pits (*e.g.,* stingrays, skates, and crabs). Brannon et al. (1985) reported that *N. virens* can penetrate 50-cm caps in the laboratory and *C. americanus* has similar burrowing abilities. Even though they have rarely been reported from the NY Bight, hemichordates were included in this list because they can burrow more than a meter into the bottom, commonly occur in nearshore waters, and little, if any, sampling in the NY Bight has been done with gear appropriate for detecting them (Appendix C).

Impacts unlikely to affect the NY Bight ecosystem or human health

2. *Reduction of habitat suitable for infaunal benthos because of frequent burial by dredged material or alteration of sediment type.* Impacts to infauna from a new ODMDS or expanded Mud Dump Site are qualitatively similar to those from a containment island except that an ODMDS should allow at least intermediate levels of recovery during use and perhaps full recovery after its use. Most infaunal organisms buried during a disposal event will die, although some survival can be expected if the overburden is <1 ft (Maurer et al. 1986).

Adult and larval organisms recolonizing deposited material will reflect many variables, such as timing of the disturbance relative to larval availability, frequency of disturbance by subsequent disposal events, and physical nature of the disposed material. As indicated in the section on offshore containment islands, benthic populations in the NY Bight cover areas much larger than the area of a prospective new ODMDS or Mud Dump Site expansion. Thus, from both population and habitat perspectives, a new ODMDS or Mud Dump Site expansion is not likely to significantly alter infaunal abundances, particularly if the disposal site is outside the Christiaensen Basin or Hudson Shelf Valley. Nonetheless, an EIS will likely have to describe effects to the benthic community, including anticipated recolonization trajectories.

3. *Reduction of habitat suitable for epifaunal benthos because of frequent burial by dredged material or alteration of sediment type.* Discussions of epifauna were separated from discussions of infauna for the same reasons as in the section on offshore containment islands; the types of organisms impacted also were identified in that section. As was true for impact 2, impacts to epifauna from a new ODMDS or expanded Mud Dump Site are qualitatively similar to those from a containment island except that an ODMDS should allow at least intermediate levels of recovery during use and perhaps full recovery after its use. Thus from both population and habitat perspectives, a new ODMDS or expanded Mud Dump Site are not likely to significantly affect epifaunal populations in the NY Bight, particularly if the ODMDS is outside the Christiaensen Basin or Hudson Shelf Valley.

4. *Reduction of habitat suitable for benthos because of hypoxic conditions created by decay of the organic fraction of dredged material.* The 1976 hypoxic event dramatically demonstrated the sensitivity of the NY Bight ecosystem to low concentrations of DO (Swanson and Sinderman 1979). General environmental conditions that favor hypoxia are a strongly stratified water column, which limits oxygen supply from the surface, and high decomposition rates of organic material below the thermocline, which increase oxygen consumption. Dredged material has a biochemical oxygen demand (BOD) that could contribute to localized hypoxia under certain circumstances. The effect of dredged material on BOD has been studied empirically and by models (Brown and Clark 1968; Houston, LaSalle, and Lunz 1989). BOD typically has two components (American Public Health Association 1985): decay of organic material (mostly bacterial respiration), which occurs over a period of days, and oxygenation of reduced inorganic materials (typically sulfides and ferrous iron), which occurs relatively quickly. In the open ocean, the latter source of BOD is not important, hence the BBRP focused upon reductions in DO concentrations due to decay of organic material.

DO concentrations in the bottom waters above ODMDSs may differ from those in reference areas, but it is unlikely that such differences would be biologically significant unless ambient DO concentrations were near the threshold necessary to sustain a healthy community. In formally designating an ODMDS at a particular site, USEPA suggests the near total loss of the benthic community within that area will not have a detrimental effect on the ecosystem. Thus, whether that loss occurs directly from disposal (burial) or indirectly (suffocation from low DO concentration) seems unimportant. Nonetheless, it is likely that the magnitude of any decline in DO concentrations may need to be described in an EIS. Relevant guideposts for this description may be 2.0 mg/l, which is the lower end of the range considered normal for inshore Bight waters (Armstrong 1979), sustains surf clams in the laboratory (Thurberg and Goodlett 1979), and does not appear detrimental to field benthic communities (Breitburg 1990). Another useful guidepost may be 4.0 mg/l, a common lower bound for DO concentrations in some legally defined water quality criteria. However, if the 4.0-mg/l level is used to identify potential impact areas, it should be noted that large parts of the NY Bight naturally have DO concentrations below 4.0 mg/l, especially on a seasonal basis.

5. *Reduced forage area for fish and macrocrustaceans due to reduced abundance of benthos within the ODMDS.* The reasoning behind this potential impact was described in impact 6 of the section on offshore containment islands. Impacts to fish foraging area from a new ODMDS or expanded Mud Dump Site are qualitatively similar to those from a containment island except that an ODMDS should allow at least intermediate use during recovery periods and perhaps full use after the ODMDS is deactivated. Some cursory studies (Wilber, in preparation) suggest secondary productivity actually is enhanced by some disposal events, potentially increasing the forage value of the area. Thus from both population and habitat perspectives, a new ODMDS or expanded Mud Dump Site is not likely to significantly affect fish foraging in the NY Bight, particularly if the ODMDS is outside the Christiaensen Basin or Hudson Shelf Valley. However, the impact may become an important component of examining the potential of fishery species to bioaccumulate contaminants that seep from capped disposal sites.

6. *Attraction of thigmotactic and rheotactic fish and crustaceans once a varied topography is established.* The reasoning behind this potential impact and its separation from impact 5 were described in the section on offshore containment islands (impact 9). This potential impact is qualitatively similar to its counterpart for a containment island. The principal difference is that the attractiveness of a new ODMDS or expanded Mud Dump Site would initially be low, then increase gradually as topography becomes more variable and relief increases from the accumulation of disposal events. Clarke (in preparation) describes how distribution of certain species of fish is influenced by the current patterns in the vicinity of underwater berms, which essentially are equivalent to ODMDS mounds. This impact is not likely to change the abundance of fish and macrocrustaceans in the NY Bight, but may have secondary effects that benefit recreational fishing. This impact also may be an important component to evaluating bioaccumulation of contaminants that seep from capped areas.

Several additional potential impacts from a new ODMDS or expanded Mud Dump Site were discussed, but dropped from subsequent examination because they were either considered too unlikely or too speculative based upon current information. Most of these were offsite impacts resulting from disposed sediments moving out of the ODMDS. Given the size of a potential expansion of the Mud Dump Site or new ODMDS and that operation of the disposal site would likely preclude discharging material near the borders, the probability of such movement is low. However, some dredged material may have moved outside the eastern boundary of the Mud Dump Site (SAIC 1991c), indicating this may still be a relevant question. The movement could have resulted from resuspension followed by advection and resedimentation of material, a phenomenon known to occur in other areas and viewed as beneficial in "dispersive" ocean disposal sites (Pequegnat and Galloway 1990). Alternatively, disposal near tops of existing mounds may induce down-slope flows of material that generate sufficient momentum to carry material outside site boundaries. Another potential impact not considered sufficiently likely to warrant detailed discussion was the possibility that dredged material, either via contaminants or a high sediment oxygen demand, could create areas inhabitable by benthic and/or epibenthic organisms.

Subaqueous offshore borrow pits

Most borrow pits are dug in inshore waters to facilitate transport of the mined material to its location of eventual use (*e.g.*, beaches, construction sites, and cement plants). Borrow pits are most often dug in sandy sediments. Unless the pit is located in an active accretion area, fine sediments are likely to accumulate at the pit's bottom. Infauna are generally more abundant in fine sediments than sandy sediments (Wigley and Theroux 1981), however, sediment contaminants, high rates of BOD, and other environmental factors can reverse this tendency (Chang et al. 1992). Many fish are naturally attracted to borrow pits due to thigmotropism, rheotropism, higher food abundance, ameliorated environmental conditions, or other factors. However, as was true for infauna, low DO concentrations and other factors can reverse this attraction at least on a seasonal basis (Murawski 1969, Harper 1973). Conover et al. (1983), Conover, Cerrato, and Bokuniewicz (1985), and Woodhead and McCafferty (1986) found fish abundances to be higher in borrow pits in lower NY/NJ Harbor than at nearby natural depths, especially during the late summer and early fall. These studies supported previous anecdotal observations that borrow pits within the harbor were attractive to fish and, hence, important to fishermen.

USACE (1991) listed the following areas of concern regarding the construction and use of borrow pits within the harbor as disposal sites for dredged material:

a. Disruption of fish assemblages that tend to concentrate within pits or at pit boundaries.

b. Reduction in suitable pelagic and benthic habitat due to chronic burial, changes to sediment type, or low concentrations of DO.

c. Reduction of productivity (presumably forage value) by benthos within a borrow pit.

d. Reduction in fish abundance from elevated turbidity levels within a disposal pit.

e. Contaminants and pathogens making benthic and pelagic habitat too toxic to support organisms, if category II or III materials are placed in the site.

f. Bioaccumulation of contaminants by fish and benthos due to contaminated material released during disposal, migration of contaminants through the cap, breaching of the cap, or burrowing of animals through the cap, if category II or III materials are placed in the site.

No other areas of concern were identified during development of the DMDMP (Conner et al. 1979, USACE 1989). Refining these impacts into more manageable units and adding others results in six areas of concern, similar to those identified for borrow-pit disposal; five of these impacts were not considered to be potential threats to the NY Bight ecosystem or human health.

<u>Impacts with potential ecological or human health significance</u>

1. *Bioaccumulation of contaminants by fish and benthos from migration of contaminants through the cap or breaching of the cap, if category II and III materials are placed in the site.* Rationales for this potential impact are the same as for impact 1 in the section on a new or expanded ODMDS and impact 3 in the section on offshore containment islands.

<u>Impacts unlikely to affect the NY Bight ecosystem or human health</u>

2. *Disruption of fish assemblages that might concentrate within borrow pits or at pit boundaries.* This potential impact has two components: (1) examining whether fish will aggregate within borrow pits or at the edges of borrow pits, and (2) examining whether disposal in close proximity to such aggregations will harm the fish, presumably via elevated levels of TSS.

Inshore borrow pits can be either attractive, unattractive, or neutral with respect to fish. Even though locally obtained information indicates that fish are attracted to borrow pits in NY/NJ Harbor, possibilities of attraction and avoidance should be considered. In most cases, it will be relatively easier to determine why fish avoid borrow pits (*e.g.*, low DO concentrations) than determining why they are attracted (*e.g.*, thigmotropism, rheotropism, higher food abundance, or ameliorated environmental fluctuations). It also will be difficult to interpret the ecological significance of fish aggregating or avoiding borrow pits. Borrow pits are a relatively recent phenomenon in the ecological history of these species, and it is unclear if they have led to an increase in the size of fish populations or, more simply, concentrated populations to an area in which they are more easily counted (Bohnsack (1989) discusses this question in the related context of artificial reefs). Quantifying this impact also may be an important component to examining impacts to recreational and commercial fishing. Table 6 lists fish species likely to be found in borrow pits constructed in the NY Bight.

3. *Disruption of seasonal movements by fish because the pit acts as a thermal refuge.* Numerous anecdotal reports indicate borrow pits ameliorate temperature fluctuations. In their review of NY Bight fishes, Grosslein and Azarovitz (1982) characterized the NY Bight as a transitional faunal province because of extensive overlap between cold-temperate and warm-temperate fishes (only 10 of the 180 species commonly found in the NY Bight are considered year-round inhabitants). Cold-temperate species enter the NY Bight during winter and leave during spring and summer. Warm-temperate species enter during summer and leave during fall and winter. Temperature is believed to be the proximate environmental cue for many of these migrations. Murawski (1969) and Broughton (1977) suggest individuals of warm-temperate

Table 6
Common and Scientific Names of Common Species from the NY Bight Likely to Aggregate In or Near Offshore Borrow Pits

Codfishes	Family Gadidae
Conger eels	Family Congridae
Cusk eels	Family Ophidiidae
Goosefish	*Lophius americanus*
Jacks	Family Carangidae
Sea robins	Family Triglidae
Ocean perch	*Sebastes* spp.
Ocean pout	*Macrozoarces americanus*
Sculpins	Family Cottidae
Toadfish	*Opsanus* spp.
Wrasses	Family Labridae
Winter flounder	*Pleuronectes americanus*
Windowpane flounder	*Scophthalmus aquosus*
Weakfish	*Cynoscion regalis*
Red hake	*Urophycis chuss*
Silver hake	*Merluccius bilinearis*
American lobster	*Homarus americanus*
Rock crabs	*Cancer* spp.

species may overwinter in pits if bottom waters are relatively warm and that such aggregations could be detrimental. Fish may become trapped within a borrow pit by cool surface waters. These fish could then be killed by thermal shock when cold water sinks to the bottom. Cold-temperate species could over-summer in the NY Bight if a large, deep pit provides an oasis of cool water. However, such aggregations could be detrimental if the fish are trapped by a sharp thermocline and pit bottom waters become hypoxic. In either case, it seems unlikely that fish populations in the NY Bight would be reduced by these processes given the small size of borrow pits relative to the geographic range of the populations and the natural variations in population size. Gadid (cods), pleuronectid (flounders), and cottid (sculpins) fishes were used as guideposts in examining this impact. Quantifying this impact also may be an important component in examining impacts to recreational and commercial fishing.

4. *Reduction in habitat suitable to infauna and epifauna from changes in granulometry and stress from chronic burial.* Dredged material disposed in borrow pits is likely to be finer than native material. Since granulometry is at least weakly correlated with the composition and abundance of benthos (Wigley and Theroux 1981), this change in surface sediment should contribute to a change in the benthic community. Organisms likely to be common before a pit is constructed include amphipods (*Protohaustorius* spp. and *Unicola irrorata*), sand worms (*Nephtys* spp.), ocean quahogs (*Artica islandica*), and surf clams (*Spisula solidissima*). Organisms likely to be present during filling of the pit include polychaetes (*Tharyx acutus, Glycera dibranchiata*, and *Spiophanes bombyx*) and bivalves (*Nucula proxima* and *Tellina agilis*). Both sandy and silty habitats and their associated benthos are common in the NY Bight. Therefore, it is unlikely that the temporary replacement of sandy habitat with finer sediments will have significant effects on populations.

5. *Reduction of habitat suitable for infauna and epifauna due to low concentrations of DO.* As indicated earlier, the 1976 hypoxic event dramatically illustrated the sensitivity of the NY Bight ecosystem to low DO concentrations. Many inshore borrow pits along the east coast of the United States have poor water quality, most notably low concentrations of DO, which can contribute to low abundances of benthos. Although this does not appear to be significant for existing borrow pits in NY/NJ Harbor (Swartz and Brinkhuis 1978; Conover, Cerrato, and Bokuniewicz 1985), the public is likely to express such concerns, especially if dredged material placed in the borrow pit has a high BOD. Relevant guideposts for this examination may be 2.0 mg/l, which is the lower end of the range considered normal for inshore NY Bight waters (Armstrong 1979) and does not appear detrimental to field benthic communities (Breitburg 1990); a legally relevant guidepost may be 4.0 mg/l. Since this impact will be temporary (*i.e.*, only relevant while the pit is deep) and the benthic community affected has no special significance, it is unlikely that populations in the Bight will be affected significantly.

6. ***Reduction in foraging area for organisms that feed upon soft-bottom benthos until the final cap has been recolonized due to changes in granulometry and stress from chronic burial.*** As discussed earlier, one reason abundance of benthos is discussed in an EIS is the general implication that benthos are frequently fed upon by fish that constitute commercial and recreational fisheries. Because natural diets are variable, foraging areas are large, no fishes in the NY Bight are thought to be food limited, and the likelihood that long-term abundances of benthos will not be affected by a borrow pit, any reduction in foraging area from a pit is not likely to significantly alter the abundance or distribution of fish in the Bight. However, as also indicated earlier, it is conceivable that a portion of the benthic community may increase in abundance because of reduced competition or increased food availability. Thus, the forage value of the area may increase to fish and macrocrustaceans feeding upon these organisms; however, this temporary and localized benefit is not likely to affect population abundances either.

Impacts to marine biota expected from filling borrow pits with dredged material should be qualitatively similar to those from using an expanded Mud Dump Site or new ODMDS. The major difference for borrow pits would be the relatively greater concerns about water quality because of reduced circulation in the pit. Other potential impacts discussed included (1) habitat changes outside the pit boundaries due to transport of sediment or low-DO water, and (2) dredged material, either via contaminants or a high sediment oxygen demand, creating areas inhabitable by benthic and/or epibenthic organisms. These impacts were not judged to be sufficiently likely to warrant detailed discussion.

Lengthening and deepening Ambrose Channel

Although it was recognized at the outset of the BBRP that this hypothetical project differed considerably from the others, the magnitude of this difference was underestimated. Not only are the types of impacts very different from the other projects, but the technical literature that needed to be reviewed was far more extensive. Since expanding Ambrose Channel was probably the least likely project to be done during the projected shelf life of the BBRP report, it was decided to limit discussion of potential impacts from this project to salinity intrusion in order to manage the program's logistics. Salinity intrusion was chosen for two reasons. First, this issue commonly is the focal point of an EIS for similar projects (*e.g.*, USACE (1987)) because the defining feature of an estuary is its salinity gradient. During one or more life-history stages, many organisms are dependent directly or indirectly upon these salinity gradients for growth, predator avoidance, and feeding. Relevant species for NY/NJ Harbor are listed in Table 7. Second, the horizontal salinity gradients integrated over depth are what determine the baroclinic portion of the pressure gradient force responsible for driving the convective mode of estuarine circulation. Modifications to the salinity field and the water depth will, therefore, result in modifications to the buoyancy-driven and wind-driven non-tidal circulations. To the extent that water quality or species distributions depend upon these non-tidal circulations, their modifications by lengthening and deepening Ambrose Channel may be very important.

Table 7
Common and Scientific Names of Common Fish, Molluscs, and Macrocrustaceans from NY/NJ Harbor

Alewife	*Alosa pseudoharengus*
American shad	*Alosa sapidissima*
Atlantic coraker	*Micropogonias undulatus*
Atlantic sturgeon	*Acipenser oxyrhynchus*
Bay anchovy	*Anchoa mitchilli*
Blueback herring	*Alosa aestivalis*
Hogchoker	*Trinectes maculatus*
Pinfish	*Lagodon rhomboides*
Spot	*Leiostomus xanthurus*
Striped bass	*Morone saxatilis*
Winter flounder	*Pleuronectes americanus*
Softshell clams	*Mya arenaria*
Hardshell clams	*Mercenaria mercenaria*
American lobster	*Homarus americanus*
Blue crabs	*Callinectes sapidus*

Note:
Taxonomy based upon Robins and others (1991).

3 Step 2: Examining Potential Impacts with Existing Databases and Models

Overview of Relevant Databases and Models

Because of its proximity to a large portion of the U.S. population and its importance to the regional economy, a considerable amount of effort has been spent studying the NY Bight, leading to a perception that the NY Bight is a thoroughly studied ecosystem. The early stages of the Section 728 program included public workshops that outlined the program's course. A major conclusion was the program should place more emphasis on synthesizing existing information than upon collecting new data. This synthesis would then be used to identify important information gaps and test the feasibility of various research approaches (*e.g.*, hydrodynamic and eutrophication modeling) that would be built upon by later efforts. Reports produced in association with these workshops were used to provide overviews of existing information about the NY Bight.

Databases

Waste Management Institute (1989a) identified 19 previous or ongoing monitoring programs within the NY Bight that may be useful for predicting impacts from the hypothetical projects examined.

The Northeast Monitoring Program (NEMP) was sponsored by the NOAA and was in effect from 1980 until 1984. NEMP replaced NOAA's Ocean Pulse Program and was replaced by NOAA's National Status and Trends Program (NSTP). NEMP's objectives included characterization of contaminants in offshore sediments and organisms, determination of the effects of offshore drilling and ocean disposal on marine ecosystems, identification of appropriate early-warning signs of stress in offshore marine ecosystems, and indication of how these types of information should be integrated into management decisions. Over 80 sample stations were located in offshore waters between the Gulf of Maine and Cape Hatteras, NC, generally at depths <600 ft. Water quality measurements included DO concentrations, organic carbon, nutrients, chlorophyll *a*, and TSS. Sediment measures included trace metals, total organic carbon (TOC), total organic nitrogen (TON), granulometry, seabed respiration, and indicators of bacterial and viral abundance (including coprostanol). Biological parameters measured included prevalence of disease among bivalves and groundfish, rates of primary production, and bioaccumulation among selected benthos and groundfish. Sampling occurred throughout the year, although many parameters were measured only once per year per station.

The NSTP is an ongoing national program that began in 1984; its goal is to establish and maintain a database on contaminant levels in groundfish, shellfish, and sediments in inshore waters. The program has two sections. The Benthic Surveillance Project (BSP) focuses upon measurement of toxic substances in surface sediments and groundfish; coprostanol and bacterial spores are also measured in sediments. The Mussel Watch Project is similar to BSP but focuses upon bivalves instead of groundfish and is based upon an earlier program developed by USEPA. Samples are collected annually. None of the stations occur within the NY Bight as defined by the BBRP, five stations are in NY/NJ Harbor, three in New Jersey coastal waters west of the barrier islands, one along the south coast of Long Island, and several stations are in Long Island Sound.

Between 1973 and 1980, NOAA sponsored the Marine Ecosystem Analysis New York Bight Project (MESA), the most comprehensive examination of the NY Bight to date. MESA's objectives were to establish baselines and diagnostic models for physical, chemical, geological, and biological parameters. They accomplished their objective by reviewing historical datasets and by collecting new information. Almost all of the new data collected under MESA were collected between 1973 and 1975, with the balance of the program spent analyzing data and preparing reports. Thus, the last broad assessment of the NY Bight is based upon data now 20 years old.

The U.S. Department of Energy (DOE) sponsored a program called Shelf Edge Exchange Processes Phase I (SEEP-I) that gathered general hydrographic, particulate, and DO concentrations along the continental shelf of the eastern United States during 1983 and 1984. Current meters also were deployed. Besides DOE, SEEP-I participants included Brookhaven National Laboratory, Lamont-Doherty Geological Observatory, North Carolina State University, and the University of Maryland. All stations were east of the Hudson Shelf Valley, many were outside the area the BBRP defined to be the NY Bight, and most were in waters deeper than 50 m (165 ft).

From 1986-1989, NOAA sponsored a program to examine the response of biota to the curtailment and eventual cessation in 1987 of use of the 12-Mile Municipal Sludge Disposal Site. Twenty-five stations were sampled in and around the 12-Mile Site. Water quality data collected include DO concentrations, nutrients, sulfides, and turbidity. Sediment data collected include metallic and organic contaminants, TOC, grain size, bacterial abundance, and seabed respiration rates. Biological data collected included infauna abundance, feeding habits of lobster and groundfish (primarily winter flounder, silver hake, and red hake), bioaccumulation in winter flounder and lobster, and prevalence of fin rot, black gill, and similar diseases among groundfish and macrocrustaceans. Sampling frequency ranged from monthly to bimonthly.

USEPA instituted a four-tiered monitoring program of the 106-Mile Deepwater Municipal Sludge Site: sludge characterization, near-field fate and short-term effects, far-field fate, and long-term effects. Tiers 1-3 had begun by 1988; a decision to implement tier 4 awaited evaluation of data from earlier tiers. Data collected included general hydrographic parameters (including deployment of current meters), distribution and abundance of benthos, distribution and abundance of fish, water quality (including heavy metals, pesticides, PCBs, coprostanol, and chlorophyll a), sediment quality (including heavy metals, PAHs, pesticides, and bacterial indicators), and disease and other pathologies among fish and benthos. When feasible, USEPA used information generated from other studies (*e.g.*, NEMP, SEEP-I) to avoid unnecessary duplications of effort.

USEPA presently sponsors the NY Bight Water Quality Monitoring Program. The principal objective of the program is to monitor water quality near New Jersey and New York beaches to determine if beach closures are necessary. A secondary objective is to investigate sources of poor water quality that could result in beach closures. Helicopters are used to sample surface and bottom waters, and analyses include DO concentration, temperature, salinity, and levels of fecal coliform bacteria, nutrients, and chlorophyll *a*. Most stations are within a few miles of the New Jersey or Long Island coast; the inner Apex is also sampled. Samples are generally collected weekly from May through October; some stations have been sampled since 1974.

The District monitors the Mud Dump Site, including specialized studies on an as-needed basis. Data collected include bathymetry, water quality, sediment quality, and bioaccumulation among benthos. SAIC (1991c) presented findings of recent monitoring studies.

NOAA sponsors the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program. MARMAP's principal objective is to describe the distribution and abundance of fish eggs and larvae along the northeast coast of the United States. Data on flotsam, including tar balls and plastics, also are collected. Over a hundred stations have been sampled between Cape Hatteras, NC, and Nova Scotia, including about 30 in the NY Bight.

NOAA, specifically the National Marine Fisheries Service (NMFS), sponsors the Bottom Trawl Survey Program, which is commonly called the NMFS Groundfish Survey. The program's objective is to provide information the NMFS needs to manage fishery resources, including distributions, abundance, age structure, and growth rates. The program began in 1963 with fall surveys, spring surveys were added in 1968, and occasional spring and winter surveys also were done. The area from Maine to North Carolina is surveyed via a stratified-random sampling method (Figure 9), which has resulted in many samples from the NY Bight.

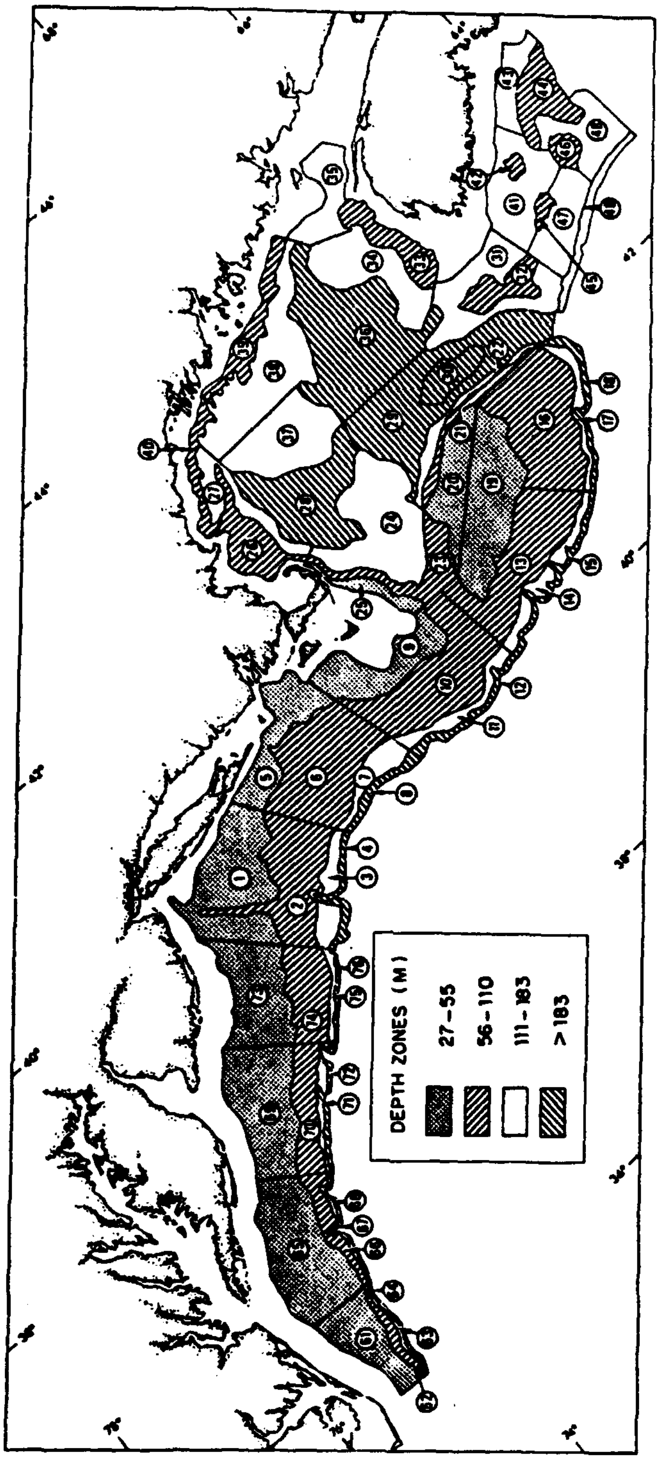

Figure 9. Strata sampled by NMFS during the Bottom Trawl Survey Program

Other monitoring programs identified by the Waste Management Institute (1989a) focused upon weather, coastal tide gauges, sewage outfalls, and bacteria levels near public beaches and shellfish beds. Two additional programs should be mentioned. The U.S. Atlantic Continental Slope and Rise Program (ACSAR, Maciolek et al. 1987) examined a few stations in the deeper portions of the NY Bight between 1983 and 1987, including seasonal studies of infaunal communities. The Hudson-Raritan Project examined long-term correlations between fish stocks and potential environmental and anthropogenic factors; results are presented in Summers et al. (1985) and summarized in Rose and Summers (1992).

All of the above programs frequently produced data reports and summaries; however, reports that include thorough evaluations and syntheses are produced rarely or sometimes not at all. This void creates several problems. First, thorough evaluation and syntheses are necessary for sound management decisions. Second, data reports are often viewed by the public as equivalent to thorough scientific studies leading to the perception that numerous synthetic studies of the NY Bight ecosystem have been made when in fact there are relatively few. Third, data reports typically do not present complex information in ways that can be readily transformed into useful conclusions and, hence, cannot be readily transformed into sound management policies. Fourth, data reports typically present results from only a portion of the program and, therefore, can lead to premature conclusions that later prove unsubstantiated. Chang et al. (1992) is an excellent evaluation of infauna associations in the NY Bight, and their work is an example of this overall problem in that it required 10 years after the last data were collected to produce the paper. The MESA reports provide another example most of the reports published in the 1980s were based upon data collected 8-10 years previously.

Hydrodynamic and water quality models

Before discussing the hydrodynamic and water quality models available for the NY Bight, two general comments are necessary. First, like all models, hydrodynamic and water quality models simplify physical and biogeochemical processes and set limits on temporal and spatial resolutions and the range of variables considered. Therefore, they approximate the interaction mechanisms of the real world (see Thompson (1992) for a concise review). Some of these simplifications result from gaps in knowledge about how nature works and others represent practical and logistical considerations necessary to implement or model the overall effort. Whether or not these simplifications are reasonable steps, or insurmountable obstacles, depends upon the purpose of the model. Second, numerical models merely consist of equations that represent physical or biogeochemical processes plus a protocol to solve those equations. Use of such models requires project-specific tailoring, which can include using a grid to represent geography and bathymetry, inputting and updating boundary conditions, selecting time intervals, and scrutinizing results to ensure the model worked as intended. Experience has shown the tailoring of a model to a specific project can be at least as important as the physical and biogeochemical processes encoded in the model. A particular application of a model may fail to meet expectations because processes are over-simplified, the model was incorrectly tailored to the situation, or both. Further, a model may be ideally suited and tailored to addressing a particular set of questions but totally inappropriate for others.

A major focus of the Section 728 program was the preliminary tailoring of existing hydrodynamic and water quality models to the Bight (Scheffner et al. 1993, Hall and Dortch 1993). Waste Management Institute (1989b) lists several models that have been done for the area. The models done by WES as part of the Section 728 program are the most comprehensive modeling efforts that have been done for the NY Bight with the possible exception of the hydrodynamic and water quality models that were part of USEPA's NY Bight Restoration Program, Long Island Sound Study, and NY/NJ Harbor Estuary Program. Recognizing that three-dimensional, time-dependent models are required, examination of hydrodynamic and water quality models for the NY Bight emphasized the models available at WES, which also are very similar to the models used by USEPA.

Ecosystem models

Ecosystem models can be useful tools for quantitatively examining specific ecosystem components (*e.g.*, a population, material pathway, or feedback loops, such as predator-prey interactions), qualitatively exploring ecosystem interrelationships, or quickly gaining a broad view of an ecosystem's important features. It is rare for a single ecosystem model to be useful for all these purposes. Narrowly focused models tend to be more suited to analytical work whereas broadly scoped models tend to be more suited to exploratory analyses and gaining a general understanding of how an ecosystem functions.

In general, analytical ecosystem models link biological and physical variables through equations believed to represent reasonable simplifications of the actual mechanisms or pathways of interaction found in nature. Most authorities recognize examinations of plankton dynamics on Georges Bank (Riley 1946, 1947; Riley, Stommel, and Bumpus 1949) as the first significant foray into ecosystem modeling. Distinctions between ecosystem modeling and other forms of ecological modeling are somewhat arbitrary and becoming less clear as researchers begin to merge concepts from various fields. In general, ecosystem models differ from traditional population, community, and food chain (web) models in that the latter three do not include physical variables (*i.e.*, the type of variables that form the basis of most impact-assessment studies). Ecosystem models also differ from most statistical models of relationships between biological and physical factors in that statistical models often emphasize empirical descriptions of relationships more than quantitative evaluations of hypothesized mechanisms. Distinctions between ecosystem modeling and water quality modeling are less clear. Streeter and Phelps (1925), who examined the balance between DO concentrations and BOD, are commonly recognized as accomplishing the first significant foray into water quality modeling. Most early water quality models did not include a true biological component and, hence, are not ecosystem models as defined here. However, many recent water quality models, especially eutrophication models, include lower trophic levels (*e.g.*, phytoplankton) or a biological process (*e.g.*, photosynthesis) and, hence, fit our definition of ecosystem models. Ecosystem models can be narrowly focused upon a few biotic-abiotic interactions (*i.e.*, a very small subset of what many would consider to be the entire ecosystem) or they can attempt to describe many interactions (see reviews by Wiegert (1975); Pomeroy and Alberts (1988); and Fransz, Mommaerts, and Radach (1991)).

The common technical difficulty in using ecosystem models is choosing appropriate variables and spatial and temporal scales. Finding efficient computer algorithms also can be difficult because the large number of equations that need to be solved simultaneously is usually larger than for physical or water quality models. Nature essentially is a continuum of time and space and physical, geochemical, and biological properties. Logistical constraints require these continuums to be simplified, which means time and space are divided into discrete units and individual physical and biological variables are aggregated into larger units or omitted altogether. A model's objectives determine the appropriate levels of discretization, aggregation, and omission. Levels appropriate for one set of objectives (*e.g.*, hypoxia) may be totally inappropriate for another set of objectives (*e.g.*, population abundance of fish). Thus, it is very important for a modeling exercise to have clearly defined goals before it begins. If the goals are well stated, the appropriate model type, variables, and scales can be determined.

Several new types of ecosystem models have emerged during the last decade. Since they are still developing, similarities and differences between them are not always clear. An informal taxonomy of ecosystem models presented by the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) (1992) will be used here.

Ecosystem process models address the interaction mechanisms that control the flow of nutrients and organic material. These models are among the oldest ecosystem models. Notable examples include those done for Narragansett Bay (Kremer and Nixon 1978), the Bristol Channel and Severn Estuary (Radford and Uncles 1980, Radford 1981), and the Ems-Dollard Estuary (Baretta and Ruardij 1988). These models use differential equations to represent ecological processes. Application of these models to coastal situations generally requires linkage to or input from a hydrodynamic model. A hydrodynamic model is needed to specify the flow field that is crucial to the distribution of water properties, to keep track of these distributions, and to determine rates of mixing between water masses with different levels of these factors. Ecosystem process models may be useful for organizing and prioritizing field studies to the extent that the processes modeled are well understood. Other beneficial features of these models include their focus upon mechanisms and the relative ease at which they simulate nonlinear feedback loops. Weaknesses include the difficulty of incorporating higher trophic levels and the need for costly ecological process data (*e.g.*, primary production, sediment respiration and growth rates) to develop, calibrate and test the model. McLaughlin and Endler (1976) present a conceptual model of the NY Bight ecosystem that could be used as the outline for a numeric ecosystem-process model.

Individual-based models (IBMs) describe population dynamics based upon the characteristics of individuals. Although this style of modeling also is relatively new, there are many examples of its use (reviewed in DeAngelis and Gross (1992)). IBMs are appealing because of their relative conceptual simplicity; their inclusion of stochastic events, episodic events, and density-dependent relationships; and their ability to allow for individual variation in responses (which may have a genetic component). Many modern population and community ecologists believe biological processes, such as competition and predation, and episodic events play a larger role in determining natural variations in distribution and abundance than physical factors. At present IBMs seem the best way to model such factors. A common disadvantage to IBMs is their need for extensive information about age-specific recruitment, growth, movement, and survival under various environmental circumstances. Botsford (1992) describes how IBMs can be used to examine recruitment of dungeness crabs. IBMs are presently being developed for striped bass (*Morone saxatilis*) and winter flounder (*Pleuronectes americanus*).

Higher-trophic-level bioenergetic models determine the amount of habitat capable of supporting a particular biological process and the spatial and temporal arrangements of that habitat. This type of modeling is relatively new so there are few examples of its use. However, it should be noted that when focused upon growth, these types of models are conceptually related to water quality and ecosystem process models that include a strong focus on phytoplankton dynamics. Brandt (1993) has used bioenergetic models to examine the growth rate potential of striped bass (*Morone saxatilis*) in the middle portion of Chesapeake Bay by following temperature, food density, and fish movement patterns.

Landscape models are similar to both bioenergetic models and IBMs. Most landscape models focus upon the spatial arrangement of habitat patches (which can be on the order of square inches to square miles) and how that arrangement affects the dynamics of populations and communities (Forman and Gordon 1986). Costanza, Sklar, and White (1990) provide an excellent example of how landscape models can be used to compare the effects of different water control structures at the Mississippi/Atchafalaya River juncture on the acreage of fresh water, brackish water, and salt marsh in a 1,450-mi^2 area of Louisiana. The BBRP did not identify any landscape models for the Bight, but some are likely to be available soon since this form of modeling is receiving a lot of attention from benthic ecologists.

Ecosystem regression models (ERMs) use statistical analyses to test for major relationships in an ecosystem (*e.g.*, the relationship between freshwater inflow rates and population size of an estuarine-dependent species). Many of these models are strictly empirical, relying upon educated inference to discern the actual underlying mechanisms after numerical analyses are completed. There are numerous examples of this type of modeling in coastal and estuarine environments (e.g., Stevens 1977; Sutcliffe, Drinkwater, and Muir 1977; Ulanowicz et al. 1982; Wilber 1992). ERMs also can explicitly examine mechanistic relationships. In most cases, a great number of potential physical and biological independent variables are available for exploring a particular dependent variable (*e.g.*, population size of a particular fish species). Natural history information can be used to prioritize the potential explanatory variables. The accuracy of statistical models based upon this prioritized list can then be compared to models based solely upon statistical grounds or upon random combinations of the variables to determine the relative strength of the models. Polgar et al. (1985), Summers et al. (1985), and Summers and Rose (1987) are excellent examples of this approach applied to anadromous fishes from northeastern U.S. estuaries. A strength of ERMs is that they provide a sound basis for developing other types of models, variables included in ERMs should be incorporated into other models. Overall linkages between man-made perturbations and biological variables also tend to be more clear with ERMs. The disadvantage of ERMs is their need for extensive databases. Rose and Summers (1992) provide several examples of ERMs for species from the NY Bight (Table 8 and Figure 10).

Table 8
Cumulative r^2 from Ecosystem Regression Models for Several Species from NY/NJ Harbor

Species	Time lag, years	CPUE	CPUE and hydrographics	CPUE Hydrographics and Pollution
American shad	4-8	9	7	76
Striped bass	2-6	44	77	84
Tomcod	1-3	24	70	86
White perch	3-8	9	22	36
American oyster	3-7	n.s.	48	53
Softshell clam	2-4	44	64	72
Hardshell clam	2-7	14	72	n.s.
Blue crab	1-2	27	38	n.s.
American lobster	6-10	34	69	77
Eel	2-7	32	39	58
Spot	1-3	15	22	32
Menhaden	2-3	14	25	n.s.
Weakfish	2-3	52	74	80
Bluefish	2-7	27	37	61
Winter flounder	2-3	29	38	51
Scup	3-6	25	57	74

Note:
Time lags indicate the contribution of spawning in previous years to the present year's catch-per-unit-effort (CPUE). Variables were added to models in the following order: lagged CPUE, hydrographic parameters, and pollution parameters. Hydrographic parameters included average air temperature (a proxy for water temperature) and river discharges for *a priori* specified months. Pollution parameters included annual dredging volume from specified river reaches, average DO concentration, and total sewage discharge. From Rose and Summers (1992). n.s. = variables added at that step were not significant.

Examination of Project Impacts and Resulting Information Gaps

Some of the potential impacts identified in Chapter 2 are shared among the hypothetical projects. For clarity, information available for examining impacts will be discussed in the same format as Chapter 2, even though discussions will seem repetitious. Chapter 4 synthesizes the information gaps into a single set of recommendations.

Some assumptions were necessary when reviewing the usefulness of existing information for addressing the selected impacts because it was not feasible for the BBRP to independently and exhaustively review all aspects and sources of information. First, and most important, conclusions reached in published studies were presumed to be correct. For example, if an investigator concluded certain species of fish were more abundant in certain parts of the NY Bight during certain times of the year, the BBRP presumed that the

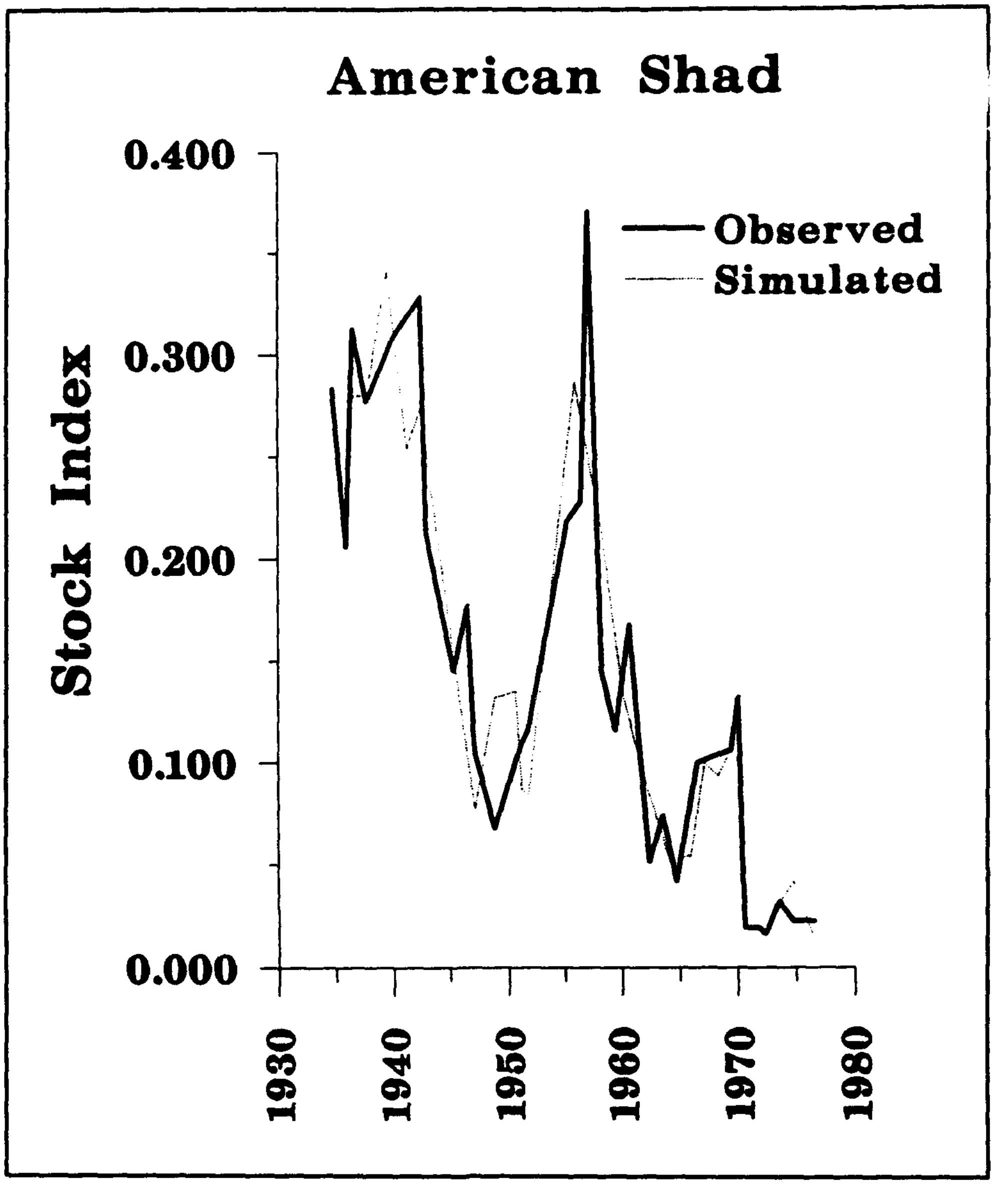

Figure 10. Observed and simulated data for an ecosystem regression model that examined abundance of American shad in the Hudson Estuary (from Rose and Summers (1992))

sampling gear and effort were suited to making such conclusions. Otherwise, reviewing the methodologies behind all the relevant studies would have been an inordinate task. Second, USEPA, NY Sea Grant Institute, and the District recently cataloged various studies about the NY Bight, including an annotated bibliography (Horvath et al. 1984), the MESA reports, USEPA's Bight Restoration Program reports, and the modeling and monitoring workshops that began the Section 728 program. The BBRP assumed these efforts were thorough, so duplicative efforts were not made, although the most recent peer-reviewed literature was examined for newer material. Undoubtedly, some useful information was missed, but it is unlikely these misses were critical. The types of studies most suited to examining the impacts identified are multi-year studies that cover a broad geographic area. Given the level of effort necessary to do such studies, it is unlikely that such efforts went unnoticed by USEPA and the District and by agencies supporting their work (NOAA, NMFS, and the State University of New York (SUNY)).

Offshore containment islands

Impacts with potential ecological or human health significance

1. ***Decreased growth of larval and early juvenile fishes from disruptions in the Hudson River plume, if the island is located within the plume.*** Some simplifications probably would be necessary to examine this impact. First, fish eggs and larvae would be viewed as inert particles whose buoyancy can only change according to simple patterns (*e.g.*, diel patterns). Second, the principal hydrographic feature causing frontal systems near the island would be limited to the buoyancy gradients caused by the plume and currents impinging upon the island. Conceptually, this impact would be examined using a hydrodynamic model capable of examining frontal systems and then coupling it with specific information about the tendency of ichthyoplankton to aggregate at fronts in the Hudson River plume. A particle tracking model, similar to the one developed for the Section 728 program, may be useful to formalize the coupling.

There are two important information gaps that would need to be filled to pursue this examination. First, information is needed about the spatial distribution of the plume and its location changes due to hydrographic and meteorological conditions. Second, very little is known about the spatial distribution of ichthyoplankton in the NY Bight. The tendency for eggs and larvae to aggregate at fronts has been well quantified in several geographic areas, but not for the NY Bight. Principal sources of information about NY Bight ichthyoplankton are Kendall and Naplin (1981), Grosslein and Azarovitz (1982), and Smith (1988). Additional information should be available from MARMAP, but summary reports could not be obtained. All studies of ichthyoplankton distributions were done at large spatial scales (typical distances between stations were >15 nm), and no efforts were made to correlate station locations with actual frontal boundaries. Hence, existing studies cannot be used to estimate the tendency for ichthyoplankton to aggregate at fronts, but they do provide information about the typical large-scale spatial and temporal distributions of ichthyoplankton.

These gaps could be filled in a tiered process. NOAA maintains a 10+-year archive of daily (or more frequent) AVHRR satellite images of the Bight (Figure 11). This database could be searched to determine likely positions of the plume when ichthyoplankton are abundant (usually spring and summer). If relevant flow features are in or near prospective project areas, the assessment's second tier would begin. Near-real-time (semi-daily) satellite imagery would

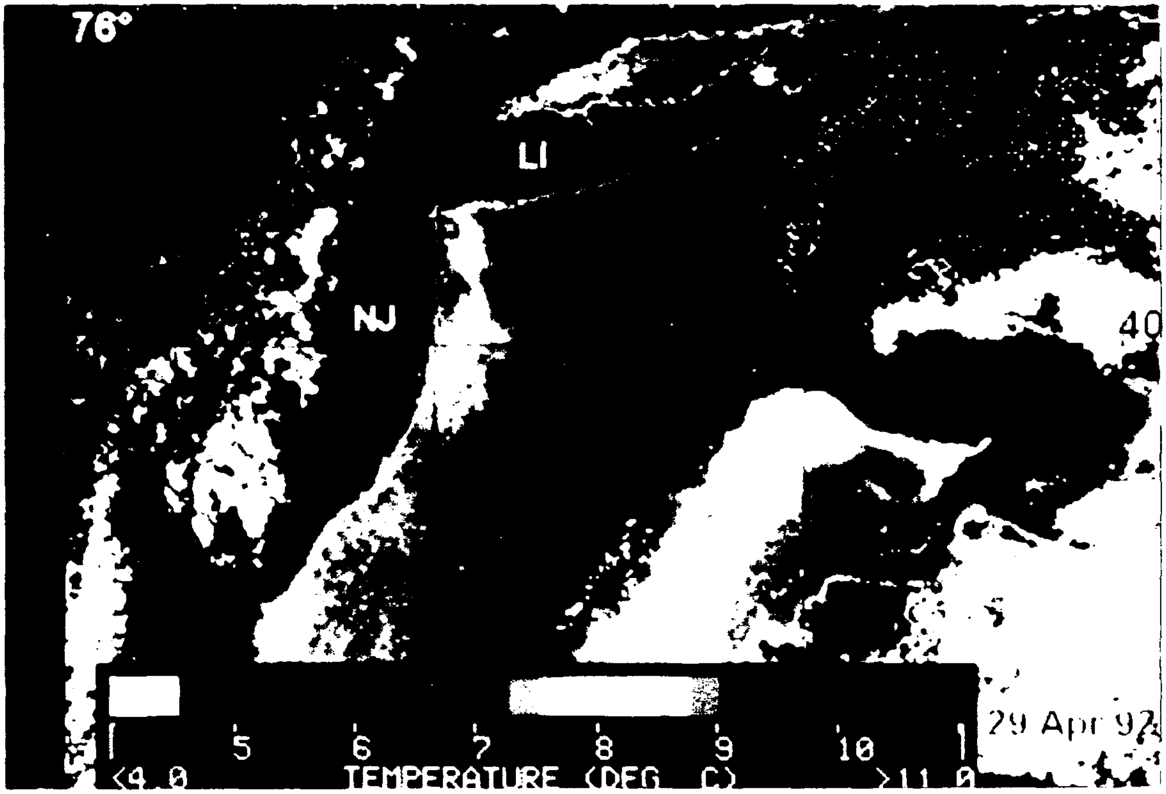

Figure 11. AVHRR satellite image of sea surface temperature showing the location of the Hudson River plume on April 29, 1992. The approximate size of the plume is 150 nm^2

be used to locate the relevant flow features and for sampling to determine if substantial aggregations of ichthyoplankton occur. If such aggregations are common, a third tier would be pursued. Hydrodynamic and particle tracking models capable of resolving the plume would be used to determine the potential amount of ichthyoplankton intercepted. CH3D-WES (the model Scheffner et al. (1993) used for the hydrodynamic portion of the Section 728 program) and similar models should be able to model topographically modified fronts if tailored properly to this specific question.

2. *Loss of viable benthic and pelagic habitat from discharges of material during a large-scale structural failure.* Examination of this impact would be simplified to two issues: (1) changes in sediment characteristics making benthic habitat unsuitable for infauna and epifauna, and (2) the toxicity of lost sediments making habitat unsuitable for infauna and epifauna. Conceptually, these issues would be examined by choosing a range of sediment discharges, inputting those discharges into a sediment transport model, and inferring biological impacts from the model results. The range of sediment discharges chosen would include both likely and worst-case scenarios and would be guided by some form of risk analysis. Depending on depth, sediment type, and other factors, a model such as LTFATE (Scheffner 1992), which could be updated to include sediment mixtures, may be sufficient for providing the

physical input upon which biological interpretations would be made. Inferring effects to biota from model data has not been rigorously tested; thus, this step could only be done qualitatively, which may be sufficient depending upon what model results show. However, it should be clear that in order for the model results to be useful, biologically relevant parameters must be part of the output. Some information is available on the effects of overburden thickness on survival by infauna (Maurer et al. 1986), but little information is available for other sediment characteristics.

3. *Bioaccumulation of contaminants by fish and benthos from discharges of contaminated material during normal operations or large-scale structural failures, if category II or III dredged material is placed in the island.* Conceptually, this impact would be examined by combining information about the rates of contaminant discharge, rates of transformation into bioavailable substances (if discharged in an inert form), rates of uptake, and dose/response relationships. As indicated earlier, any containment island for dredged material would incorporate state-of-the-art construction and management techniques to minimize inadvertent discharges of contaminated material. Actual discharge rates probably would not be predictable in a strict quantitative sense. Instead, and probably preferably, consequences of various discharge rates representing scenarios widely believed to be biased towards over-predicting actual discharges would be used.

Factors affecting rates of transformation and uptake are summarized in McFarland, Lutz, and Reilly (1989a,b,c) USEPA and USACE (1991) and described in more detail by Nagel and Loskill (1991). In short, these are active research areas in government, academic, and private laboratories both in the U.S. and elsewhere (most notably Europe), which reflect a general recognition that more information about these processes is needed to effectively manage anthropogenic activities in coastal environments. Procedures currently used for assessing bioaccumulation in the regulatory setting, although conservative, focus on measuring *potential* for bioaccumulation rather than *predicting* rates of bioaccumulation in the field. Once uptake into organisms is estimated, contaminants would have to be traced through the food web. These types of analyses are in their infancy. Baird and Ulanowicz (1989) and Baird, McGlade, and Ulanowicz (1991) show excellent examples of a technique that may be helpful in this regard (Wulff, Field, and Mann (1989) provide additional information about exact modeling procedures). Using a technique called network analysis, which was adopted from economics, they quantitatively trace food web pathways revealing key nodes of the overall web. A network analysis of the NY Bight food chains could be modified to include potentials for contaminant uptake and transfer, providing a sound basis by which hypotheses regarding bioaccumulation in the field can be formulated and tested. Such modeling would have to be done specifically for the NY Bight and probably require some fieldwork to provide necessary input data.

Impacts unlikely to affect the NY Bight ecosystem or human health

4. *Permanent reduction of habitat useable by soft-bottom (i.e., unconsolidated bottom) infauna from usurpation of ocean bottom by the island.* Ideally, this impact would be described and placed in its appropriate context by using a series of maps that show historic and present distributions and abundances of infauna from both seasonal and annual perspectives. It is rare for such information to be available, and most EISs do not include information about infauna at this level of resolution. There are several obstacles to assembling information at this level of resolution. Infaunal populations and communities vary at temporal scales from days to decades and at spatial scales from inches to miles. Guidelines for examining these scales of variability have been available for some time in statistical texts (*e.g.*, Cochran (1953)), and have been concisely revisited in recent ecological literature (Livingston 1987, Morrisey et al. 1992). Essentially, temporal and spatial scales are continuums ranging from broad (*e.g.*, decades or miles) to narrow (*e.g.*, days or feet), and sampling must be done at a level narrower than the level at which one wishes to generalize. For example, monthly or bimonthly sampling is necessary to characterize seasonal variation.

Like most offshore areas, infaunal variability in the NY Bight has only been examined at a few temporal and spatial scales and only within subsections of the entire area (Appendix C). Most of the information has been collected from the NY Bight Apex and near coastal areas; there has been little sampling effort in waters deeper than 180 ft. Sampling gear has typically been a Smith-MacIntyre grab or similar devices, efficiencies of which have been reviewed most recently by Blomqvist (1991). Animals living in deep burrows may be under-represented because of limited penetration depth, particularly in sandy areas (which are common in the NY Bight). Smaller animals living at the surface may be under-represented because they can be displaced when the bow-wave from the grab hits bottom. Smaller animals also may be under-represented because many studies used 1.0-mm sieves or larger, rather than the conventional 0.5-mm sieve, to separate organisms from the sediment.

Cognizant of the above caveats, a synthesis of the various individual studies should provide reasonably accurate descriptions of spatial variability on the order of miles and temporal variability on the order of 1-3 years for areas shallower than about 180 ft. Current information is insufficient for characterizing information at:

a. Small- and medium-spatial scales (<1 mile); for example, differences that might exist between the crests and troughs of sand waves.

b. Short- (seasonal) and long-time (>3-year) scales.

c. The distribution and abundance of large deep-burrowing organisms, such as hemichordates, some bivalves, and large polychaetes.

d. All scales of patchiness and temporal variation in waters deeper than about 180 ft.

Assuming any offshore containment island will be in waters shallower than 180 ft, none of these gaps appear critical for examining this impact.

5. *Permanent reduction of habitat useable by soft-bottom epifauna from usurpation of ocean bottom by the island.* The type of information ideally suited to examining this impact would be in a format similar to that for infauna. As indicated earlier, it is difficult to quantitatively sample epifaunal communities. Most of the information about the distributions and abundances of epifaunal communities comes from epifauna that were a bycatch during infaunal surveys and general information about life history because no major NY Bight surveys used gear specifically designed for sampling epifauna (Appendix C). A synthesis of this information would be more suited towards formulating hypotheses for subsequent monitoring programs than for characterizing habitat, particularly if the island is in waters deeper than 180 ft. However, as indicated earlier, this information gap probably is not critical because it is unlikely epifaunal populations in the NY Bight will be reduced significantly by a containment island.

6. *Reduction in foraging area for organisms that feed upon soft-bottom benthos.* This impact could be examined effectively by combining maps of infaunal and epifaunal abundance with information on the feeding habits of fish and macrocrustaceans into maps of potential forage value (*e.g.*, Lunz and Kendall 1982, Clarke and Lunz 1985). A caveat to such an analysis is differences between actual and potential forage value are not well characterized and can vary with sediment type and prey density (Lipcius and Hines 1986; Eggleston, Lipcius, and Hines 1992). The difficulty of implementing the infaunal and epifaunal mapping portions of this strategy have already been discussed. Most fish and macrocrustaceans have varied diets that change ontogenetically, seasonally, and geographically; hence, many species could experience a reduction in foraging area. Information about food habits of fish and macrocrustaceans are concisely summarized by Pearce et al. (1981) and Grosslein and Azarovitz (1982) and could be readily integrated into this assessment framework. Thus, the weak link in this analysis would be the information about infaunal and epifaunal abundances. However, given the overall context of this impact, this shortcoming does not appear critical.

7. *Increased habitat suitable for hard-bottom benthos from the presence of the island walls and material used to armor its base.* Examination of this impact requires a division between organisms that attach to hard-bottom substrate (*e.g.*, mussels) and mobile benthic organisms that aggregate in hard-bottom areas (*e.g.*, lobsters); the latter element will be discussed under impact 9. Ideally, to examine potential impacts to attached hard-bottom organisms, measurements of colonization rates and community dynamics on large, uniform blocks of substrate would be used. No such habitat naturally occurs in the NY Bight. Studies of artificial reefs in the NY Bight do not fill this information gap substantially. Artificial reefs in the area consist predominantly

of small blocks of substrate and rubble and mostly occur in waters shallower than 90 ft (Jensen 1975). Studies of these reefs emphasized fish. Studies of encrusting invertebrates consist mainly of abstracts or unquantitative reports (*e.g.*, Bulloch 1965, Ogren 1967, Pearce and Chess 1968). The few quantitative examinations of invertebrates focused on the feasibility of building artificial reefs with solid waste materials (*e.g.*, Carleton et al. 1982, Woodhead and Jacobson 1985) and may not be relevant to colonization of a containment island's walls. Thus, natural history observations would have to be relied upon to predict the characteristics of the community that would colonize the island's base and walls. This estimate would probably only be qualitative, but should be sufficient to address EIS requirements.

8. *Increased forage area for organisms that feed upon hard-bottom benthos*. Ideally, this impact would be examined using the same strategy outlined for impact 6, except that hard-bottom prey and predators would be used instead of soft-bottom prey and predators. As indicated for impact 7, existing information is only suited to qualitatively describing the community of attached invertebrates that will colonize the island walls and base. Compared to soft-bottom fish and macrocrustaceans, relatively little is known about the diets of predators in hard-bottom areas, because of the difficulty of sampling in these areas. However, it is reasonable to assume diets are broad. Preliminary studies by Briggs (1977) and Steimle and Ogren (1982) of 13 fish species found at artificial reefs indicated few species feed heavily upon reef biota. Instead, fish seemed to hover near reefs between foraging bouts over nearby soft-bottom areas. Only qualitative examinations of this impact are possible with existing information because of a lack of information about potential prey densities and predator food habits. However, these information gaps do not appear critical given the overall context of this impact.

9. *Attraction of thigmotactic and rheotactic fish and crustaceans*. As indicated in the section on offshore containment islands, this impact focuses upon organisms attracted to structure and currents for reasons not fully explained by foraging behaviors. It is not clear how this impact should be examined. Thigmotaxis and rheotaxis have been recognized for decades, but there have been few quantitative studies of the phenomena. Table 5 lists species from the NY Bight likely to exhibit strong thigmotactic and/or rheotactic behaviors. Although thigmotaxis and rheotaxis can occur at many spatial scales, examination of this potential impact focused upon large features, such as the Hudson Shelf Valley, the Mud Dump Site, and the larger artificial reefs of the Long Island and New Jersey coasts. Appendix D summarizes results from large-scale studies of fishes in the NY Bight. None of these studies sampled at scales capable for resolving thigmotaxis and rheotaxis near these features. Thus, information from smaller structures, such as artificial reefs, constitutes the bulk of information upon which this impact could be examined.

Scarett (1968) and Briggs and Zawacki (1974) describe the demography of lobsters inhabiting artificial reefs in the Bight, and Scarett (1968) examines how different reef designs affect the size and gender of lobsters attracted. Ogren (1968), Olla, Bejda, and Dalemartin (1975); and Briggs (1977) provide fishery-independent information about fish use of artificial reefs, especially by tautogs (*Tautoga onitis*) and black sea bass (*Centropristis striata*). Bohnsack (1989) provides the best paradigm by which site-specific information can be extrapolated to populations. Essentially, species that are obligate reef dwellers and are habitat-limited have the best potential for realizing an increase in their population size by the presence of a large offshore island. Collectively, these studies could only provide a qualitative examination of this potential impact, but this information gap does not appear critical given the overall context of the impact.

10. *Concentration of larval and early juvenile fish at topographically controlled frontal zones.* Some simplifications probably would be necessary to examine this impact. First, fish eggs and larvae would be viewed as inert particles whose buoyancy can only change according to simple patterns (*e.g.*, diel patterns). Second, the principal hydrographic features capable of causing frontal systems near islands would be limited to internal waves that propagate shoreward along the thermocline from the continental shelf break and surface currents impinging upon the island. Thus, eggs and larvae would be viewed as particles being advected from one part of the NY Bight to another and the question would be what proportion is intercepted by the island-induced fronts. Conceptually, this impact would be examined similar to impact 1. A hydrodynamic model capable of examining frontal systems would then be coupled with specific information about the tendency of ichthyoplankton to aggregate at fronts. A particle tracking model could formalize the coupling.

The hydrodynamic portion of this assessment would be relatively straightforward for fronts caused by currents. A properly tailored three-dimensional model should be able to examine the relevant features. However, fronts induced by internal waves may not be resolvable by hydrodynamic models. Some sort of experimentation with real and/or hypothetical data would be necessary to explore how well models such as CH3D-WES (the model Scheffner et al. (1993) used for the hydrodynamic portion of the Section 728 program) can resolve internal waves and to modify those models accordingly. CH3D-WES and similar models should be able to model current-induced fronts around an island if tailored properly to this specific question. The tendency for eggs and larvae to aggregate at fronts has been well-quantified in several geographic areas, but not for the NY Bight. Principal sources of information about Bight ichthyoplankton are Kendall and Naplin (1981), Grosslein and Azarovitz (1982), and Smith (1988). Additional information should be available from MARMAP, but summary reports could not be obtained. All studies of ichthyoplankton distributions were done at large spatial scales (typical distances between stations were >15 nm), and no efforts were made to correlate station locations with actual front boundaries. Hence, existing studies cannot be used to estimate the tendency for ichthyoplankton to aggregate at fronts, but they do provide information about the typical large-scale spatial and temporal distributions of ichthyoplankton. This information probably would be sufficient as input to guide and interpret modeled test cases that examine this potential impact.

11. *Loss of viable pelagic and benthic habitat from discharges of material during normal operations.* Given the simplifications made for this potential impact in the previous section, three perturbations are considered: (1) TSS making pelagic habitats unsuitable for ichthyoplankton and fish, (2) changes in sediment type making benthic habitat unsuitable for infauna and epifauna, and (3) toxicity of inadvertently discharged sediments making benthic habitat unsuitable.

LaSalle et al. (1991) reviewed laboratory studies that examined effects of TSS on ichthyoplankton and fish (Table 9). General trends are discernable; however, effects of particular levels of TSS are not always consistent between studies, species, or life history stages. Although effects of high TSS

Table 9
Summaries of Results from Experiments that Examined Effects of Various Concentrations of Suspended Solids on Various Life History Stages of Fishes

Species	Stage	Range Tested (mg/L)	Effects Measured
Yellow perch	Eggs	50-5,000	No effect on hatching success, but some time delays at concentrations over 100 mg/l
White perch	Eggs	50-5,250	Some decreases in hatching success at concentrations over 1,500 mg/l
Striped bass	Eggs	50-5,000	Some decreases in hatching success at concentrations over 1,000 mg/l
Alewife	Eggs	50-5,000	No effect on hatching success, but some time delays at concentrations over 100 mg/l
Blueback herring	Eggs	50-5,000	No effects
Yellow perch	Larvae	50-1,000	Decreased survival above 500 mg/l
White perch	Larvae	50-1,000	15-49% mortality
Striped bass	Larvae	50-1,000	Decreased survival at concentrations over 500 mg/l
Alewife	Larvae	50-1,000	Decreased survival at concentrations over 500 mg/l

Note:
From LaSalle and others (1991).

concentrations have been examined on many species, common species from the NY Bight have not been studied (*e.g.*, flounders and hakes). If deemed necessary for EIS requirements, these gaps could be filled by additional work. However, it should be noted that relationships between field and laboratory results of these types of tests are difficult to establish.

Maurer et al. (1986) and Wigley and Theroux (1981) present information that should help discern effects from sedimentation on benthic organisms. Given the small spatial extent of this perturbation and improbable significance to overall population abundance, it may not be necessary to distinguish quantitatively between areas where all infauna are killed from burial, and areas where only a portion of the infaunal community was affected (either by burial or changes in sediment texture). Exploration of various hypothetical scenarios should be sufficient. Relatively simple modifications to models such as STFATE could help determine the footprint of material released in the water column.

Generalizations about the toxicity of sediments at the levels commonly encountered are difficult because there is only a weak correlation between bulk concentrations and toxicity (Long (1992) provides an excellent example for mercury). Considerable research is under way to help clarify these matters as part of USEPA's efforts to establish national sediment quality criteria. Until this research is completed, the procedures recommended for examining sediment toxicity are site-specific bioassays with organisms believed to be minimally affected by laboratory conditions (USEPA and USACE 1991). Although it is widely thought that these tests are conservative, an effort is under way to improve them. A major issue requiring clarification is the relationship between laboratory and field toxicity. Bioassays seem the most effective way of examining this impact at present and may prove the best overall method if only weak correlations can be drawn between actual sediment concentrations in sediments and effects to biota.

Expansion of the Mud Dump Site or designation of a new ODMDS

<u>Impact with potential ecological or human health significance</u>

1. *Bioaccumulation of deleterious substances by fish and benthos, if category II and III materials are placed in the site.* This potential impact would be examined in a fashion similar to impact 3 of the section on offshore containment islands. The principal difference between the ODMDS and island contexts would be that the unknowns about rates of exposure from an island would be exchanged for a different set of unknowns about rates of exposure from a failed cap. However, it does seem reasonable that exposure from a failed cap would be lower than from a large-scale failure of a containment island's structural components.

Four potential sources of contaminants were considered for this impact: (1) bioturbation, (2) relatively dense capping material displacing less dense material below it, (3) pore waters within the contaminated material displacing pore waters within the cap, and (4) scouring by currents or waves.

Both in theory and nature, bioturbation can affect sediment properties (see Miller-Way and Clarke (in preparation) for an excellent review). Yet few physical or chemical models of sediment dynamics explicitly incorporate bioturbation because the spatial and temporal scales needed to characterize bioturbation are much finer than the scales at which models of sediment dynamics are commonly applied. In general, the importance of this exclusion is unc but will vary with a model's purpose. Bioturbation can bias measurements of sediment properties in many ways; thus, integrated community-wide effects could effectively be neutral. The BBRP did not find an extensive database of bioturbation measurements for the Bight; hence, the importance of this process to capping can only be estimated from natural history observations.

Displacement of less dense disposal material by relatively denser capping material is possible, but has not yet proven a major problem. This issue is being studied as part of the ongoing efforts by WES and USEPA to provide guidelines on cap design, construction, and monitoring. Displacement of pore waters within a cap by waters from disposed contaminated dredged material can be examined by simple models or by more formal numerical models, such as RECOVERY (Boyer et al., in preparation), which was developed under a contract from the Corps' New England Division and subsequently refined by WES as part of Section 728 and other programs. To date, empirical measurements combined with simplified sediment models have proven adequate for examining the potential of waves and currents to breach a sediment cap. More refined analyses would require including effects of sediment mixtures, bioturbation, and other factors on erosion.

Impacts unlikely to affect the NY Bight ecosystem or human health

2. *Reduction of habitat suitable for infaunal benthos because of frequent burial by dredged material or alteration of sediment type.* A reasonable approach for examining this impact would be similar to the approach described for impact 4 of the section on offshore containment islands; the information available for implementing this approach has already been described. For this potential impact, the major difference between a containment island and a new or expanded ODMDS is that the latter could allow at least intermediate levels of recovery by infauna between disposal events. Assessment of this impact could include estimates of recovery, if necessary. Several studies of recolonization have been done for large estuarine disposal sites (*e.g.*, Chesapeake Bay, Galveston Bay, Long Island Sound, Mobile Bay, and Rhode Island Sound). Similar studies are lacking for ocean areas, although documentation of recolonization (which may not be sufficiently detailed to show rates of recolonization) by a viable community (which may not be the original community) are common, including the Mud Dump Site (SAIC 1991c). However, as noted earlier, it is not likely that the lack of information about species-specific burial and recolonization rates are critical since the ODMDS designation process typically assumes an area's habitat value is greatly reduced (*i.e.*, in order for the overall balance of factors considered to represent the public's interest to be positive, benthic communities are not required to partially recover between disposal events). If necessary, this information gap could be filled by additional studies of the Mud Dump Site or other ODMDSs.

3. *Reduction of habitat suitable for epifaunal benthos because of frequent burial by dredged material or alteration of sediment type.* A reasonable approach for examining this impact would be similar to the approach described for impact 5 of the section on offshore containment islands; the information

available for implementing this approach has already been described. For this impact, the major difference between a containment island and a new or expanded ODMDS is the latter could allow at least intermediate levels of recovery by epifauna between disposal events. Assessment of this impact could include estimates of recovery, if necessary. It should be noted that even less information about recolonization by epifauna is available than for recolonization by infauna. However, as was true for infauna, it is not likely that the lack of information about species-specific burial and recolonization rates for epifauna are critical because the ODMDS designation process typically assumes an area's habitat value is greatly reduced as a worst-case scenario. If necessary, this information gap could be filled by additional studies of the Mud Dump Site or other ODMDSs.

4. *Reduction of habitat suitable for benthos because of hypoxic conditions created by decay of the organic fraction of dredged material.* Monitoring of ODMDSs often involves simple water quality measurements, including DO concentrations, during routine sampling. Some studies show small differences in DO concentrations between disposal and reference areas, but severe, long-term depressions in DO concentration do not occur from the ocean disposal of dredged material. If these studies are deemed insufficient for EIS requirements, additional measurements of DO concentrations could be taken at the Mud Dump Site and structured to complement rather than repeat existing studies. For example, seasonal patterns in DO concentrations could be examined more closely and measurements could be taken during and soon after disposal levels. If a purely empirical approach is deemed insufficient, several modeling approaches are available. Simple models of DO concentrations could be used to look at both short-term and long-term levels (see Houston, LaSalle, and Lunz (1989) for an example). Such models require information about the BOD of dredged material, thermocline depth, bathymetry, and likely velocities of bottom currents, information readily available for most parts of the NY Bight. Another approach would be to tailor the water quality model described by Hall and Dortch (1993) to focus upon DO, BOD, and sediment oxygen demand at the small spatial and temporal scales relevant to a disposal event and ODMDS. From a technical standpoint, any of the above strategies should answer the unresolved technical issues pertaining to this potential impact.

5. *Reduced forage area for fish and macrocrustaceans due to reduced abundance of benthos within the ODMDS.* A reasonable approach for examining this impact would be similar to the approach described for impact 6 of the section on offshore containment islands and could incorporate recolonization as outlined above. Information available for implementing this approach has already been described. As indicated earlier, this would be a qualitative assessment but should be sufficient to meet EIS requirements.

6. *Attraction of thigmotactic and rheotactic fish and crustaceans once a varied topography is established.* As indicated for impact 9 of the section on offshore containment islands, this is a difficult impact to examine and existing information from the NY Bight may not be very useful. Clarke (in preparation) has examined fish use of large (10^7 yd^3) stable mounds of dredged

material in the Gulf of Mexico. Using trawl and hydroacoustic surveys, fish distributions around the mound were examined and compared to currents and potential food resources. A similar study could be done at the Mud Dump Site to provide a quantitative examination of this potential impact. Otherwise, natural history information and the few quantitative surveys of small artificial reefs would have to be relied upon to examine this impact, which may be sufficient given the impact's overall context. Extrapolation of this information to the population level would be done using Bohnsack's (1989) paradigm.

Subaqueous offshore borrow pits

Impact with potential ecological significance

1. *Bioaccumulation of contaminants by fish and benthos due to migration of contaminants through the cap, breaching of the cap, or burrowing of animals through the cap.* The procedure and information available for examining this impact are essentially the same as for impact 1 in the section on a new or expanded ODMDS.

Impacts unlikely to affect the NY Bight ecosystem or human health

2. *Disruption of fish assemblages that might concentrate within borrow pits or at pit boundaries.* As indicated earlier, this potential impact has two components: (1) examining whether fish will aggregate within borrow pits or at the edges of borrow pits, and (2) examining whether disposal in close proximity to such aggregations will harm fish, presumably via elevated levels of TSS abrading gills and other sensitive membranes.

Ideally, the first component would be examined by correlating information about the physical nature of existing borrow pits with fish abundance and then extrapolating those relationships to whatever pits are proposed for the NY Bight. The difficulty in implementing this approach is existing studies focus on inshore borrow pits (*e.g.*, Conover, Cerrato, and Bokuniewicz (1985)) and may not be relevant to offshore borrow pits. Studies of recreational fishing and NMFS's groundfish survey may partially fill this information gap. Long and Figley (1981) describe how fishing efforts by recreational fishermen are partitioned in the NY Bight. Not surprisingly, the edges of the Christiaensen Basin are heavily fished, presumably because the sharp topographic gradients attract fish. This information could be used to provide a basis for estimates of the attraction potential of borrow pits that have reasonable water quality. The NMFS groundfish survey uses a stratified random sampling design, and one stratum approximates the Hudson Shelf Valley (Figure 9). Over the years, numerous trawls have been made in this stratum and should be able to characterize the major differences between the valley and relatively shallower adjacent areas. The difficulty in applying this information to assessment of potential impacts from a borrow pit would be the differences in scale and would require access to the original data for reanalysis since existing summaries and data reports do provide the raw information in a suitable format.

Examination of the second component would be done by combining information about the species and size-class composition of potential aggregation with laboratory measurements of tolerances to high TSS concentrations. As indicated for impact 11 of the section on offshore containment islands, LaSalle et al. (1991) summarized the information available about effects of various TSS concentrations on fish. Many of the species studied are not likely to be species attracted to pits in the NY Bight. However, given the overall context of this potential impact, this information gap does not appear critical.

3. *Disruption of seasonal movements by fish because the pit acts as thermal refuge.* This potential impact would be examined in a fashion similar to the impact above except that emphasis would be placed on migrating fish. The general migration pathways of fish from the NY Bight are reasonably well known. The difficulty would be in estimating the tendency of fish passing the pit to remain in the pit. No studies were found of this phenomenon that were directly applicable to the NY Bight, but the information discussed under impact 2 could partly fill this gap. Given the overall context of this potential impact, this information gap does not appear critical.

4. *Changes in granulometry and stress from chronic burial altering the suitability of habitat to infauna and epifauna.* The procedure and information available for examining this impact are essentially the same as for impact 2 in the section on a new or expanded ODMDS.

5. *Reduction of habitat suitable for infaunal and epifaunal benthos due to low concentrations of DO.* The procedure and information available for examining this impact are essentially the same as the modeling aspect for impact 4 in the section on a new or expanded ODMDS.

6. *Reduction in foraging area for organisms that feed upon soft-bottom benthos until the final cap has been recolonized due to changes in granulometry and stress from chronic burial.* The procedure and information available for examining this impact are essentially the same as for impact 5 in the section on a new or expanded ODMDS.

Lengthening and deepening Ambrose Channel

Ward (1991) identified 11 models used to examine salinity intrusion in estuaries. Models are simplifications of nature. Whether or not the simplifications incorporated into a model's code and input information are appropriate depends upon what questions are being asked. From a biological perspective, the first necessary step to modeling the harbor would be to review what is known about the biological resources to determine the levels of salinity resolution needed to estimate effects and how those levels vary spatially, recognizing that changes in salinity and bottom depth lead to changes in circulation that may affect the distribution of water properties relevant to biota. This information would then be used to guide model development and input conditions. Since those questions have not been specified, the BBRP could not examine in detail the utility of existing information for addressing this impact, but some general comments can be made.

First, some features of the harbor, such as the navigation channels and sills, are far more important to circulation patterns than implied by their area. The four systems commonly used to represent horizontal space in numerical modeling (finite elements, boundary-fitted orthogonal grids, transformed coordinates, and nested grids), vary in their ability to represent these bathymetric features. Finite elements are best suited to describing complex bathymetry, but they can impose insurmountable computational problems.

Second, the physical processes governing salinity intrusion are difficult to model accurately. Salinity affects water density, a major factor controlling estuarine hydrodynamics, so any model of salinity intrusion must consider salinity-driven circulations. This is an important point because early models of estuarine circulation used salinity as a conservative tracer of water movement. In these models, tides, winds, and inflows would be used to compute water movements, and salinity distributions would be superimposed upon the results. Differences between simulated and observed salinity distributions would be adjusted by adding empirically derived correction factors to the model. The correct approach includes salinity as a dynamically active part of the model hydrodynamics through its effects upon the baroclinic part of the pressure gradient field. This coupling greatly increases computational demands and makes the equations more complicated (*i.e.*, nonlinear). Salinity also affects vertical turbulent fluxes, which affect salinity intrusion, requiring a three-dimensional, time-dependent model regardless of the extent of vertical salinity stratification and further increasing computational complexity.

Third, there really is no such thing as an "average" circulation pattern in an estuary. Instead, there are a multitude of circulation patterns occurring over different time and length scales. These include the tidal circulations (made complex by bathymetry and the interconnection of the Harbor/Bight/Long Island Sound system), buoyancy-driven convection owing to horizontal salinity gradients, (*e.g.*, Pritchard (1967a,b)), local-wind-driven motions (*e.g.*, Weisberg and Sturgis (1976), Weisberg (1976)) and non-local wind-induced motions (*e.g.*, Wang and Elliot (1978)). Thus, examination of effects from a deepened channel will yield a range of responses rather than a unique solution. Depending upon the sensitivity of the biological resources to salinity, full characterization of this range may be necessary, which greatly increases modeling efforts.

The hydrodynamic model of the Bight done under the Section 728 program and the model done for USEPA under the NY/NJ Harbor Estuary Program could be re-tailored to examine salinity intrusion in the harbor from a deepening of Ambrose Channel, which probably would include collecting additional field data for model calibration and verification. However, a detailed review of the harbor ecosystem (which probably could be done with existing information) and project specifications would determine whether the expense of an intensive modeling effort is warranted. If an intensive modeling analysis is deemed necessary, some discussion should be held on whether CH3D-WES or the Mellor-Blumberg model, which was used by USEPA, would best address the issue of salinity intrusion. The models are similar in that both include salinity as a dynamically active part of the model. However, they differ in subtle ways, such as how space is represented and vertical turbulence is computed. Explicitly defining the model's goals should help determine whether one of these models is better able to address salinity intrusion for a deepening of Ambrose Channel or whether both are adequate.

4 Step 3: Synthesis of Information Gaps

When synthesizing the information gaps identified in Section 3, the BBRP focused upon gaps not likely to be addressed by the site-specific surveys that would accompany planning of a particular project. Instead, the BBRP emphasized system-wide studies that were crucial to interpreting site-specific studies correctly (Table 10). In addition, when examining the hypothetical projects, information gaps related to management of present activities became apparent and are discussed below. The information gaps identified cross jurisdictional boundaries between agencies and the boundaries between applied and academic research; thus, it is unclear who should take the lead in filling them. Information gaps are not listed in any particular order within the general categories.

Table 10
Major Information Gaps Identified by the BBRP for Assessing Impacts to Large-Scale Projects in the Bight

Information Gap	Relevant Projects
Synthesis of biological and physical studies of the NY Bight into a process-oriented view of the ecosystem focused upon impact assessment	All projects
Importance of the Hudson River plume to fishery dynamics, water quality and material exchanges between ocean and estuary	All projects, especially if in plume
Bioaccumulation of contaminants by fish from an east coast perspective	All projects
Field toxicity of contaminated material to individuals and populations	All disposal-oriented projects
Model general flow patterns around and above borrow pits and large natural depressions	Borrow pit disposal
Maps of infauna and epifauna distributions and abundances	All disposal-oriented projects
Quantitative surveys of hard-bottom benthos distributions and abundances	Offshore containment islands

General Information Gaps

1. *A synthesis of past studies into a process-oriented view of the NY Bight ecosystem and quantitatively testing conceptual models of how the NY Bight ecosystem functions.* Most of the effort monitoring biological resources in the NY Bight has been spent describing the abundance of species rather than examining processes that result in these abundances. The NY Bight is a large and complex ecosystem, so it is reasonable for past efforts to have emphasized descriptions over processes. However, experiences in Chesapeake Bay, Delaware Bay, and the Gulf of Mexico clearly show that a process-oriented approach, which includes elucidating the cause-and-effect relationships between species and between species and the physical and geochemical environments, is necessary to characterize long-term and cumulative impacts from waste disposal, dredging, and other anthropogenic activities. Such a view is needed to ensure existing information is used in the most efficient way possible for examining impacts to the ecosystem and to provide clear focal points for future monitoring and research efforts.

An essential component to developing a process-oriented view of the NY Bight ecosystem is the testing of conceptual models of how this ecosystem functions. Several authors have postulated models for some of the ecosystem's more important components. Falkowski, Hopkins, and Walsh (1980) posited a model for hypoxia off the New Jersey coast which can be tested with the hydrodynamic and water quality models developed under the Section 728 program. Another hypothesis these models can be used to test regards the formation and variation of the "cool pool," a patch of winter water that persists in the NY Bight throughout summer and has been hypothesized to be important to fisheries dynamics (Ketchum and Corwin 1964). Another hypothesis that can be examined using models similar to those in the Section 728 program regards the Hudson Shelf Valley/Canyon serving as a conduit for the nutrients needed to fuel coastal productivity. Numerous similar hypotheses exist. Tests of these hypothesized mechanisms, whether the testing is done empirically or with models, are essential to improving understanding of the NY Bight ecosystem and should be done before additional descriptive surveys or broad-scale model development are undertaken.

2. *Determination of the importance of the Hudson River plume in plankton dynamics and material exchanges between Hudson/Raritan estuary and the Atlantic Ocean.* The Hudson River plume is one of the few features in the NY Bight whose potential significance to the ecosystem is much greater than implied by its area. In other coastal areas, river plumes have been shown to be important components of coastal ecosystems and variations in plume characteristics often are correlated with variations in fisheries, water quality, and sediment transport. Given the large potential importance of the Hudson River plume, its use as a conduit for transporting anthropogenic discharges to the ocean, and that disposal activities occur within the plume, clearly understanding the role of the plume in the NY Bight ecosystem seems essential. The NY Bight National Undersea Research Center, which is managed jointly by

Rutgers University and SUNY/Stony Brook, also has identified this information gap and encourages research to fill it.

Examination of the plume's importance to ichthyoplankton could be done in a tiered fashion. First, NOAA maintains a 10+-year archive of daily (or more frequent) AVHRR satellite images of the Bight (Figure 11). This database could be searched to determine likely positions of the plume when ichthyoplankton are abundant (usually spring and summer). Additional databases that might have relevant images include LANDSAT, SPOT, and SEASTAT SAR. If relevant flow features are in or near prospective project areas, the assessment's second tier would begin. Near-real-time (semi-daily) satellite imagery would be used to locate the relevant flow features for sampling to determine if substantial aggregations of ichthyoplankton occur. If such aggregations are common, a third tier would be pursued. Hydrodynamic and particle tracking models capable of resolving the plume would be used to determine the potential amount of ichthyoplankton intercepted. CH3D-WES (the model Scheffner et al. (1993) used for the hydrodynamic portion of the Section 728 program) and similar models should be able to model topographically modified fronts if tailored properly to this specific question.

3. *Bioaccumulation of contaminants by fish from an east coast perspective.* Contaminant concentrations within fish and other organisms represent a summation of ingestion, absorption, biochemical transformation, and excretion. Most fishes from the NY Bight are only seasonal residents of the ecosystem, migrating from as far away as Florida and Canada. These migrations bring fish into contact with many potential point sources and nonpoint sources of contamination, only some of which are dredged material or material at the bottom of navigation channels. It seems reasonable to assume exposures to contaminants (*i.e.*, input potentials) are not continuous and opportunities exist for body burdens to decrease from metabolic transformations and excretion. If true, a subsequent hypothesis would be that a portion of the contaminants measured in the bodies of organisms from the NY Bight were acquired outside the New York/New Jersey area. However, the relative size of this portion is unclear. To address this issue, bioaccumulation of contaminants would need to be examined in the context of normal migrations, which could be an expensive effort given the geographic and life-history ranges that need to be sampled. Yet such efforts seem necessary to prioritize regulatory and potential clean-up efforts. Recent developments that show stress-inducible proteins (e.g., cytochrome P450 and other metabolic products) are relatively inexpensive markers of contaminant exposure, may help to resolve this issue (*e.g.*, Renton and Addison (1992), Stein et al. (1993)).

4. *Toxicity of contaminated material to fish and benthos and the potential for bioaccumulation directly and through food chains.* As indicated by the active research programs within the government, academia, and private sectors, effective management of contaminated dredged material would greatly benefit from additional knowledge about bioaccumulation processes at all levels of the food chain. To date, research efforts have emphasized implementation of mandated regulatory programs rather than field assessments of effects from

current activities, but attention to the latter is increasing. Relevant research areas include: (1) relationships between contaminant concentrations in sediments and acute and chronic toxicity, (2) identification of chronic toxicological effects and methods to predict those effects, (3) geochemical and biochemical degradation pathways of contaminants and the toxicity of degradation products, and (4) accumulation of contaminants and their degradation products through food chains to fishery organisms.

Contaminant-related impacts identified for the hypothetical projects are at least qualitatively similar to the management problems currently faced. Although it is recognized that additional research on the effects of contaminants in an ecosystem is needed, current information indicates levels of contamination commonly found in dredged material can be managed in coastal systems under existing guidelines. Thus, it is unclear what specific tasks could be undertaken in preparation for a large-scale construction project to better address contaminant-related concerns other than continued support of ongoing research efforts. Suggestions include (1) correlations of field- and laboratory-based measurements of acute and chronic toxicity, (2) long-term monitoring of contaminant fluxes at particular sites and correlating those fluxes with distributions of benthos, and (3) characterization of the relative importance of the various food chains in the NY Bight in order to prioritize field assessments of trophic-based bioaccumulation.

Information Gaps Related to Descriptive Impacts and Project Planning

1. *Generic modeling of the general water-flow patterns around and above subaqueous pits.* Qualitative and quantitative examinations of many of the potential impacts from disposing dredged material in borrow pits require knowledge of how water flows around and above large depressions. One specific question relevant to these examinations is what features (*e.g.*, size, shape, pit depth, water depth, current speed, etc.) induce water to separate and flow around a depression, leaving a semi-quiescent area above the pit proper, as opposed to flowing over the depression. Such modeling could be done easily and inexpensively with existing data and the results should be portable to a wide range of circumstances and environments. This knowledge would greatly improve assessments of the potential for hypoxia in existing and proposed borrow pits, the degree borrow pits and natural depressions confine fine dredged material placed in them, and the attractiveness of borrow pits and natural depressions to thigmotactic and rheotactic fishes.

2. *Maps of infaunal and epifaunal abundances and value as food to bottom-feeding fishes.* Four of the hypothetical projects involved usurpation of some portion of the sea bottom, either permanently or for many years, resulting in local loss of infauna and epifauna. Even if an EIS will require additional site-specific information about benthos, a synthesis of existing information about distributions and abundances would be a valuable planning tool

since some general decisions about siting are necessary in the early planning stages of a project. This synthesis could provide general guidance on site selection and maximize the cost-effectiveness of any site-specific sampling. Over 30 studies of infauna have been conducted in the NY Bight. Additionally, much is known about which sediment types these organisms inhabit and the distribution of those sediments. If synthesized together, comprehensive information would be available about infaunal and epifaunal distributions, although this information is still somewhat qualitative for epifaunal organisms, given the sampling difficulties. This information also would serve as input to assessments of potential effects from a reduction in forage area for fish and macrocrustaceans. Additional work that may prove fruitful would be the development of gear that quantitatively samples epifauna for the site-specific surveys likely to be done during planning.

3. *Distributions and abundances of hard-bottom benthos and fish and the food habits of hard-bottom fishes.* Evaluation of an offshore containment island will include a balancing of several public-interest factors. One factor likely to be portrayed as a benefit is the potential for organisms to exploit the hard-bottom substrate offered by an island. Existing information only allows a qualitative assessment of this impact. Quantitative surveys of existing hard-bottom areas (mostly artificial reefs) would greatly improve the rigor of this assessment and thereby allow a more precise balancing of the public-interest factors. This information also would improve the rigor of any assessment of potential forage value associated with the hard-bottom substrate, if additional studies are done to better characterize the feeding habits of fishes found in this type of habitat.

5 Step 4: Potential Mitigation/Habitat Enhancement Projects

It is awkward to discuss potential mitigation for hypothetical projects because determination of how much mitigation, if any, is necessary is done by balancing many factors not examined in the BBRP. However, since the overall intention of the BBRP was to anticipate the types of information needed to review large-scale projects, it seems reasonable to include potential mitigation projects in this assessment. For simplicity, these discussions focused upon benthos and fish, as was true for the other aspects of the BBRP.

Planning and implementation of potential projects for the NY Bight could create conflicts between commercial and recreational fishing interests. All of the potential projects would involve elimination and/or modification of soft-bottom habitat, depending on the particular scenario for each project. Most of the soft-bottom habitat in the NY Bight is sandy and flat and much of this area is used for commercial fishing (trawl finfishing for several species including yellowtail, winter and summer flounder; shellfishing for ocean quahogs, surf clams, and ocean scallops; and pot fishing for lobsters). The potential projects would eliminate and/or modify this habitat (by converting a relatively flat bottom to a rough bottom, which is more difficult or impossible to trawl over). Since it is difficult to create more flat soft-bottom habitat in the NY Bight (upland would have to be converted to ocean bottom, or holes filled), any habitat creation/modification would probably be hard-substrate (*e.g.*, edges of containment islands) or rough soft-bottom (*e.g.*, sand capping mounds at dredged material disposal sites and borrow pits).

This will benefit recreational fishing, possibly at the expense of commercial fishing. Since specific sites for these potential projects have not been, and will not be, chosen under the Section 728 program, it is not known at this time whether commercial fishing efforts are concentrated in potentially impacted areas. It is also possible that potentially impacted areas are important recreational fishing areas.

Offshore Containment Islands

Construction of an offshore containment island will permanently eliminate a portion of the flat soft-bottom habitat (probably mostly sand). This type of habitat probably cannot be replaced. Converting upland to flat sandy bottom is feasible if land is available, but any newly created bottom would be in inshore areas, which have different physical and chemical regimes and biota than off-shore areas. Filling old borrow pits also could create flat soft-bottom habitat, but these areas also would differ physically, chemically, and biologically from offshore areas because the pits are within the harbor. Thus, out-of-kind (*i.e.*, converting soft bottoms to hard-bottom habitat) mitigation would seem necessary.

Out-of-kind mitigation could involve creating microhabitats in the island walls tailored to attracting particular species. A potential drawback of this option is the public health concern of at least indirectly encouraging fishing next to a potential source of contaminants even though extraordinary care would be taken to prevent contact between this material and living resources. This microhabitat enhancement could include:

a. Varying the shape of the island to create lagoons or pockets of quiescent water attractive to some organisms.

b. Creating holes, protuberances, and other irregularities in the island wall and base, which could attract organisms such as tautog, cunner, black sea bass, scup, crabs and lobsters, who could utilize this habitat.

c. Creating resting/breeding habitat for shore birds (such as terns, gulls and ospreys) on the top of the island.

Expansion of the Mud Dump Site or Designation of a New ODMDS

Dredged material mounds act as *de facto* artificial reefs. By controlling their size and spatial arrangement, a network of mounds could provide valuable habitat to benthos and some fishes. This is already being done to some extent at the existing Mud Dump Site. The Mud Dump Site may attract lobsters and crabs, possibly because of the rough terrain, but the exact mechanism of attraction is not known. The addition of a sand cap to the filled mounds at any ODMDS probably would result in attracting the same organisms, but without the potential problem of sediment contaminant uptake. There may be more opportunity for enhancing habitat at a new ODMDS because this concept can be built into the management plan for the site and there might be more opportunity to select size, elevation, shape, and interspersion of mounds.

Subaqueous Offshore Borrow Pits

The opportunities for enhancing the habitat of an offshore borrow pit are similar to those for an ODMDS. Pits could be only partially filled, which could be done in several different ways, creating a variable topography. Various species of fish would be expected to be attracted to this engineered pit, as they are in many other pits. The difference would be that all other existing pits are located in the harbor; thus, a somewhat different species composition might be found at an ocean pit. Alternatively, pits could be completely filled to create a rough bottom. Lobsters, crabs, and various species of fish would be expected to colonize the area. The essential difference between these alternatives is that the former would include a pit rim, which may have special habitat value to fish.

Lengthening and Deepening of Ambrose Channel

This project differs from the other four in that it generates dredged material rather than consuming it. Although excavating a borrow pit produces dredged material, it is assumed that all of this material will be used for some useful purpose, *e.g.*, beach nourishment, construction material, or fill. While this could also be done with the sand generated from the dredging of Ambrose channel, it is also possible that some material would not be suitable for beach nourishment or upland construction. This material would be fine sand or silt, not rock, unless the Kill van Kull channel also is deepened, and could be used for capping (doubling as habitat enhancement) at the Mud Dump Site or new ODMDS, capping material disposed in borrow pits (ocean and/or harbor), creating artificial reefs, or construction offshore berms for wave attenuation or habitat development.

Other Habitat Enhancement Options

Offshore berms involve the deposition of non-contaminated dredged material in the nearshore ocean environment to retard beach erosion. Dredged material is normally placed parallel to shore to a height above the bottom that would create an impediment to waves that would normally strike the shore front. Besides acting as a wave break, these berms can act as artificial reefs, attracting various species of marine invertebrates and fish. There is ample opportunity to implement this concept along the ocean beaches of the NY Bight, especially considering the enormous beach erosion problem in the area. An important consideration would be the loss of existing habitat, the importance of which would need to be determined.

There is considerable opportunity for the District to construct artificial reefs in the NY Bight and to enhance existing ones. Resource agencies and the public generally favor improving habitat for marine organisms in this manner.

One potential drawback is that locations would need to be chosen to generally avoid areas of commercial trawl and clam fisheries, although some commercial fisheries, *e.g.*, black sea bass, may benefit from reef construction. Reefs have been constructed from products of dredging projects (rock, shell, sand and silt), both in this area, and in many other locations. A cooperative agreement to enhance fisheries exists between the District and NOAA which may facilitate reef construction in the NY Bight. The importance of the loss of existing habitat would need to be evaluated. Reefs would probably be built on relatively flat, sandy areas, which are the most common habitat in the NY Bight.

Addition of individuals to a stock could be accomplished by the District under various scenarios. One scenario would be as direct mitigation for loss of bottom habitat, *e.g.*, addition of seed clams to surf clam, ocean quahog, or ocean scallop beds. Another scenario is enhancement of fish or invertebrate stocks in conjunction with artificial reef creation (whether project-related or restoration), *e.g.*, planting of kelp (*Laminaria*) beds or transplanting of fish from other reefs to speed up the colonization process and potentially mix the gene pool.

The creation of wetlands would compensate, to a limited extent, for the usurpation of habitat in the Bight, since many marine fish and invertebrates use coastal wetlands as a nursery area. However, opportunities for wetland creation in the Bight proper are extremely limited. Also, it would be extremely difficult, or impossible, to make a direct connection between the marine organisms affected by project implementation in the Bight and additional, or restored, coastal wetlands at a considerable distance from these projects. In this regard, there probably is much more opportunity for restoration of wetlands in the NY area than for actual creation, not only because of lack of land for creation, but because many coastal wetlands in this area are degraded. An example of restoration would be to convert *Phragmites*-dominated wetlands in the NJ Hackensack Meadowlands to a more productive habitat, such as *Spartina* marsh, which would contribute more as a marine fish nursery area. There is also the possibility that a limited amount of wetlands could be created as part of a lagoon/beach environment at the edge of a containment island.

Hole filling is a restoration concept that involves filling a relatively small hole or trench to convert a relatively unproductive bottom to a more productive one. It could involve filling a hole that is accumulating contaminated sediments with sand, which could add to the fishable bottom in the Bight. This differs from the borrow pit concept in that no sediment would be removed from the hole for the purpose of beneficial use and the site would not be used for disposal of contaminated dredged material.

Bottom restoration involves the removal of contaminated, or otherwise unwanted, sediment from an area to increase its productivity. One scenario could be to hydraulically dredge a surface layer of fine sediments to expose underlying sand, which may have been covered over because of natural and/or anthropogenic processes. This procedure could also add to the fishable bottom in the Bight.

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Appendix A Authorizing Legislation for the Section 728 Study

Water Resources and Development Act of 1986 (PL99-662) Sec 728 New York Bight Study

(a) The Secretary shall study a hydroenvironmental monitoring and information system in the New York Bight in the form of a system using computerized buoys and radio telemetry that allows for the continual monitoring (at strategically located sites throughout the New York Bight) of the following: wind, wave, current, salinity, and thermal gradients and sea chemistry, in order to measure the effect of changes due to pollution, including changes due to continued dumping in the Bight.

(b) In addition, the Secretary shall study a proper physical hydraulic model of the New York Bight and for such an offshore model to be tied into the existing inshore physical hydraulic model of the Port of New York and New Jersey operated by the United States Army Corps of Engineers.

(c) The Secretary shall coordinate fully with the Administrator of the Environmental Protection Agency in carrying out the study described in this section and shall report any findings and recommendation to Congress. The Secretary and the Administrator shall also consider the views of other appropriate Federal, State, and local agencies, academic institutions, and members of the public who are concerned about water quality in the New York Bight.

(d) There is authorized to be appropriated no more than $1,000,000 per fiscal year for each of fiscal years 1987, 1988, 1989, 1990, and 1991.

Appendix B
BRAG Members

Members of the Biological Review and Assessment (BRAG)

Henry Bokuniewicz, Ph.D. State University of New York, Stony Brook, NY. Marine Geology

Phil Lobel, Ph.D. Woods Hole Oceanographic Institute, Woods Hole, MA. Ichthyology

Robert Weisberg, Ph. D. University of South Florida, St. Petersburg, FL. Physical Oceanography

Other Experts that Met with BRAG

Tom Fredette, Ph. D. U.S. Army Engineer Division, New England, Waltham, MA. Benthic Ecology and Monitoring (October 8, 1991)

Brian May. U.S. Army Engineer District, New York, NY. Operation of the Mud Dump Site (July 14-16, 1992)

Robert Dieterich. U.S. Environmental Protection Agency, Region II, New York, NY. USEPA Bight Restoration Plan (July 14-16, 1992)

H. Lee Butler. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Hydrodynamic Modeling (March 12-13, 1992)

Ross Hall. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Water Quality Modeling (March 12-13, 1992)

Billy H. Johnson, Ph.D. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Hydrodynamic and Sediment Transport Modeling (March 12-13, 1992)

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Gary Ray, Ph.D. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. Benthic Ecology

BRAG Meetings

October 8, 1991, New York, NY
March 12-13, 1992, Vicksburg, MS
July 14-16, 1992, Stony Brook, NY
December 9-10, 1992, St. Petersburg, FL
July 19-20, 1993, Woods Hole, MA

Appendix C
Inventory of NY Bight Benthos Surveys

A REVIEW OF ECOLOGICAL STUDIES
OF NEW YORK BIGHT BENTHOS

Prepared for

COASTAL ECOLOGY BRANCH
WATERWAYS EXPERIMENTAL STATION
U.S. ARMY ENGINEERS

Prepared by

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1.0 INTRODUCTION

The purpose of this document is to provide a review of benthic ecological studies performed in the New York Bight and Bight Apex. Our objective was to provide a synopsis of the studies in terms of sampling methodologies and intensity in various locales within the Bight. A secondary objective was to evaluate gear effectiveness by providing information on abundances of infauna and commercially-important species.

The New York Bight Apex was defined as all offshore marine areas seaward of a line drawn between Rockaway Point, NY and Sandy Hook, NJ as indicated on NOAA chart 12326. The New York Bight was defined as all offshore marine areas depicted on NOAA chart 12300 exclusive of the Apex that are west of Montauk Point, NY and landward of the 1000-fathom depth contour, not including Long Island Sound. Benthic invertebrates were defined as all invertebrates that live on or in the sea floor that are large enough to be retained by a 0.5 mm sieve.

2.0 METHODS

Literature Acquisition

Benthic studies were identified through a combination of agency contacts, computerized literature search, and review of references cited in benthic literature. We relied heavily on Reid and Steimle (1988), who summarized benthic studies performed in the Middle Atlantic Region through September 1984. We also performed an electronic literature search of the U.S. Government Documents and the Biological Abstracts data bases. Review of the references cited in recent publications also provided us with citations for benthic studies. Finally, agency contacts helped us uncover additional benthic surveys. Mr. Robert Reid of NOAA's NMFS Sandy Hook Laboratory, graciously provided us with many of their reports as well as raw data from several of the benthic studies. Other agency contacts are listed in Table 2-1.

Preparation of the Annotated Bibliography

Each report that was acquired was reviewed in terms of sampling locations and dates, methodology, type of data reported, and archival status of samples that were not fully analyzed. In some cases, the information was not included in the document. Our intent was to focus on published literature, with studies involving multiple sampling events receiving the highest priority. In reality, the studies were generally reviewed in the order that they were received, so that our efforts were concentrated on the most accessible information. Several reports could not be obtained for review as they were not available in the libraries we used (University of New Hampshire including the Federal Repository of Government Documents, NMFS libraries at Woods Hole (MA) and Sandy Hook (NJ), and NOAA's Sandy Hook laboratory). These include Rowe 1971, Raytheon 1977, Swartz 1976, EG & G 1982, Pearce et al. 1977d, and Caracciolo and Steimle 1984. Raw data for several studies including U.S. Deptartment of Commerce (1989) and Reid et al. (1991a and b) were obtained in machine readable form (referred to as SHL data) from Mr. Robert Reid of NOAA's Sandy Hook Laboratory. Mr. Brian O'Gorman of NOAA's Northeast Fisheries center provided machine readable data for the NMFS annual groundfish, sea scallop, and surf clam/ocean quahog surveys from 1982-1992. These surveys included data for commercially important invertebrates, e.g. American lobster (*Homarus americanus*), rock crab (*Cancer irroratus*), sea scallop (*Placopecten magellanicus*) ocean quahog (*Artica islandica*) and surf clam (*Spisula solidissima*).

The study area was subdivided into relatively homogeneous areas or strata based on a preliminary review of the information. Results from the benthic survey conducted during the U.S. Bureau of Land Management (now Minerals Management Services) Middle Atlantic Outer Continental Shelf Environmental Studies (Boesch et al. 1977, Boesch 1979) provided a framework for defining strata. Additional (and more intensive) analysis by Reid et al. 1991b confirmed the definitions. In the New York Bight Apex, the Mud Dump, Sewage Dumpsite, Christiaensen Basin, and "all remaining areas" were defined as strata. In the New

York Bight outside of the Bight Apex, the Hudson Shelf Valley was defined as a stratum (depths over 55 m (30f)), and used to divide the area into northern (generally off Long Island) and southern (off New Jersey) areas. Within these two areas, strata were defined based on depth. Areas with depths less than 27 m (15 f) were defined as near-coastal, and depths from 28-55 m (15-30 f) were defined as mid-coastal.

The data from the NMFS surveys were assigned to the depth strata already defined by NMFS. For the groundfish, these were near coastal (<27m), mid-shelf (27-55m), outer shelf (56-110m), and shelf break/slope (111-366m). In addition, the dredged material dumpsite and sewage sludge dumpsite were defined as strata. Within these depth strata, the survey area within the New York Bight was divided into northern (generally off Long Island) and southern (off New Jersey) halves (see Figure 2-1). For the NMFS shellfish surveys, areas were divided by depth into near coastal (9-27m), mid-coastal (28-55m) and deep (56-110m). The Bight survey areas were then divided into northern and southern areas as done for the groundfish (see Figure 2-1). The sampling effort for each stratum including number of sampling events for each year and the year(s) and month(s) of each sampling event, were tabulated from the benthic studies where reported. Total infaunal density and density of the commercially-important surf clam *Spisula solidissima*, American lobster *Homarus americanus*, sea scallop *Placopecten magellanicus*, rock crab *Cancer irroratus* and ocean quahog *Arctica islandica* were averaged by sampling event and stratum, when reported, and displayed graphically. The NMFS survey results were displayed separately from other results. The "n" was also tabulated, and refers to the number of samples (independent station and replicate collections) within a stratum and sampling event. In most cases, "n" indicates the number of stations, since the available data were already averaged over replicate. "N" values calculated from the SHL data (U.S. Dept. of Commerce 1989; Reid et al. 1991a,b) represent the total number of replicates and stations. The "n" values from the NMFS surveys represent the total number of stations per sampling event since only one sample was collected at each station.

3.0 RESULTS

A total of 33 studies were reviewed (Table 3-1), published between the years of 1972 and 1991. The majority could be assigned to four large sampling efforts. The Continental Margin Assessment Program surveyed fish food resources from Cape Cod south to Cape Hatteras from 1962-1965 (Wigley and Theroux 1981). The results of this study are summarized by major taxonomic groups rather than at the species level. A monitoring program for a power plant located near Little Egg Inlet, NJ was conducted from 1972-1978 (Garlo et al. 1979; Garlo 1980, 1982a). Environmental studies were done throughout the Middle Atlantic region from 1975-1977 in order to evaluate likely effects of oil and gas drilling (Boesch et al. 1977; Boesch 1979). Most of the remaining benthic studies were conducted by National Marine Fisheries Service's Sandy Hook Laboratory. At least 17 benthic studies were conducted between 1966 and 1989 (Reid et al. 1991b). Most studies examined the benthic community at various existing and proposed dumpsite locations in the Bight Apex region. These studies include NOAA's Marine Ecosystems Analysis (MESA) New York Bight Project, the Ocean Pulse program, which was integrated into Northeast Monitoring Program (NEMP), and the Sludge Dumpsite Monitoring Program. Benthic invertebrates were also collected during NMFS's groundfish, clam, and scallop surveys. Maps of the study areas from the reports (where available) are included in Appendix A.

The majority of studies that we reviewed for this bibliography used grab samplers to collect macroinfauna (Table 3-1). A variety of trawls and dredges were also used. Approximately two-thirds used a 1.0-mm sieve to screen the samples, but most recent studies used a smaller screen size. Most studies reported abundance measurements, although some included only biomass, and some reported both measures. Some reports presented no data, or did not include details on how data were averaged to obtain the results that were presented. In these cases, data presentation variables in Table 3-1 were classified as "unavailable".

A sampling event was defined as the collection of a series of samples. Usually a sampling event consisted of a cruise where replicate samples were collected at stations over a period of days. The sampling event was categorized according to the month when most samples were collected. In cases where sample collection took place over a period of weeks (Boesch et al. 1977, Boesch 1979), a sampling event was defined as the season when samples were collected. The numbers of sampling events was then tabulated for each of the defined strata (Table 3-2). The year and month or season for sampling events in each stratum (when reported) along with the gear and sieve size utilized were also tabulated and are shown in Table 3-3. This information could not be derived from many of the studies and is thus listed as "unavailable" in Table 3-2. These studies do not appear in Table 3-3. The numbers of samples in each stratum by year for the NMFS annual shellfish surveys are displayed in Table 3-4. The number of samples by month, year, and stratum for the NMFS groundfish surveys are shown in Table 3-5. In most cases, insufficient information was provided on the sampling locations to assign the events to strata. In addition, some studies summarized results in a way that precluded a determination of the number or date of sampling events per stratum. Since raw data were rarely included in the reports, it was not possible to derive this information from the published documents. The results show that sampling frequency for benthic studies was highest from 1973-1976. The reports that were reviewed indicate that sampling efforts for the benthos have been concentrated in the Christiaensen Basin, "other" Bight Apex areas and in the near-coastal southern areas.

The mean, minimum, and maximum for total infaunal density by stratum and sampling event is presented in Figure 3-1. This information was tabulated mainly from reports where the information had already been computed or from reports where raw data were presented and total density could be computed. Total density was computed from machine readable data from Reid et al. 1991a,b and U.S. Dept. of Commerce 1989. The sampling events were grouped by season (winter = January-March, spring = April-June, summer = July-September and fall = October-December). Results from studies using different grab types and sieve sizes can be compared to evaluate gear effectiveness. No data from dredge-type gear types were included in this assessment. There were no consistent differences in total infaunal density that could be related to sieve size at any of the strata. The Smith-McIntyre grab was used in all the studies that were evaluated at the mid-coastal south, Hudson Shelf Valley and mid-coastal north strata. Results from these strata do not provide insight into gear comparability. In the near-coastal south stratum, no differences in total density were noted between studies that utilized the Ponar grab (Garlo et al. 1979, Garlo 1980) and the remaining studies, which all used the Smith McIntyre grab. In the Bight Apex, total density was similar whether a Petersen grab (Steimle and Stone 1973), Shipek grab (Botton 1979) or Smith-McIntyre grab (remaining studies) was used. In the Christiaensen Basin, total density from a study using a Shipek grab (Botton 1979) was within the range of that from a study using a Smith-McIntyre grab. In some, but not all cases, total infaunal density estimates were similar among studies regardless of stratum or gear type. Sediment grain size was not considered in the comparison and may account for the variability within a study and between studies.

Densities of the surf clam *Spisula solidissima* were compared among studies within a stratum (Figures 3-2,3). In the mid-coastal north stratum, no surf clams were collected in either the benthic studies or the NMFS surveys. This stratum was not included in the graphic comparison. In the near-coastal south region, surf clam densities did not appear to be related to sieve size (Figure 3-2). In terms of gear type, densities from dredging, computed on a per tow basis, are not comparable to densities from grabs, calculated per m^2. In addition, dredges tend to capture adults while grabs capture juveniles. There were no consistent differences in results from dredges, Ponar grab samples (Garlo et al. 1979; Garlo 1982a) or Smith-McIntyre grab samples (remaining studies, Figure 3-2). However, the hydraulic dredging performed in the NMFS surveys captured more clams. Results from the Hudson Shelf Valley were from studies that used the Smith-McIntyre grab, and thus provide no information on gear comparability. In the Bight Apex, average densities from Reid et al. (1991b), which used a Smith-McIntyre grab and 0.5 mm sieve, were generally higher than average but within the range of densities from Steimle and Stone (1973), which used a Petersen grab and 1.0 mm sieve, and NAI and AOSSI (1990), which used a Shipek grab and 1.0 mm sieve. In the mid-coastal south and near-coastal south, densities collected by grabs were roughly similar to those collected by dredges.

Rock crab were collected in benthic studies, most using a Smith-MacIntyre grab (Figure 3-4) as well as in the NMFS groundfish surveys (Figure 3-5). In the Bight Apex, results using a Petersen grab (Steimle and Stone 1973) showed strong seasonal variation. When individual seasons were compared, results were similar between the two gear types.

Ocean quahog were collected by both Smith MacIntyre grab and dredge, (NMFS, Ropes and Merrill 1971, assumed to be dredge). When ocean quahog were present, as at the mid-coastal south and mid-coastal north, the dredges captured higher numbers than the grabs (Figures 3-6,7).

American lobster and sea scallop were rarely collected by grab samplers. The NMFS groundfish survey, which uses an otter trawl, captured low to moderate numbers of lobster (Figure 3-8). The NMFS scallop survey, which used a scallop dredge, captured large numbers of scallops in most strata (Figure 3-9).

Dominant species by stratum are presented in Table 3-4. Several trends are evident. Nearshore coastal areas, typified by coarse sediments, include dominant peracarid crustaceans *Pseudunciola obliquua* and *Tanaissus lilljeborgi*. Amphipod *Ampelisca agassizi* appeared in the deeper coastal strata and Hudson Shelf Valley. Several species occurred throughout the New York Bight, including polychaetes *Spiophanes bombyx* and *Tharyx acutus* and bivalve *Tellina agilis*, generally in medium-fine silty sand. Bivalve *Nucula proxima* replaced it in finer sediments. *Spisula solidissima*, the surf clam and the sand dollar *Echinarachnius parma* appeared in medium sand in the Bight Apex and in coarse sediments to the south. The opportunistic polychaete "*Capitella capitata*" appeared in the Christiaensen Basin and the Sludge Dumpsite as well as other Bight Apex stations. However this list does not take into account cessation of sludge dumping activities in 1985. Although this species has been diagnostic of organic enrichment in the New York Bight, variability in abundance levels make it difficult to use as a monitoring tool (U.S. Dept. of Commerce 1989). Since the sludge phaseout, numbers of *Capitella capitata* have decreased by two orders of magnitude, but not the level at of reference sites (Reid et al. 1991a). Tomato seeds, diagnostic of sewage sludge, appeared in the Christiaensen Basin and at other Bight Apex stations. According to Reid et al. (1991a), tomato seeds have shown no change with cessation of sewage sludge cessation.

4.0 DISCUSSION

There have been a large number of benthic surveys in the New York Bight. The majority of studies have been conducted by NOAA's Sandy Hook Laboratory, who have processed the samples and analyzed the data. Most of the information is in a summary form, much of it in figures, designed to address specific questions and hypotheses. Thus the raw data must be obtained in order to address other hypotheses.

There were no obvious differences among grab types. Total infaunal density and densities of rock crab, ocean quahog, and surf clam showed no consistent relationship with the type of grab sampler that was employed. Grab samplers vary in the depth of penetration into the sediment, which depends on the type of sediment encountered. Motile surface dwellers may escape because of surface disturbance or avoidance. High natural variability in infaunal density may have masked any trends among gear types.

The sieve size used for elutriating benthic samples can affect infaunal density and species composition. In the late 1970's, there was a change from use of mainly 1.0 mm sieves to use of a 0.5 mm size or smaller. In a study using a gradation of sieve sizes, a 1.0 mm sieve retained over 40% of the polychaetes, 13% of the crustaceans, and nearly 90% of the molluses. Use of 0.5 mm sieve size captured over 90% of the polychaetes, over 50% of the crustaceans, and all molluscs (Holme and McIntyre 1971). Use of a 0.3 mm sieve size in the Georges Bank monitoring program doubled numbers of small infaunal species such as syllid polychaetes and increased numbers of small crustaceans such as tanaids by 20% (Batelle and Woods Hole 1983). Densities tabulated from the available reports show no relationship with sieve size. Infaunal densities are inherently variable because of variations due to seasonal patterns of recruitment, mesoscale topography, sediment grain size, and patchy distributional patterns. Therefore, it is difficult to separate this natural variability from the effects of sieve size.

Dredges, which employ a larger sieve size (4-38 mm in the studies we examined) and sample a larger surface area, are more effective at collecting large invertebrates. Grab samplers, which sample a relatively smaller surface area, collect juveniles of the larger invertebrates (bivalves, crustaceans) captured by dredges. Thus these gear types are not really comparable. Surf clams and ocean quahogs were collected by both grabs and dredges. Scallops were rarely collected by grabs, but were effectively collected by scallop dredges.

Gear effectiveness is affected by sediment type, depth, and weather. Dredges generally are considered semi-quantitative, as the exact area or volume sampled is not known. In a study off New Jersey, the hydraulic dredge captured surf clams more efficiently than a dry dredge, particularly young of the year (Garlo 1982b). This was primarily due to a deeper bite into the sediment. Use of a small biological trawl (SBT) and anchor dredge by Boesch (1979) produced highly variable catches, a result of differing sampling efficiencies and the patchy distribution of the fauna. The anchor dredge captured more deep dwelling species, mainly molluscs, and fewer surface dwellers such as echinoderms and decapods than the SBT.

American lobster were not collected by grab, probably because of their preference for cobble substrate and cryptic life habits as juveniles. Adult lobsters were successfully collected in otter trawls.

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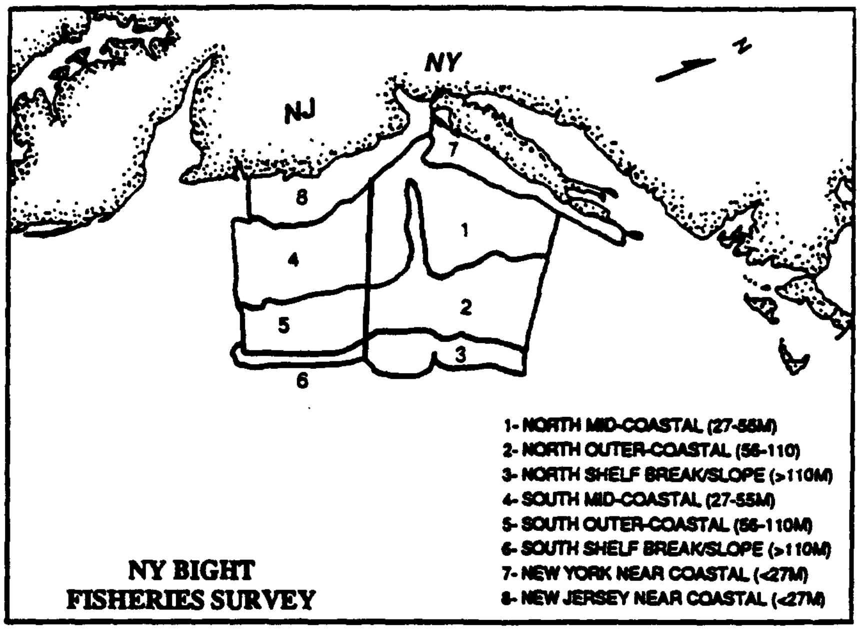


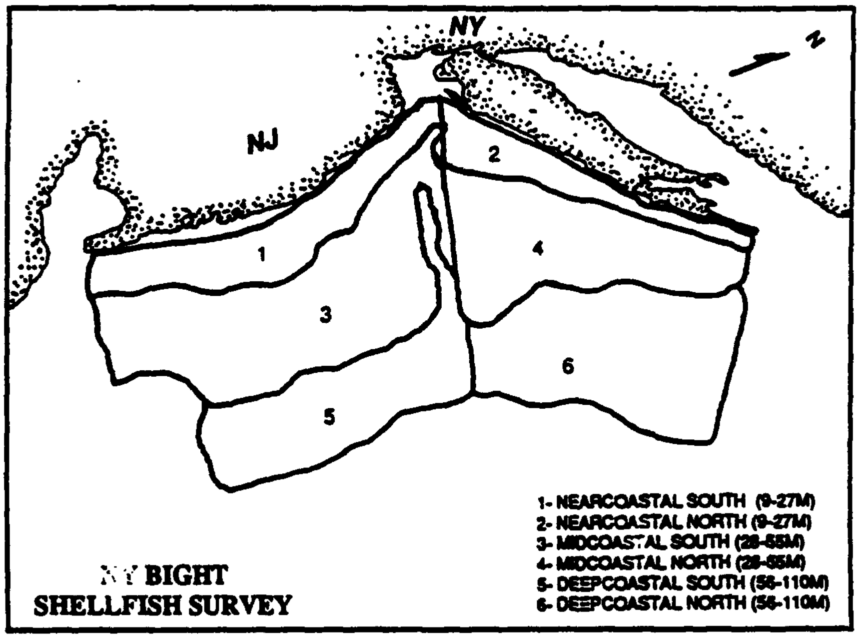


Figure 2-1. *Map of strata for NMFS Shellfish and Groundfish Surveys within the New York Bight.*

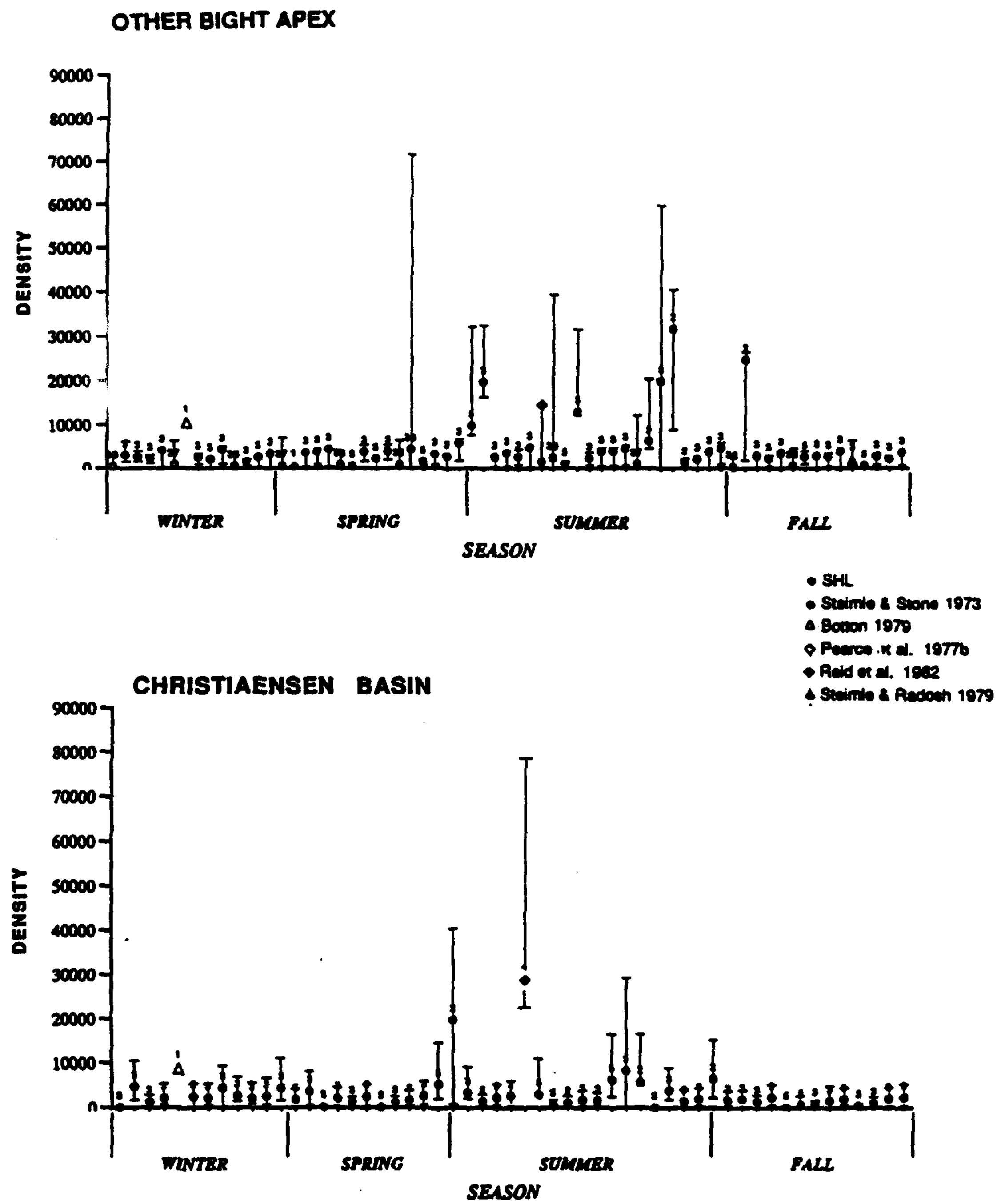
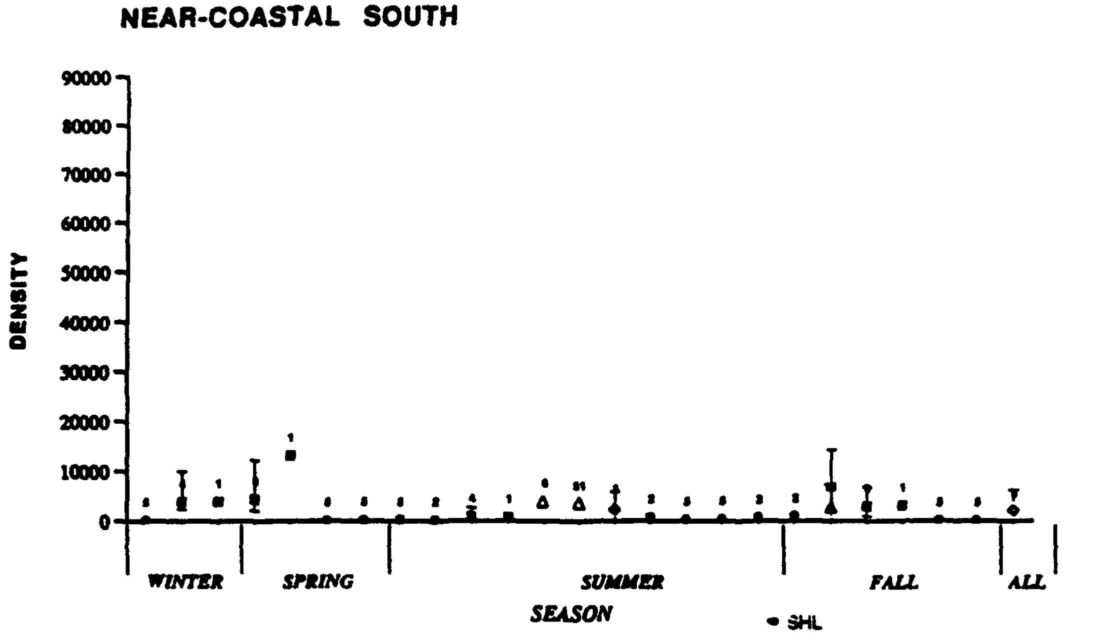


Figure 3-1. Mean density (per m²) and range of the total number of infauna and number of stations (n) per sampling event by stratum and season in the New York Bight.



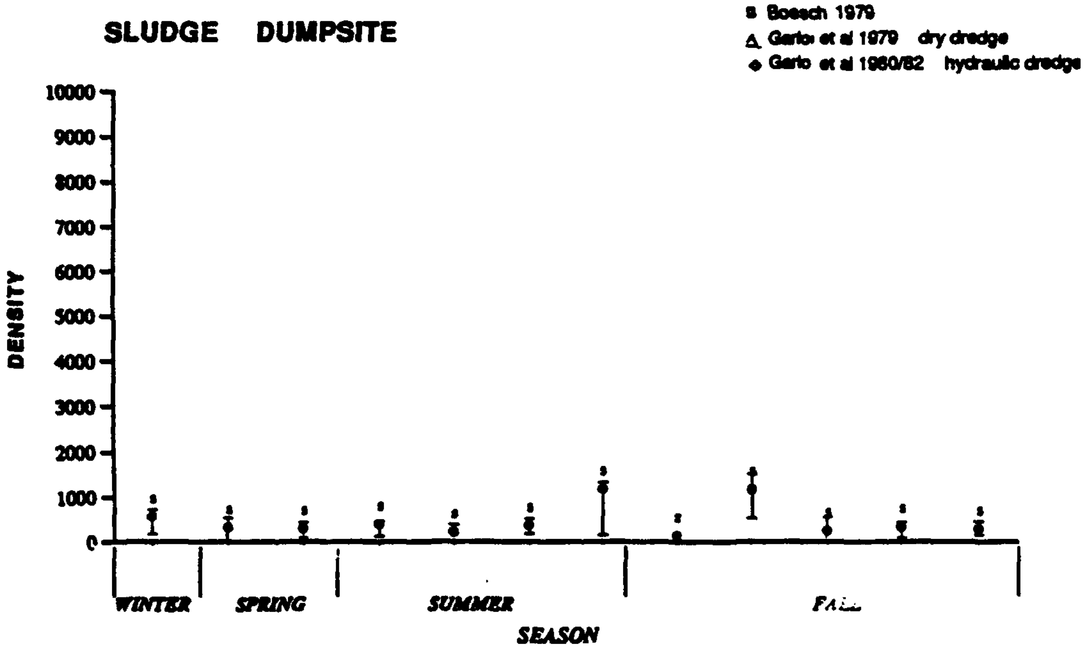


Figure 3-1. Mean density (per m²) and range of the total number of infauna and number of stations (n) per sampling event by stratum and season in the New York Bight.

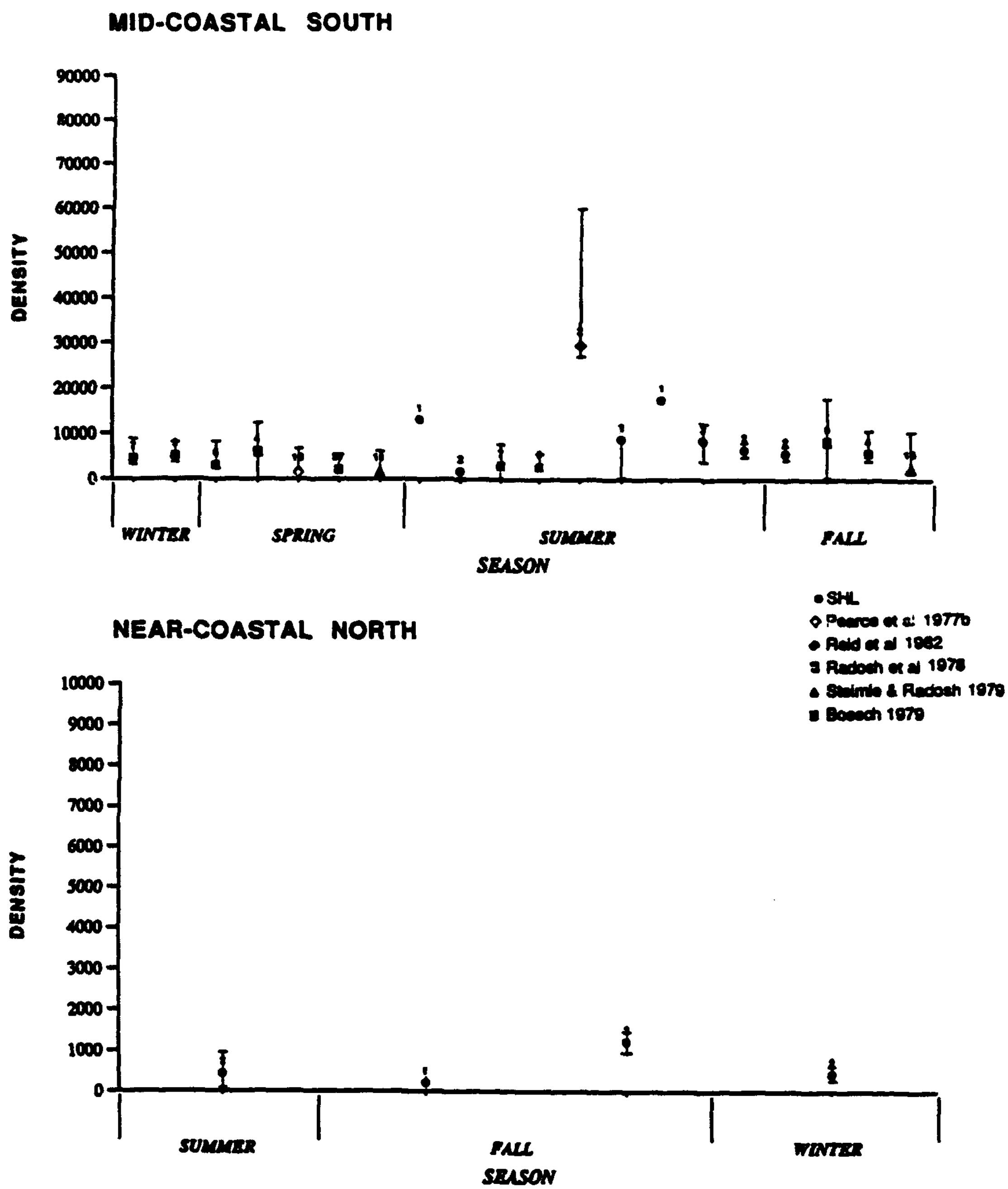


Figure 3-1. Mean density (per m^2) and range of the total number of infauna and number of stations (n) per sampling event by stratum and season in the New York Bight.

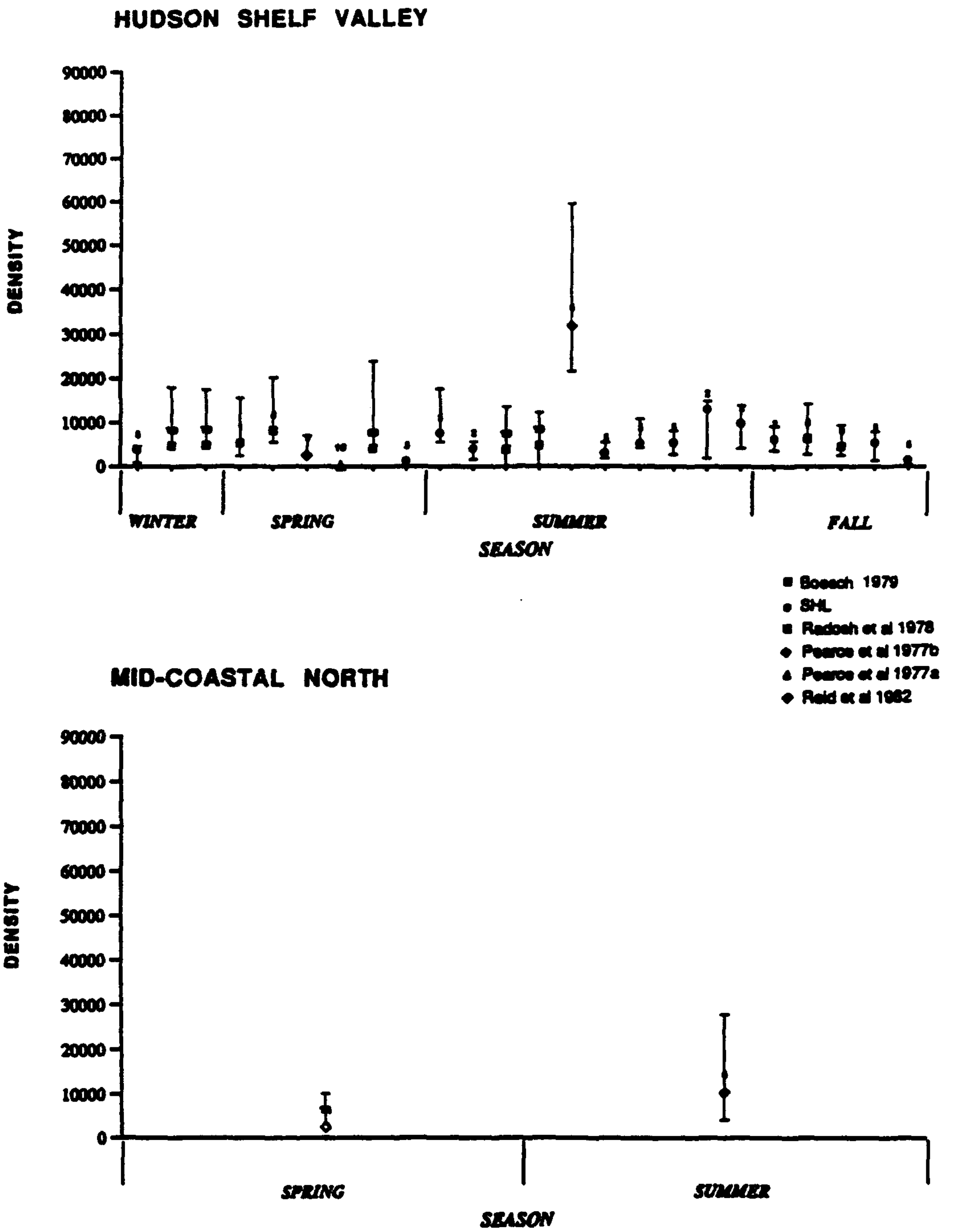


Figure 3-1. Mean density (per m²) and range of the total number of infauna and number of stations (n) per sampling event by stratum and season in the New York Bight.

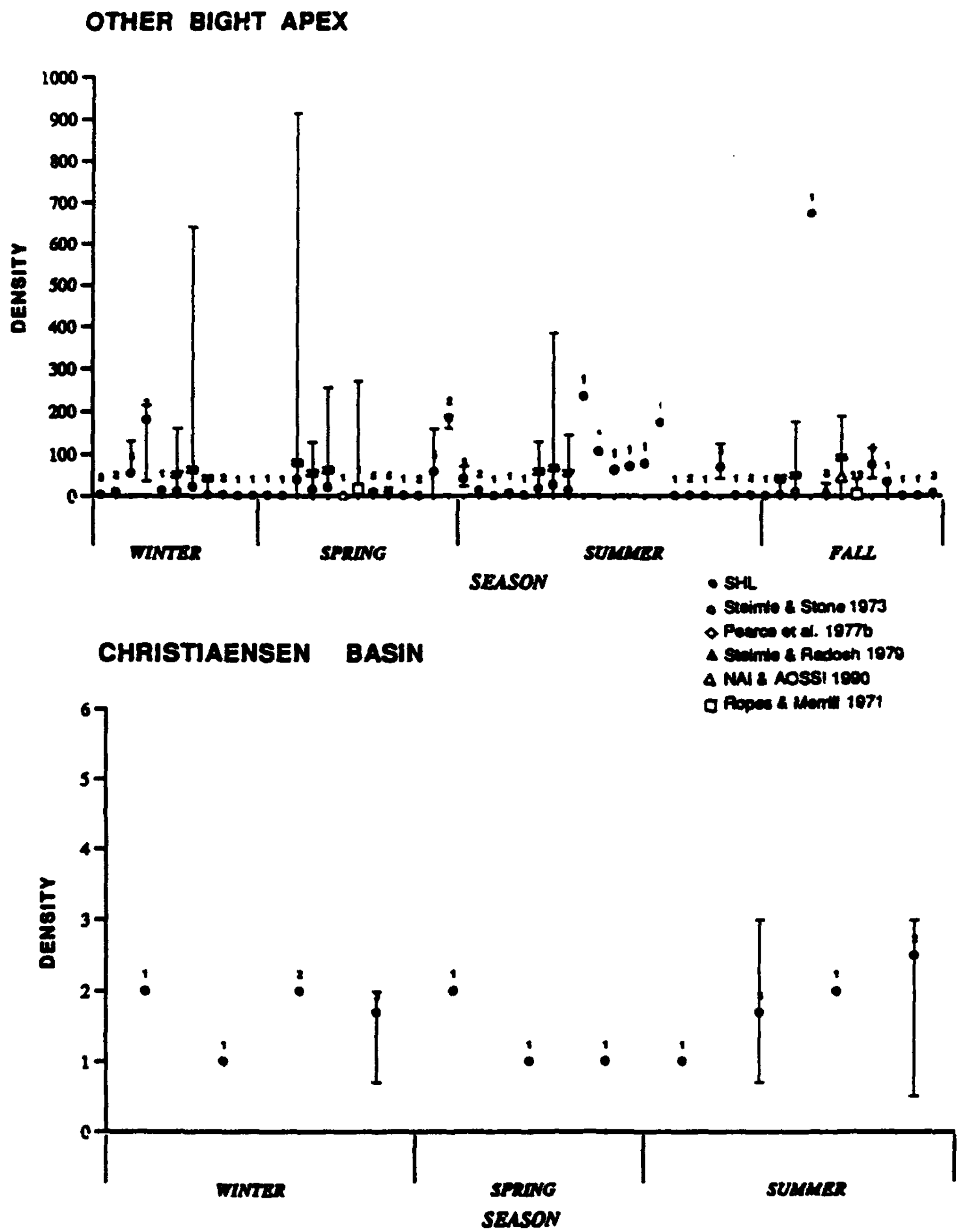
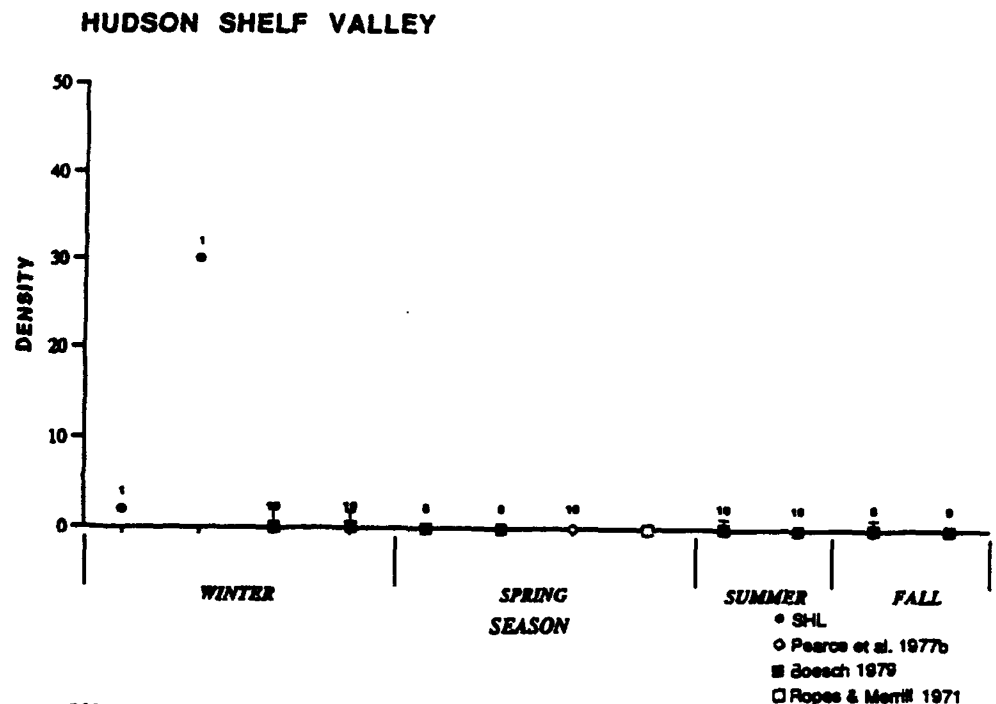


Figure 3-2. Mean density (per m², grab; per tow, dredge) of the surf clam *Spisula solidissima* and the number of stations (n) per sampling event by stratum and season.



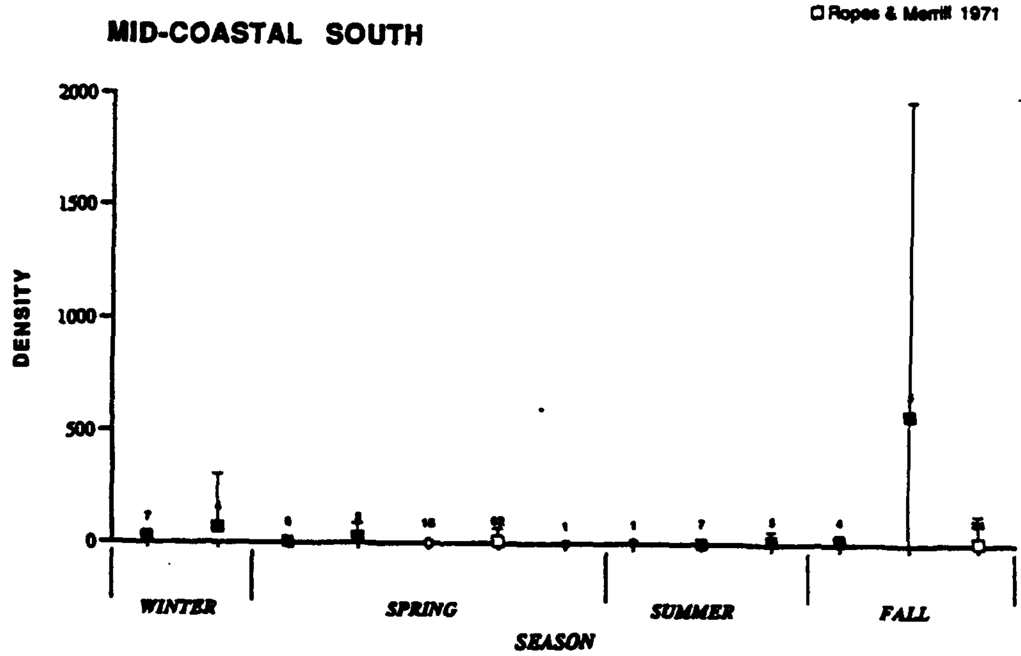


Figure 3-2. Mean density (per m², grab; per tow, dredge) of the surf clam *Spisula solidissima* and the number of stations (n) per sampling event by stratum and season.

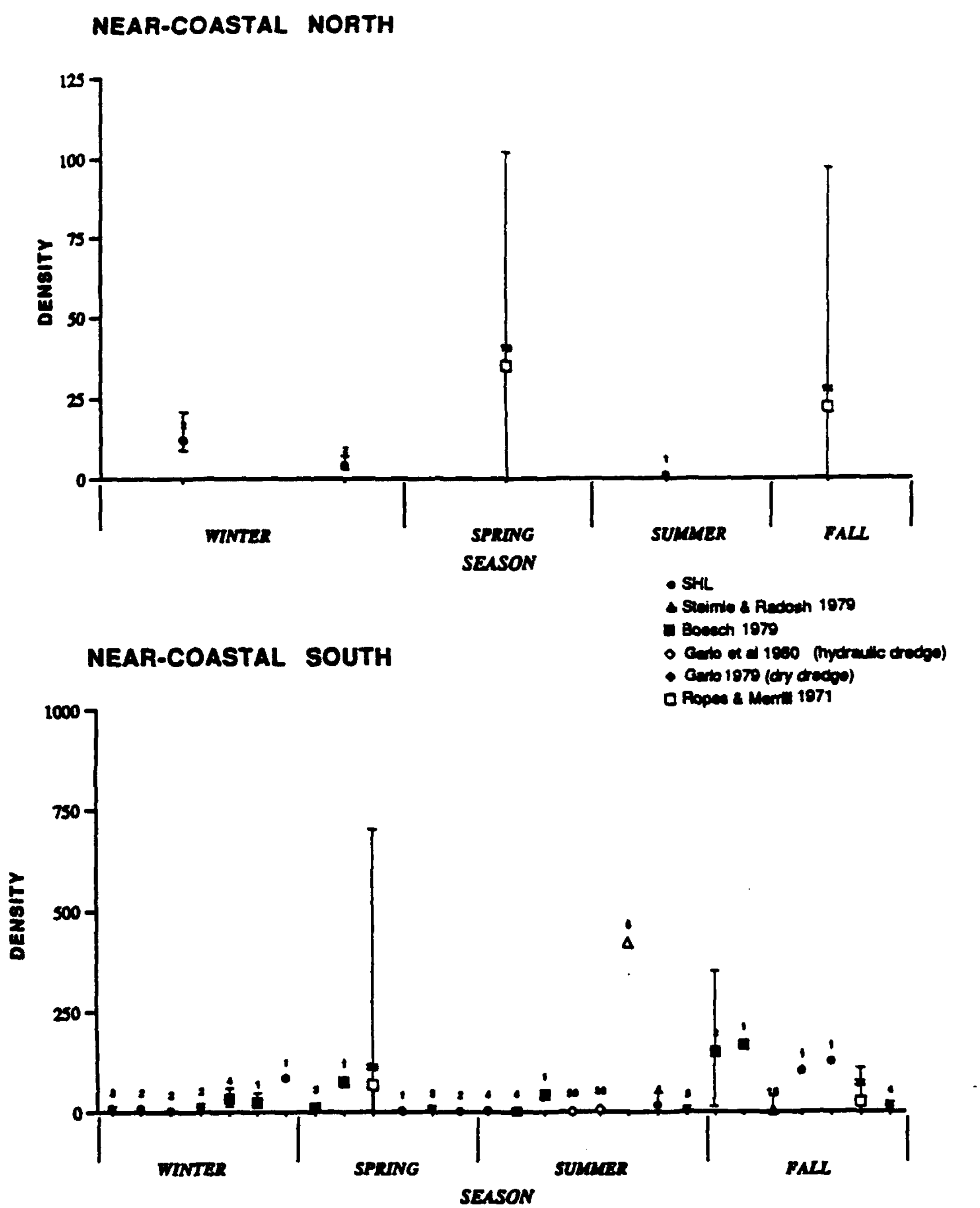


Figure 3-2. Mean density (per m², grab; per tow, dredge) of the surf clam *Spisula solidissima* and the number of stations (n) per sampling event by stratum and season.

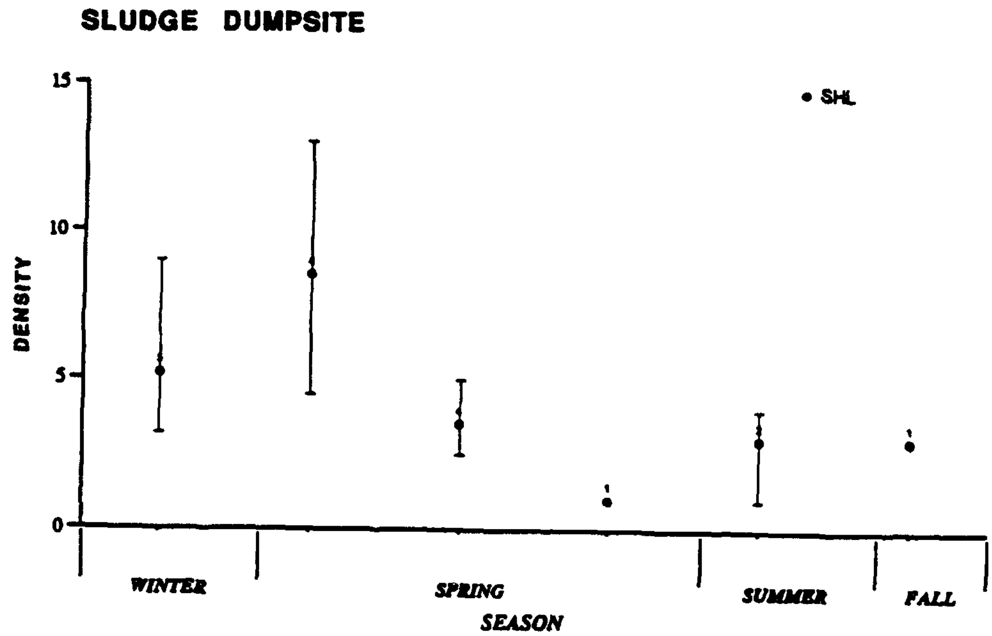


Figure 3-2. Mean density (per m², grab; per tow, dredge) of the surf clam *Spisula solidissima* and the number of stations (n) per sampling event by stratum and season.

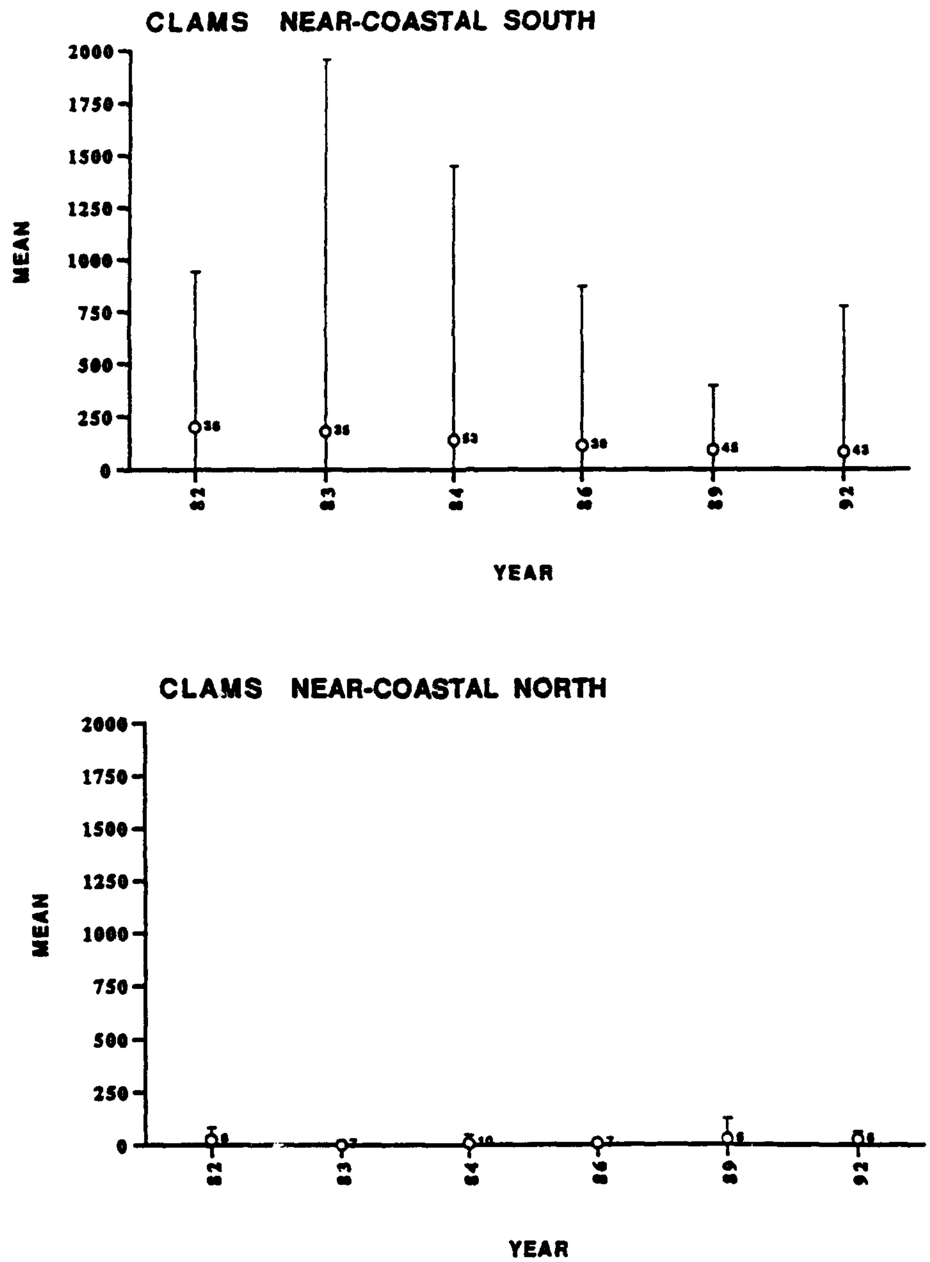


Figure 3-3. Mean catch per unit effort and range for the surf clam *Spisula solidissima* and number of stations (n) per sampling event by year, season, and stratum collected during NMFS shellfish surveys.

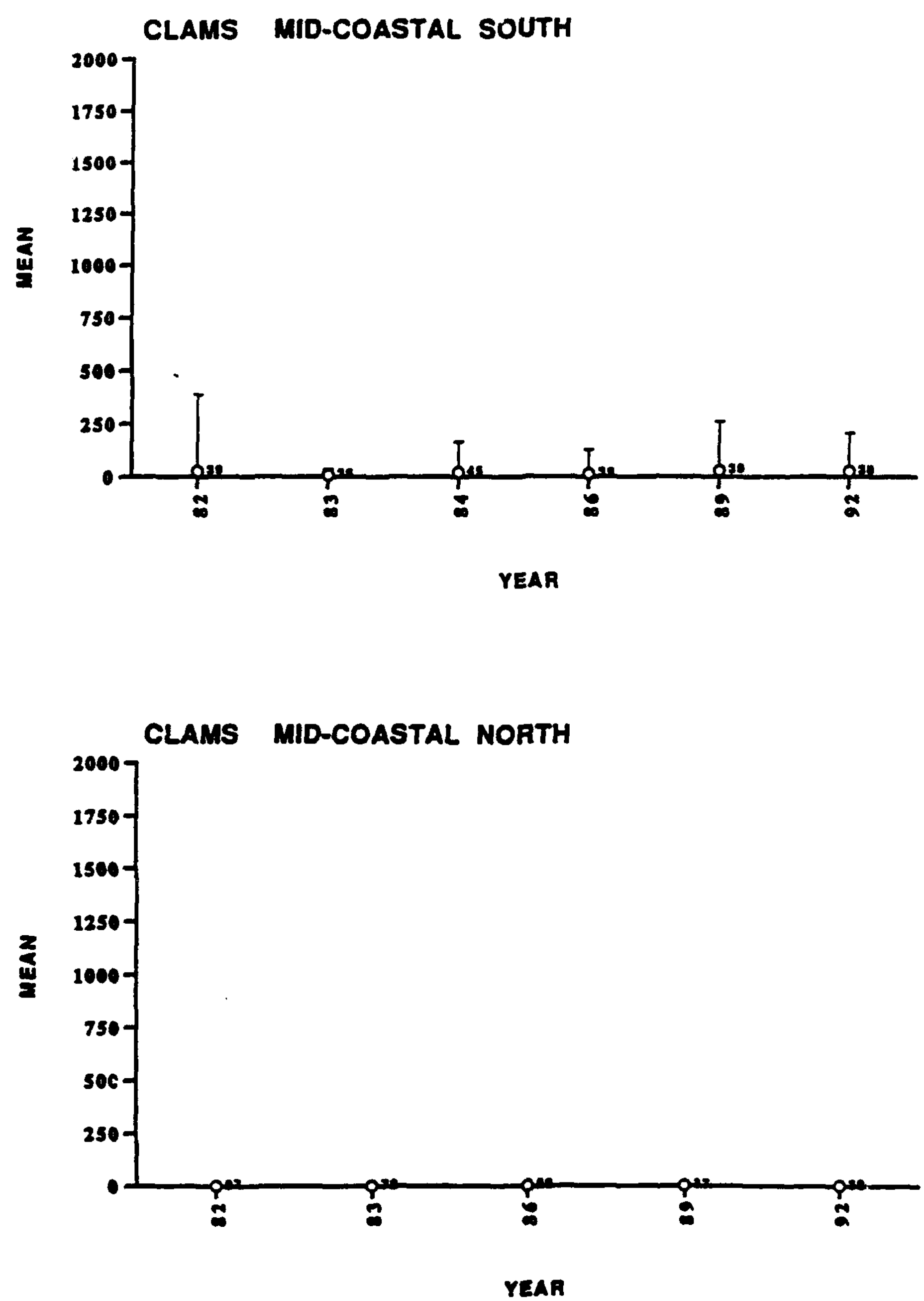
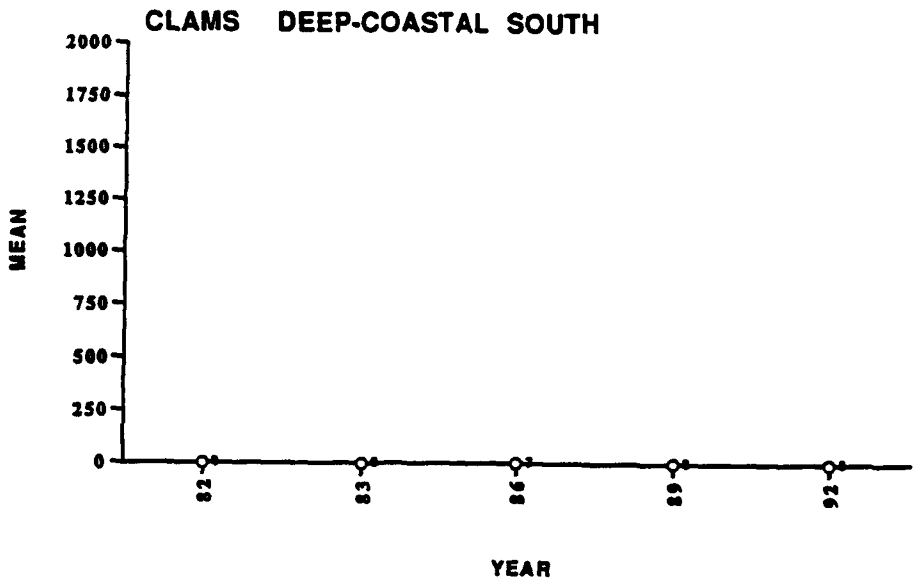


Figure 3-3. Mean catch per unit efffort and range for the surf clam *Spisula solidissima* and number of stations (n) per sampling event by year, season, and stratum collected during NMFS shellfish surveys.



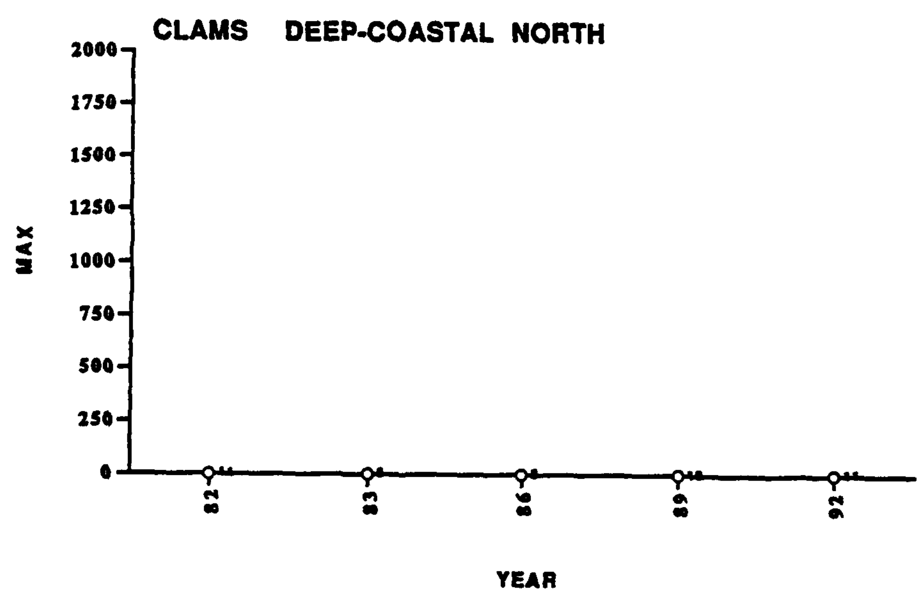


Figure 3-3. Mean catch per unit efffort and range for the surf clam *Spisula solidissima* and number of stations (n) per sampling event by year, season, and stratum collected during NMFS shellfish surveys.

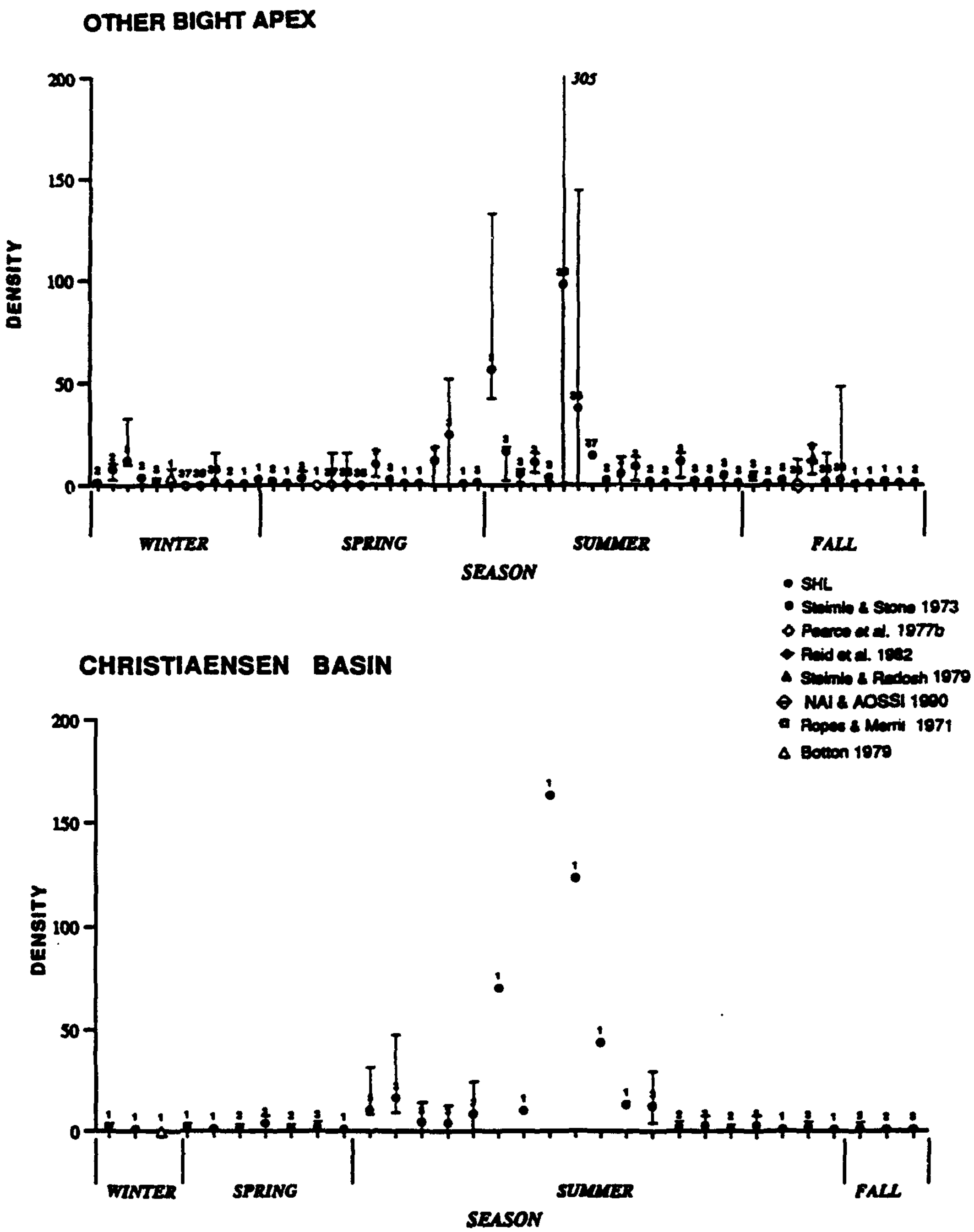


Figure 3-4. Mean density (per m²) and range of the rock crab and number of stations (n) per sampling event by stratum and season.

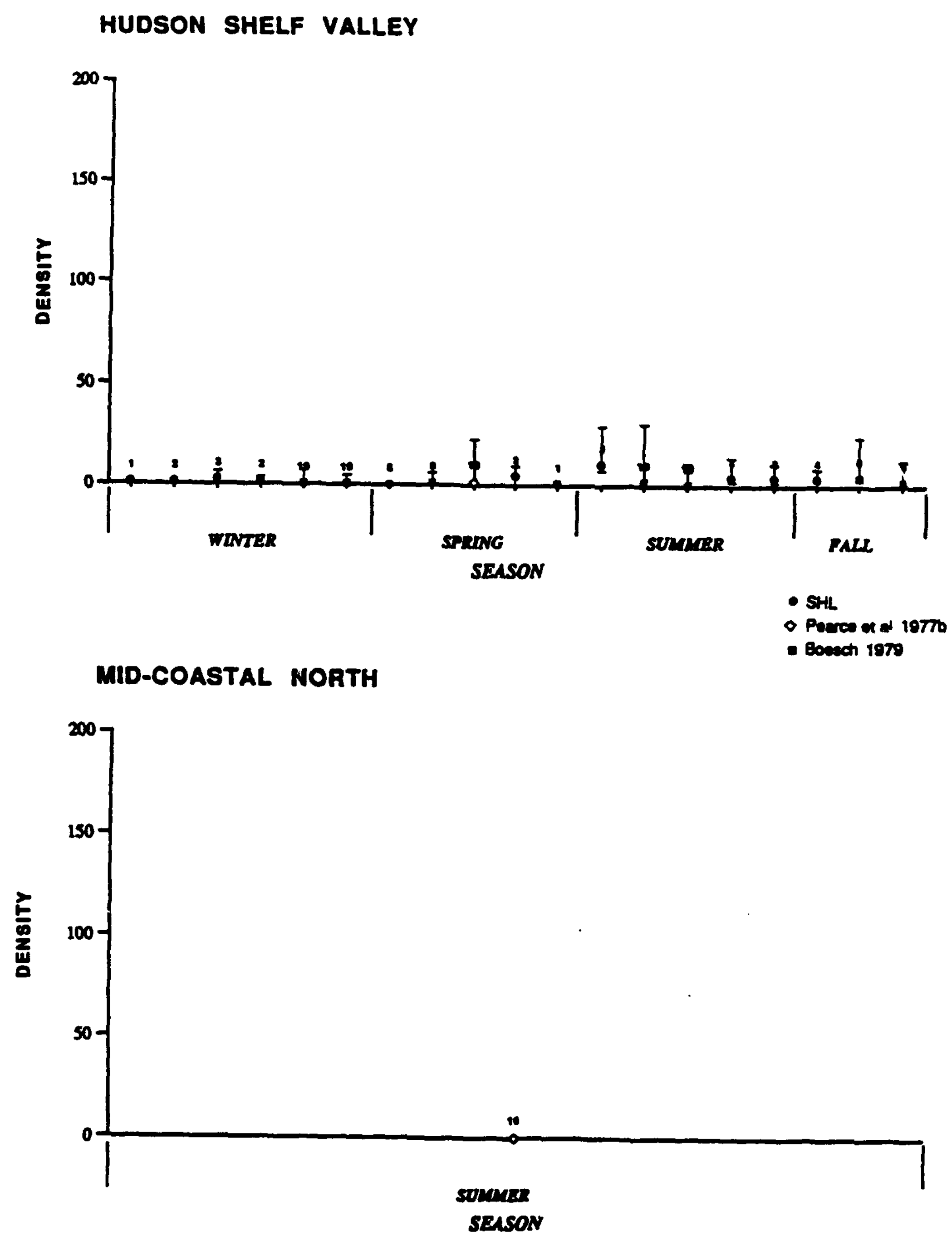


Figure 3-4. Mean density (per m²) and range of the rock crab and number of stations (n) per sampling event by stratum and season.

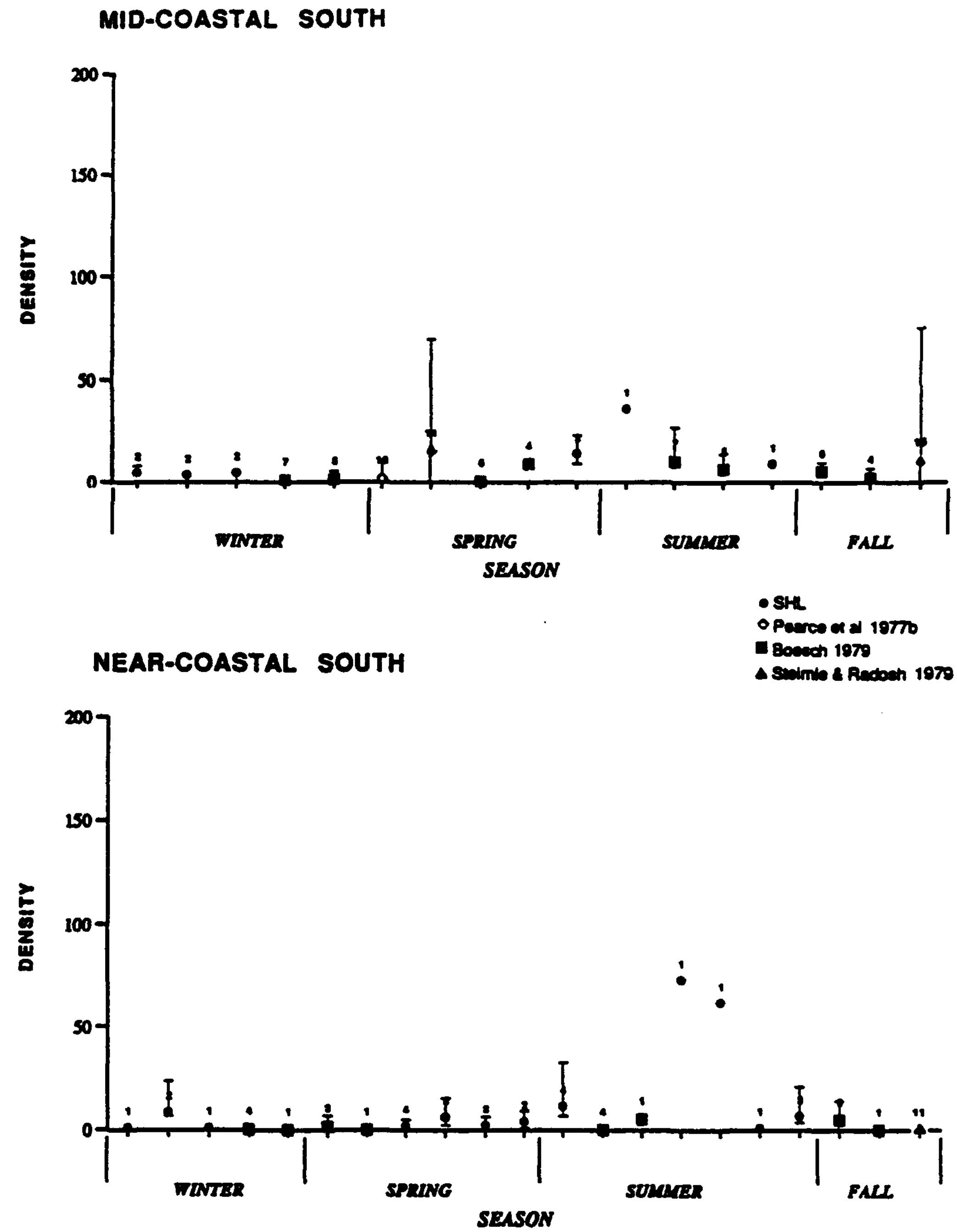


Figure 3-4. Mean density (per m²) and range of the rock crab and number of stations (n) per sampling event by stratum and season.

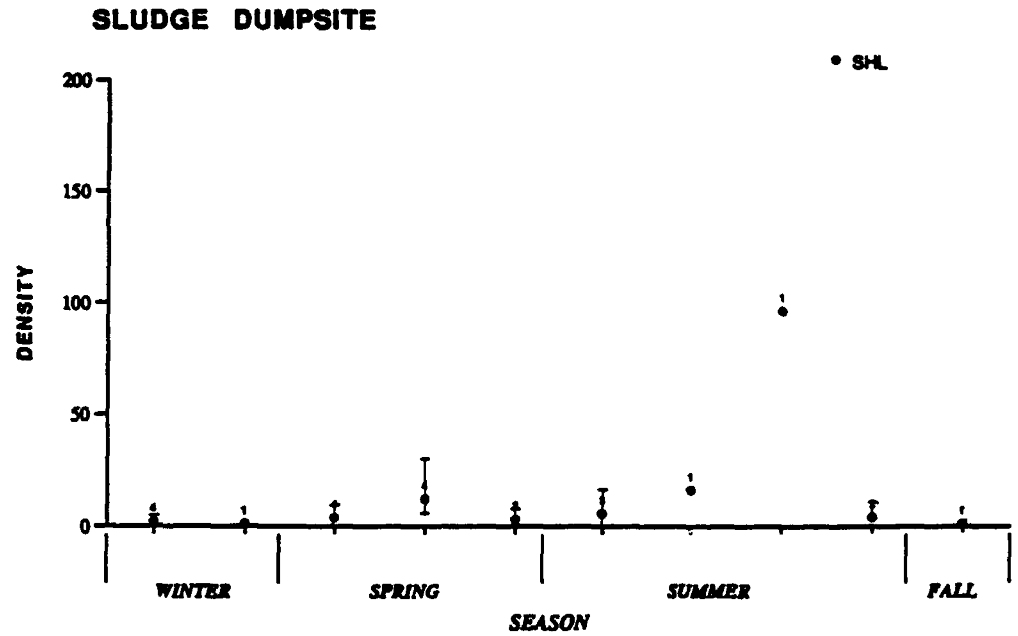


Figure 3-4. Mean density (per m²) and range of the rock crab and number of stations (n) per sampling event by stratum and season.

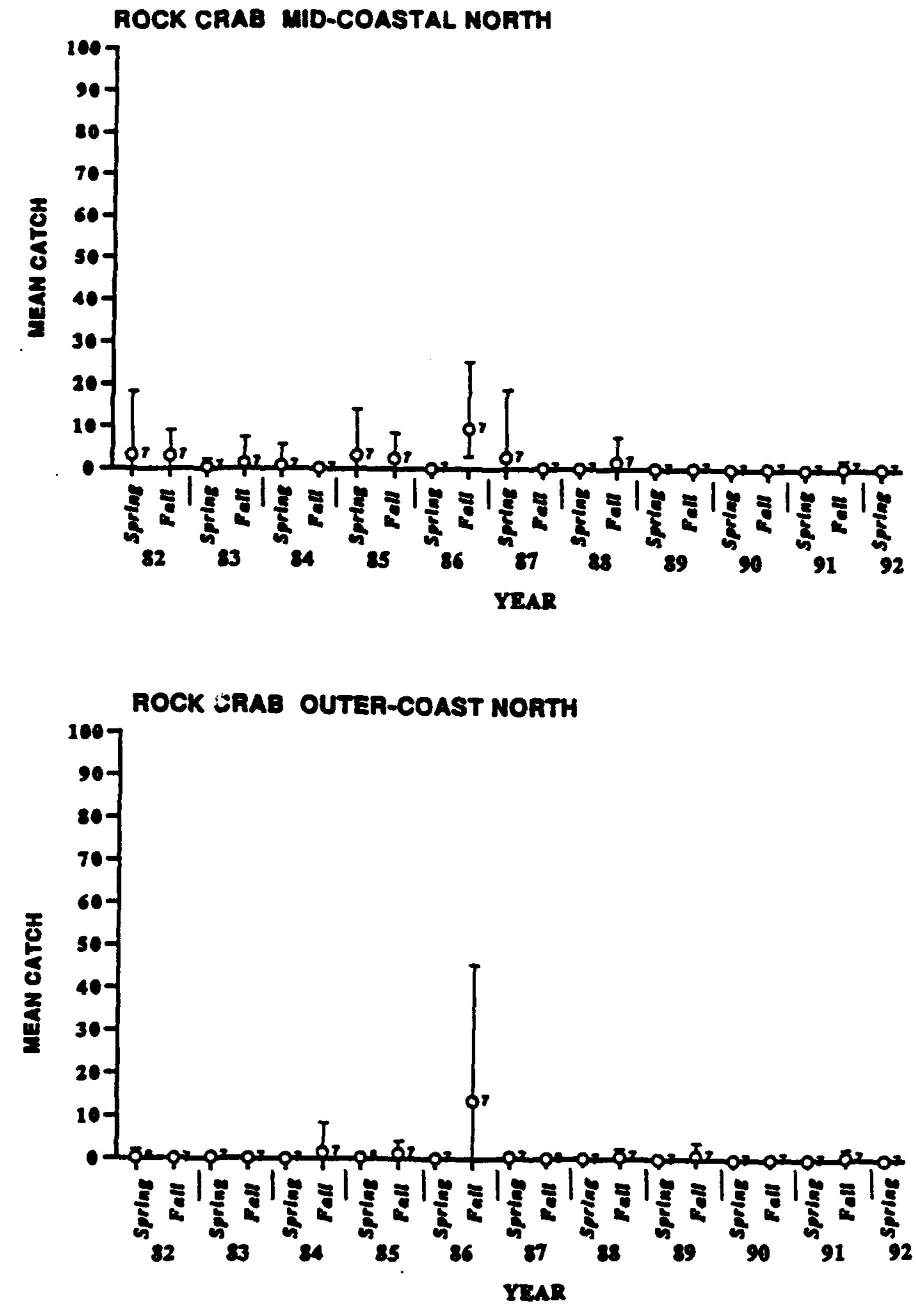
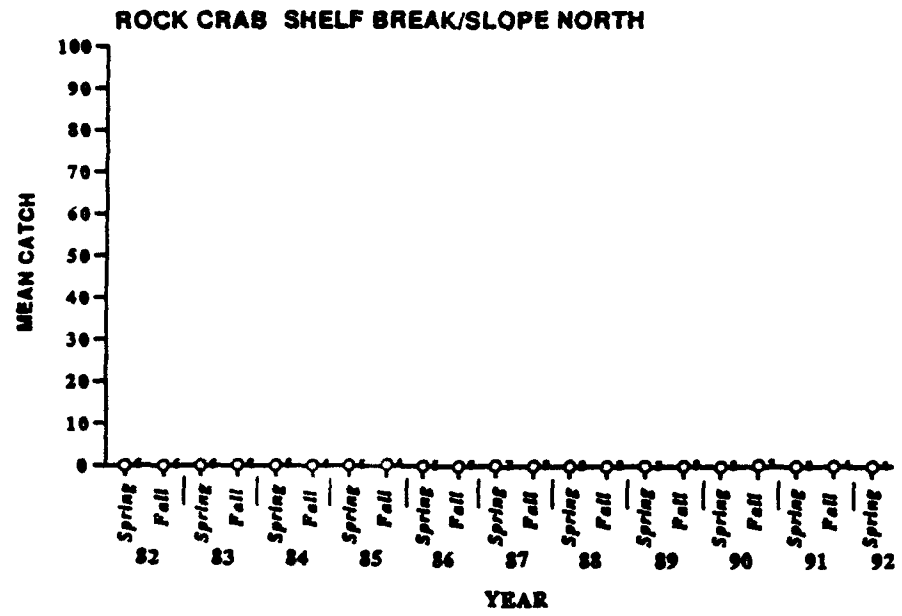


Figure 3-5. Mean catch per unit effort, range and number of stations (n) of rock crab collected during NMFS groundfish surveys by year, season and stratum.



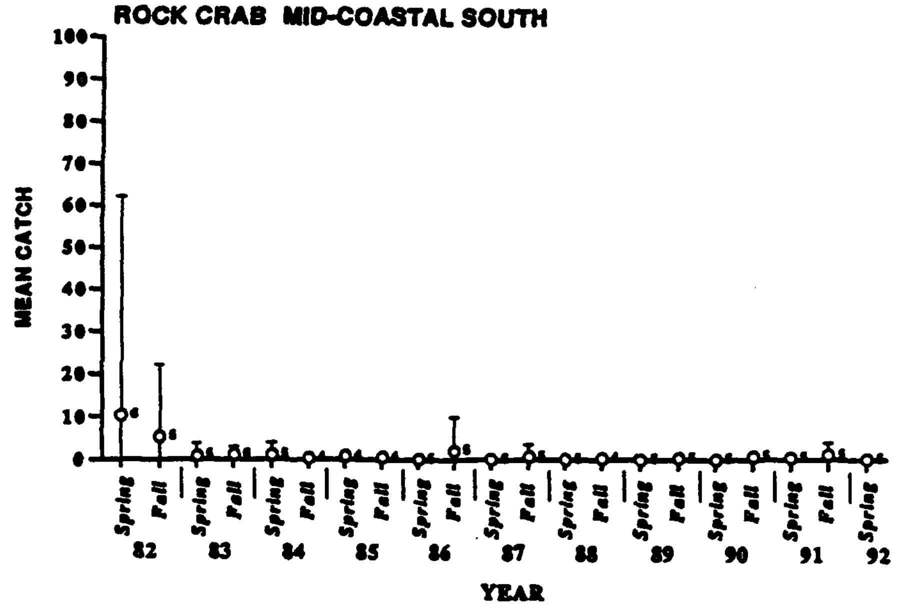
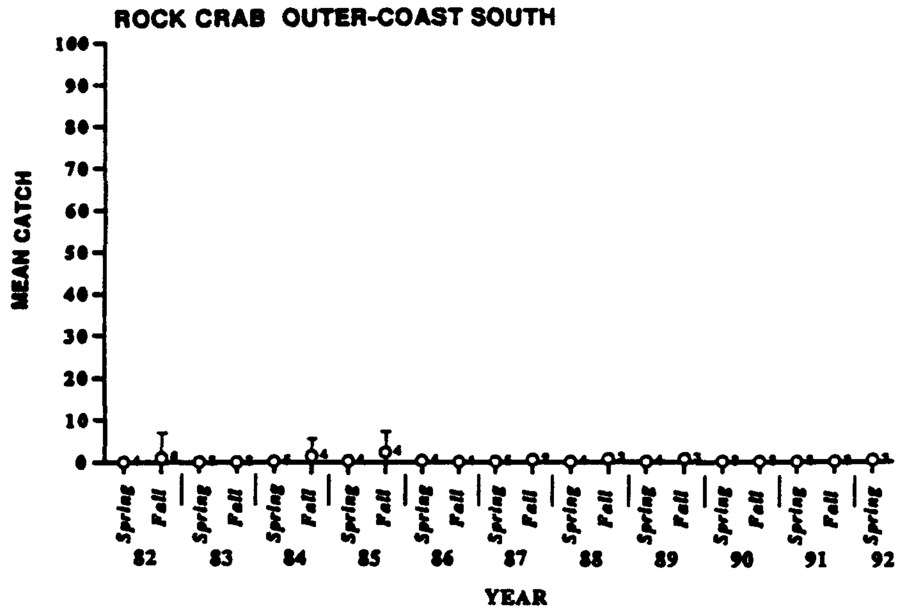


Figure 3-5. (Continued).



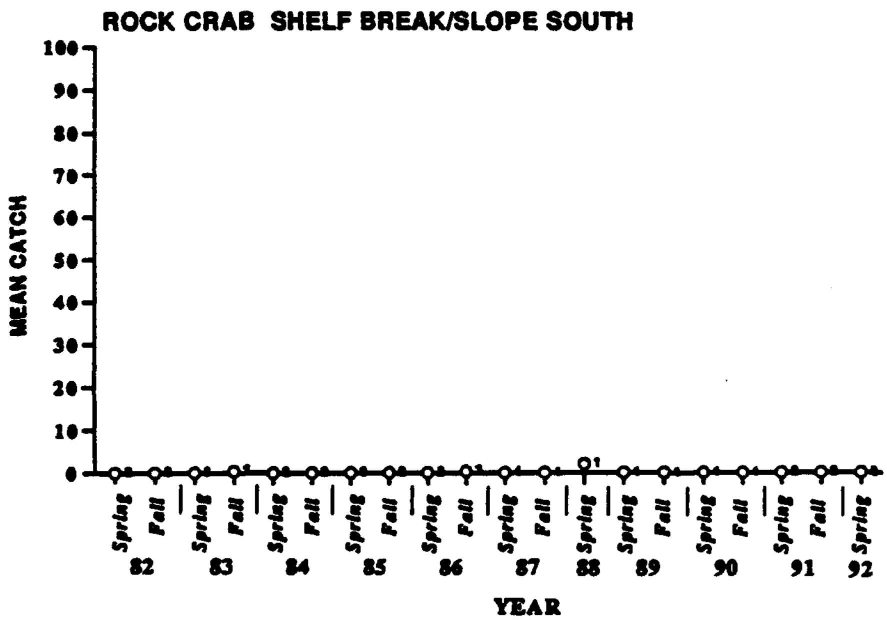
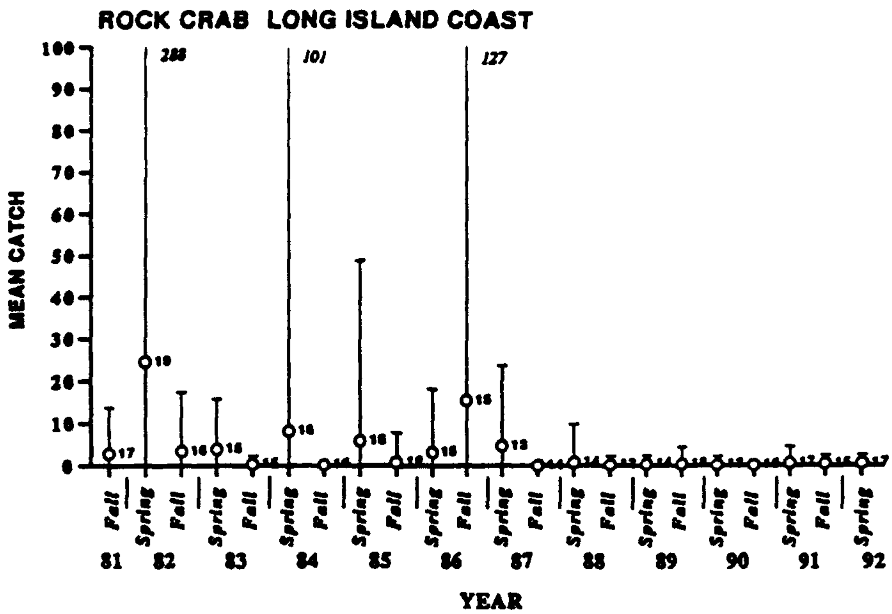


Figure 3-5. (Continued).



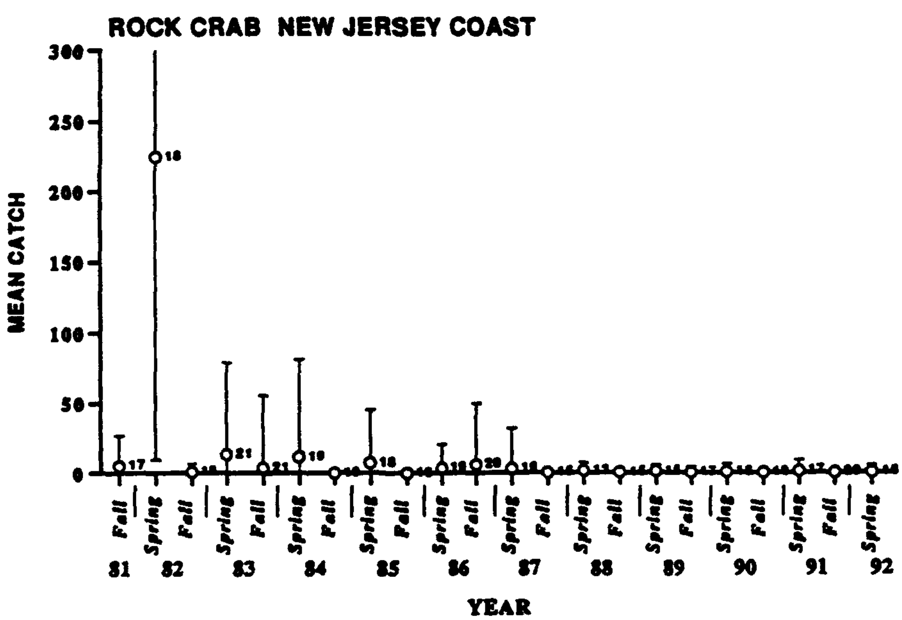
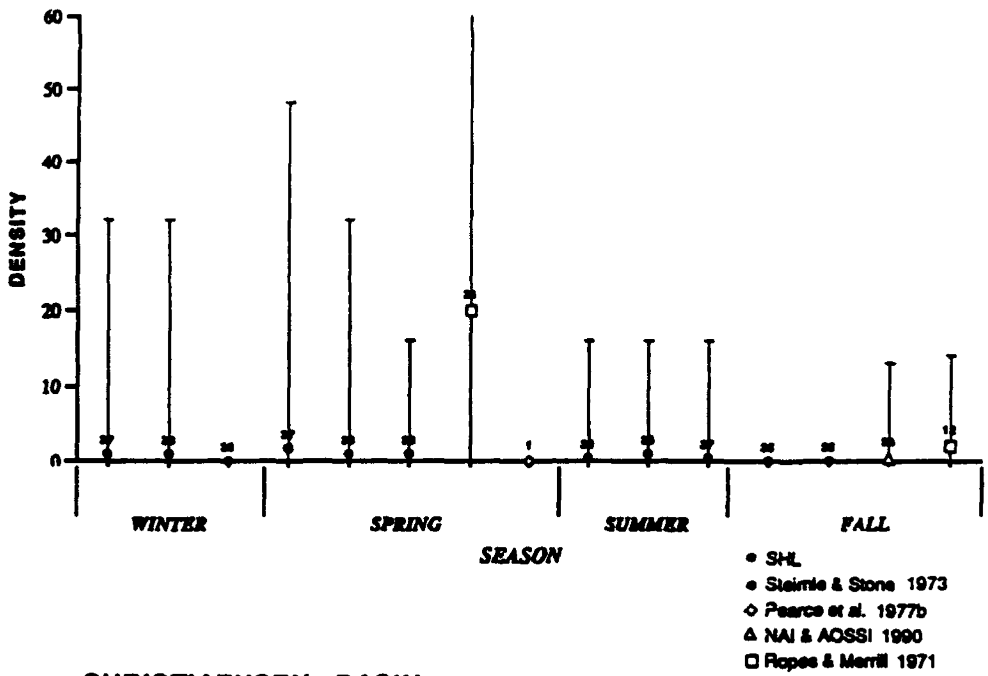


Figure 3-5. (Continued).

OTHER BIGHT APEX



CHRISTIAENSEN BASIN

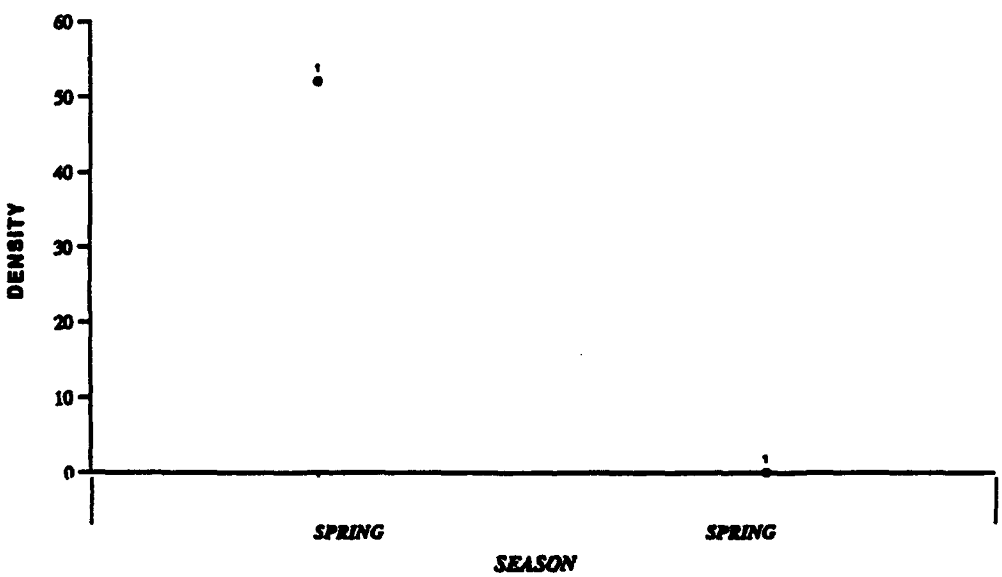
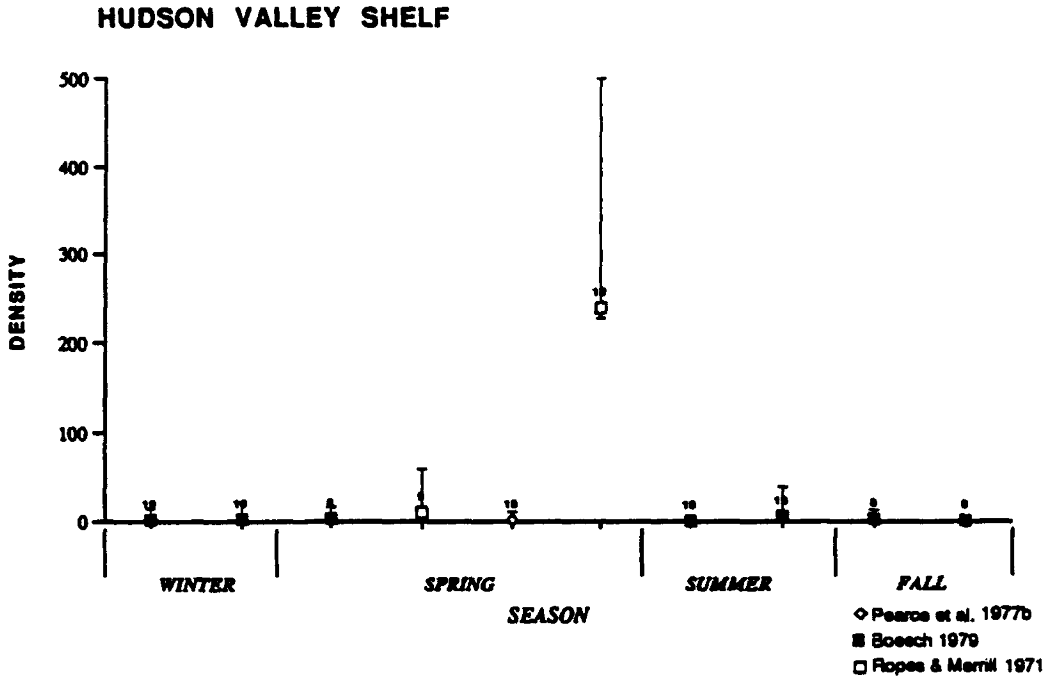


Figure 3-6. Mean density (per m^2) and range for the ocean quahog and number of stations (n) by year, season and stratum.



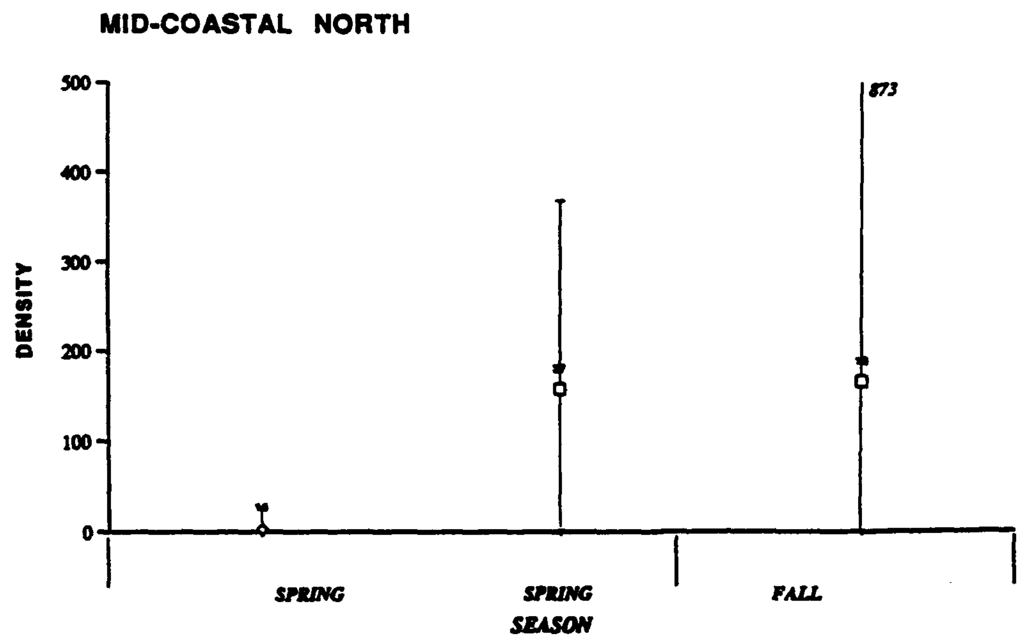


Figure 3-6. Mean density (per m²) and range for the ocean quahog and number of stations (n) by year, season and stratum.

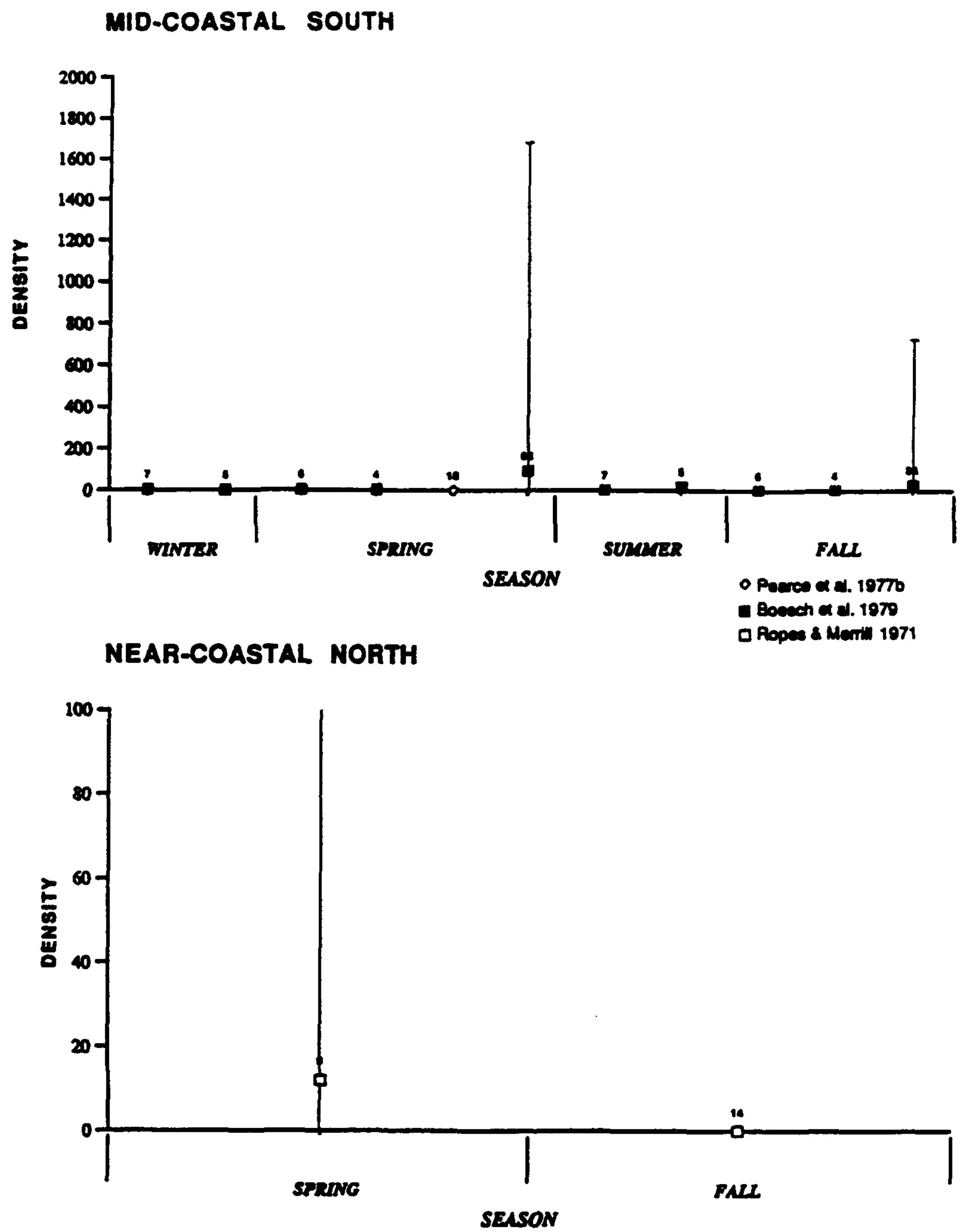


Figure 3-6. Mean density (per m²) and range for the ocean quahog and number of stations (n) by year, season and stratum.

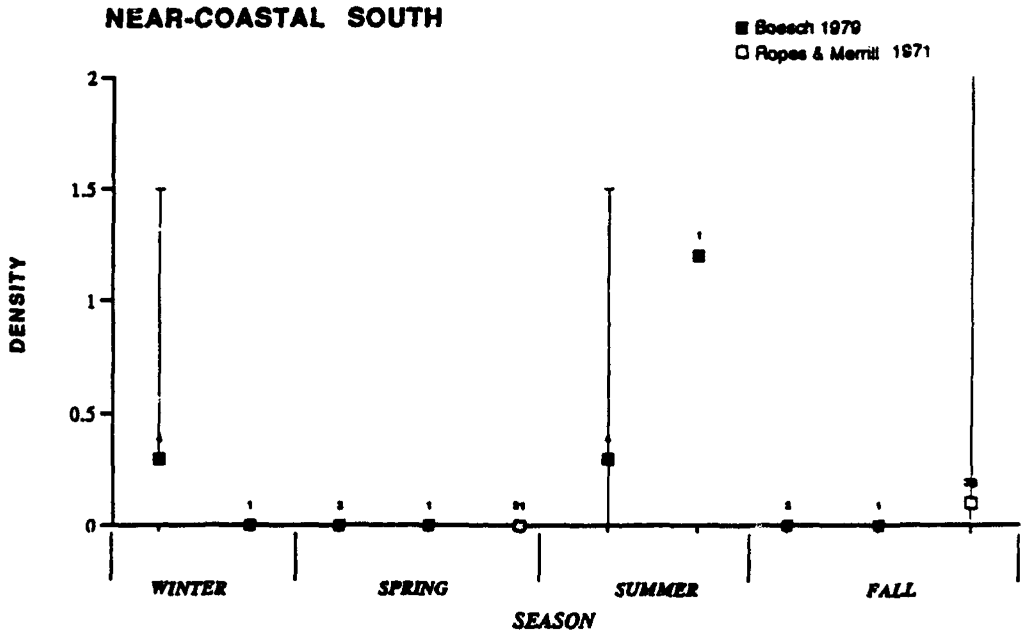
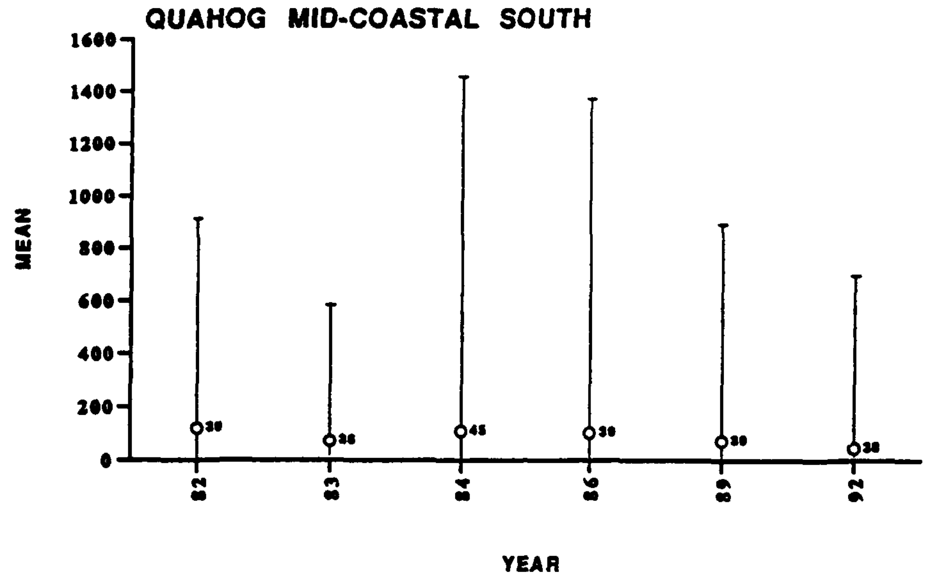


Figure 3-6. Mean density (per m²) and range for the ocean quahog and number of stations (n) by year, season and stratum.



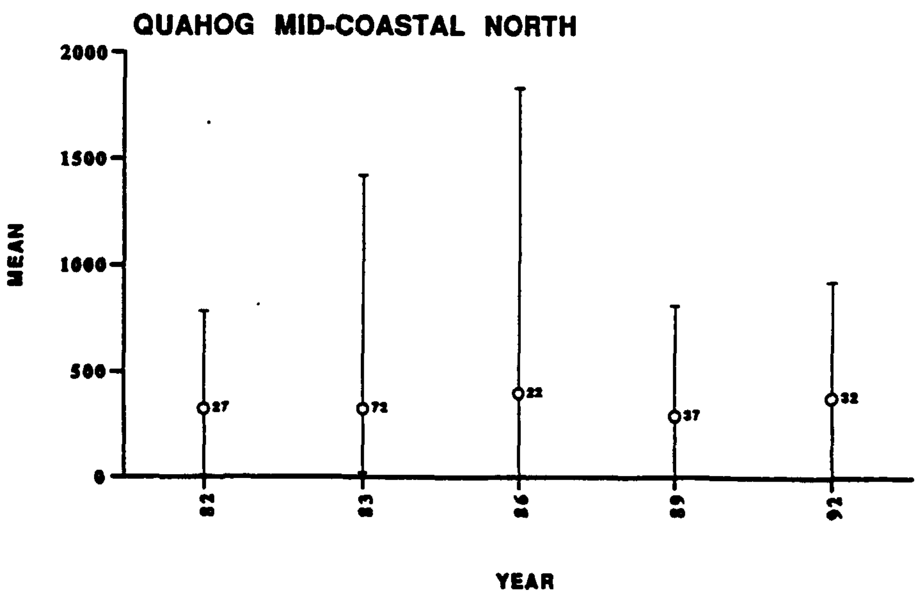


Figure 3-7. Mean catch per unit effort and range for ocean quahog and number of stations (n) by year, season, and stratum collected during NMFS shellfish surveys.

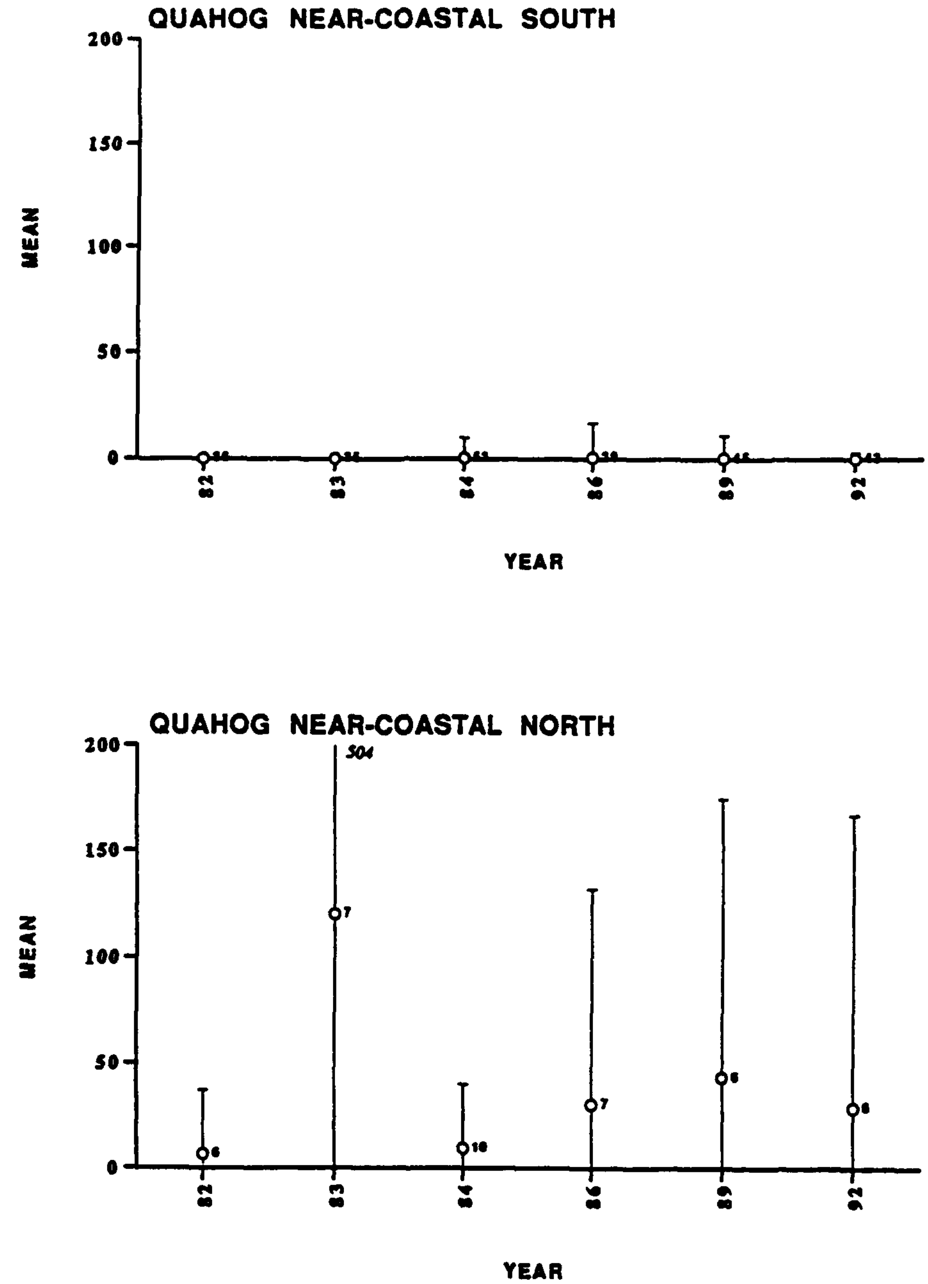


Figure 3-7. Mean catch per unit effort and range for ocean quahog and number of stations (n) by year, season, and stratum collected during NMFS shellfish surveys.

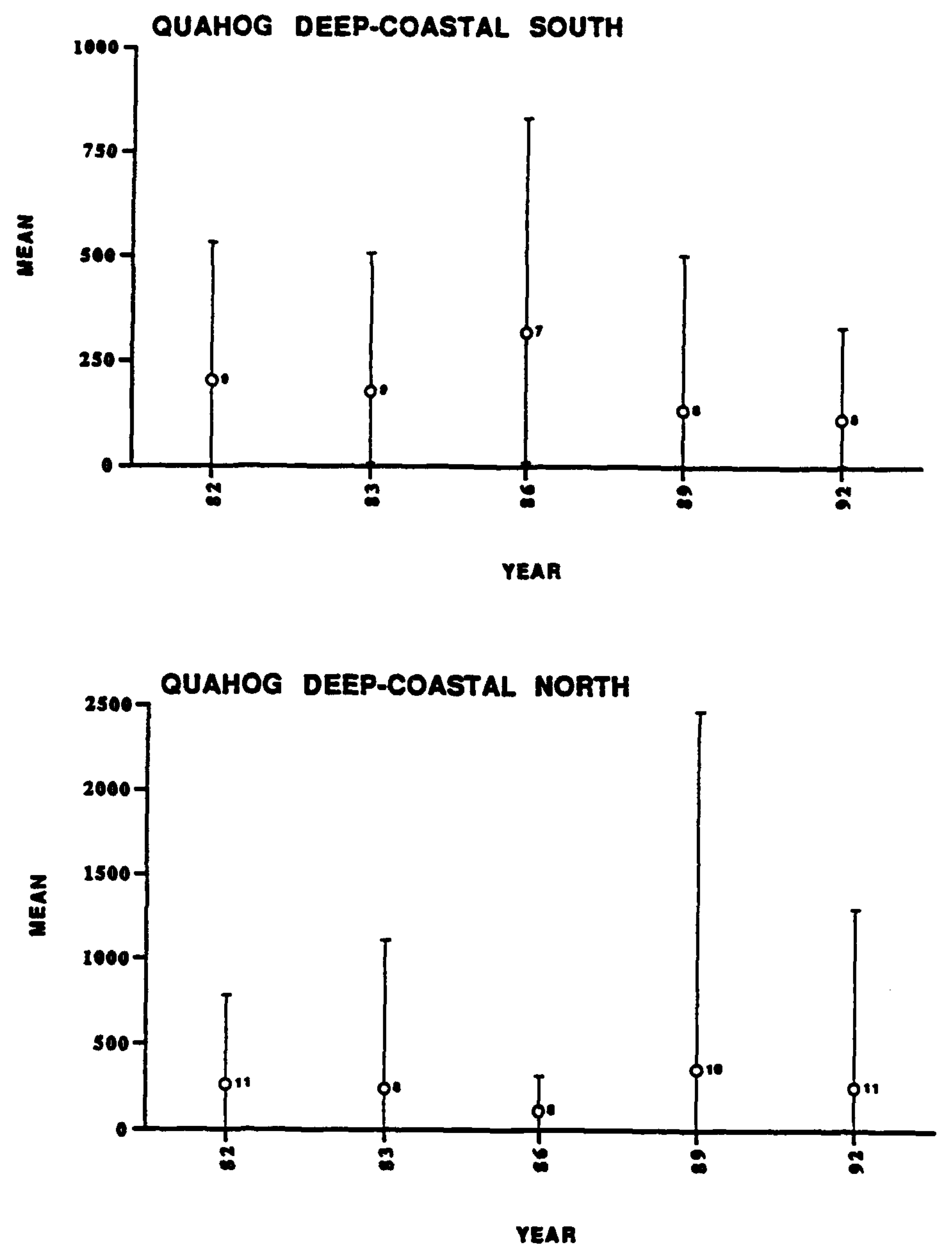
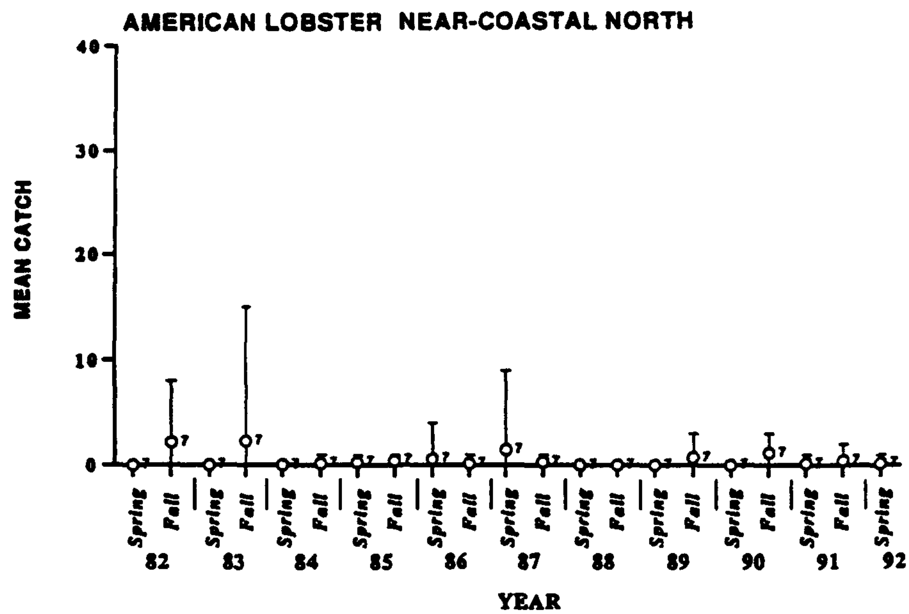


Figure 3-7. Mean catch per unit effort and range for ocean quahog and number of stations (n) by year, season, and stratum collected during NMFS shellfish surveys.



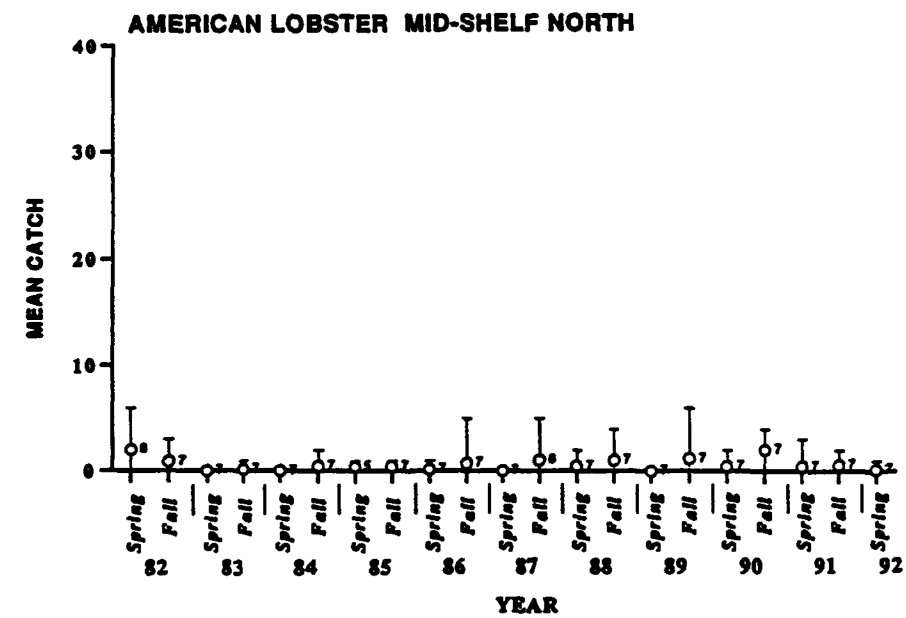
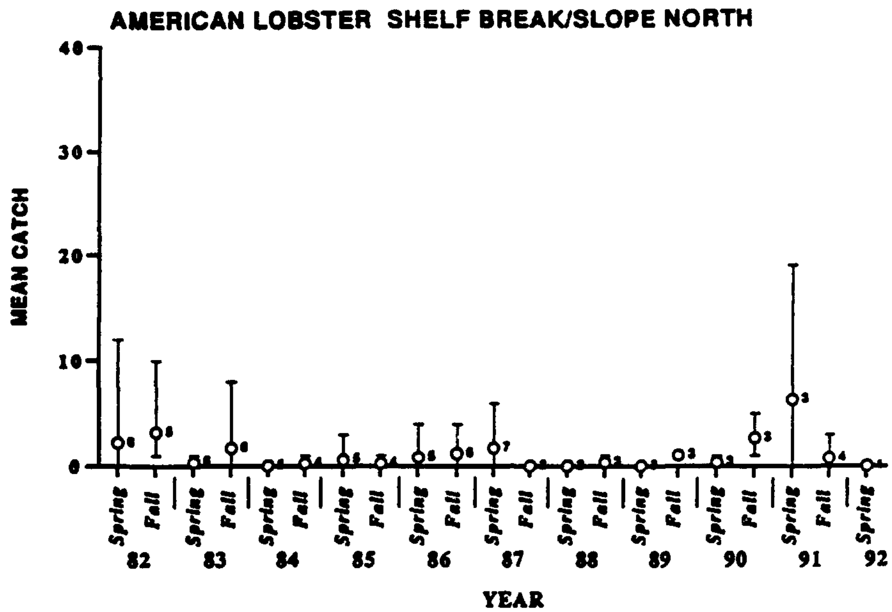


Figure 3-8. Mean catch per unit effort, range and number of stations (n) of American Lobster collected during NMFS groundfish surveys.



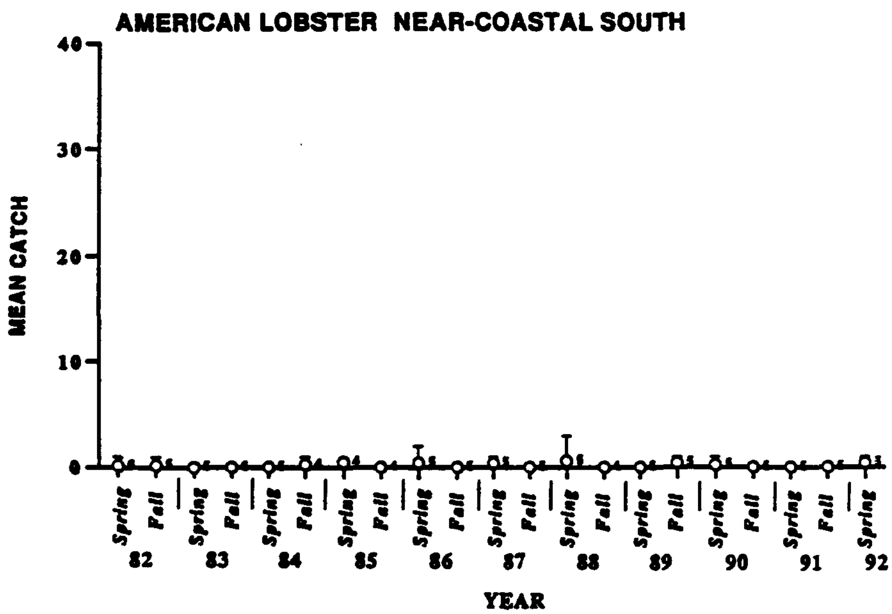
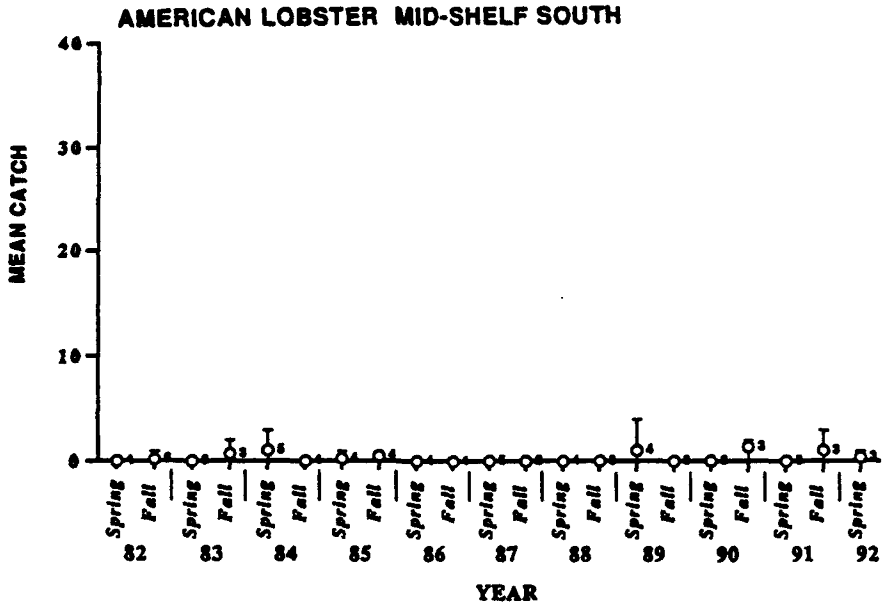
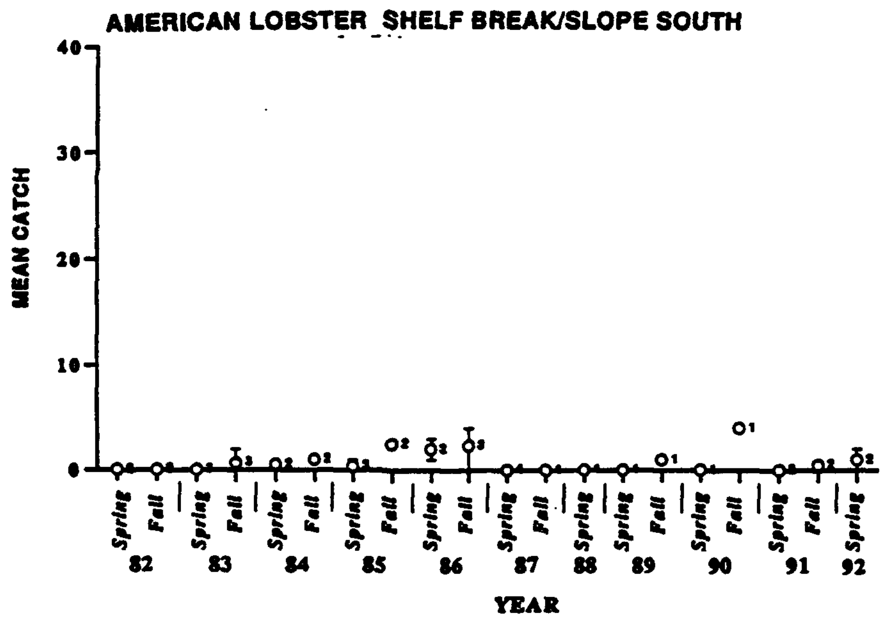


Figure 3-8. (Continued).





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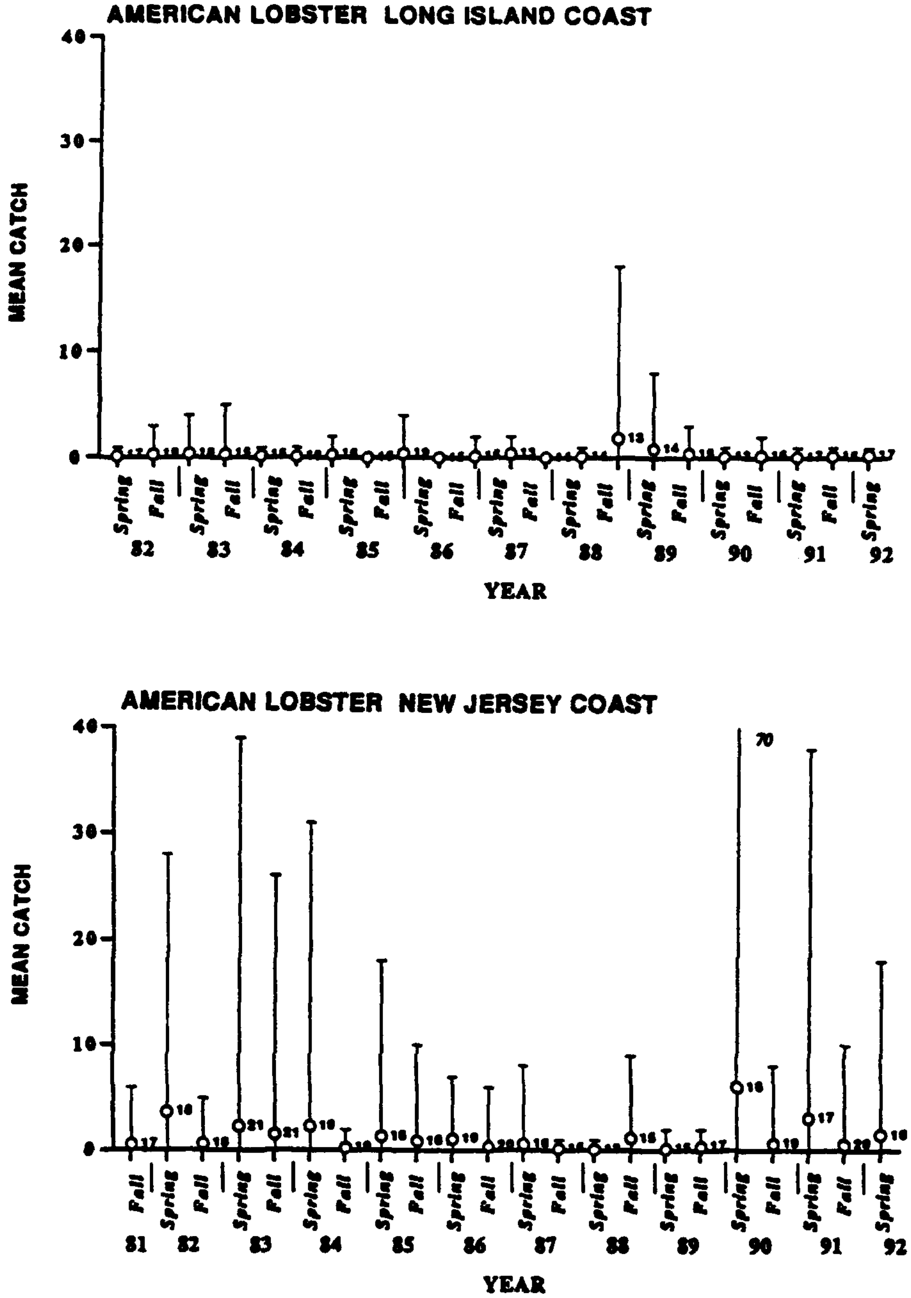
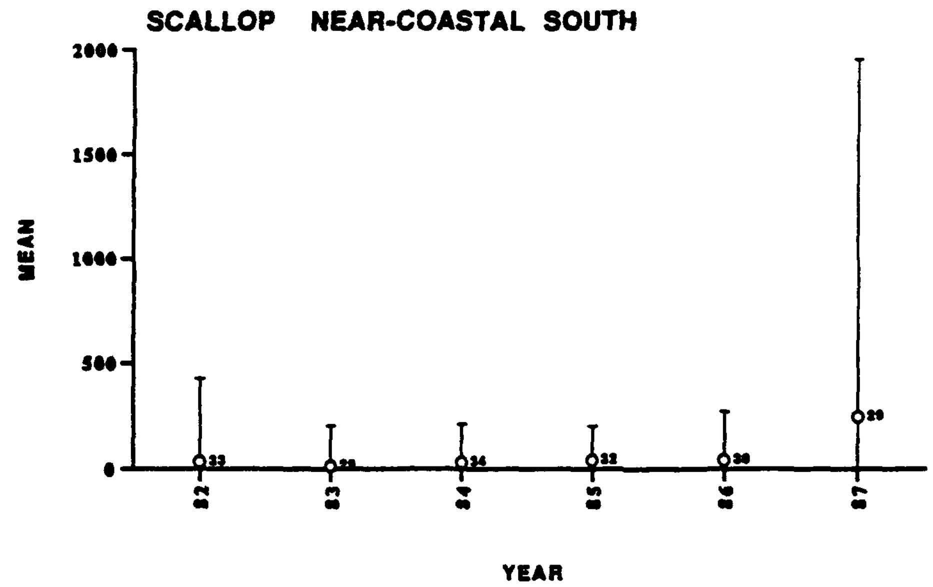


Figure 3-8. (Continued).



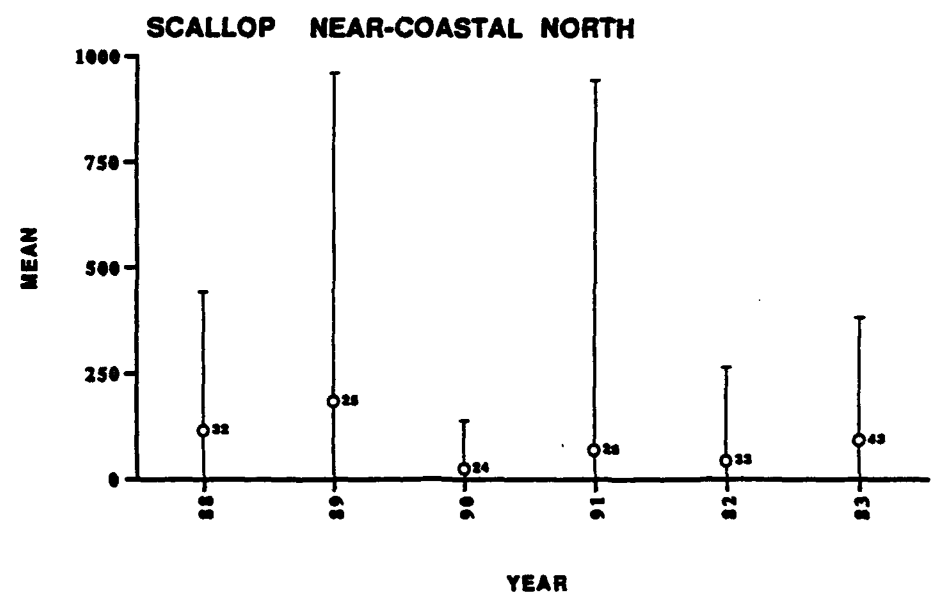
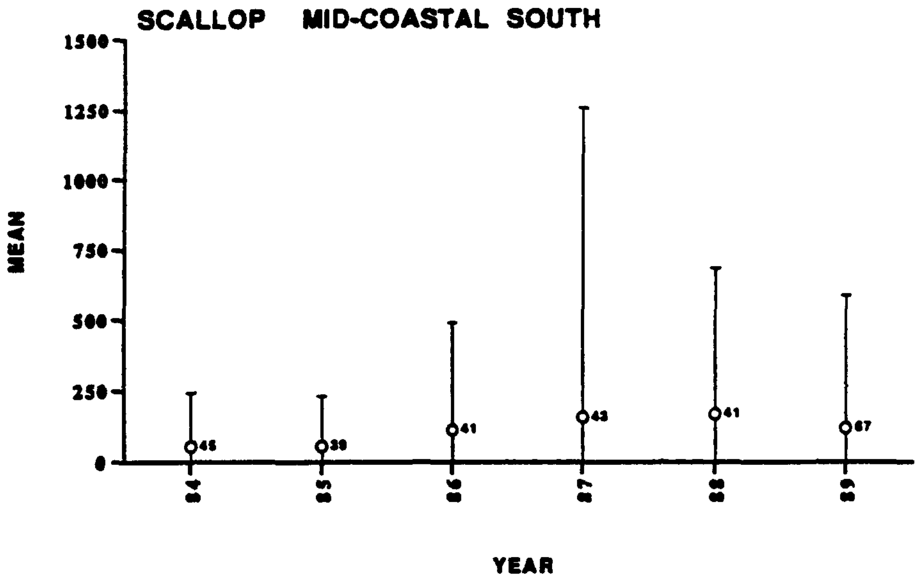


Figure 3-9. Mean catch per unit effort and range for sea scallop and number of stations (n) per sampling event by year, season and stratum collected during NMFS shellfish surveys.



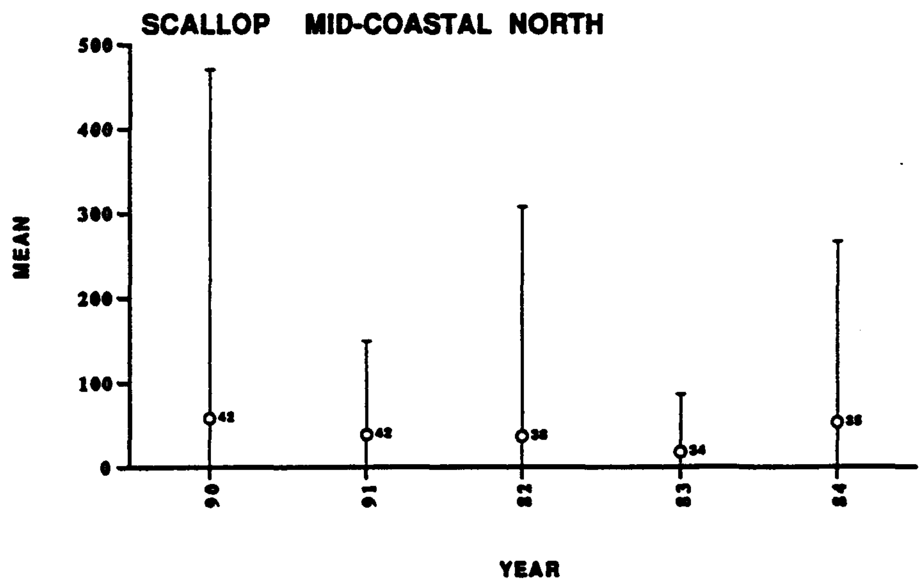


Figure 3-9. Mean catch per unit effort and range for sea scallop and number of stations (n) per sampling event by year, season and stratum collected during NMFS shellfish surveys.

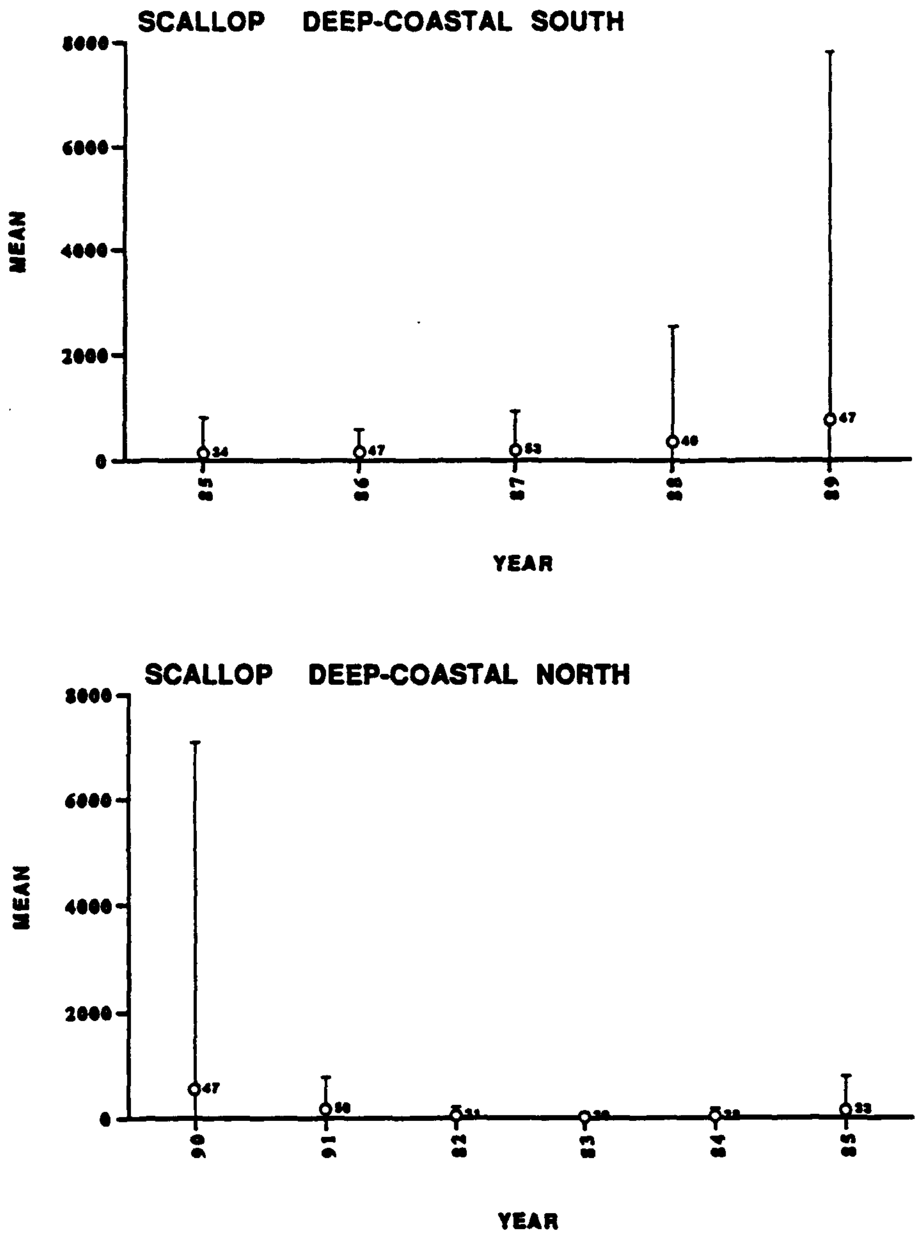


Figure 3-9. Mean catch per unit effort and range for sea scallop and number of stations (n) per sampling event by year, season and stratum collected during NMFS shellfish surveys.

TABLE 2-1. AGENCY CONTACTS FOR ANNOTATED BIBLIOGRAPHY FOR BENTHIC STUDIES IN THE NEW YORK BIGHT

New Jersey

Northeast Fisheries Center, NMFS Sandy Hook Laboratory, Highlands, NJ.
Mr. Robert Reid
Ms. Claire Steimle, Lionel A. Walford Library

State of New Jersey Department of Environmental Protection and Energy; Division of Fish, Game and Wildlife, Marine Fisheries Administration, Bureau of Marine Fisheries, Trenton, NJ.
Ms. Lori M. Giust

Massachusetts

Northeast Fisheries Center, Woods Hole, Massachusetts.
Ms. Lynn Forbes, NMFS Documents Library
Mr. Brian O'Gorman, Computer Specialist

TABLE 3-1. MACROFAUNAL STUDIES IN THE NEW YORK BIGHT INCLUDING LITERATURE REFERENCES, METHODOLOGY, YEARS, AVAILABLE DATA, ARCHIVAL STATUS, AND ANCILLARY DATA.

REFERENCE[1]	COLLECTION GEAR[2]	SIEVE SIZE (mm)	PRESERVATION METHOD[3]	STUDY YEARS	DATA PRESENTATION[13]						ARCHIVAL STATUS[10]	ANCILLARY DATA[11]	STATION LOCATION[12]
					DATA TYPE[4]	DATA VALUES[5]	TAXON LEVEL[6]	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]			
Azarovitz et al., 1979	LP/OT	--	--	75-76	A	D/$\bar{x}$	S(s)[22]		E		--	--	Not cited
Boesch, 1979	SM	0.5	F/A	75-77									
Boesch et al., 1977	SM SBT/AD	0.5 4.0	F/A	75-76	A WB A WB A	$\bar{x}$ $\bar{x}$ $\bar{x}$ $\bar{x}$ D	S(d)/AT P AT P S(d)	St St AS AS R[13]	E E E E E[13]	 V V	--	SE	Map
Botton, 1979	Sh	1.0	F/A	76	A/DB	$\bar{x}$	S	St	E		--	SE SC	Map LL
Caracciolo et al., 1978	SM	1.0	F/A	75-76	--- unavailable --- (probably same as Pearce et al., 1977(b))								
Caracciolo & Steimle, 1983	SM	1.0	F/A	73-74	A[f]	$\bar{x}$[f]	S(s)[f] AT[f]		ES[f]		--	SC SE SA T	Map
Garlo, 1980	Po	1.0	F/A	72-74	A DB	$\bar{x}$ $\bar{x}$	S/P/AT AT	St/AS St/Rg	ES EA		--	SE T DO SA	Map LL
Garlo, 1982a	HD	38	--	76-77	A/WB	$\bar{x}$	S(s)[14]	Rg/AS	E		--	T DO SA	Map
Garlo et al., 1979	Po DD/HD SBIT	1.0 38 38	F/A R	76 76 72-76	A[t] A[t] B[t] A[ft]	D[t] D[t] D[t] $\bar{x}$[ft]	S(s)/P/AT[t] S(s)/AT[t] AT[t] AT[ft]	AS[t] AS[t] SA	E[t] E[t] E[t] E[ft]		--	T DO SA	Map
Guist, 1992	HD Po	72 1.0	FI F	91	A	$\bar{x}$	S(s)[14]	Rg/AS	E		--	--	Map/LL

(continued)

TABLE 3-1. (Continued)

REFERENCE[1]	COLLECTION GEAR[2]	SIEVE SIZE (mm)	PRESERVATION METHOD[3]	STUDY YEARS	DATA PRESENTATION[13]						ARCHIVAL STATUS[10]	ANCILLARY DATA[11]	STATION LOCATION[12]
					DATA TYPE[4]	DATA VALUES[5]	TAXON LEVEL[6]	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]			
Jones & Haedrick, 1977	SBIT GMST	--	--	73	A/WB	D	S/S(d)	AS	ES		--	--	Map
NMFS, 1972	SM	1.0/ 0.5	F/A	--	A A A A[f]		S(s)[14] S(s) S(s) S[f]	St St AS[f]	E E		IP	SC SE DO T SA	
NMFS[26] groundfish survey scallop survey calm survey	 OT SD CD	 -- 38 1	 FI -- 	 21-92 82-92 82-92	 A A A	 D D D	 S S(s) S(s)	 R R R	 E E E	 X X X	 -- -- --	 T T T	 LL LL LL
NAI & AOSSI, 1990	HD Sh	 1.0	 F/A	89	A A	D x̄	S S(s)[14]	St Rg/AS	a E		--	SE	Map Map/LL
Pearce et al., 1977(b)	SM	1.0	F/A	75	A	D	S/AT	R	E		IP	T SA DO SC SE	Map LL
Pearce et al., 1977(c)	SM	1.0	F/A	73-74	--- currently unavailable --- probably same as above								
Pearce et al., 1977(a)	SM	0.5	F/A	74, 76	A	D	S	St	E		--	T SA DO SE SC	Map LL
Pearce et al., 1978	SM	1.0	F/A	73	--- currently unavailable --- probably same as Pearce et al., 1977(b)								Map
Pearce et al., 1981	SM			73-74	A A/B	x̄ x	AT P	St/AS	E	 V	IP		

(continued)

TABLE 3-1. (Continued)

REFERENCE[1]	COLLECTION GEAR[2]	SIEVE SIZE (mm)	PRESERVATION METHOD[3]	STUDY YEARS	DATA PRESENTATION[23]						ARCHIVAL STATUS[10]	ANCILLARY DATA[11]	STATION LOCATION[12]
					DATA TYPE[4]	DATA VALUES[5]	TAXON LEVEL[6]	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]			
Radosh et al., 1978	SM	1.0	F/A	74	A A	$\underline{D}$ $\bar{x}$	AT S(d)	R St	E E[13]		--	SE T SA DO SC	Map
Reid et al., 1982	SM	0.5	F/A	80	A		AT	St	E		--	SC SE	Map
Reid et al., 1991(a)	SM	0.5	F/A	86-89	A[f]	$\bar{x}$[f]	S(s)[f]	St[f]	E[f]		IP	--	Map
Reid et al., 1991(b)	SM	0.5	F/A	80-85	A/WB	$\bar{x}$	S(d)	St[13]	E		IP[7]	SE SC	Map LL
Ropes & Merrill, 1971	?[25]	--	--	60,63, 65	A	D	S(s)[14,18]	St	E	V	--	--	LL
Ropes et al., 1979	HD/SD/OT/CD	--	--	75-77	A B	$\bar{x}$ $\bar{x}$	S(s)[13,18]	Rg	EA		--	--	--
Stehlik et al., 1991	GT CD	-- --	-- --	78-87 78-80 82-84 86	A A	$\bar{x}$ $\bar{x}$	S(s)[16] S(s)[16]	Rg Rg	EA EA	V V	--	T	Map
Steimle 1985	SM	1.0/ 0.5	F/A	73, 80-82	WB	$\bar{x}$	P	St	E/EA		--	--	Map
Steimle 1990	SM	1.0/ 0.5	F/A	78-85	WB WB	$\bar{x}$ $\bar{x}$	AT P	St St	EA E		IP[7]	SC SE	Map
Steimle & McNulty, 1983[17]													
Steimle & Radosh, 1979	SM	0.1	F/A	75-76	A	$\bar{x}$,D	S(s)/AT	St/R	E		IP	--	Map
Steimle & Stone, 1973	Pe	1.0	F/A	66-67	A A	$\underline{D}$ $\bar{x}$	S/AT AT	St St	E ES		--	T SA DO SE	Map LL

(continued)

TABLE 3-1. (Continued)

REFERENCE[1]	COLLECTION GEAR[2]	SIEVE SIZE (mm)	PRESERVATION METHOD[3]	STUDY YEARS	DATA PRESENTATION[13] DATA TYPE[4]	DATA VALUES[5]	TAXON LEVEL[6]	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]	ARCHIVAL STATUS[10]	ANCILLARY DATA[11]	STATION LOCATION[12]
US Dept of Commerce, 1989	?[18] ?[19]	--	--	86-89 86-88	A/WB[f] A/B	$\bar{x}$[f] $\bar{x}$	P/S(s)[f] S/AT	ST[f] ST	E[f] EA		IP	T SA SC DO SE	Map
Vanzloff et al., 1979	HD	--	R	74			S(s)[14,15,2]						Map
Wigley & Theroux, 1981	SM/C/VV	1.0	F/A	57, 62-65	A/WB A/WB	$\bar{x}$ x	P AT/P	AS/Rg AS/Rg	ES ES	V[20]	--	SE SC T	Map
Wilk et al., 1983	?[21]	--	--	68-78	A[f]	$\bar{x}$[f]	S(s)[f]	St[f]	EA[f]		--	--	Map

TABLE 3-1. (Continued)

[1]Full reference in literature cited except for NMFS Surveys

[2]Collection gear:
SM - Smith MacIntyre
Po - Ponar
Sh - Shipek Grab
VV - Van Veen
C - Campbell
Pe - Petersen
OT - Otter Trawl
SBT- Small Biology Trawl
SBIT-Semi-Balloon Trawl
GMST-Gulf of Mexico Shrimp Trawl
GT - Groundfish Trawl
LP - Lobster Pots
AD - Anchor Dredge
CD - Clam Dredge
SD - Scallop Dredge
HD - Hydraulic Dredge
DD - Dry Dredge

[3]Preservation Method:
F - Formalin
A - Alcohol
R - Refrigerated

[4]Data Type:

A - Abundance
DB- Dry Biomass
WB- Wet Biomass
B - Biomass - unknown

[5]Data Values:
D - discrete (number not averaged)
x - mean

[6]Taxonomic level:
F - Family
P - Phyla, Class, Order
S - Species (all)
S(d)-Species (dominants only)
S(s)-Species (selected)
AT - All taxa (Total)

[7]Spatial summarization:
R - by Replicate
St- by Station
Rg- by Region (Stations averaged)
AS- All Stations averaged

[8]Temporal Summarization:
E - by Event
EA- Events averaged (yearly or seasonally)
ES- Events averaged (over entire study)

[9]V = depth data available
X = mean depth of tow

[10]Archival Status:
IP - some samples in progress

[11]Ancillary Data:
DO - Dissolved Oxygen
SA - Salinity
SC - Sediment Chemistry
SE - Sediment grain size
T - Temperature

[12]Station Location:
Map = stations located on map
LL = Latitude and longitude provided

[13]Not all stations or events presented

[14]Spisula solidissima Only (Surf Clam)

[15]Artica islandica Only (Ocean Quahog)

[16]Brachyuran Crabs Only

[17]No abundance data; discussion of benthic communities and list of dominant taxa provided.

[18]Macrobenthos

[19]Megabenthos

[20]Biomass and abundance also presented by sediment type, sediment organic content and temperature strata.

[21]Trawl data not specified - megabenthos collection

[22]Lobster only

[23]t = values presented in publication
f = only figures presented in report; no attempt made to further analyze data.

[24]Tissue analysis for metals.

[25]Collection method not specified, tow or dredge.

[26]Data provided by NMFS for study years 1982-1992.

TABLE 3-2. INDEPENDENT SAMPLING EVENTS FOR EACH YEAR BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

YEAR	REFERENCE	# OF EVENTS	STUDY YEARS	STRATUM[1]								
				DN	SD	CS	BA	BSV	NCN	NCN	NCS	NCS
1957	Wigley & Theroux, 1981	1	57,62-65	-- not cited (Atlantic Coast) --								
1960	Ropes & Merrill, 1971[12]	1	60,63,65					X			X	X
1962	Wigley & Theroux, 1981	1		-- not cited (Atlantic Coast) --								
1963	Wigley & Theroux, 1981	8		-- not cited (Atlantic Coast) --								
1963	Ropes & Merrill, 1971[12]	2					X	X	X	X	X	X
1964	Wigley & Theroux, 1981	4		-- not cited (Atlantic Coast) --								
1965	Wigley & Theroux, 1981	2		-- not cited (Atlantic Coast) --								
1965	Ropes & Merrill, 1971[12]	2				X	X	X	X	X	X	X
1966	Steimle & Stone, 1973	10	66-67				X					
1967	Steimle & Stone, 1973	1					X					
1972	Garlo, 1980	10	72-74								X	
1972	Steimle, 1990	1	78-85				X					
1973	Garlo, 1980	12									X	
1973	Steimle, 1990	3			X	X	X					
1973	Steimle, 1985[2]	1	73,80-82		X	X	X					
1973	Pearce et al. 1977(c)			-- unavailable --								
1973	Pearce et al. 1978			-- unavailable --								
1973	Pearce et al. 1981[3]	1	73-74				X					
1973	Jones & Haedrick, 1977	2	73					X				
1973	Carraciolo & Steimle, 1983[3]	2	73-74	-- not cited (Bight Apex) --								
1974	Azarovitz et al. 1979	12	75-76	-- not cited (New Jersey Coast) --								
1974	Carraciolo & Steimle 1983[3]	3		-- not cited (Bight Apex) --								
1974	Garlo, 1980	12									X	
1974	Pearce et al., 1977(c)	3		-- unavailable --								
1974	Pearce et al., 1981[3]	2					X					
1974	Radosh et al., 1978	1	74					X				

(continued)

TABLE 3-2. (CONTINUED)

YEAR	REFERENCE	# OF EVENTS	STUDY YEARS	STRATUM[1] DM	SD	CB	BA	BSV	NCN	NCN	NCS	NCS
1975	Azarovitz et al., 1979	12[10]						-- not cited (New Jersey Coast) --				
1975	Azarovitx et al., 1979	8[11]						-- not cited (New Jersey Coast) --				
1975	Boesch, 1979	1	75-77					X			X	X
1975	Boesch et al., 1977[4]	1	75-76					X			X	X
1975	Carraciolo et al., 1978	1	75-76					-- unavailable --				
1975	Pearce et al., 1977(b)	1	75				X	X			X	X
1975	Ropes et al., 1979	1	75-77					-- not cited (New York Bight) --				
1975	Steimle & Radosh, 1979	1	75-76									X
1976	Azarovitz et al., 1979	12[10]						-- not cited (New Jersey Coast) --				
1976	Azarovitz et al., 1979	6[11]						-- not cited (New Jersey Coast) --				
1976	Boesch, 1979	4						X			X	X
1976	Boesch et al., 1977[4]	3						X			X	X
1976	Botton, 1979	1	76			X	X					
1976	Carraciolo et al., 1978	1						-- unavaiable --				
1976	Garlo, 1982a	1	76-77								X	
1976	Garlo et al., 1979	2[6]	76								X	
1976	Garlo et al., 1979	5[7]	72-76								X	
1976	Pearce et al., 1977(a)	1	74,76					X				
1976	Ropes et al., 1979	12/16						-- not cited (New York Bight) --				
1976	Steimle & Radosh, 1979	1					X				X	X
1977	Boesch, 1979	3						X			X	X
1977	Garlo, 1982a	1									X	
1977	Ropes et al., 1977	1						-- not cited (New York Bight) --				
1978	Stehlik et al., 1991	4[8]	78-77					-- not specified (Atlantic Coast) --				
1978	Stehlik et al., 1991	1[9]	78-80 82-84 86					-- not specified (Atlantic Coast) --				
1979	Reid et al., 1991(b)	1	80-85		X	X	X	X				X
1979	Stehlik et al., 1991	3[8]						-- not specified (Atlantic Coast) --				
1979	Stehlik et al., 1991	1[9]						-- not specified (Atlantic Coast) --				
1979	Steimle, 1990	2	78-85		X	X	X	X				X

(continued)

TABLE 3-2. (CONTINUED)

YEAR	REFERENCE	# OF EVENTS	STUDY YEARS	STRATUM[1] DN	SD	CB	RA	ESV	ICN	MCN	ICS	MCS
1980	Reid et al., 1982	1	80			X	X	X		X	X	X
1980	Reid et al., 1991(b)	1-2			X	X	X	X		X	X	X
1980	Stehlik et al., 1991	3[8]				-- not specified (Atlantic Coast) --						
1980	Stehlik et al., 1991	2[9]				-- not specified (Atlantic Coast) --						
1980	Steimle, 1985	1			X	X	X	X	X	X	X	X
1980	Steimle, 1990	2	73,80-82		X	X	X	X			X	
1981	Reid et al., 1991(b)	1			X	X	X	X	X	X	X	
1981	Stehlik et al., 1991	4[8]				-- not specified (Atlantic Coast) --						
1981	Steimle, 1985	1			X	X	X	X	X	X	X	X
1981	Steimle, 1990	1			X	X	X	X			X	
1982	Reid et al., 1991(b)	1-3			X	X	X	X	X	X	X	X
1982	Stehlik et al., 1991	2[8]				-- not specified (Atlantic Coast) --						
1982	Stehlik et al., 1991	1[9]				-- not specified (Atlantic Coast) --						
1982	Steimle, 1985	1			X	X	X	X	X	X	X	X
1982	Steimle, 1990	5			X	X	X	X			X	
1983	Reid et al., 1991(b)	1-3			X	X	X	X	X	X	X	X
1983	Stehlik et al., 1991	2[8]				-- not specified (Atlantic Coast) --						
1983	Stehlik et al., 1991	1[9]				-- not specified (Atlantic Coast) --						
1983	Steimle, 1990	3			X	X	X				X	
1984	Reid et al., 1991(b)	1			X	X	X	X	X	X	X	X
1984	Stehlik et al., 1991	2[8]				-- not specified (Atlantic Coast) --						
1984	Stehlik ete al., 1991	1[9]				-- not specified (Atlantic Coast) --						
1984	Steimle, 1990	1-2			X	X	X	X			X	
1985	Reid et al., 1991(b)	1(2)			X	X	X	X	X	X	X	X
1985	Stehlik at al., 1991	2[8]				-- not specified (Atlantic Coast --						
1985	Steimle, 1990	3			X	X	X	X			X	
1986	Reid et al., 1991(a)[5]	6	86-89			X	X					
1986	Stehlik et al., 1991	2[8]				-- not specified (Atlantic Coast) --						
1986	Stehlik et al. 1991	1[9]				-- not specified (Atlantic Coast) --						
1986	US Dept. of Commerce, 1989	1	86-89			X	X					

(continued)

TABLE 3-2. (CONTINUED)

YEAR	REFERENCE	# OF EVENTS	STUDY YEARS	STRATUM[1] DM	SD	CB	BA	HSV	NCN	MCN	NCS	MCS
1987	Reid et al., 1991(a)[5]	12				X	X					
1987	Stehlik et al., 1991	2[8]				-- not specified (Atlantic Coast) --						
1987	US Dept. of Commerce, 1989	1				X	X					
1988	Reid et al., 1991(a)[5]	12				X	X					
1988	US Dept. of Commerce 1989	1				X	X					
1989	Reid et al., 1991(a)[5]	9				X	X					
1989	US Dept. Commerce 1989	12				X	X					
1990	NAI and AOSSI, 1990	1	89				X					
1992	Giust, 1992	1	91								X	

[1]Stratum
- DM - Dredged Material Dumpsite
- SD - Sewage Sludge Dumpsite
- CB - Christiansen Basin
- BA - Bight Apex
- HSV - Hudson Shelf Valley
- NCN - near Coastal North
- MCN - Mid Coastal North
- NCS - Near Coastal South
- MCS - Mid Coastal South

[2]Probably same as Steimle, 1990
[3]Probably same as Pearce et al., 1977(c)
[4]Same as Boesch, 1979
[5]Probably same as US Dept. of Commerce, 1989
[6]Gear type - Ponar, Dry Dredge, Hydraulic Dredge
[7]Gear type - Semi Balloon Trawl
[8]Gear type - Ground Fish Trawl
[9]Gear type - Clam dredge
[10]Gear type - Otter trawl or Lobster pot
# of events is estimated
[11]Gear type - Lobster pot
# of events is estimated
[12]Only stations where clams were actually caught are presented.
Sample collections many have been conducted in other strata.

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]							
STRATUM: SEWAGE DUMP REFERENCE	GEAR	SIEVE	73	79	80	81	82	83	84	85
Steimle, 1985	SM	0.5[a]	8[1.0]		7	7	8			
Steimle, 1990	SM	0.5[a]	8[1.0]	12[1.0]	7,11	7	2,8,11	7,11	8	6,9
Reid et al., 1991(b)	SM	0.5		12	7,12	8	1,9,11	7,11	8	6,10

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

			YEAR AND MONTH OR SEASON[b]							
STRATUM: NEAR COASTAL NORTH REFERENCE	GEAR	SIEVE	63	65	80	81	82	83	84	85
Ropes & Merrill, 1971	?	?	10,12	5-6, 10-11						
Steimle, 1985	SM	0.5			7	7	8			
Reid et al. 1991(b)	SM	0.5				8	9	9	8	9

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]									
STRATUM: MID-COASTAL NORTH REFERENCE	GEAR	SIEVE	60	63	65	75	80	81	82	83	84	85
Ropes & Merrill, 1971	?	?	5	10	5-6, 10-11							
Pearce et al., 1977(b)	SM	1.0				4						
Reid et al., 1991(b)	SM	0.5					7,8	8	9	7,9	8	9,10
Reid et al., 1982	SM	0.5					7,8					
Steimle, 1985`	SM	0.5					7	7	8			

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]												
STRATUM: MID-COASTAL SOUTH REFERENCE	GEAR	SIEVE	60	63	65	74	75	76	77	80	81	82	83	84	85
Ropes & Merrill, 1971	?	?	5	10	5-6, 10-11										
Radosh et al., 1978	SM	1.0				5									
Boesch, 1979	SM SBT/AD	0.5 4.0					F	W,Sp, Su,F	W,Sp, Su						
Boesch, et al., 1977	SM SBT/AD	0.5 4.0					F	W,Sp, Su							
Pearce et al., 1977(b)	SM	1.0					4								
Steimle & Radosh, 1979	SM	0.1					4	7,8,9, 10,11							
Reid et al., 1982	SM	0.5								7,8					
Reid et al., 1991(b)	SM	0.5								8	8	9	9	8	10
Steimle, 1985	SM	0.5								7	7	8			

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]													
STRATUM: CHRISTIAENSEN BASIN REFERENCE	GEAR	SIEVE	65	73	76	79	80	81	82	83	84	85	86	87	88	89
Ropes & Merrill, 1971	?	?	5-6													
Steimle, 1985	SM	0.5[a]		$8^{1.0}$			7	7	8							
Steimle, 1990	SM	0.5[a]		$8^{1.0}$		$12^{1.0}$	7,11	7	2,9,12	7,12	8	1,9				
Botton, 1979	Sh	1.0			2											
Reid et al., 1991(b)	SM	0.5				12	7,8,12	8	1,9,11	7,8,11	8	6,10				
Reid et al., 1982	SM	0.5					7,8									
Reid et al., 1991(a)	SM	0.5											7,8,9,11	1,3,5,7,8,9,11	1,3,5,7,8,9,11	1,3,5,7,8,9
US Dept. of Commerce, 1989	--	--											7,8,9,10,11,12	1-12	1-12	1,2,3,4,5,6,7,8,9

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]																			
STRATUM: OTHER BIGHT APEX REFERENCE	GEAR	SIEVE	60	65	66	67	72	73	74	75	76	79	80	81	82	83	84	85	86	87	88	89
Rowe & Merrill, 1971	?	?	10	5-6, 10-11																		
Steimle & Stone, 1973	Pe	1.0			2,3,4, 5,6,7, 8,9,10, 11	1																
Steimle, 1990	SM	0.5[a]					$12^{1.0}$	$5,12^{1.0}$				$12^{1.0}$	7,11	7	2,8,11	7	8	6,9				
Steimle, 1986	SM	0.5[a]						$8^{1.0}$					7	7	8							
Pearce et al., 1981	SM	--						$8^{1.0}$	3,4,8													
Pearce et al., 1977(b)	SM	1.0								4												
Steimle & Radosh, 1979	SM	0.1									7,8,9, 10,11											
Botton, 1979	Sh	1.0									2											
Reid et al., 1991(b)	SM	0.5										12	7,8, 12	8	1,9	7,8,9	8	6,9,10				
Reid et al. 1982	SM	0.5											7,8									
Reid et al., 1991(a)	SM	0.5																	7,8,9, 11	1,3,5, 7,8,9, 11	1,3,5, 7,8,9, 11	1,3,5,7, 8,9
US Dept. of Commerce, 1989	--	--																	7,8,9, 10,11, 12	1-12	1-12	1,2,3,4, 5,6,7,8, 9
NAI & ADRRI, 1990	HD Sh	-- 1.0																				11

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

STRATUM: OTHER BIGHT APEX REFERENCE	GEAR	SIEVE[a]	60	65	66	67	72	73	74	75	76	79	80	81	82	83	84	85	86	87	88	89
			YEAR AND MONTH OR SEASON[b]																			
Ropes & Merrill, 1971	?	?	10	5-6, 10-11																		
Steimle & Stone, 1973	Pe	1.0			2,3,4, 5,6,7, 8,9,10, 11	1																
Steimle, 1990	SM	0.5[c]					$12^{1.0}$	$5,12^{1.0}$				$12^{1.0}$	7,11	7	2,8,11	7	8	6,9				
Steimle, 1986	SM	0.5[c]						$8^{1.0}$					7	7	8							
Pearce et al., 1981	SM	--						$8^{1.0}$	3,4,8													
Pearce et al., 1977(b)	SM	1.0								4												
Steimle & Radosh, 1979	SM	0.1									7,8,9, 10,11											
Botton, 1979	Sh	1.0									8											
Reid et al., 1991(b)	SM	0.5										12	7,8, 12	8	1,9	7,8,9	8	6,9,10				
Reid et al. 1982	SM	0.5											7,8									
Reid et al., 1991(a)	SM	0.5																	7,8,9, 11	1,3,5, 7,8,9, 11	1,3,5, 7,8,9, 11	1,3,5,7, 8,9
US Dept. of Commerce, 1989	--	--																	7,8,9, 10,11, 12	1-12	1-12	1,2,3,4, 5,6,7,8, 9
MAI & AOBSI, 1990	NB Sh	-- 1.0																				11

[a] Sieve size (mm) unless otherwise noted.
[b] Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

			YEAR AND MONTH OR SEASON[b]														
STRATUM: HUDSON SHELF VALLEY REFERENCE	GEAR	SIEVE	60	63	65	73	74	75	76	77	79	80	81	82	83	84	85
Ropes & Merrill, 1971	?	?	5	10	5-6												
Jones & Headrick, 1977	SBIT/SMST	-				2,3,11											
Radosh et al., 1978	SM	1.0					5										
Boesch, 1979	SM SBT/AD	0.5 4.0						F	W,Sp,Su, F	W,Sp,Su							
Boesch et al., 1977	SM SBT/AD	0.5 4.0						F	W,Sp,Su								
Pearce et al., 1977(b)	SM	1.0						6									
Pearce et al., 1977(a)	SM	0.5							2,3								
Reid et al., 1991(b)	SM	0.5									12	8,12	8	1,8,9	7,9	8	6,10
Steimle, 1990	SM	0.5[c]									$10^{1.0}$	7,11	7	2,8		7,8	8,9
Reid et al., 1992	SM	0.5										7,8					
Steimle, 1995	SM	0.5										7	7	8			

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-3. YEAR AND MONTH OR SEASON OF SAMPLING, GEAR TYPE AND SIEVE SIZE BY STRATUM FOR BENTHIC STUDIES IN THE NEW YORK BIGHT.

STRATUM: NEAR-COASTAL SOUTH REFERENCE	GEAR	SIEVE[a]	YEAR AND MONTH OR SEASON[b] 63	65	72	73	74	75	76	77	79	80	81	82	83	84	85	91
Ropes & Merrill, 1971	?	?	10	5-6,10-11														
Garlo, 1980	Po	1.0			3,4,5,6,7,8,9,10,11,12	1-12	1-12											
Boesch, 1979	SM SBT/AB	0.5 4.0						F	W,Sp,Su,F	W,Sp,Su								
Boesch et al., 1977	SM SBT/SB	0.5 4.0						F	W,Sp,Su									
Garlo, 1980b	HB	S10/36							9	9								
Garlo et al., 1979	Po SB/HB								7,9									
	SBIT	38							6,7,8,9,10									
Steimle & Radosh, 1979	SM	0.1							7,8,9,10,11		12	8,12	8	1,9	6,7,9	8	6,10	
Reid et al., 1991(b)	SM	0.5									12 1.0	7,11	7	2,8,12	7	8	1,9	
Reid et al., 1982	SM	0.5										7,8						
Steimle, 1985	SM	0.5										7	7	8				
Glunt, 1992	HB Po	72 1.0																6,7,8

[a]Sieve size (mm) unless otherwise noted.
[b]Numbers indicate month
F = Fall, W = Winter, Sp = Spring, Su = Summer

TABLE 3-4. NUMBER OF SAMPLES COLLECTED IN EACH STRATUM BY YEAR FOR SCALLOPS AND CLAMS DURING NMFS SUMMER SHELLFISH SURVEYS.

YEAR	NEAR COASTAL SOUTH		MID COASTAL SOUTH		DEEP COASTAL SOUTH		NEAR COASTAL NORTH		MID COASTAL NORTH		DEEP COASTAL NORTH	
	S	C	S	C	S	C	S	C	S	C	S	C
1982	--	36	33	39	38	9	--	6	33	27	31	11
1983	--	35	29	36	34	9	--	7	43	72	30	8
1984	--	33	34	45	35	--	--	10	45	--	29	--
1985	--	--	32	--	34	--	--	--	39	--	33	--
1986	--	39	30	39	47	7	--	7	41	22	34	8
1987	--	--	29	--	53	--	--	--	43	--	37	--
1988	--	--	32	--	49	--	--	--	41	--	28	--
1989	--	45	25	39	47	8	--	6	67	37	33	10
1990	--	--	24	--	47	--	--	--	42	--	30	--
1991	-	--	26	--	50	--	--	--	42	--	30	--
1992	--	43	--	38	--	8	--	6	--	32	--	11

S = scallop dredge
C = clam dredge

near coastal = 9-27m
mid coastal = 28-55m
deep = 56-110m

TABLE 3-5. NUMBER OF INDEPENDENT SAMPLING EVENTS IN THE NMFS DATABASE BY YEAR, SEASON AND DEPTH STRATUM.

YEAR	SEASON	NORTH MID-COASTAL	NORTH OUTER COASTAL	NORTH SHELF-BREAK SLOPE	SOUTH MID-COASTAL	SOUTH OUTER COASTAL	SOUTH SHELF-BREAK SLOPE	LONG ISLAND NEAR COASTAL	NEW JERSEY NEAR COASTAL	DREDGED MATERIAL SITE	SEWAGE SLUDGE SITE
1981	Fall	0	0	0	0	0	0	17	17	0	0
1982	Spring	7	8	6	6	4	2	19	18	0	0
	Fall	7	7	5	5	6	2	16	18	0	0
1983	Spring	7	7	6	5	3	3	15	21	0	0
	Fall	7	7	6	6	3	3	15	21	0	0
1984	Spring	7	7	5	5	5	2	18	19	0	0
	Fall	7	7	4	4	4	2	16	19	0	0
1985	Spring	7	5	5	4	4	3	16	18	0	0
	Fall	7	7	4	4	4	2	19	16	0	0
1986	Spring	7	7	5	5	4	2	15	19	0	0
	Fall	7	7	6	5	1	3	15	20	0	0
1987	Spring	7	7	7	5	5	4	13	16	0	0
	Fall	7	8	3	5	2	1	14	15	0	0
1988	Spring	7	7	0	5	4	0	14	13	0	0
	Fall	7	7	3	4	3	1	13	15	0	1
1989	Spring	7	7	3	5	4	1	14	15	0	0
	Fall	7	7	3	5	3	1	18	17	0	0
1990	Spring	7	7	3	5	3	1	13	16	0	0
	Fall	7	7	3	5	3	1	16	19	0	0
1991	Spring	7	7	3	5	3	2	17	17	0	0
	Fall	7	7	3	5	3	2	15	20	0	0
1992	Spring	7	7	0	5	3	2	17	16	0	0
	Fall	7	7	0	0	0	0	0	0	0	0

TABLE 3-6. DOMINANT BENTHIC SPECIES IN STRATA FROM THE NEW YORK BIGHT.

Near Coastal North[1]	Mid Coastal North[2]
1 *Pseudunciola obliquua*	1 *Spiophanes bombyx*
2 *Tanaissus lilljeborgi*	2 *Ampharete arctica*
3 *Cirrophorus brevicirratus*	3 *Ampelisca agassizi*
4 *Aricidea (Acesta) catherinae*	4 *Tharyx acutus*
5 *Euclymene zonalis*	5 *Euclymene zonalis*
Sludge Dump[1]	
1 *Capitella capitata*[10]	
2 *Spiophanes bombyx*	
3 *Tharyx acutus*	
4 *Tellina agilis*	
5 *Parougia caeca*	
Other Bight Apex	
1 *Nucula proxima*[1]	1 Longfin squid[3]
2 *Tomato seed	2 Rock crab
3 *Prionospio steenstrupi*	3 Starfish (unclassified)
4 *Tharyx acutus*	4 Shortfin squid
5 *Cossura longocirrata*	5 American lobster
6 *Phoronis architecta*	
(Medium Sand Assemblage[4])	(Fine Silty Sand[4])
1 *Tellina agilis*	1 *Nucula proxima*
2 *Protohaustorius deichmannae*	2 *Nephtys incisa*
3 *Echinarachnius parma*	3 *Pherusa affinis*
4 *Unciola irrorata*	4 *Clymenella torquata*
5 *Spisula solidissima*	5 *Leptocheirus pinguis*
1 *Byblis serrata*[2]	1 *Tharyx acutus*[5]
2 *Euclymene zonalis*	2 *Capitella capitata*
2 *Ampharete arctica*	3 *Chone* sp.
3 *Aglaophamus circinata*	4 *Ampelisca abdita*
3 *Echinarachnius parma*	5 *Erichthonius brasiliensis*
(*Mytilus edulis* Aggregation,[4] with underlying medium sand assemblage)	
1 *Mytilus edulis*	
2 *Harmothoe extenuata*	
3 *Cancer irroratus*	
4 *Nereis succinea*	
5 *Harmothoe imbricata*	

(continued)

TABLE 3-6. (CONTINUED)

Christiaensen Basin	
1 Tomato Seed[1] 2 *Nucula proxima* 3 *Capitella* sp. 4 *Capitella capitata* 5 *Tharyx acutus* *Asabellides oculata*	1 *Amage auricula*[5] 2 *Nucula proxima* 3 *Tharyx acutus* 4 *Chone* sp. 5 *Capitella capitata*
1 Rock crab[3] 2 Longfin squid 3 Starfish (unclassified) 4 Shortfin squid 5 American lobster	
Hudson Shelf Valley	
1 *Ampelisca agassizi*[1] 2 *Euchone incolor* 3 *Tharyx dorsobranchialis* 4 *Levinsenia gracilis* 5 *Nucula delphinodonta*	1 *Ampelisca agassizi*[6] 2 *Unciola irrorata* 3 *Erichthonius rubricornis* 4 *Ampelisca vadorum* 5 *Notomastus latericeus*
(Infauna-Shelf Break[7]) *Ampelisca agassizi* *Unciola irrorata* *Aricidea neosuecica* *Lumbrineris latrielli* *Onuphis pallidula* *Spiophanes wigleyi* *Onuphis atlantica* *Amphioplus macilentus* *Thyasira flexuosa* *Harbansus bowenae*	(Megafauna-Shelf Break[7]) *Astropecten americanus* *Amphilimna olivacea* *Pontophilus brevirostris* *Munida valida* *Cancer borealis*
1 *Spiophanes bombyx*[2] 2 *Tharyx acutus* 3 *Byblis serrata* 4 *Ampharete arctica* 5 *Scalibregma inflatum*	1 *Paraonis gracilis*[8] 2 *Polycirrus* sp. #1 3 *Heteromastus filiformis* 4 Rhynchocoela 4 *Phylo michaelseni* 4 *Drilonereis longa*

(continued)

TABLE 3-6. (CONTINUED)

Near-Coastal South

1 *Goniadella gracilis*[1]	1 *Polygordius* sp.[6]
2 *Echinarachnius parma*	2 *Goniadella gracilis*
3 *Tharyx acutus*	3 *Spiophanes bombyx*
4 *Caulleriella c.f. killariensis*	4 *Tanaissus lilljeborgi*
5 *Pseudunciola obliquua*	5 *Tellina agilis*
1 Capitellidae[9]	
2 Ampharetidae	
3 *Tellina agilis*	
4 *Spisula solidissima*	
5 *Spiophanes bombyx*	

Mid-Coastal South

(Coarse Sand[6])	(Fine Sand[6])
1 *Spiophanes bombyx*	1 *Spiophanes bombyx*
2 *Pseudunciola obliquua*	2 *Lumbrineris impatiens*
3 *Goniadella gracilis*	3 *Polygordius* sp.
4 *Rhepoxinius epistomus*	4 *Nucula proxima*
5 *Spisula solidssima*	5 *Tellina agilis*
1 *Unciola inermis*[1]	1 *Protodrilus symbioticus*[2]
2 *Ampelisca agassizi*	3 *Tharyx acutus*
3 *Exogone hebes*	4 *Goniadella gracilis*
4 *Corophium crassicorne*	5 *Lumbrineris acuta*
5 *Unciola irrorata*	*Echinarachnius parma*

*not a marine organism; typical of areas with sewage sludge.

Sources:

[1]US Dept. of Commerce 1989; Reid et al. 1991a,b, from grabs.
[2]Pearce et al. 1977b.
[3]US Dept. of Commerce 1989, from tows.
[4]Steimle and Stone 1973.
[5]Botton 1979.
[6]Boesch et al. 1977, Boesch 1979.
[7]Steimle and McNulty 1983. (not in order)
[8]Pearce et al. 1977d.
[9]Garlo 1980.
[10]*Capitella capitata* is actually a species complex (Grassle and Grassle 1976).

APPENDIX A

MAPS FROM NEW YORK BIGHT BENTHIC STUDIES

(No map available for Ropes and Merrill 1971)

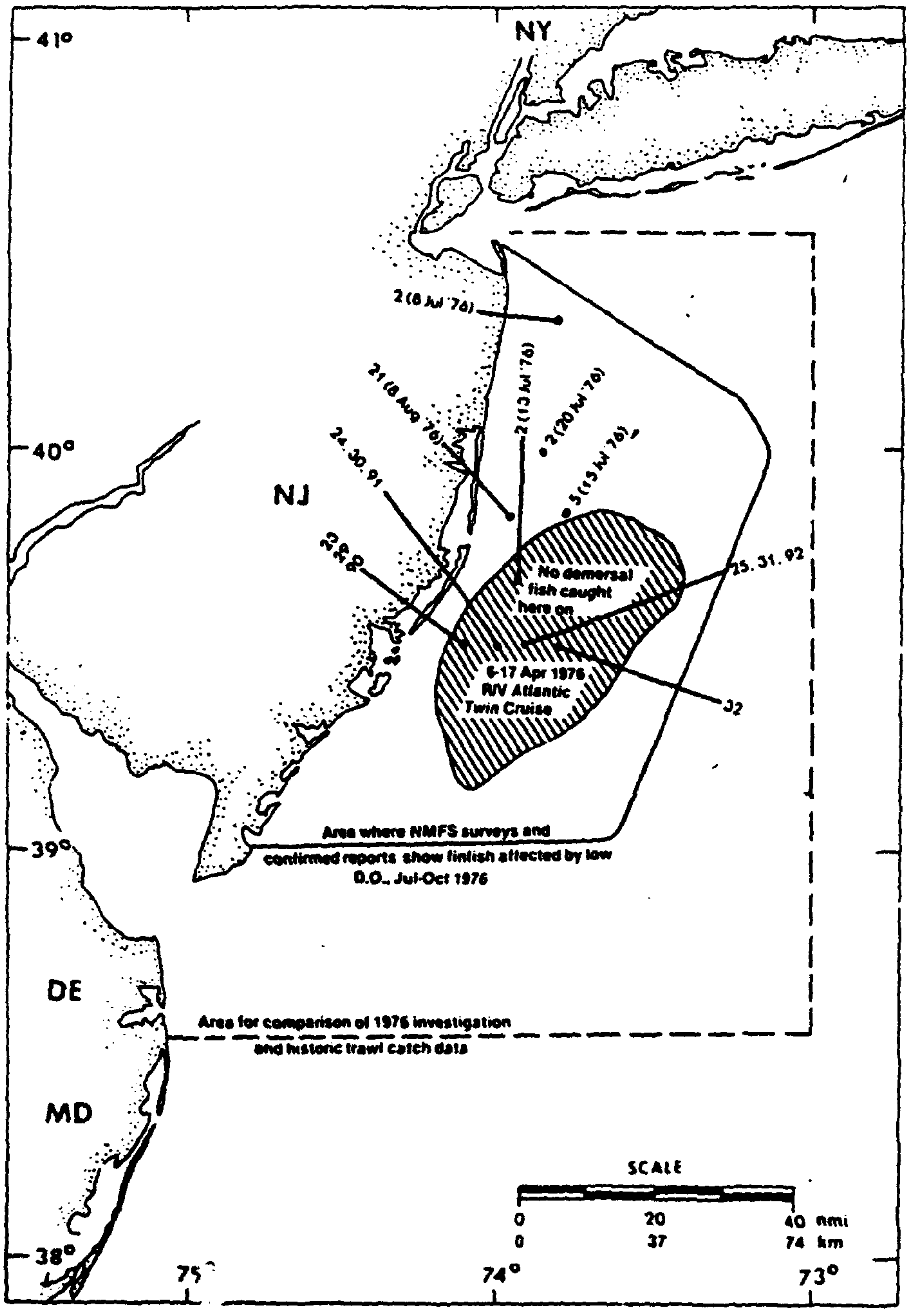


FIGURE 13-1.—Finfish survey areas and location of stations.

BOESCH ET.AL. 1977, Boesch 1979

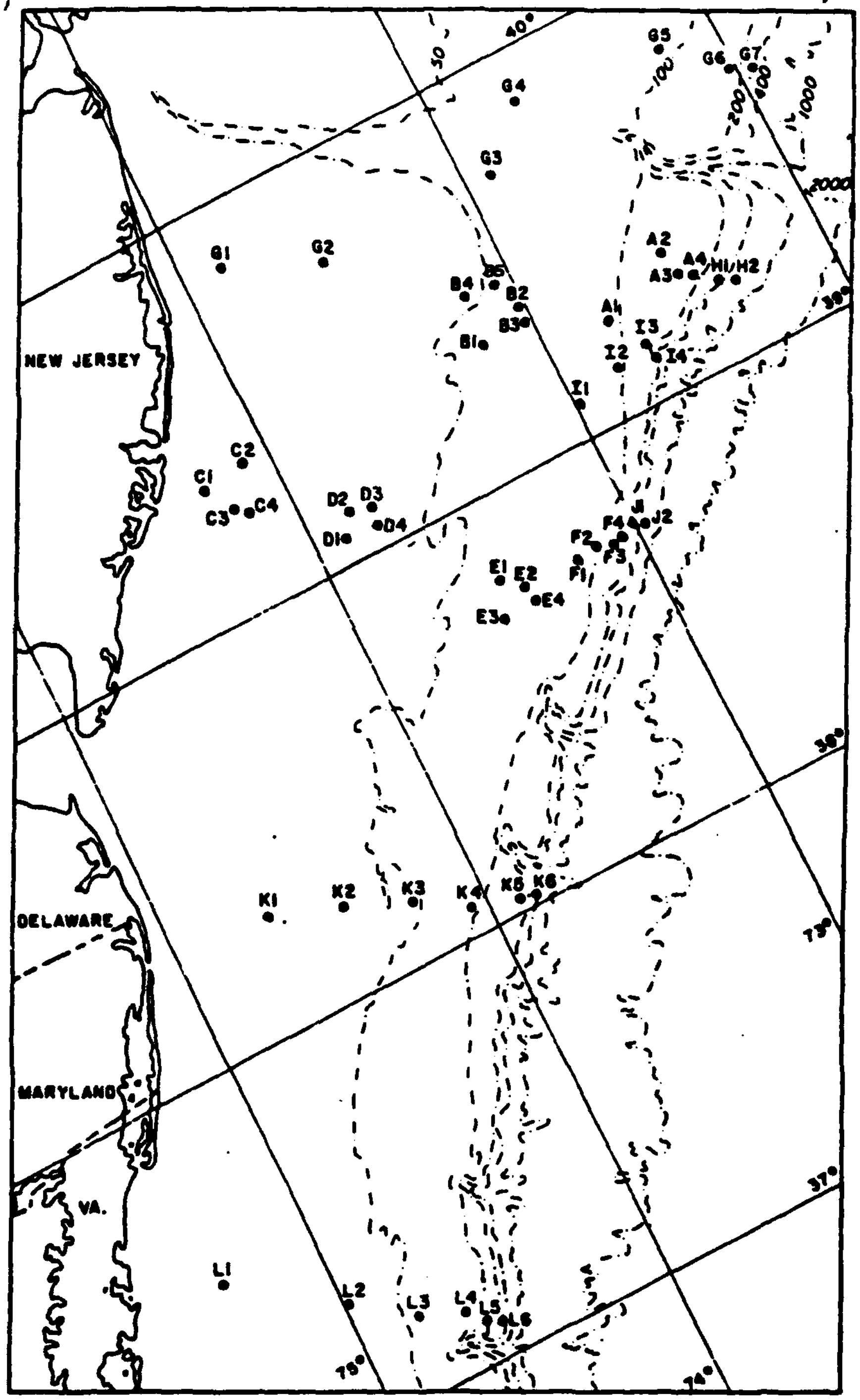


Figure 6-2. Stations sampled for macrobenthos.

6-4

BOESCH et al. 1977
BOESCH 1979

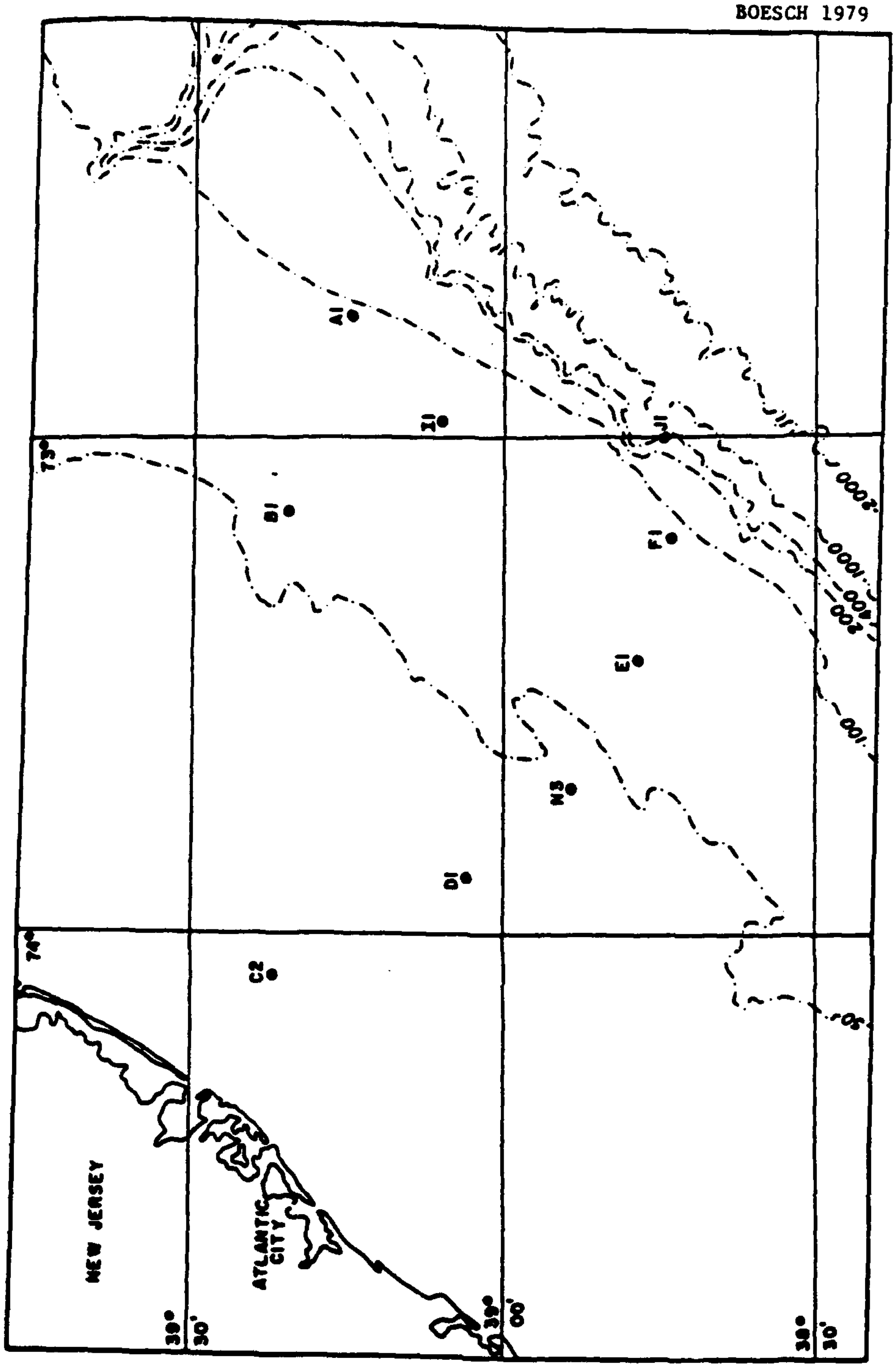


Figure 6-5. Stations sampled quarterly for megabenthos with dredge and trawl.

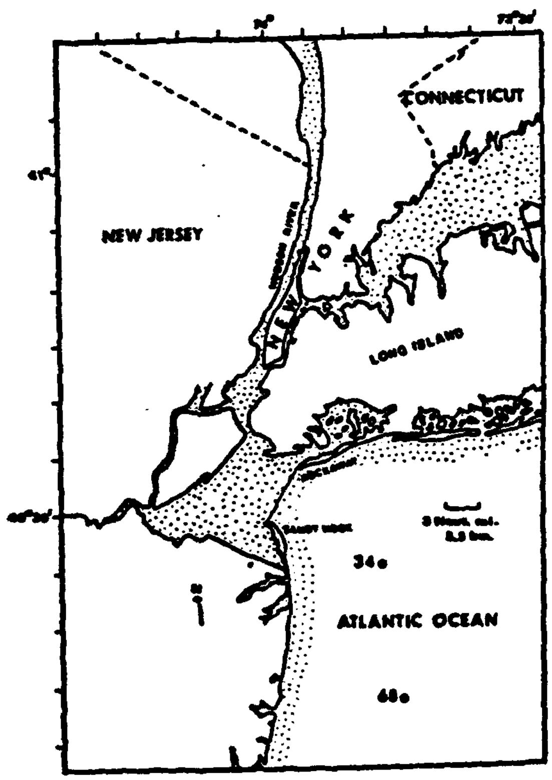


Figure 1. Location of the study sites within the New York Bight.

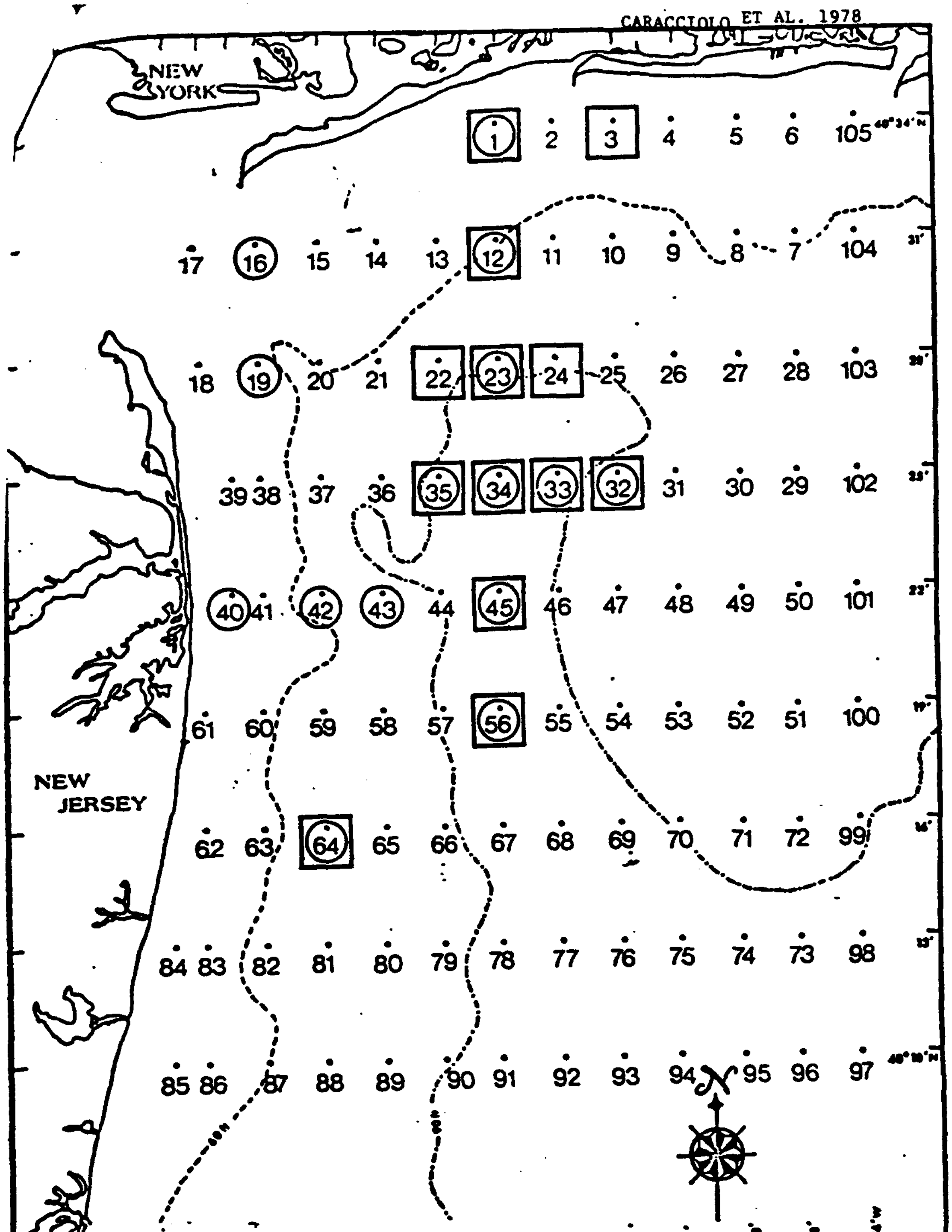


Figure 1. Standard N. Y. Bight, MESA SYMAP station positions.
□ = First monitoring cruise station; ○ = Second

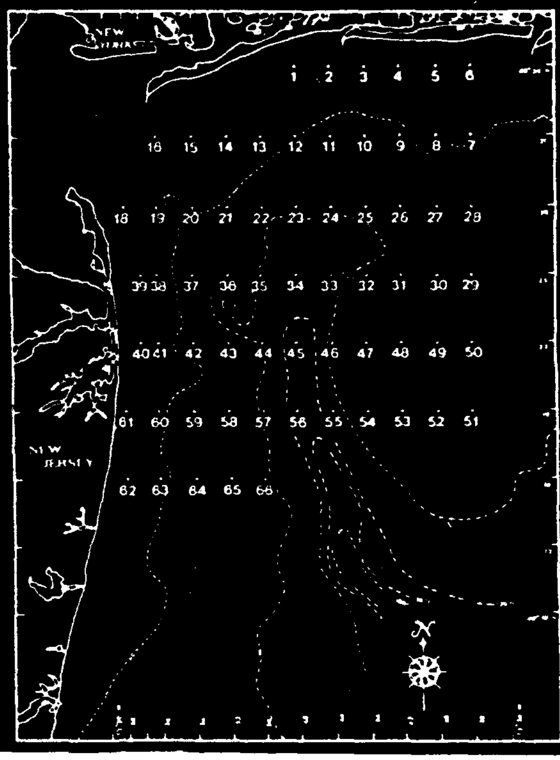
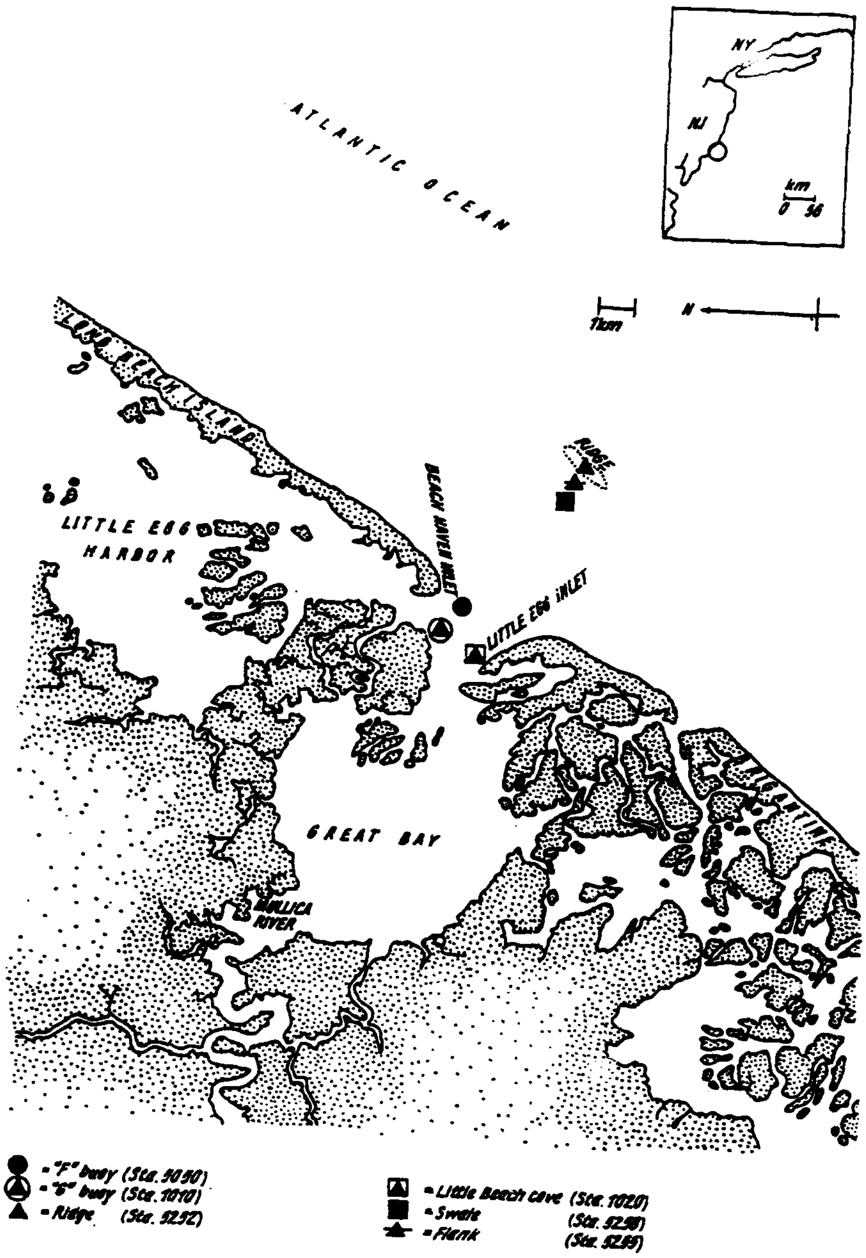
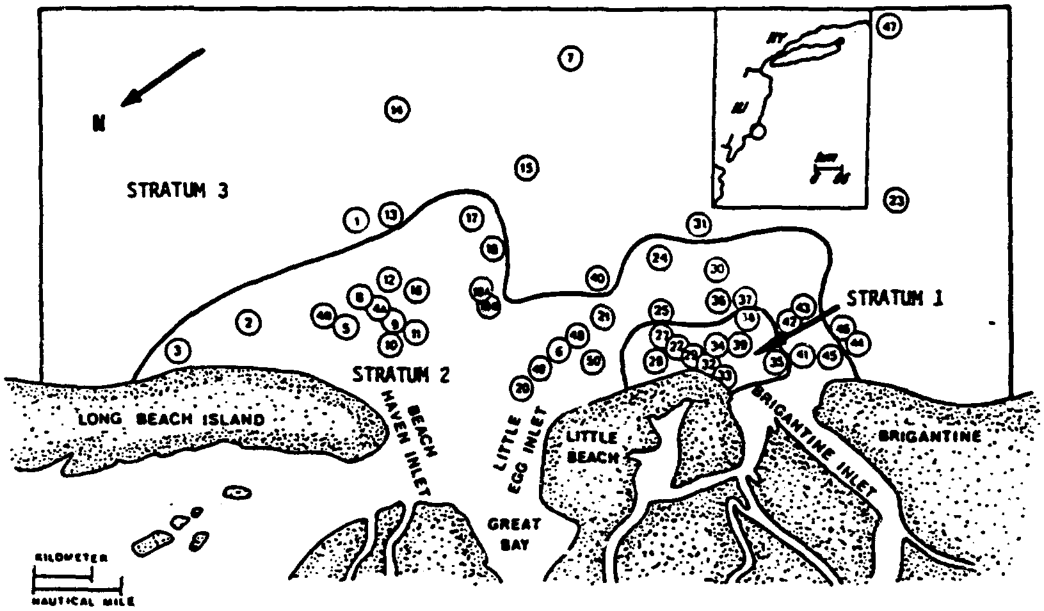


Figure 2.—New York Bight apex study area with station positions, and dredging spoils (DS) and sewage sludge (SS) dump sites indicated.

GARLO 1980



NY
NJ
km
0 36
ATLANTIC OCEAN
1km
N
LONG BEACH ISLAND
RIDGE
BEACH HAVEN INLET
LITTLE EGG HARBOR
LITTLE EGG INLET
GREAT BAY
MULLICA RIVER
= "F" buoy (Sta. 9050)
= "G" buoy (Sta. 1010)
= Ridge (Sta. 5252)
= Little Beach cove (Sta. 1020)
= Swale
= Flank


N
STRATUM 3
STRATUM 2
STRATUM 1
LONG BEACH ISLAND
BEACH HAVEN INLET
LITTLE EGG INLET
LITTLE BEACH
GREAT BAY
BRIGANTINE INLET
BRIGANTINE
KILOMETER
NAUTICAL MILE

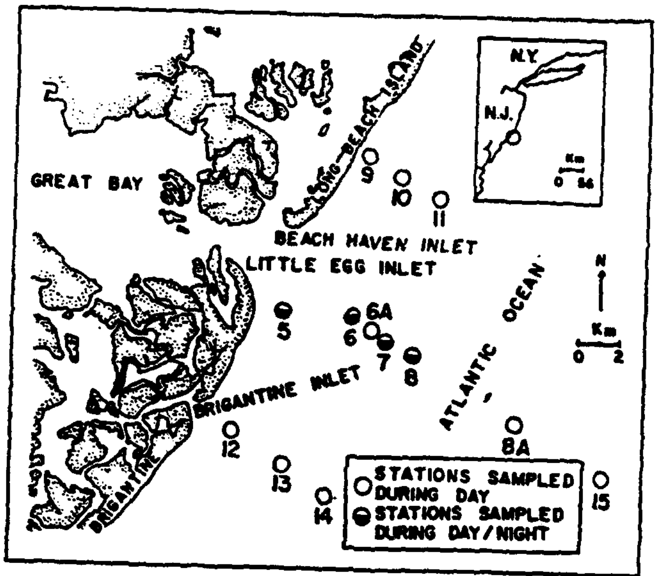


Figure 1. Stations sampled with a 7·6-m semiballoon trawl in the vicinity of Little Egg Inlet, New Jersey from 1972 to 1976.

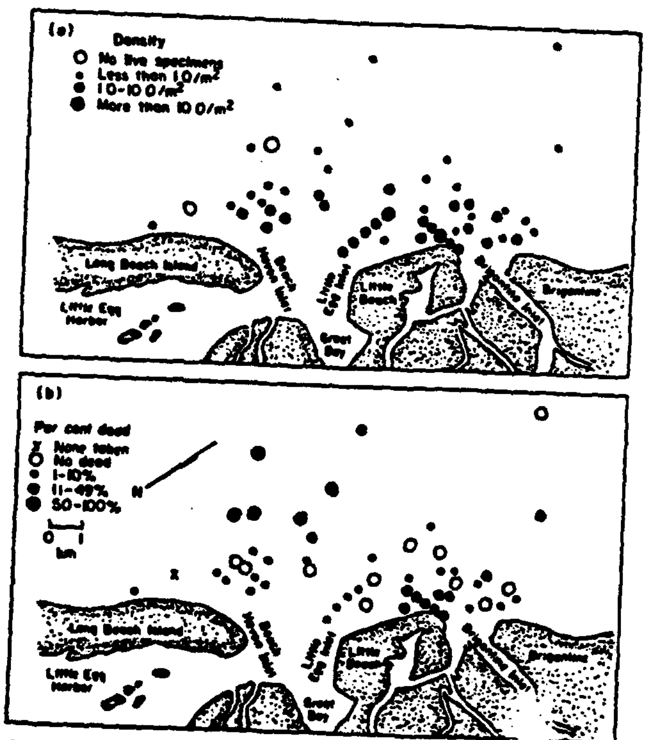
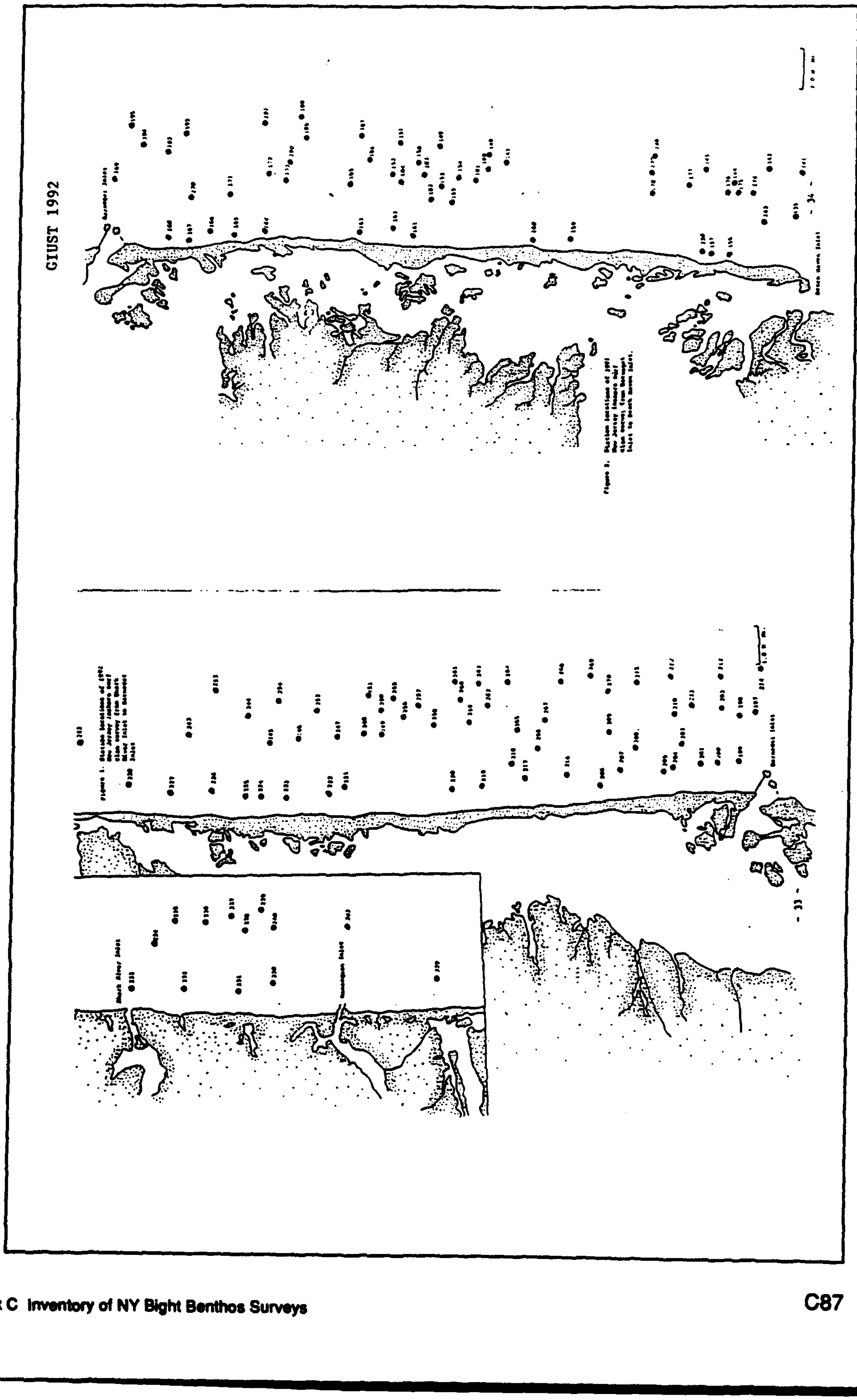


Figure 4. The density of live, adult *Spisula solidissima* and the per cent dead collected with a hydraulic clam dredge in the vicinity of Little Egg Inlet, New Jersey in September 1976.


GIUST 1992

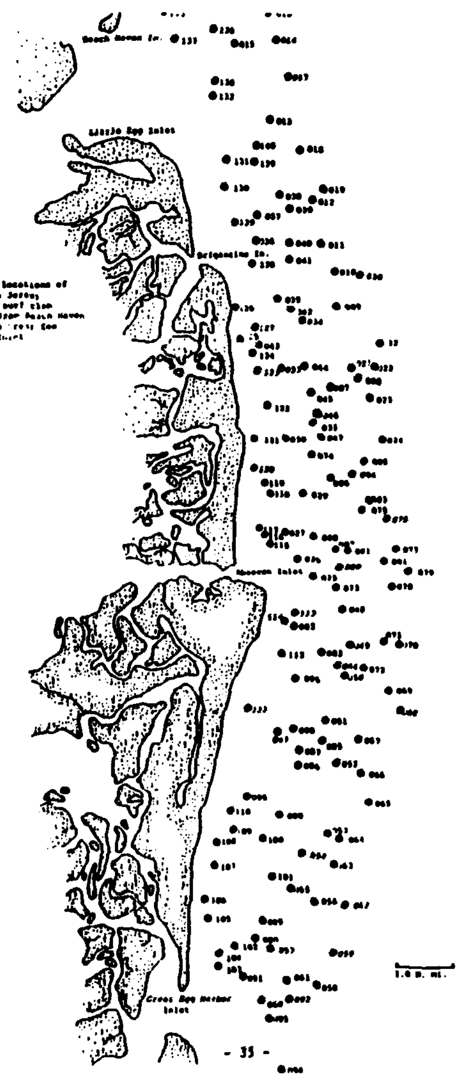


Figure 3. Station locations of 1991 New Jersey inshore surf clam survey from Beach Haven Inlet to Great Egg Harbor Inlet

- 35 -

JONES & HAEDRICK 1977

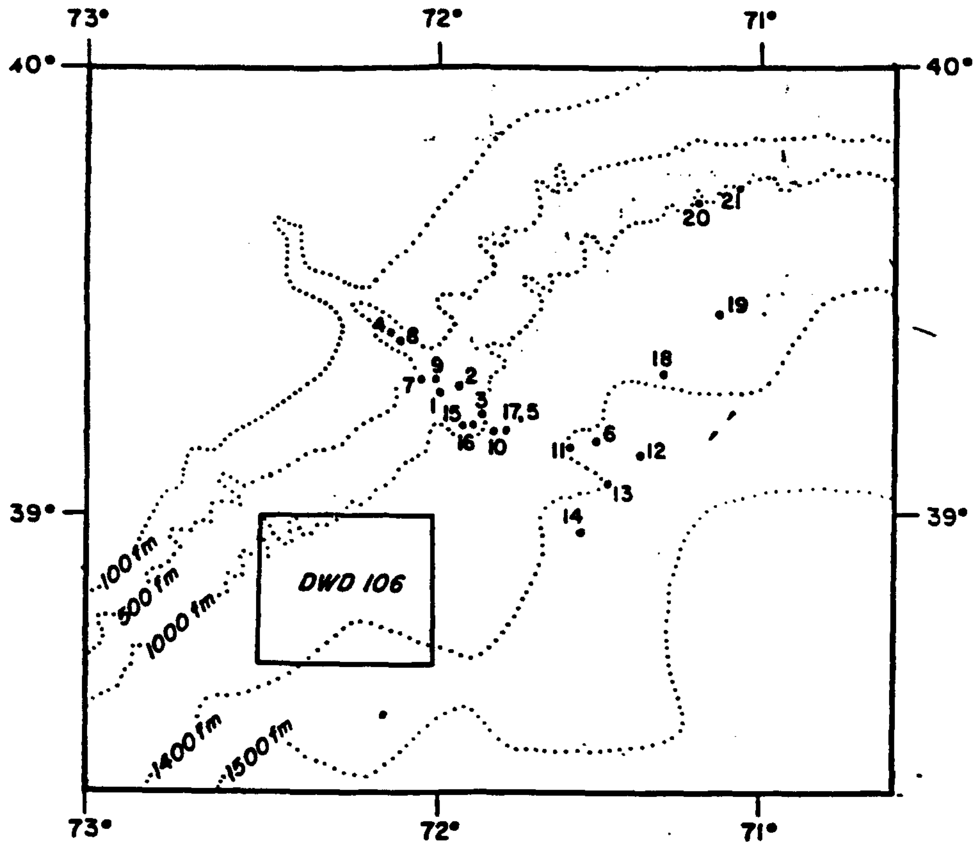


Figure 1.--Station locations for trawl-captured invertebrates.

453

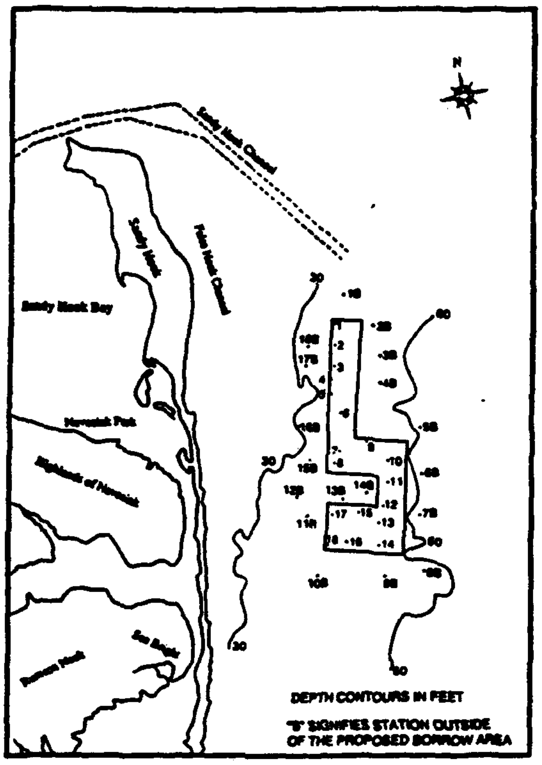


Figure 3.3-1. Approximate Location of Benthic Stations Inside and outside of the Proposed Borrow Area.

12

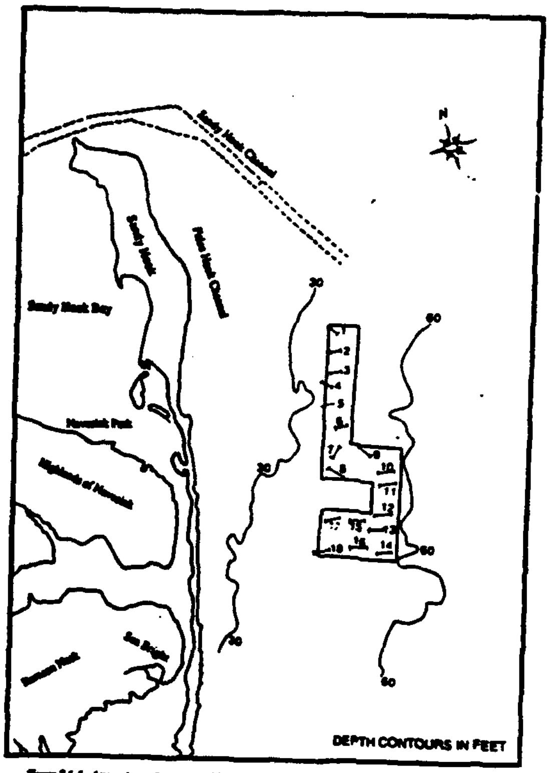


Figure 3.1-1. Approximate Location of Proposed Borrow Area and Hydraulic Clam Dredge Tows.

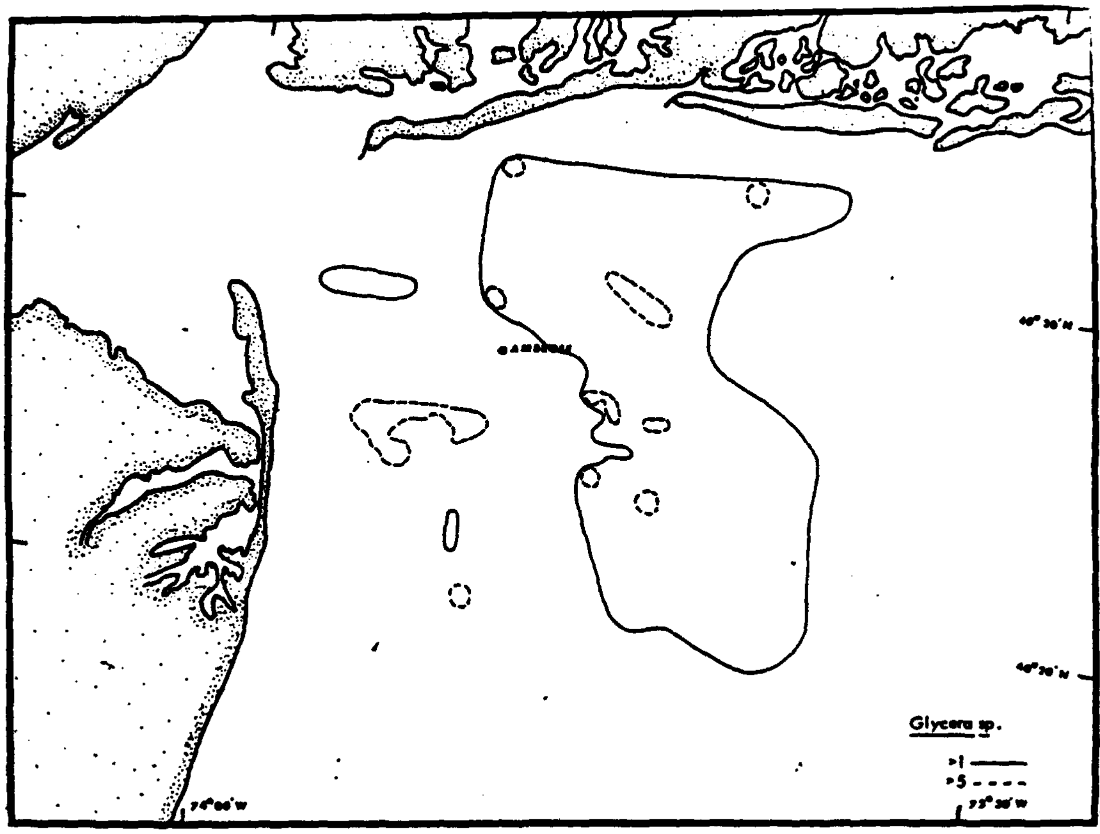


Figure 2-42

Note: This is not a station map but an example of the density distribution maps provided by the author

PEARCE ET AL. 1977a

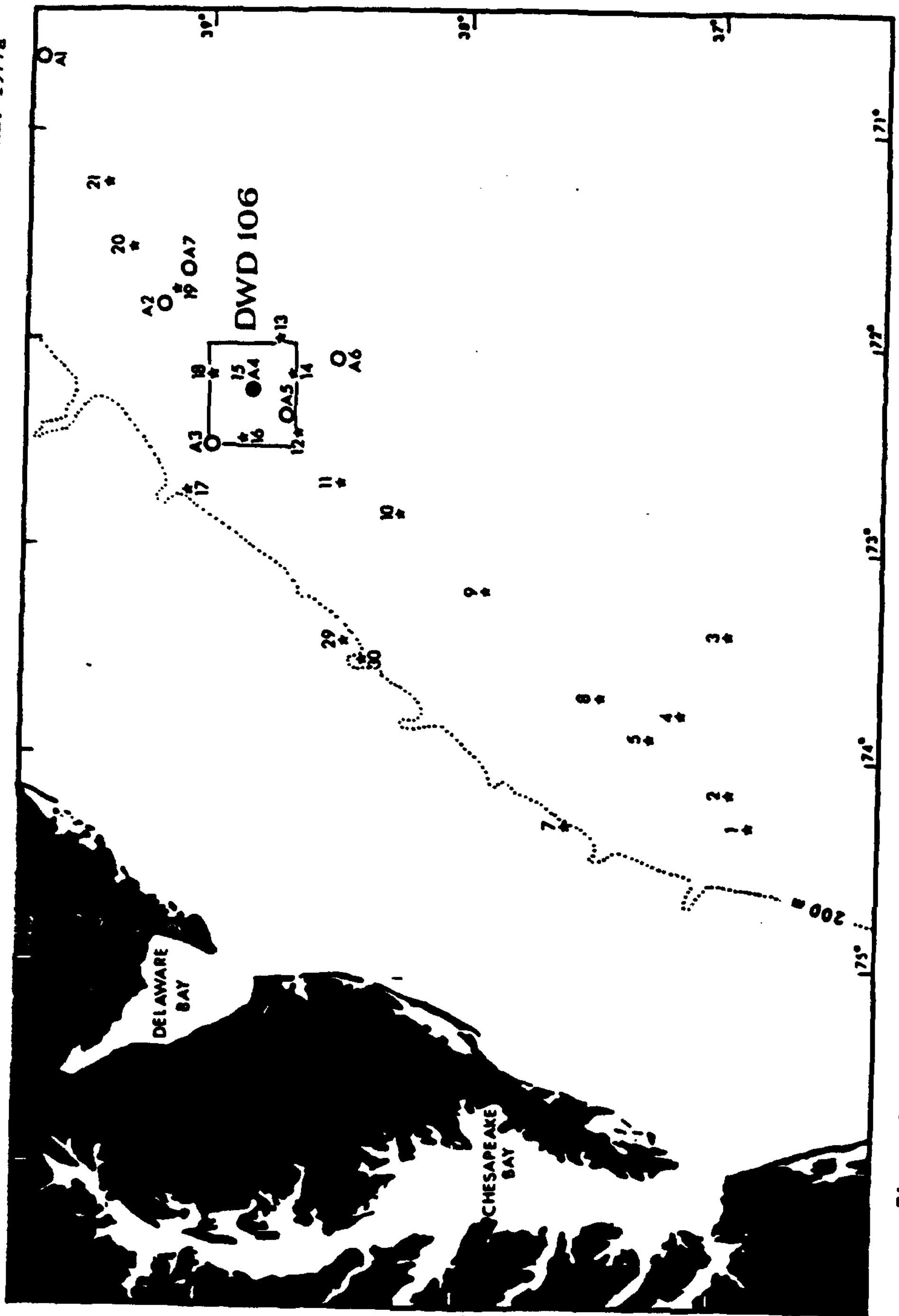


Figure 2.-- Locations of Smith-McIntyre benthic grab stations. Open circles (o) indicate 1974 sampling sites; stars (*) represent 1976 stations.

468

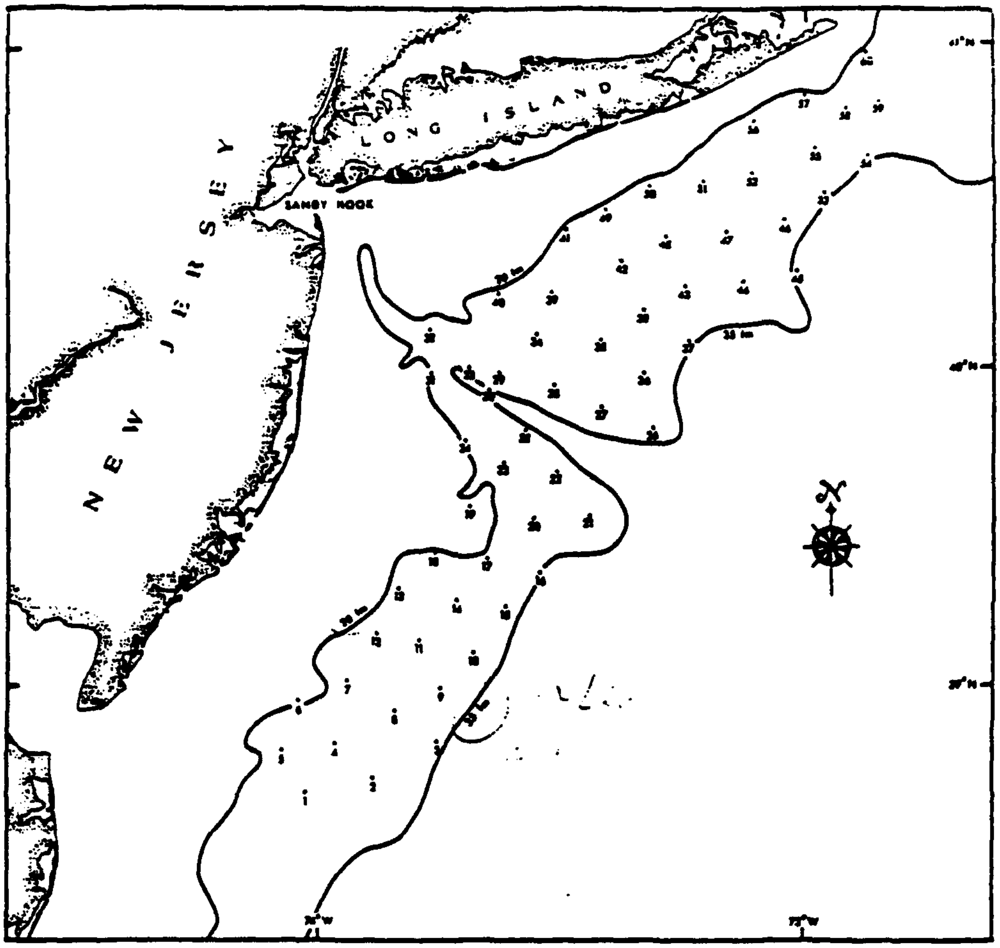
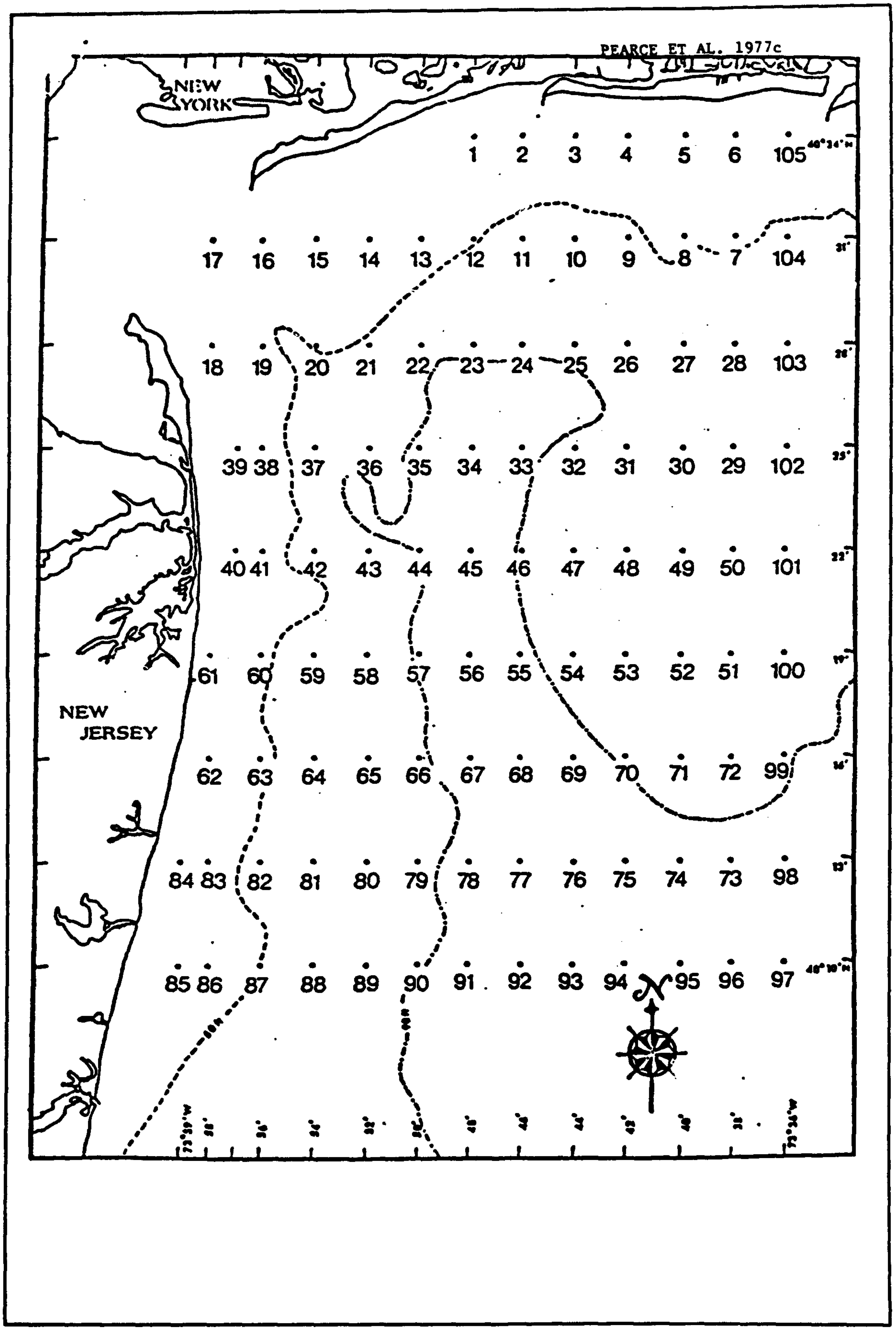
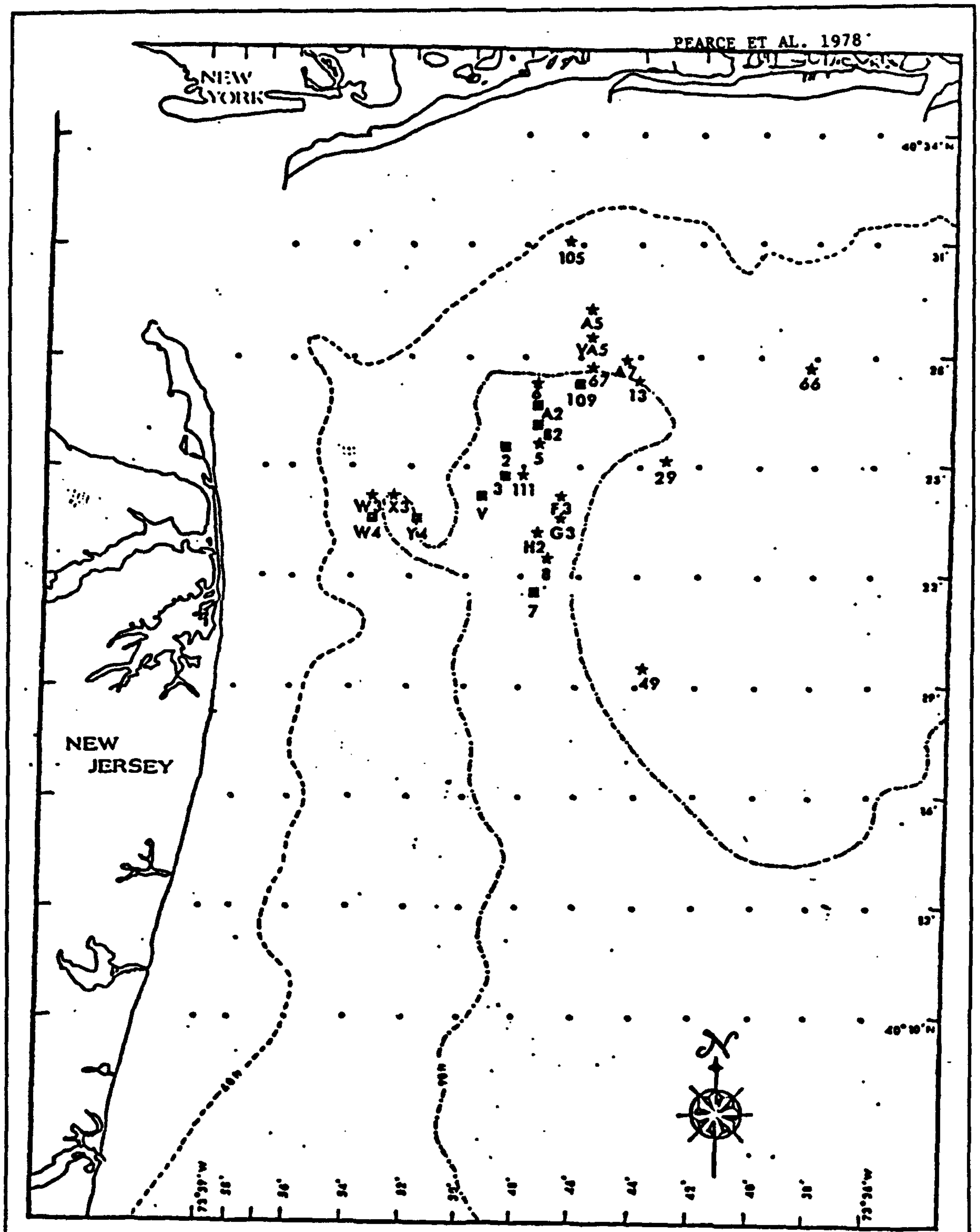


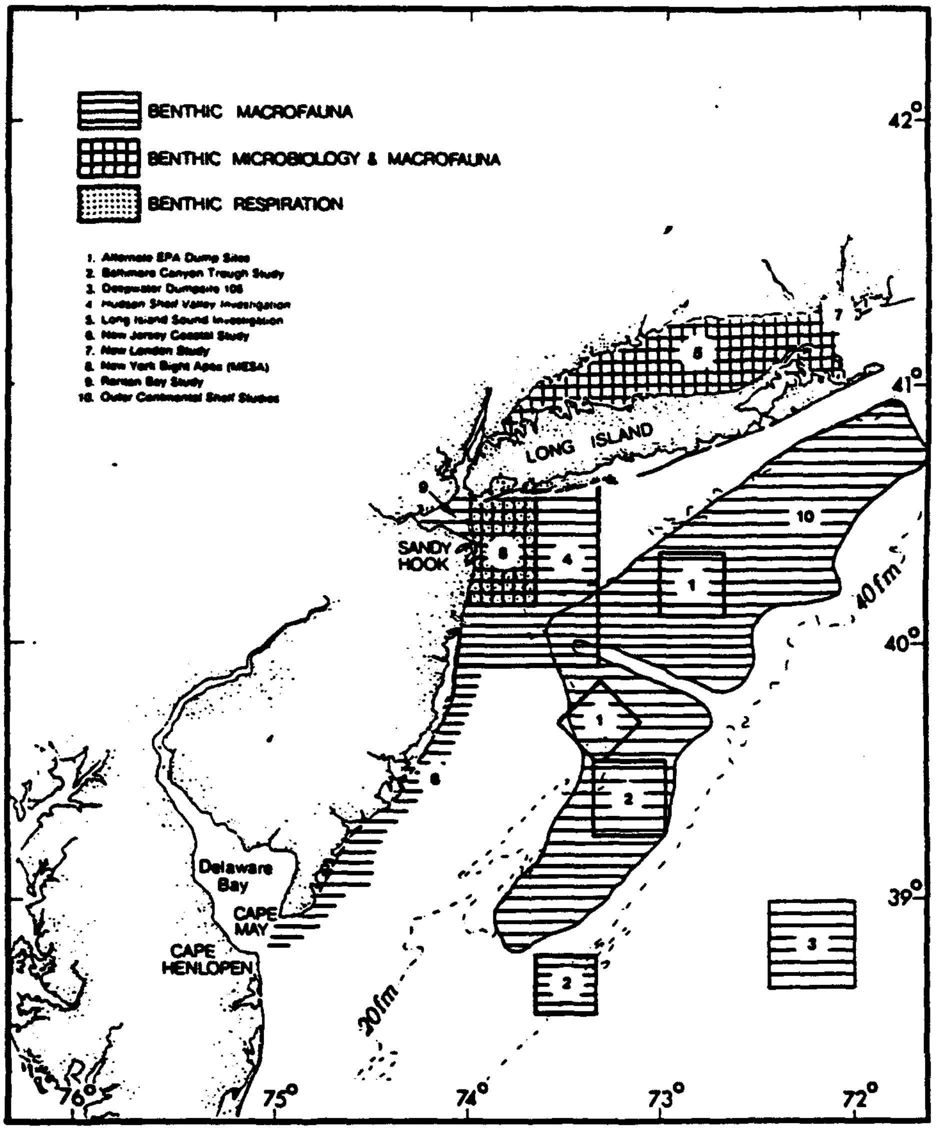
Figure 1. Outer continental shelf station positions.

2


PEARCE ET AL. 1977c
NEW YORK
NEW JERSEY
1 2 3 4 5 6 105
17 16 15 14 13 12 11 10 9 8 7 104
18 19 20 21 22 23 24 25 26 27 28 103
39 38 37 36 35 34 33 32 31 30 29 102
40 41 42 43 44 45 46 47 48 49 50 101
61 60 59 58 57 56 55 54 53 52 51 100
62 63 64 65 66 67 68 69 70 71 72 99
84 83 82 81 80 79 78 77 76 75 74 73 98
85 86 87 88 89 90 91 92 93 94 95 96 97


PEARCE ET AL. 1978
NEW
YORK
NEW
JERSEY
105
A5
YA5
67
109
13
66
A2
B2
5
2
3
111
29
W3
X3
W4
Y4
V
F3
G3
H2
8
7
49

Map 3. Areas investigated by NEFC personnel, 1968-80



Source: Sandy Hook Laboratory staff

Radosh et al 1978

RADOSH ET AL 1978

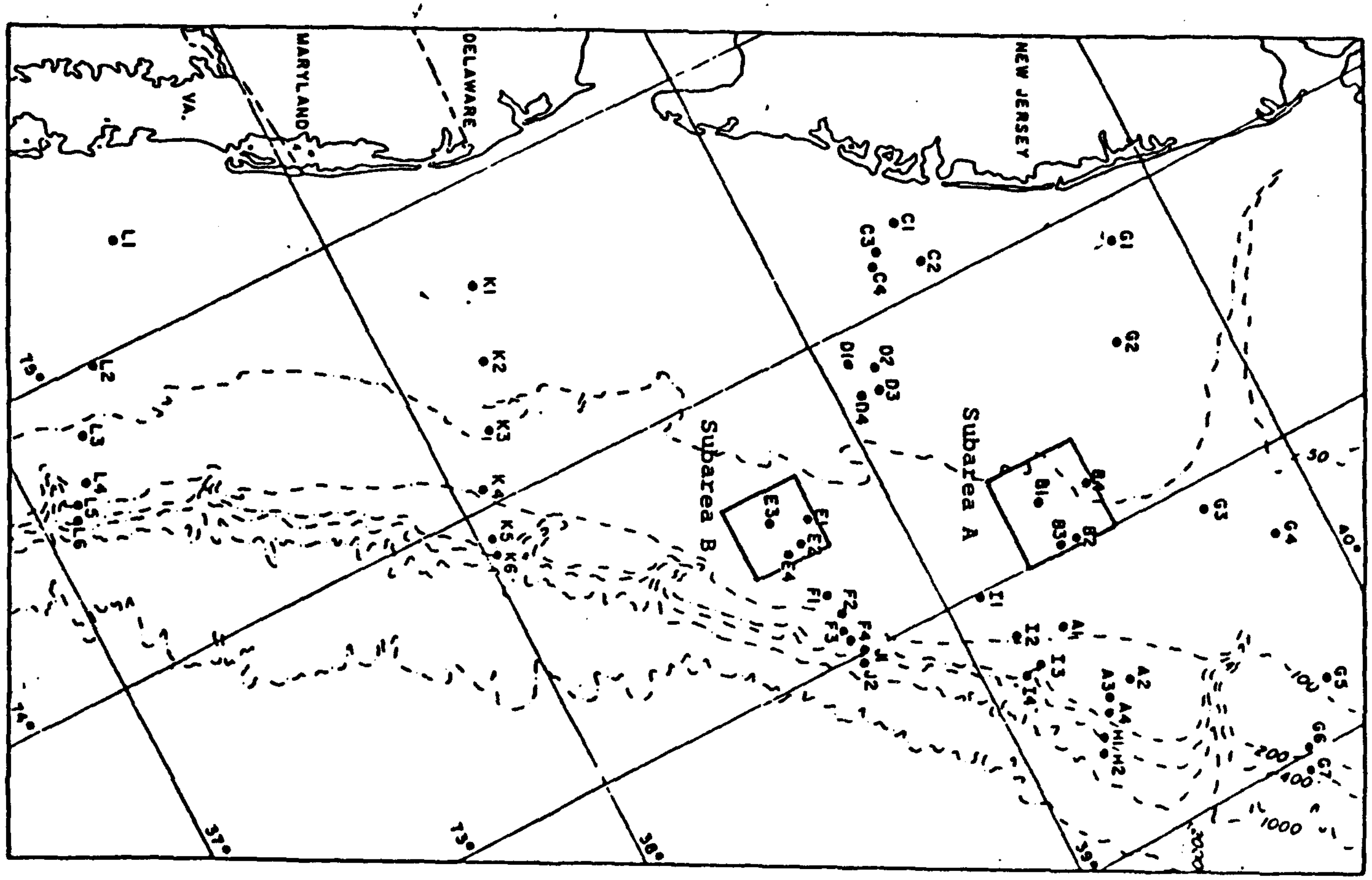


Figure 2. Middle Atlantic Outer Continental Shelf showing NMFS Subareas A and B (☐) and V.I.M.S. Benchmark Study Stations (•).

4

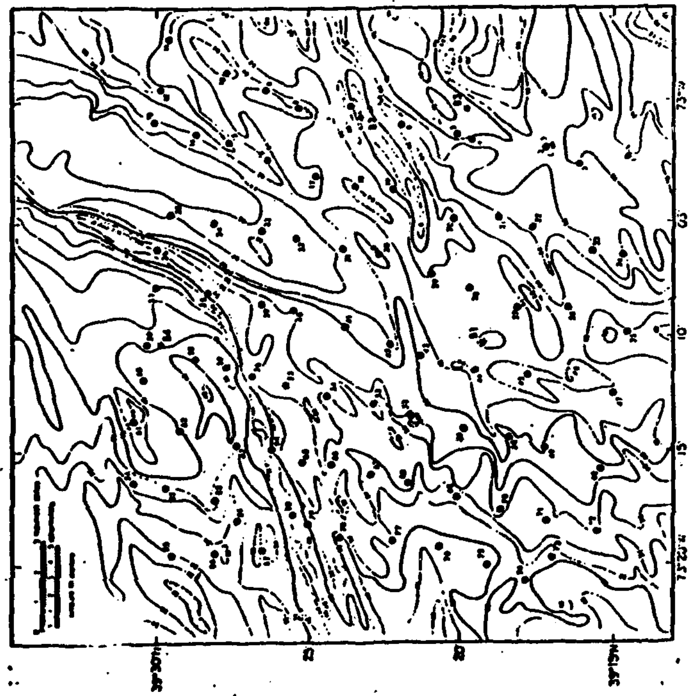


Figure 3. Bathymetries and sampling pattern in Subarea A. Approximate locations of VIMS "B" stations also shown (*).

5

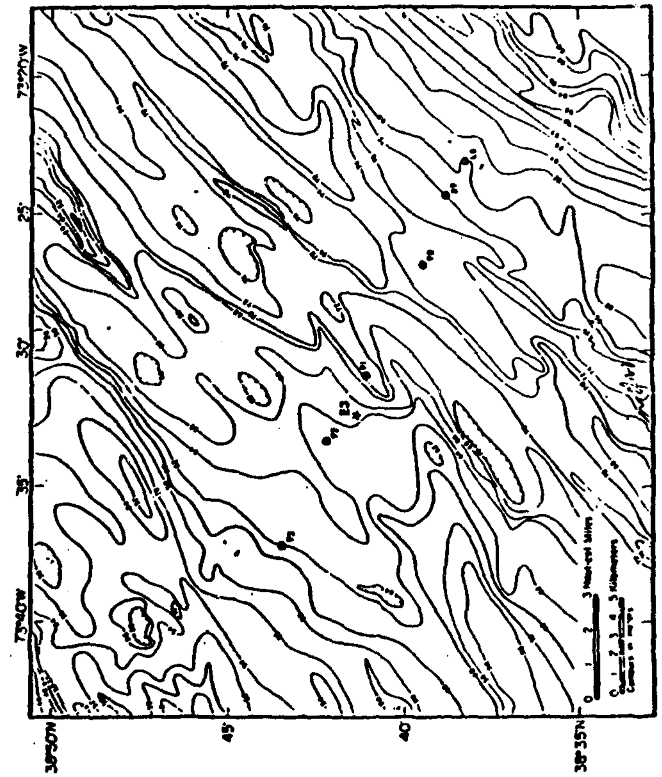


Figure 4. Bathymetries and sampling pattern in Subarea B. Approximate location of VIMS station E3 also shown (*).

6

BEST DOCUMENT AVAILABLE

REID ET AL. 1982

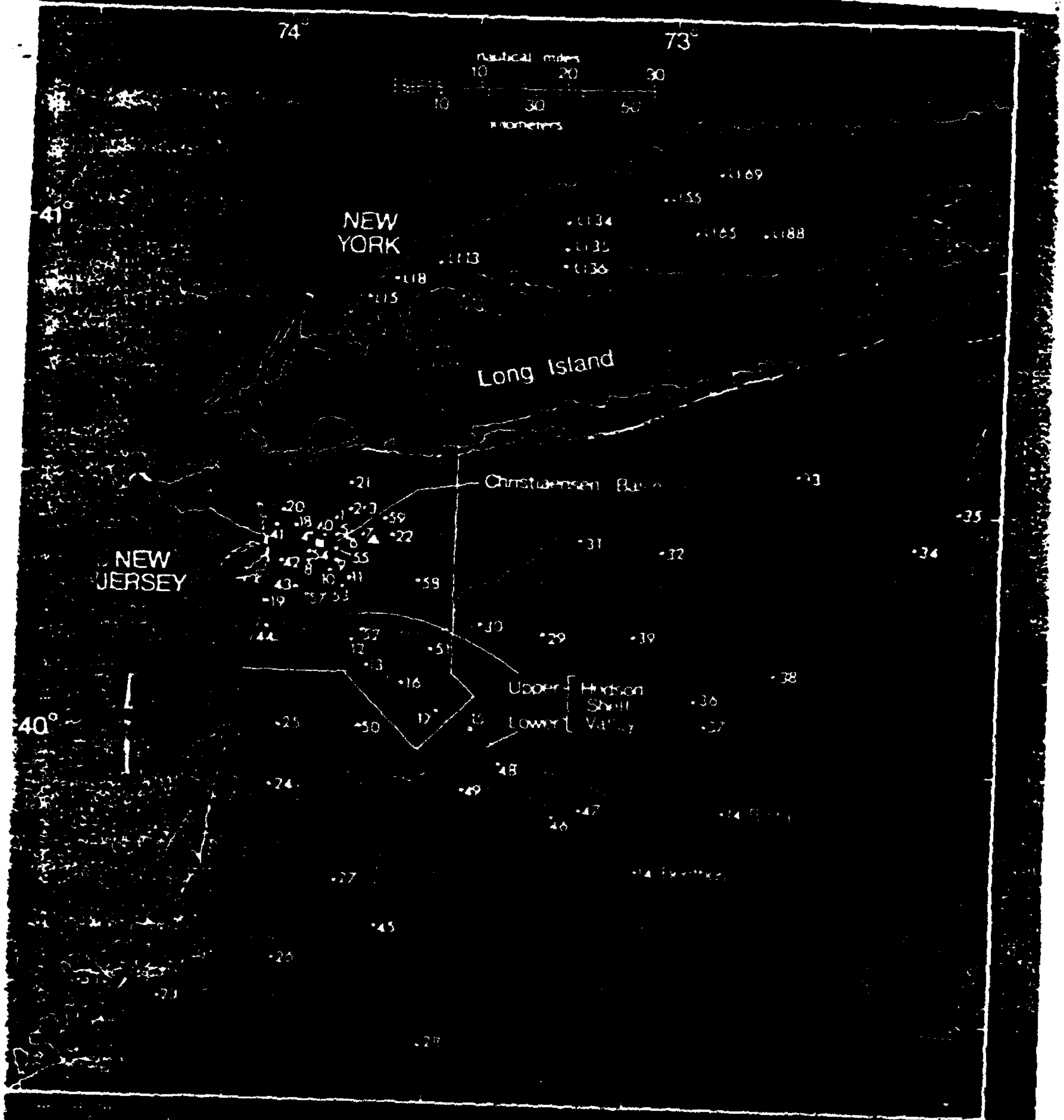


Figure 1. Station locations in New York Bight and Long Island Sound. Stations within box were a priori considered "contaminated" for comparison with other stations. "Replicate" stations (see text) are 4, 6, 7, 15, 26 and 31 (Standard NEMP sites), and 40–43. Single grabs were taken at the remainder of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

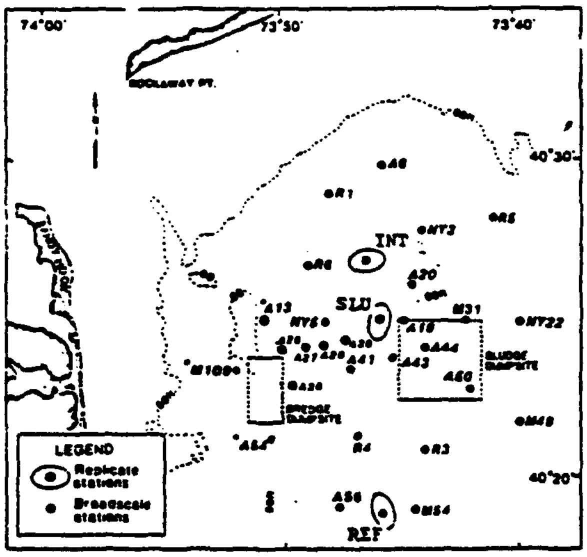


Figure 1. Locations of dumpsites and stations in inner New York Bight. From EPD (1988).

REID ET AL. 1991b

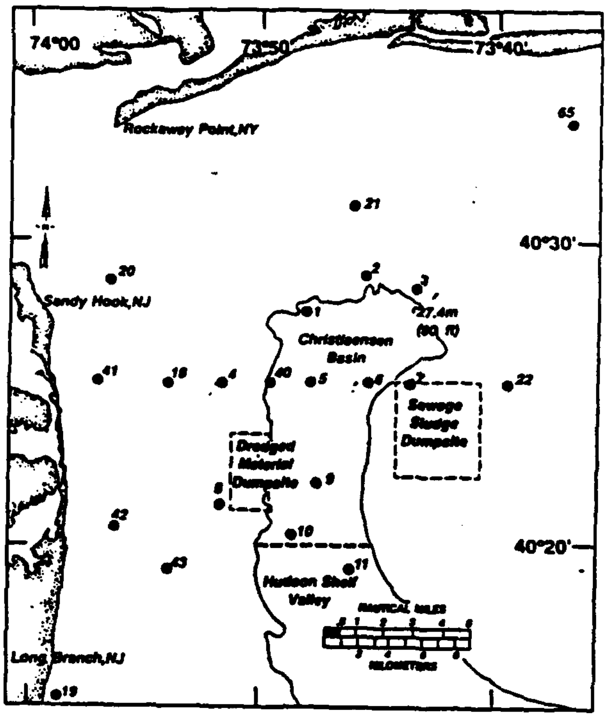


Figure 2
Details of inner New York Bight.

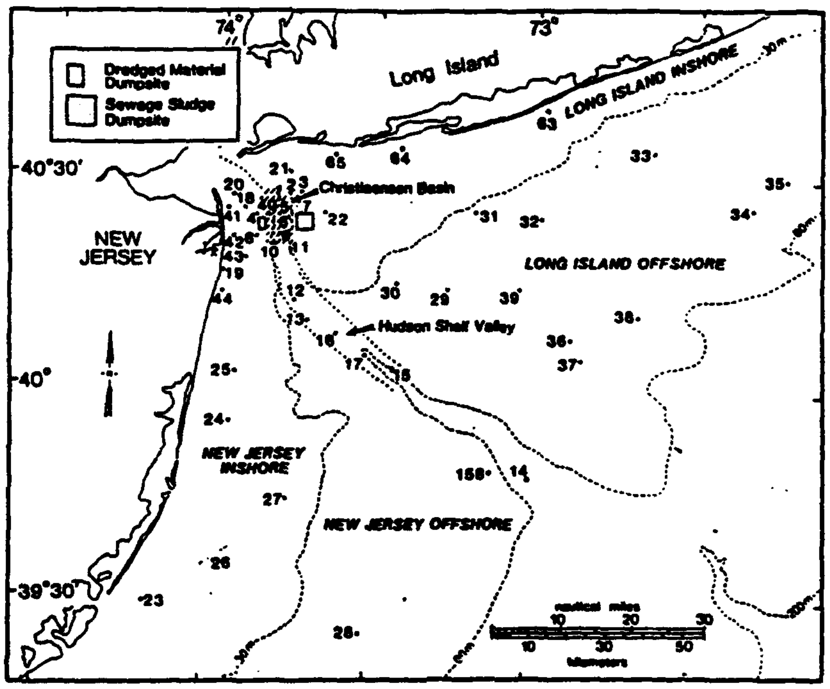


Figure 1
Station locations in New York Bight, with subareas discussed in text. Diagonal lines indicate Christiaensen Basin.

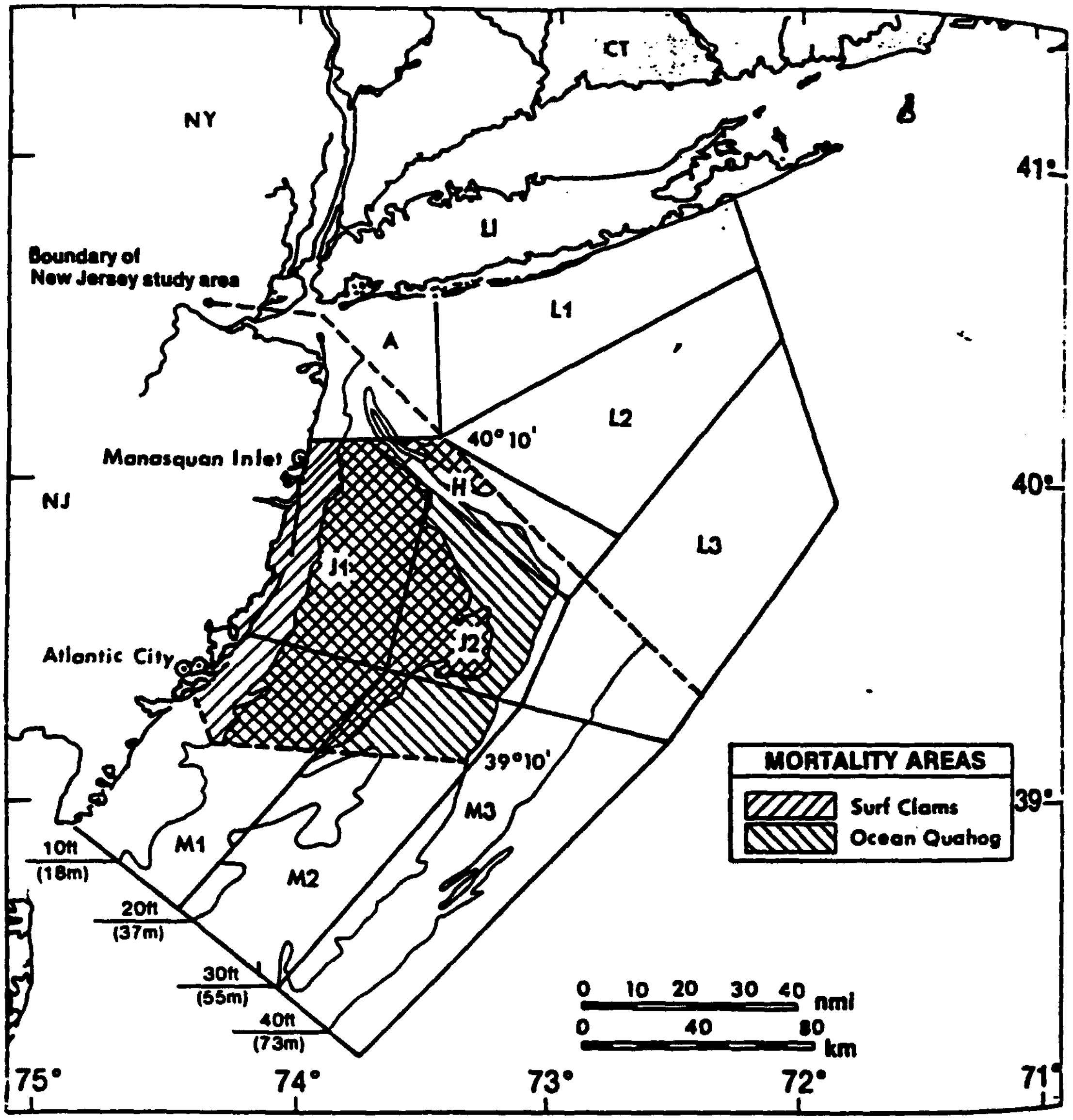


FIGURE 11.1-1.—Surf clam and ocean quahog mortality areas in New York Bight by depth zones. From data collected during January 26 to March 16, 1977, NMFS assessment cruise.

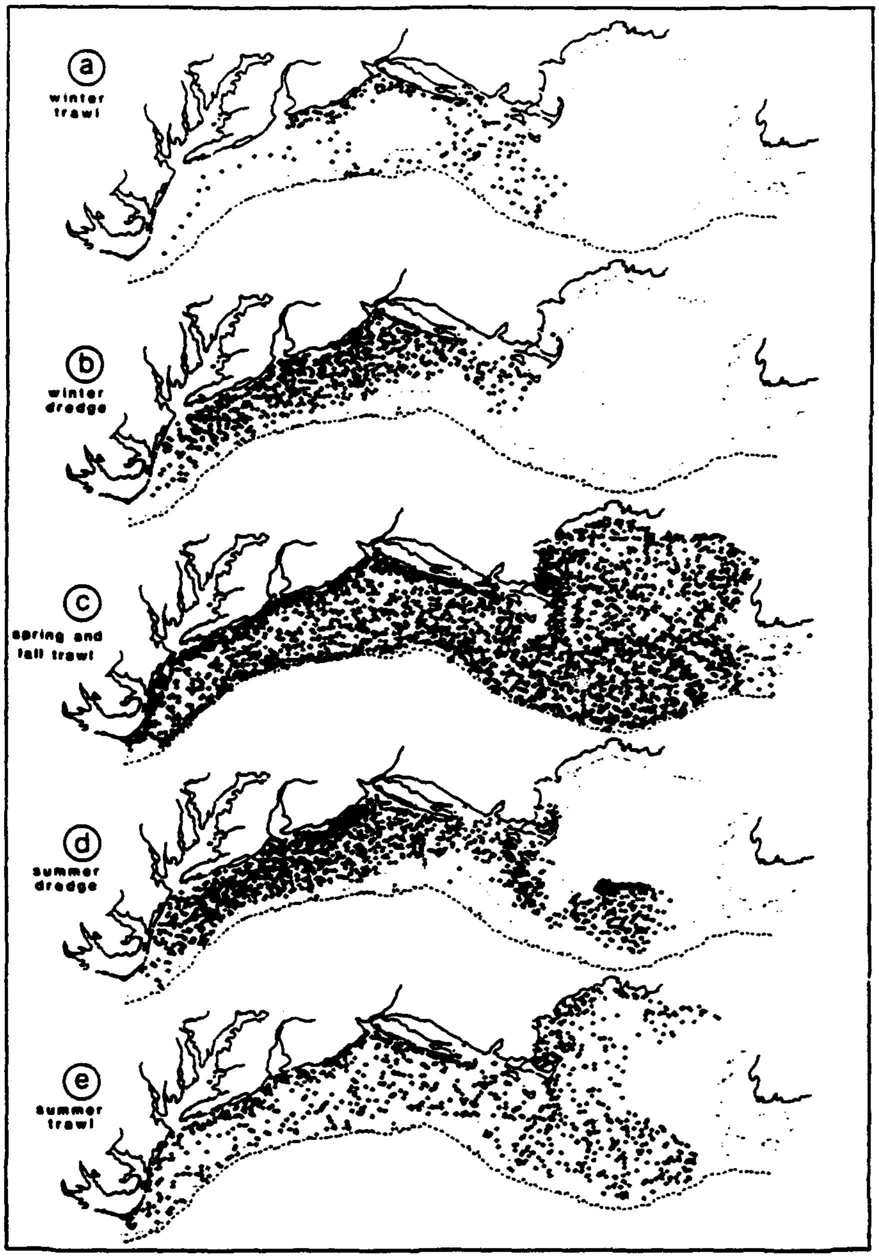


Figure 2
Cumulative station locations: (a) winter trawl, (b) winter dredge, (c) spring trawl (fall trawl similar but not shown), (d) summer dredge, (e) summer trawl.

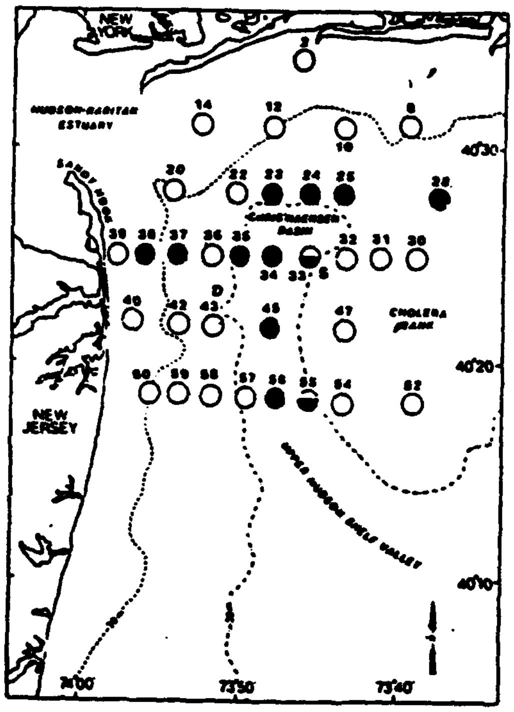


Figure 1. New York Bight apex station locations and numbers for the 1973 survey. Stations covered by ● have total biomass $\leq 100\ g\ m^{-2}$ and production $\leq 100\ Kcal\ m^{-2}\ year^{-1}$; stations covered by ◒ have total biomass $\leq 100\ g\ m^{-2}$ but estimated production $\geq 100\ Kcal\ m^{-2}\ year^{-1}$; stations covered by ○ have total biomass $\geq 100\ g\ m^{-2}$ and production $\geq 100\ Kcal\ m^{-2}\ year^{-1}$. The dredge spoil and sewage sludge dumpsites are indicated by the D and S notations, respectively.

STEIMLE 1985, cont

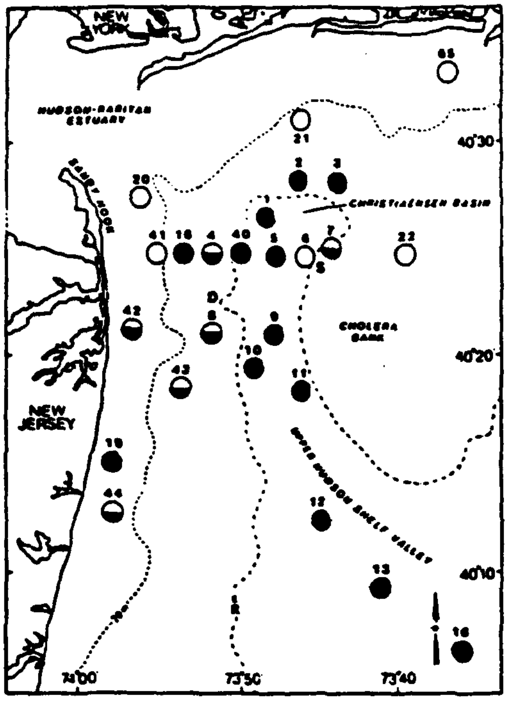


Figure 2. New York Bight apex station location and numbers for the 1980–1982 survey. See Fig. 1 for key to symbols.

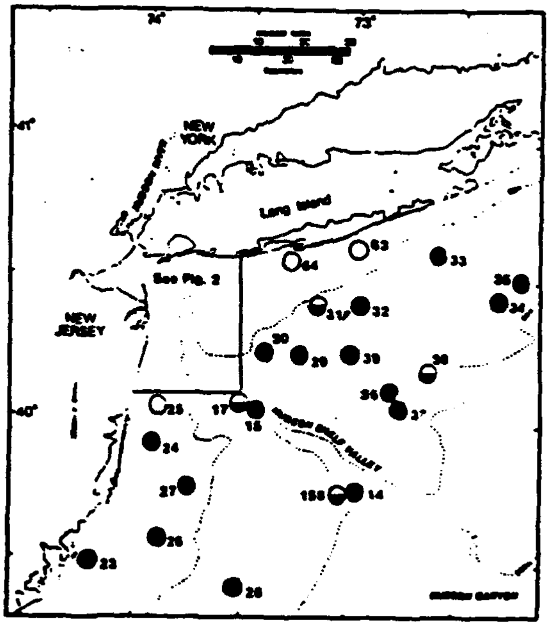


Figure 3. New York Bight station location and numbers for the 1980–1982 survey. See Fig. 1 for key to symbols.

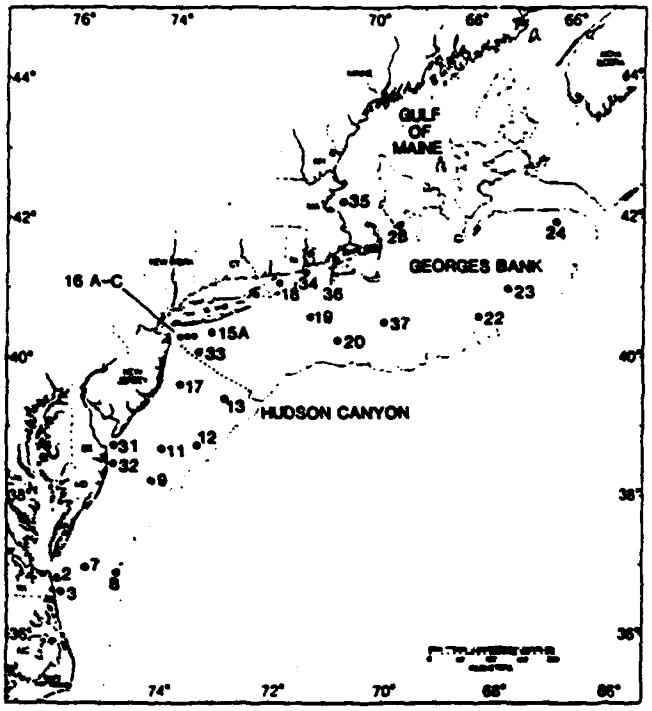


Figure 1
Location of benthic sampling sites on continental shelf, northeastern United States.

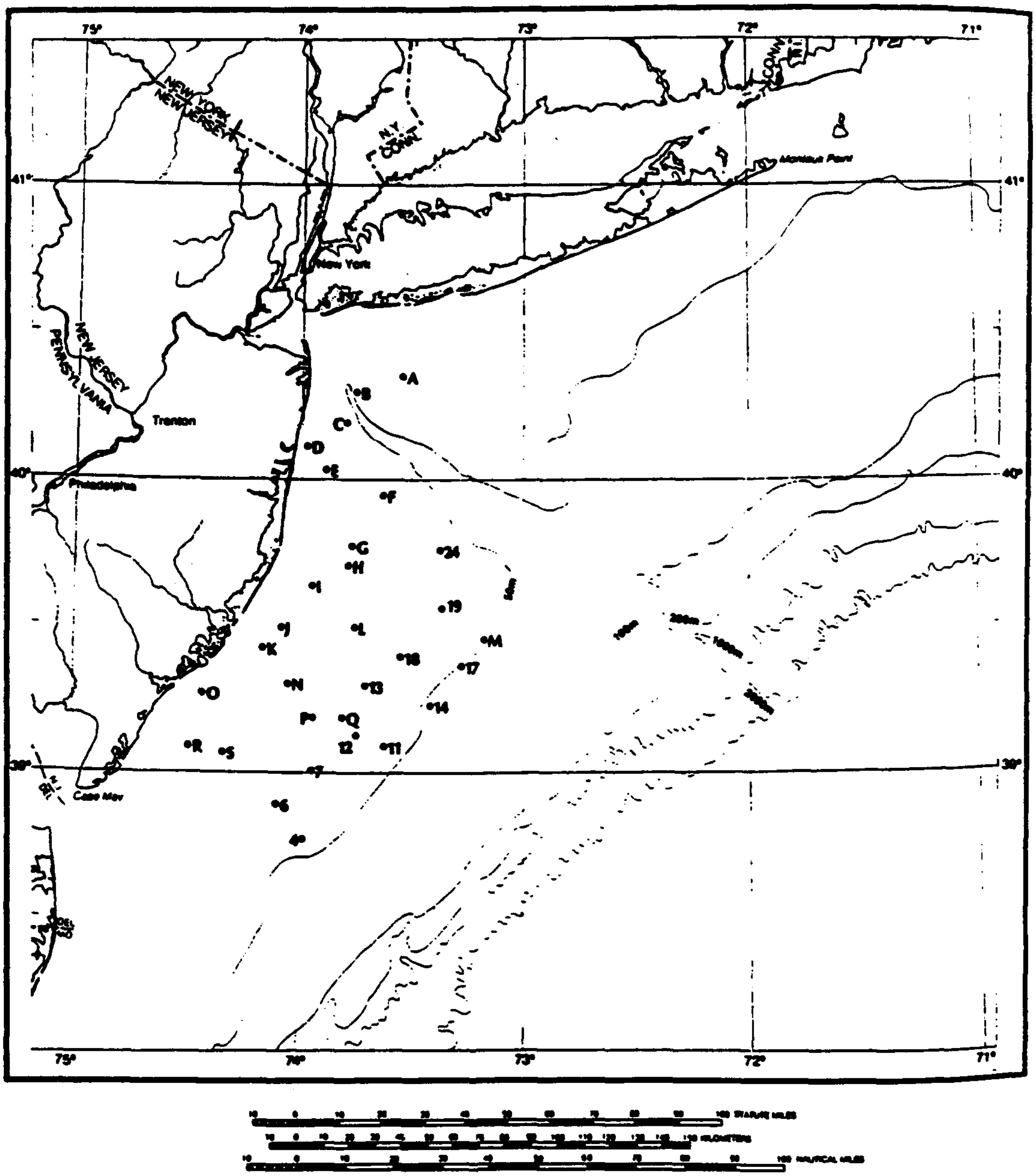


FIGURE 12-1.—Station locations for benthic grab collections. Numbered stations are part of Outer Continental Shelf series used for yearly comparisons.

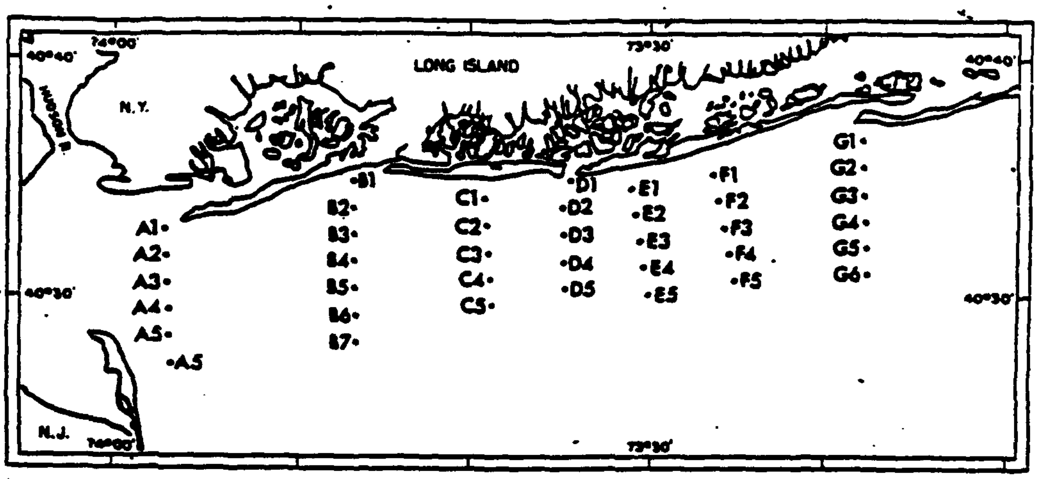


Figure 1.—RV *Challenger* survey, 1966-67. Locations of transects and collecting stations. Station D-1 is at the mouth of Jones' Inlet.

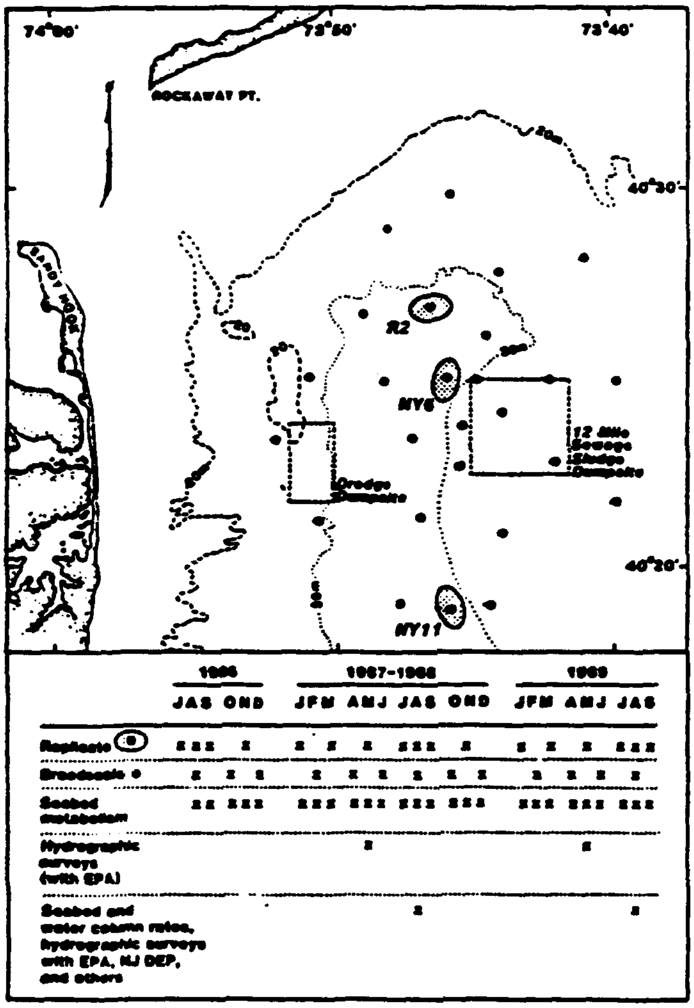


Fig. 4. Replicate, broadscale, and seabed metabolism stations (also Fig. 19) and survey schedule of the 12-mile dumpsite study.

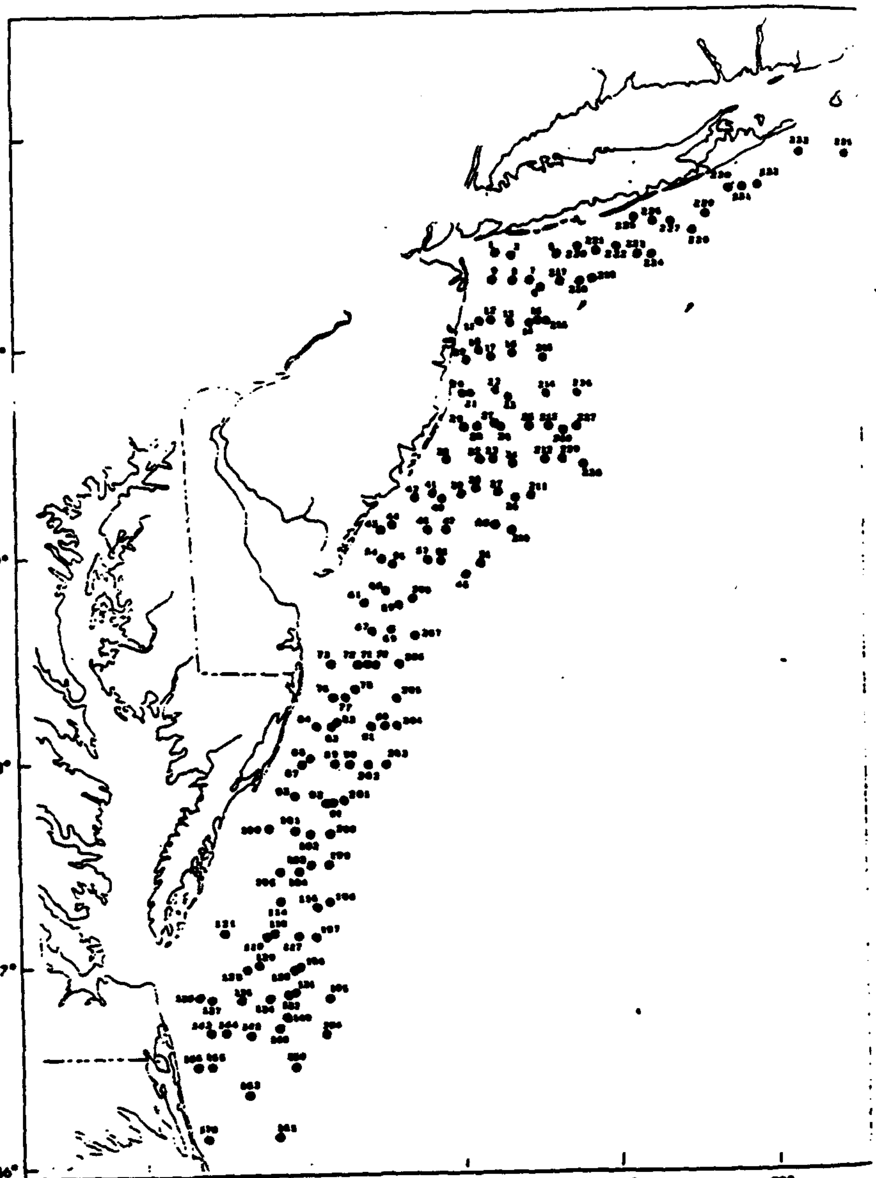


FIGURE 1.—Station location and number relative to the mid-Atlantic coast of the United States.

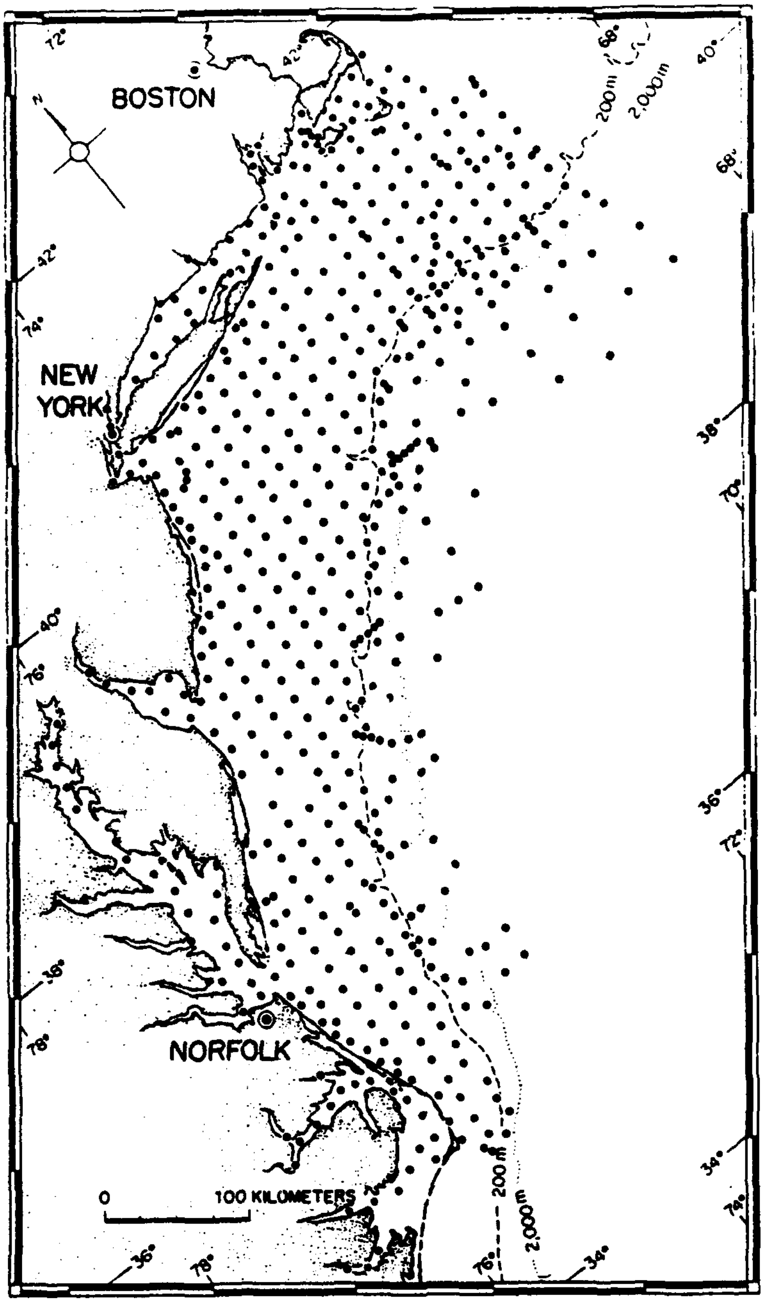


FIGURE 2.—Chart showing station locations where quantitative samples of macrobenthic invertebrates were obtained.

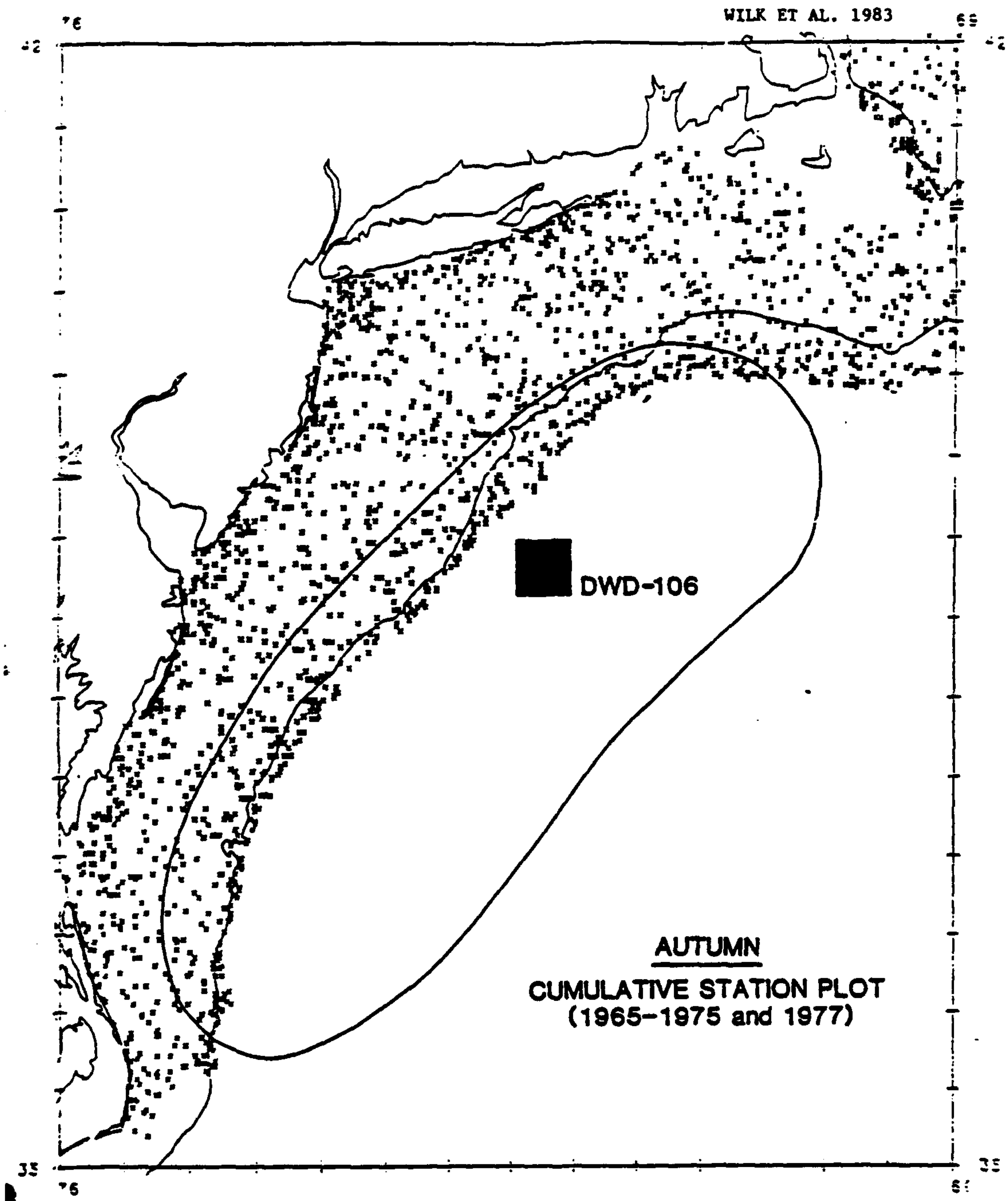


Figure 5.--Cumulative station plots of trawl sets for 12 standardized NMFS autumn bottom trawl surveys (1965-1975 and 1977) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI). 9-23

Appendix D
Inventory of NY Bight Fish Surveys

A REVIEW OF ECOLOGICAL STUDIES
OF NEW YORK BIGHT FISHERIES

Prepared for

COASTAL ECOLOGY BRANCH
WATERWAYS EXPERIMENTAL STATION
U.S. ARMY ENGINEERS

Prepared by

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25 Nashua Road
Bedford, New Hampshire 03110-5500

R-11095.03

March 1993

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1.0 INTRODUCTION

This document provides a review of fisheries ecological studies performed in the New York Bight and Bight Apex. The objective was to summarize the sampling methodologies and intensity of the studies in various locales within the Bight. A secondary objective was to evaluate gear effectiveness by providing information on abundances of commercially important species.

The New York Bight Apex was defined as all offshore marine areas seaward of a line drawn between Rockaway Point, NY and Sandy Hook, NJ as indicated on NOAA chart 12326. The New York Bight was defined as all offshore marine areas depicted on NOAA chart 12300 exclusive of the Apex that are west of Montauk Point, NY and landward of the 1000-fathom depth contour, not including Long Island Sound.

2.0 METHODS

Literature Acquisition

Fisheries studies were identified through a combination of agency contacts, computerized literature search, and review of references cited in fisheries literature. We performed an electronic literature search of the U.S. Government Documents and the Biological Abstracts data bases. Review of the references cited in recent publications also provided us with citations for fisheries studies. Finally, agency contacts helped us uncover additional fisheries surveys. Mr. Stuart J. Wilk of NOAA's NMFS Sandy Hook Laboratory graciously provided us with references and many of their reports. Other agency contacts are listed in Table 2-1.

Preparation of the Annotated Bibliography

Each report was reviewed for sampling locations and dates, methodology, type of data reported, and archival status of samples that were not fully analyzed. In some cases, the information was not included in the document. The intent was to focus on published literature, with studies involving multiple sampling events receiving the highest priority. In reality, the studies were generally reviewed in the order that they were received, so efforts were concentrated on the most accessible information.

The study area was subdivided into relatively homogeneous areas or strata based on a preliminary review of the information. Strata generally coincided with the strata used in the "Review of Ecological Studies of New York Bight Benthos", also prepared by NAI. In the New York Bight Apex, the Mud Dump, Sewage Dumpsite, Christiaensen Basin, and "all remaining areas" were defined as strata. In the New York Bight outside of the Bight Apex, the Hudson Shelf Valley was used to divide the area into northern (generally off Long Island) and southern (off New Jersey) areas. Within these two areas, strata were defined based on depth. Areas with depths less than 27 m (15 f) were defined as near-coastal, depths from 28-55 m (15-30 f) were defined as mid-coastal, depths from 55-110 m (30-60 f) were defined as outer shelf, depths from 111-183 m (60-100 f) as shelfbreak, and greater than 183 m as shelf rise. The sampling effort for each stratum including number of sampling events for each year and the year(s) and month(s) of each sampling event, were tabulated (when reported) from the fisheries studies that were available.

The most comprehensive survey was the National Marine Fisheries Service (NMFS) Groundfish Survey. This survey is a multi-year sampling effort in the spring and fall of each year with samples collected on the continental shelf from Florida through the Gulf of Maine. Mr. Brian O'Gorman of NOAA's NMFS Northeast Fisheries Center in Woods Hole, MA graciously provided machine-readable NMFS groundfish survey data for dominant species from the New York Bight area collected from 1982-1992. These data were used to prepare figures of catch per unit effort (CPUE) for selected groundfish. Only the data from the NMFS Groundfish Survey were used to prepare CPUE figures due to the large sample sizes, and uniformity of sampling gear and collection methods.

Sampling effort in the NMFS Groundfish Survey was allocated to relatively homogeneous sampling strata defined by NMFS (Figure 2-1). These sampling strata differed from those we defined for the other fisheries and benthic studies. Because of the paucity of sampling efforts in the shelfbreak (111-183 m) and slope (>183 m) strata, we combined these two strata into shelfbreak/slope. The sampling strata used in the NMFS Survey were Long Island Near Coastal (<27 m), New Jersey Near Coastal (<27 m), North Mid-shelf (28-55 m), North Outer Shelf (56-110 m), North Shelfbreak/Slope (>110 m), South Mid-shelf (28-55 m), South Outer Shelf (56-110 m), and South Shelfbreak/Slope (>110 m). In addition to these sampling strata, the Dredged Material Dumpsite and the Sewage Sludge Dumpsite were included as separate strata. The sampling effort for each strata was tabulated by season and year.

3.0 RESULTS

A total of 28 studies published between 1973 and 1991 were reviewed (Table 3-1). The largest single source of data was from the NMFS Groundfish Surveys. The NMFS Groundfish Survey began in 1963 and the sampling methods and design have changed only slightly since the beginning of the survey (Depres-Patanjo 1988). There have been no significant changes in sampling methods or design since 1981. The purpose of the NMFS Survey was to assess groundfish stocks on the continental shelf from Cape Hatteras to Nova Scotia each spring and fall. The continental shelf was divided into sampling strata and sampling stations were allocated to each stratum in proportion to its area. Within each sampling stratum specific sampling stations were randomly distributed. At each station a "Number 36 Yankee" bottom trawl with roller gear, and a 12.5 mm liner in the cod end is deployed for a 30 minute tow with a tow speed of 1.8 m/s relative to the bottom. The entire catch is sorted by species, counted, weighed and measured. Age samples, stomach contents, sex, reproductive condition data are also collected. Data are processed by computer and are available as computer files through the Northeast Fisheries Center in Woods Hole. The long time series, large sample sizes, consistency in data collection methods and objectives coupled with availability of the data as computer files makes the NMFS Survey the best single source for fisheries data in the New York Bight (Table 3-2).

Several of the studies cited in Table 3-1 make use of the NMFS Survey data. McEachran and Musick (1975) used catch data from the NMFS Survey to determine the distribution and relative abundance of skates. Wilk and Silverman (1976) is a tabulation of fish catches and hydrographic data from the NMFS Survey between 1968 and 1972. Wilk et al. (1977) used data from the NMFS Survev ^s one of the sources for their data tabulation of fish catches and associated environmental data in New York Bight between 1974 and 1975.

More fisheries studies were directed to the Near Coastal South stratum than any other stratum (Table 3-3). The majority of the studies in this stratum were associated with a proposed power plant near Little Egg Inlet. These studies used a variety of sampling gear including gill nets (Danila 1974, 1975, 1976) lobster pots (Margraf and Miller 1974; Miller 1975) and otter trawls (Milstein 1974, 1975; Milstein and Hamer 1976; Thomas and Milstein 1974) to monitor the fisheries resources in the vicinity of Little Egg Inlet. These studies took place during most months of year between 1973 and 1975 (Table 3-4) and provide a good synopsis of the fisheries resources of the New Jersey Coast in the early 1970's, but because of the small geographic are covered, have limited application to the rest of the New York Bight.

The NMFS Survey data were used to calculate mean catch, maximum and minimum catches and number of samples for in each sampling stratum for selected groundfish species (Figures 3-1 through 3-14). Only the NMFS Survey data were used for these calculations because of the relatively large sample sizes, similarity of collection methods among years and the range of years and geographic areas sampled.

4.0 DISCUSSION

The NMFS data indicate that the demersal fish of New York Bight show a distribution that is strongly contagious in space and time. This is not surprising since most fish have specific habitat requirements at different times of the year. In general, abundances of Atlantic cod, black sea bass, ocean pout, scup, winter flounder, and skate sp. were greatest in the near coastal strata and decreased with depth to the shelfbreak/slope strata. Silver hake were relatively abundant in all sampling strata. Red hake appeared to be most abundant in sampling strata deeper than 55 m.

Several species were also more numerous at specific times of the year. Winter flounder were most abundant in the near coastal strata during the spring, and scup were most abundant in the near coastal strata in the fall. The increase in winter flounder abundance in the spring is probably associated with an offshore movement as inshore waters begin to warm. The increase in abundance of scup in the fall is probably associated with a movement of young-of-the-year scup out of the bays and estuaries. Ocean pout catches were greatest in the spring when ocean pout are feeding over sand and gravel areas that make them more vulnerable to trawling.

Haddock distribution was strongly contagious. Catches were generally very low, but large catches occurred in the north outer coastal strata and the south outer coastal strata during the fall of 1987.

In general, there was a trend of decreasing abundance of demersal fish in the New York Bight area with time. This trend is most evident in the Atlantic cod, ocean pout, red hake, silver hake and winter flounder catches. The NMFS groundfish survey has undergone relatively few changes in gear since 1981. Therefore, any apparent trends in demersal fish abundance are probably real and not an artifact of sampling methods. Beginning in 1985, new trawl doors were used because the old design was no longer readily available. Otter trawl performance is sensitive to the type of trawl doors used and there may be a slight differences in the performance of the NMFS trawl with the new doors. However, any biases in catch data due to the introduction of new trawl doors are minor compared to decrease in abundance of commercially important groundfish in recent years. Total commercial CPUE of groundfish in the North Middle Atlantic (Cape Cod through New Jersey) has decreased steadily since a peak in 1982 (NOAA 1992). For these reasons, the most recent year's data provide the most accurate picture of the dynamic fisheries resources of New York Bight.

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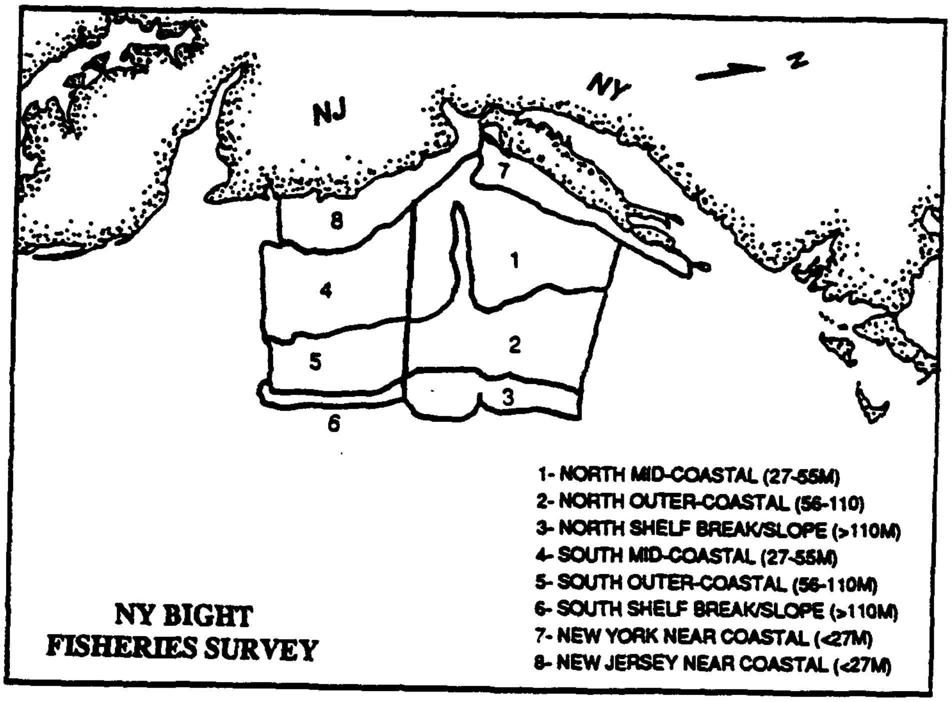
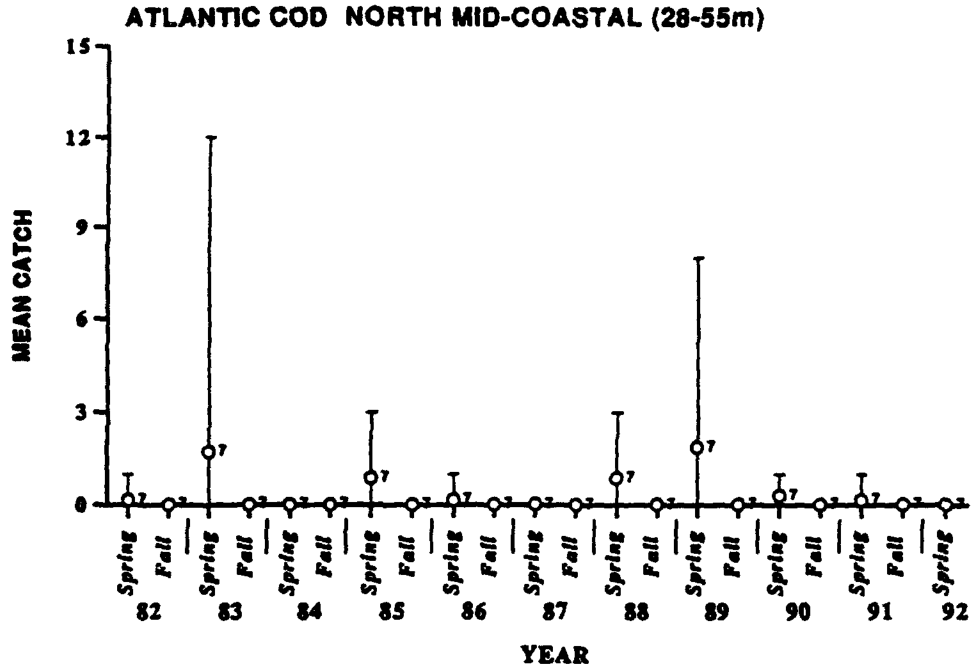


Figure 2-1. Sampling Strata used in NMFS Groundfish Survey.



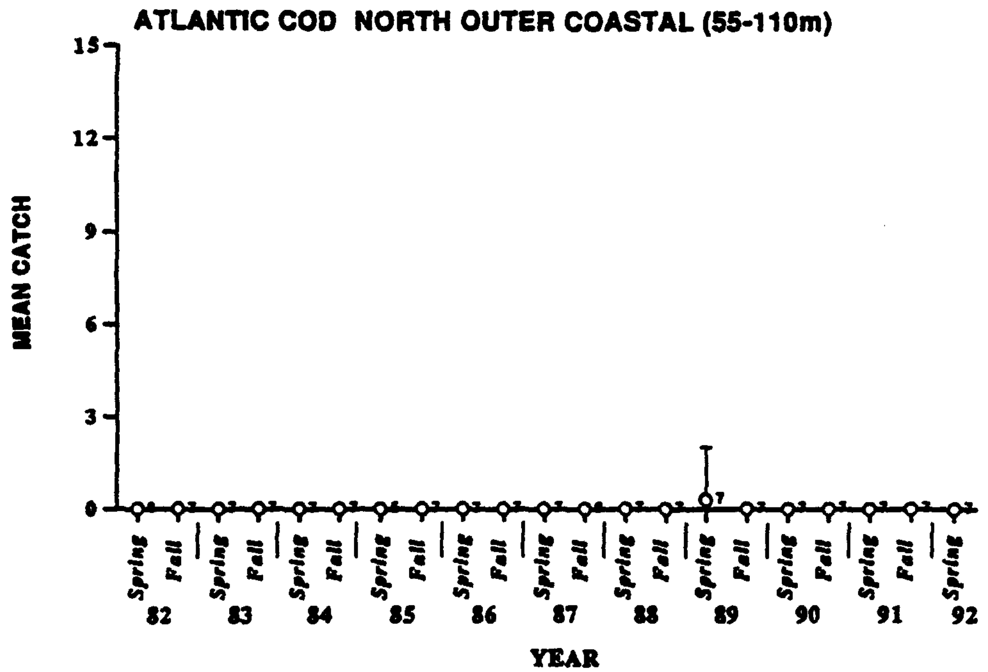
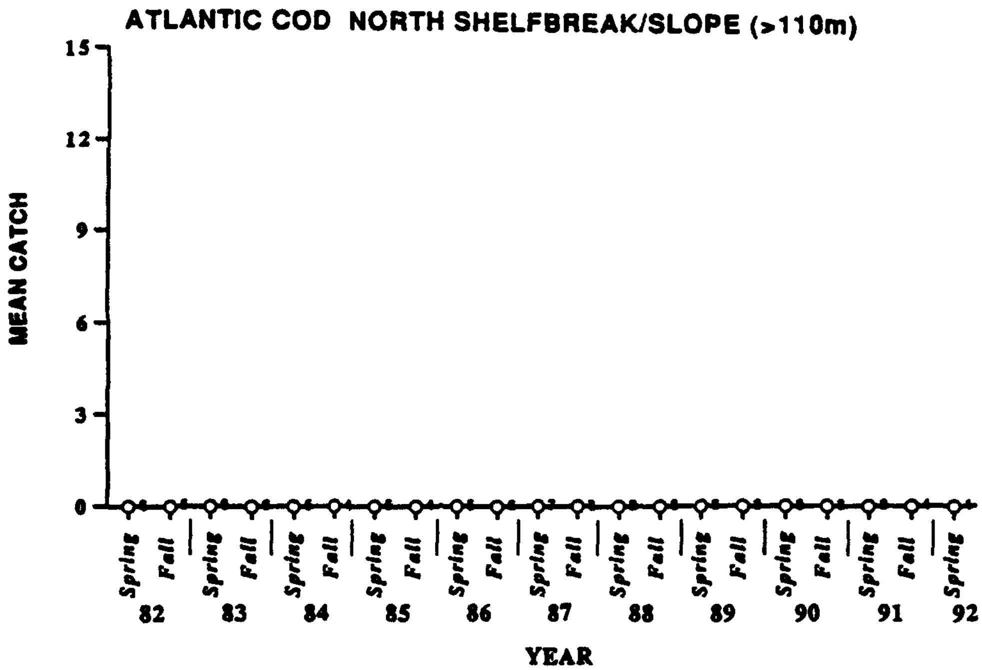
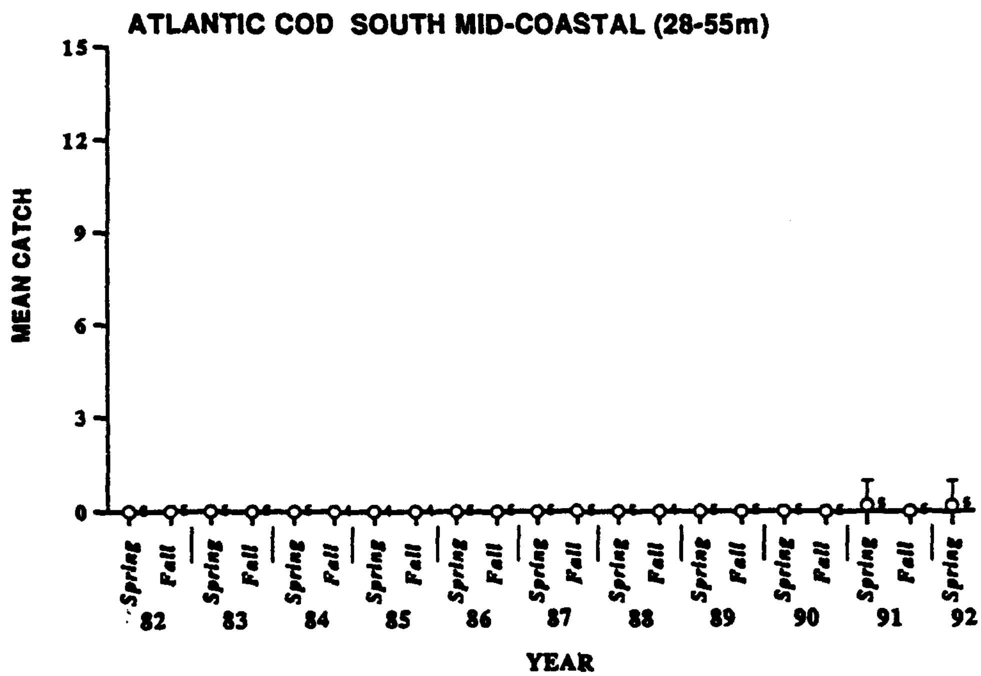


Figure 3-1. Mean catch, minimum catch and maximum catch, and number of samples (n) of Atlantic cod by year and season in sampling strata of New York Bight.





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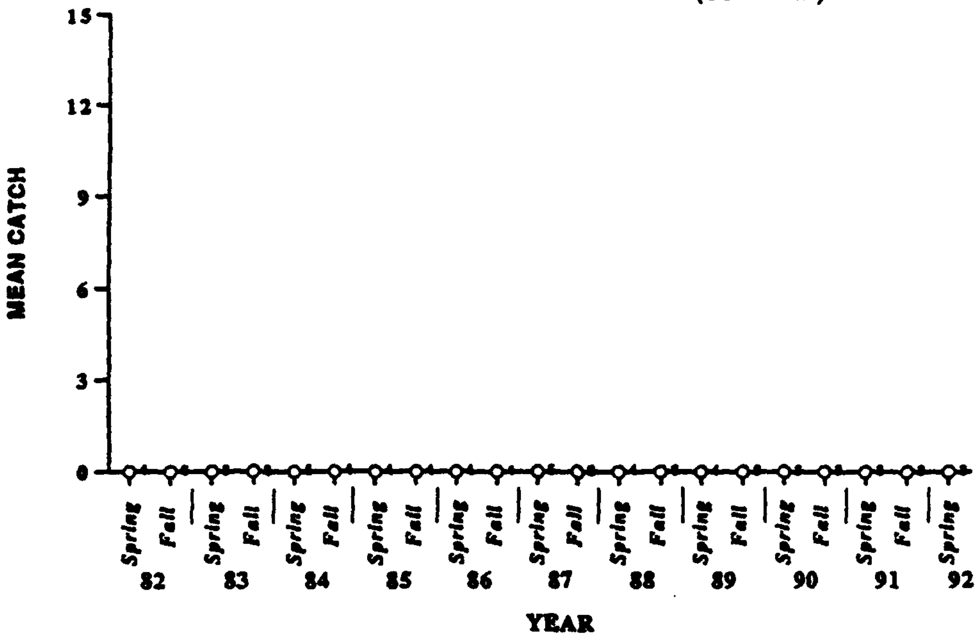
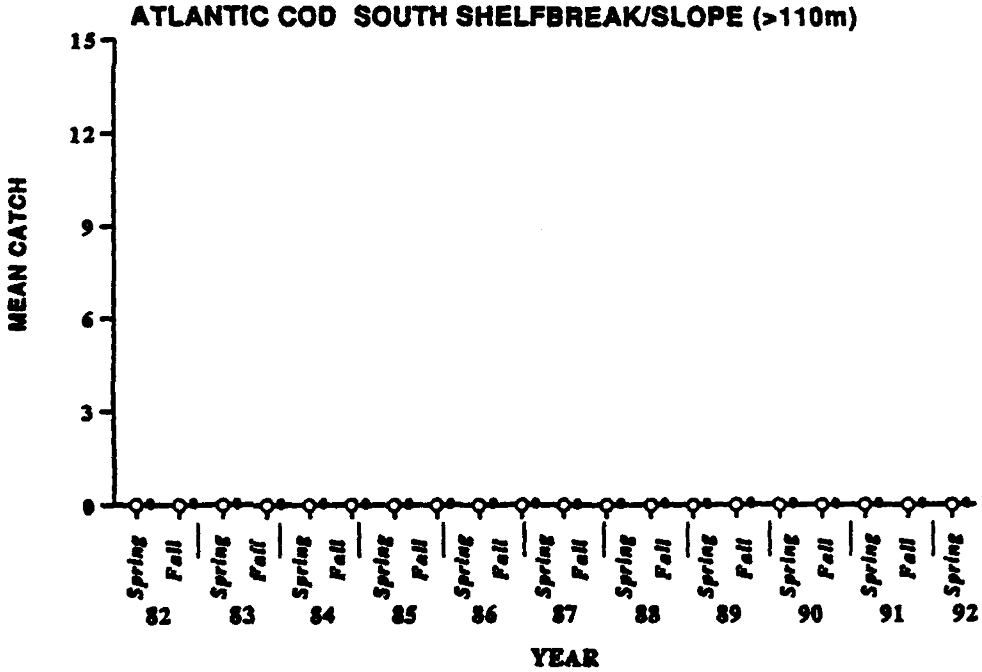
ATLANTIC COD SOUTH OUTER-COASTAL (55-110m)



ATLANTIC COD SOUTH SHELFBREAK/SLOPE (>110m)



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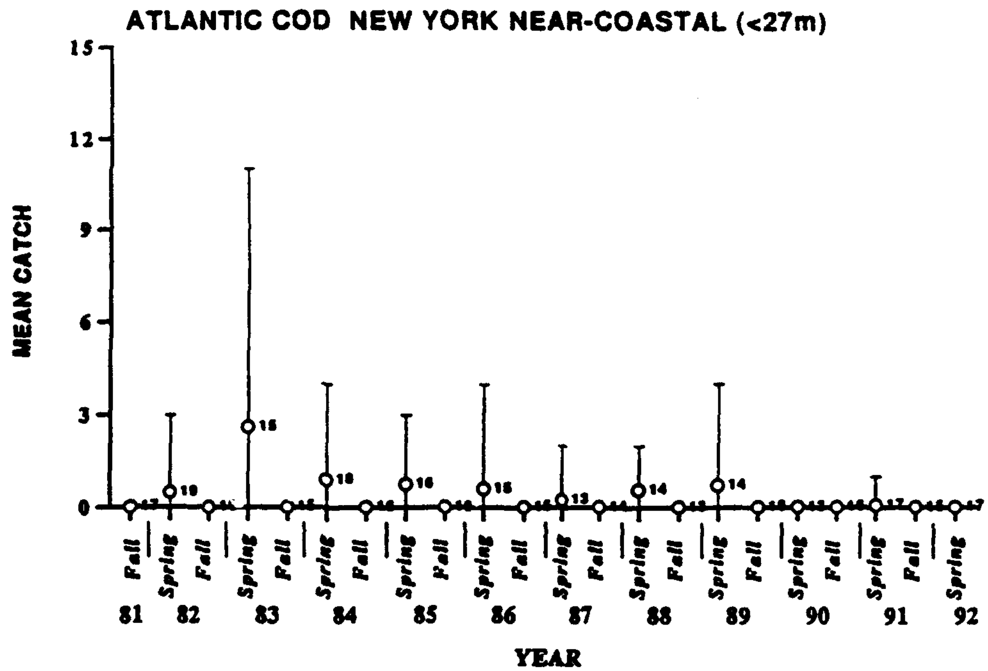

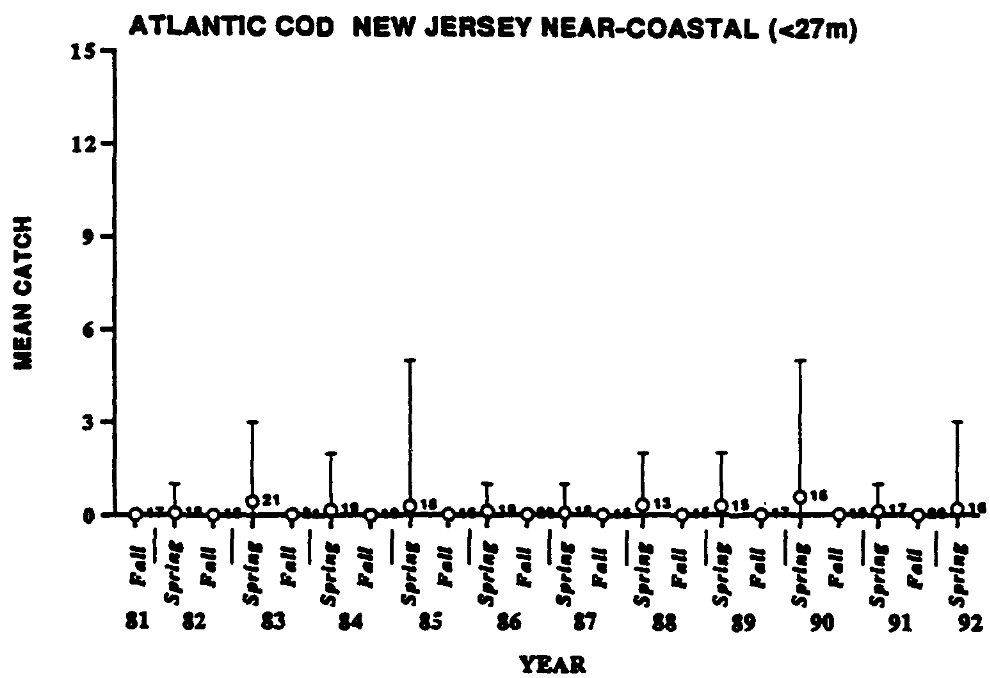

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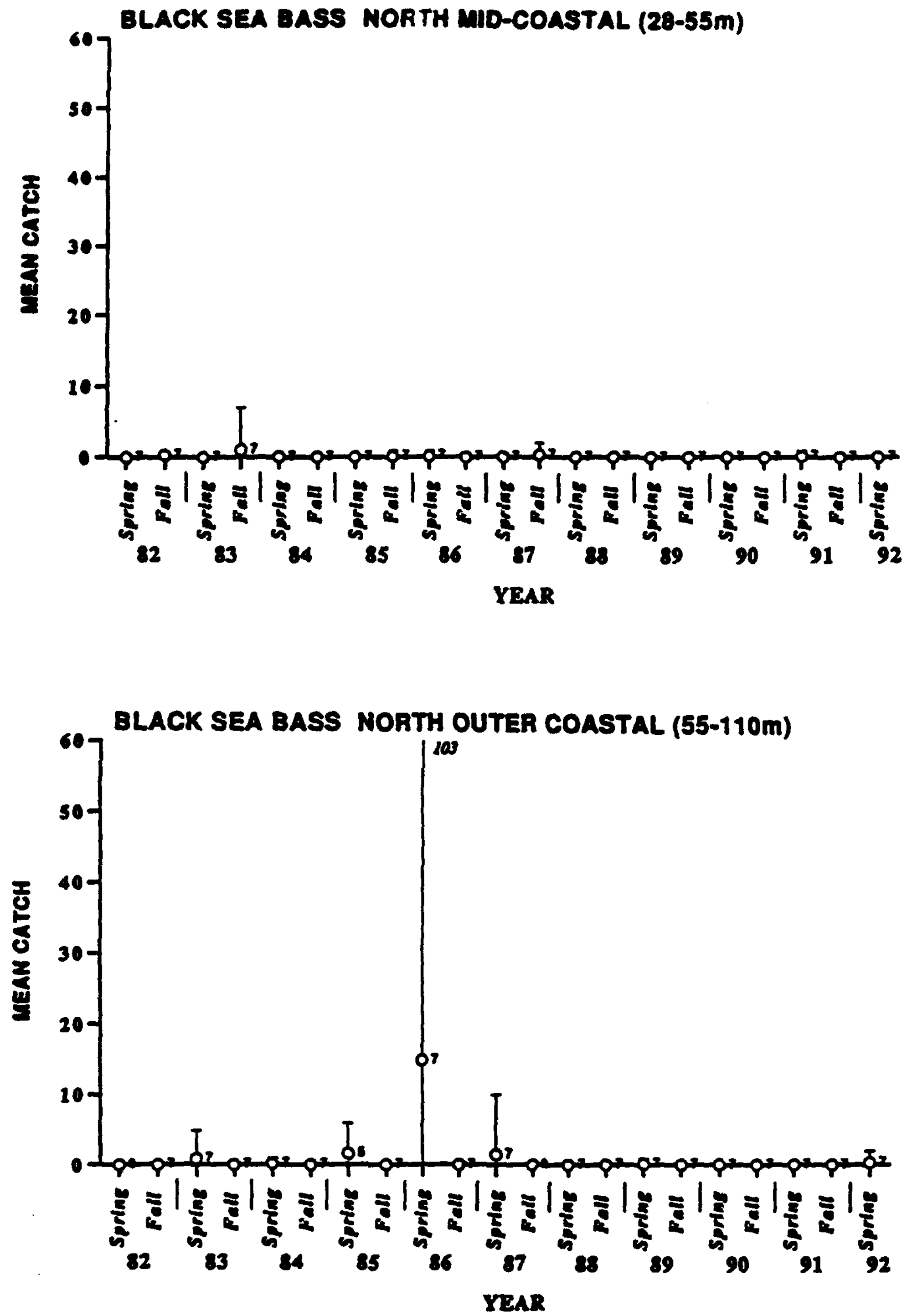
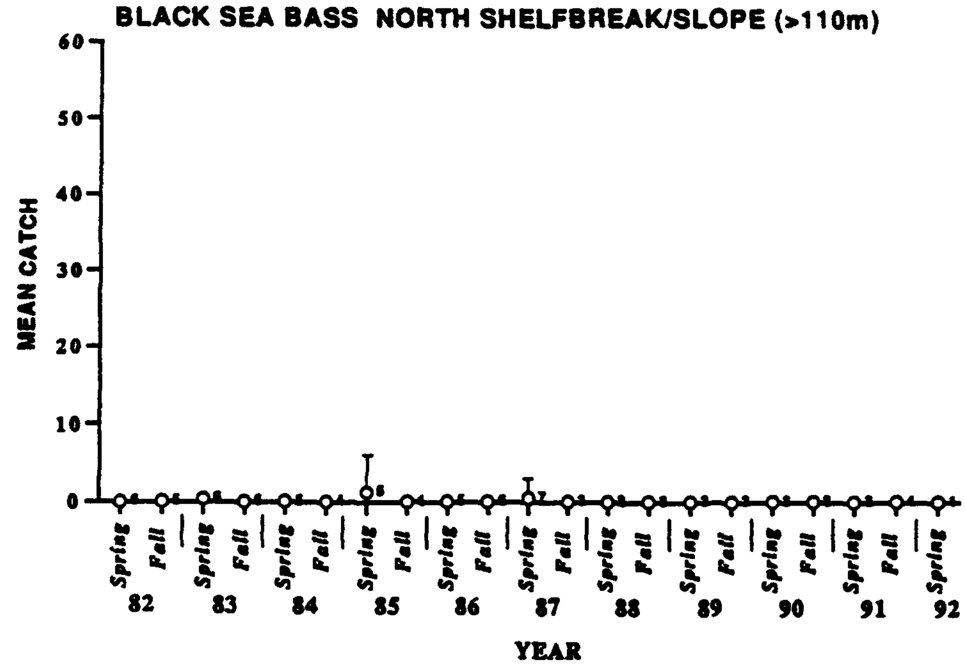
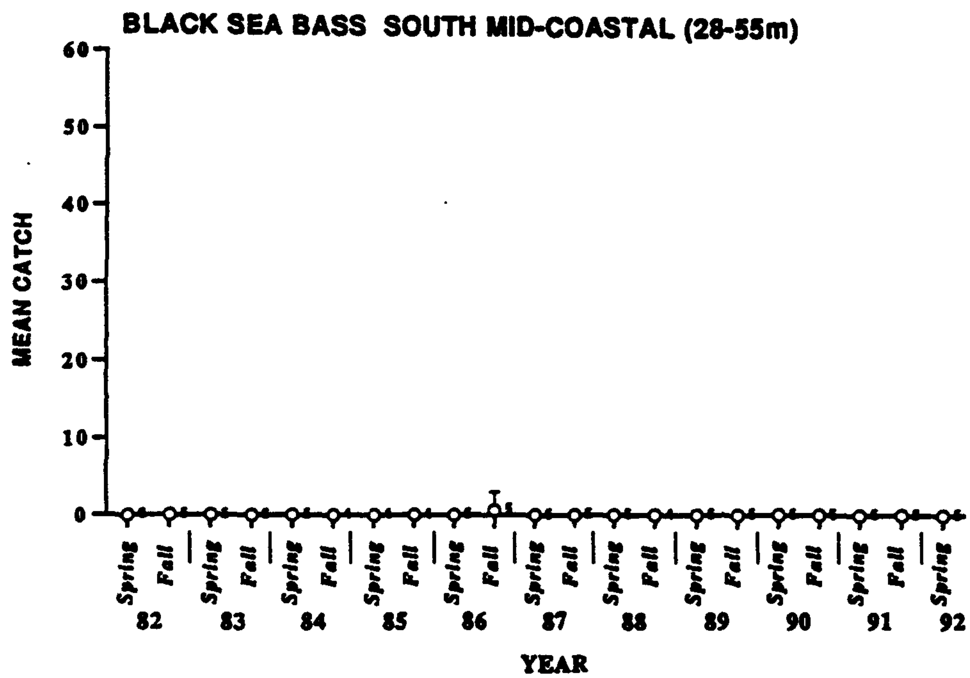


Figure 3-2. Mean catch, minimum catch and maximum catch, and number of samples (n) of black sea bass by year and season in sampling strata of New York Bight.





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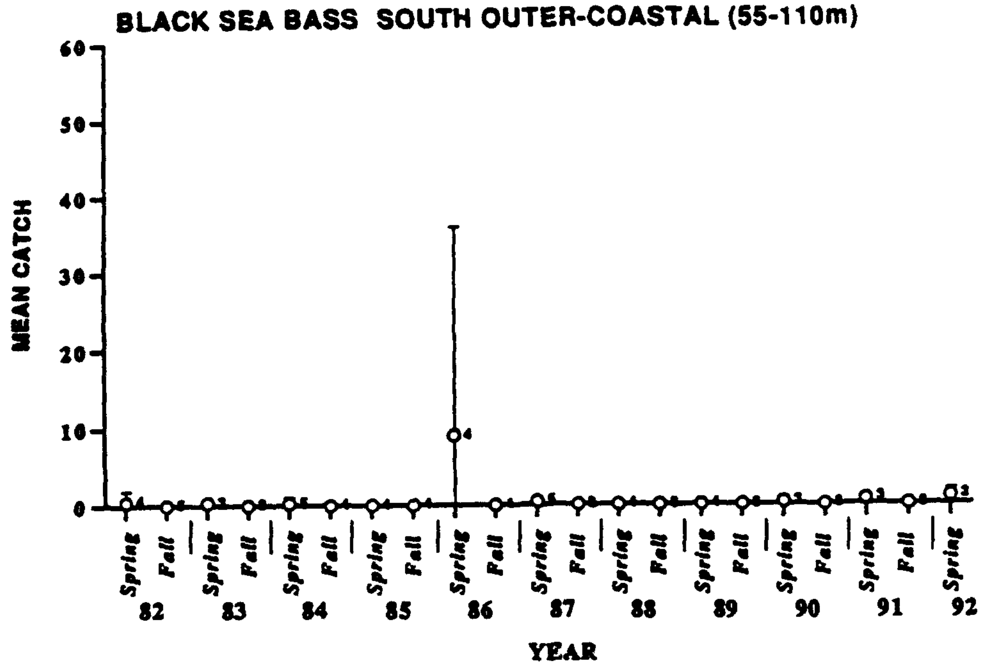

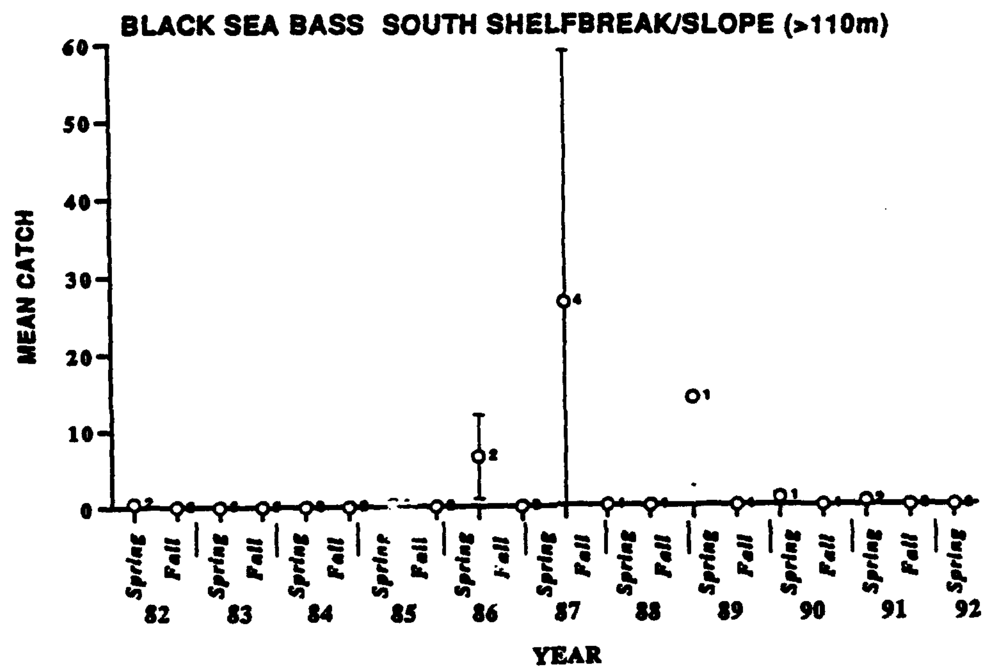

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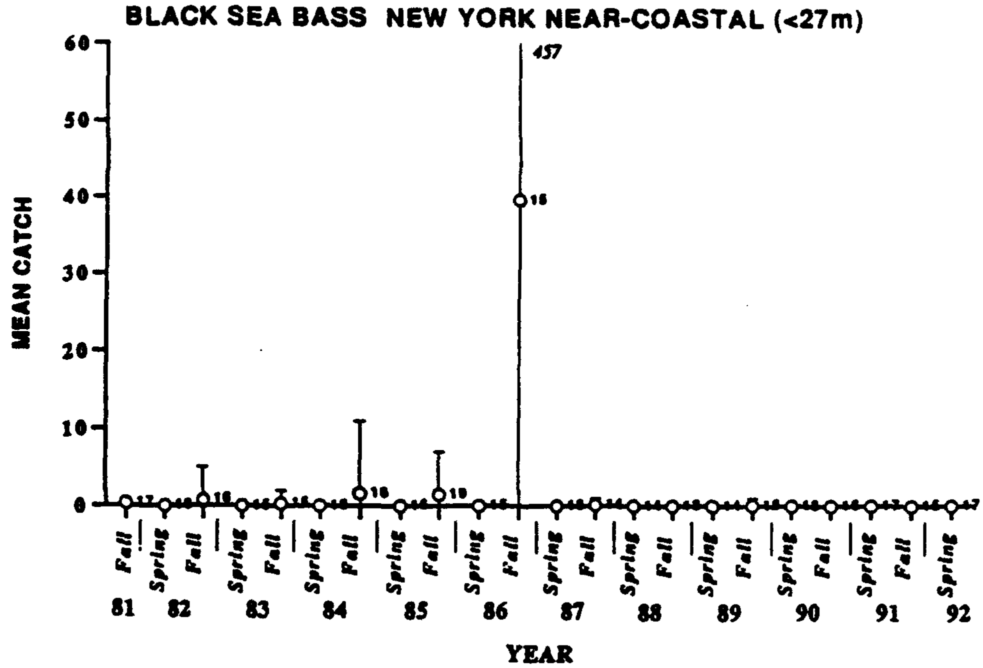

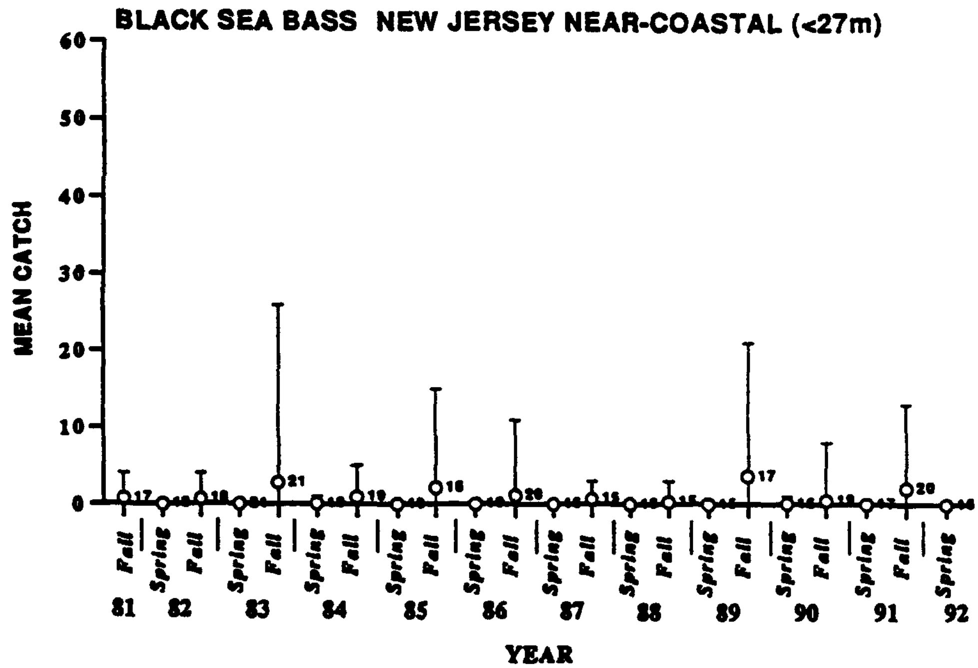

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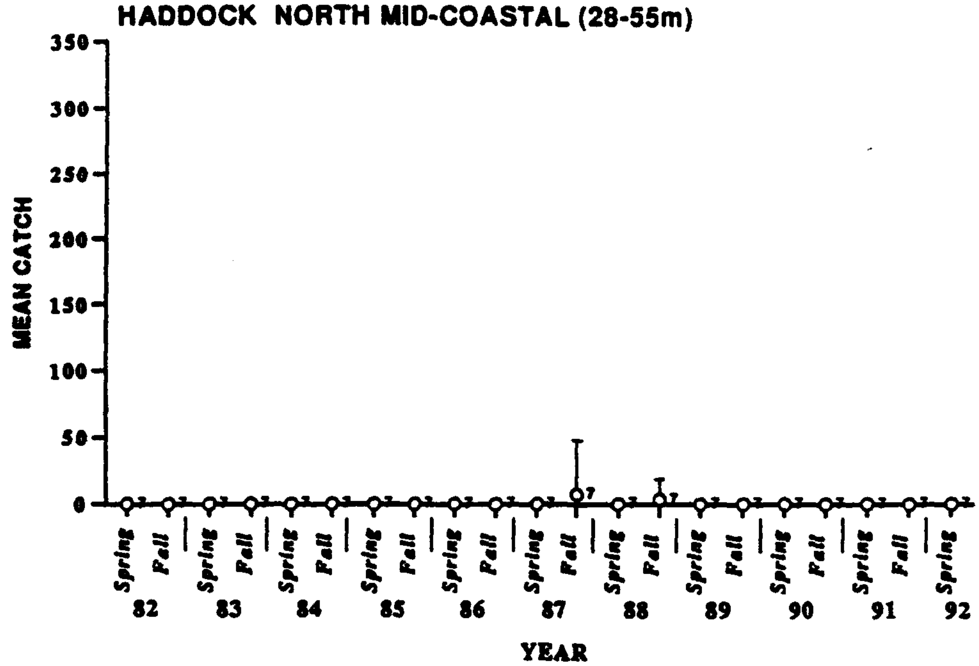


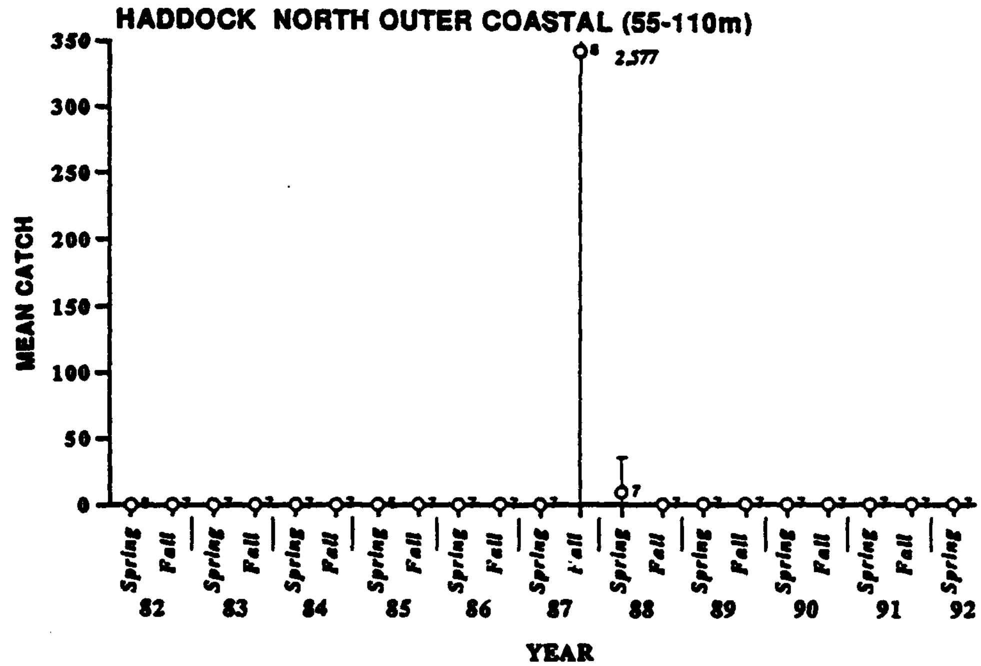
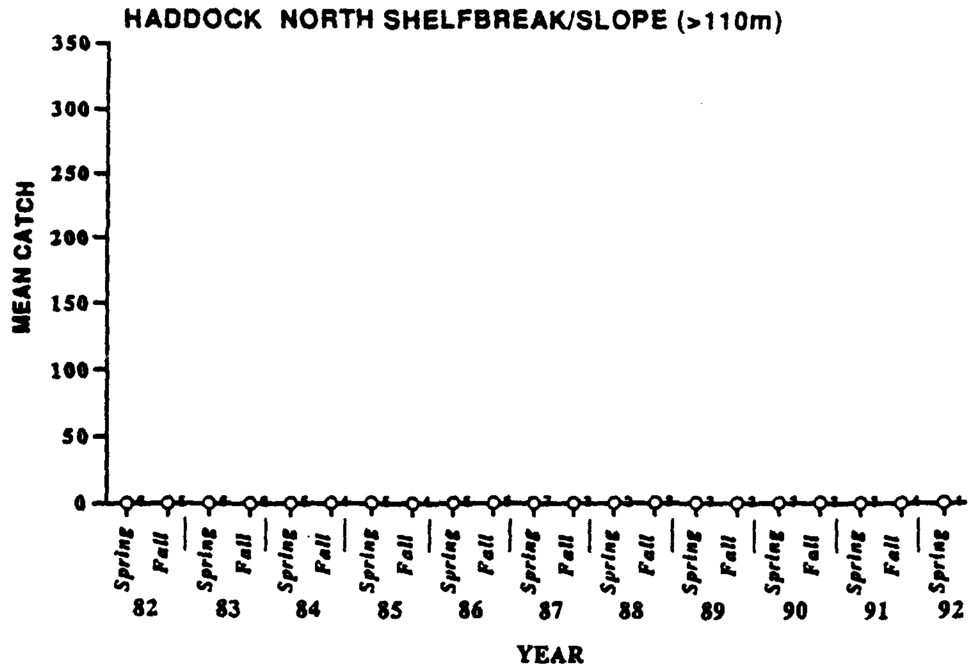
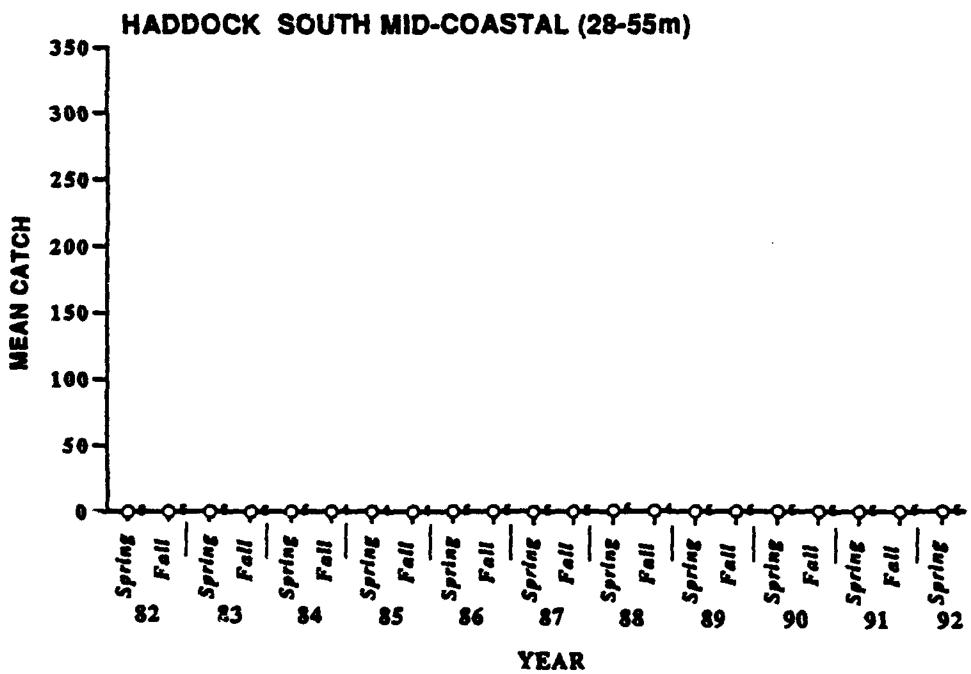


Figure 3-3. Mean catch, minimum catch and maximum catch, and number of samples (n) of haddock by year and season in sampling strata of New York Bight.





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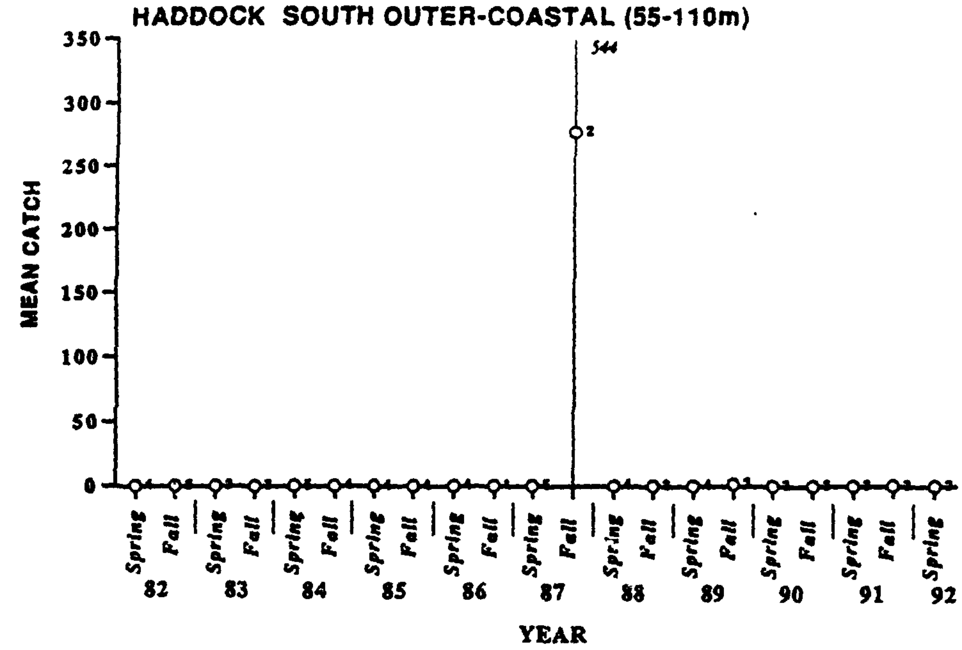


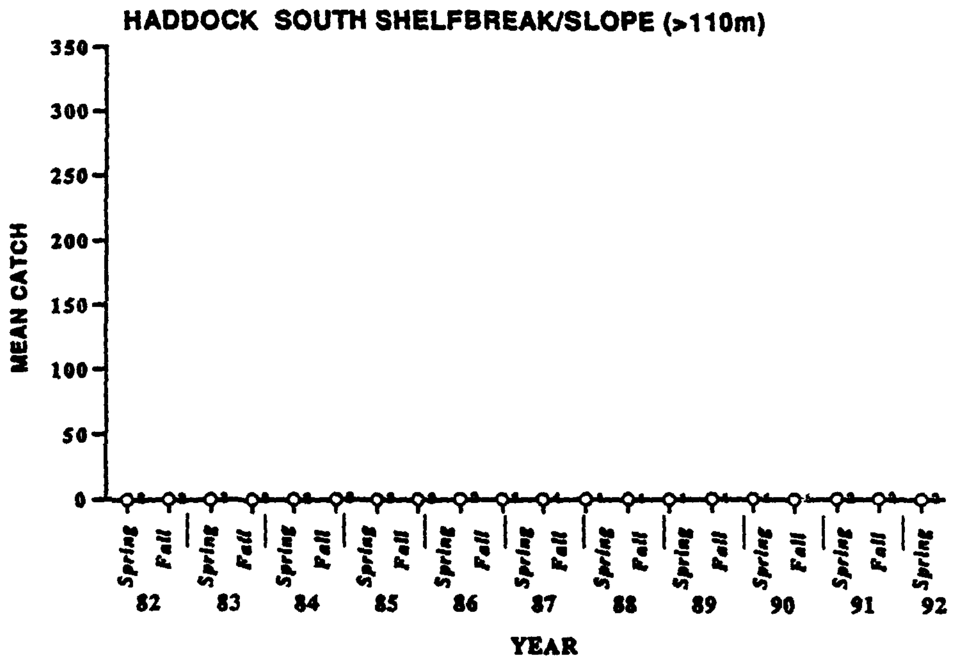
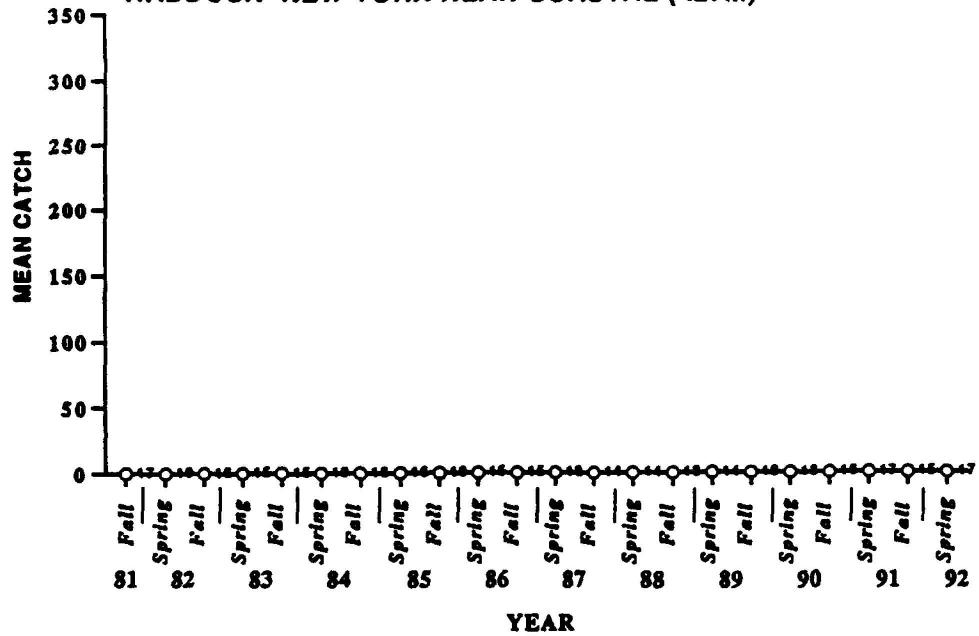


Figure 3-3. (Continued).

HADDOCK NEW YORK NEAR-COASTAL (<27m)



HADDOCK NEW JERSEY NEAR-COASTAL (<27m)

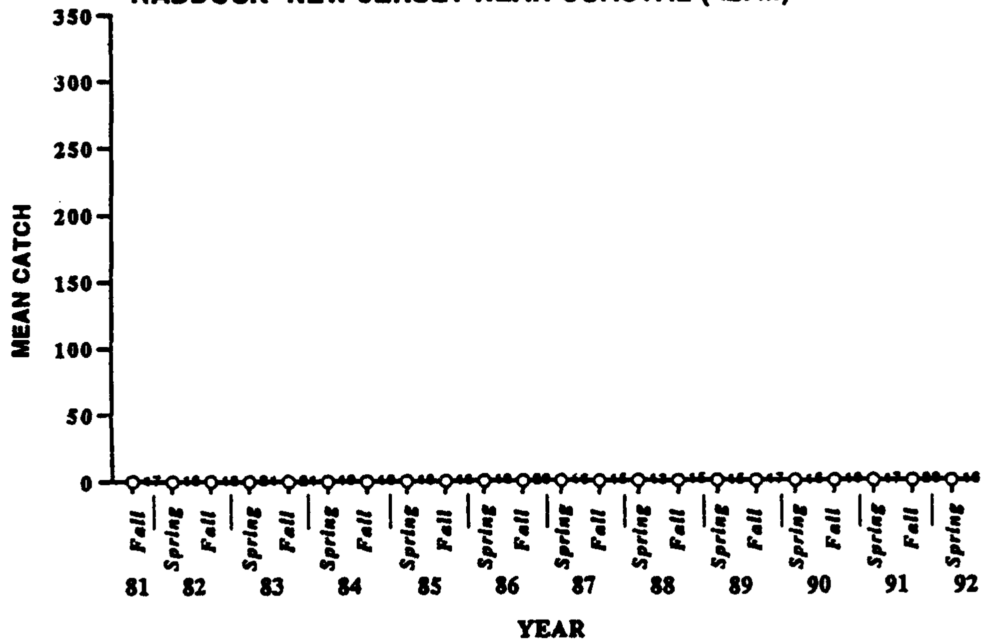
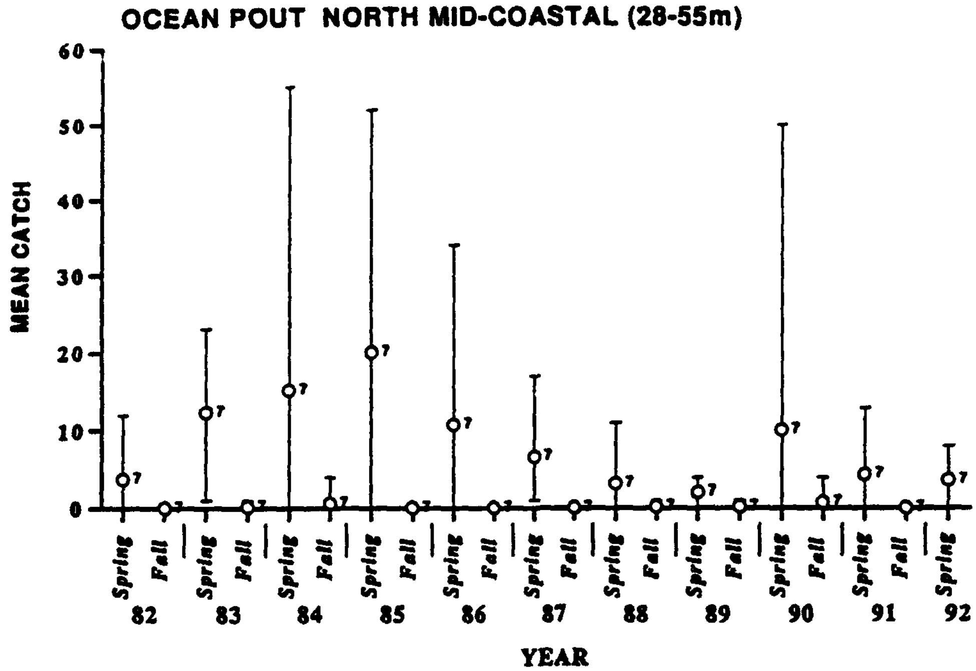


Figure 3-3. (Continued).



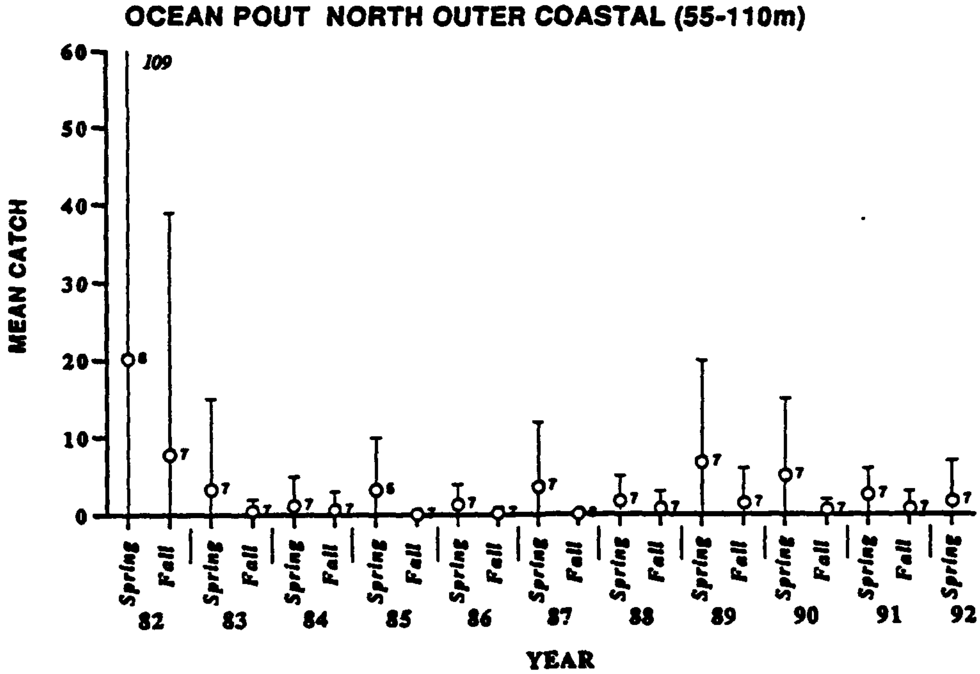
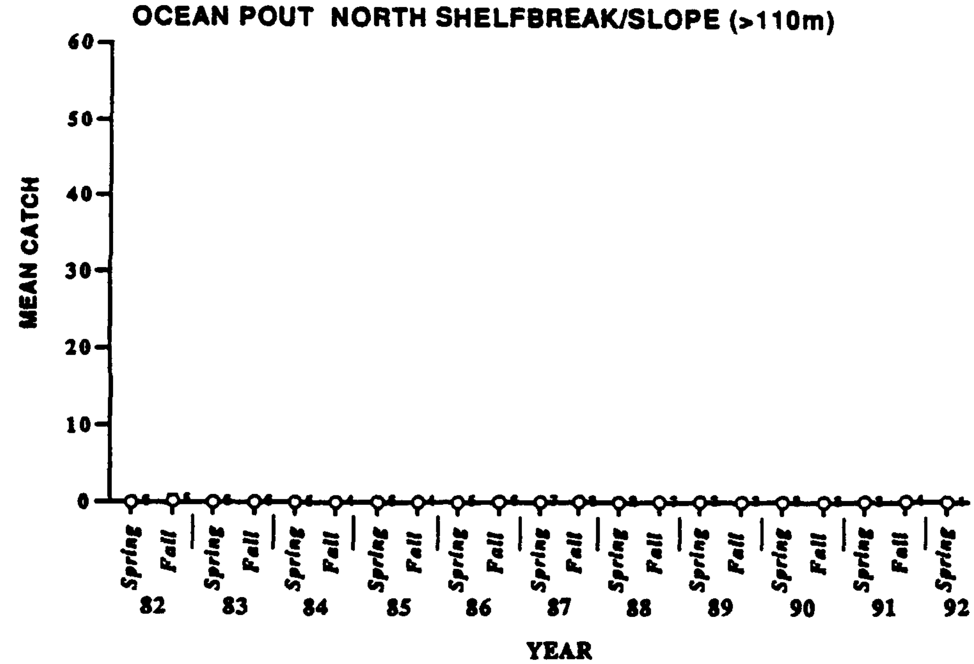


Figure 3-4. Mean catch, minimum catch and maximum catch, and number of samples (n) of ocean pout by year and season in sampling strata of New York Bight.



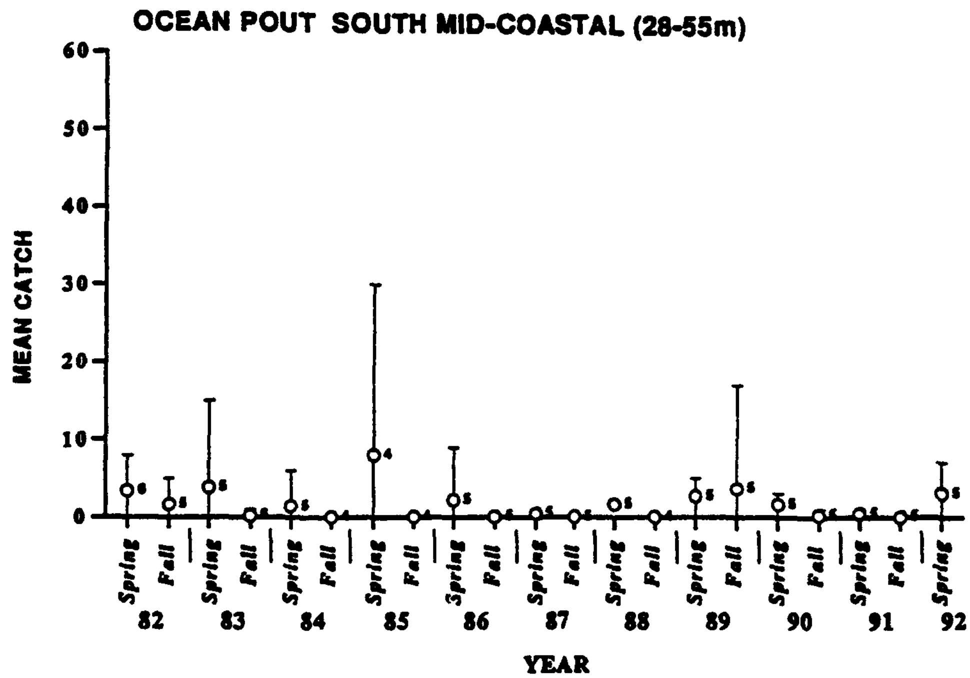
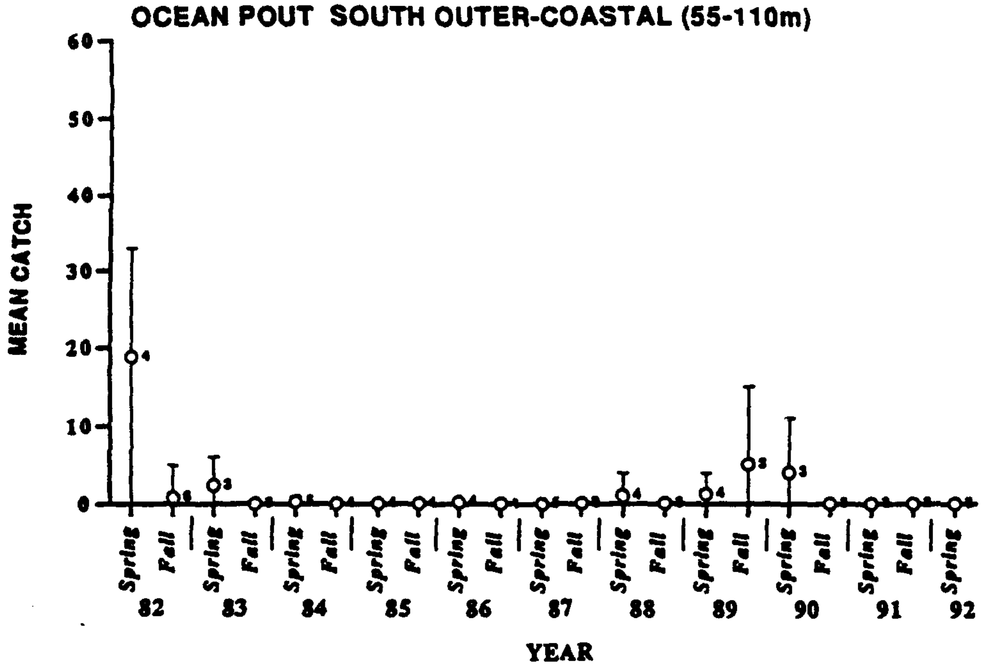
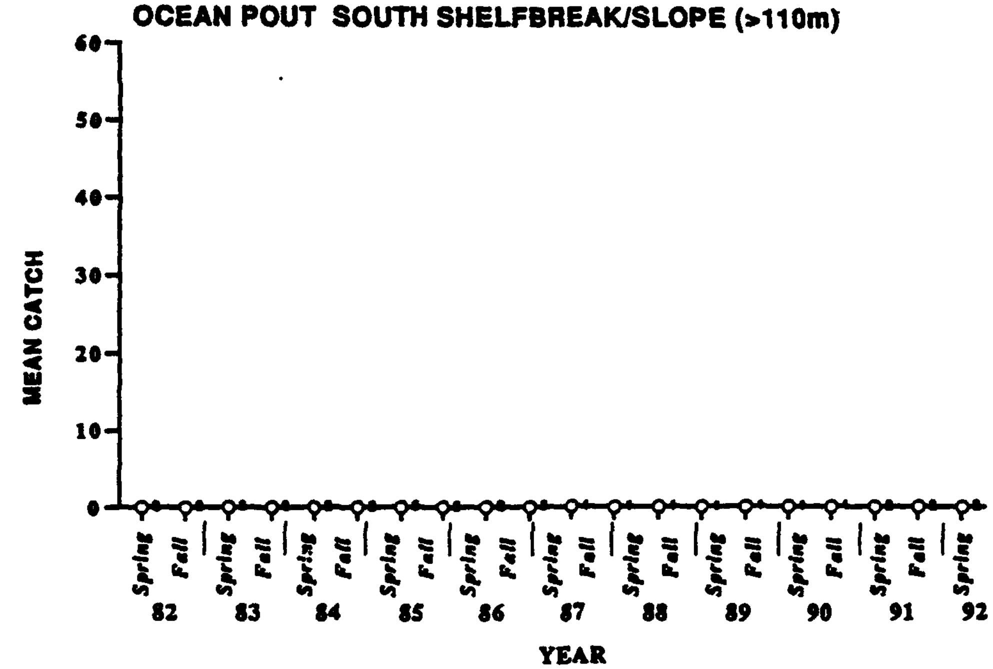


Figure 3-4. (Continued).





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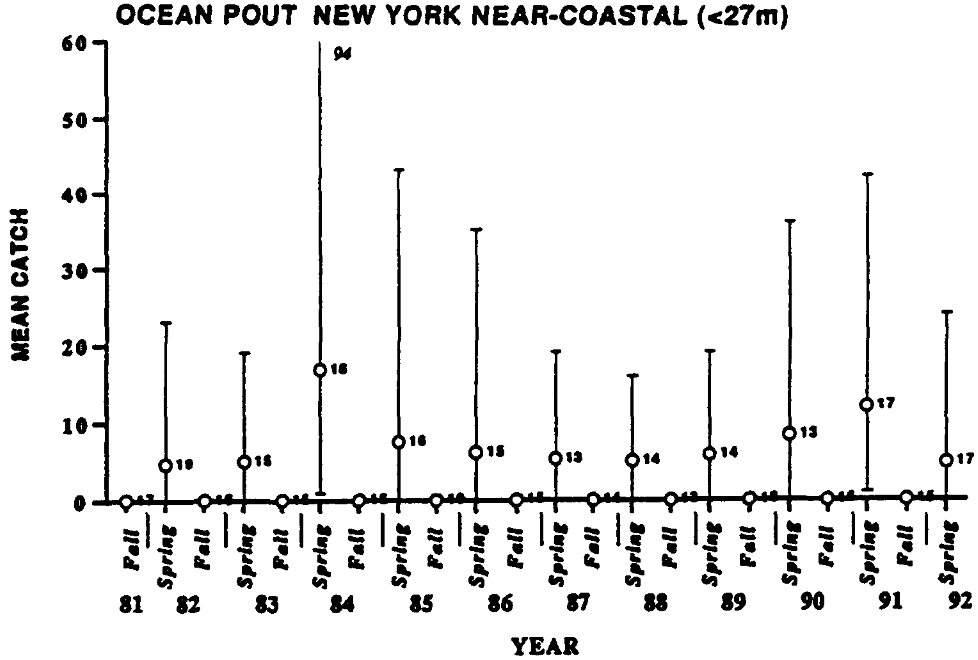


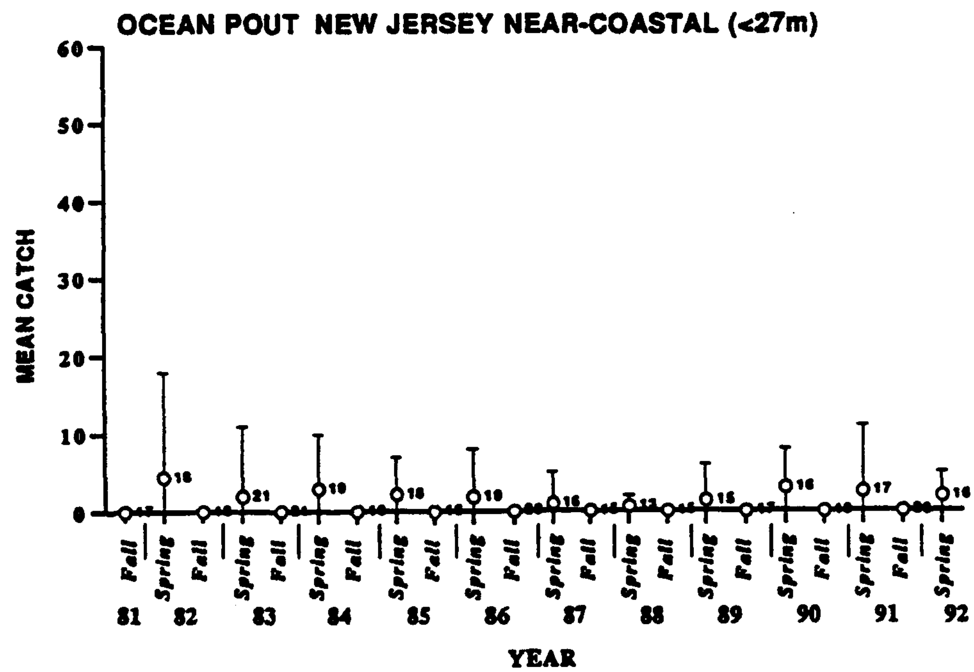
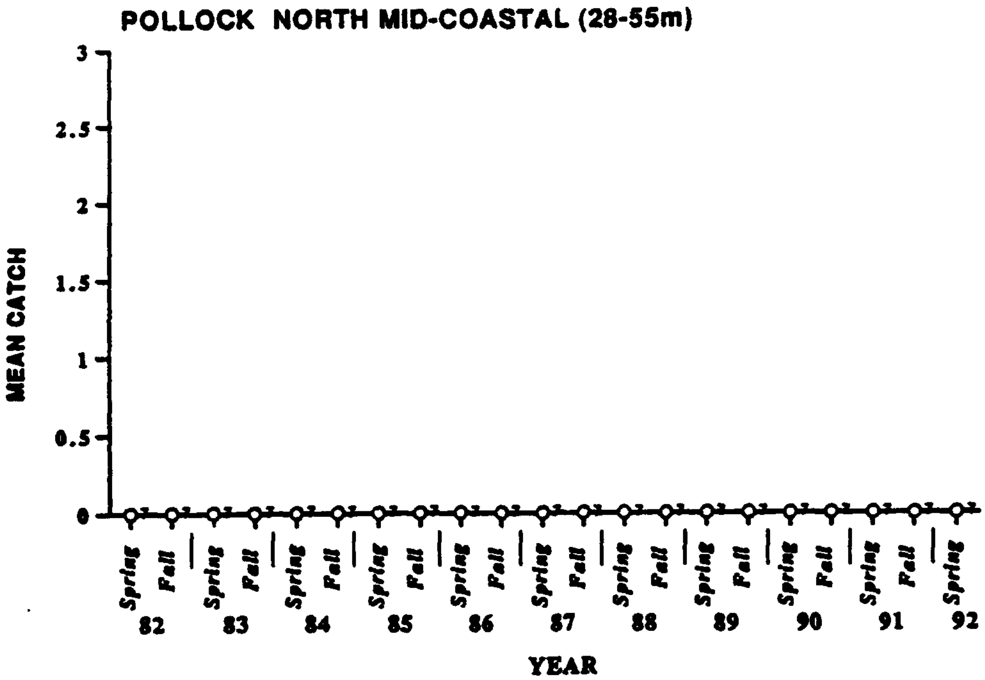


Figure 3-4. (Continued).



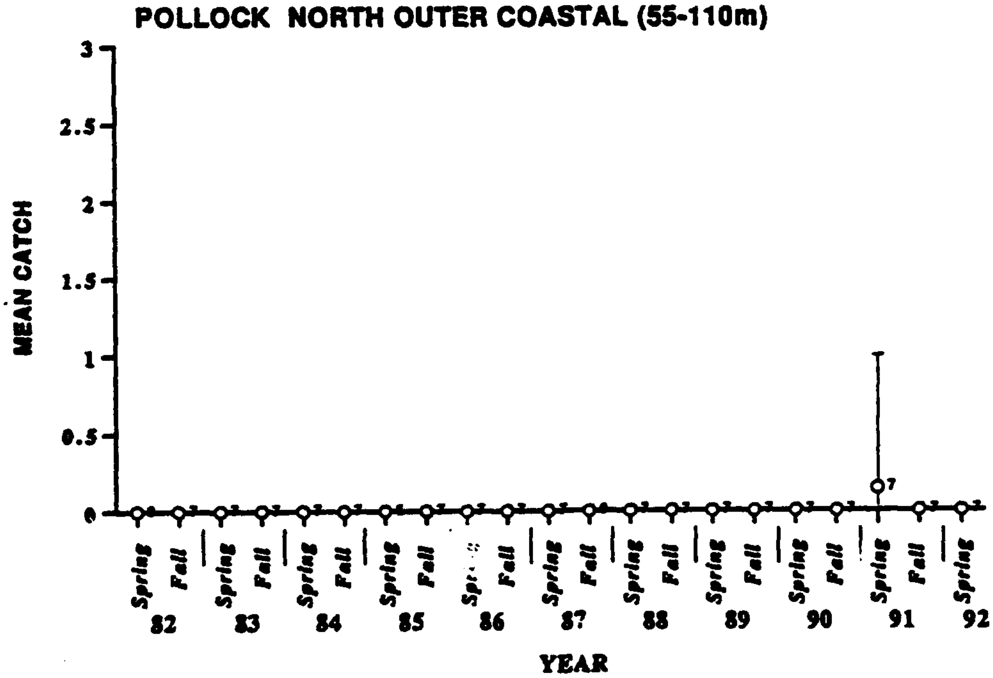
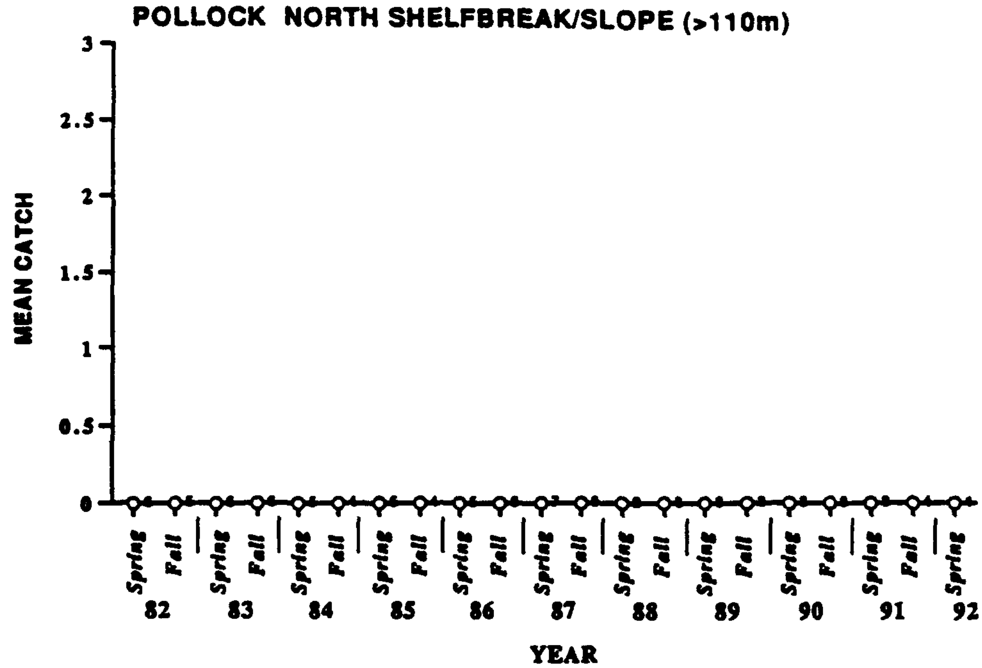


Figure 3-5. Mea: :h, minimum catch and maximum :atch, and number of samples (n) of po..ock by year and season in sampling strata of New York Bight.



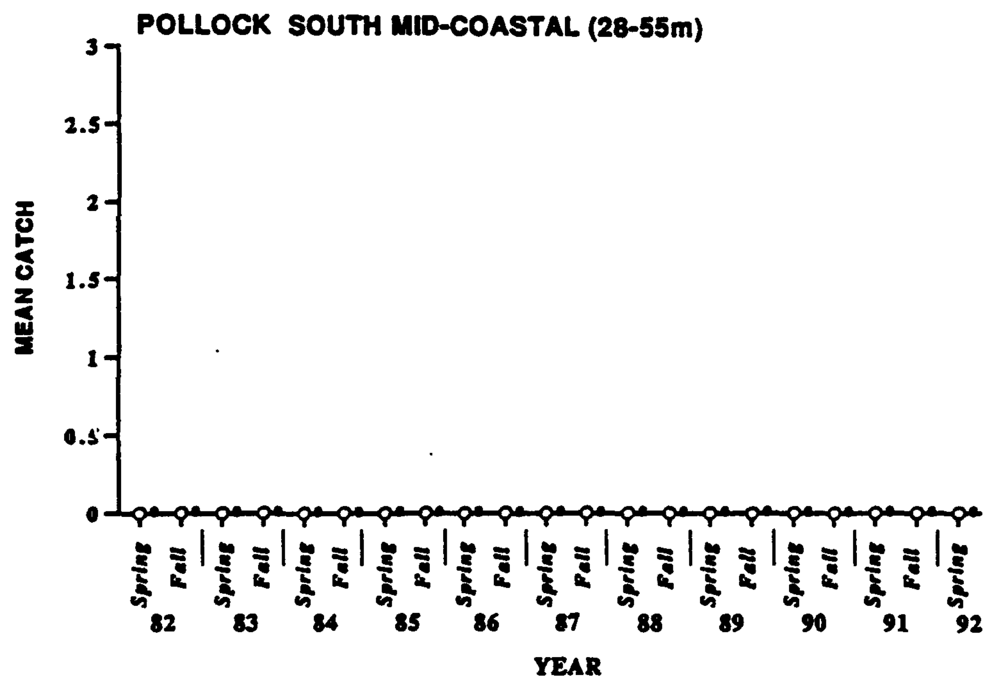
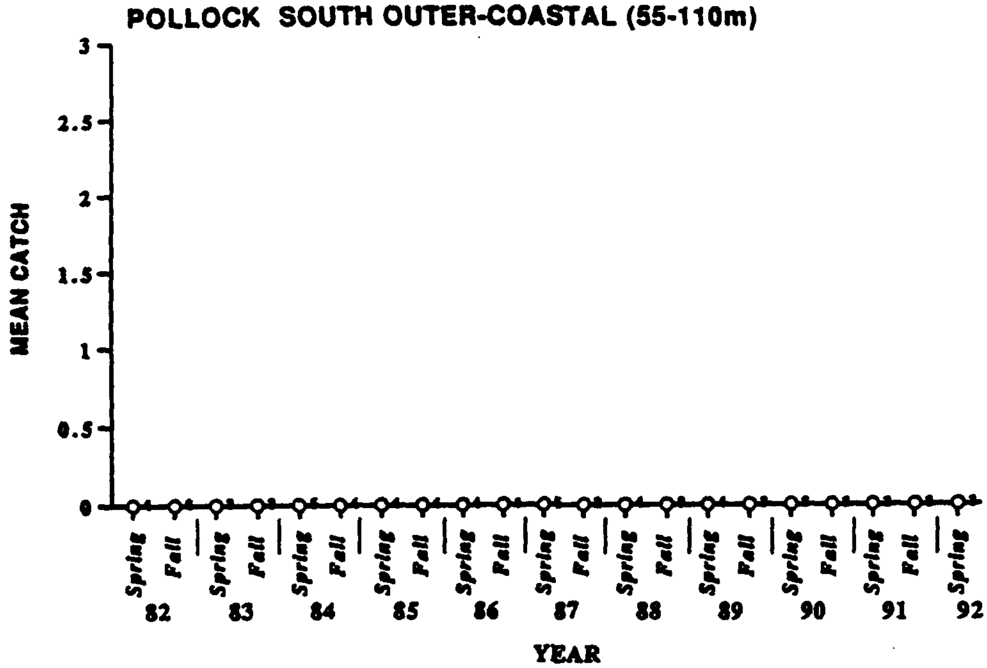


Figure 3-5. (Continued).



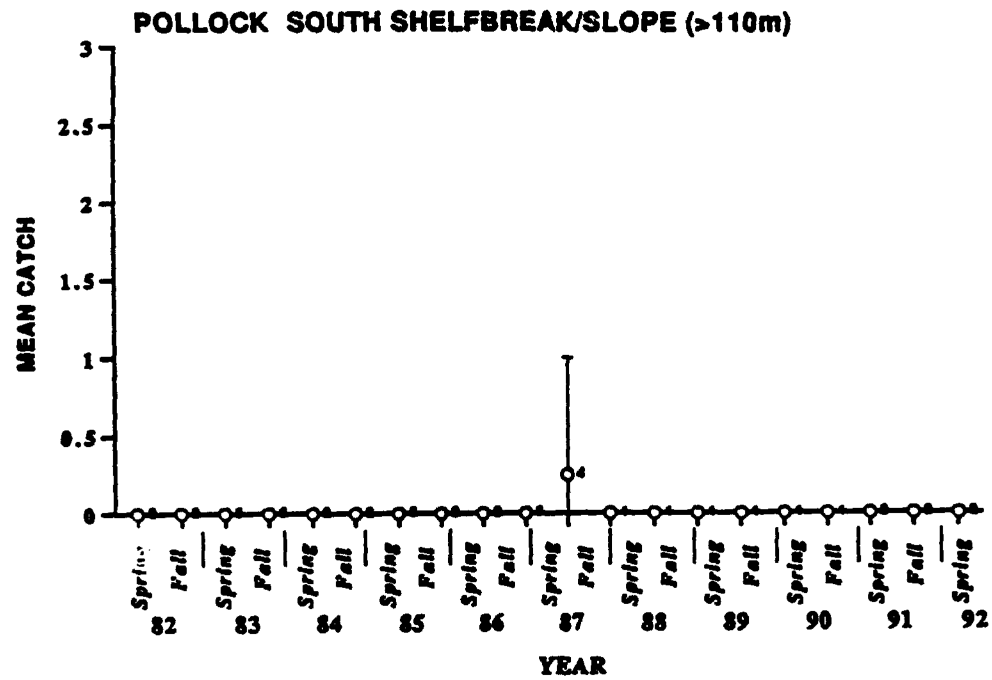
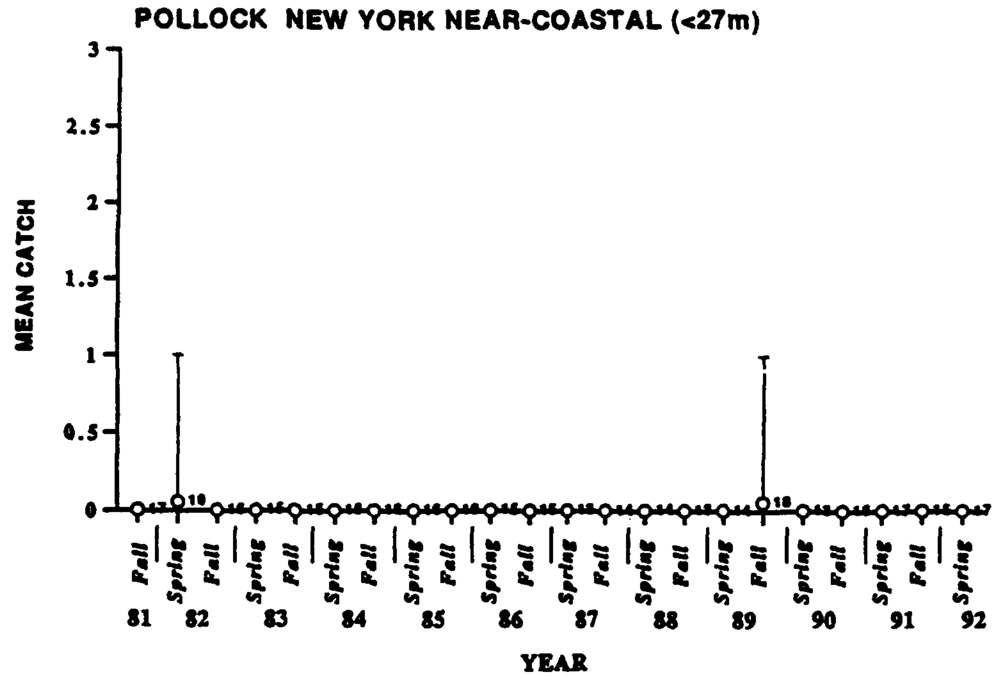


Figure 3-5. (Continued).



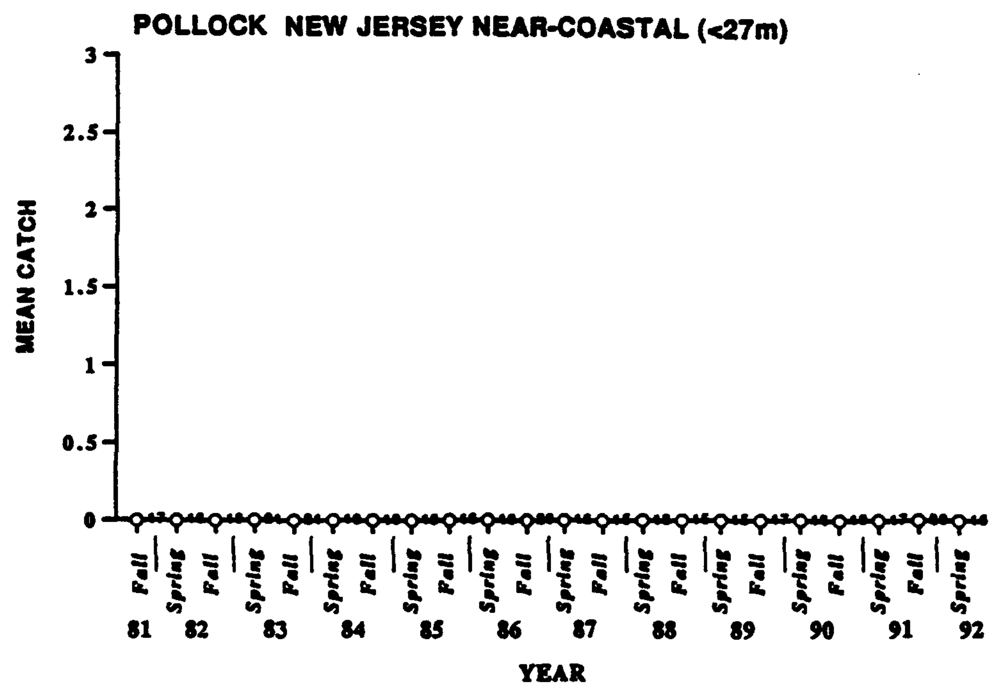


Figure 3-5. (Continued).

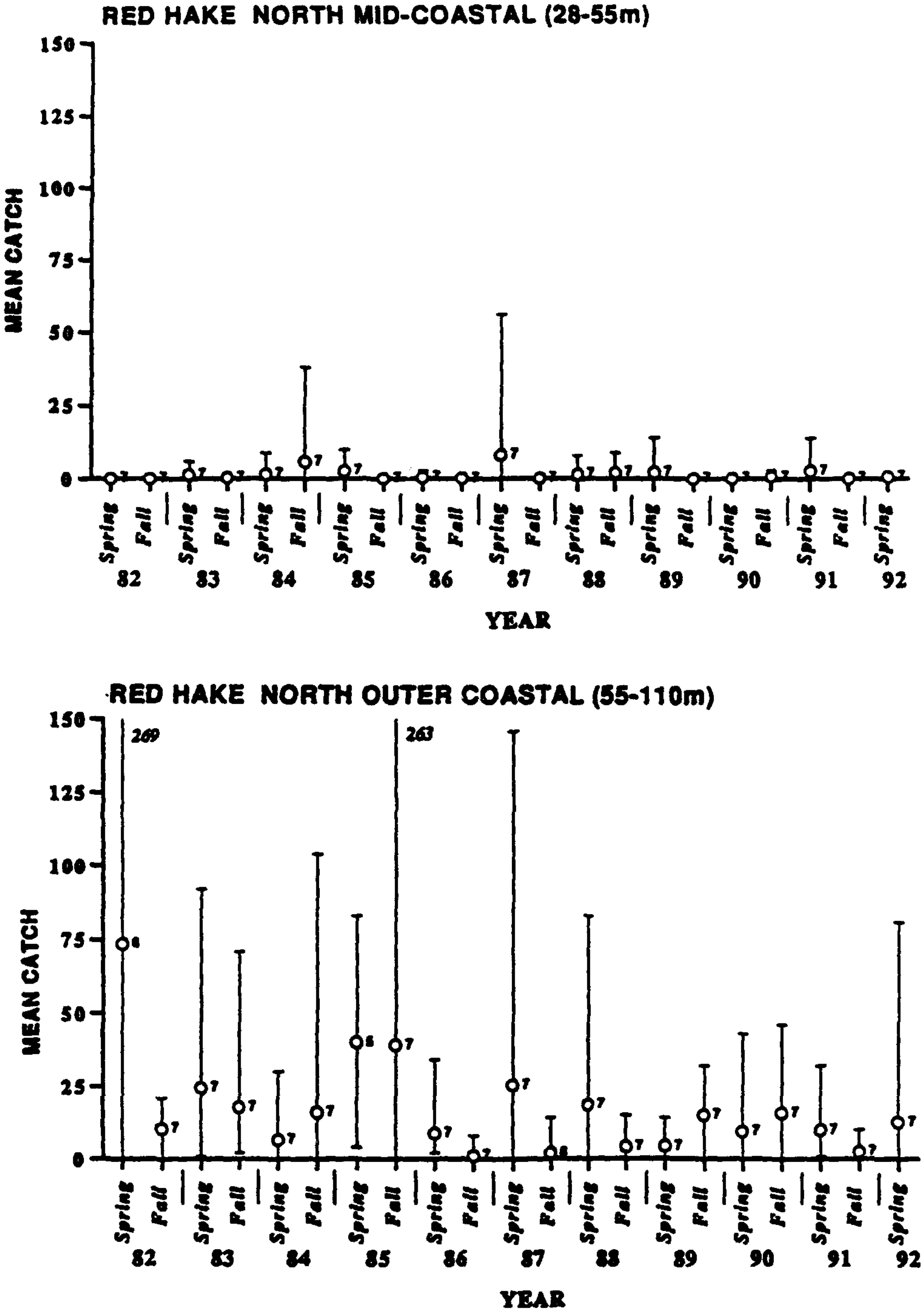
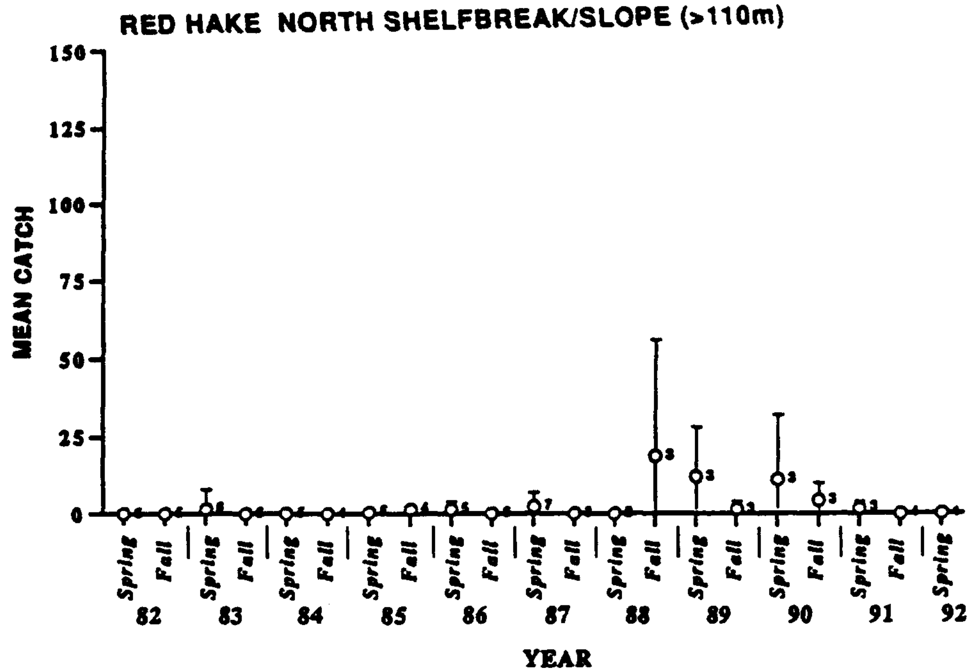


Figure 3-6. Mean catch, minimum catch and maximum catch, and number of samples (n) of red hake by year and season in sampling strata of New York Bight.



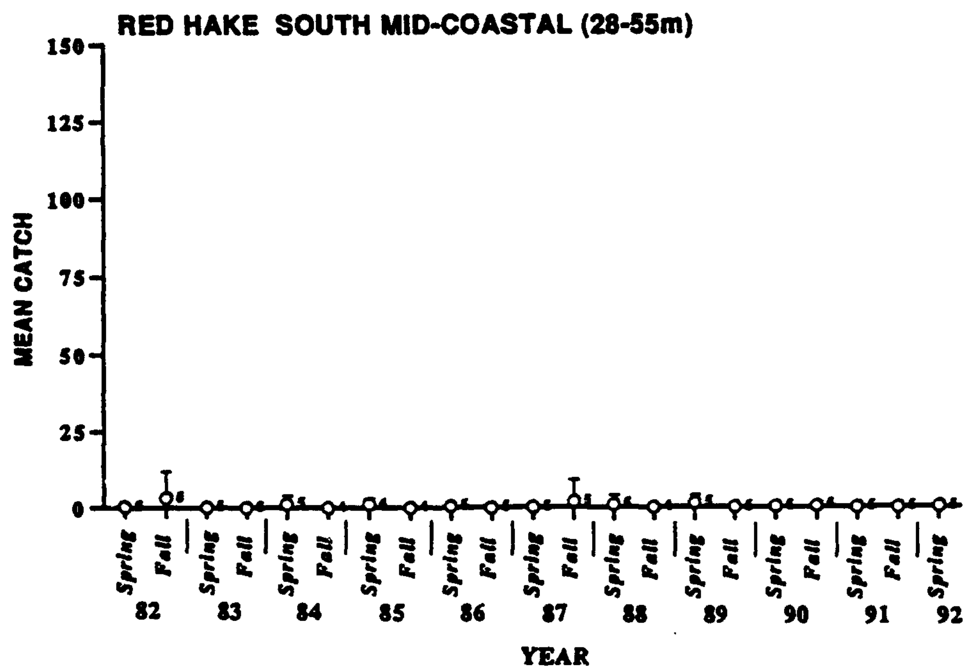
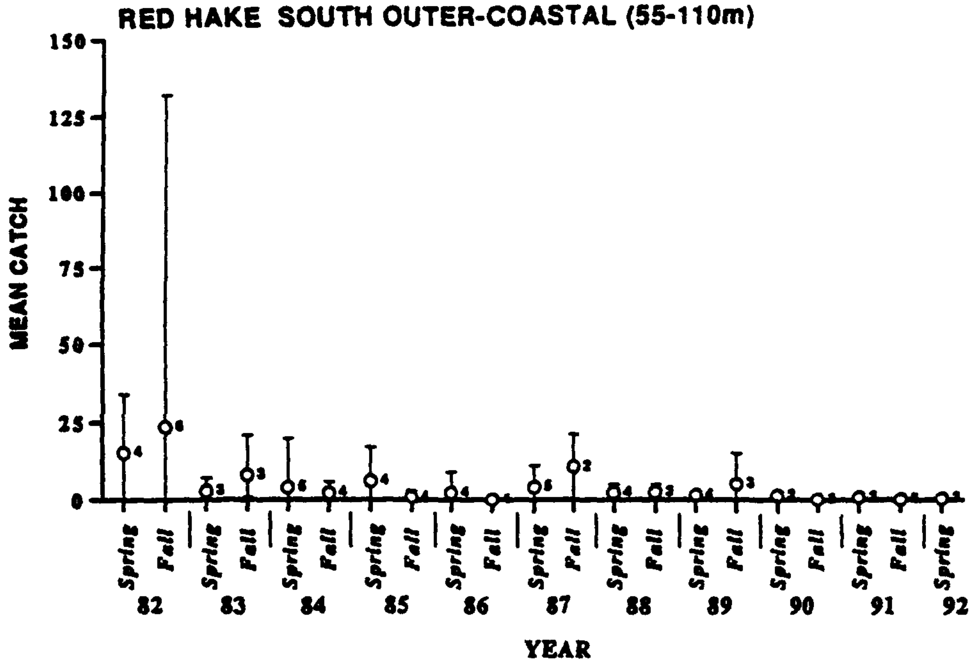


Figure 3-6. (Continued).



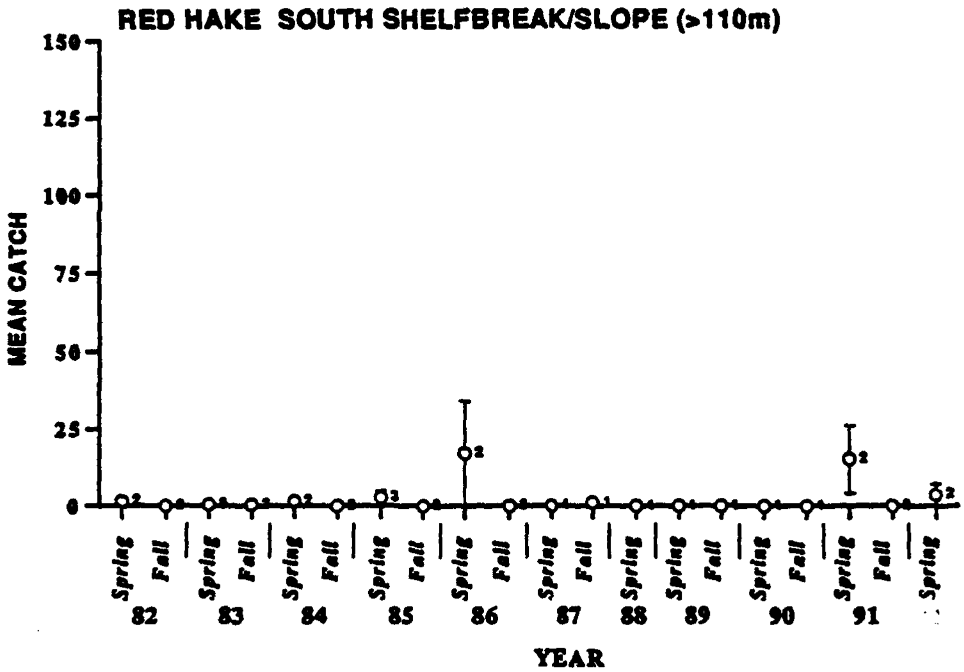
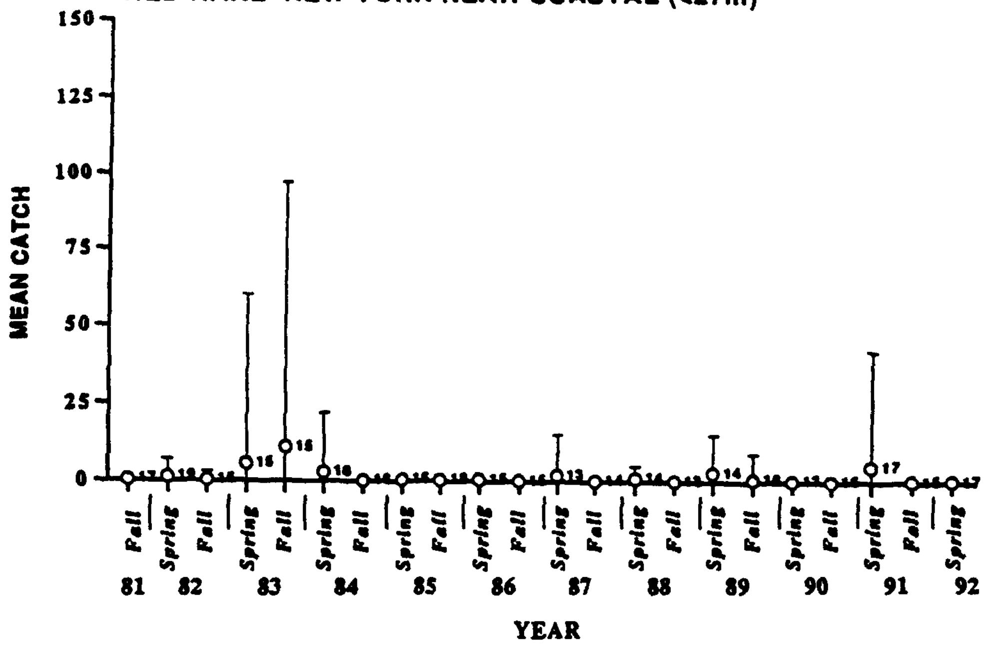


Figure 3-6. (Continued).

RED HAKE NEW YORK NEAR-COASTAL (<27m)



RED HAKE NEW JERSEY NEAR-COASTAL (<27m)

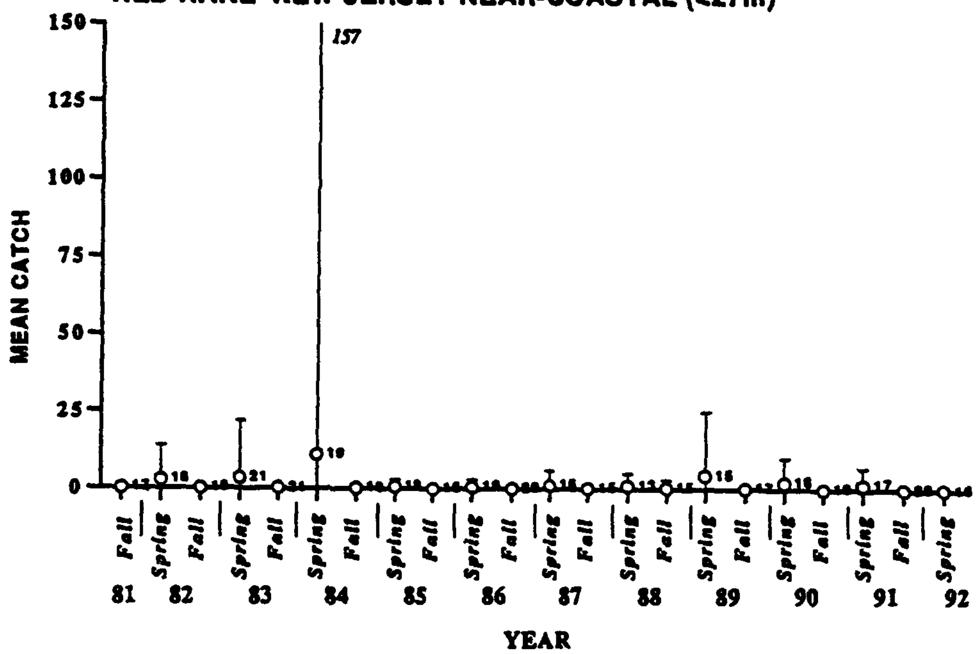
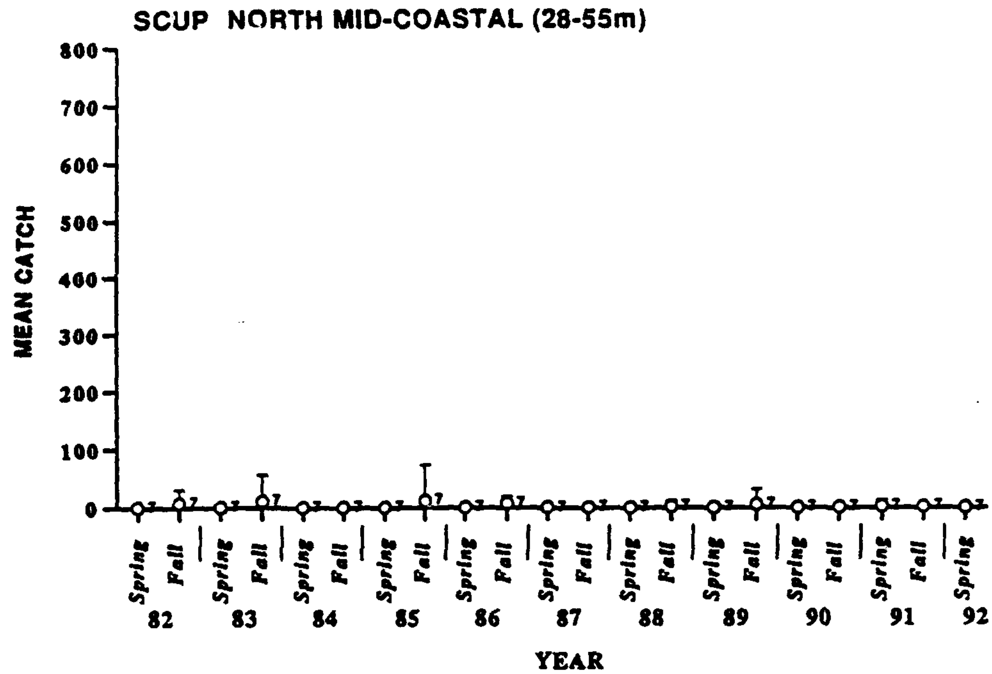


Figure 3-6. (Continued).



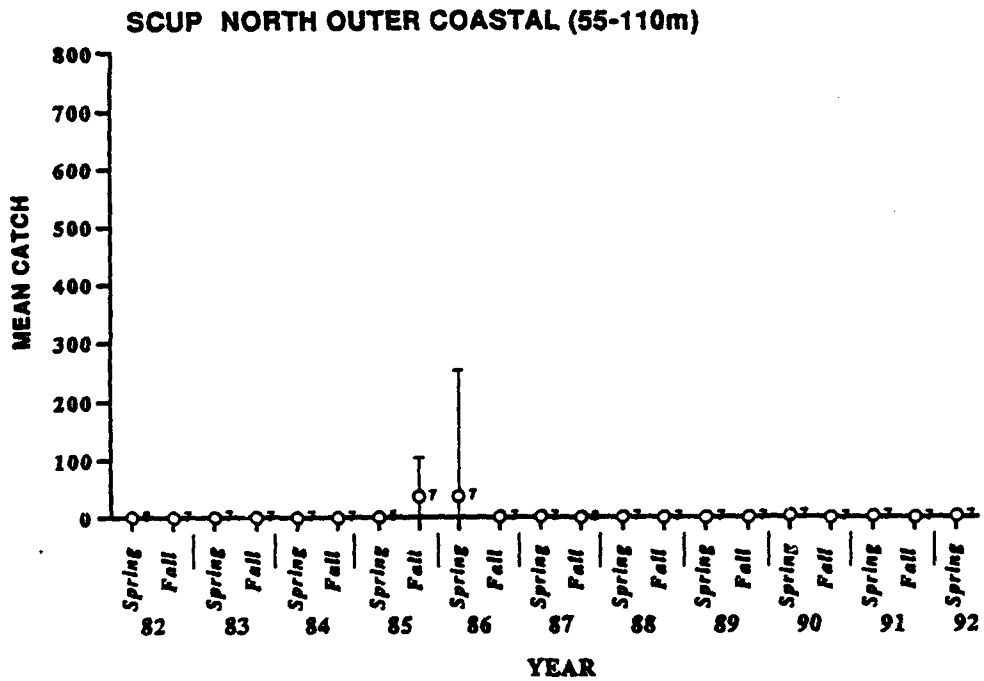
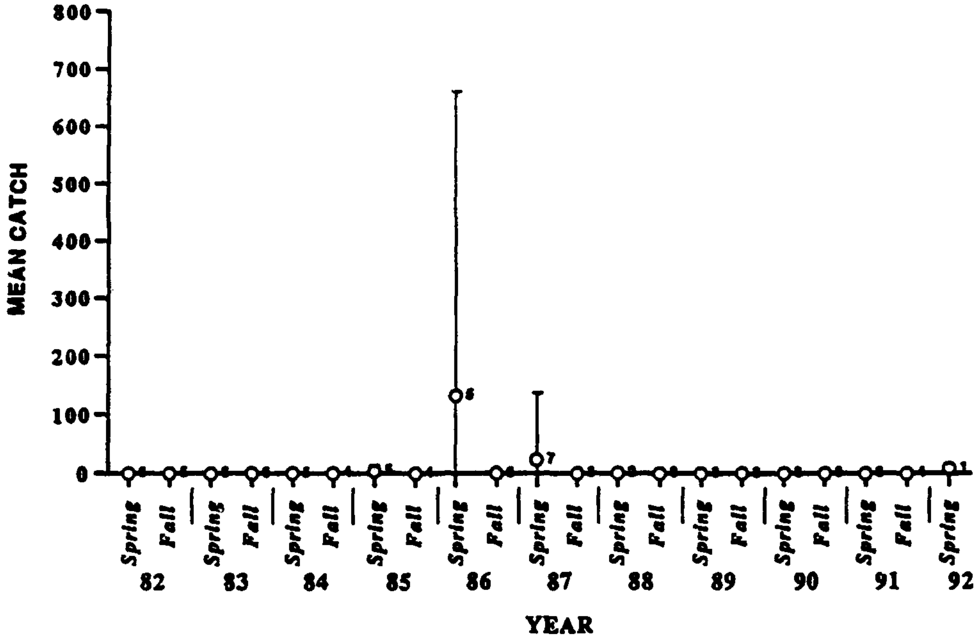


Figure 3-7. Mean catch, minimum catch and maximum catch, and number of samples (n) of scup by year and season in sampling strata of New York Bight.

SCUP NORTH SHELFBREAK/SLOPE (>110m)



SCUP SOUTH MID-COASTAL (28-55m)

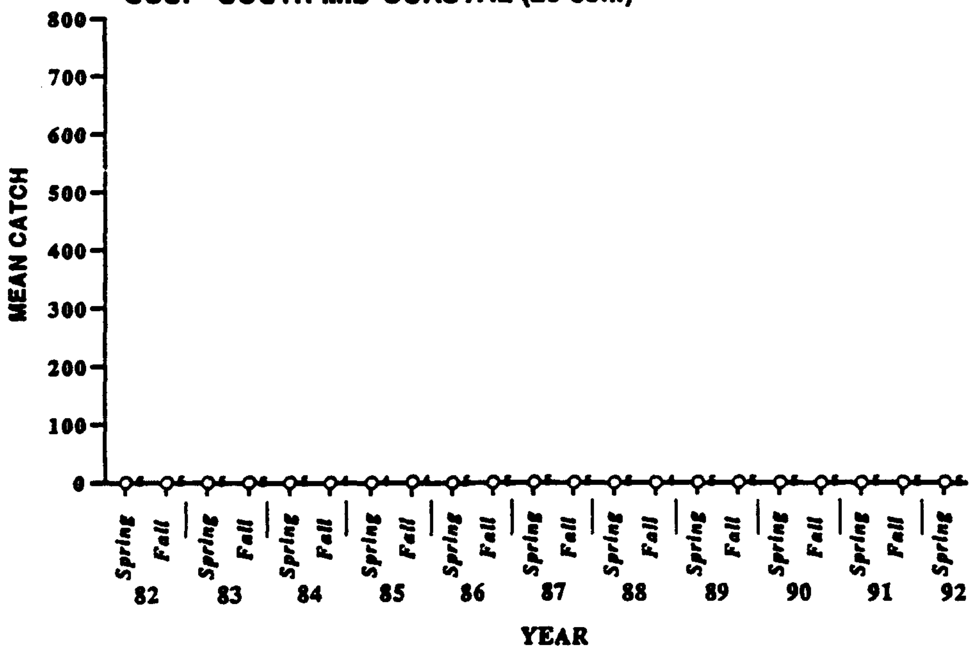
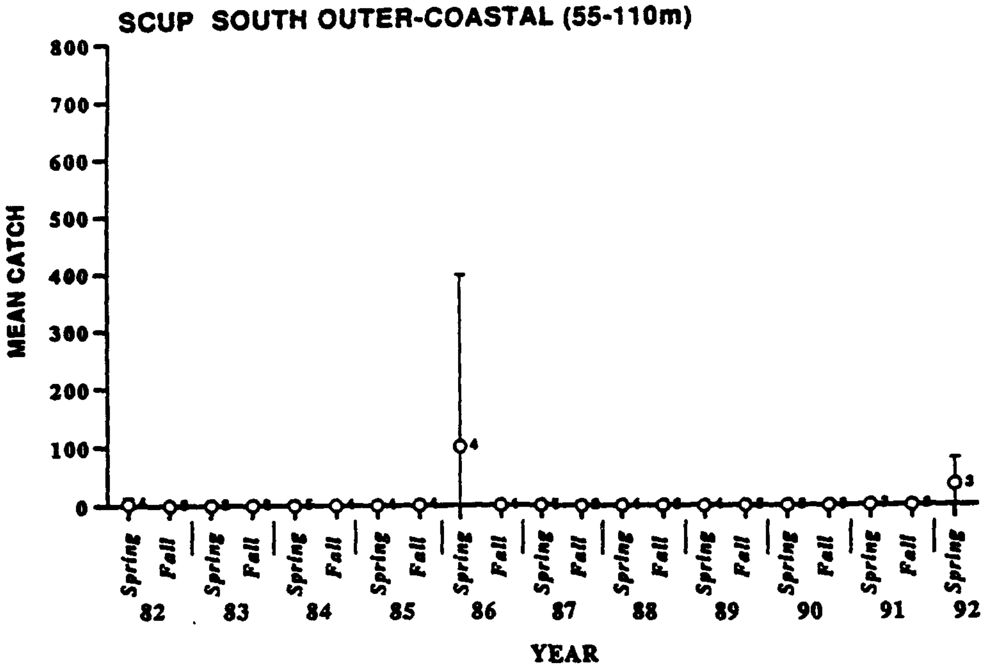


Figure 3-7. (Continued).



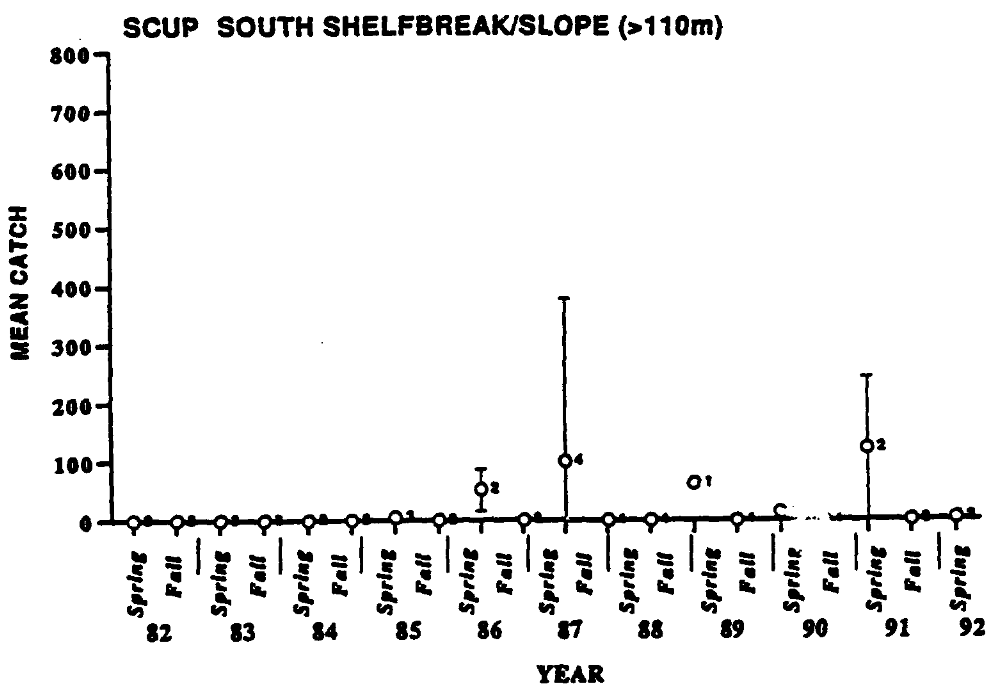


Figure 3-7. (Continued).

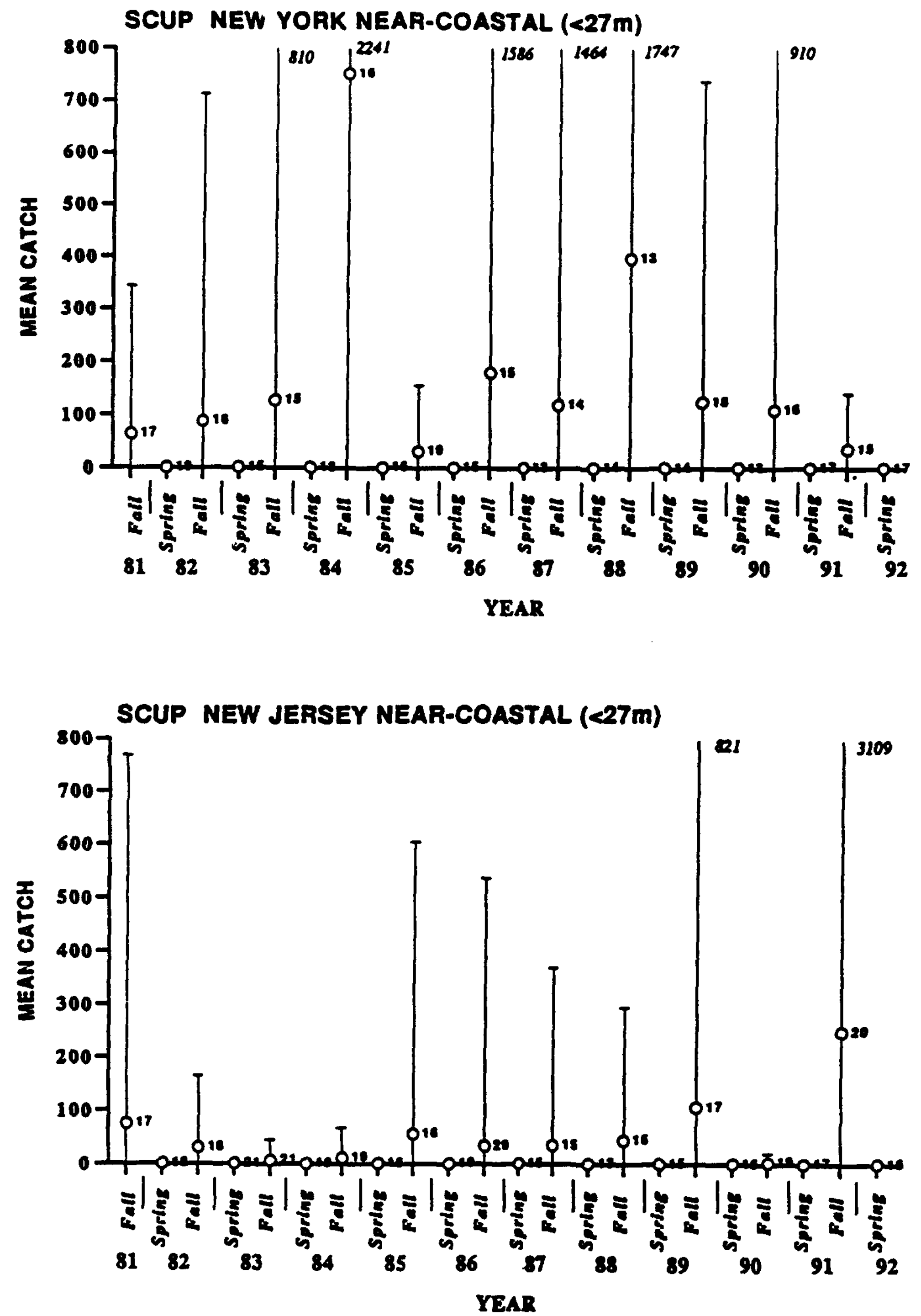
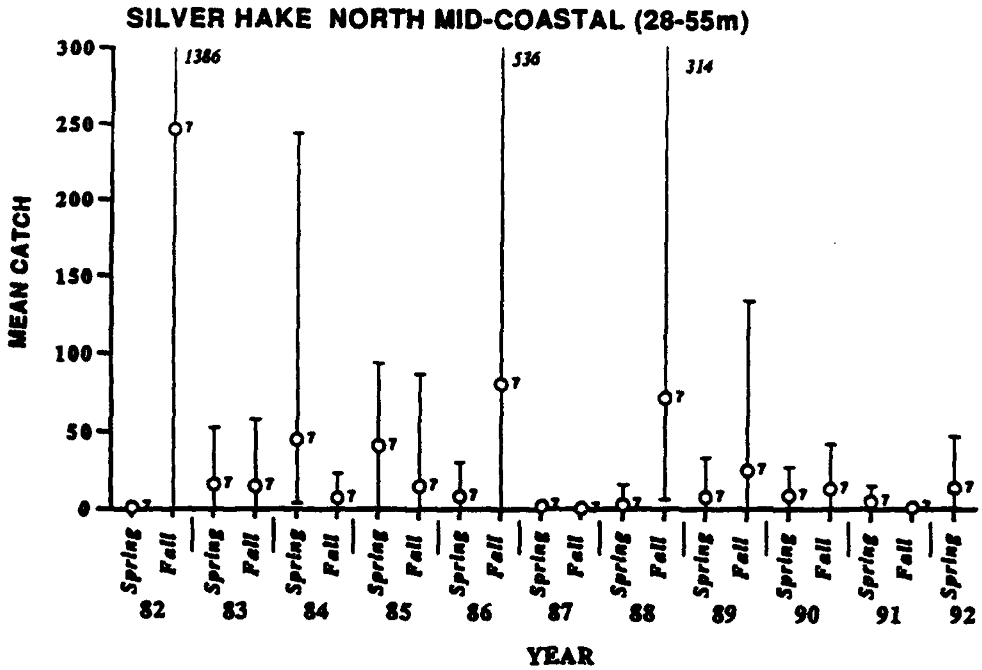


Figure 3-7. (Continued).



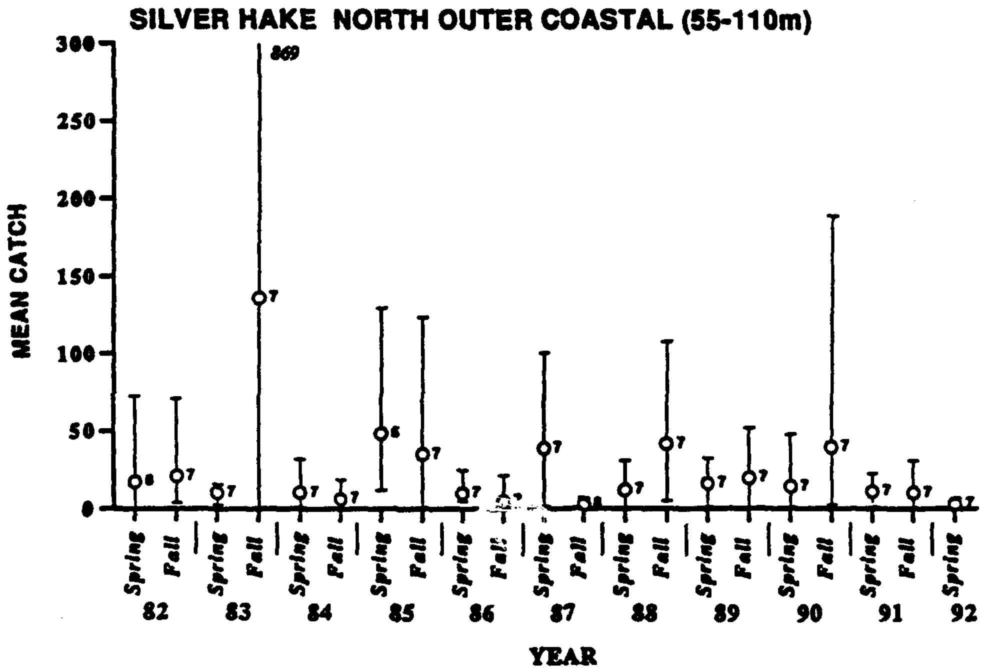
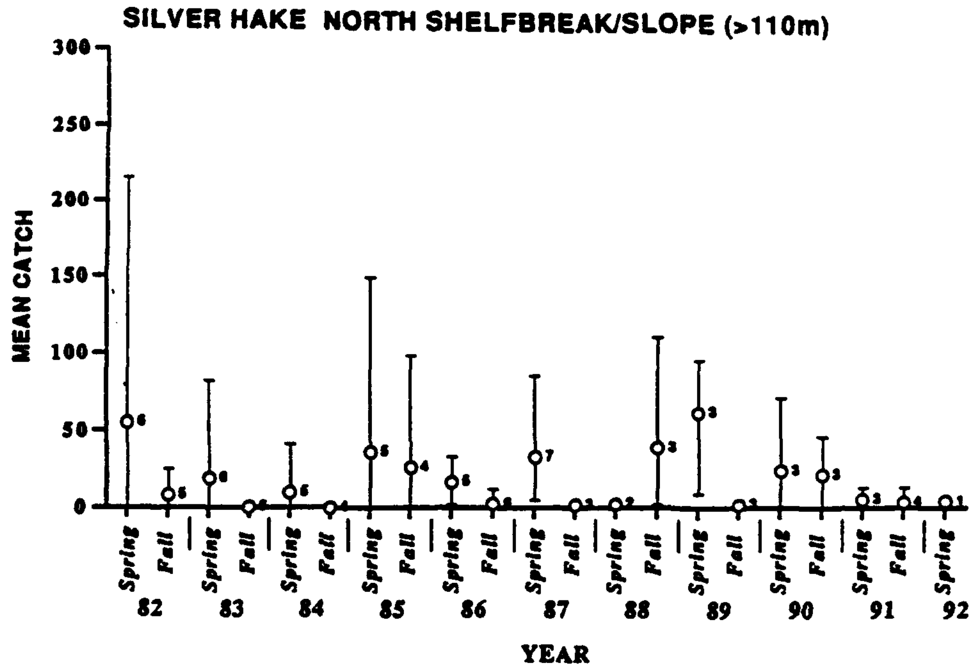


Figure 3-8. Mean catch, minimum catch and maximum catch, and number of samples (n) of silver hake by year and season in sampling strata of New York Bight.



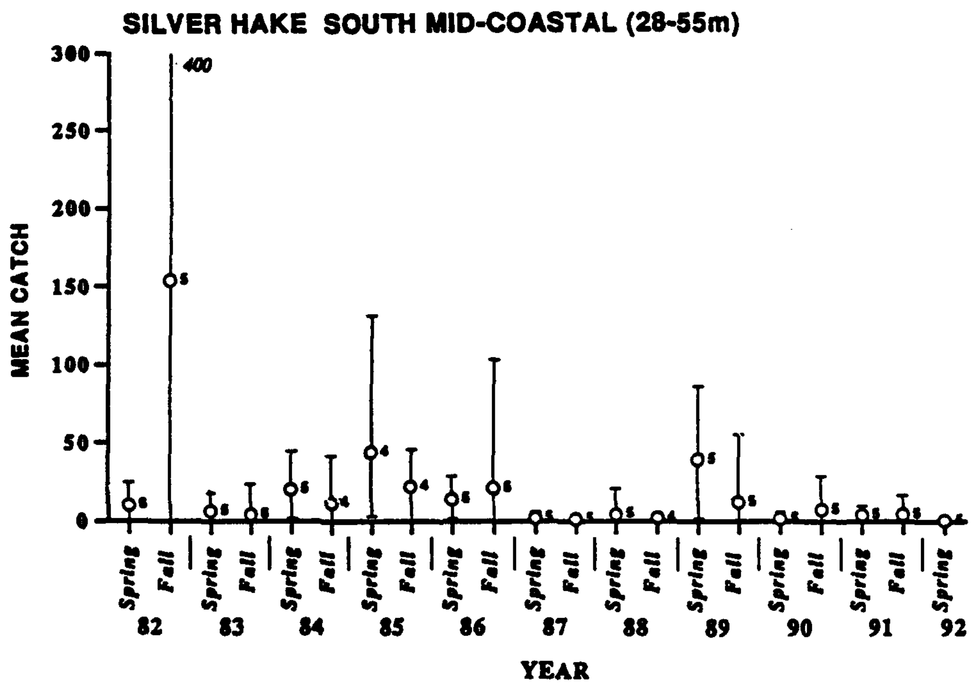
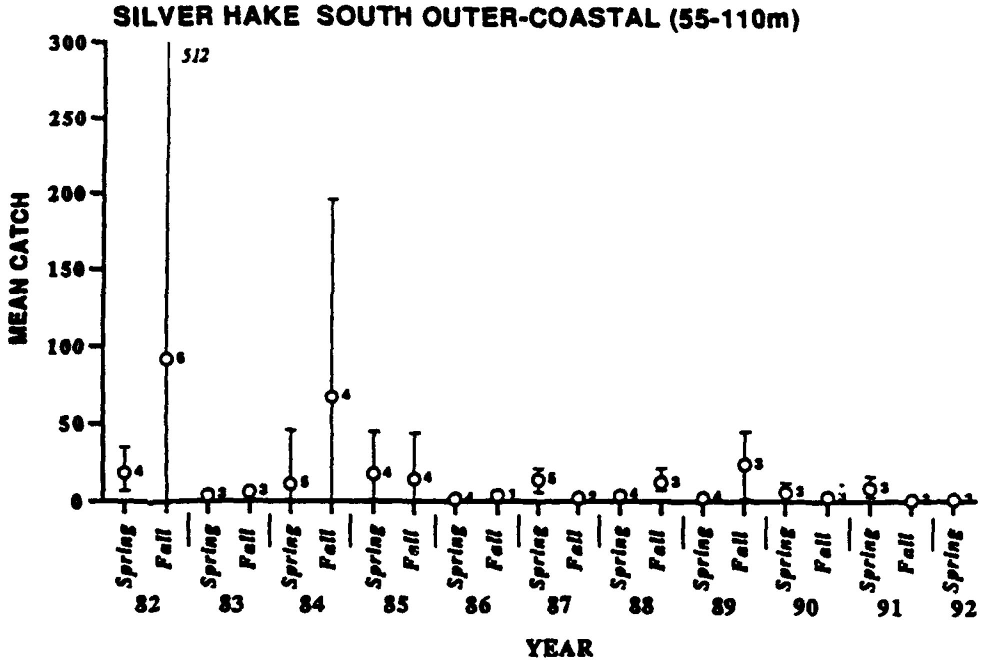


Figure 3-8. (Continued).



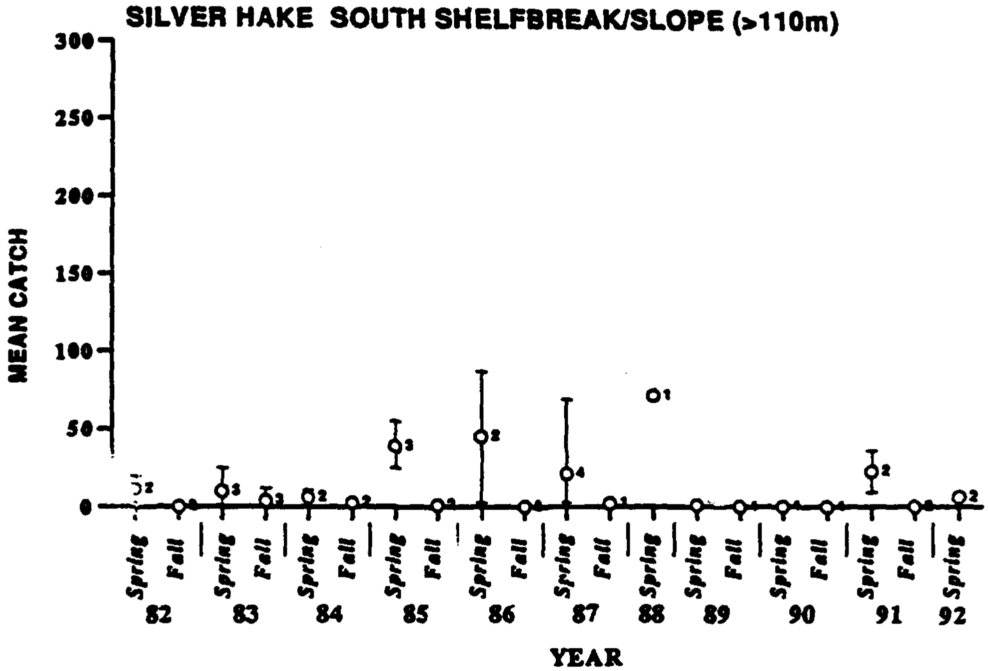
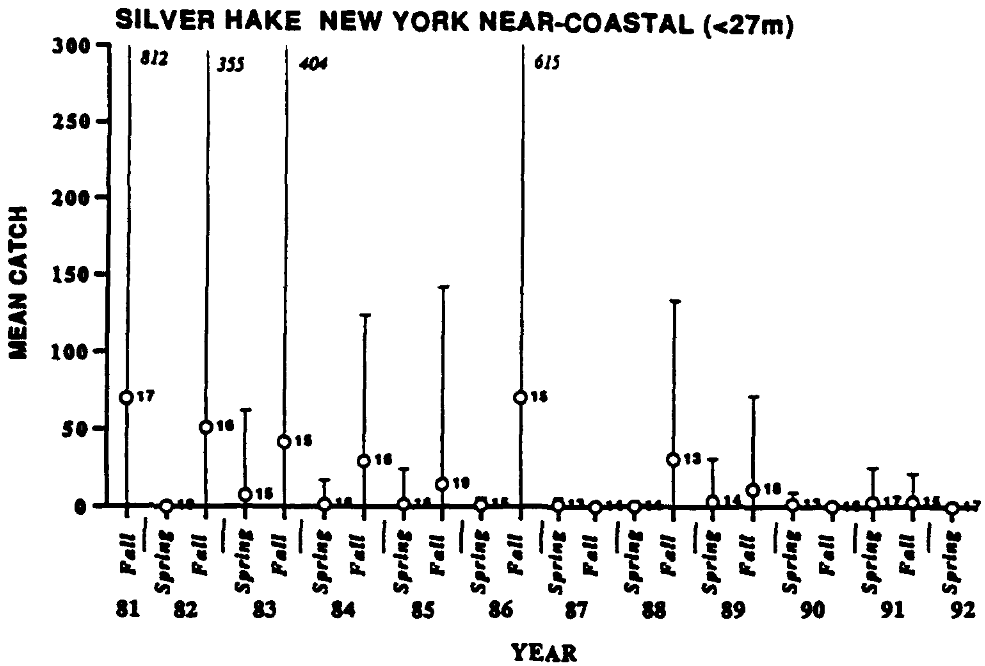


Figure 3-8. (Continued).



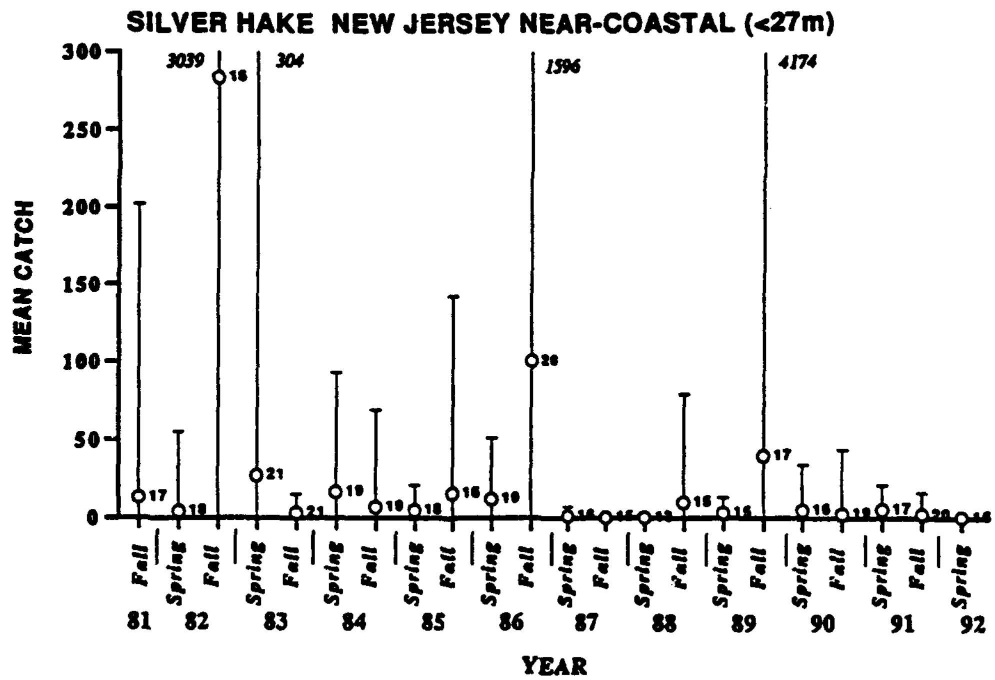
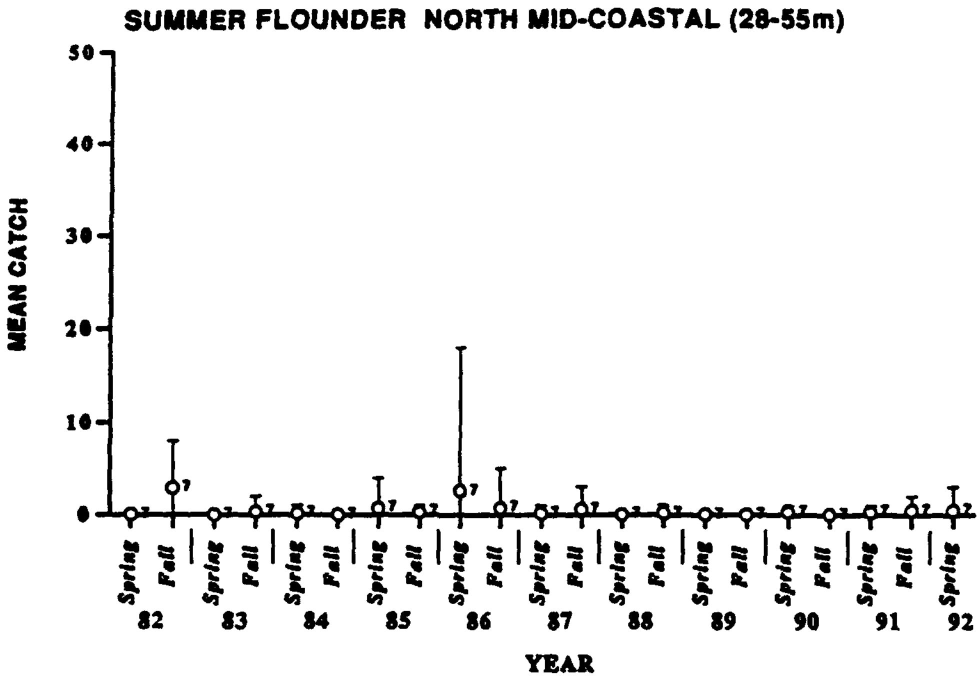


Figure 3-8. (Continued).



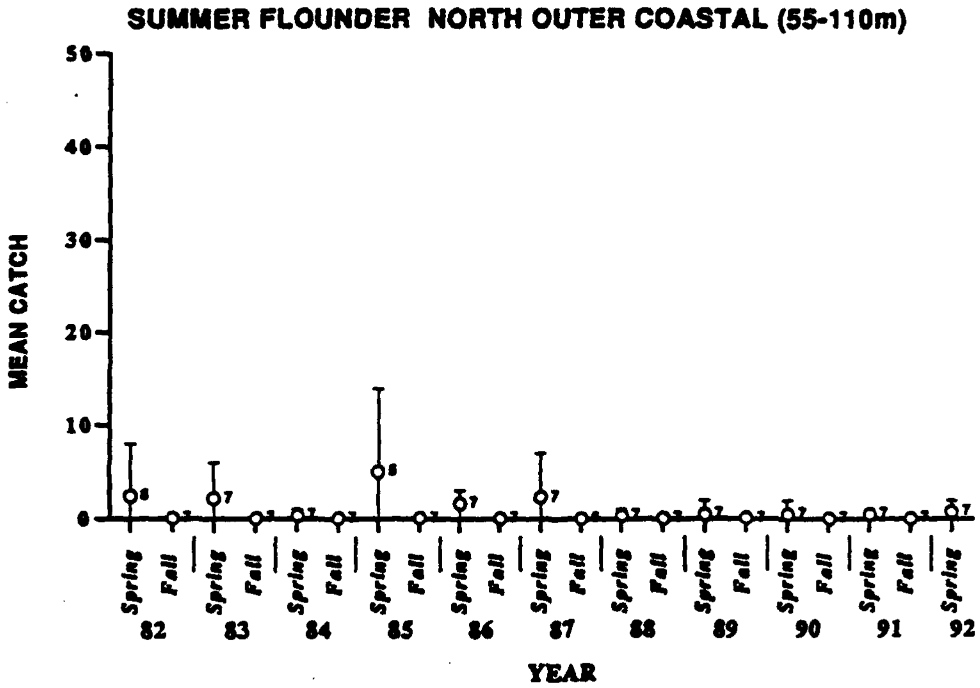
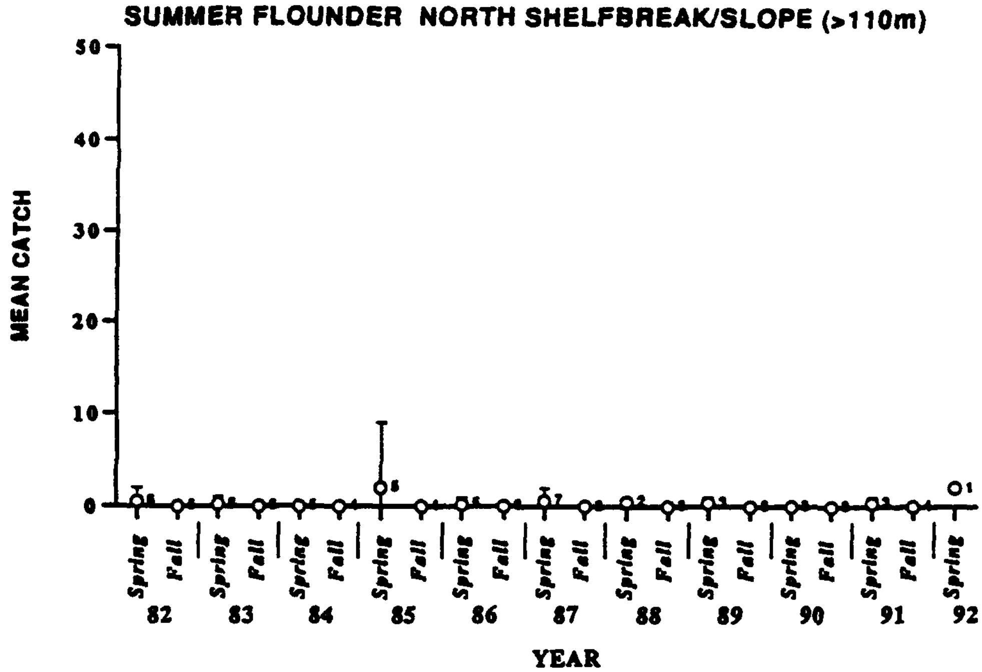


Figure 3-9. Mean catch, minimum catch and maximum catch, and number of samples (n) of summer flounder by year and season in sampling strata of New York Bight.



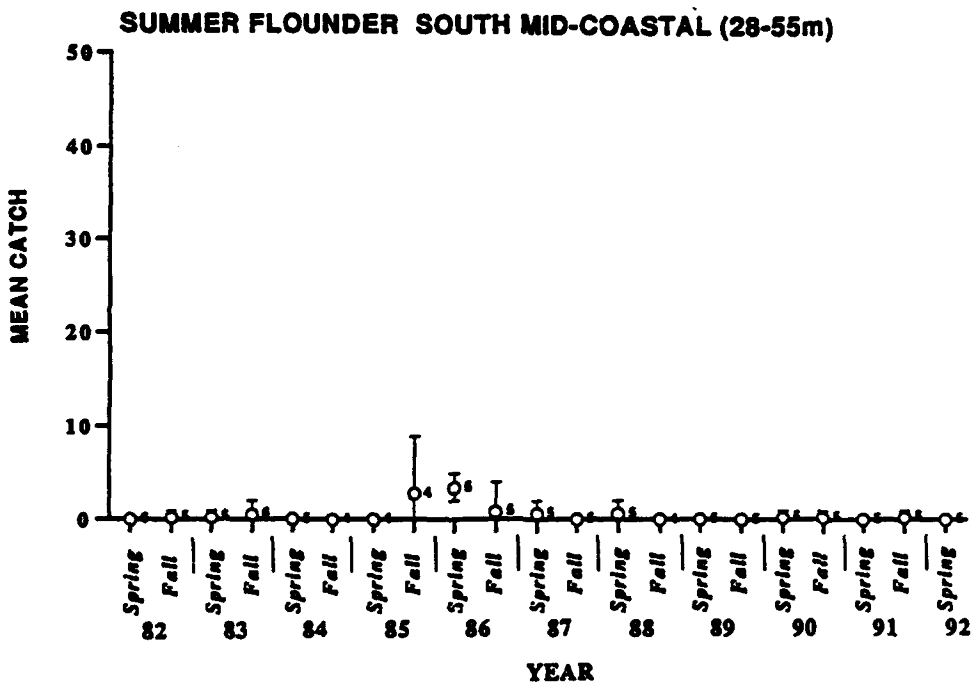
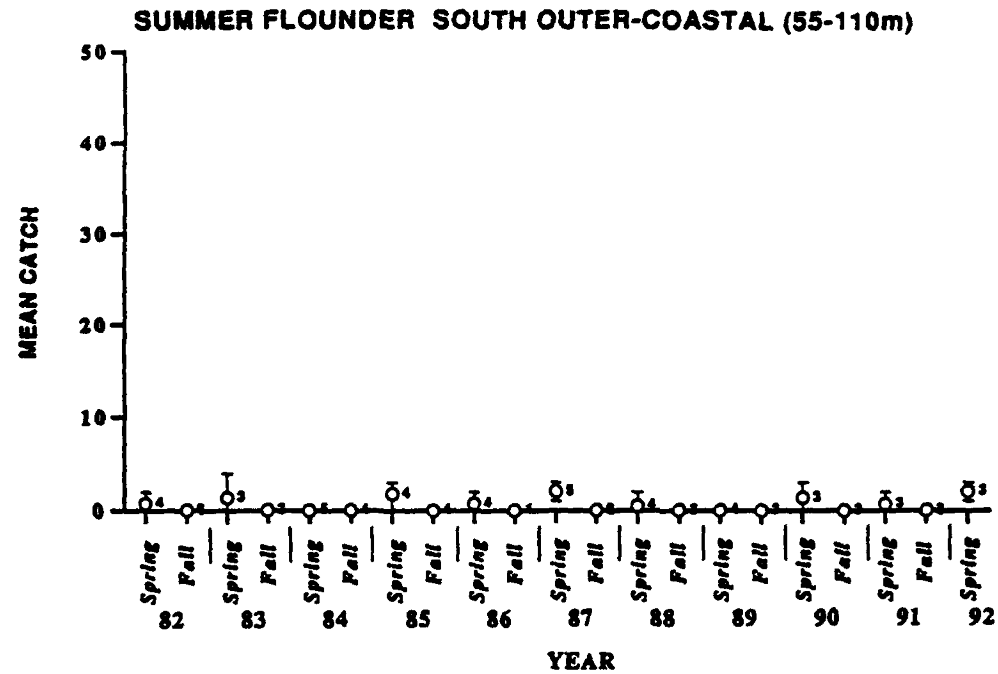


Figure 3-9. (Continued).



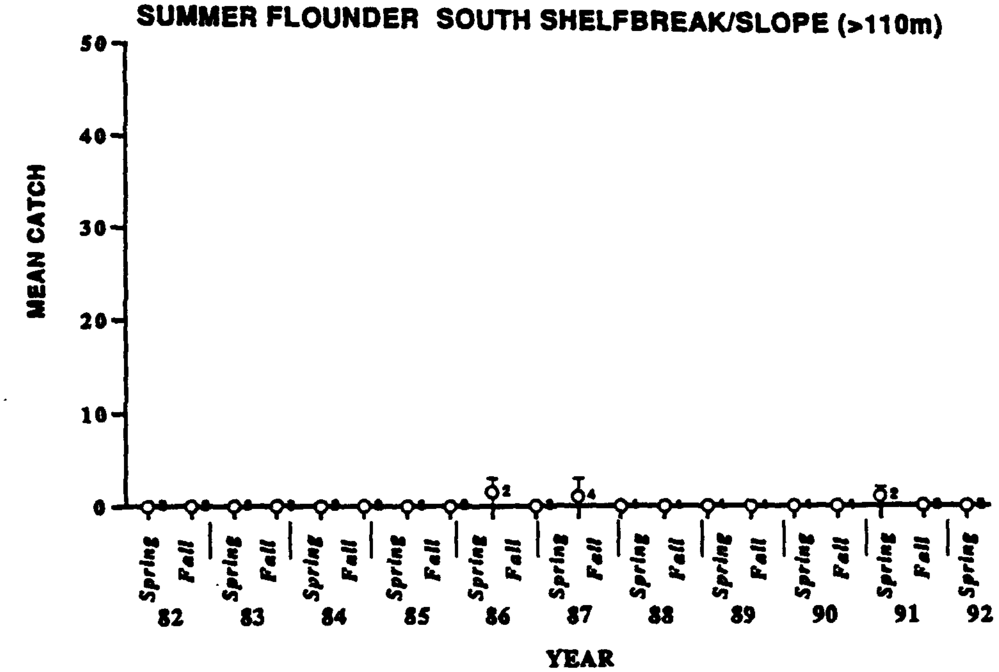
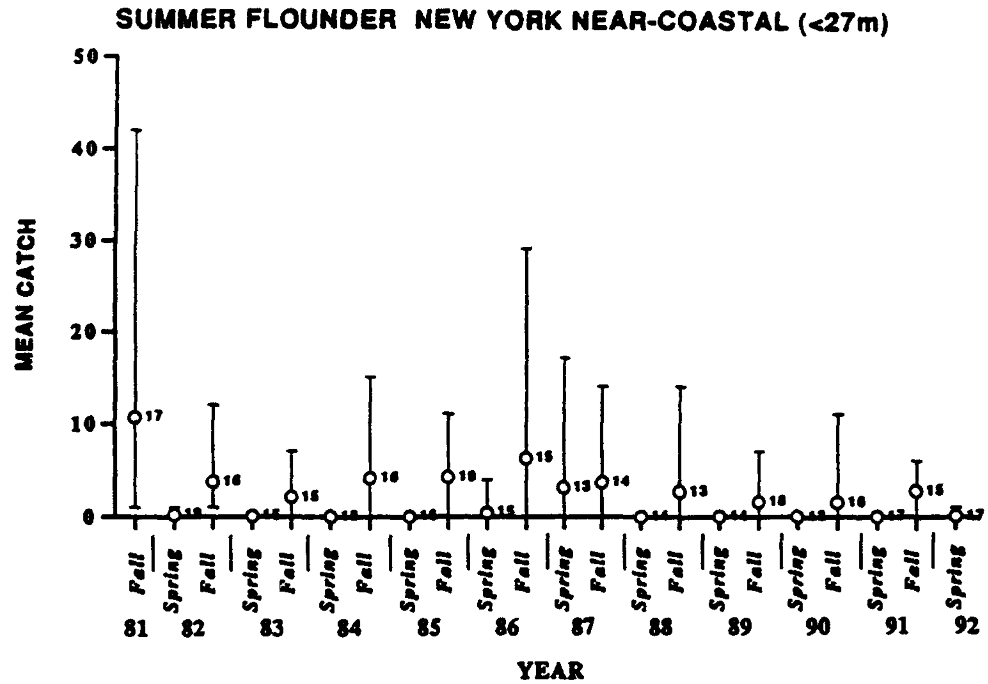


Figure 3-9. (Continued).



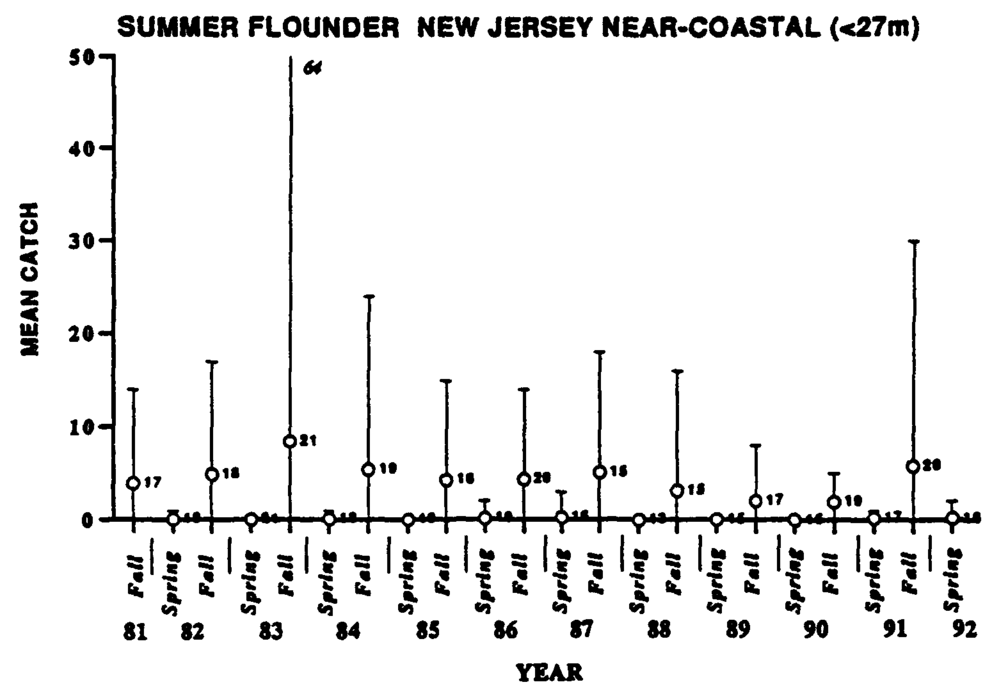
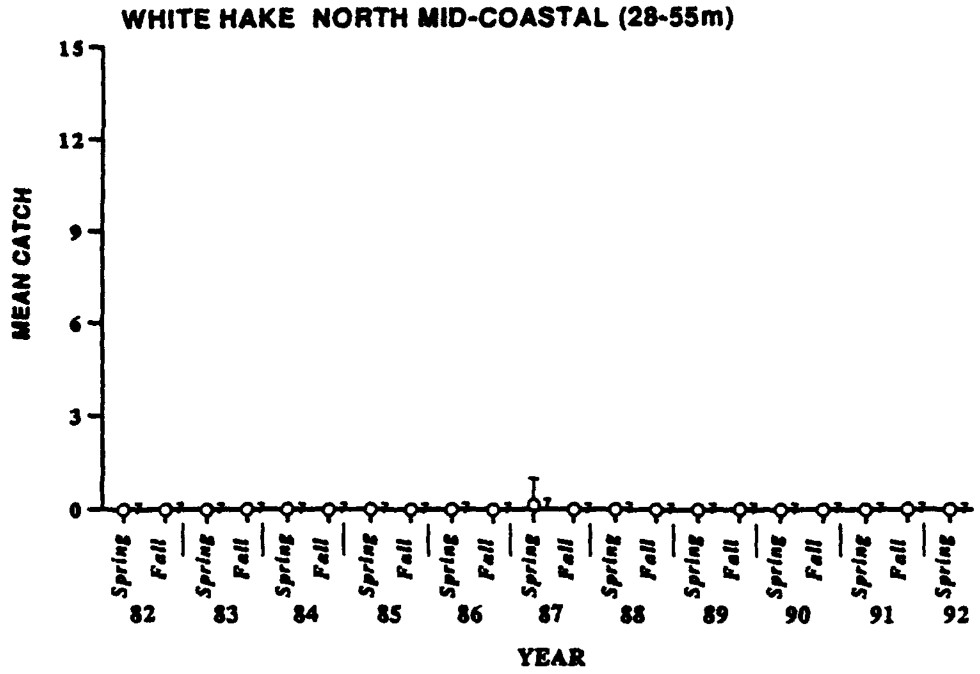


Figure 3-9. (Continued).



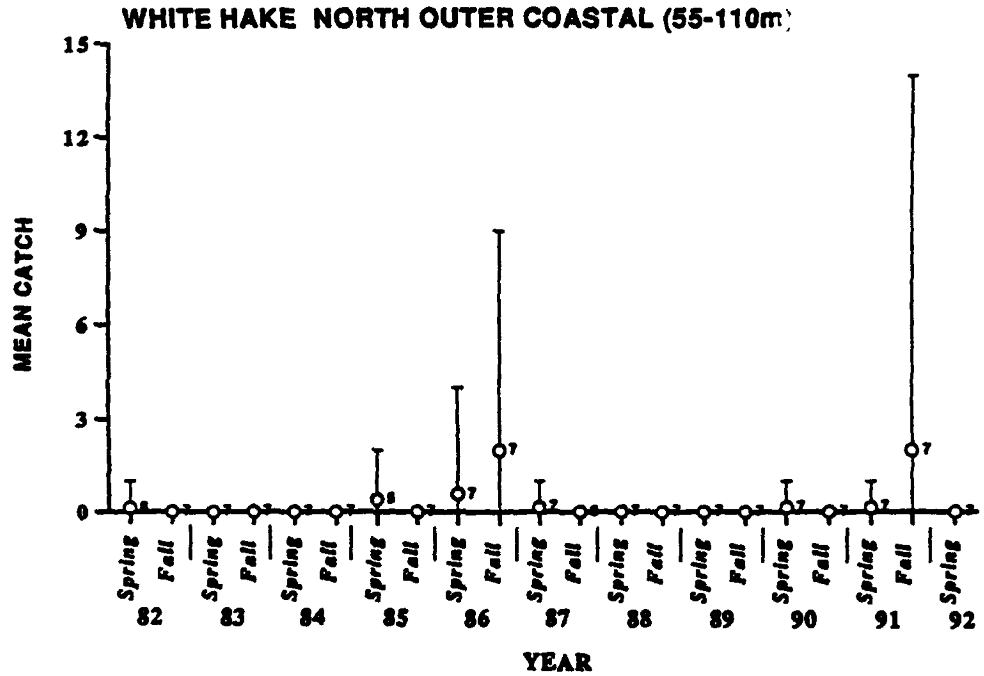
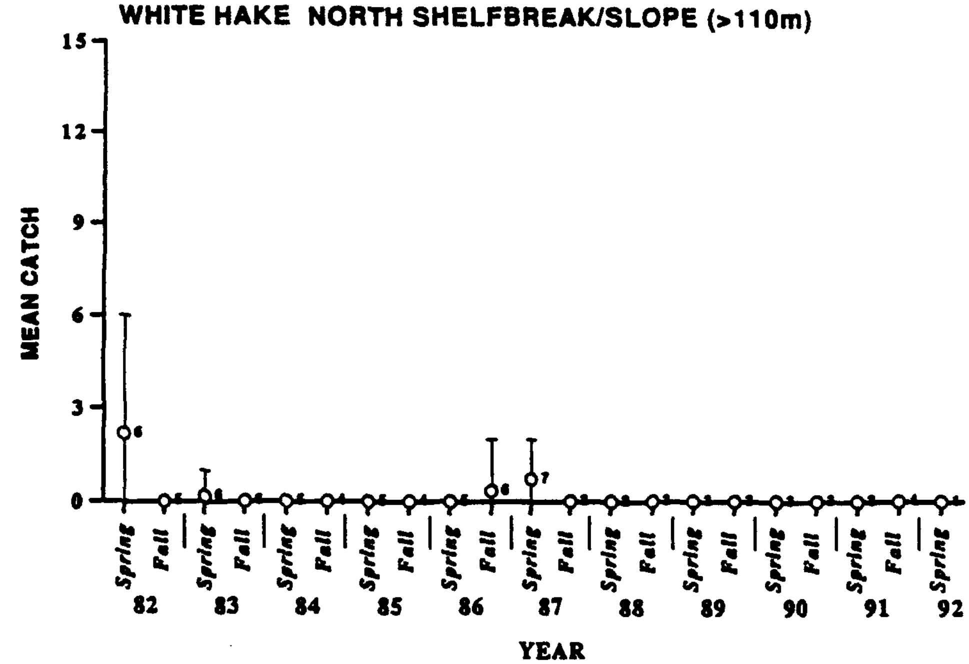


Figure 3-10. Mean catch, minimum catch and maximum catch, and number of samples (n) of white hake by year and season in sampling strata of New York Bight.



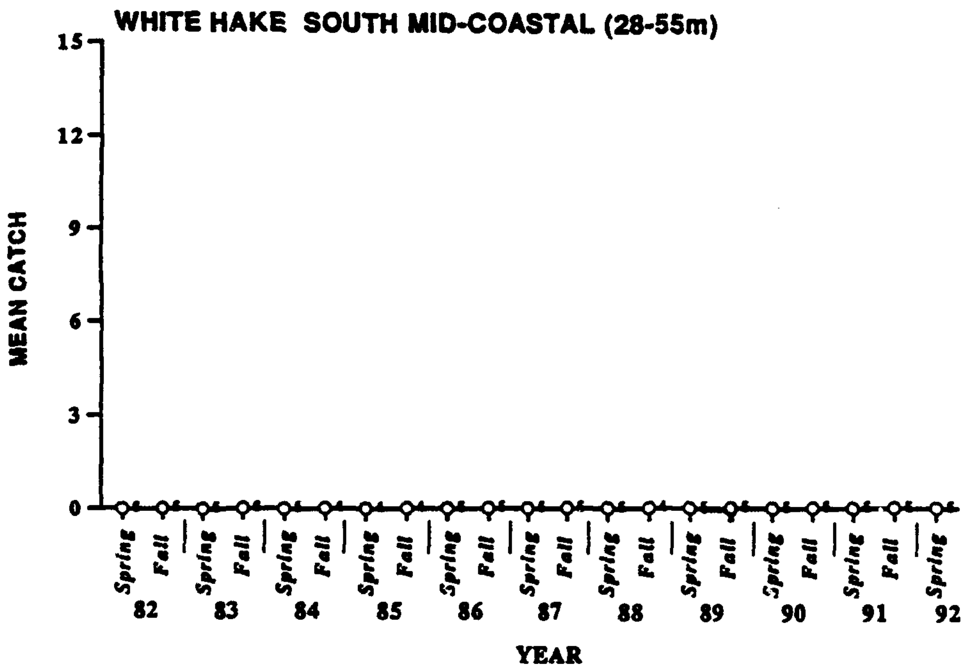
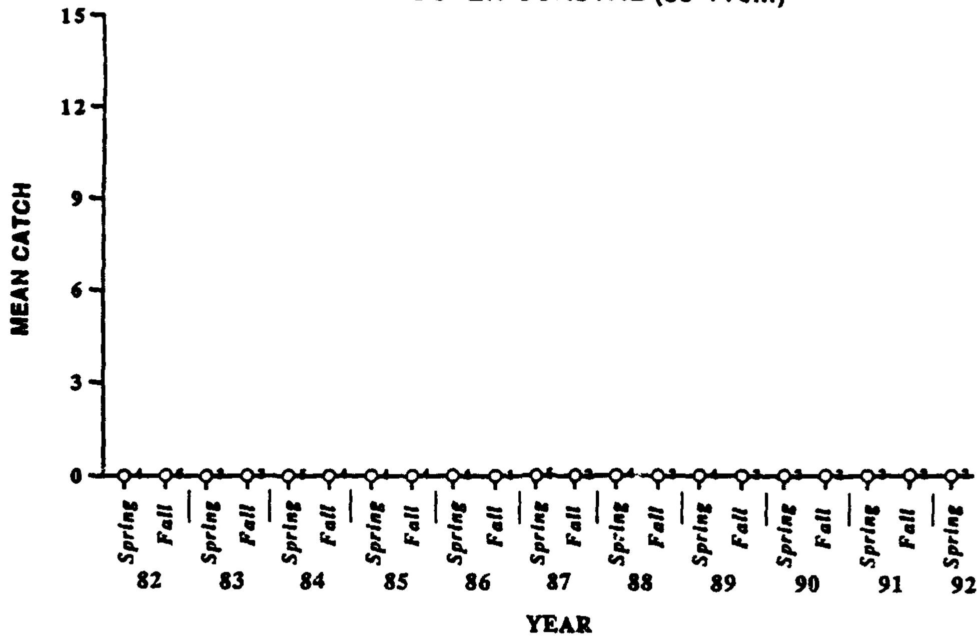


Figure 3-10. (Continued).

WHITE HAKE SOUTH OUTER-COASTAL (55-110m)



WHITE HAKE SOUTH SHELFBREAK/SLOPE (>110m)

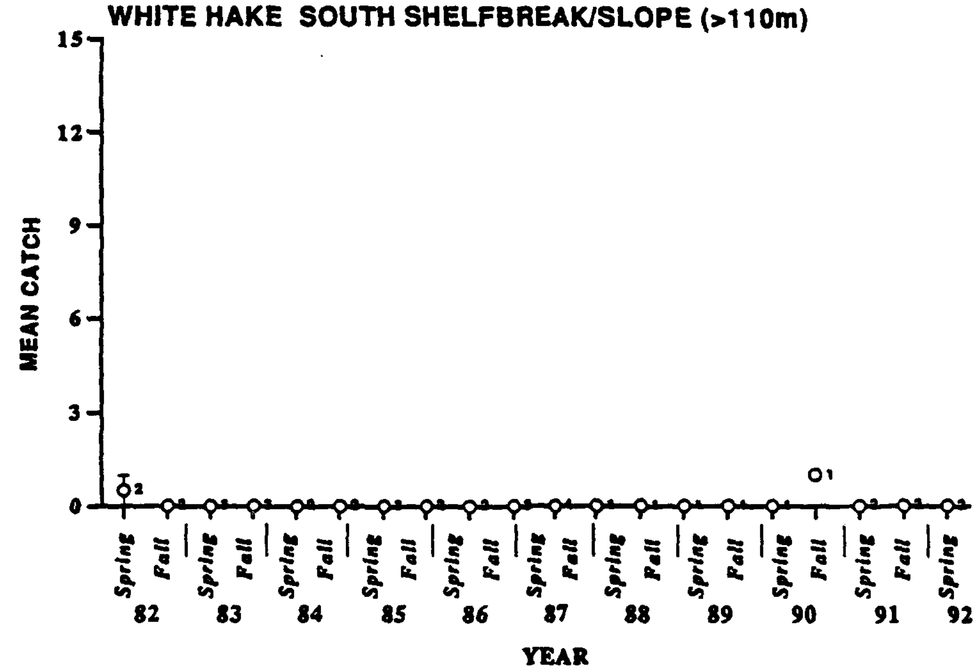
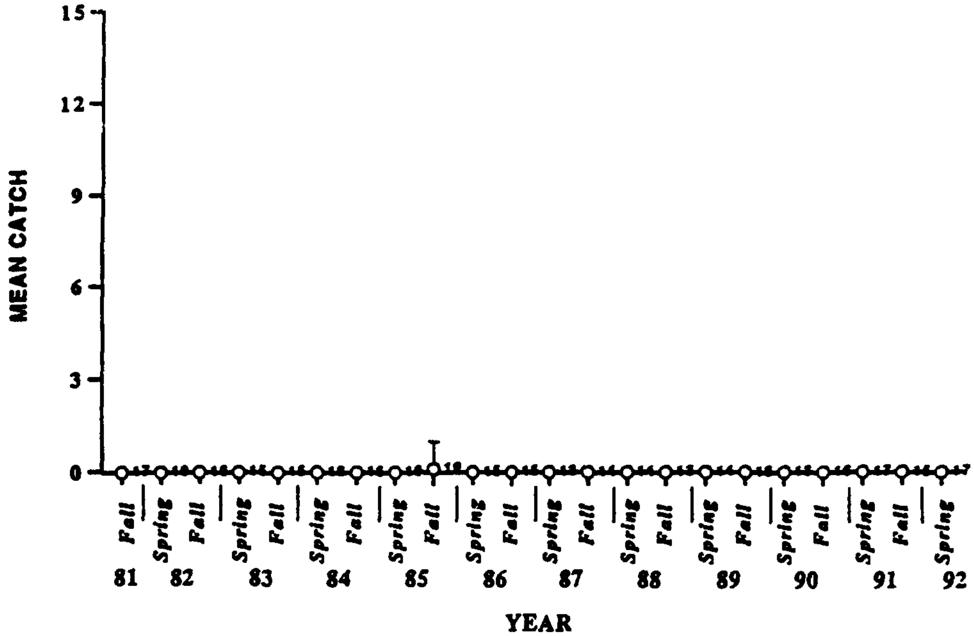


Figure 3-10. (Continued).

WHITE HAKE NEW YORK NEAR-COASTAL (<27m)



WHITE HAKE NEW JERSEY NEAR-COASTAL (<27m)

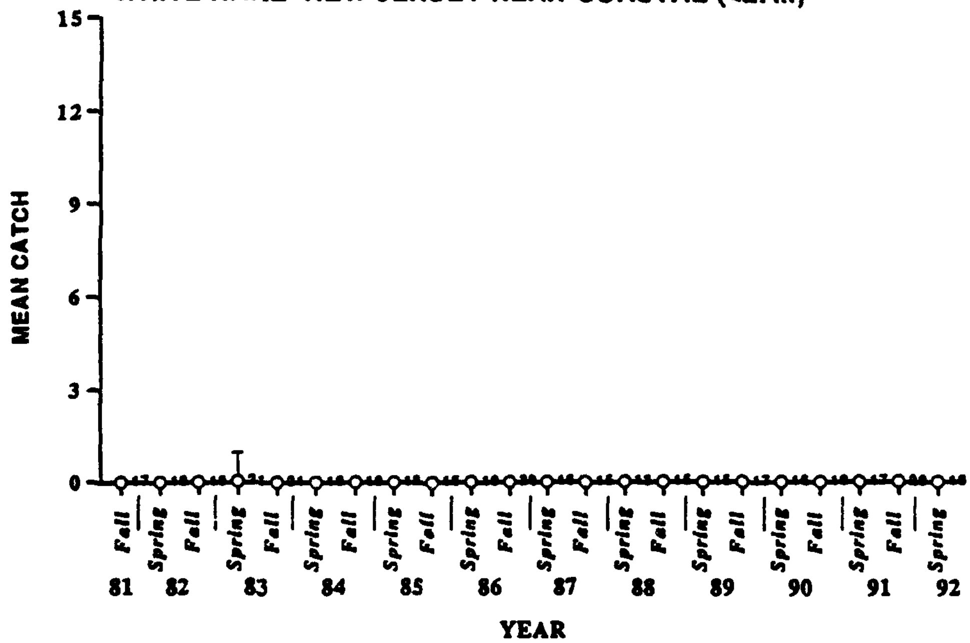
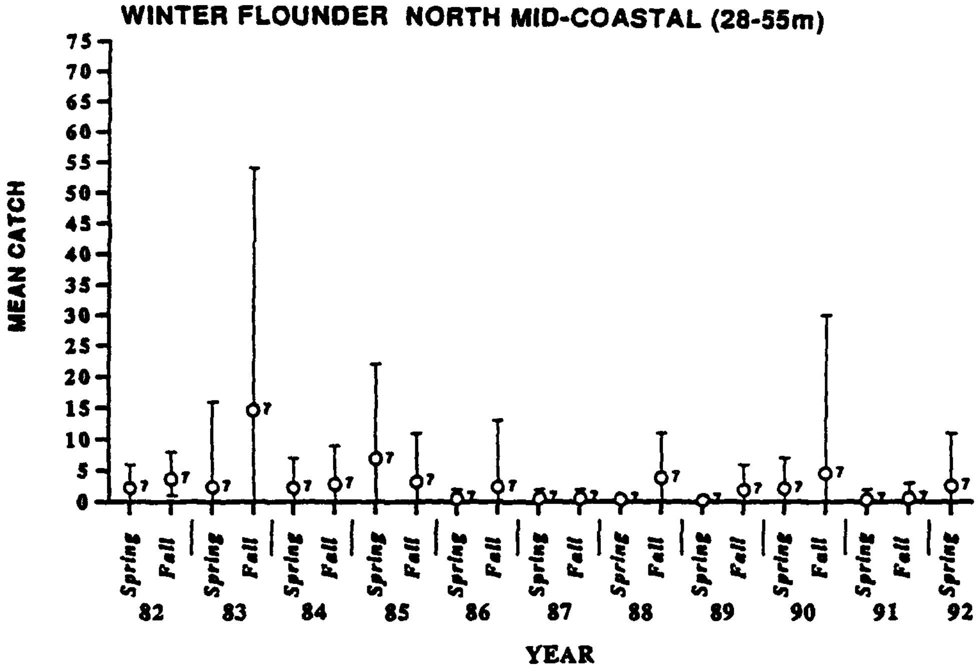


Figure 3-10. (Continued).



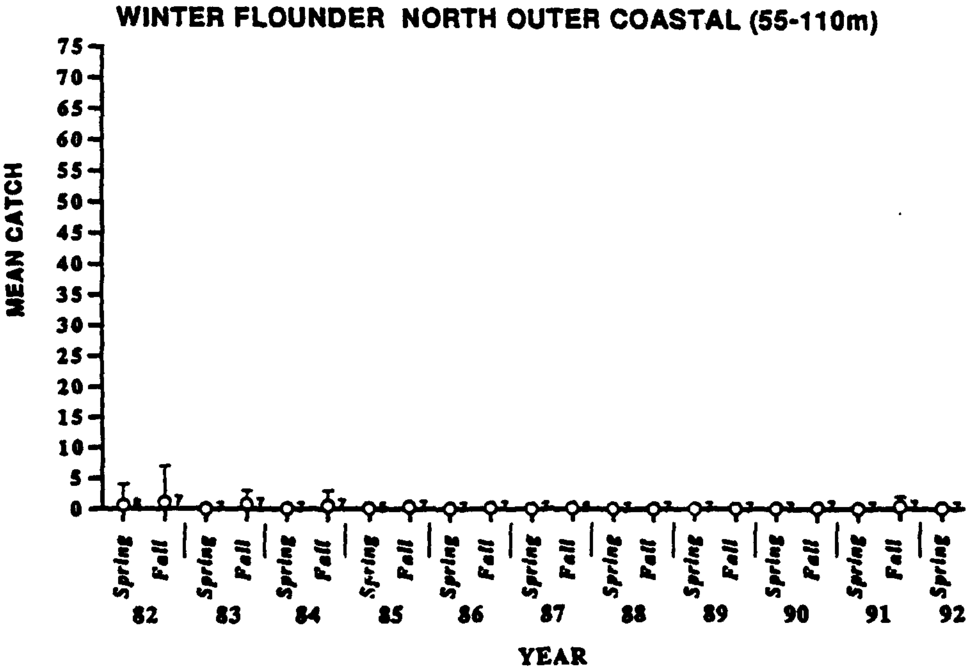
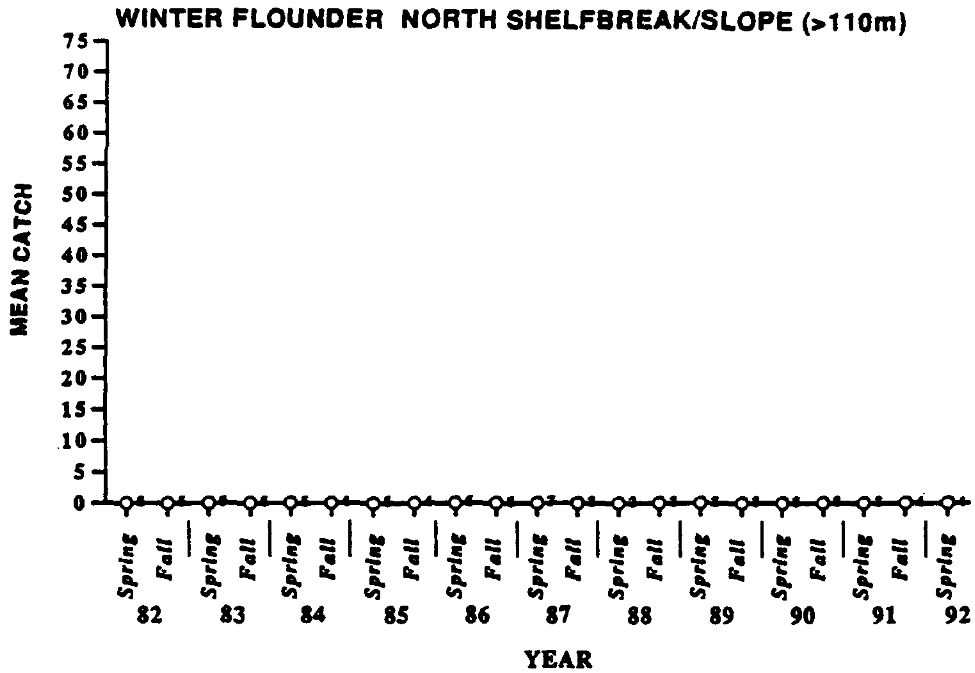


Figure 3-11. Mean catch, minimum catch and maximum catch, and number of samples (n) of winter flounder by year and season in sampling strata of New York Bight.



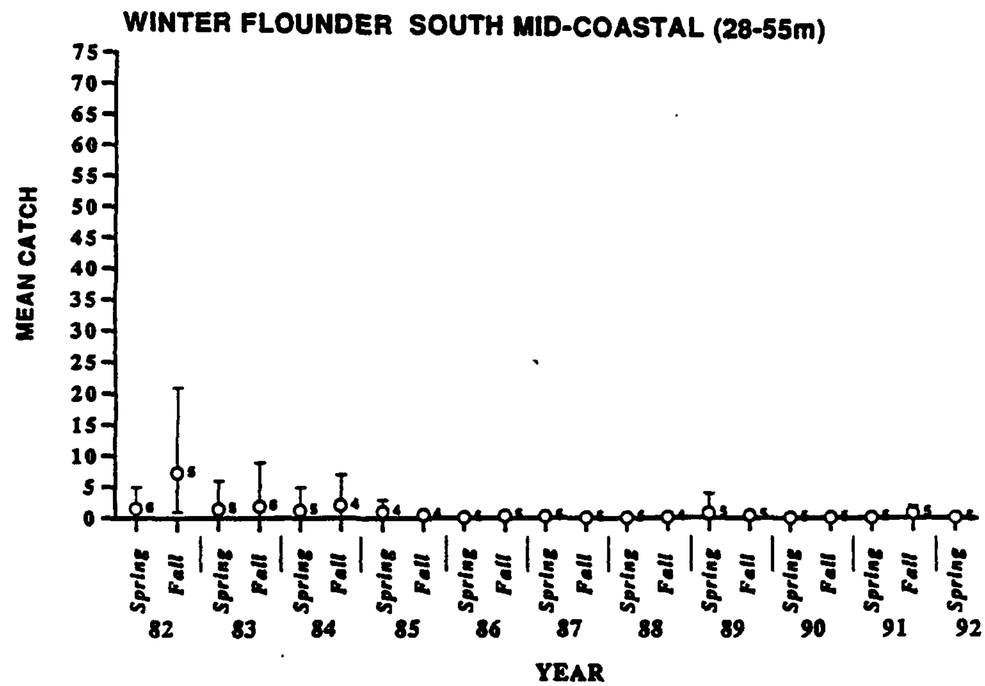
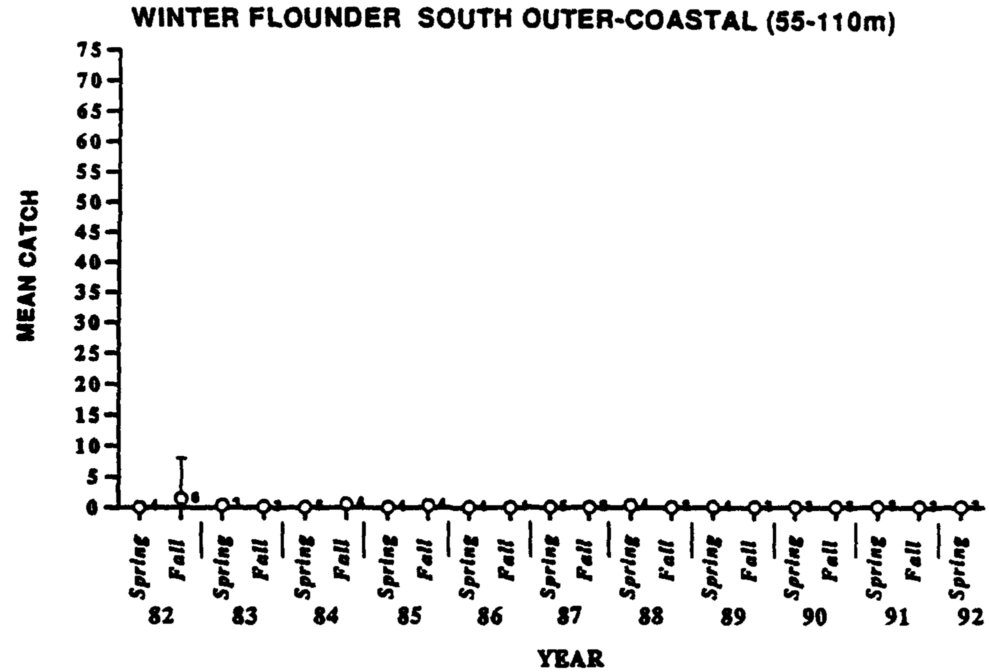


Figure 3-11. (Continued).



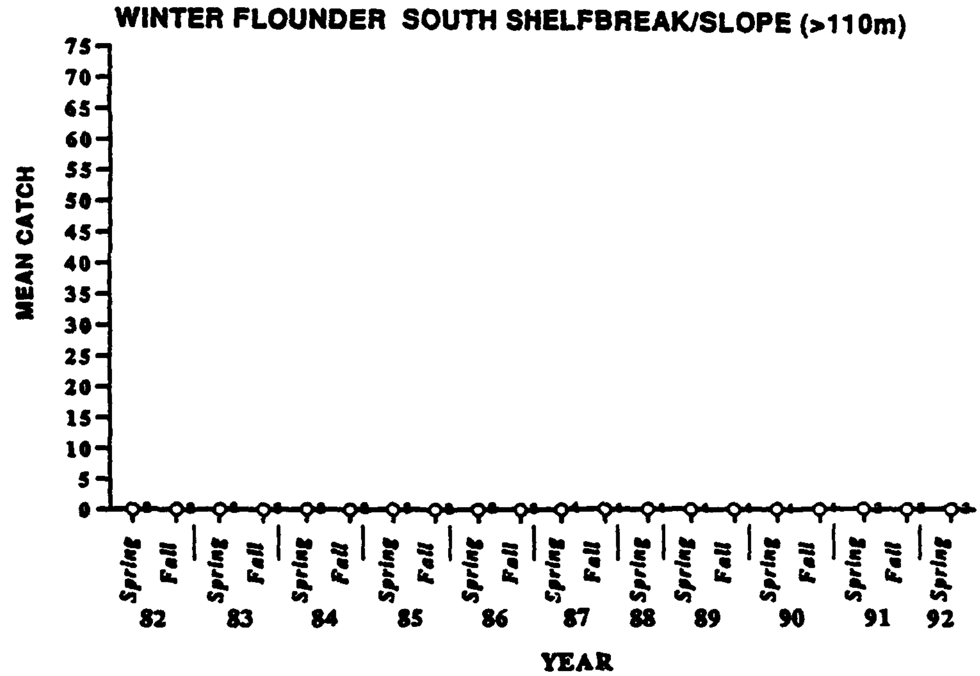
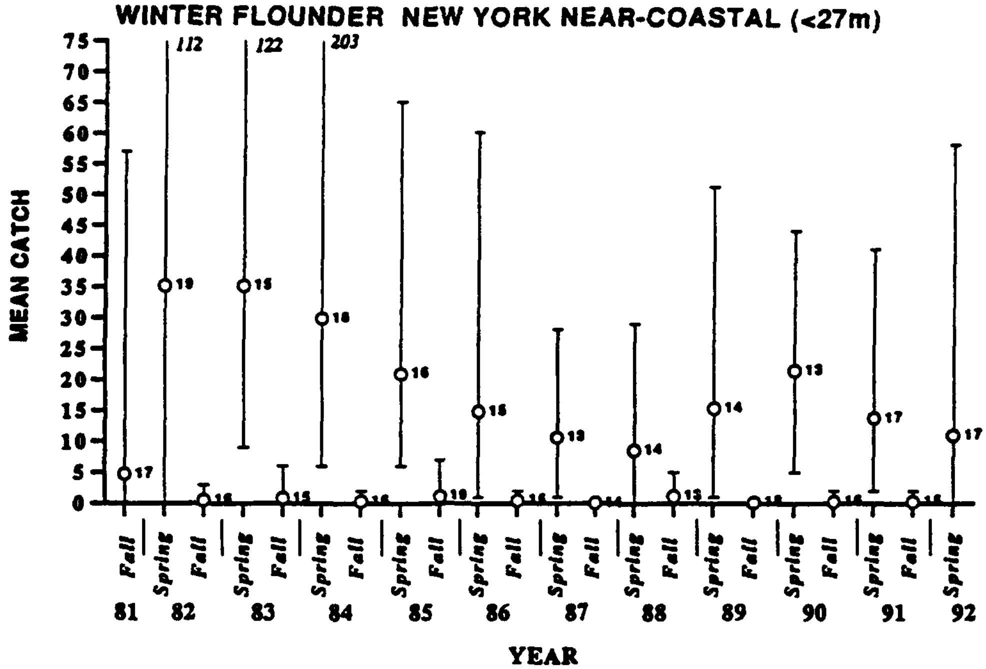


Figure 3-11. (Continued).



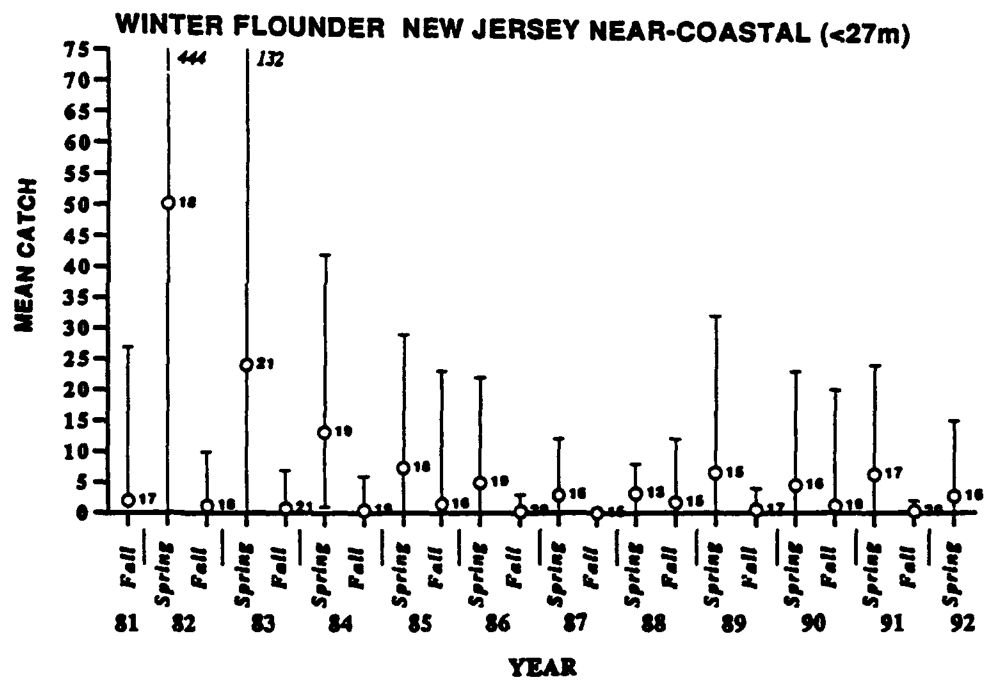
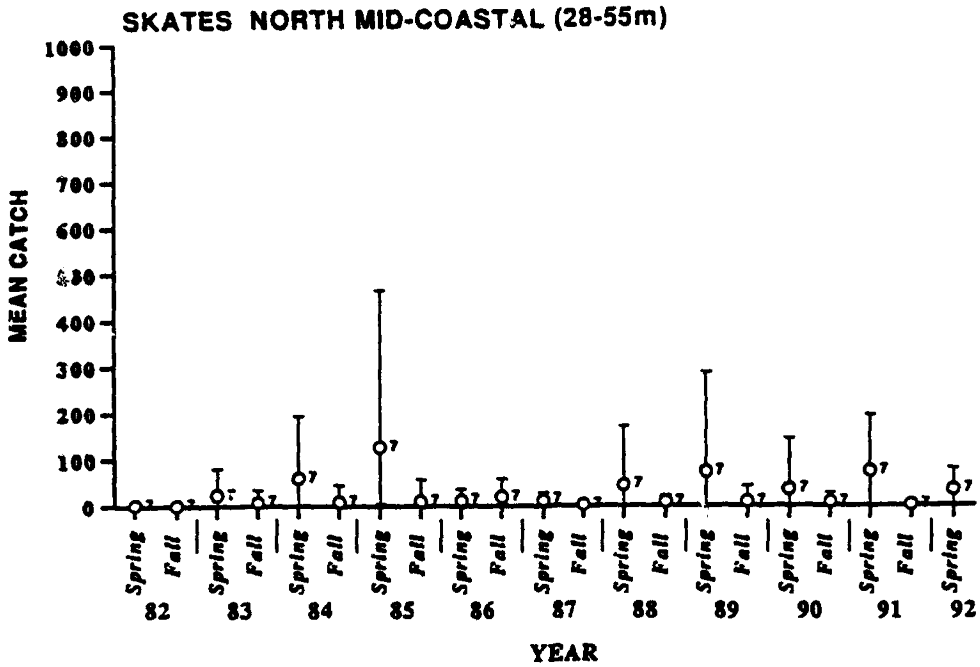


Figure 3-11. (Continued).



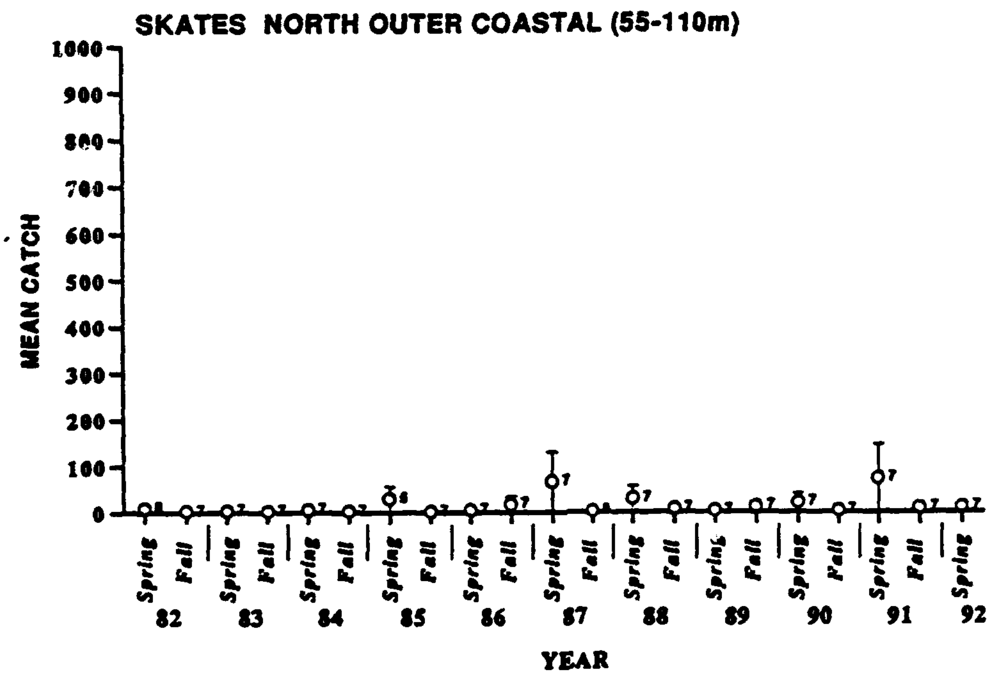
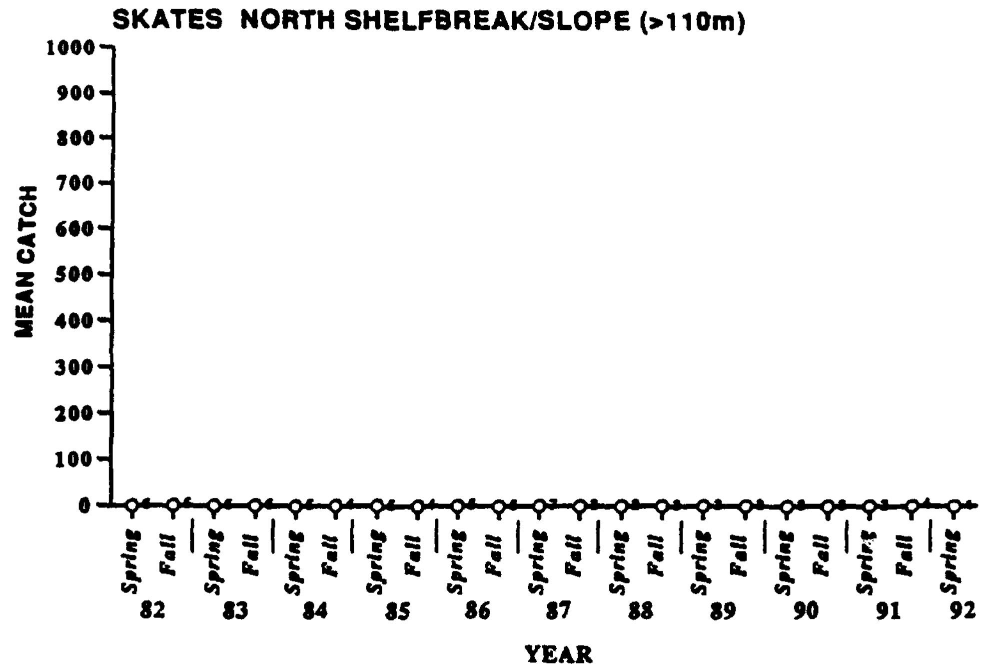


Figure 3-12. Mean catch, minimum catch and maximum catch, and number of samples (n) of skates by year and season in sampling strata of New York Bight.



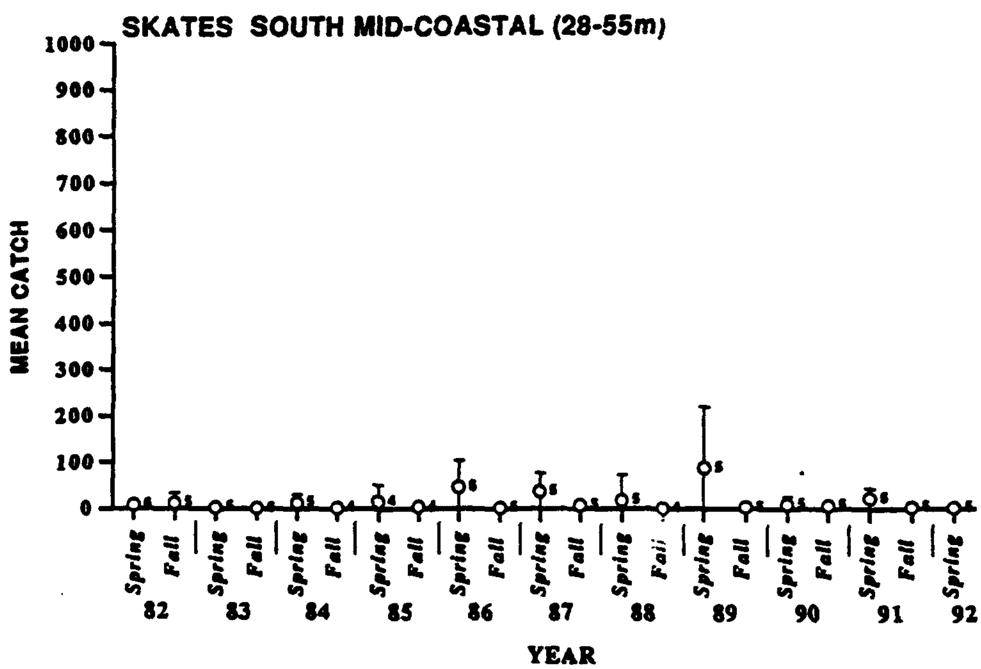
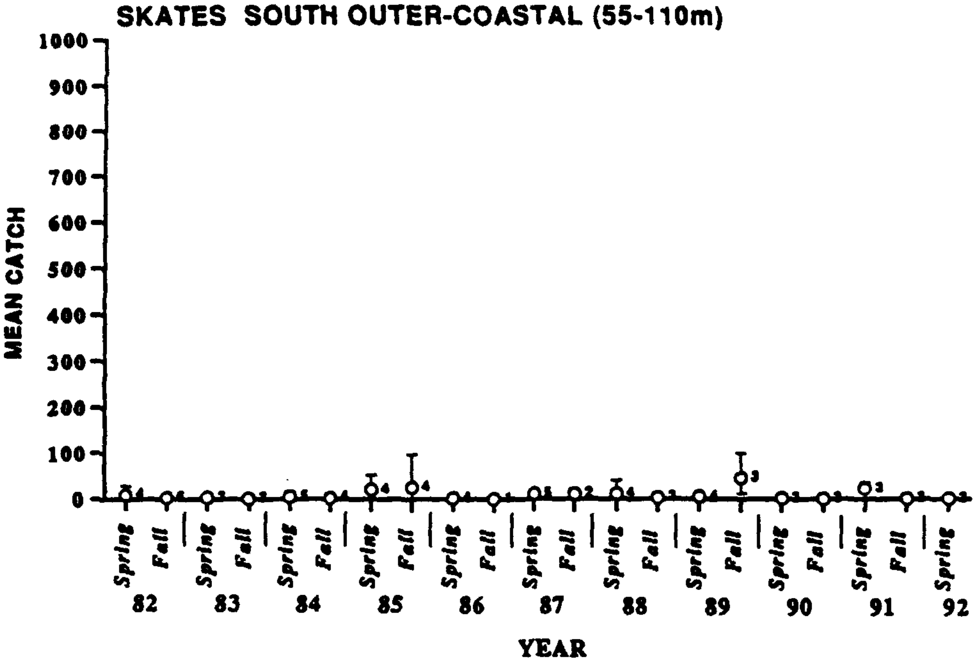


Figure 3-12. (Continued).



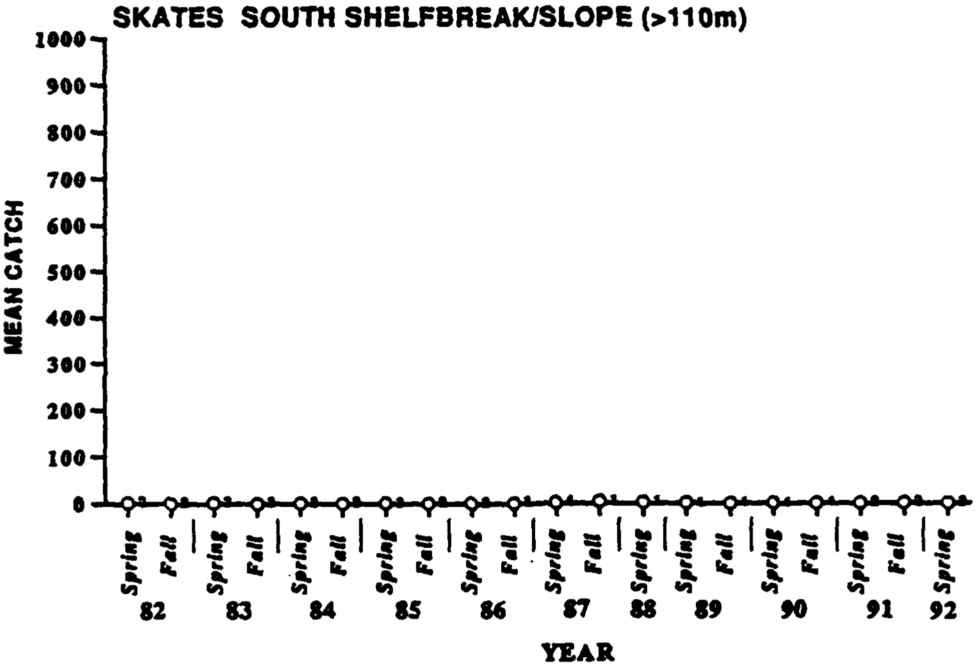
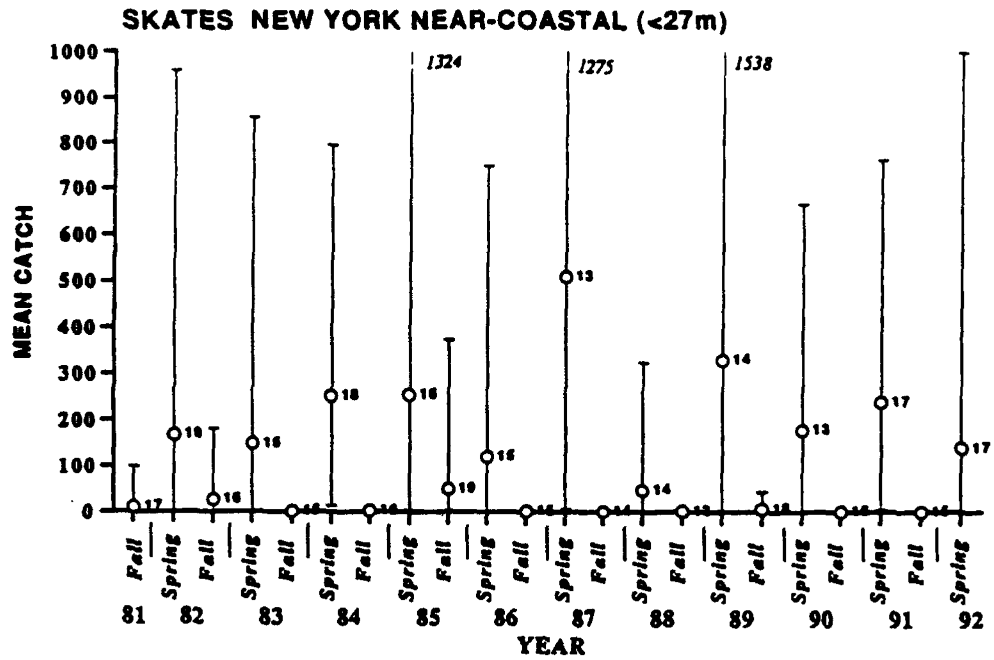
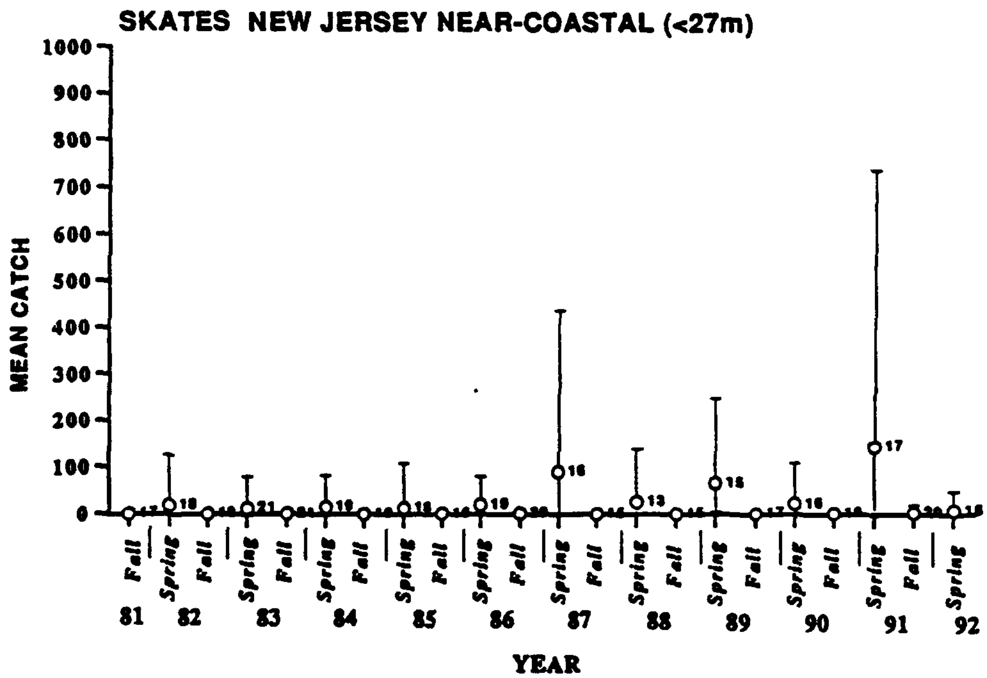


Figure 3-12. (Continued).





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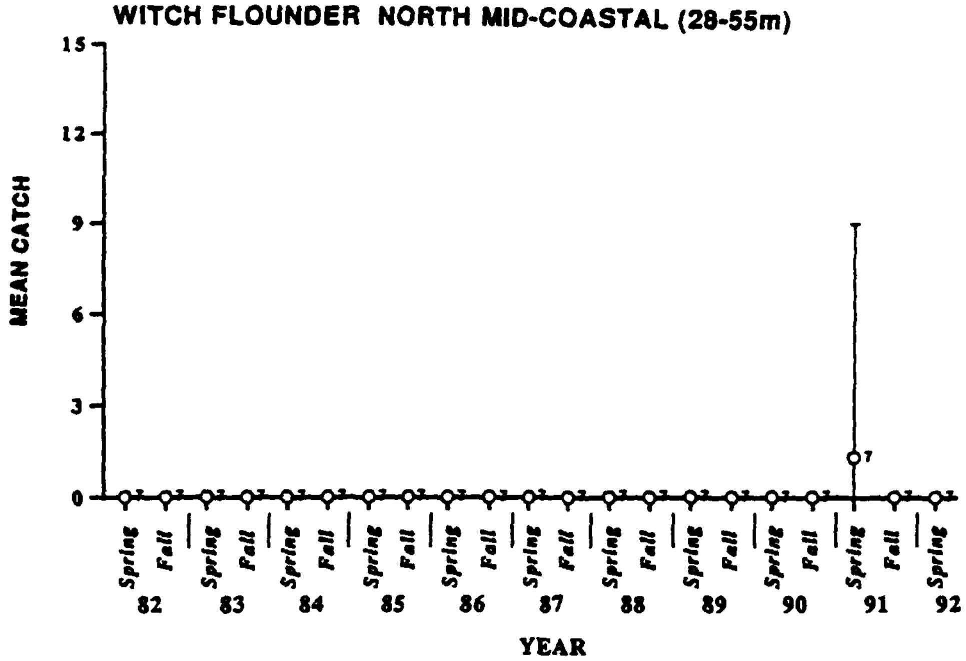


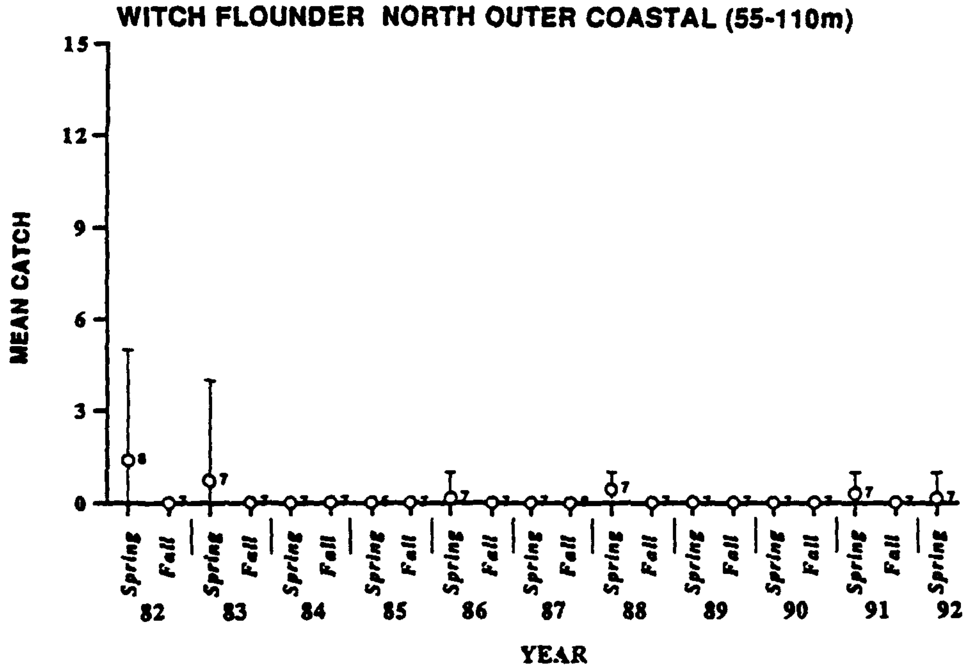
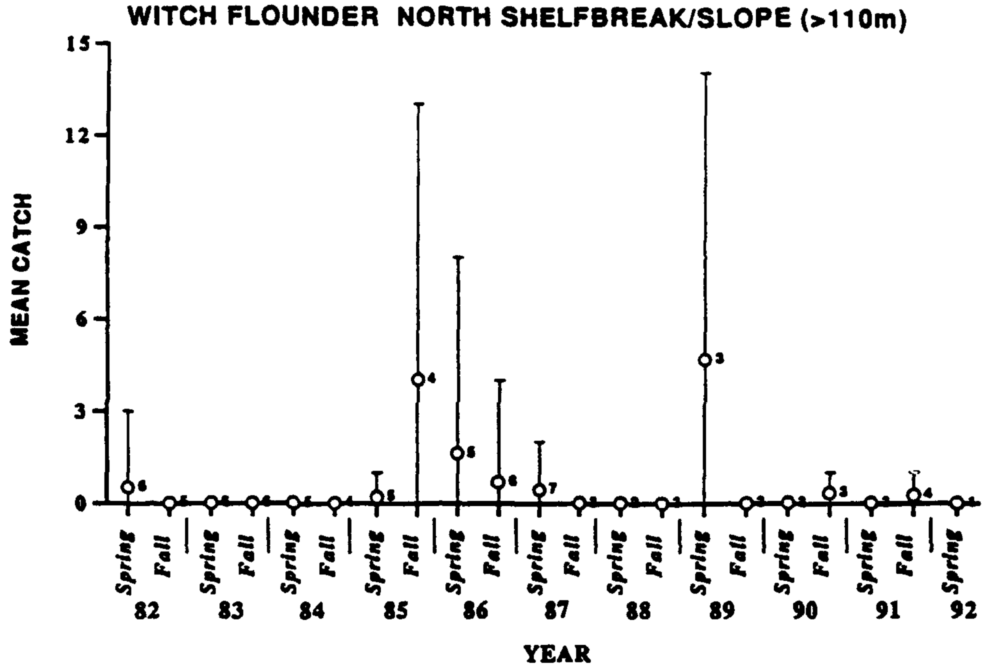


Figure 3-13. Mean catch, minimum catch and maximum catch, and number of samples (n) of witch flounder by year and season in sampling strata of New York Bight.



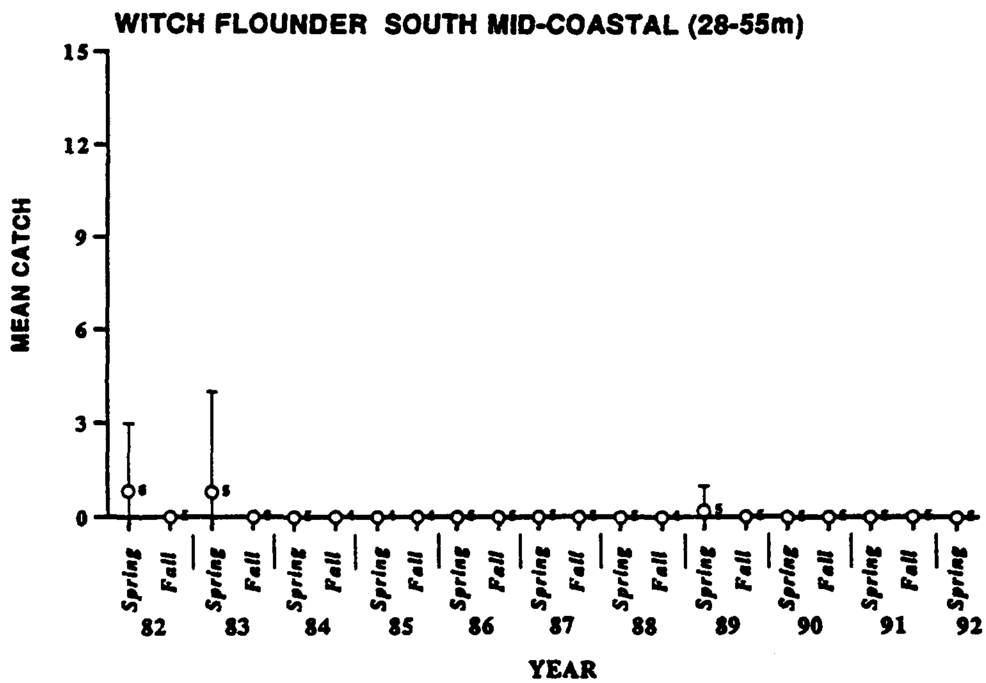
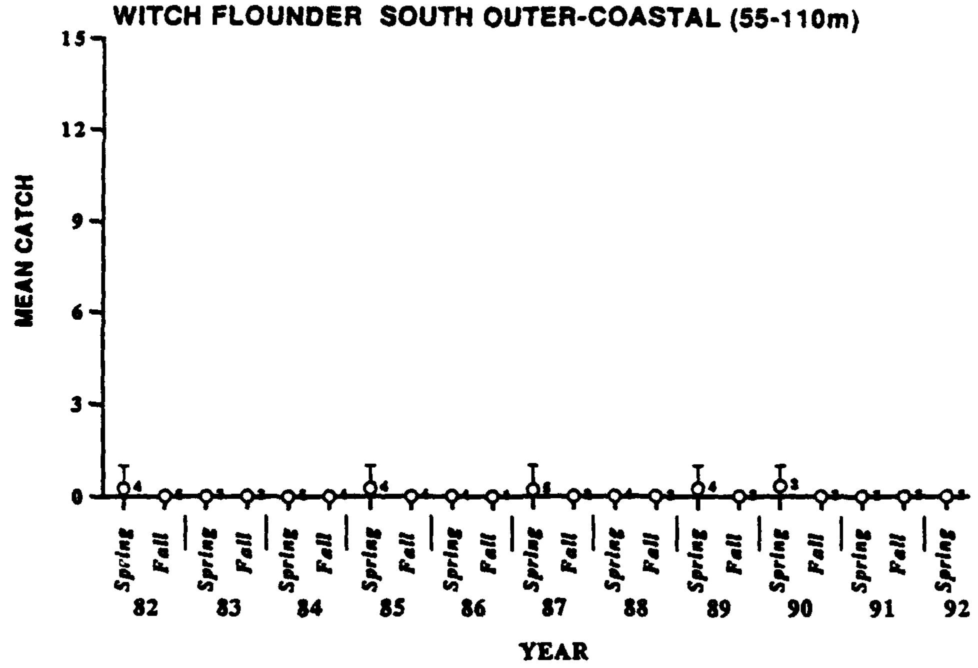


Figure 3-13. (Continued).



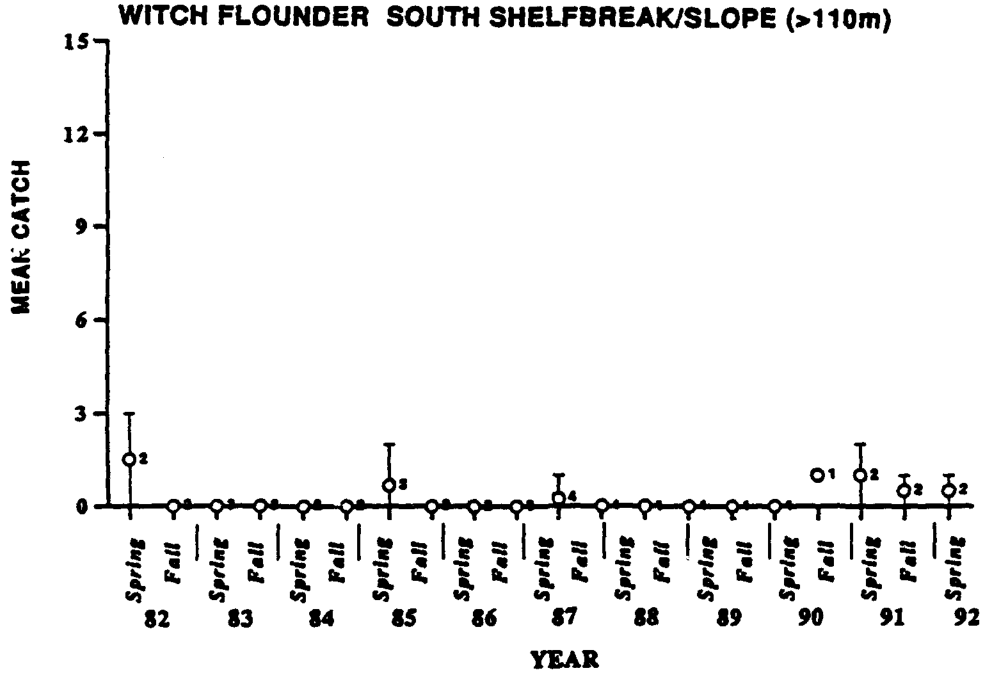


Figure 3-13. (Continued).

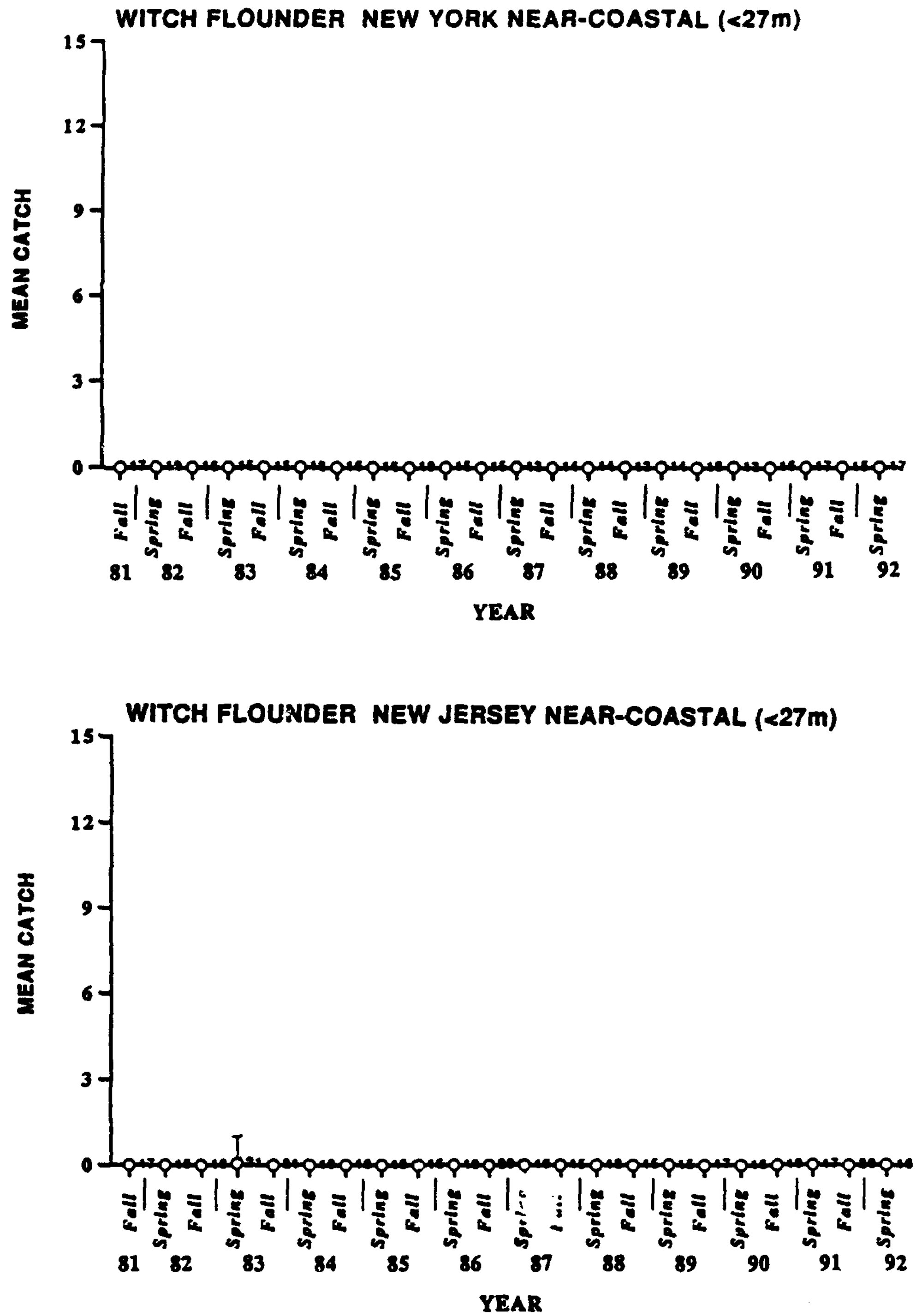
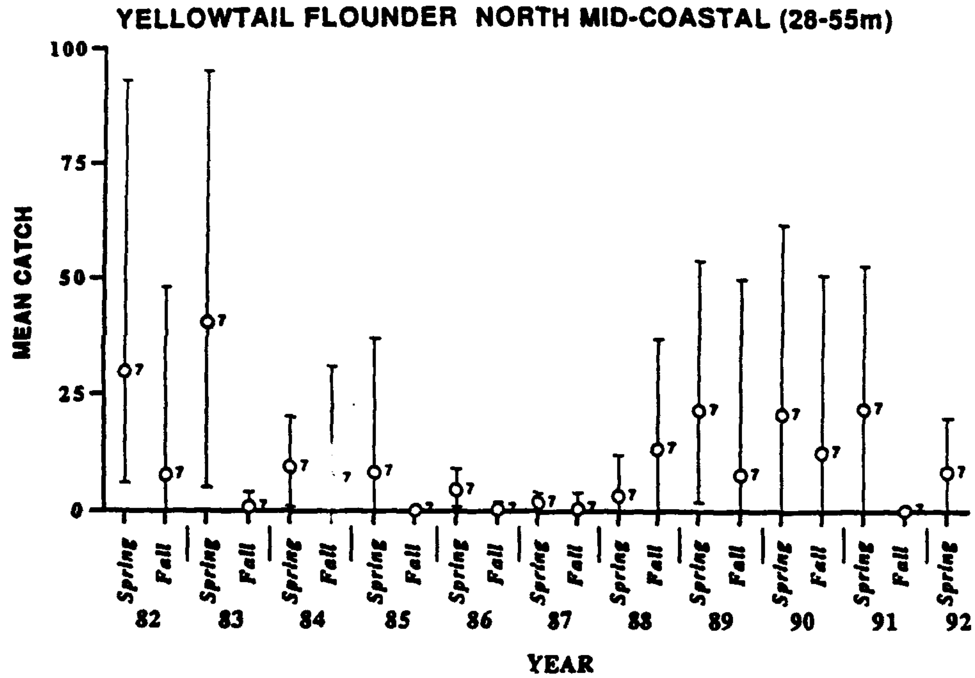


Figure 3-13. (Continued).



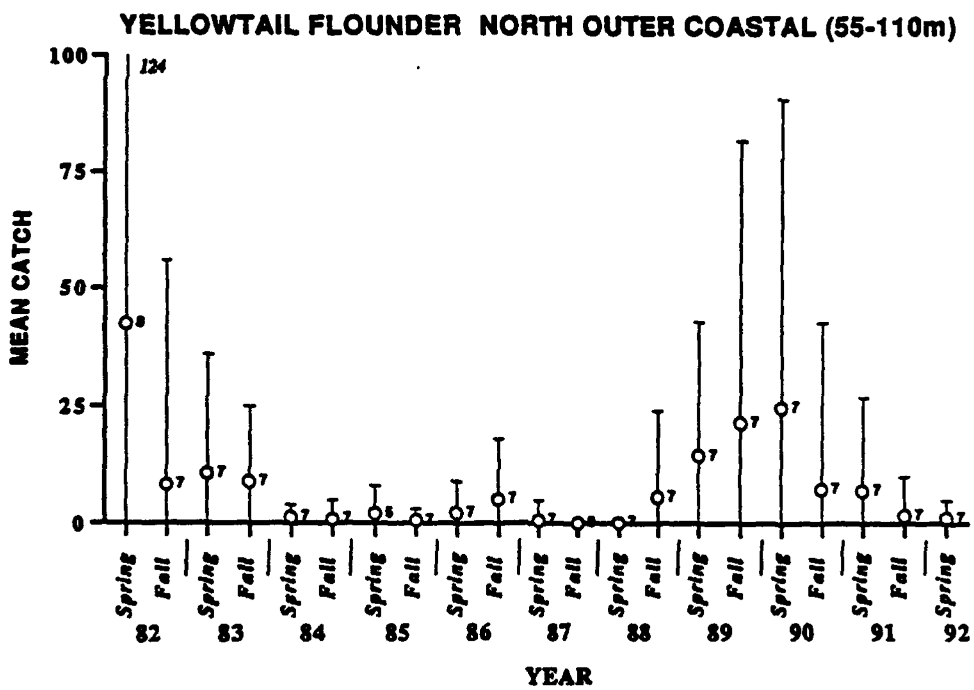
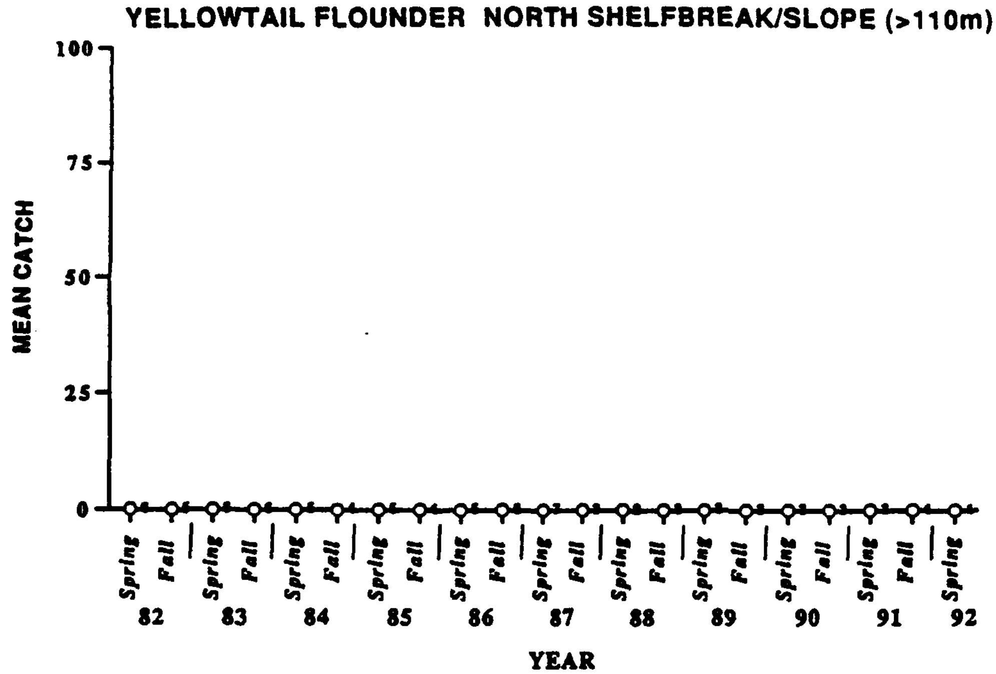


Figure 3-14. Mean catch, minimum catch and maximum catch, and number of samples (n) of yellowtail flounder by year and season in sampling strata of New York Bight.



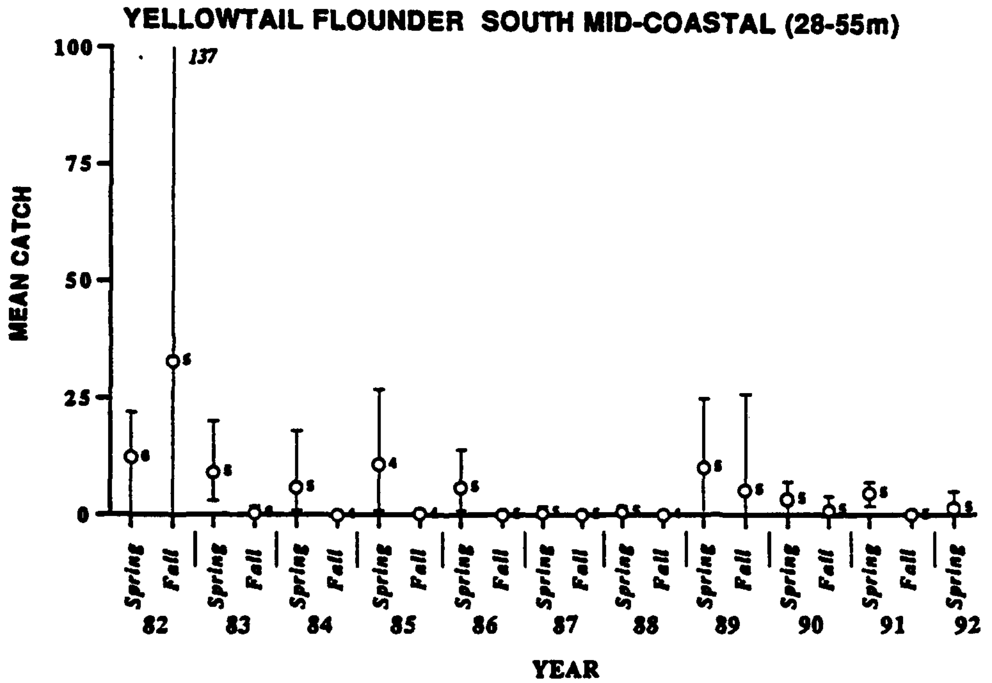
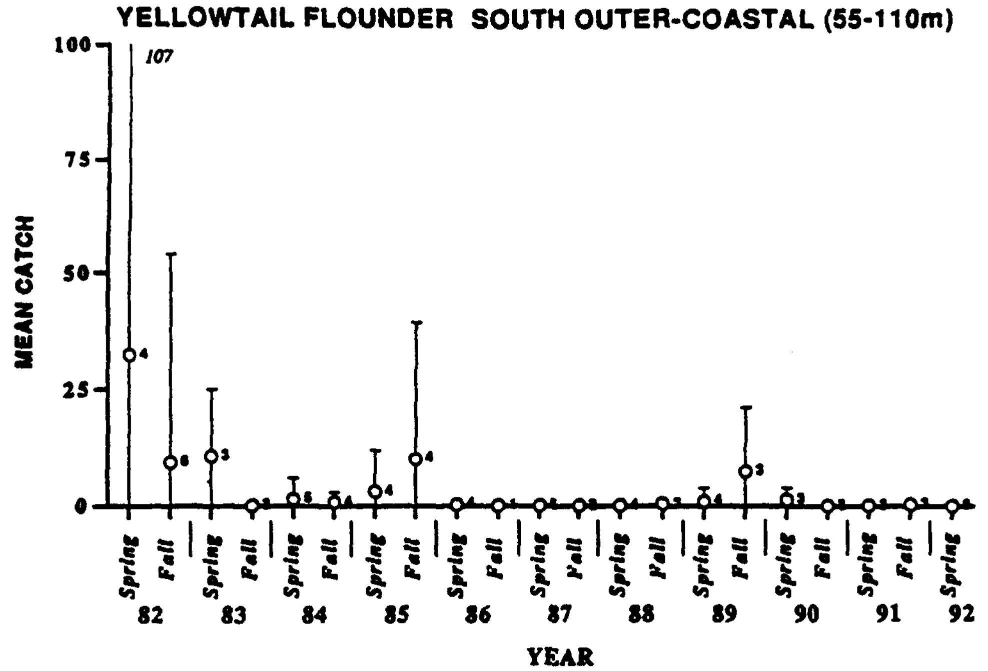


Figure 3-14. (Continued).



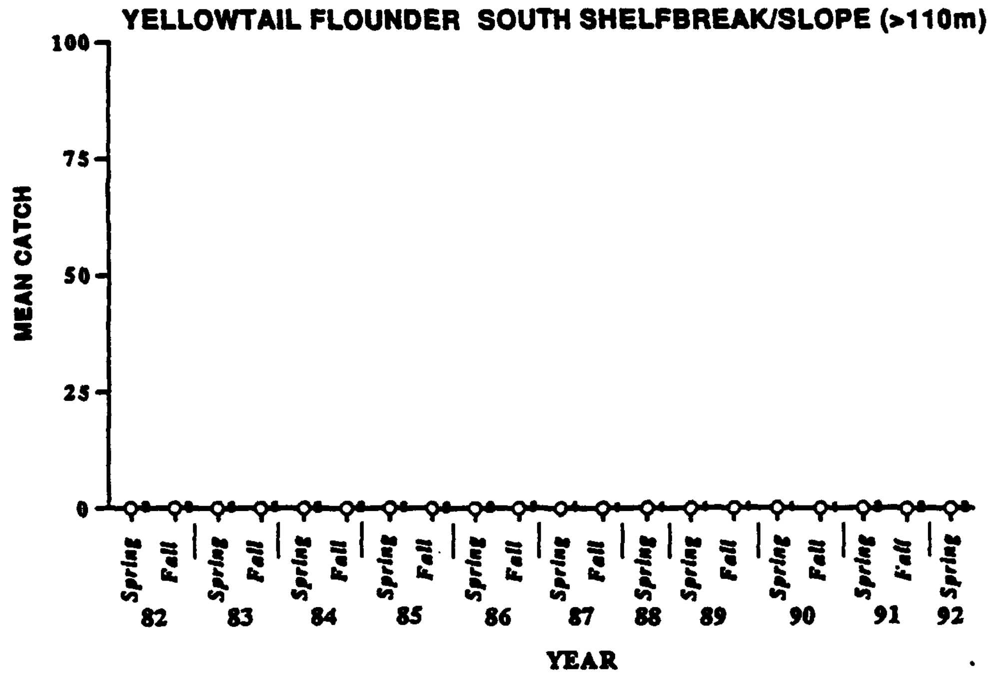
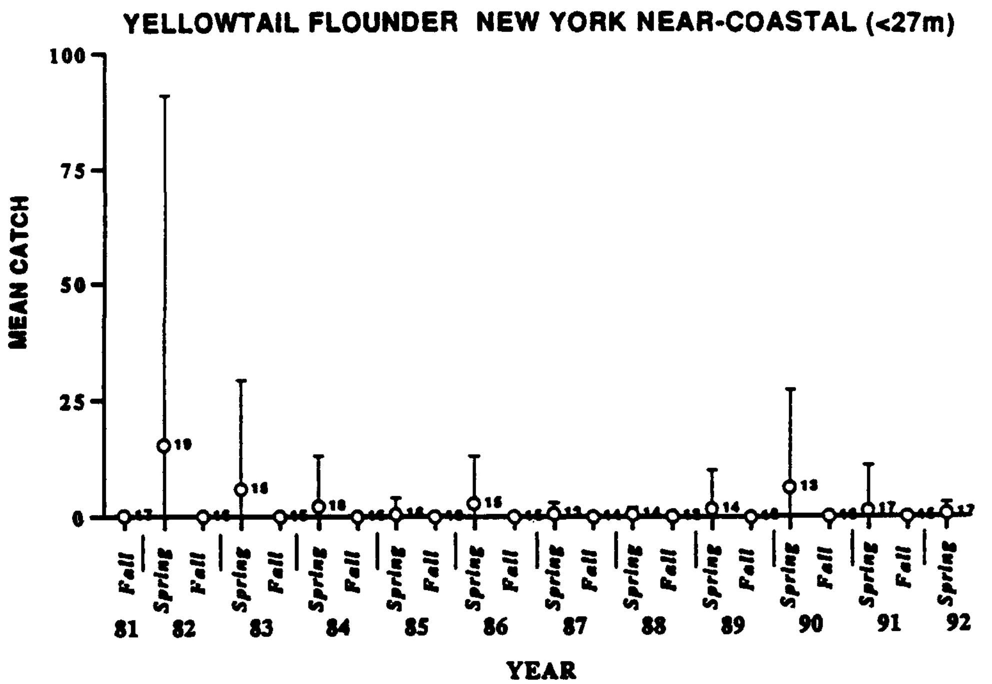


Figure 3-14. (Continued).



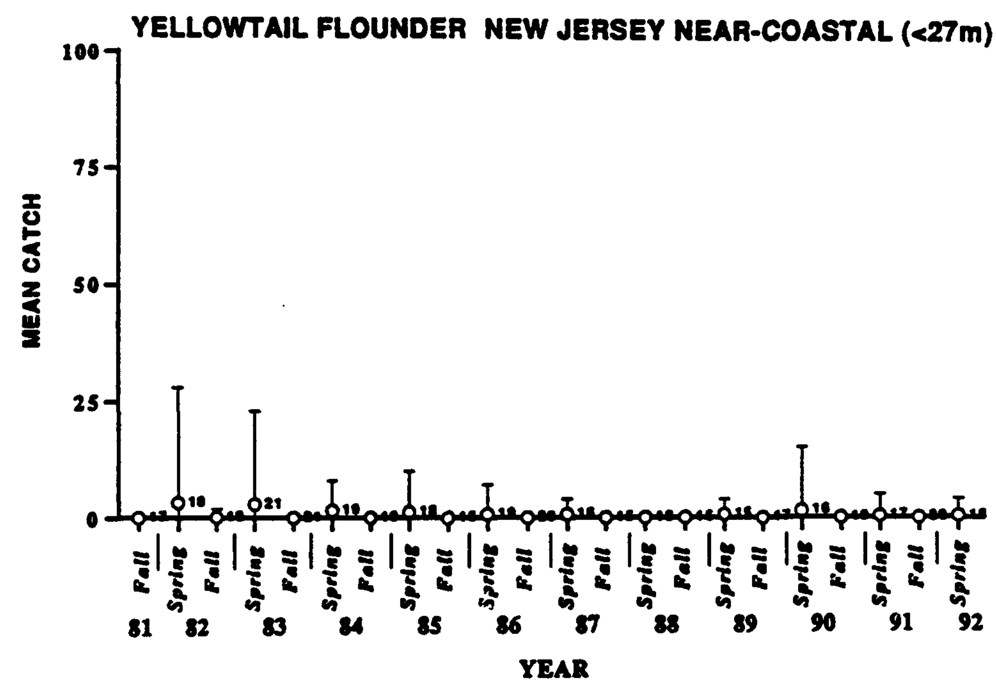


Figure 3-14. (Continued).

TABLE 2-1. AGENCY CONTACTS FOR ANNOTATED BIBLIOGRAPHY FOR FISHERIES STUDIES IN THE NEW YORK BIGHT

New York

Marine Sciences Research Center. State University of New York at Stony Brook, Stony Brook, NY.
Mr. Robert K. Cowen
Mr. William Wise

Hudson River Foundation. 40 West 20th Street, Ninth Floor, New York, NY.
Dr. John Waldman

U.S. Environmental Protection Agency - Region 2. Marine and Wetlands Protection Branch. 26 Federal Plaza, New York, NY.
Mr. Bob Dieterich

Department of Environmental Conservation - Region 1. Stony Brook, New York.
Mr. Victor Vecchio

Department of Environmental Conservation - Region 2. 21st Street, Long Island City, NY.
Mr. Bill Hewitt

New York State Department of Environmental Conservation, Bureau of Water Quality Management. 50 Wolf Rd., Room 201., Albany, NY.
Ms. Jo Ann Moisides

New Jersey

Northeast Fisheries Center, NMFS, Lionel A. Walford Library. Sandy Hook Laboratory, Highlands, NJ.
Ms. Claire Steimle

State of New Jersey Department of Environmental Protection and Energy: Division of Fish, Game and Wildlife, Marine Fisheries Administration, Bureau of Marine Fisheries. 401 E. State St., CN 409, Trenton, NJ.
Ms. Lori M. Giust

RHODE ISLAND

U.S. Environmental Protection Agency - Region 2, Office of Research and Development. Narragansett, RI.
Mr. Dick Latimer

Massachusetts

Northeast Fisheries Center, NMFS Documents Library. Water St., Woods Hole, Massachusetts.
Ms. Lynn Forbes

TABLE 3-1. FISHERIES STUDIES IN THE NEW YORK BIGHT INCLUDING LITERATURE REFERENCES, METHODOLOGY, YEARS, AVAILABLE DATA, ARCHIVAL STATUS AND ANCILLARY DATA.

REFERENCE[1]	STUDY YEARS	COLL. GEAR[2]	MESH SIZE (mm) BODY	MESH SIZE (mm) COD	TRAWL SPEED (m/s)	TRAWL TIME (min)	PRESERV.[3] METHOD	DATA TYPE VALUE[4] CLASS	DATA TYPE DATA[5] TYPE	DATA TYPE TAXON[6] CLASS	DATA TYPE SPATIAL[7]	DATA TYPE TEMPORAL[8]	DATA TYPE DEPTH[9]	ANCILLARY[10] DATA	ARCHIVAL[11] STATUS	LOCATION[12]
Azarovitz et al. 1979	71,73-76	BT 50/70T 3/40T(36) OT(36)	-	12.7	-	15,30				not cited[13]				-	-	M
Bieder 1976	72-75	Varies	-	-	-	-	F/A	$\bar{x}$	L[14]	Ss	AS	EA		-	-	-
Byrne, et al. 1990	90	3-1T	120/80	6.3	-	20	FI	D D	A[20] B[20]	Ss Ss	AS AS,Rg	E E	x	T,DO,SA	-	M
Byrne, 1990	88-89	3-1T	120/80	6.3	-	30,20	FI	$\bar{x}$	A[19,20]	Ss	Rg	ES	x	T,DO,SA	IP	M
Byrne, et al. 1991	90-91	3-1T	120/80	6.3	-	20	FI	D D	A[20] B[20]	Ss Ss	AS AS,Rg	E E	x	T,DO,SA	-	M
Danila 1975	74	GN(900)	25.4[14] 50.8 76.2 101.6 127.0			30		D,$\bar{x}$ D D	A A B	S,AT S,AT S,AT	Rg,AS St Rg,AS	EA,ES E EA,ES	x	T,DO,SA	-	Text
Danila 1974	73-74	GN(500)	82.5[15] 114.2 139.6			30		D D,$\bar{x}$	A A	S,AT S,AT	St Rg,AS	E EA,ES	x	T,DO,SA	-	M
Danila 1976	75	GN(900)	82.5[15] 114.2 139.6			30		D D,$\bar{x}$	A,B[17] A,B	S,AT S,AT	St AS	E EA,ES	x	T,DO,SA	-	M
Despres-Patanjo et al. 1988	18															
Greig et al. 1976		T SN					R	$\bar{x}$	T	Ss				SC	-	LL
Grosslein & Azarovitz 1982	73-74	OT(41) OT(36) 3/4 OT(36)		13	3.04	30		$\bar{x}$	B[19,20]	Ss	AS	ES		T	-	M
Margraf & Miller 1974	73	LP	6.3	-	-	Varies	-	D,$\bar{x}$ D	A,B A	S,P,AT S,AT	St,AS St	ES E	x x	T,DO,SA	-	Text

(continued)

TABLE 3-1. (Continued)

REFERENCE[1]	STUDY YEAR[2]	COLL. GEAR[3]	MESH SIZE (mm) BODY	COD	TRAWL SPEED (m/s)	TIME (min)	PRESERV. METHOD[3]	DATA TYPE VALUE[4] CLASS	DATA[5] TYPE	TAXON[6] CLASS	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]	ANCILLARY[10] DATA	ARCHIVAL[11] STATUS	LOCATION[12]
[illegible] & Musick 1975	67-7[illegible]	[illegible]36)		6.3	3.04	30					uncer-tain[21]				-	M
Miller 1975	74	LP				Varies		D,$\bar{x}$	A,B	S,P,AT	St,AS	EA,E	x	T,DO,SA	-	Text
Milstein 1974	73	SBIT(25)	38	13	1.74	15	FI	D D,$\bar{x}$ D,$\bar{x}$ $\bar{x}$	A A,B[22] A,B A[22]	S,AT S,AT S,AT S,AT	St AS Rg Rg	E ES EA EA	x x	T,DO,SA	-	M
Milstein 1975	74	SBIT(25)	38	13	1.74	15	FI	D D,$\bar{x}$ $\bar{x}$ $\bar{x}$	A A[23] A B	S,AT S,AT S,AT S,AT	St AS,Rg St AS	E EA,ES EA EA	x	T,DO,SA	-	M
Milstein 1977	72-75[24]															
Milstein et al. 1977	72-76	SBIT(25)	38	13	1.03	15		D D,$\bar{x}$	A,B[25] A,B[26]	AT AT	St AS	E EA		T,DO,SA WC	-	Loran A
Milstein & Hamer, 1976	75	SBIT(25)	38	13	3.38	15	FI	D,$\bar{x}$ D	A,B A	S,AT S,AT	St,AS St	EA,ES E	x	T,DO,SA	-	M
NMFS Groundfish Survey	81-92	OT(36)		12.5	1.8	30	FI	D	A,B,L,T	S	St	E	X	T	--	LL
Saila & Pratt 1973	60		not cited[27]					D	B[28]	Ss						M
Thomas 1974	73[30]															
Thomas & Milstein 1973	72	SBIT(16) SBIT(25) GN(640-750)	29 82.5-133.2	29	29	10 15		D D D	A A A	S,AT S,AT S,AT	St St St	E E E	x x x	T,DO,SA	-	29
Thomas & Milstein 1974	29-33	ST						D	A	S	Rg,AS	ES,EA			-	Not cited
U.S. Dept. of Commerce 1989	86-88	T	-	-	-	15		$\bar{x}$	A,B	S	St	EA				M

(continued)

TABLE 3-1. (Continued)

REFERENCE[1]	STUDY YEARS	COLL. GEAR[2]	MESH SIZE (mm) BODY	MESH SIZE (mm) COD	TRAWL SPEED (m/s)	TRAWL TIME (min)	PRESERV.[3] METHOD	DATA TYPE VALUE[4] CLASS	DATA[5] TYPE	TAXON[6] CLASS	SPATIAL[7]	TEMPORAL[8]	DEPTH[9]	ANCILLARY[10] DATA	ARCHIVAL[11] STATUS	LOCATION[12]
Vecchio 1991	87-90	OS(1800)	76.1 101.5 152.3				FI	D D D	A L Ag	Ss	St,AS St,AS St,AS	E,EA,ES ES ES		T,SA	-	M
Wilk et al. 1977	74-75	OT(36) OT(41) 3/4 YT		12.7	1.81	30	FI,R	D	A,B	AT,S	St	E	x	SA,T	-	LL
Wilk & Silverman 1976	68-72[30]	3/4OT(36)	127	51	1.56	Varies	FI,R	D D	A,B A,B,L	AT S	St St	E E	x	SA,T	-	LL

Abbreviations

[1]Reference: full citation in references cited.

[2]Collection gear
- 3/4OT(36) - Three Quarter Yankee No. 36 otter trawl
- OT(36) - No. 36 Yankee trawl
- OT(41) - No. 41 Yankee trawl
- 3/4 YT - Three Quarter Yankee trawl
- SBIT(25) - 16 ft Semi-balloon trawl
- SBIT(16) - 25 ft Semi-balloon trawl
- ST - Shrimp Trawl
- BT - Bay Trawl
- 50/70 T - 50/70 Trawl
- T - Trawl (unspecified)
- 3-1T - 3 in 1 Trawl
- GN( ) - Gill Net (parenthesis indicates length in feet)
- SN - Surface Nets (unspecified)
- OS(1800) - 1800 ft Ocean Seine
- LP - Lobster Pot

[3]Preservation Method
- FI - Field Identification
- R - Refrigeration/freezing
- F/A - Formalin/Alcohol

[4]Value Class
- D - Discrete (values not averaged)
- $\bar{x}$ - Mean

[5]Data Type
- A - abundance
- B - Biomass, weight
- L - Length
- T - Tissue
- Ag - Age

[6]Taxon Class
- P - Phyla/Class/Order
- F - Family
- S - Species or Genus
- Ss - Selected species
- AT - All species combined

[7]Spatial Class
- St - Station
- Rg - Region
- AS - All stations combined

[8]Temporal Class
- E - Event
- EA - Events averaged (season or year)
- ES - All events averaged

[9]Depth
- X - indicates that depth data are available

[10]Ancillary Data
- T - Temperature
- DO - Dissolved Oxygen
- SA - Salinity
- SC - Sediment Chemistry
- WC - Water Chemistry

[11]Archival Status
- IP - Some samples in progress

(continued)

TABLE 3-1. (Continued)

[12]Location
M - Map
LL - Latitude & Longitude
Text - General site description in text

[13]Fish mortality discussed in general terms, data is presented in a separate paper cited in text.

[14]100 ft x 12 ft for each mesh size.

[15]300 ft x 12 ft for each mesh size. Catch by mesh size data also presented.

[16]Sex and stomach content data also available.

[17]1974 data also included.

[18]A brief description of NMFS Northeast Fisheries Center's 1988. No data included.

[19]Figures only = no attempt made to further analyze.

[20]Data includes area outside of New York Bight.

[21]Current lab copy incomplete: no data present. Article presents data on distribution and bottom trawl survey program. 1963-abundance of skates.

[22]1972 data included.

[23]ANOVA on replicate samples presented. Night-Day collection data available.

[24]Summary report of Little Egg Inlet Studies 1972-1975 which are included elsewhere in this table.

[25]1976 data only.

[26]1972-1976 data.

[27]Report of commercial landings.

[28]Summary of other sections presented in this volume. General information on selected species presented. Beach Seine and shark line data included.

[29]Location and Methods included in part 1 of this report - currently unavailable.

[30]Study years for New York Bight stations is 1968-1971.

TABLE 3-2. NUMBER OF INDEPENDENT SAMPLING EVENTS IN THE NMFS DATABASE BY YEAR, SEASON AND SAMPLING STRATUM.

YEAR	SEASON	SAMPLING STRATUM									
		NORTH MID-COASTAL	NORTH OUTER COASTAL	NORTH SHELF-BREAK/ SLOPE	SOUTH MID-COASTAL	SOUTH OUTER COASTAL	SOUTH SHELF-BREAK/ SLOPE	LONG ISLAND NEAR COASTAL	NEW JERSEY NEAR COASTAL	DREDGED MATERIAL SITE	SEWAGE SLUDGE SITE
1981	Fall	0	0	0	0	0	0	17	17	0	0
1982	Spring	7	8	6	6	4	2	19	18	0	0
	Fall	7	7	5	5	6	2	16	18	0	0
1983	Spring	7	7	6	5	3	3	15	21	0	0
	Fall	7	7	6	6	3	3	15	21	0	0
1984	Spring	7	7	5	5	5	2	18	19	0	0
	Fall	7	7	4	4	4	2	16	19	0	0
1985	Spring	7	5	5	4	4	3	16	18	0	0
	Fall	7	7	4	4	4	2	19	16	0	0
1986	Spring	7	7	5	5	4	2	15	19	0	0
	Fall	7	7	6	5	1	3	15	20	0	0
1987	Spring	7	7	7	5	5	4	13	16	0	0
	Fall	7	8	3	5	2	1	14	15	0	0
1988	Spring	7	7	0	5	4	0	14	13	0	0
	Fall	7	7	3	4	3	1	13	15	0	1
1989	Spring	7	7	3	5	4	1	14	15	0	0
	Fall	7	7	3	5	3	1	18	17	0	0
1990	Spring	7	7	3	5	3	1	13	16	0	0
	Fall	7	7	3	5	3	1	16	19	0	0
1991	Spring	7	7	3	5	3	2	17	17	0	0
	Fall	7	7	3	5	3	2	15	20	0	0
1992	Spring	7	7	0	5	3	2	17	16	0	0
	Fall	7	7	0	0	0	0	0	0	0	0

TABLE 3-3. NUMBER OF INDEPENDENT SAMPLING EVENTS BY YEAR AND STRATUM.

		# OF EVENTS PER STRATUM[1]										
YEAR	REFERENCE	BA	CB	SD	DM	NCS	MCS	NCN	MCN	OS	SB	SR
29	Thomas & Milstein 1974					x[2]						
30						x						
31						x						
32						x						
33						x						
68	Wilk & Silverman 1976	1	1					1	1			
69		1				3	2	1	1			
70		2	1			3						
71		1				4	2	1	1			
72	Milstein et al. 1977					x						
	Thomas & Milstein 1973					1[3] 12[4] 6[5]						
73	Danila 1974					14						
	Gosslein & Azarovitz 1982	2				2	2	2	2	2	2	2
	Margraf & Miller 1974					12						
	Milstein 1974					28						
	Milstein et al. 1977					x						
74	Danila 1974					1						
	Danila 1975					10						
	Grosslein & Azarovitz 1982	2				2	2	2	2	2	2	2
	Miller 1975					13						

(continued)

TABLE 3-3. (Continued)

		# OF EVENTS PER STRATUM[1]										
YEAR	REFERENCE	BA	CB	SD	DM	NCS	MCS	NCN	MCN	OS	SB	SR
74	Milstein 1975					26						
	Milstein et al. 1977					x						
	Wilk et al. 1977	6	1	1	1	6	5	6	6	6	6	6
75	Danila 1976					13						
	Milstein et al. 1977					x						
	Milstein & Hamer 1976					27						
	Wilk et al. 1977	5	2			5	5	5	5	5	5	5
76	Milstein et al. 1977					15						
86	U.S. Dept. of Commerce 1989	4	4									
87	U.S. Dept. of Commerce 1989	7	7									
	Vecchio 1991							x				
88	Byrne 1990	2				2						
	U.S. Dept. of Commerce 1989	6	6									
	Vecchio 1991							x				
89	Byrne 1990	3				3						
	Vecchio 1991							x				

(continued)

TABLE 3-3. (Continued)

		# OF EVENTS PER STRATUM[1]										
YEAR	REFERENCE	BA	CB	SD	DM	NCS	MCS	NCN	MCN	OS	SB	SR
90	Byrne et al. 1990	3				3						
	Byrne et al. 1991	2				2						
	Vecchio 1991							32				
91	Byrne et al. 1991	3				3						

[1] BA = Bight Apex
CB = Christiaensen Basin
SD = Sludge Dump
DM = Dredged Material
NCS = Near Coastal South
MCS = Mid-Coastal South
NCN = Near Coastal North
MCN = Mid-Coastal North
OS = Offshore
SB = Shelfbreak
SR = Shelf rise

[2] X indicates that the number of events is not known.
[3] 16 ft semi-balloon trawl.
[4] 25 ft semi-ballon trawl.
[5] Gill net.

TABLE 3-4. YEAR AND MONTH OF SAMPLING, GEAR TYPE AND METHOD BY STRATUM FOR FISHERIES STUDIES IN THE NEW YORK BIGHT.

STRATUM: BIGHT APEX		MESH (mm)		TRAWL		YEAR							
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	68	69	70	71	72	73	74	75
Wilk & Silverman 1976	3/4 OT(36)	12.7	51	1.56	Varies[1]	7,8	10	7,8	8[15]				
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30							6,7,8, 9,10, 11	1-6
Grosslein & Azarovitz 1982	OT(41) OT(36) 3/4 OT(36)		13	3.04	30						3,9, 10	3,4,9, 10	

						YEAR							
·						86	87	88					
U.S. Dept. of Commerce, 1989	T	-	-	-	15	7,8, 9,11	1,3, 5,7, 8,9, 11	1,3, 5,7, 8,9					

(continued)

TABLE 3-4. (Continued)

STRATUM: CHRISTIANSEN BASIN		MESH (mm)		TRAWL		YEAR							
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	68	69	70	71	72	73	74	75
Wilk & Silverman 1976	3/4 OT(36)	127	51	1.56	Varies[1]	7[18]		8[10]					
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30							6	2,4

						YEAR							
						86	87	88					
U.S. Dept. of Commerce, 1989	T	-	-	-	15	7,8, 9,11	1,3, 5,7, 8,9, 11	1,3, 5,7, 8,9					

STRATUM: SEWAGE SLUDGE DUMPSITE		MESH (mm)		TRAWL		YEAR
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	74
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30	6

(continued)

TABLE 3-4. (Continued)

STRATUM: DREDGE MATERIAL DUMPSITE		MESH (mm)		TRAWL		YEAR
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	74
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30	8

STRATUM: NEAR COASTAL SOUTH		MESH (mm)		TRAWL		YEAR				
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	29	30	31	32	33
Thomas & Milstein 1974	ST	-	-	-	-	F,W,S,Su	F,W,S,Su	F,W,S,Su	F,W,S,Su	F,W,S,Su

(continued)

TABLE 3-4. (Continued)

STRATUM: NEAR COASTAL SOUTH		MESH (mm)		TRAWL		YEAR							
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	69	70	71	72	73	74	75	76
Wilk & Silverman 1976	3/4 OT(36)	127	51	1.56	Varies[1]	6,9	5,7,8	3^{18},7^{15} 8^{15},11^{15}					
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30						6,7,8, 9,10, 11	2,3,4, 5,6	
Thomas & Milstein 1973	SBIT(16) SBIT(25) GN				10 15				8 2-12 4,5,6				
Milstein 1974	SBIT(25)	38	13	3.88	15					1-12			
Danila 1974	GN(500)	Varies								3-11	1		
Margraf & Miller 1974	LP	6.3			Varies					5-10			
Milstein 1975	SBIT(25)	38	13	3.38	15						1-12		
Danila 1975	GN(900)	Varies			30						2-10		
Miller 1975	LP				Varies						1-10		
Milstein & Hamer 1976	SBIT(25)	38	13	3.38	15							1-12	
Danila 1976	GN(900)	Varies			30							1-12	
Grosslein & Azarovitz 1982	OT(36)(41) 3/4 OT(36)		13	5.91	30						4,9,10		
Milstein et al. 1977	SBIT(25)	38	13	1.03	15				6-10	6-10	6-10	6-10	6-10

(continued)

TABLE 3-4. (Continued)

STRATUM: MID-COASTAL SOUTH		MESH (mm)		TRAWL		YEAR						
REFERENCE	**GEAR**	**BODY**	**COD**	**SPEED (m/s)**	**TIME (min)**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Wilk & Silverman 1976	3/4 OT(36)	127	51	1.56	Varies[1]	6,9[15]		8[15] 11[15]				
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30						6,7,8, 9,11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30					3,9, 10	3,4,9, 10	

STRATUM: NEAR COASTAL NORTH		MESH (mm)		TRAWL		YEAR							
REFERENCE	**GEAR**	**BODY**	**COD**	**SPEED (m/s)**	**TIME (min)**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
Wilk & Silverman 1976	3/4 OT(36)	127	51	1.56	Varies[1]	7	10		8[15]				
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30							6-11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30							4,9,10	

						YEAR							
						87	88	89	90				
Vecchio 1991	OS(1800)	Varies				?	?	?	32				

(continued)

TABLE 3-4. (Continued)

STRATUM: MID-COASTAL NORTH		MESH (mm)		TRAWL		YEAR							
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	68	69	70	71	72	73	74	75
Wilk & Silverman 1976	3/4 OT(36)	127	51	1.56		8[19]	10		8[15]				
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30							6-11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30						3,9, 10	3,4,9, 10	

STRATUM: OUTER SHELF		MESH (mm)		TRAWL		YEAR		
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	73	74	75
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30		6-11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30	3,9, 10	3,4,9, 10	

(continued)

TABLE 3-4. (Continued)

STRATUM: SHELF BREAK		MESH (mm)		TRAWL		YEAR		
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	73	74	75
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30		6-11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30	3,9, 10	3,4,9, 10	

STRATUM: SLOPE/RISE		MESH (mm)		TRAWL		YEAR		
REFERENCE	GEAR	BODY	COD	SPEED (m/s)	TIME (min)	73	74	75
Wilk et al. 1977	OT(36) OT(41) 3/4 YT		12.7	1.81	30		6-11	2-6
Grosslein & Azarovitz 1982	OT(36) OT(41) 3/4 OT(36)		13	5.91	30	3,9, 10	3,4,9, 10	

[1]Superscript indicates tow time if constant for year.

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13. ABSTRACT *(Maximum 200 words)*

The New York Bight Biological Review Program (BBRP) was developed under the authorization of Section 728 of the Water Resources and Development Act of 1986 (PL99-662). Its objective was to identify the types of databases and models that are needed, but currently unavailable, for examining impacts to marine biological resources from large-scale projects within the NY Bight. The BBRP used five hypothetical projects to accomplish this objective. In doing so, it was expected that impacts examined via these hypothetical projects would be representative of impacts that would result from whatever future projects actually are pursued in the NY Bight. In this manner, the adequacy of existing information for examining the more important biological impacts from future projects will have already been reviewed and plans outlined for obtaining critical missing information with sufficient lead time to allow the gaps to be filled in a scientifically reliable manner. The BBRP's work was periodically reviewed by an independent group of scientists from academia, the Biological Review and Assessment Group (BRAG), to ensure assessments were scientifically reasonable.

The hypothetical projects chosen to guide the BBRP were: (1) use of offshore containment islands for disposal of dredged material, (2) expansion of the Mud Dump Site to accommodate more dredged material, (3) use

(Continued)

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of a new offshore dredged material disposal site, (4) use of offshore borrow pits as disposal sites for dredged material, and (5) lengthening and deepening Ambrose Channel (the main entrance to NY/NJ Harbor). For simplicity, the types of organisms considered were limited to macroinfauna, epifauna, fish, and macrocrustaceans.

Information gaps identified by examining these hypothetical projects were synthesized into a set of recommendations that are not likely to be addressed by the site-specific surveys that would accompany planning of a particular project. Instead, these recommendations focus upon system-wide studies that are crucial to correctly interpreting the more limited, site-specific studies. These information gaps include:

1. Synthesizing past studies into a process-oriented view of the NY Bight ecosystem and quantitatively testing conceptual models of how that ecosystem functions.
2. Determining the importance of the Hudson River plume in plankton dynamics, fishery recruitment, and material exchanges between Hudson/Raritan estuary and the Atlantic Ocean.
3. Examination of bioaccumulation of contaminants by fish from an east coast perspective.

Three additional recommendations were made for information that would facilitate the planning of particular projects. These recommendations could be addressed inexpensively with existing data and include:

1. Generic modeling of the general flow patterns of density stratified waters around and above subaqueous pits.
2. Mapping infaunal and epifaunal abundances and value as food to bottom feeding fishes.
3. Quantifying the distributions and abundances of hard-bottom benthos and fish and the food habits of hard-bottom fishes.