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Northeast Monitoring Program

106-Mile Site Characterization Update

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts

August 1983

NOAA TECHNICAL MEMORANDUM NMFS-F/NEC

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14. ***Ecosystem Definition and Community Structure of the Macrobenthos of the NEMP Monitoring Station at Pigeon Hill in the Gulf of Maine.*** By Alan W. Hulbert, Kenneth J. Pecci, Jonathan D. Witman, Larry G. Harris, James R. Sears, and Richard A. Cooper. May 1982. xii + 143 p., 16 figs., 10 tables, 9 app. NTIS Access. No. PB83-112474.

15. ***Seasonal Phytoplankton Assemblages in Northeastern Coastal Waters of the United States.*** By Harold G. Marshall and Myra S. Cohn. July 1982. vi + 31 p., 8 figs., 2 tables. NTIS Access. No. PB83-116715.

(continued on inside back cover)

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106-Mile Site Characterization Update

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TABLE OF CONTENTS

Ecological Overview v

Summaries xi

1. Introduction 1-1

2. Physical Oceanography 2-1

3. 106-Mile Site Sediment Characteristics 3-1

4. Nutrient Variability 4-1

5. Phytoplankton Biomass and Community Size Composition 5-1

6. Seasonal Zooplankton Standing Stock and Dominant Species 6-1

7. Fish Eggs and Larvae 7-1

8. Benthic Fauna 8-1

9. Fish and Fisheries 9-1

10. Demersal Fish Species Groups 10-1

11. Mammals, Birds, and Turtles 11-1

12. Contaminant Inputs, Fate and Effects 12-1

Appendix "A" A-1

ECOLOGICAL OVERVIEW

Kenneth Sherman[1]

The 106-mile ocean waste disposal site (106-mile site) is located in a physically dynamic zone characterized by periodic shifts in water masses. The major shifts consist of the extension of shelf water onto the site area or conversely the movement of more saline slope water from the site onto the shelf. In addition, the site is periodically overrun by warm Gulf Stream rings. Because of the great water depth, slowly sinking waste would reach the bottom only after a lengthy period, ranging from days to weeks depending on the nature of the waste; water soluble wastes would not reach the bottom unless they were absorbed by particles, ingested by organisms, or precipitated with other constituents in the water column. The oceanographically dynamic location of the 106-mile site extends the potential area of influence (PAI) of dumped wastes over a wide area off the northeast coast encompassing approximately 116,000 km^2.

The western one-third of the PAI extends over the outer portion of the continental shelf off the coast of New York, New Jersey, Delaware, Maryland, Virginia and North Carolina. This is a shelf region off the northeast and mid-Atlantic megalopolis that supports important fisheries, including cod, haddock, menhaden, bluefish, mackerels, silver and other hakes, anchovy, and sand lance. The fish and shellfish that inhabit the PAI sector of the shelf either as eggs, larvae, juveniles or adults constitute a significant segment of the commercial and recreational fisheries that contribute one billion dollars annually to the economics of the coastal states from Maine to North Carolina.

Nine of the chapters in the present 106-mile site characterization report deal with important components of the shelf ecosystem including nutrients (Matte et al.), phytoplankton (Evans-Zetlin and O'Reilly),

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ichthyoplankton (Smith et al.), zooplankton (Green), benthos (Steimle and McNulty), fish and fisheries (Wilk et al.), and marine mammals, turtles, and birds (Powers and Payne). Collectively these chapters focus on the populations at risk from any excessive exposure to toxic substances that may be transported onto the shelf during incursions of shelf-slope front water. These ecosystem components are linked as food webs within the ecosystem and therefore any adverse impact on any one of these components may result in a perturbation to the ecosystem.

The nature of the coupling includes linkages between the nutrient flux and the relatively high primary production on the shelf (annual mean 300 g cm^2/yr) and the zooplankton, benthos, ichthyoplankton, and fish populations within the PAI. The phytoplankton, in part, supports a relatively high standing stock of zooplankton which peaks at about 50 cc/100 m^3 off Southern New England (SNE) in spring and summer and between 50 cc/100 m^3 and 70 cc/100 m^3 off the Mid-Atlantic Bight (MAB) from summer through autumn. The bimodal pulse in the ammonium-nitrogen fraction of the nutrient pool results in large part from ammonia produced coincident to the two pulses in zooplankton standing stocks off SNE in spring and summer, and the late-summer early-autumn maximum of the ammonium-nitrogen fraction and zooplankton in the MAB.

Spawning strategies of the major fish species are characterized as having developed a larval production cycle in synchrony with the production of their zooplankton prey. The principal prey of fish larvae are the naupliar, copepodite and adult stages of three dominant copepod species, *Calanus finmarchicus*, *Pseudocalanus minutus*, and *Centropages typicus*. For example, in SNE Atlantic mackerel larvae are in synchrony with the ascending limb of the spring zooplankton curve. In the Mid-Atlantic Bight the larvae of anchovies, bluefish, hake, searobins, croakers, and silver and other hake species peak in abundance from June through October in synchrony with the increase in zooplankton abundance. Based on information given in this report, it is clear the PAI as it extends

onto the continental shelf is an important fish production area contributing significantly to the stocks supporting the commercial and recreational fisheries of the adjacent coastal states.

The fish stocks representing the mid-size predator component of the ecosystem of the northeast continental shelf have recently undergone significant perturbation. During the period 1968 through 1975, the biomass of principal fish species declined approximately 50%. The decline has been correlated with heavy fishing mortality. Recent observations indicate that zooplankton has not undergone any large-scale change in abundance or species composition since early measurements made 70 years ago. The declines in fish abundance during the late 1960s and early 1970s are, therefore, not attributable to a lack of food at the lower end of the food chain. This is in contrast to those fish species in the same ecosystem which undergo wide annual fluctuations in abundance. It appears from a synthesis of available ecological information that fishing mortality has imposed greater perturbations on fish populations of the PAI on the northeast shelf than any observed change in the levels of abundance of zooplankton.

The pelagic ecosystem of the PAI within and adjacent to the immediate vicinity of the disposal site location has not been, as yet, subjected to intensive study. Plankton and fish populations of the region are, however, significantly lower than on the shelf. Species of commercial, recreational, and aesthetic interest near the disposal site are large pelagics including sharks, tunas, billfish and the toothed and baleen whales. Although estimates for the total outer shelf and offshelf fishery are not readily available, an analysis is given in the characterization of the New Jersey offshore recreational fishery. It is estimated to operate at a level of 800 vessels with a combined value of $73 million. Ancillary costs for equipment, maintenance, mooring, insurance, fuel, bait and other costs are estimated at $11 million annually, bringing the total estimated value of the offshore fishery to the economy of New Jersey to $84 million. Additionally, the recreational fishery of other states with large

offshore sport fishing fleets, including New York, Connecticut, Delaware and Maryland, are dependent on large pelagic fishes inhabiting the offshore grounds adjacent to the 106-mile site.

Current and Future Assessments.

A major program to measure the actual or potential impacts of waste disposal at 106-mile site is now in operation. A study of the northeast continental shelf was initiated by the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, to provide information on ecosystem perturbations affecting the natural production of the fishery resources of the area. The investigation is comprised by the Marine Resources Monitoring, Assessment and Prediction (MARMAP) and the Ocean Pulse Programs of the National Marine Fisheries Service. These programs measure temporal and spatial change in critical components of the shelf ecosystem. Since 1977 the shelf has been surveyed systematically to measure changes in primary production (^{14}C), chlorophyll a, phaeophtyin, nutrients (NO_2, NO_3, SiO_3, NH_4, and PO_4), zooplankton, ichthyoplankton, fish, benthos, seabirds, water-column temperature, salinity, and circulation. Between 6 and 8 surveys are done each year. The sampling area extends over 260,000 km^2 of the shelf on each survey, including the PAI. Sampling stations are located approximately 25-35 km apart from the Gulf of Maine to Cape Hatteras. Thirty-two surveys were conducted between 1977 and 1981. This recurrent sampling has covered 7.2 million km^2 and is the basis for measuring changes in the abundance of key ecosystem populations. In addition the Ocean Pulse Program of the Northeast Fisheries Center and the Northeast Monitoring Program of NOAA are measuring the incidence of contaminant loadings in selected populations and habitats in relation to physical and chemical change on the northeast shelf, including the PAI. These combined monitoring and asessment efforts provide a mesoscale characterization of the shelf ecosystem. Within this matrix, additional special studies aimed at measuring low-level changes in the contaminant loadings of key populations and their environments, and resulting effects, must be considered an essential component of site-specific studies designed to measure potential impacts of any future ocean

disposal of wastes at the 106-mile site. The early initiation of the MARMAP and Ocean Pulse and Northeast Monitoring programs have provided an important benchmark for the resources at risk and allow for periodic assessments of changes in living marine resources, as these might be related to natural variation or to anthropogenic inputs.

SUMMARIES

Physical Oceanography.....xii

106-Mile Site Sediment Characteristics.....xiii

Nutrient Variability.....xiv

Phytoplankton Biomass and Community Size Composition.....xvi

Seasonal Zooplankton Standing Stock and Dominant Species.....xviii

Fish Eggs and Larvae.....xix

Benthic Fauna.....xx

Fish and Fisheries.....xxii

Mammals, Birds, and Turtles.....xxvii

Contaminant Inputs, Fates, and Effects.....xxix

PHYSICAL OCEANOGRAPHY

Investigations of ocean dumping in the Middle Atlantic Bight have shown that waste inputs caused environmental degradation at the coastal and shelf sites. Other investigations, further offshore in slope waters, have not demonstrated extensive degradation despite several years of research activities in the vicinity of the 106-mile dumpsite. Physical oceanographic characteristics of the 106-mile disposal site were used to develop a Potential Area of Influence (PAI).

The entire region falling within the PAI is characterized by a range of hydrographic similarities; it is a high-energy area with significant near-surface and bottom currents, the latter principally flowing parallel to the bathymetry. The area is affected by major storm systems, weather fronts and seasonal differences in insolation and winds. Warm core rings traverse the entire region irregularly.

The PAI must be characterized as a highly dispersive environment where waste contaminants will be mixed effectively and transported in unpredictable ways from points of input.

106-MILE SITE SEDIMENT CHARACTERISTICS

The sedimentary regimes into which settlable waste particles may fall are the continental slope and rise and outer continental shelf. Particles in these areas are predominantly silt and clay on the slope/rise and sand on the shelf. Outer shelf sediments contain a higher proportion of fine grained sediments than inner shelf or near shore sediments. Chemically, sedimentary concentrations of elements and organic compounds increase with decreasing particle size and are generally higher in slope/rise sediments than outer shelf sediments which, in turn, contain higher concentrations than shallower sediments. If settlable solids are routinely dumped at the 106-mile site it is recommended that attention be given to possible consequences of increasing the mass flux onto deep ocean organisms normally experiencing a very dilute rain of particles and to measuring the contaminant input with sediment traps rather than direct analysis of sediments.

NUTRIENT VARIABILITY

Nutrients are extremely important in the phytoplankton productivity scheme which, in turn, affects the fisheries production system. Moreover, levels of normal nutrients are affected by the introduction of organic wastes to aquatic ecosystems. To effectively manage ocean disposal of a range of wastes, especially those with high contents of organic matter, it is important to understand the normal levels of nutrients present, their relationship to plankton populations, and the effects of nutrient enrichments or deficiencies on fisheries production systems.

As part of an extensive monitoring and assessment program by the Northeast Fisheries Center, water samples for nutrient analyses (nitrite, nitrate, ammonium nitrogen, orthophosphate, and silicate) were collected on 11 cruises from Cape Hatteras to Nova Scotia between May 1979 and March 1980. Surveys were usually limited to the continental shelf, less than 200 m.

Generally, nutrient concentrations in samples increased with depth, the bottom layer always having higher concentrations than the surface layer. Nitrate increased in concentration to seaward. Other nutrients, however, showed no consistent increase to seaward. Excluding estuarine input and ammonium nitrogen, the highest concentrations of nutrients throughout the water column occurred during the fall, winter, and spring (generally unstratified conditions). The lowest concentrations of nutrients (except ammonium nitrogen) occurred during the summer throughout the euphotic layer. Below the euphotic layer concentrations increased in the summer. Ammonium nitrogen concentrations were highest in August, a time of maximal regeneration by zooplankton and other organisms, and lowest in April.

For water just west of the 106-mile site, nitrate concentrations in surface water ranged from 0.2 uM/l in the summer and fall to about 2 um/l in spring. Bottom water nitrate ranged from 15 uM/l in the fall to 25 uM/l in the spring. Nitrite concentrations in surface water

ranged from 0.05 to 0.1 uM/l with the maximum occurring in the spring. Bottom water nitrite ranged from 2.0 to 8.0 uM/l with the maximum occurring in June. Ammonium nitrogen concentrations in surface water ranged from 0.1 uM/l in April to 0.2 uM/l in August. Bottom water ammonium nitrogen ranged from 0.1 uM/l in April to 2.0 uM/l in August. Orthophosphate concentrations in surface water ranged from 0.1 uM/l in July to 0.4 uM/l in September and April. Ortho- phosphate in bottom water ranged from 0.6 uM/l in late June to 1.0 uM/l in September and April. Silicate concentrations in surface water ranged from 1.0 uM/l in July to 6 uM/l in May. Bottom water silicate ranged from 1.5 uM/l in March to 10 uM/l in June. Generally, nutrients in bottom water just west of the 106-mile site remained relatively high throughout the year, while nutrients in the surface layer tended to become depleted in summer except for ammonium nitrogen.

PHYTOPLANKTON BIOMASS AND COMMUNITY SIZE COMPOSITION

The phytoplankton are often noted as being the basis of aquatic food chains and are, therefore, regarded as an essential component of the fisheries production system. In recent years it has become apparent that contaminants associated with wastes being dumped or discharged into waterways via point and nonpoint sources may affect phytoplankton populations, their productivity, and their relative usefulness within the food webs. Marine scientists therefore believe that the phytoplankton, collectively, are an extremely important component of the ecosystem and must be understood prior to implementing new waste disposal activities in marine waters or continuing or increasing waste loading.

In this characterization, the 106-mile site and the slope and continental shelf water adjacent to it are characterized. Average water column chlorophyll a estimates spanning October 1977-March 1982 were pooled by area and month, irrespective of year, to form a synthetic year of averaged water column biomass estimates. To examine chlorophyll distribution, the area potentially affected by material dumped at the 106-mile site was divided into two subareas: 1) the slope (the area seaward of the shelf break), and 2) the outer shelf (approximately between 60 to 200 m). Data were not available for the area beyond the 2000 m isobath. Additionally, to put the slope-outer shelf in perspective, data collected over the shelf were examined. Areas on the shelf were defined by bathymetry (0-20, 20-40, 40-60, and 60-200 m).

The annual cycle of biomass was generally bimodal in all five regions examined. Highest biomass concentrations over the entire shelf were observed consistently during spring blooms in February (depths <40 m) and March (depths >40 m). The lowest concentrations were consistently observed during the stratified season. In water <60 m (Regions 1, 2, and 3), the lowest concentrations of biomass were observed in May. At depths >60 m (Regions 4 and 5), corresponding to outer shelf and slope, biomass concentrations were consistently low from May through October. A secondary peak in biomass was observed in the

November-December time period over the entire shelf. Additional peaks were also observed at depths <20 m during September and in August at depths between 20-40 m.

A recurrent gradient in biomass concentrations was observed in monthly and annual averages. Highest biomass concentrations were measured inshore (0-20 m); lowest were found at depths >200 m in Region 5.

Community size composition varied over the year. Netplankton (>20 m) strongly dominated the February-March spring bloom over the entire shelf generally accounting for 70% of the standing stocks. Generally nannoplankton (<20 m) dominated communities during mid-year stratified periods when biomass concentrations were at a low. During fall bloom, netplankton and nannoplankton contributed to community biomass in near equal amounts. In waters less than 200 m, netplankton dominated slightly in the fall bloom, while in water <200 m nannoplankton slightly dominated.

At depths <60 m, netplankton were slightly more abundant than nannoplankton throughout the annual cycle. Nannoplankton were slightly more abundant between 60-200 m and nannoplankton clearly dominated the annual biomass at depths >200 m.

Phytoplankton concentrations throughout an annual cycle at outer shelf areas distributed bimodally. Highest standing stocks 2.12 mg chl$\underline{a}$/m^3 (outer shelf area) and 1.43 mg chl$\underline{a}$/m^3 (deeper waters, >200 m) were observed during the March spring bloom. During this period netplankton strongly dominated the community. Secondary peaks were observed in November and December averaging 1.12 mg chl$\underline{a}$/m^3 in Region 4 (outer shelf), and 0.79 mg chl$\underline{a}$/m^3 in Region 5 (>200 m). During this time netplankton and nannoplankton were present in near equal quantities in both regions.

Lowest standing stocks were observed during the nannoplankton-dominated stratified season from May through October averaging 0.62 and 0.44 mg chl$\underline{a}$/m^3 in Regions 4 and 5, respectively.

SEASONAL ZOOPLANKTON STANDING STOCK AND DOMINANT SPECIES

Data from selected stations from five years of MARMAP surveys were analyzed for total zooplankton standing stock, patterns of species dominance and abundance cycles of the copepods, *Calanus finmarchicus*, *Centropages typicus*, and *Pseudocalanus minutus*, in the Potential Area of Impact (PAI) of the 106-mile site and adjacent waters off southern New England and the Mid-Atlantic Bight. The PAI on the continental shelf corresponds to waters between 50 and 200 m depth of which one-third is in southern New England and two-thirds is in the Mid-Atlantic Bight. Comparisons of the timing of seasonal maxima for zooplankton standing stock indicate that the occurrence of yearly maxima are not synchronous in the PAI and onshore areas in southern New England and the Mid-Atlantic Bight, but that both areas support similar levels of biomass during peak production.

C. typicus is abundant throughout the year in the Mid-Atlantic Bight in both the inshore waters and the PAI, but shows seasonal fluctuations in both areas in southern New England. *P. minutus* decreases in abundance in inshore waters with seasonal warming in both areas. In waters of the PAI, its abundance is sustained at comparatively higher levels. *C. finmarchicus* becomes entirely restricted to PAI in the warm months. In southern New England the distribution of *C. finmarchicus* extends inshore throughout the year with the greatest densities found in the waters of the PAI.

FISH EGGS AND LARVAE

The continental shelf from North Carolina to Nova Scotia provides spawning and nursery grounds for coastal fishes representing >200 taxa. No one area can be singled out as insignificant to the reproductive success of some representatives of the coastal fish community. Annual abundance curves for the 4-year period from 1977-80 are remarkably similar for both eggs and larvae in the Middle Atlantic Bight and in that part of the Bight potentially influenced by dumping at the 106-mile site. Spawning is most intense in spring and summer; least intense in late autumn and winter, but economically important species spawn in winter. Larvae are most abundant in winter and again during the late spring and summer time period. The high standing crop of larvae in winter is attributable to sand lance, a taxon that spawns demersal eggs, and one that increased dramatically in biomass during the late 1970's. Three of the top five numerically dominant larvae in the shelf portion of the area potentially influenced by dumping at the 106-mile site represent economically important species that contributed to the 1.1 billion dollar fishing industry off northeastern United States. In addition, the early life cycle of the bluefish, an important recreational species, is closely tied to both shelf and slope waters in the potentially influenced area.

BENTHIC FAUNA

This review of information available on benthic fauna at risk from waste dumping at the 106-mile site has led to several generalizations. First, within the Potential Area of Influence (PAI) there are several distinguishable benthic communities that are related primarily to sediment type on the outer continental shelf (OCS), to temperature at the shelf break, and to bathymetry and/or food supply at the continental slope and rise. The dominant infaunal groups within the PAI are amphipods and polychaetes on the OCS and at the shelf break; polychaetes, bivalve molluscs and minor taxa (e.g. Pogonophora) on the continental slope and rise. The dominant megafauna of the OCS, shelf break, and upper slope are echinoderms (especially brittlestars) and decapod crustacea; in deeper areas, echinoderms, especially the brittlestar, *Ophiomusium lymani*, are the overwhelming dominants. Benthic fauna in major cayons transecting the slope differs in species composition somewhat from that on the adjacent slopes.

Second, the benthic fauna on the shelf show strong affinities to more northern fauna, while on the shelf break and upper slope, with consistently slightly warmer temperatures, there are species with more southern affinities.

Third, the density and biomass of the infauna decreases proportionally with increasing depth within the PAI, reflecting the average rate of organic production available to the bottom. The megafauna, however, has a peak in biomass at the continental slope/rise interface, which has not been adequately explained. Detritus is the primary source of food for the benthic fauna within the PAI and most dominant species are deposit feeders. Generally, a predominantly deposit feeding community is regarded as more stable than a filter feeding dominanted community since filter feeders depend on suspended material that can vary seasonally in abundance, while deposit feeders use both intermittent inputs of detritus as they reach the seabed and, later, the residual organic matter in the sediments when new supplies of detritus are reduced. Bacteria may play a crucial role in converting sediment organics and detritus into food that can be used by benthic organisms.

Fourth, drastic changes in the benthic habitat within the PAI are known but are probably rare. In the 1880's a shift of cold shelf water onto the shelf-break and upper slope off southern New England is thought to be responsible for mass mortalities of many fish species, including tilefish; possibly some of the benthic invertebrates inhabiting this habitat were affected as well. Periodic disruptions due to turbulent currents in deeper waters are also known, especially in major canyons.

Fifth, the benthic fauna of the OCS, shelf-break, and upper slope are used as food by several fish species and decapod crustacea that are commercially valuable. These resource species include permanent residents such as grey sole, tilefish, and red crabs, as well as seasonal residents such as black sea bass, scup, summer flounder, and lobster. These, and other species, depend primarily on the benthic invertebrate fauna for food and thus the benthic community within the PAI should be protected from degradation or contamination so as to maintain productive fisheries.

FISH AND FISHERIES

The following summarizes findings which are relative to defining the "resources at risk" associated with the 106-mile site. In general, the chapter summarizes several rather diverse data sources which either quantitatively or qualitatively desribe and/or define the fish and fisheries resources which could be potentially impacted by present levels of dumping as well as future disposal operations at the 106-mile site. More specifically, a rather terse, and somewhat distilled, interpretation of the most pertinent data is as follows:

1) Commercial Landings and Values - Provides the most quantitative information relative to catch and value for the 106-mile site's potential area of impact (PAI) on a year-by-year and species-by-year basis. This information source demonstrates the continuous increases in landings and values that have occurred, within the limitations of these data. It should be noted, that catches have almost doubled and values almost tripled since 1975 (i.e., 1975 = 9,208 mt = $9.2 million; 1980 = 16,496 mt = $27.6 million). Landings and values by year (1972-1980), on a selected species basis, provides information for the purpose of demonstrating which resources are the most sought after in terms of weight and/or value over time. From these data, American lobster and sea scallop historically represent the big "cash crops" in the invertebrate category, along with ocean quahog in more recent years. Under the finfish category, summer flounder, tilefish, scup, and swordfish dominate, both historically as well as at present, in catch and value.

2) Japanese Longline Fishery -- Observed Data - Provides observed Japanese longline catch-per-unit-of-effort (CPUE) from Fishery Reporting Zone No. 16 by species and species groups (i.e., tunas, billfishes, sharks, rays, and other finfish) for the years 1979-1981. The PAI ellipse is almost entirely within this particular fishing zone; therefore, the species composition and calculated catch rates can be termed representative of the area considered within the context of this chapter. Thus, it is interesting to note that the bigeye tuna,

yellowfin tuna, albacore, swordfish, blue shark, and lancetfish make up, on an average, greater than 86% of the CPUE from this reporting zone. At present, this fishery is dominated by the Japanese distant water longline fleet, with little, if any, U.S. participation, except in the area of swordfish fishing. However, if and when this situation begins to reverse, and there is every indication it will, these valuable oceanic fishery resources will obviously become more important to domestic fishermen at which time any adverse man-induced change in abundance and/or distribution could have economic ramifications throughout the U.S. fishery. The data presented, regarding the present fishery, indicate the potential for large scale U.S. participation, and therefore, the potential of any man-induced change must also be taken into account (i.e., 106-mile site's PAI).

3) National Marine Fisheries Service Research Survey Cruises - This seasonal research vessel bottom trawl survey data set was distilled to a series of spring and autumn computer-generated cumulative plots. Twenty-four species of finfish and six species of invertebrates were specifically selected to illustrate seasonal and geographic trends in distribution and abundance relative to the 106-mile site and its PAI. Any number of conclusions can be drawn from these data regarding the relationship between individual species and the PAI associated with the 106-mile site. Some of the most obvious include: 1) Species, such as offshore hake, white hake, Gulf Stream flounder, American lobster, and sea scallop, tend to remain in the PAI throughout the year based on their narrow range of ecological requirements (i.e., temperature and/or depth) or sessile nature. 2) Species which tend to migrate inshore and offshore seasonally and therefore are more or less abundant in the PAI at any one particular point in time and space. Included in this category are: spiny dogfish, little skate, river herrings, silver, red, and spotted hake, black sea bass, scup, butterfish, northern searobin, summer and fourspot flounder, and longfin squid. 3) Species which either winter or summer in or near the PAI, and then, for all practical purposes, migrate either north or south entirely out of the area. An example of this type of relationship would be the Atlantic mackerel which winters in the Mid-Atlantic and, with the advent of spring

warming, moves inshore to spawn and then north and east to summer. 4) Species which are found in relatively small numbers in the PAI, although they might be very abundant in adjacent areas. Examples of this species category include: ocean pout, longhorn sculpin, and windowpane, yellowtail, and winter flounder.

4) Survey of New Jersey's Offshore Recreational Fishery - Although this survey only deals with the big-game fishery off New Jersey, with moderate extrapolation one can project and expand these results, at least as far as Cape Hatteras to the south and Rhode Island to the north and east. Results of the survey include: Participation - New Jersey's canyon fleet consisted of approximately 800 boats including 714 private-, 82 charter-, and four party- boats; Effort - 5,473 trips were made during the 1981 season, with private boats accounting for 89% of the activity; Catch - total catch for all species was approximately 40,000 fish, with yellowfin tuna, albacore, bigeye tuna, and white marlin accounting for 92% of the total. The estimated weight of the aforementioned four species was just slightly less than two million pounds (907 mt); and Value - 800 boats made up the canyon fleet with an estimated individual value of slightly greater than $90,000. Therefore, the value of the entire fleet was estimated at approximately $73 million. In addition, boats owners participating in this fishery spent approximately $11.1 million during 1981 for the following: boats and boating equipment, $4.6 million; boat maintenance, $2.2 million; mooring and storage, $0.7 million; insurance, $0.6 million; fishing equipment, $0.7 million; fuel, $1.8 million; and bait, ice, and food, $0.6 million.

The above stated facts and figures should leave the reader with little, if any, doubt as to: first, the magnitude and importance of this offshore recreational fishery; and second, the impact any adverse changes in distribution and/or abundance of tunas and billfishes would have on the fishery.

5) Tilefish Fishery Catch and Effort - Provides catch and effort information for the years 1973-1981 based on information extracted from fishermen logbooks and governmental records of landings. Based on these

data, since 1978, this fishery has undergone dramatic change as illustrated by an all but doubling of fishing effort, a 50% decline in CPUE, and a relatively constant harvest (landings). The combined simultaneous occurrence of increased effort, decreased CPUE, and stable yield over time are usually indicative of stock decline; therefore, it would be safe to assume that the tilefish stock is probably under some type of stress (i.e., fishing pressure) at this point in time. It is then logical to ask the following question: What would be the impact on this already tenuous situation if it were complicated and compounded by environmental stress (i.e., 106-mile site's PAI)?

6) Survey of New Jersey's Ocean Fishing Grounds - This source of information temporally and spatially delineates selected recreational and commercial ocean fishing grounds for 22 species based on a one-year survey of actively involved fishermen. It illustrates the ocean fishing grounds for the following species: Atlantic mackerel, tilefish, summer flounder, scup, black sea bass, butterfish, silver and red hake, Atlantic cod and pollock, yellowfin tuna, albacore, bigeye tuna, white and blue marlin, swordfish, ocean quahog, American lobster, red crab, sea scallop, and short- and long-finned squid. It can be concluded that if one takes into account the data presented previously (e.g., commercial landings and value, recreational landings and value (big-game), and the distribution and abundance of important species), the information illustrated in the above mentioned data set is relevant in terms of potential adverse impact which might be caused by dumping at the 106-mile site.

7) Foreign Landings and Values -Demonstrates both the amount and value of silver and red hake, Atlantic mackerel, butterfish, dogfish spp., and squid spp. within the geographic limitation of the "fishing windows" associated with the 106-mile site and its PAI. As a point of interest, these six species and/or species groups total approximately 21,000 mt (46.5 million pounds), worth more than $8.7 million at an average of almost $350 per mt. These data illustrate the amount and value of these resources; this information coupled with recent (1980-1983) joint U.S.-foreign ventures, indicate the growing importance

of these fisheries to U.S. commercial fishing interests. Therefore, any potential man-induced changes must be weighed heavily against potential industry growth which could be lost or accrued by this relatively new concept (joint ventures) in the U.S. commercial fishery.

MAMMALS, BIRDS, AND TURTLES

The distributions of marine birds, mammals, and turtles in the vicinity of the 106-mile site and Philadelphia dumpsite are described from data provided in several sources of literature, in particular contract reports on the Cetacean and Turtle Assessment Program to the Bureau of Land Management and of the Manomet Bird Observatory to the U.S. Department of Energy and the National Marine Fisheries Service.

Sightings of cetaceans were plotted by season: winter (December-February), spring (March-May), summer (June-August), and fall (September-November). The following species were recorded in the vicinity of the 106-mile site's Potential Area of Influence (PAI) throughout the year; bottlenosed dolphin, *Tursiops truncatus*; grampus, *Grampus griseus*; pilot whales, *Globicephala* spp.; sperm whale, *Physeter macrocephalus*; minke whale, *Balaenoptera acutorostrata*; and fin whale, *B. physalus*. Spotted dolphins, *Stenella* spp.; white-sided dolphin, *Lagenorhynchus acutus*; sei whale, *B. borealis*; humpback whale, *Megaptera novaeangliae*; and beaked whales (Ziphiidae) were found seasonally. At the 106-mile (PAI) site cetaceans were generally common from spring through fall. Bottlenosed dolphins, pilot whales, and grampus were most abundant. Estimates of bottlenosed dolphins ranged from 630 (±167) in spring to 3177 (±1375) in summer; pilot whale estimates ranged from 377 (±126) in spring to 2577 (±1089) in summer; and estimates of grampus were 1238 (±269) in spring to 4014 (±1582) in summer. Sperm whales and spotted and striped dolphins were also abundant in this deepwater area. Humpback, fin, sei, and sperm whales are endangered species.

Sightings of loggerhead, *Caretta caretta* and leatherback turtles, *Dermochelys coriacea* were plotted. The loggerhead turtle was the more common species and its abundance was greatest in shelf waters from May to November. The leatherback turtle was most common from August through October inshore along the coast of New Jersey. Both species are found near the shelf-break within the 106-mile site's PAI. The loggerhead turtle is a threatened species; the leatherback turtle is endangered.

Sightings of cetacean and turtle species suggest considerable movement into and out of the 106-mile site's PAI seasonally. Although several species can be seen in this area throughout the year, individual residence times could not be determined from available data.

Distributions of sea birds were plotted and mean densities were calculated for the dumpsite areas for the same seasons as given for cetaceans. A total of 27 species was recorded. Seasonal densities for all species combined in each area were considered to be low (<10 birds/km^2/season). However, in spring the majority of red phalaropes, Phalaropus fulicarius, that migrate off the northeastern United States occur within the 60 and 200 m isobaths west of the 106-mile site's PAI, and local densities there can exceed 1000 birds/km^2. Similarly, high densities of Wilson's storm-petrals, Oceanites oceanicus, occur along the shelf-break in April and May and this species is attracted to oily slicks.

CONTAMINANT INPUTS, FATES, AND EFFECTS

Inputs - The 106-mile site has been used since 1961 with inputs since 1973 occurring under permits issued by EPA under the Marine Protection, Research, and Sanctuaries Act. Between 1973 and 1981 input waste volumes varied from 242,000 m^3 to 795,000 m^3. Volumes were most likely lower prior to 1973. The lowest input since 1973 occurred in 1981 when only one industrial waste dumper continued to use the site on a routine basis. Inputs have been almost exclusively industrial wastes with some sewage sludge in 1977 to 1978 and small annual amounts of cleanout from sludge digestors. Five waste sources have accounted for more than 90 percent of total inputs in any year. Three of these sources have annually accounted for 65 to 93 percent of total input. Physical and chemical characteristics of the five major wastes have been compared and combined with input volumes to reveal that one industrial source has contributed the vast bulk of elements, two industrial sources have dominated the input of organic carbon, and sewage sludge even though its volume has been small it has been a non-trivial source of both inorganic and orgaic chemical contamination. Detailed chemical analyses of the three large volume wastes are discussed. Possible future inputs are described.

Fates - All wastes have been dumped from moving barges with the three major wastes discharged at a rate of about 80 m^3 per kilometer of barge track. This procedure yielded initial waste dilutions by a factor of 5000 with waste distributed over long (50 km for 4000 m^3, or one million gallon waste volumes), narrow (abouth 50 m) swaths in the surface mixed layer. Subsequent dispersion was vertically limited to the mixed layer depth of about 150 m or as little as 20 m during the seasonal stratification period of summer/fall.

Wastes did contain suspended solids and two were sources of solids via precipitation upon neutralization by seawater of their initially acidic or basic conditions. There was no field evidence, however, that waste particles fell sufficiently fast to descend below the mixed layer. Waste plumes horizontally dispersed, on average, at a rate

consistent with a diffusion velocity of 1 cm s^{-1} so that, during summer/fall when vertical mixing was more limited, wastes were diluted by a factor of 10^5 and horizontally distributed over 50 km^2 within one day of a dump. Storm events greatly enhanced mixing so that while in theory 10 days would be required to dilute wastes by a factor of 10^6 such dilutions were achieved more quickly. The important characteristics of the site in controlling the the fate of wastes are: its depth which prevents exposure of benthic organisms to waste plumes, the volume flow of water available for diluting waste plumes, the volume flow of water available for diluting wastes which is conservatively estimated to be 10^{10} m^3 d^{-1}, and the mean trajectory of flow towards the Gulf Stream. The largest annual volume of waste (795,000 m^3 in 1978) corresponded to a daily input of 2000 m^3 (one 4000 m^3 barge-load every other day) so in that year the large-scale dispersion during summer/fall achieved a dilution factor of at least 5 x 10^6 prior to entrainment of waste into the Gulf Stream. This extreme dilution prevented any, except sporadic, observations of waste-contaminated water outside of recently created, relatively small-scale, discrete waste plumes.

Effects - Because wastes dispersed within the mixed layer were at concentrations of 10 ppm (v/v) or less within one-day old discrete plumes, and the site is not occupied by a resident fishery, effects of waste dumping were sought in plankton which, by definition, are not readily able to migrate from contaminated water. Laboratory toxicity tests were useful in: establishing the relative order of toxicity among wastes, demonstrating that open-ocean phytoplankton are more sensitive to contamination than their coastal analogs, showing that the effects of dumping on phytoplankton could be a change in the species composition of communities, and indicating that while actual concentrations of wastes in the ocean would not be lethal to zooplankton they could cause significant decreases in the rate of egg production. Field studies did show that copepods exposed to waste plumes lost their capacity to generate eggs. Field verification of the hypothesis that phytoplankton communities would be altered within plumes was not unambiguously achieved due to natural variability in species composition. Because effects on copepod reproductive capacity and possible effects of

phytoplankton communities occurred only over the small scales of newly created plumes they were of no ecological consequence. As plumes became further diluted through mixing with seawater and unaffected plankton, the short-term, within-plume effects were progressively diminished. Examination of plankton organisms for histological or pathological evidence of damage or disease revealed conditions that were attributable to natural causes, not waste dumping.

Chapter 1. INTRODUCTION

J. B. Pearce[1] and D. Miller[2]

Disposal of a variety of wastes in coastal waters, such as at the New York Bight dredged material and sewage sludge disposal sites, has gone on for over half a century but offshore dumping is a relatively new activity. The 106-Mile Ocean Waste Disposal Site (106-mile site) has been used for offshore disposal of toxic wastes deemed to be too deleterious to be disposed in inshore waters.

The Marine Protection, Research, and Sanctuaries Act of 1972 (Public Law 92-532) ended unregulated transportation of wastes for disposal in ocean waters of the United States. Under MPRSA, the National Oceanic and Atmospheric Administration (NOAA) was given responsibility to conduct monitoring and research to determine the environmental effects of the disposal of waste materials into the ocean. The Coast Guard was given enforcement authority. The Environmental Protection Agency (EPA) was charged with designating ocean disposal sites and issuing permits for ocean disposal. Hazard assessment is an approach being employed by EPA to evaluate the potential impact of waste contaminants on the marine environment systematically.

Hazard assessment involves several components, each of which includes acquisition and synthesis of information. Such information provides answers to questions in an order which leads to a regulatory decision. The initial step in hazard assessment is characterization and designation of a disposal site. Site characterization is the acquisition and synthesis of physical, chemical, and biological information about the site. The objective of site characteristics of a given site and the types of waste which may be considered for disposal

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at the site. The site designation process is not an authorization for disposal of specific wastes. Each specific disposal activity proposed for a designated site requires an individual permit.

After a site has been designated, waste characterization is necessary to describe the specific chemical, physical and biological properties of the waste to be disposed of. Coupling of information from separate site and waste characterizations constitutes the initial step of the hazard assessment process and provides a basis for determining the scope of further assessment studies.

The basis for an ocean disposal permit decision is the assessment of potential hazard to the environment posed by the proposed waste material. Hazard assessment is a process which provides the necessary data and interpretive methods for estimating the probability of harm to the environment. The principal components of this procedure are exposure assessment and effects assessment. Exposure assessment consists of estimating the duration and intensity of an exposure of the biological communities to be protected to a contaminant. Effects assessment consists of estimating the biological response of these communities in terms of stimulation, toxicity, disease, or bioaccumulation. In the event that a positive permit decision is made, monitoring activities will be initiated for the purpose of field validations of the hazard assessment predictions.

In the context of the hazard assessment protocol, site characterization documents should provide environmental managers and decision makers with a review and synthesis of existing information pertinent to the following questions:

- What will be the fate of disposed material in space and time?
- Are contaminant materials already prevalent which should be considered when evaluating the hazards of a proposed disposal activity at the site?
- What biota and ecosystem functions may be at risk at this locality?

The present site characterization update report is intended to augment existing environmental baseline documents for the 106-Mile Ocean Waste Disposal Site. Systematic efforts to obtain baseline information at this site began in May, 1974 (NOAA, 1974). An extensive baseline report was issued in 1977 using data from three baseline cruises, several special experimental cruises, and information available from the National Marine Fisheries Service (NMFS) (NOAA, 1977). Additional experimental studies were conducted between 1976 and 1978 on the characteristics, dispersion and effects of waste disposal at the 106-mile site (NOAA, 1981). Much of this information has been summarized in an environmental impact statement (EIS) prepared for the 106-mile site (U.S. EPA, 1980). Additional environmental information for the mid-Atlantic outer continental shelf (OCS) is now available in a Bureau of Land Management EIS prepared for anticipated oil and gas lease sales (U.S. Department of Interior, 1982).

Existing baseline reports and studies at the 106-mile site are limited generally in their usefulness due to a paucity of data for this region. Often the data cited represent only a few short-term (1 to 2 day) studies. Obviously, such studies cannot provide information on the distribution and abundance of a particular resource at any one time, nor describe the temporal and spatial variability of a particular parameter or resource category adequately. Yet this is particularly important, as it is now recognized that the 106-mile site has a highly diverse and dynamic biological community, which is a reflection of "the complex water mass structure of the area, seasonal changes, and natural variability" (NOAA, 1981). In light of limitations of the present 106-mile site reports, it is important that site characterization updates be provided as pertinent additional information becomes available.

This update report draws primarily on information gathered by several investigations of the Northeast Fisheries Center (NEFC), National Marine Fisheries Service, plus recent studies at the 106-mile site sponsored by the National Ocean Survey (NOS). For almost two decades, the NEFC has collected information on distribution and abundance of a range of fish species over the continental shelf. Data

are available on the standing stocks of adults as well as for fish eggs and larvae of a number of the important commercial and recreational species.

Also, as part of its Ocean Pulse and MARMAP programs, the NEFC has made collections and measurements on phytoplankton populations which constitute the base of the food web of living marine resources. Data also have been collected on the nutrients which are involved in the primary production process and the growth and development of phytoplankton species. In addition, relatively intensive studies have been made in recent years of the benthic populations, those organisms which live on or in the sediments which form the seafloor. Much of this information recently has been computerized, making it accessible for site characterization update purposes.

Studies sponsored by NOS concerning waste disposal at the 106-mile site have provided information on (1) physical oceanographic processes which disperse and dilute organic and inorganic contaminants, (2) meterological and physical oceanographic conditions and events at the 106-mile site, and (3) effects of various categories of wastes on ocean water quality and biota.

The present site characterization update reviews the physical processes which are deemed important in transporting wastes that may be disposed at the 106-mile site. It describes the spatial and temporal distribution of nutrients, plankton, fish eggs and larvae, adult fish stocks and marine mammals, birds and turtles. It provides information on sediment characteristics and the benthic community, and details available information on past contaminant inputs. It describes studies on the fate and effects of these inputs. A complimentary report also has been prepared which reviews important physical oceanographic processes of the entire mid-Atlantic Bight continental shelf which may influence transport of contaminants (Ingham, 1982).

The region described in this 106-mile site report is enlarged from that of the earlier baseline documents to encompass the larger area that can be occupied by water masses advected from the dump site (Fig.2-1). This area is termed here the potential area of influence (PAI) for the 106-mile site. The PAI has been delineated solely for the purpose of

describing environmental characteristics of the largest area which might experience water transport from the waste disposal site. It is evident from the chapter on the fate of waste materials (Chapter 12), and Appendix 1, that the PAI is not an area with subunits having equal probability for receiving wastes from the 106-mile site, nor equal likelihood of experiencing environmental change. The rationale for the size and location of the PAI for the 106-mile site is given in Chapter 2 (Physical Oceanography) and discussed further in Appendix 1.

This document will not only be of value in hazard assessments as these are related to waste disposal but will also be useful in regard to outer continental shelf mineral exploration and development activities. The document is a first in a series of regional assessments or Water Management Unit (WMU) descriptions being developed by the Northeast Fisheries Center as a contribution to the Regional Action Plan (RAP) of the NMFS Northeast Regional Office and Northeast Fisheries Center.

We welcome comments from its early users.

Chapter 2. Physical Oceanography

James J. Bisagni[1]

2.1 Introduction

Studies of the middle Atlantic Bight Apex have shown that waste inputs have caused environmental degradation within coastal and shelf waters. Farther offshore in the slope waters however degradation has not been demonstrated, despite several years of work in the vicinity of the 106-Mile Dumpsite. A group of physical oceanographic processes in the vicinity of the site can be used to outline a region of the western north Atlantic which may theoretically be affected by waste dumping at the site. This region will be called the "potential area of influence", or PAI. The purpose of this chapter is to describe which physical oceanographic processes are important in dispersing and diluting waste material which may be dumped, and their usefulness in describing the PAI. The processes covered in this report include:

1. Seasonal vertical density stratification
2. The shelf water/slope water front
3. Gulf Stream and Gulf Stream rings
4. Waste density in relation to the density of sea water
5. Near-surface currents
6. Bottom currents and sediment transport

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2.2 General Setting

The 106-Mile Dumpsite is a rectangular area of 37 X 43 km bounded by 38° 40'N, 39° 00'N, 72° 00'W and 72° 30'W, located over the continental slope and rise south of Hudson Canyon (Fig. 1). A description of the physical characteristics of the dumpsite has been given in NOAA Dumpsite Evaluation Report 77-1 (NOAA, 1977), including the following elements:

"The morphological and geological character of the DWD-106 ocean bottom is characteristic of lower slope-upper rise regions of the Western Atlantic. Depths vary from 1700 to 2750 meters with gradients ranging from about 4% in the shallower slopes to 1% over the deeper rise. Sediments within the dumpsite area are composed of large sand and silt fractions, with silts predominating. The slope region is covered by a soft, silty sediment of recent origin and is relatively tranquil, with little evidence of significant net current action except for some erosion by tidal currents. Near the slope-rise boundary there is very little sediment of recent origin, suggesting that current action is strong enough in the region to periodically sweep away sediment accumulation. The upper continental rise appears as a tranquil, almost current-free region, with nearly uniform sedimentation. No evidence was found of any waste material reaching the bottom within the dumpsite boundaries.

The physical oceanographic environment in DWD-106 is extremely complex and variable in all but near-bottom water. Normally the surface layer of DWD-106 is Slope Water, which lies between fresher Shelf Water to the west and more saline Gulf Stream Water to the east. Overrunning of Shelf Water occurs periodically, however, and Gulf Stream Water in the form of southward-moving Gulf Stream eddies is present about 20% of the time. Anticyclonic (clockwise) or warm core Gulf Stream eddies and

meanders within the Slope Water region can import large parcels of relatively warm and saline Western North Atlantic Water and waters from the Gulf Stream into the DWD 106 area. These large water parcels move through the Slope Water region, generally in a southwest direction, until they either dissipate or rejoin the Gulf Stream in the vicinity of Cape Hatteras. Mixing of the slope and eddy water also occurs, in association with the continual decay process of eddies and meanders, altering the normal temperature-salinity characteristics of DWD-106 Water." Occasionally a seaward excursion of the shelf-slope front brings highly variable Shelf Water into the upper waters of the dumpsite, often producing a very complex vertical structure consisting of thin layers of cool, low salinity Shelf Water interspersed with warm, high-salinity Slope Water. Mixing of Shelf and Slope Waters across the Shelf Water/Slope Water front may also be caused by the strong circulation of the eddies or meanders. Evidence from the February 1976 cruise supports this by showing a major injection of Shelf Water into the Slope Water due to a rather weak eddy located offshore of the Virginia Capes. The annual meteorological cycle leads to a period of stratification from May to October, during which a seasonal thermocline develops, overlain by a mixed layer which is about 30 to 40 m deep in later summer. The top of the permanent thermocline lies at about 100 to 200 m, and between the two thermoclines is a layer of weak thermal gradients, apparently a residue from winter conditions. During the fall-spring period (October-May) the water column is nearly isothermal to about 100 to 200 m depth, although inversions of up to 6° C can occur due to the mixing of low salinity, cool Shelf Water into the upper 100 m above the high salinity, warm Slope Water. Density structure is important in the mixing and dilution of dumped waste materials, both pollutants and living organisms have a tendency to layer in

stable regions just above the thermocline.

Available data reveal net current action to be toward the southwest octant at all depths, approximately parallel to local isobaths. Current reversals were associated with the passage of warm core eddies, and changes in surface current occurred in response to storm passages and other wind field changes. Surface flow in this direction would be consistent with average currents detected from navigational effects. The net current speeds recorded (maximum = 11 cm/sec) are much lower than turbulent speeds due to wind forcing (in the surface layer) or those due to passage of an anticyclonic eddy.

The climate of DWD-106 is typical mid-latitude marine with synoptic and seasonal patterns similar to a land location but with warmer winters, cooler summers, and stronger winds than at a corresponding coastal station. The mean temperature varies from about 4° C in February to 24° C in August. Northwesterly winds prevail from October through March, when the region is influenced by northerly pressure centers, the Icelandic low, and the North American High. Southwest winds dominate from April through September when the influence of the Bermuda High to the south prevails. Due to migrating weather systems, however, winds are quite variable in all seasons, most so in winter. The average wind is almost twice as strong (10 m/sec) in January-February as in July (5 m/sec). Waves are moderate, with an average wave height reaching a hazardous level of 3.5 m or more about 10% of the time in the winter, and around 1% in the summer. Both winds and waves increase continuously with distance from shore."

Because of the water depth, suspended or slowly sinking waste dumped at the 106-Mile Dumpsite would not reach bottom until days or weeks have passed. Those waste components which are in solution will not reach bottom at all, unless they are adsorbed onto particles, absorbed by organisms, or undergo chemical

precipitation in reaction with other constituents of the water column. The extended residence time of some wastes in the water column would lead to long drift trajectories for those materials. Accordingly, the area potentially influenced by wastes dumped at the site would be large.

The configuration of the potential area of influence (PAI) of the dumped wastes has been developed, using a general understanding of the oceanographic processes and circulation features commonly found in the waters of the outer continental shelf, slope and Gulf Stream. Recognizing that the main perturbation in circulation in the slope water is the aperiodic passage of warm core rings (eddies) shed by the Gulf Stream, the characteristics of these features were used to establish the approximate dimensions of the PAI. Inspection of Oceanographic Analysis charts prepared from satellite infrared imagery by the National Earth Satellite Service and National Weather Service shows that a typical warm core ring in the vicinity of the dumpsite has a diameter of about 90 nm (170 km) and takes up to 100 days to drift through the Site and southwestward to the vicinity of Cape Hatteras, where it "runs out of space" and is recaptured by the Gulf Stream. During the southwest drift from the dumpsite the rings gradually diminish in diameter and their drift rate slows. Occasionally they stall off Virginia before they re-enter the Gulf Stream. The rotary currents (clockwise) of warm core rings are vigorous enough to pull shelf water into the slope water area and push slope water along the bottom onto the continental shelf as far as the 50-m isobath.

With the assumption that some waste materials remain in the upper water column for 100 days, the approximate PAI was generated by successively plotting typical warm core ring positions from northeast to the southwest through the slope water area, beginning at the point of first contact with the

northeastern corner of the dumpsite and allowing for injection of slope water onto the Shelf. This plotted area of influence (Fig. 2) however, carries no information regarding probability of occurrence or concentration of waste materials, but merely states possible occurrence of wastes dumped at the 106-Mile Dumpsite within the previous 100 days. The eastern boundary of the PAI approximately coincides with the average position of the Gulf Stream, which may at any time recapture warm core rings carrying waste materials. Once recaptured, the water involved would be carried toward the northeast relatively rapidly (up to 3.5 kts or 180 cm/sec).

2.3 Vertical Density Stratification at the 106-Mile Site Potential Area of Influence (PAI)

Processes which modify the density of oceanic waters in the vicinity of the 106-Mile Dumpsite and its potential area of influence area (PAI) are either meteorological or oceanographic in nature. These processes alter two physical characteristics of seawater, i.e. temperature and salinity, causing changes in its density. It is the density of seawater, and the rate at which it changes with respect to an increase in depth which controls whether a specific dumped waste will sink and mix into the ocean or remain less diluted at the ocean's surface. This density gradient is largely controlled by temperature and secondarily by salinity. When the change in temperature with depth is large, a thermocline is formed while large salinity changes with depth signify that a halocline is present. Generally, density is inversely proportional to temperature and directly proportional to salinity. Normally salinity has less of an effect on the density of seawater than does temperature.

Any meteorological or oceanographic process which modifies the temperature or salinity of seawater may in fact change the water's density and alter the ocean's ability to mix with, and hence dilute and disperse dumped wastewaters. It is the density gradient which is the singlemost important factor controlling the vertical penetration of ocean-dumped waste. When the gradient is large, a pycnocline is formed and vertical penetration of wastes is inhibited while a small gradient signifies that waste penetration of the gradient will be only slightly impeded.

One of the most important processes controlling the density gradient in the upper ocean is the seasonal meteorological cycle leading to vernal (spring) warming and maximum summer water temperature followed by fall cooling with winter water

temperature minima. This seasonal heating of surface waters causes these waters to decrease their density resulting in a strong seasonal thermocline and pycnocline, forming a very stable water column.

Wright (1976a) discusses meteorologically-induced temperature stratification for the slope water region. This paper is also pertinent to the waters of the continental shelf and thus includes almost the entire PAI for the 106-Mile Site. Wright (ibid) subdivided the slope water into surface, permanent thermocline and deep layers based on thermal characteristics. The surface layer (0-200m) is affected by the seasonal warming and as a consequence decreases in density which leads to temperature stratification and the development of a seasonal pycnocline. This lasts from late spring to early fall when atmospheric cooling and oceanic mixing destroy it. During this stratified period a warm (20-25°C) mixed layer 30-40 m deep develops (e.g. Fig. 3). Below the mixed layer, temperature decreases rapidly (as great as 0.5° C/m) within the seasonal thermocline forming a seasonal density gradient or pycnocline. The seasonal pycnocline can inhibit downward sinking of materials, (Orr et al. 1980, Kohn and Rowe 1981) by acting as a floor where materials would accumulate. Mixing of materials across the pycnocline may occur periodically during the spring, summer and early fall by the passage of storms and weather fronts which may destroy the temperature stratification. Deep mixing and cooling during the winter season extends to the bottom on the continental shelf and to about 200 m depth in the slope water region (Fig. 4). These processes are especially significant to the fate of certain wastes dumped at the 106-Mile Dumpsite.

A permanent thermocline layer is present in the slope water at 150-600m. This layer exhibits thermal gradients of about 0.02° C/m and remains unchanged by the seasonal meteorological cycle.

The deep slope water layer (600m to bottom) exhibits slow temperature decreases to a minimum of 2.2° C depth. Changes of temperature and salinity within the permanent thermocline and deep layers are related to the incursions of anomalous water masses such as the Gulf Stream or warm core Gulf Stream rings. To date, the permanent thermocline has not been shown to affect the behavior of dumped wastes, although little work has been done in this area. Dumped waste has not been detected within the deep slope water layer.

Vertical thermal stratification of the PAI is also affected by irregular inshore and offshore movements of the shelf/slope front. The front exists at the seaward limit of less-saline shelf water which extends into the slope water as a thinning wedge. The bottom of this front usually is close to the 100m isobath and extends to the sea-surface some 30-80 km seaward of the front's near-bottom position (Wright 1976b). At the surface the location of the front is highly variable and less-so near bottom and often forms large, wave-like motions with wavelengths of 100 km or more along its seaward edge which propagates at speeds of about 5 cm/sec (Gunn 1977, Halliwell 1978).

The shelf/slope front itself can also extend far seaward into the slope water along the surface. Workers have shown that in the late winter and early spring seasons the front has often been located seaward of the 200 m shelf break and sometimes has been lying nearly 100 km seaward of the shelf break, thus overspreading the entire 106-Mile Dumpsite (Fig. 5) (Gunn 1979), Hilland and Armstrong 1980, Hilland 1981). Causative mechanisms for this movement are believed to include increased freshwater land runoff, Ekman transport (Boicourt and Hacker 1976, Beardsley and Flagg 1976), wind-induced frontal momentum imbalances (Csanady 1978), warm-core Gulf Stream rings (Morgan and Bishop 1977) and local baroclinic instability over steep topography

(Flagg and Beardsley, 1973).
One consequence of seasonal surface heating of the shelf waters is the development of a "cold pool" of near-bottom water. The cold pool is generally located inshore of the shelf/slope front and remains undisturbed until winter mixing again occurs (Ketchum and Corwin, 1964). Sub-surface parcels of "cold pool" water may become detached by a process termed "calving" and have often been noted in the slope water as deep temperature inversions to 120 m (Cresswell, 1967) and represent one method by which shelf water may stratify the slope water region.

Movement of the shelf-slope front into the 106-Mile Dumpsite would have varying consequences depending on the season. Offshore movement during the winter and early spring would replace the surface slope water layer with colder, less-saline shelf water, resulting in a reversed thermocline with warmer, more-saline slope water underlying the surface shelf layer. When this anomalous condition occurs the resulting density stratification may inhibit vertical mixing of materials. During summer and early fall however, the same overspreading would have little effect due to the uniform surface heating of both the shelf and slope waters.

2.4 Gulf Stream Effects

Thermal structure across the 106-Mile Dumpsite's PAI is also affected by the aperiodic passage of warm core Gulf Stream rings and possibly by the Gulf Stream itself. Both of these features possess thermal characteristics which are quite different from surrounding waters and may drastically influence the behavior of dumped waste.
The region near the 106-Mile Site is minimally impacted by northward meandering of the Gulf Stream while the area east of

70°W may be most disturbed by it (Fig. 6). A northward meander extending into the 106-Mile Site however, if it occured, would displace a large volume of slope water, as the Stream extends to or near bottom. This would import much warmer and more saline waters into the region. A near-surface thermocline may still exist, but the permanent thermocline would now be located some 400m deeper. Zones of strong current shear with currents as great as 200 cm/sec would accompany such an excursion.

Extreme northward extension of Gulf Stream meanders sometimes forms clockwise rotating warm core rings of Gulf Stream water surrounding central cores of water from the Sargasso Sea (Saunders, 1971) (Fig. 7). These rings move generally to the west or southwest through the slope water at 2-10 km/day (4-20 cm/sec) until they encounter either another meander or the Gulf Stream off Cape Hatteras. However, they have been observed to stop or even move in other directions for days or even weeks. XBT and infrared satellite imagery data for 1974-1975 show that although several rings formed each year, usually only 3 moved far enough west to affect the 106-Mile Site annually during this period (Bisagni, 1976). A vertical temperature section through a ring centered just northeast of the site during July 1975 is shown in Fig. 8. The seasonal thermocline extended to 50 m across the ring, while the main thermocline began at 500m, much deeper than the surrounding slope water. Between 50 and 500m depth in the ring's core was a thick layer of nearly isothermal (isopycnal) water of about 15°C. A thick layer such as this would exhibit a minimal density gradient and might allow the deep penetration of certain types of materials. Other workers studying the production of warm core rings from 1976-1980 found 3 to 6 rings occurred aperiodically throughout each year at the 106-Mile Site (Mizenko and Chamberlin 1981).

The presence of a Gulf Stream meander or a discrete warm core

ring within the 106-Mile Site PAI may allow dissolved wastes to penetrate and mix to appreciable depths due to thick isopycnal layers and the deeper permanent thermoclines of these features relative to slope water. Zones of high current shear near the edge of a ring or meander would certainly affect the horizontal dispersion of dumped wastes. Aperiodic, offshore movements of shelf water into the site due to entrainment currents associated with meanders or rings can further complicate the hydrography within the PAI.

The water mass variability and seasonality discussed above makes the PAI region one of the most dynamic and changeable areas in the western north Atlantic (Bisagni and Kester, 1981) and does not readily allow prediction of individual waste plume dispersion or trajectory unless the hydrography in the vicinity of the plume is explicitly known at the time of the dump. However, some general observations can be developed regarding vertical dispersion and mixing of wastewaters based on the presence or absence of a seasonal pycnocline and the density of the dumped waste itself. There generalizations are discussed below.

Waste with densities less than that of seawater will probably not reach the ocean bottom within the PAI but will be most affected by horizontal dispersion as they remain at or near the ocean's surface. Vertical barge-wake mixing will be limited by the seasonal pycnocline (if it exists). Also, this mixing is instantaneous, e.g. the waste may form surface slicks despite barge turbulence. However distribution of the waste throughout the seasonal mixed layer will eventually occur. In the absence of the seasonal pycnocline, deeper penetration of this type of low density waste may occur.

Wastes with densities close to that of seawater also will probably not reach the ocean bottom within the PAI. Vertical barge-wake mixing to the seasonal pycnocline (if present) or

deeper (if absent) will be almost instantaneous; further dispersion is of the horizontal type. Wastes of this type may collect at high concentrations along the seasonal pycnocline within a few hours after dumping.

Wastes with densities much greater than that of seawater will most probably possess high sinking rates. The fate of this waste may be to accumulate on the ocean bottom. Wastes of this type are almost exclusively affected by their sinking rates. In this case barge-wake mixing and horizontal dispersion are almost insignificant.

2.5 Southwest Drift Within the 106-Mile Site Potential Area of Influence

Horizontal movement of dissolved wastes dumped within the 106-Mile Site's PAI will be initially controlled by the movements of the near-surface waters at and near the 106-Mile Dumpsite. As the dumped waste settles or diffuses into deeper layers, the near-surface currents become less criticial while deeper currents gain in importance. Direct current measurements for the region however are relatively few in number and there are no long-term current meter data at the 106-Mile Site itself. Ingham et al. (1977) summarized vector-averaged currents for a series of arbitrarily selected depth layers collected at Site D by the Woods Hole Oceanographic Institution about 200 km east-northeast of the 106-Mile Dumpsite, (Fig. 2). This summary is given in Table 1 and is derived from reports by Pollard (1970), Tarbell and Webster (1971), Tarbell (1974), Chausse and Tarbell (1971) and Pollard and Tarbell (1975).

The Site D data show that the net currents were toward the west-northwest octant at all depths moving approximately parallel to the isobaths. Assuming that these currents would continue to

follow the bathymetry throughout the 106-Mile PAI, this would cause the currents to rotate toward the west-southwest in agreement with previous reports. This hypothesis is supported by drift-bottle data along the outer continental shelf, as summarized by Warsh (1975). It is for this reason that the potential area of influence is skewed towards the southwest relative to the 106-Mile Dumpsite. Surface flow as observed from the Site D data is consistent with average currents detected in the region from navigational offsets and portrayed by the U.S. Naval Oceanographic Office (USNOO, 1965). These surface current speeds (maximum = 11 cm/sec) are much lower than those which would occur under turbulent conditions, such as occurs in the surface layer with wind-forcing or due to passage of an anticyclonic warm-core Gulf Stream ring.

The movement of warm-core Gulf Stream rings themselves through the Slope Water provides additional insight intensity into the long-term water currents and trajectories within the PAI region. Bisagni (1976) showed that the movement of 13 warm-core Gulf Stream rings observed during 1974 and 1975 was towards the west or southwest paralleling the bathymetry (Fig. 9). Movement of the rings however is often interrupted by periods of time (days or weeks) when the rings remain stationary or reverse direction. Bisagni (ibid) determined a mean speed of 8 cm/sec (3.8 nm/day) to the southwest from the translational speeds of 5 long-lived warm core Gulf Stream rings during 1974 and 1975. This estimate is consistent with other similar observations reported by Gotthardt (1973).

Near-surface current measurements made at and near the 106-Mile Dumpsite have been reported by Bisagni (1981). Short-term current measurements were conducted through a series of 3 buoy experiments which utilized radio-direction-finding (RDF) buoys drogued between 5 and 30m depth. These short-term studies showed

differing results. During March 19,79 buoys drogued at 5, 10 30m depth and deployed at the 106-Mile Site moved westward, (Fig. 10) to positions inshore of the 200m shelf break at speeds of between 5 and 50 cm/sec over a 2 or 3 day period. This motion may have been caused by subsurface onshore movement of a warm slope water layer beneath the colder, fresher shelf water at the surface as proposed by Boicourt and Hacker (1976). Buoys deployed at the site during May 1979 and drogued at similar depths moved northeasterly, parallel to the bathymetry at between 20 and 120 cm/sec well offshore of the continental shelf (Fig. 11). This movement was in response to entrainment of the buoys within the inshore edge of warm core Gulf Stream ring 79-A. Finally, during May 1980 buoys released at both the 106-Mile Site and at 39° 05'N, 72° 53'W on the continental shelf moved southwesterly at between 11 and 21 cm/sec apparently in response to local winds, (Fig. 12).

Based on the results of these short-term RDF buoy studies, a long-term (3 month) current study was conducted in the late summer and fall of 1980 (Bisagni 1981). This study utilized 2 satellite-tracked drogued buoys (numbers 03020 and 03021) which were deployed near the center of the 106-Mile Dumpsite in September 1980 (Julian Day 248) and tracked via satellite until December 31, 1980. The 2 buoys were equipped with window shade type drogues centered at 10m depth within the mixed layer above the seasonal pycnocline. Figure 13 shows the deployment positions for both buoys and the trajectory for each until October 15, 1980 (Julian Day 287). These data were superimposed upon the interpreted infrared satellite imagery for Julian day 266 showing the location of the shelf-slope front, the Gulf Stream and warm core rings 80-A and 80-B (Fig. 13). Initially both buoys indicated current speeds of generally less than 25 cm/sec towards the southwest until reaching the vicinity of

warm-core ring 80-A. Entrainment of both buoys along the eastern margin of the ring within a seaward extension of shelf water (Julian days 269-277) was accompanied by anticyclonic current speeds of up to 54 cm/sec (1 knot) (Bisagni, in press). After interacting with ring 80-A, both buoys moved farther to the southwest and eventually became entrained within the Gulf Stream off Cape Hatteras and moved rapidly to the northeast with speeds greater than 150 cm/sec (3 knots). Movement of the buoys from the 106-Mile Site to a position offshore of Cape Hatteras resulted in cross-frontal movement and required 35 days, or about 1 month's time. A volume transport (volume/unit time) estimate for the seaward extension of shelf water along the eastern margin of ring 80-A indicated that the instantaneous value would be as large as 1900 km^3/year but may be intermittent in nature.

2.6 Bottom Currents and Sediment Transport Within the 106-Mile Site Potential Area of Influence (PAI)

The movement of sediments within the 106-Mile PAI may be indicative of the movements of wastes which might become associated with the sediments. Generally, the movement of sediment is governed by several important factors including:

1. Grain size
2. Composition
3. Cohesiveness
4. Percent water content
5. Current velocity and duration
6. Bottom boundary-layer phenomena and turbulence
7. Deposit feeding benthos.

Erosional bottom current velocities, which are the current speeds needed to erode sediments, will vary based on these above variables. Once in suspension, however, the sediments remain in

suspension until a lesser depositional current velocity is reached (usually a lower value than the erosional velocity). Alternatively some sediments may move along the bottom, never becoming suspended in the water. Hjulstrom (1939) discusses the relationship between erosional and depositional bottom current velocities and grain size. The empirically derived curve presented by Hjulstrom is shown in Fig. 14. Based on this curve, continental shelf sands could be eroded with currents of about 25 cm/sec while finer sediments on the slope and continental rise would require somewhat higher velocities.

Bumpus (1973) studied long-term near bottom currents on the shelf by releasing thousands of seabed drifters. The long-term bottom drift was directed west to southwest at speeds of 1-2 cm/sec over the outer continental shelf between Cape Cod and Cape Hatteras along the shoreward edge of the PAI (Fig. 15). Superimposed upon these weak long-term near-bottom drift currents are currents in the tidal (6-24 hour) and sub-tidal (2 to several days) frequencies. Tidal currents are usually forming rotary, constantly varying in direction, thus described as tidal ellipses. Scott and Csanady (1976) noted moderately strong (20 cm/sec) tidal currents 11 km south of Long Island during September 1975. Tidal currents generally decrease in magnitude away from the coast (Fig. 15) and with increasing depth, (Beardsley et al. 1976, Patchen et al. 1976).

Subtidal currents, which generally decrease towards the bottom are caused by temporary changes in sea level due to meterological forcing (e.g. local winds or waves caused by some distant oceanic or meteorological event) (Ou et al. 1981; Bennett and Magnell 1979; Scott and Csandy, 1976; Beardsley and Flagg 1976). Beardsley and Butman (1974) propose that offshore winter storms dominate the shelf circulation by causing strong westward wind stresses south of New England which in turn drive surface

water shoreward due to Ekman transport. This causes the sea-level to rise along the coast and results in current flow to the west. Storms located over the land cause large current oscillations but little net along-shore flow. Bishop and Overland (1977) showed that during the winter season wind-driven circulation predominates on the shelf. Boicourt and Hacker (1976) showed near-bottom currents of 12-36 cm/sec increased in magnitude away from shore on the shelf while Beardsley et al. (1976) showed that shelf currents turned in a more shoreward direction with closeness to bottom. Seasonal thermoclines and pycnoclines on the continental shelf however have been shown to de-couple currents above the pycnocline from those below it (Han et al. 1980), thus causing significant vertical shear during the stratified seasons.

Sediment transport on the continental shelf, slope and rise is controlled to a great extent by the effect of the above described currents. Biscaye and Olsen (1976) measured suspended particulate concentrations in the New York Bight and found resuspension of fine bottom sediments due to erosional currents. McClennan (1973) reported that sediments off the New Jersey coast in 4 water depths between 59 and 143m were being reworked, as evidenced by ripple marks and sedimentary structure analysis. Mean currents measured at 1.5-2.0m above bottom varied between 11.8 and 19.5 cm/sec, Based on critical erosional velocities, the shelf sediment may be eroded as much as 30% of the time by currents and 8% of the time by wind waves. Swift et al. (1976) showed the importance of storm events in causing large sediment transports on the shelf due to sustained southwesterly near-bottom currents of greater than 50 cm/sec for 12 hours or more. These short-term but efficient large scale storm-related transports are separted by long periods of quiescent, minimal transport. Swift et.al. (ibid) indicated westward transport of

bottom sediments south of Long Island and southward transport east of the New Jersey shore.

Further offshore from the continental shelf lies the continental slope in water depth of 200-2500m. The near-bottom slope area is generally a tranquil environment devoid or nearly devoid of competent currents able to transport sediments, (Fig. 15), (Heezen 1975). Several canyon systems incise the slope region from Cape Cod south to Cape Hatteras and have been shown to possess erosional currents (maximum currents of 27 cm/sec) with flow reversals (Keller et al. 1973; Nelsen et al. 1978). Sediment texture studies and organic carbon analysis suggest long-term down-canyon (seaward) transport of fine sediments to the continental rise (Fig. 15).

At the boundary between the upper continental rise and the base of the continental slope (2500 m) a narrow band exists which appears to be an area of considerable erosion, based on the bedforms present. The erosion of hemipelagic ooze in this region may be quite intermittent however, judging on data from camera stations (Heezen, ibid). The upper continental rise (2500-3500m) is an area of slow uniform sedimentation and has been at least for the last thousand years (Heezen, ibid). Across the lower continental rise (depths greater than 3500m) is an area of many current-induced bedforms, the result of the Western Atlantic Undercurrent (Fig. 15) (Heezen, ibid), which may at times extend onto the upper continental rise located offshore of the Wilmington Canyon area (Stanley and Kelling, 1967).

Based on these above observations, the PAI from the 106-Mile Site clearly includes both depositional and erosional sedimentary environments which are not easily delineated. Waste trajectories along the bottom across this region therefore would be extremely difficult to predict. Dumped wastes which reach bottom on the continental shelf (water depths of less than 200m) may move

shoreward, although erratically, while wastes which reach the bottom on the slope or rise would tend to move seaward. Seaward transport of sediments may be maximal in the many canyon systems present.

2.7 Conclusions

Physical oceanographic characterization of the 106-Mile Dumpsite were used to develop a potential area of influence ellipse given in Fig. 2. The entire region is rather similar, being a high-energy area with significant near-surface and bottom currents flowing mostly parallel to the bathymetry. The entire area is affected by storm systems, weather fronts and seasonal differences of insolation and winds. Warm-core Gulf Stream rings irregularly traverse the entire region also, importing Gulf Stream and Sargasso water together with high speed rotational currents.

Based on these factors, the PAI ellipse together with the site itself must be characterized as a highly dispersive environment where both suspended and dissolved waste constituents are rather effectively mixed and transported in a rather unpredictable way from the point of input. More current data are clearly needed, especially during the winter season, to allow a reliable assessment of the long-term trajectories from the 106-Mile Site to points within the PAI. Information concerning specific fates of wastes dumped at the 106-Mile Site may be found in Chapter 12.

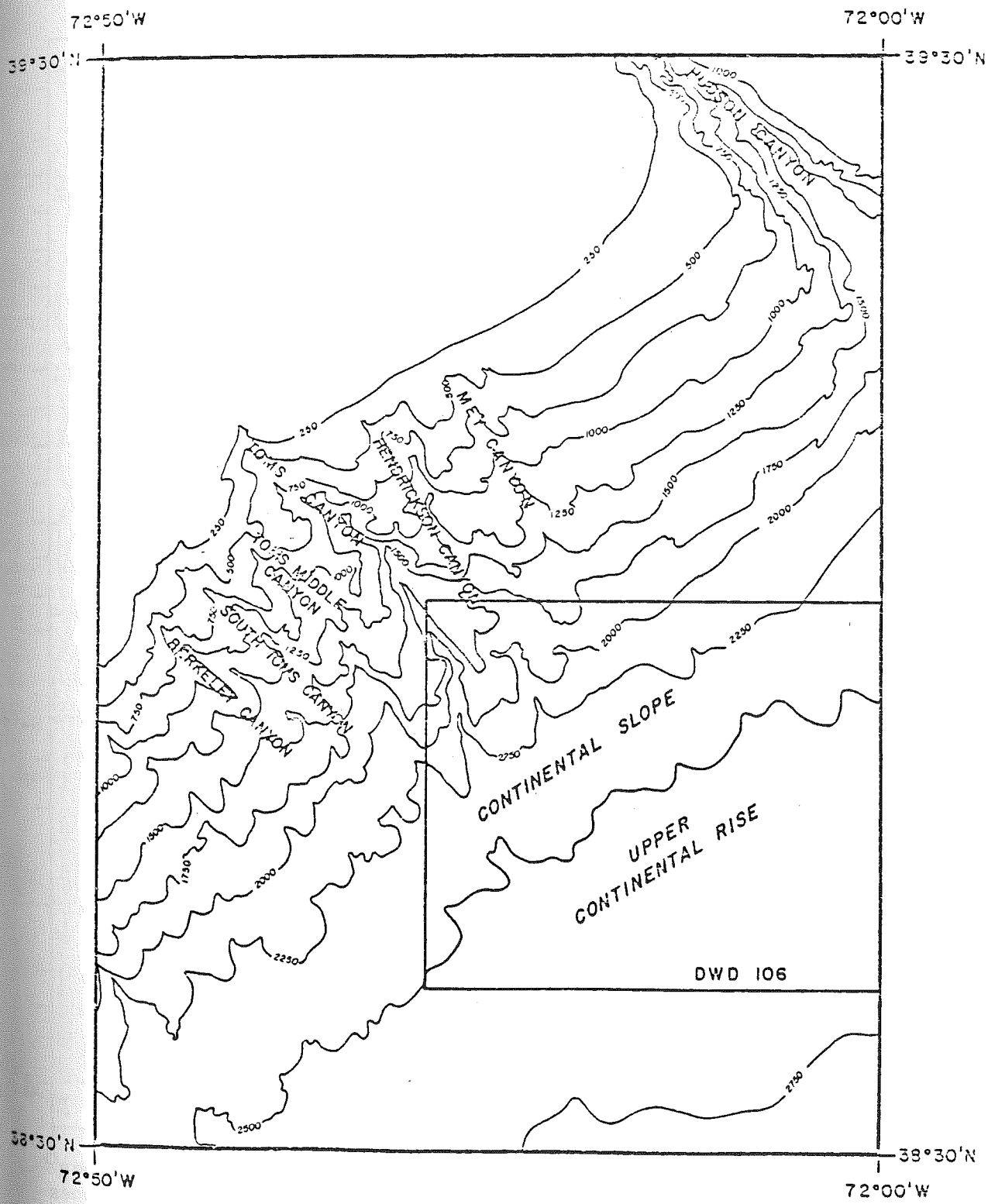

Figure 1. Bathymetry in the vicinity of the 106 Mile Dumpsite.

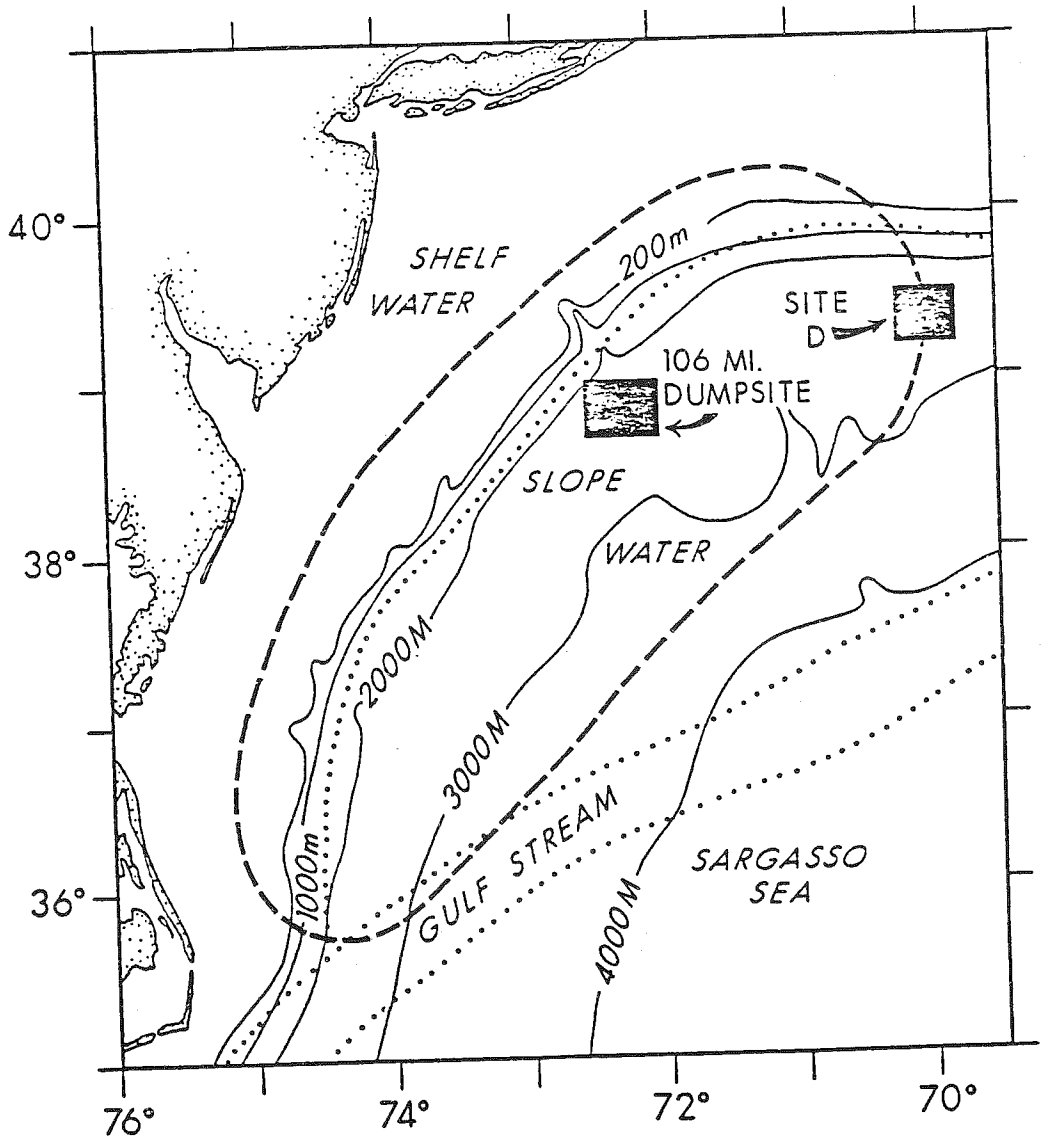

Figure 2. Location of the 100-day potential area of influence (PAI) for the 106 Mile Dumpsite (heavy dashed line) and several bathymetric contour lines. Also shown are the major water masses of the region; dotted lines indicate approximate locations of oceanic frontal zones located at their boundaries.

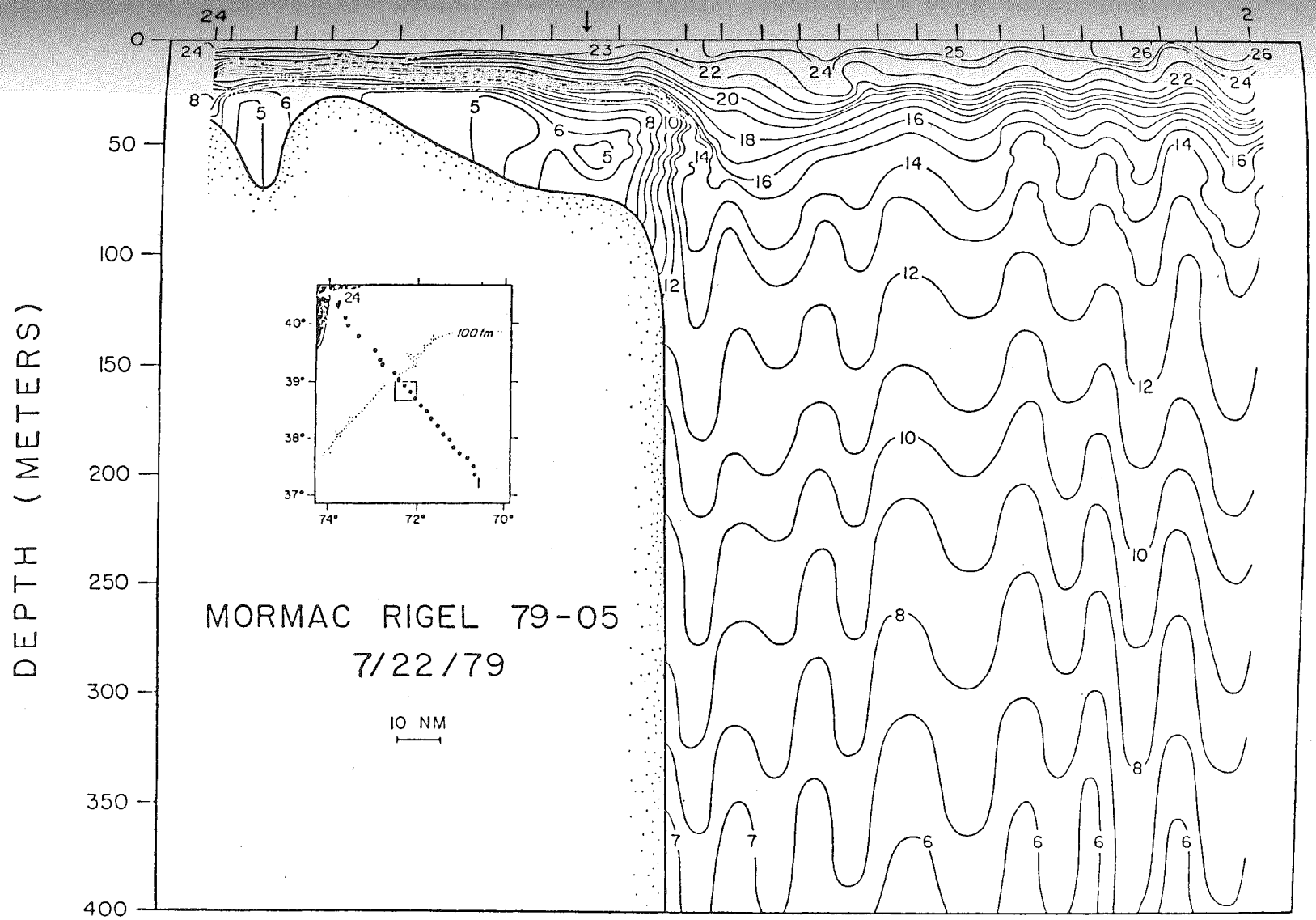

Figure 3. Expendable bathythermograph (XBT) temperature section conducted by the Rigel along a southeast bearing line from New York City through the 106 Mile Dumpsite, July 1979. (After Hughes and Cook, 1979)

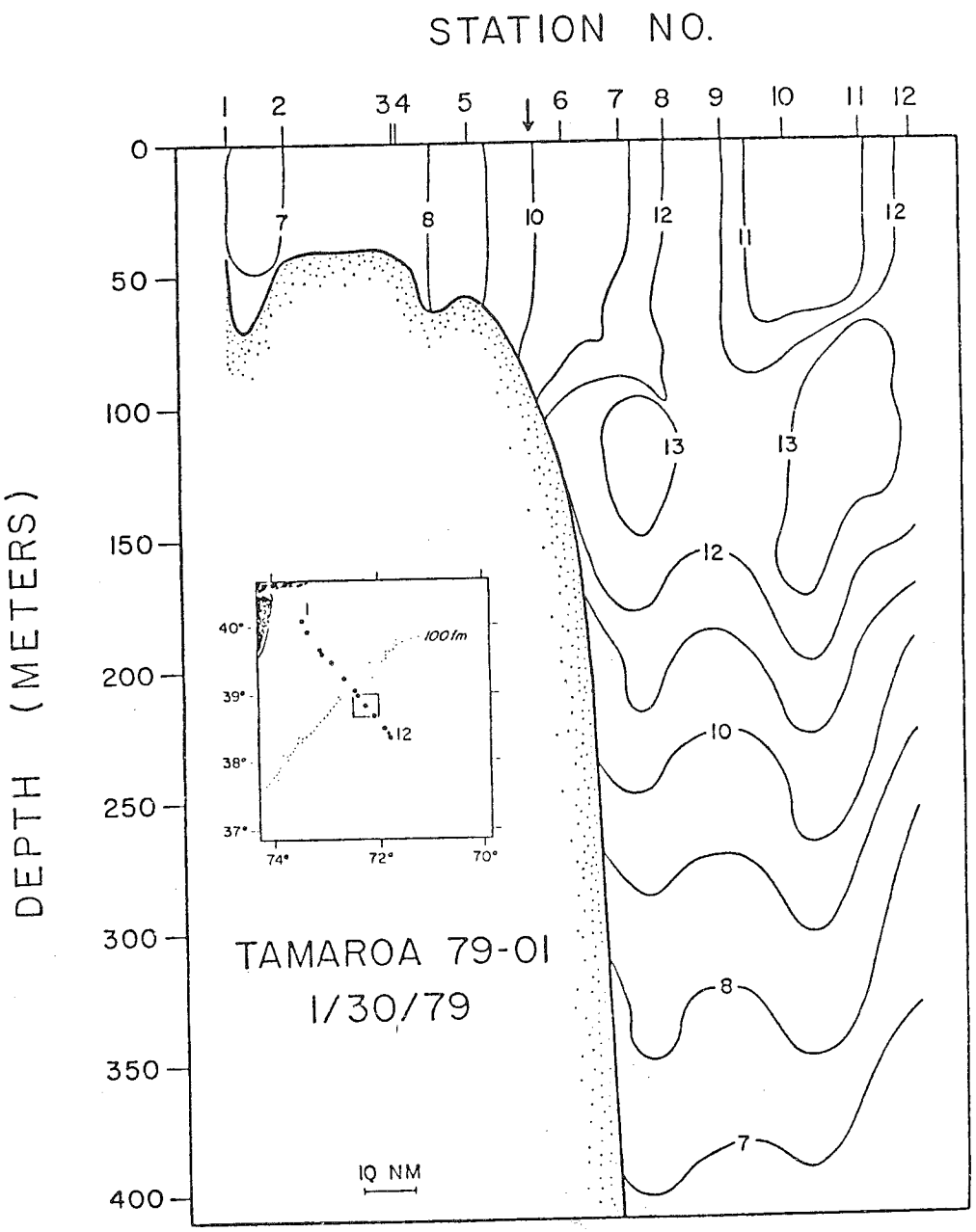

Figure 4. Expendable bathythermograph (XBT) temperature section conducted by the USCG Tamaroa along a southeast bearing line from New York City through the 106 Mile Dumpsite, January 1979. (After Hughes [illegible])

Figure 4. Expendable bathythermograph (XBT) temperature section conducted by the USCG Tamaroa along a southeast bearing line from New York City through the 106 Mile Dumpsite, January 1979. (After Hughes [illegible])

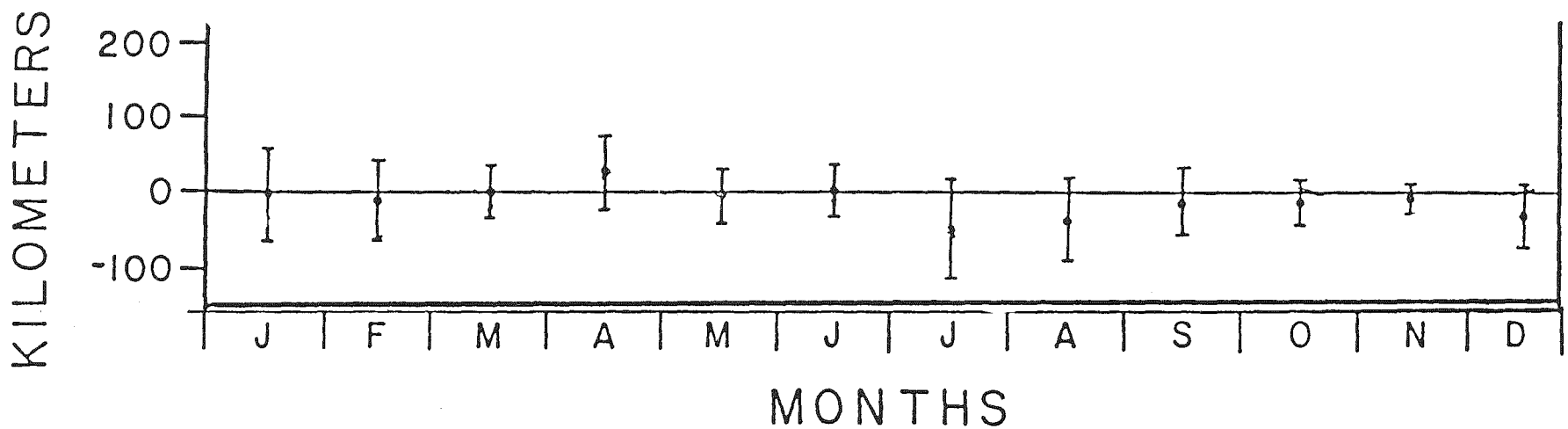

Figure 5. 1973-1977 mean monthly shelf/slope front positions (± 1 standard deviation) along a southeast bearing line from Sandy Hook, New Jersey relative to the 200m shelf break near the 106 Mile Dumpsite. Positive value indicate the front was located seaward of the 200m shelf break, while negative values indicate the front lay shoreward of the 200m shelf break. (Adapted from Gunn, 1979)

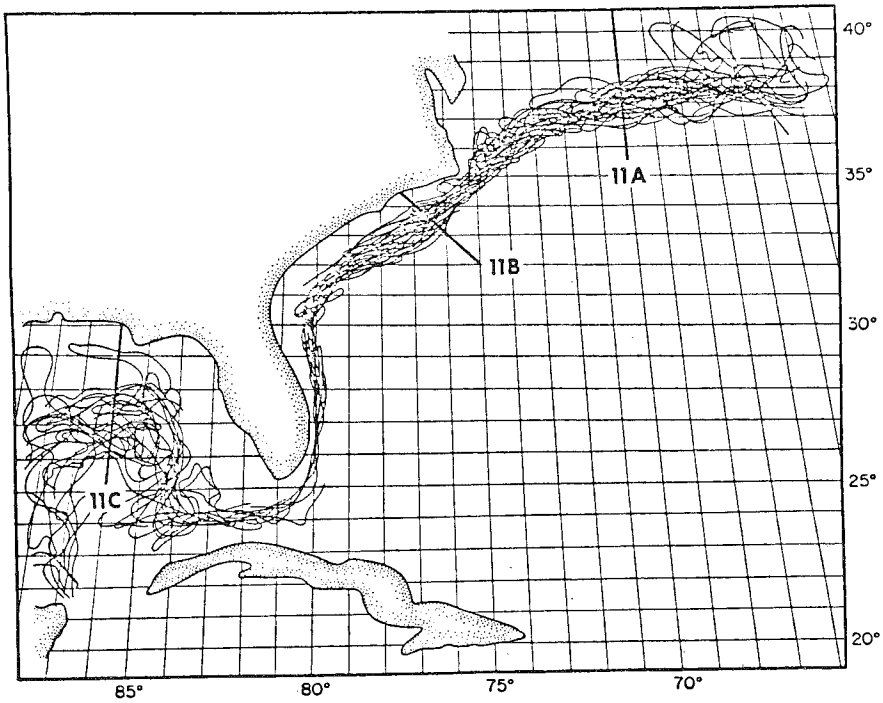

Figure 6. Nine months of weekly composite Gulf Stream north wall locations (March-November 1976) from infrared imagery obtained by GOES satellites. (After Maul et al., 1978)

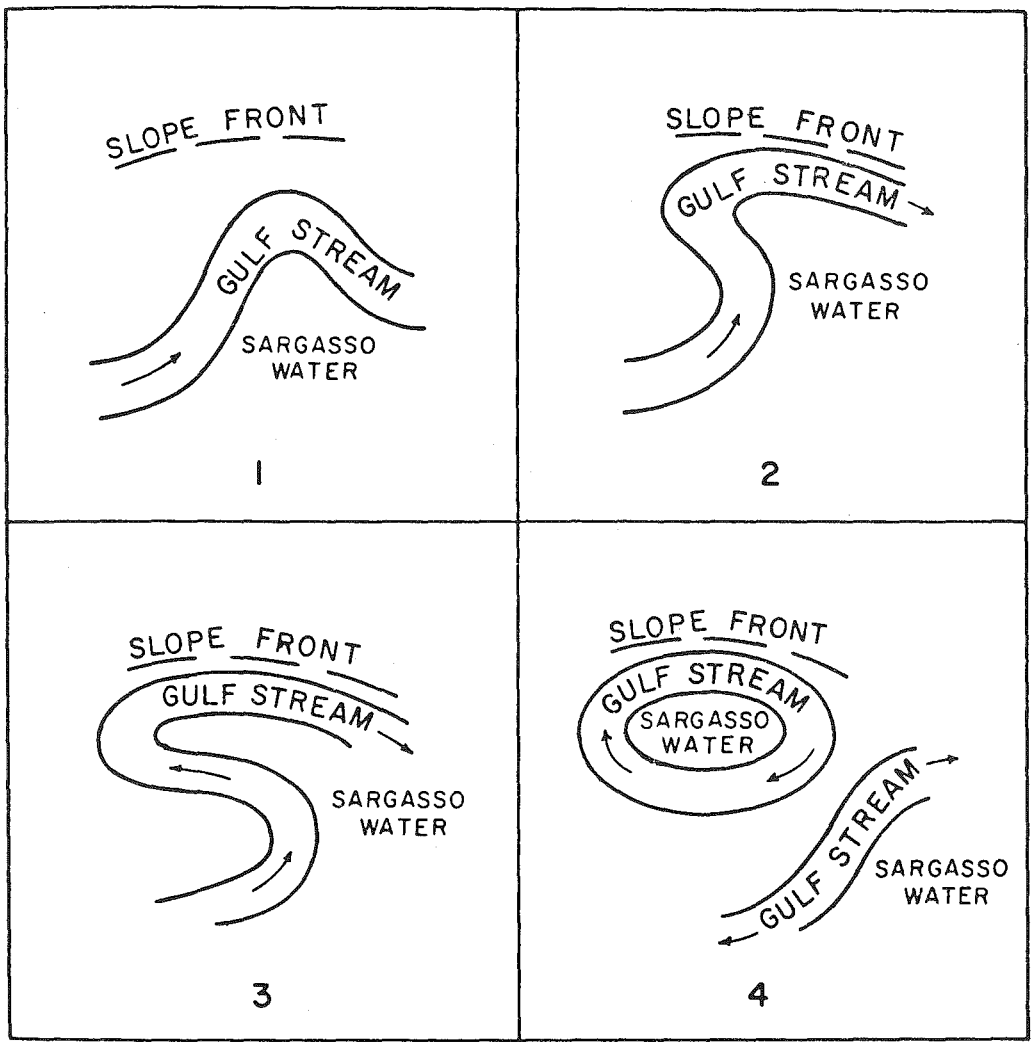

Figure 7. Schematic of warm-core Gulf Stream ring formation. (After Gotthardt, 1973)

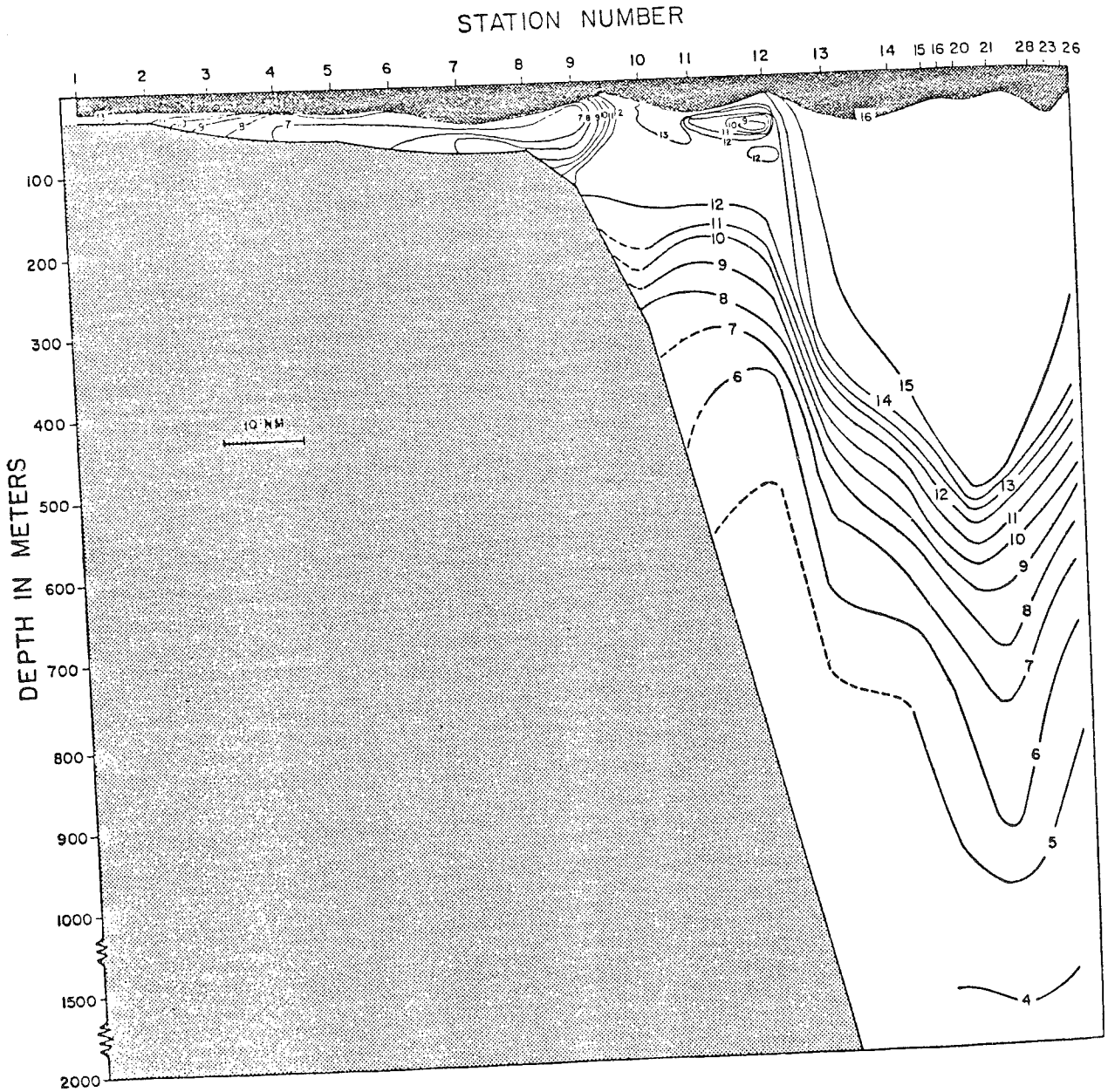

Figure 8. Expendable bathythermograph (XBT) temperature section through a warm core Gulf Stream ring centered northeast of the 106 Mile Dumpsite in July 1975. Near-surface shaded area indicates the depth of the seasonal thermocline with sea-surface temperatures at about 25°C.

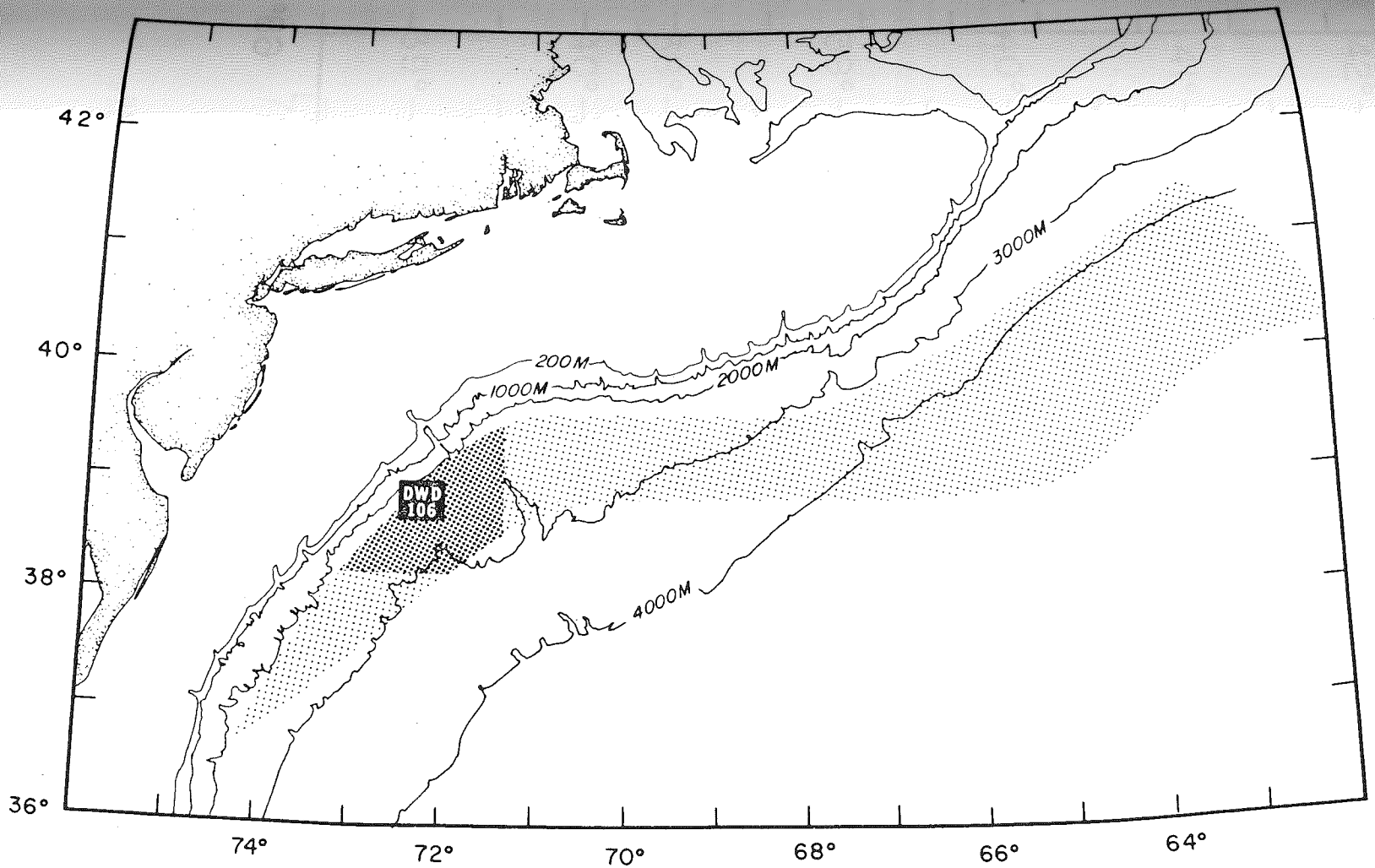

Figure 9. Trajectory envelopes for the movement of the centers of 13 warm-core Gulf Stream rings (light shaded area) and sector about the 106 Mile Dumpsite (darker shaded area) when a ring occupied some or all of the site. (After Bisagni, 1976)

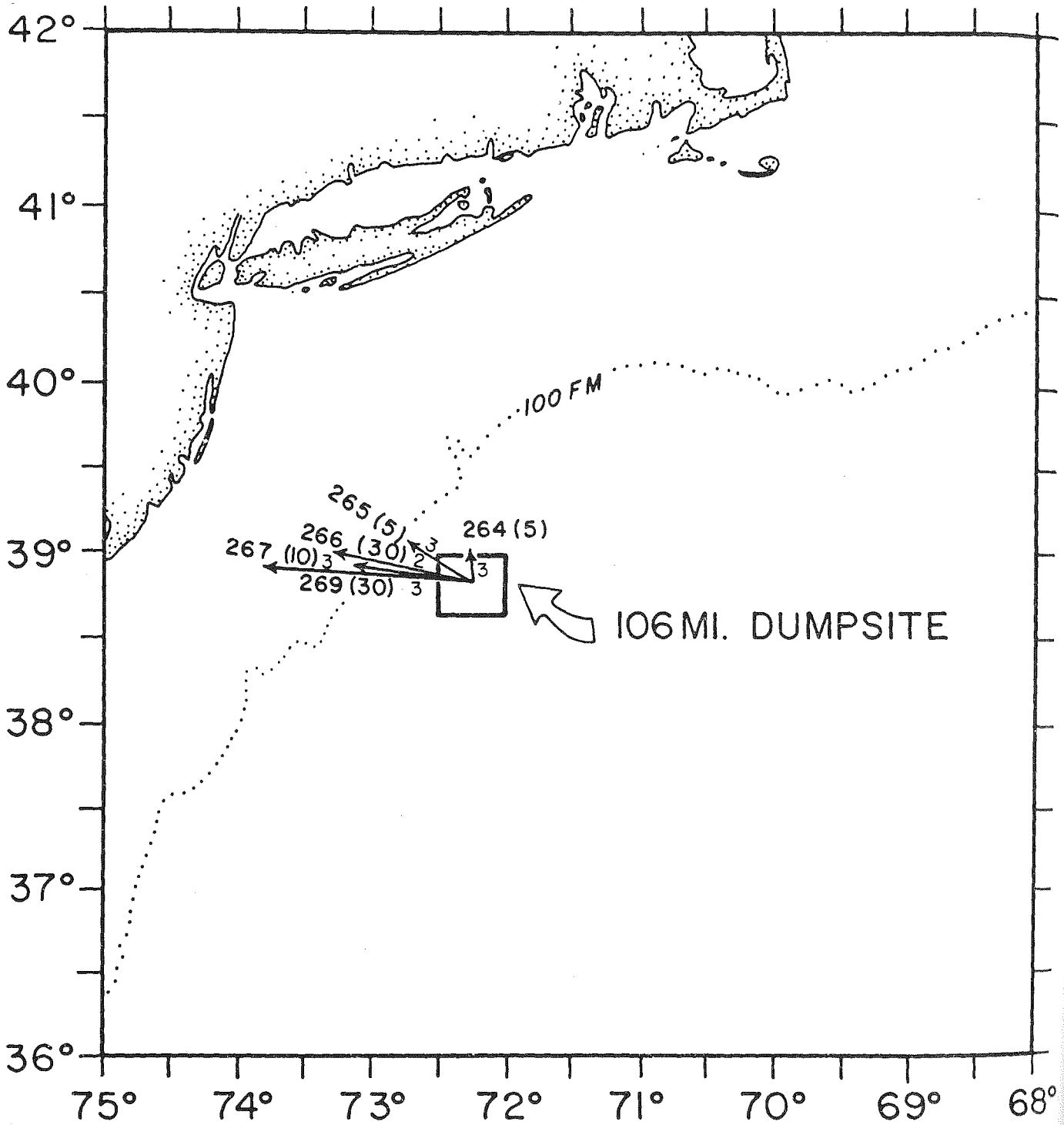

Figure 10. March 7-17, 1979, RDF drogued buoy trajectories for buoys 264, 265, 266, 267, and 269. Drogue depths (m) are given in parentheses. Numbers alongside the arrows indicate the number of days between successive positional fixes.

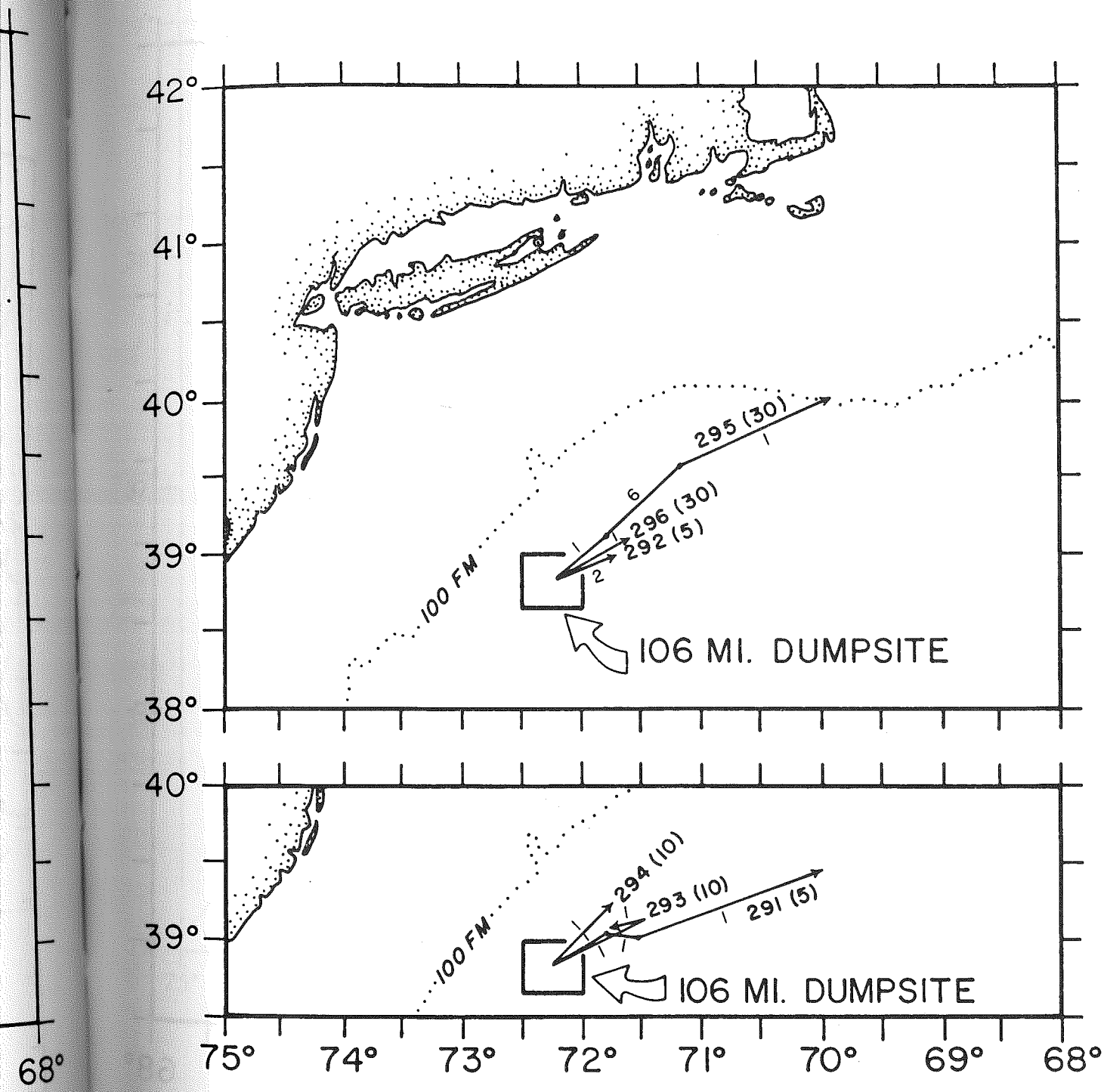

Figure 11. May 9-18, 1979, RDF drogued buoy trajectories for buoys 291 through 296. Drogue depths (m) are given in parentheses. Numbers alongside the arrows indicate the number of days between successive positional fixes.

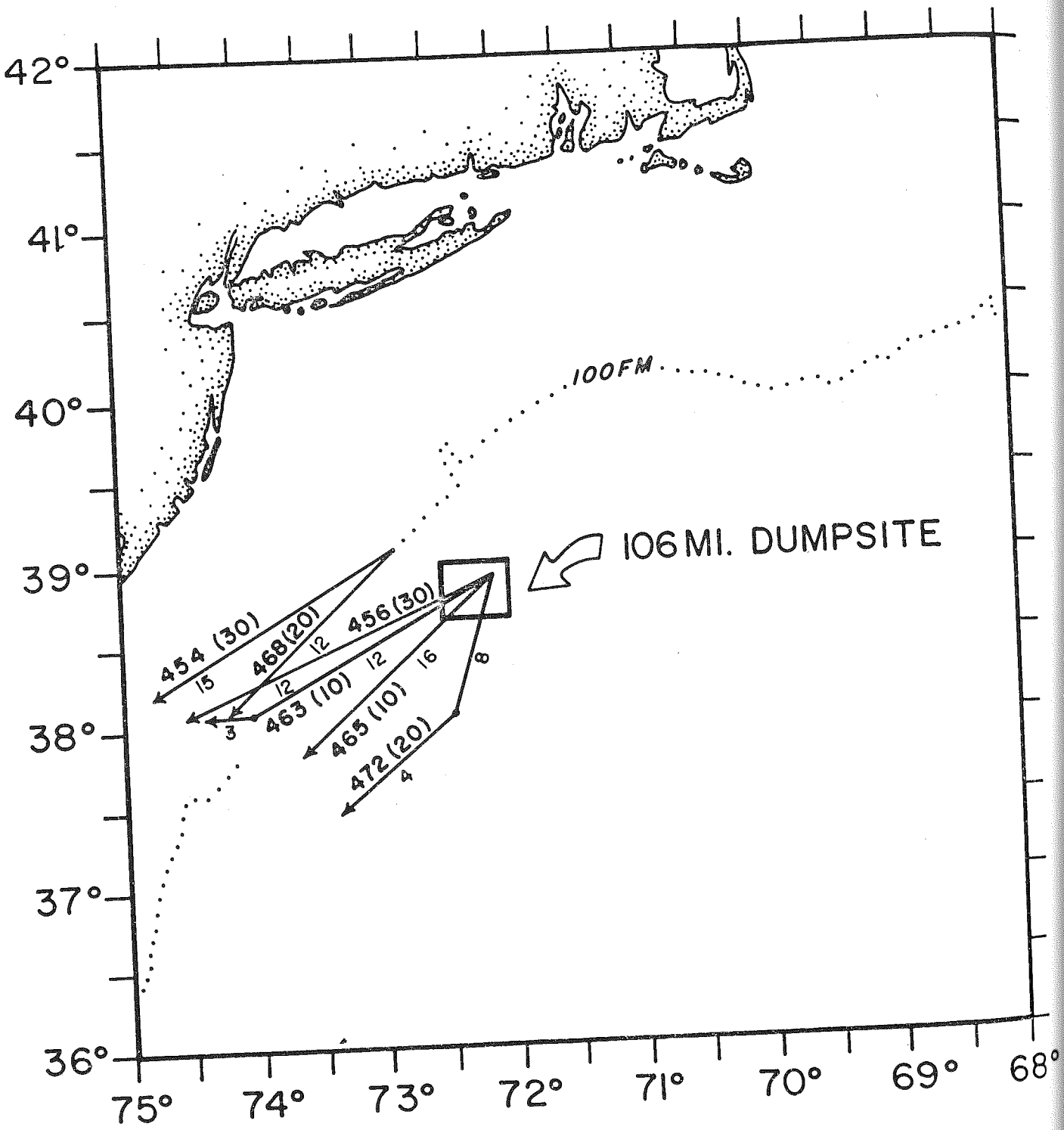

Figure 12. May 8-24, 1980, RDF drogued buoy trajectories for buoys 454, 465, 456, 463, 468 and 472. Drogue depths (m) are given in parentheses. Numbers alongside the arrows indicate the number of days between successive positional fixes.

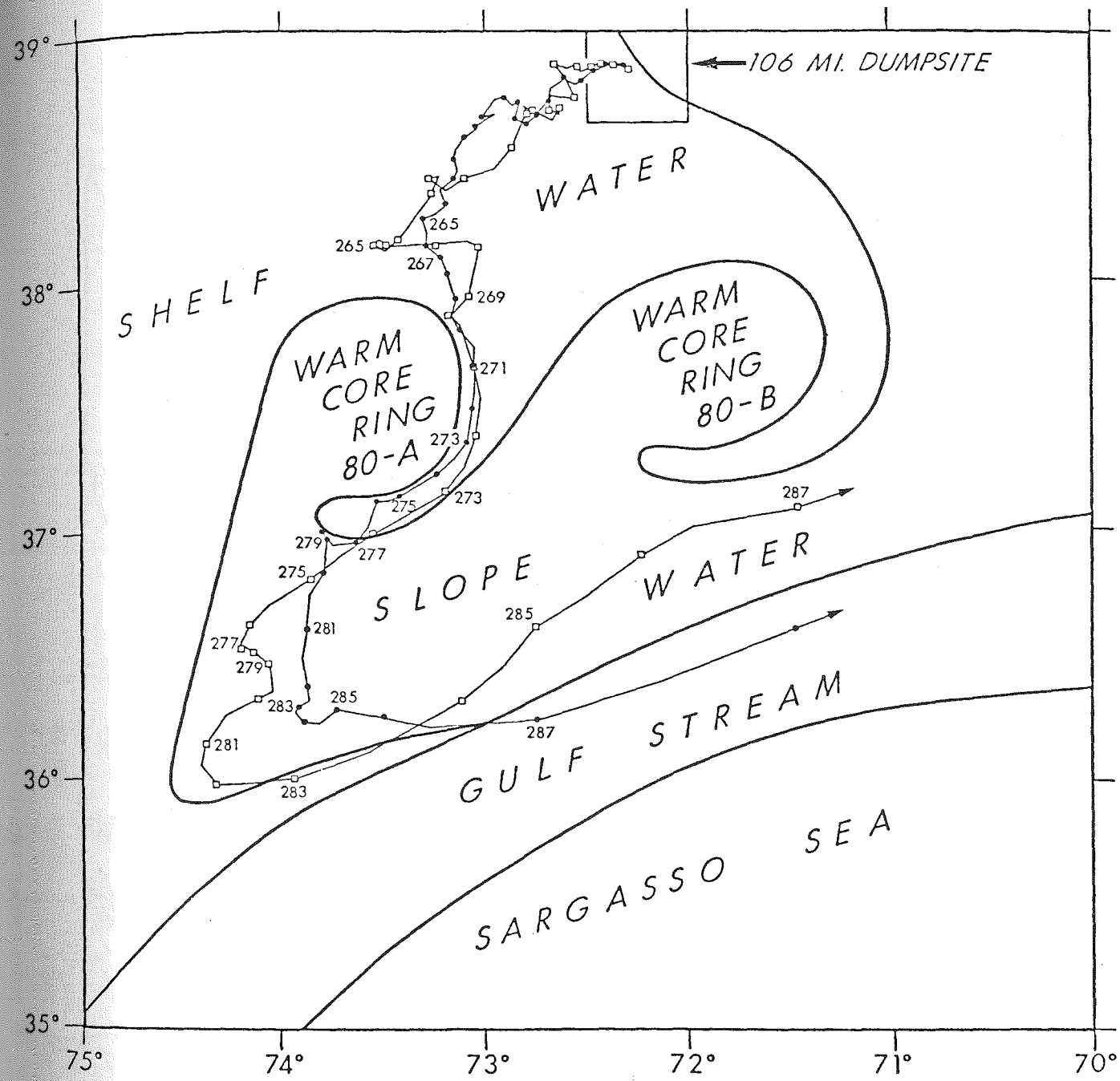

Figure 13. Synoptic surface water mass analysis for September 22, 1980 (Julian day 266) based on AVHRR (Advanced Very-High Resolution Radiometer) infrared satellite imagery (National Earth Satellite Service Oceanographic Analysis). Also shown are the 12-hour, splined trajectories of satellite-tracked buoys 03020 (squares) and 030021 (dots) with Julian days and the location of the 106 Mile Dumpsite. (After Bisagni (in press)).

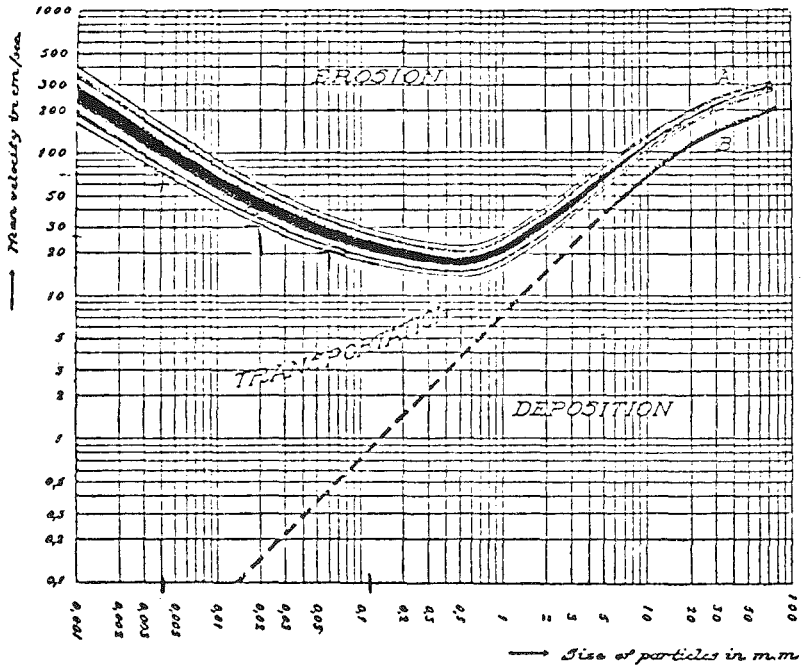

Figure 14. Approximate curves showing erosional depositional velocities of uniform sediments. (After Hjulstrom, 1939)

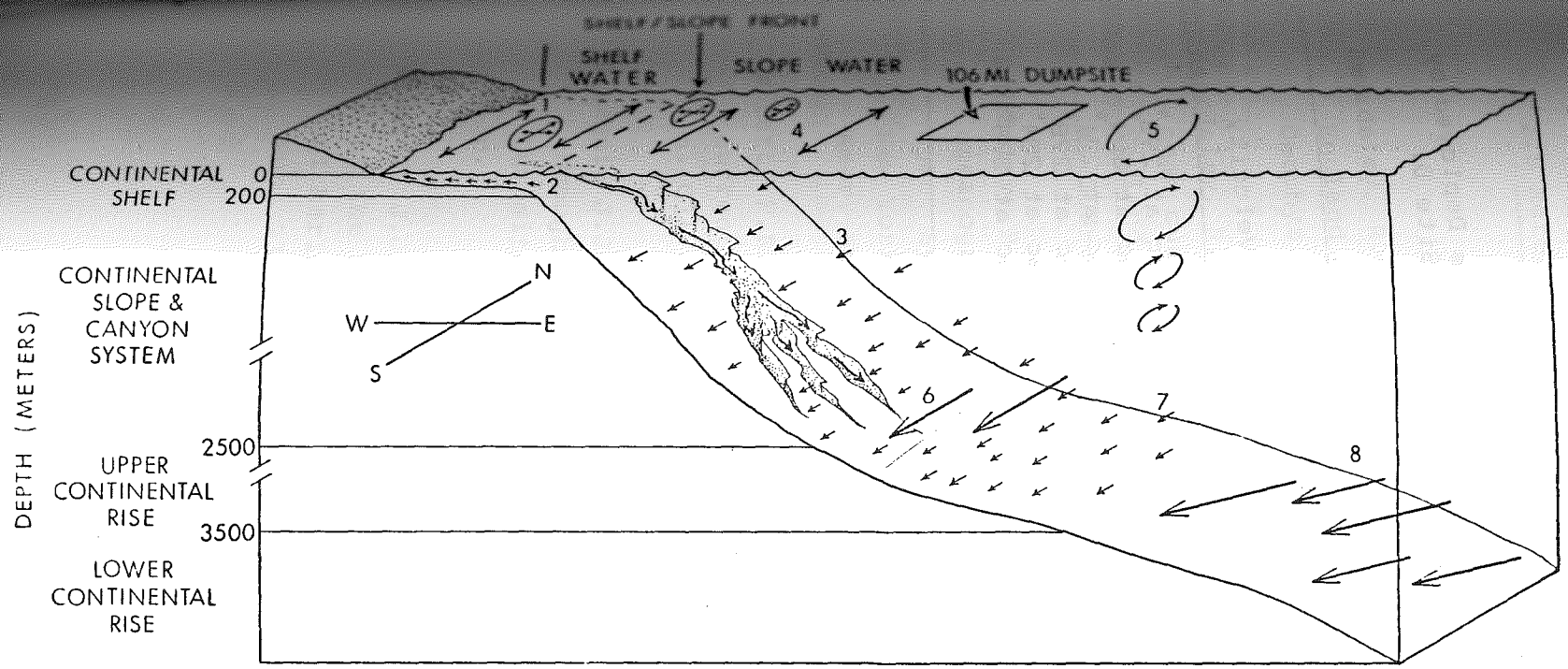

Figure 15. Schematic cross-section of the continental margin and overlying waters eastward to and beyond the 106 Mile Dumpsite showing the major types of near-surface and bottom currents which would affect waste disposal at the 106 Mile Dumpsite: (1) Tidal currents, (2) Long-term onshore bottom currents, (3) Net down canyon currents with otherwise weak currents on the continental slope, (4) Sub-tidal currents of varying magnitudes, (5) Powerful currents associated with warm-core Gulf Stream rings and meanders, (6) Erosional currents at the base of the continental slope, (7) Weak currents on the upper continental rise, (8) Erosional currents on the lower continental rise due to the Western Atlantic Undercurrent. (Distances, water depths and current arrows shown are not to scale but are for schematic purposes only.)

Table 1. Average Current Velocities from Meters Deployed by Woods Hole Oceaographic Institution Near Site D. (After Ingham et al, 1977)

Meter Depths (m)	Cumulative Record Length (days)	Average Velocity
0-20	261	11 cm/sec at 298°
20-60	205	6 cm/sec at 304°
60-150	385	8 cm/sec at 271°
150-600	326	2 cm/sec at 298°
900-1100	249	3 cm/sec at 284°
1900-(bottom-50)	574	2 cm/sec at 278°

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Chapter 3. 106-MILE SITE SEDIMENT CHARACTERISTICS

Thomas P. O'Connor[1]

3.1 SEDIMENT CHARACTERISTICS

3.1.1 Sediment types

Descriptions of the seafloor in the context of the 106-mile site are those of a system unmodified by dumping. If in the future large volumes of particulate wastes are dumped at the site, changes along the seafloor could occur. It is worth summarizing some of what is known about sediment composition, chemistry, stability and rate processes in the region which could receive wastes. The information may be useful in assessing future uses of the 106-mile site.

The region of interest is the continental slope and rise off the U.S. east coast north of Cape Hatteras and the outer continental shelf. Physiographic properties of the slope and rise have been described by Heezen (1975 and 1977) and Bisagni (1977) in sections of larger reports on the 106-mile site. Boesch (1977) has summarized information on sediment distributions and dynamics on the continental shelf. The site itself overlies depths between 1750 m in the northwest corner to 2800 m in the southeast. By definition it overlies the continental slope (200 to 2500 m) and upper continental rise (2500 to 3500 m). Except possibly for a narrow band between these physiographic provinces they are depositional regimes. The lower continental rise, however, at depths of 3800 m or more is under the erosional influence of the

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Western Boundary Undercurrent. Unless waste dumped at the 106-mile site descends slowly enough that it can be expected to reach the Undercurrent before intersecting the seafloor, it is a useful conservative assumption to consider settled wastes as no longer subject to horizontal dispersion. The quiescent nature of the seafloor in the region of the 106-mile site was evident in the Rowe and Gardner (1979) observation from a submersible that bottom water was free of a nepheloid layer.

Sediments on the slope and rise are primarily silts and clays with less than 10 percent sand-sized particles. An exception seems to be in sediments lying along seaward extensions of submarine canyons. Seaward of the Hudson Canyon, Pearce et al. (1975) and Rowe and Clifford (1978) found sediments to contain 50 percent or more sand while to the south (including below the 106-mile site) silts and clays were dominant. In general, the sediments are about 30 percent calcium carbonate by weight and contain about 1 percent organic carbon (Rowe and Clifford, 1978).

Under certain hydrographic conditions waste particles could migrate over the outer continental shelf. The shelf is characterized by sandy sediments with the outer shelf (100 to 200 m) sediments containing a higher proportion of fine sands than shallower locations and 5 to 10 percent silt and clay. As depths increase down the slope the percentage of silt and clay increases, reaching the 90 percent value typical of slope and rise sediments at a depth of about 600 m (Boesch, 1977). The sparcity of silt and clay, except in depressions, on the inner shelf is due to a lack of supply, the probability that small particles which do reach the sea from estuaries migrate beyond the shelf before settling far enough to reach the seafloor (Schubel and Okubo, 1972), and the fact that as depths increase the effect of surface waves on sediment resuspension increases. Butman et al. (1977) observed bottom currents at 90 m (their deepest measurement) to be sufficiently large under the influence of winter-storm waves to resuspend sediments. Boesch (1977) noted that ripple marks,

evidence of sediment movement, have been observed to depths of 200 m. It may be that fine-grained sediments on the outer shelf are episodically transferred to deeper water but, as with slope and rise regimes, it is a conservative assumption to consider the outer shelf to be depositional.

3.1.2 Inorganic constituents

Results of heavy metal analyses of sediments collected along the continental slope from about 37.0°N to 39.5°N by Grieg and Wenzloff (1977) are summarized in Table 1 and compared with average concentrations in deep-sea clays. Since the clay-sized fraction of slope sediments is about 40 percent by weight and such sediments are 30 percent calcium carbonate (Rowe and Clifford, 1978), the Grieg and Wenzloff (1977) concentrations should be multiplied by about 3.5 to compare them with deep-sea clay concentrations. Doing so makes the columns in Table 1 more similar, though the clay concentrations are still higher to some extent. Basically, the metal concentrations in slope sediments are what one would expect in a natural system where clays are diluted with silts, sands and calcium carbonate. The exception is Cd. Even without considering clay dilution with other particles, the Cd concentrations reported by Grieg and Wenzloff (1977) exceed those in deep-sea clays. The high Cd concentrations cannot, however, be due to waste dumping at the 106-mile site. Assuming that Grieg and Wenzloff's (1977) 1.0 ppm average concentration of Cd in the upper 4 cm of sediment applies over an area that is 270 km long (37.0°N to 39.5°N) and, conservatively, 50 km wide, 540 mt of Cd must be accounted for, assuming a sediment density of 1.0. Even during a year of considerable dumping activity (1978, O'Connor [1983]) only about 0.4 mt of Cd was dumped.

The chemical characteristics of continental shelf sediments vary directly with sediment grain size distribution. Bothner (1977) has contoured total organic carbon concentrations showing mid-shelf concentrations of 0.1 percent (dry weight) with lower concentrations toward shore and increasing concentrations toward the slope. Outer shelf organic carbon concentrations are in the 0.5 to 1.0 percent range, the higher concentrations being on the upper slope and typical of deeper ocean sediments. Trace metal concentrations cannot be readily summarized because of the grain size dependence. Representative metal data in Table 2 indicates concentrations to be higher in the finer sediments, a relationship well established for larger data sets (Bothner, 1977; Harris et al., 1979). The grain size effect is most evident in the data of Harris et al. (1977) where their relatively gentle method of metal extraction would emphasize metals associated with particle surfaces.

3.1.3 Organic constituents

There is less data on xenobiotic organic compounds in slope sediments than for heavy metals. Harvey and Steinhauer (1976) included three sediment samples from the continental slope and rise off the northeast U.S. in their set of 14 samples from the shallow and deep Western Atlantic. Those three samples, from depths of 2325 to 3785 m, had PCB (polychlorinatedbiphenyl) concentrations in the range of 0.001 to 0.005 ppm on a dry weight basis. Shelf sediment concentrations except those in New York Bight or close to shore fell within that same range. LaFlamme and Hites (1978) found a 0.05 ppm (dry weight) concentration of non-alkylated PAH (polyaromatic hydrocarbons) in a sediment sample taken from the abyssal plain of the North Atlantic (position 32° 25'N, 70° 13'W, depth ca. 5000 m). Concentrations in slope sediments are probably higher than that but less than found in shelf sediments (0.5 in Gulf of Maine, 0.8 in Buzzards Bay, 5.8 in New York Bight, [LaFlamme and Hites, 1978]). Smith et al. (1977) reported sediment concentrations in the range of 0.005 to 0.5 ppm over the shelf for a sediment extract operationally defined as aromatic hydrocarbons. This fraction contained polynuclear aromatic hydrocarbons (Bieri, 1977). As with total organic carbon and metals, concentrations increased as particle size decreased so concentrations tended to be highest on the outer shelf and seaward. Farrington and Tripp (1977) analyzed hydrocarbons in the region of ocean dumping in the New York Bight and at sixteen other stations on the continental shelf and slope and abyssal plain. Of that fraction of total hydrocarbons which could be attributed to fossil fuels, the concentrations were about 1 ppm or less in shelf, slope, and abyssal sediments except in the New York Bight.

3.1.4 Effects of dumping

Components of waste dumped at the 106-mile site could reach the seafloor directly below the site only if they sink rapidly enough to descend the requisite 2000 m before being horizontally transported away from the site. Ingham et al. (1977) have summarized current velocities measured at various depths at the Woods Hole Oceanographic Institution Site-D, about 100 km north-northeast of the dumpsite, and indicated their usefulness in describing flow at the 106-mile site. Using their data, the depth-weighted average velocity through the dumpsite is calculated to be 2.5 cm s^{-1} to the southwest. The longest straight line through the site, a diagonal, is about 65 km. So, if a waste component were sinking while being horizontally transported it would traverse 65 km and be beyond the site in, at most, 30 days. To reach the seafloor in that time it would have to sink at about 0.1 cm s^{-1}. This is a relatively fast rate, corresponding to the Stokes settling velocity of a 40 micron sphere (coarse silt) with a density of 2.6 g cm^{-3} (quartz). None of the wastes routinely dumped at the 106-mile site in large annual volumes were characterized as containing particles of such size or density. There is no evidence of sediment contamination due to dumping. Waste chemicals, if they are not decomposed, must reach the seafloor at some time either by being carried with slowly settling waste particles or by incorporation into sinking biological debris. However, the times required for doing so allow for considerable horizontal dispersion and, therefore, dilution of waste among natural sediments.

The effect of dumping settleable solids at the 106-mile site may be more physical than chemical. The flux of waste particles to parts of the seafloor could overwhelm the ambient mass flux and threaten benthic organisms with burial. Ambient fluxes onto the seafloor at the 106-mile site and at three seaward locations were measured by Rowe and Gardner (1977) who deployed near-bottom sediment traps for five- to fifteen-day periods in the summer of 1976. Recalculated to an annual basis, their fluxes ranged from 5 to 17 mg $cm^{-2}yr^{-1}$, averaging 14 mg $cm^{-2}yr^{-1}$ for the three traps at the 106-mile site. This should be compared with expected fluxes of waste to estimate the physical hazard dumping may present.

So long as mass fluxes of waste are small relative to ambient fluxes, organisms will not be physically threatened. However, those small fluxes will be difficult to detect by examining sediments. The mass fluxes of Rowe and Gardner (1977) correspond to a sediment build-up rate of 0.015 cm yr^{-1} (O'Connor et al., 1983). If waste fluxes are of a similar magnitude, quantifying them by sediment analysis would require sampling the upper few tenths of millimeters of sediment--a very difficult task. Moreover, waste particles will be subject to biological mixing into sediments (bioturbation). Dayal et al. (1979) found the distribution of Cs-137 in sediment near a cannister of low-level radioactive waste to be consistent with the cannister's leaking at depth in the sediment and Cs-137 being mixed by bioturbation with a coefficient of 1.14 cm^2 yr^{-1}. This cannister was among those at a once used disposal site at a depth of 2800 m located at 38°30'N and 72°06'W, about 20 km south of the 106-mile site. Sediment characteristics there are certainly appropriate in consideration of 106-mile site. However, Dayal et al. (1979) noted that other investigators at other sites have found sedimentary distributions of radionuclides to be consistent with lower bioturbation coefficients. Nevertheless, using a low coefficient of 0.1 cm^2 yr^{-1}, O'Connor et al. (1983) calculated

that maximum concentrations of sediment contamination even after ten years of dumping would be ten times less if bioturbation is considered than if it is not. Essentially, without inclusion of bioturbation it is assumed that waste particles would simply sit atop the seafloor.

It is recommended, therefore, that if settleable solids are dumped in significant amounts their flux to the seafloor be measured with sediment traps. Measuring contamination directly on the seafloor will be very difficult unless the waste flux is very large relative to the ambient mass flux.

Table 1. Concentrations of transition metals in slope sediments and deep sea clays.

Metal	Concentration (ppm, dry) in slope sediments[a] ave	(s.d)	Average concentration (ppm, dry) in deep-sea clays[b]
Cd	1.0	(0.5)	0.4
Cr	24.7	(2.4)	90
Cu	25.4	(3.2)	250
Hg	0.2		0.X
Ni	31.7	(4.0)	225
Pb	16	(3)	80
Zn	49.6	(5.7)	165

a Grieg and Wenzloff (1977) analysis of upper 4 cm of sediment. Averages are for 16 samples (14 for Pb). Six samples were not included, four from shelf and two near Hudson Canyon, where concentrations were lower presumably because sediments were dominated by sand-sized particles.

b Riley and Chester (1971) summary from Turekian and Wedepohl (1961). Concentrations are for clays on a carbonate-free basis. While Pacific clays display about three times the concentrations of most of these elements as Atlantic clays, the listed concentrations are simple averages of clay concentrations observed in both oceans.

Table 2. Transition metal concentrations in surfical shelf sediments.

Station[a]	Depth(m)[b]	Percent[b] silt & clay	Concentration (ppm dry) determined by rigorous[c]/gentle[d] extraction[e]				
			Cr	Cu	Ni	Pb	Zn
D1	31	<1	23/ 0.9	5/ 0.4	4/ 0.7	8/3.7	20/ 4.3
D2	33	<1	13/ 0.5	<2/<0.1	2/ 0.2	7/0.8	14/ 1.7
D3	35	<1	18/ 0.6	<2/<0.1	2/ 0.3	7/1.2	14/ 2.1
D4	50	5	22/ 1.4	<2/ 0.8	6/ 0.8	12/5	25/ 6
E1	68	2	10/ 1.1	<2/<0.2	3/<0.2	9/1.6	15/ 2.5
E2	65	5	18/ 2.1	3/ 1	4/ 1.2	10/6	23/10
E3	65	<1	5/ 1.0	<2/ 0.4	<2/ 0.1	6/2	7/ 1.8
E4	78	4	8/<1	<2/ 0.4	3/ 0.8	8/4.4	14/ 4.0
F1	85	1	11/ 1.1	3/ 0.2	3/ 0.5	11/2.6	47/ 3
F2	112	5	16/ 1.9	2/ 0.6	5/ 1.3	10/3.2	22/ 6
F3	152	8	16/ 1.3	<2/ 1.0	8/ 1.0	10/4.0	29/ 7.2
F4	185	4	21/ 2	3/<0.4	6/ 1.3	11/4.6	29/ 7.3
A1	90	8	18/ 1.5	<2/ 0.7	8/ 1.2	11/5	24/ 6.3
A2	130	23[b]	33/ 3	7/ 2.5	13/ 3.3	11/8	40/13
A3	135	18[b]	29/ 2	3/ 1.2	12/ 2.4	10/5.7	32/ 9
A4	197	15[b]	26/ 3	3/ 1.0	9/ 1.6	10/6	38/10

[a] Station designations of BLM Mid-Atlantic OCS study.

[b] Boesch (1977). Chemical analyses not necessarily from same samples measured for grain size. Ranges on depth and percent silt/clay averaged. Outer shelf sediments near Hudson Canyon higher in percent silt/clay than at other outer shelf areas.

[c] Bothner (1977) extractions with concentrated acids ("total digests").

[d] Harris et al. (1977) extractions with 5N nitric acid, room temperature, two hours ("acid leachable metals").

[e] Both Bothner and Harris et al. report Cd concentrations to be less than 0.1 ppm.

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CHAPTER 4. NUTRIENT VARIABILITY

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4.1 INTRODUCTION.

An important attribute of the ecosystem of the northwest Atlantic continental shelf is its high phytoplankton productivity (O'Reilly and Busch, 1982), which is dependent, in part, on the availability of nutrients (nitrogen, phosphorus, and silicon). Estimates of phytoplankton production place this shelf system among the most productive shelf ecosystems in the world. As part of extensive monitoring and assessment programs by the National Marine Fisheries Service's Northeast Fisheries Center (NEFC) to characterize this system and identify its various interrelated processes, water samples for nutrient analysis were collected on MARMAP (Marine Monitoring Assessment and Prediction) cruises from Cape Hatteras to Nova Scotia several times a year for a period of three years. Apart from smaller scale localized studies, the efforts of the NEFC represent the first attempt to characterize nutrient distributions and processes shelf-wide. One of the objectives of the program, to identify the character and extent of any current or future man-induced impacts on the system, led to the examination of a portion of this data set to describe conditions in the region of the 106-Mile Ocean Waste Disposal Site.

Figures derived from 180 horizontal and vertical distributions of dissolved inorganic nutrients using first year data are presented here to describe the spatial and temporal distributions of inorganic nutrients over the Middle Atlantic mid- and outer continental shelf. A forthcoming atlas of nutrient distributions over the continental shelf from Cape Hatteras to Nova Scotia, being

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prepared by NEFC's Environmental Chemistry Investigation at Sandy Hook, will contain the data on which these figures are based. Nutrient distribution information such as this should permit a clearer determination of the potential impact of the timing and nature of a disposal activity on phytoplankton production levels.

4.2 NUTRIENT DISTRIBUTIONS AND PRODUCTIVITY.

In order to provide some context for the interpretation of the results of this chapter, some expected patterns of nutrient distribution and their relationship to productivity should be reviewed. Nutrients, light, and temperature are key factors in the regulation of primary production. Photosynthesis is limited to the illuminated surface layers of the sea and is dependent on the availability of various substances such as nitrogen, phosphorus, and silicon. The absorption of these substances by plankton in this photosynthetic or euphotic zone reduces the concentration of these nutrients and limits further growth of plankton populations. Some nutrients can be regenerated as planktonic organisms die, with the resultant nutrients recycled within the euphotic zone. However, there is also a continuous loss of nutrients as phytoplankton sink below the euphotic zone or are consumed by zooplankton. Nutrients therefore tend to accumulate in the deeper, darker layers of water where photosynthesis does not take place. Levels of production in the euphotic zone depend heavily on the rate at which these nutrients from enriched deeper waters are returned to the productive euphotic layer by mixing processes.

Temperature, as well as directly affecting the rate of photosynthesis, influences the supply of nutrients by affecting water density. Density distributions can inhibit vertical mixing processes which restore nutrients to surface depleted layers. Summer warming of surface waters establishes a relatively stable density distribution. Below the warmed surface layer, waters are progressively cooler and therefore heavier as depth increases. The

summer season is also usually associated with decreased storm activity, which at other times of the year would contribute to the break up of any layering. This water layering or stratification impedes vertical mixing and the exchange of nutrients between deeper nutrient-rich waters and the warmed nutrient poor surface layer.

Changing light and temperature regimes therefore result in a seasonal cyclic pattern of primary production. In the early spring, the water column is well-mixed and contains sufficient nutrients to support increased primary production as the intensity and availability of light increases, resulting in a spring bloom of phytoplankton. As surface water temperatures rise and the summer stratification of the water column develops and begins to retard nutrient transfer from deeper waters, phytoplankton concentrations increase next to the thermocline (the gradient representing the region in the water column of maximum temperature change with depth) and nutricline (the region in the water column of maximum change in nutrient concentration with depth) and decrease in the surface layer. The breakup of these stratified conditions in autumn due to the cooling of surface waters and increased storminess gives rise to a smaller bloom of phytoplankton before the decreased light availability and temperature again begin to severely limit the relative size of the plankton population. The effects of upwelling, water mass movements, and eddies are superimposed on this seasonally changing productivity pattern and can alter the expected nutrient regime both temporally and spatially.

4.3 METHODS.

Over 18,000 measurements of dissolved inorganic nutrient concentrations (nitrite, nitrate, ammonium nitrogen, orthophosphate, and silicate) were reviewed. These values were determined from filtered sea water samples collected between May 1979 and March 1980 on 11 cruises. Horizontal distributional maps were generated for each nutrient species at the deepest sampling

level (bottom water for most stations, but not for all those where station depth exceeded 200 m), and for a weighted average of the upper one-fourth of the water column (but not exceeding 30 m in depth). Maps were produced using SYMAP programs, Version 5 (Harvard Center for Environmental Design Studies, Laboratory for Computer Graphics and Spatial Analysis). Vertical nutrient distributions were also generated for two cross-shelf transects near disposal areas. Surveys were usually limited to the continental shelf in waters less than 200 m deep. Figure 1 indicates the distribution of station locations sampled during the period covered by this data set and the potential area of influence (PAI) of the 106-Mile Site. The 106-Mile Site is east of the principal survey area. The most seaward stations occurring at and east of the 200 m isobath were not always sampled to the bottom when occupied. Eighteen stations located at or east of the 200 m isobath fell within the PAI. Figure 2 shows the location of the two cross-shelf transects. Transect 2 begins at the mouth of Delaware Bay and runs southeast extending into the lower portion of the 106-Mile Site PAI. Transect 3 intersects the PAI ellipse just north of the 106-Mile Site and has its origin at the mouth of the Hudson River estuary. The mid-shelf region was taken to be the area of the shelf between the 50 to 100 m isobaths while the outer shelf was defined as the region east of the 100 m isobath extending to the 200 m isobath.

4.4 RESULTS.

4.4.1 Mid-Shelf Nutrient Spatial and Temporal Variability

Bottom water column nitrate concentrations in the mid-shelf region north of Transect 2 were higher than surface concentrations throughout the year. Nitrate concentrations in bottom water generally increased seaward, with isopleths of nitrate generally paralleling the isobaths. The seaward extent of the 1 μM (micro mole) contour was generally in the vicinity of the 60 m isobath, although its position

varied east-west by some 60 km over the year in the mid-shelf region south of Delaware Bay and north of Transect 2 (Figure 2). Highest observed bottom water concentrations across this mid-shelf region were reached in May when the 5 μM contour line was at its most shoreward excursion (Figure 3). Lowest observed bottom water nitrate concentrations occurred in April, with secondary minimal values in June. Vertical nitrate profiles along Transect 2 demonstrated the expected stratification of mid-shelf water during warmer months and well-mixed uniform conditions in early spring (Figure 4). The average location of the 0.2 μM nitrate contour line in the Transect 2 vertical profile generally corresponds with the mean depth of the euphotic zone (26 m) for this mid-shelf location (O'Reilly et al., 1981) and indicates nitrate depletion by phytoplankton in the euphotic layer at this time of year.

Observed values for nitrite in the surface layer at the same mid-shelf region were lowest in May and October (Figure 6) with little variability over the sampling period, demonstrating a behavior similar to that of surface layer nitrate. Nitrite distributions in bottom waters were not as uniform as those of nitrate. Bottom water nitrite isopleths also did not parallel isobaths as well as nitrate isopleths. Highest nitrite concentrations in bottom waters of this mid-shelf area were observed in October (Figure 6) and corresponded with an observed nitrate maximum. Unlike nitrate, observed concentrations in May were less than in April or June; variations over the sampling period were again small. Nitrite was not as vertically stratified as nitrate in August in the mid-shelf region along Transect 2, but did exhibit similar vertical patterns the rest of the year.

Highest observed ammonium nitrogen concentrations in the mixed surface layer in the mid-shelf region occurred in August and the lowest in April. Bottom water exhibited a maximum in August and a minimum in March. A gradient in ammonium nitrogen concentration associated with the Delaware River discharge was observed in vertical profiles along Transect 2 during August, September, and October (Figure 7).

Highest surface layer phosphate concentrations observed mid-shelf north of Transect 2 were in April and the lowest in May (Figure 8). May surface and bottom water phosphate distributions were the most uniform with respect to the coast, with isopleths of phosphate concentration generally paralleling the coast throughout the PAI. Lowest observed bottom water phosphate values in the mid-shelf area occurred in March, and the highest in October. At this time the 0.6 μM isopleth was 50 km west of its March position (Figure 9).

Observed silicate concentrations in the surface water layer across the mid-shelf region were lowest in August and highest in June. There was an area with elevated values in April and June off Cape May, New Jersey near the western boundary of the PAI. In October, regions of reduced silicate concentration extended 70 km seaward from the New Jersey coast (in the same area as the April and June high) and 70 km off the coast of Virginia at the southwest edge of the PAI. In bottom waters, highest silicate concentrations were observed in May and October while the lowest values were in March, similar to phosphate concentrations. A well-mixed water column is expected in March and this was the only period sampled that did not exhibit an area of reduced silicate concentration in mid-shelf bottom waters off the mouth of the Delaware River at the western edge of the PAI. This area of reduced concentration extended to the southeast in April and May, to the northeast in June, to the

north in September, and to the northwest in October. This region of depletion was also reflected to some extent in the surface layer as were the elevated silicate values north of Transect 2 and southeast of the 106 site observed in April and June.

4.4.2 Outer Shelf and Slope Nutrient Spatial and Temporal Variability

Observed nitrate values for the surface mixed layer of continental slope water west of the 106-Mile Site were generally 0.2 μM or less during the summer and fall, as were the more inshore values from spring to fall. In spring, nitrate values in surface waters adjacent to the 106-Mile Site increased to 2 μM or more. Bottom water concentrations were again typically higher than surface concentrations throughout the year. Evidence suggests that deeper slope water nitrate concentrations at the 106-Mile Site remained above 15 μM through the spring, reaching values of 25 μM or more by June and then decreasing to between 5 and 10 μM at the greatest sampling depths in the fall. Vertical profiles along Transect 3 show, as do those along Transect 2, the expected stratification of nitrate distribution in warmer months, and mixing in early spring (Figures 4, 5). Offshore, the mean depth of the euphotic zone for this region (approximately 40 m, O'Reilly et al., 1981) again approximates the depth of the 0.2 μM contour, as in the case of the mid-shelf region.

Variations of nitrite concentrations in surface waters adjacent to the 106-Mile Site were similar to those of nitrate. Nitrite was highest in spring, reaching 0.1 μM or more and exhibiting little difference from the observed mid-shelf values the rest of the year, typically being below 0.05 μM throughout summer and fall. Highest bottom water concentrations occurred in June, when nitrite values in slope waters adjacent to the site were observed to be from 2

to 8 μM or more. Concentrations of 0.2 μM were more characteristic of the bottom waters in this area in the spring. There were several observations of less than 0.05 μM after the June maximum through the early winter months.

Highest observed ammonium nitrogen concentrations (0.2 μM) in the mixed surface layer of the outer shelf near the 106-Mile Site occurred in August, as in the southeast mid-shelf region. Lowest observed surface layer values (around 0.1 μM) were also concurrent, occurring in April in both locations. Lowest ammonium bottom water concentrations at the outer shelf area were also around 0.1 μM (in July), with an observed maximum of 2.0 μM or more occurring in August corresponding to the surface layer maximum. Gradients in ammonium concentration associated with the Hudson River plume were observed at certain times of the year in vertical profiles along Transect 3, as reported by Waldhauer et al. (1980).

Data indicate that surface layer phosphate concentrations for the outer shelf adjacent to the 106-Mile Site ranged from 0.4 to 0.1 μM, with maxima occurring in September and April and a minimum in July (Figures 8, 10). Bottom water isopleths followed the same pattern as that of surface waters, with maxima of approximately 1 μM in April and September and a minimum of 0.6 μM in late June to early July (Figure 11).

Highest observed silicate levels in outer continental shelf and slope surface waters adjacent to the 106-mile site occurred in May when regional waters contained silicate concentrations of 6 μM or more. By July, values had dropped to below 1 μM. Observed bottom water values of silicate in this area peaked in June when the 10 μM contour line moved to 20 km west of the disposal site. Lowest observed bottom

water values occurred in March when the 1.5 μM contour occupied the June position of the 10 μM contour line.

4.5 DISCUSSION.

Nitrate data demonstrated the expected seasonal stratification of the water column throughout the surveyed area of the PAI, and the subsequent nitrate depletion of surface layers by phytoplankton during the summer months. Data indicate shoreward migration of nutrient-rich water from late summer through fall. The location of the 1 and 5 μM bottom nitrate isopleth positions varied shoreward-seaward up to 100 km from winter to summer during the sampling period (Figures 2, 3). These figures indicate large temporal variability in nutrients in shelf waters over the PAI.

Figures 12 and 13 indicate the seasonal cross sectional locations of the 1 μM NO_3, isopleth along Transects 3 and 2, respectively. Waters above and shoreward of the individual isopleths generally contain less than 1 μM NO_3, while those seaward and below the 1 μM isopleth locations have NO_3 concentrations of 1 μM or more. On Transect 3, between 140 and 150 km offshore, the 1 μM nitrate contour was found between 35 and 45 m and not below 50 m except during well-mixed spring conditions (Figure 12). During spring, the 1 μM isopleth passed through the 45 m level approximately 140 km seaward of the mouth of the Hudson River estuary but still exhibited a 20 km shoreward protrusion in the water column between 25 and 45 m, on an otherwise vertical orientation. On Transect 2, a similar semi-stratified distribution was observed, although not quite as distinct, with the 1 μM nitrate contour not dropping below the 40 m level seaward of the 110 km offshore position, usually being observed between 20 and 40 m (Figure 13). Again there was a small area, in this case from 100 to 120 km offshore and between 30 and 40 m deep, where the 1 μM contour was always observed, its location being somewhat shoreward and shallower than the one on Transect 3. A spring shoreward protrusion of the 1 μM nitrate contour of about 5 km was also observed between 25 and 40 m. These

shoreward-seaward migrations and the scale of the smallest area which always contained the 1 μM contour (10-20 km) are characteristic of the scale of movement reported by Wright (1972) for the seasonal change in location of the average bottom water position of the shelf/slope front.

The area of apparent nutrient temporal variability on the shelf south of Transect 2 seems to be less extensive than that north of the region (based on seasonal 1 and 5 μM contour locations, Figures 2 and 3). To the north, monthly nutrient contours move across a broader area of the shelf which exhibits a general northerly increase in width. This trend of northerly increasing spatial variation is also indicated in the temporal variation of the surface shelf water front (Ingham, 1976). Frontal influences therefore are suggested in these nutrient data and it appears that bottom waters in the mid-shelf region and west of the 106-Mile Site are strongly influenced by cross-shelf transport of slope water rich in nutrients.

Bottom water nitrate concentrations in the mid-shelf region southeast of the 106-Mile Site undergo significant variations over the course of a year. During the warmer summer months, a stratified water column develops over the site with a biologically-depleted surface layer. A tongue of nutrient-rich water can at the same time extend along the bottom of the shelf (as it did in August on Transect 2 southwest of the site; Figure 4) and up into the depleted surface layer. In winter, non-stratified well-mixed conditions exist, with an shoreward intrusion of nutrient-richer waters occurring below 20 m (Figure 4).

Bottom concentrations of nitrate on the outer shelf near the 106-Mile Site remain high year round, with the relative magnitude of seasonal change being smaller than over the more inshore mid-shelf area. In summer, a stratified water column and a nutrient-depleted surface layer develops. The depth of this depleted layer is somewhat greater than in the mid-shelf region (Figure 5) and

coincides with a deeper euphotic layer offshore (40 m for the water near the 106-Mile Site; 26 m for the mid-shelf area north of Transect 2 southwest of the 106-Mile Site.

Despite the formation of a nutrient-depleted surface layer, relatively high levels of primary productivity are sustained shelf-wide throughout the summer (O'Reilly and Busch, 1981). Stratification of the water column at this time of year would be expected to greatly reduce nutrient transport from nutrient richer bottom waters and replenishment of nutrient-depleted surface layers. During this period nutrient regeneration within the upper water column may therefore be crucial for the maintenance of phytoplankton stocks and productivity rates in the region. If this were the case, any activities affecting upper water column regenerative processes by directly interfering with these processes, or nutrient loading by increasing the supply of locally available nutrient species, would be expected to have an impact on phytoplankton abundance and production. At other times of the year when vertical mixing is not so impeded, or when upwelling and onshore movement of nutrient-rich deeper waters takes place, water mass transport may be the dominant process in influencing the quantities of nutrients available for assimilation by phytoplankton. Cross-shelf transport of bottom waters may then have a relatively greater influence on the productivity of the outer to mid-shelf region than it would have in the slope waters nearer the 106-Mile Site, where deeper water concentrations of some nutrient species remain relatively high throughout the year. In slope waters vertical mixing processes due to storms, ring passages, etc. could potentially resupply nutrient-richer waters to surface layers from deeper layers independent of any advection mechanisms. Inshore regions do not have this year-round deeper water pool for potential nutrient resupply. The presence of a permanent thermocline, which exists year-round in deeper slope waters at depths not less than 200 m, should retard any vertical movement of bottom slope nutrient-rich waters up into the warmed offshore surface layer. Examination of the larger data set

generated by NEFC's coastal surveys, and not yet fully processed, may permit the determination of the frequency of incidence and importance, if any, of offshore surface layer nutrient supply from nutrient richer waters above the permanent thermocline.

4.6 CONCLUSIONS.

Initial examination of inorganic nutrient data from the region west and southwest of the 106-Mile Ocean Waste Disposal Site indicates a high degree of temporal and spatial variability in concentrations of various nutrient species. Isopleths of bottom water nitrate concentrations over the mid- and outer shelf generally parallel isobaths shoreward of the site and exhibit large seaward-shoreward excursions over the course of a year. In summer, a thermally stratified water column develops with a surface layer, extending to the depth of the mean euphotic zone, becoming depleted of nutrients by phytoplankton activity. The relatively high levels of primary productivity sustained shelf-wide throughout the summer indicate that nutrient regeneration in the upper water column may be a crucial process in maintaining summer phytoplankton stocks and productivity rates. Any disposal activities affecting upper water column regenerative processes and/or the nutrient loading of this depleted surface layer may therefore have an impact on summer phytoplankton abundance and production levels. During winter and spring, the water column is well-mixed resulting in increased surface layer nutrient availability and a probable decreased relative dumping impact potential. Deeper water nutrient concentrations in waters just west of the 106-Mile Site remain high year round leading to the possibility of summer surface layer nutrient resupply by any vertical mixing processes independent of slope water advection mechanisms. Bottom waters of the shallower inshore areas of the shelf along the western extent of the PAI of the 106-Mile Site undergo relatively large seasonal changes. A significant portion of this variability seems to be due to cross-shelf transport of nutrient-rich slope water.

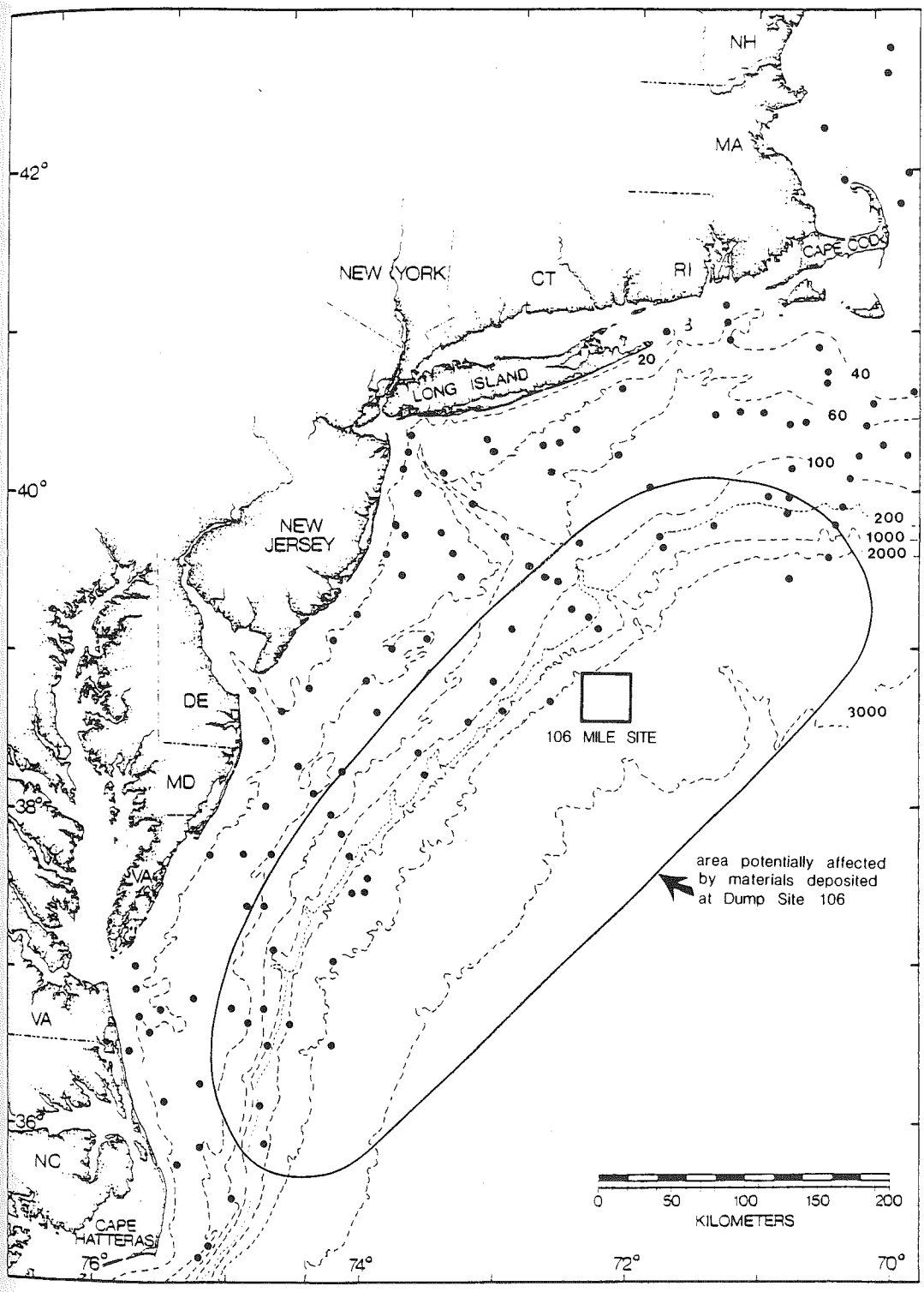


Figure 1. Distribution of station locations sampled between May 1979 and March 1980.

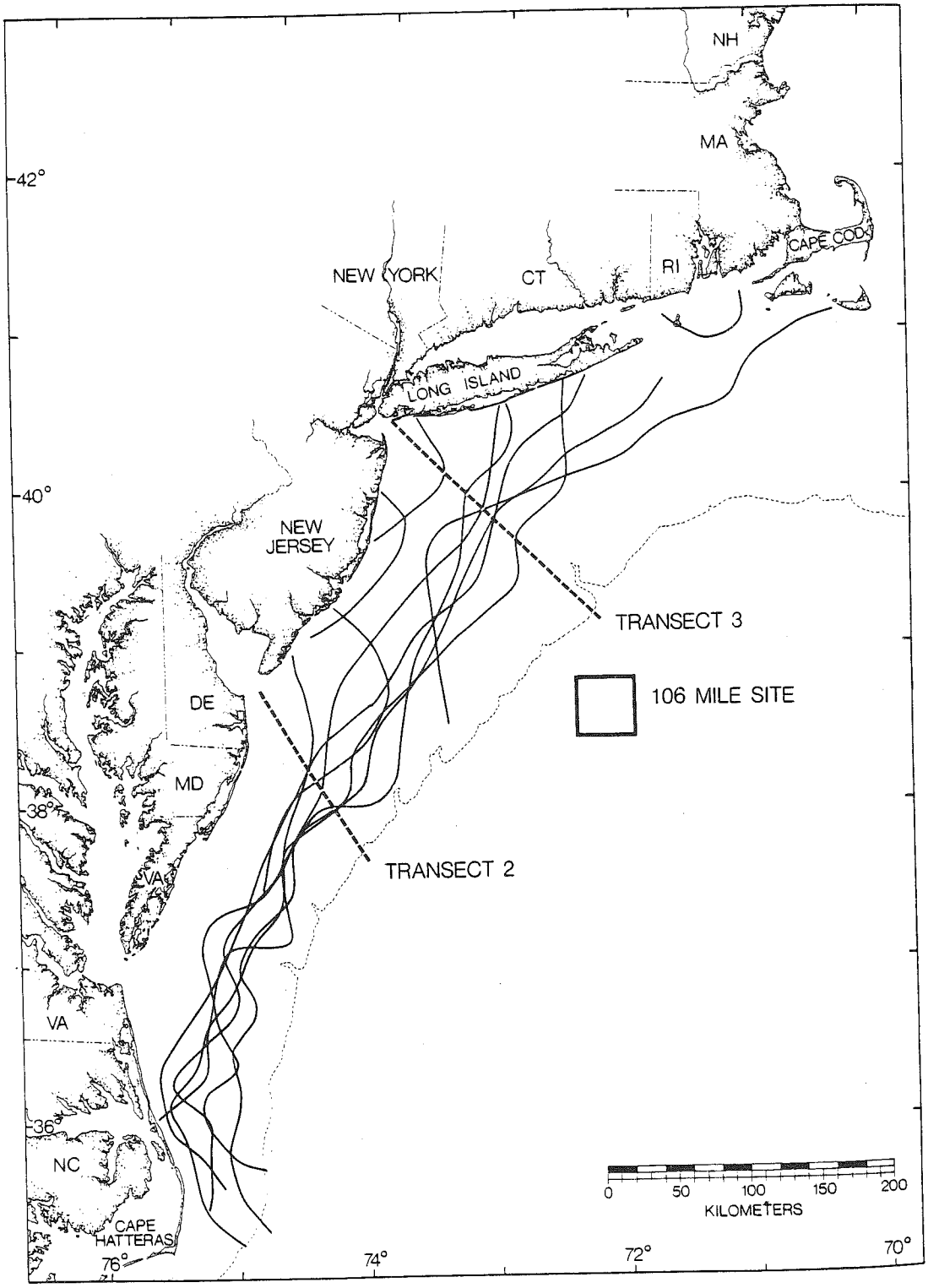


Figure 2. Locations of the 1 uM NO_3 bottom water contour, April 1979 to March 1980.

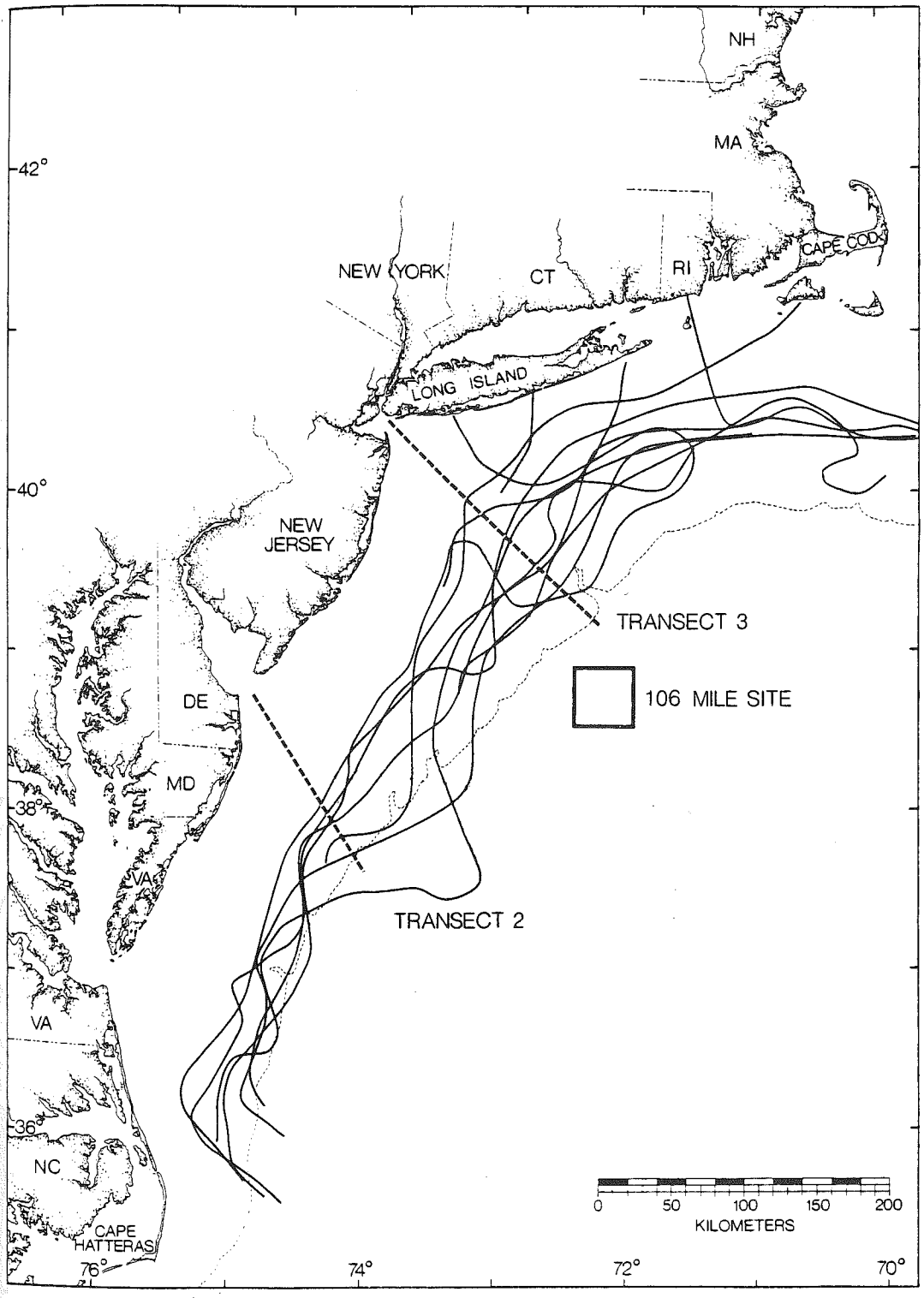


Figure 3. Locations of the 5 uM NO_3 bottom water contour, April 1979 to March 1980.

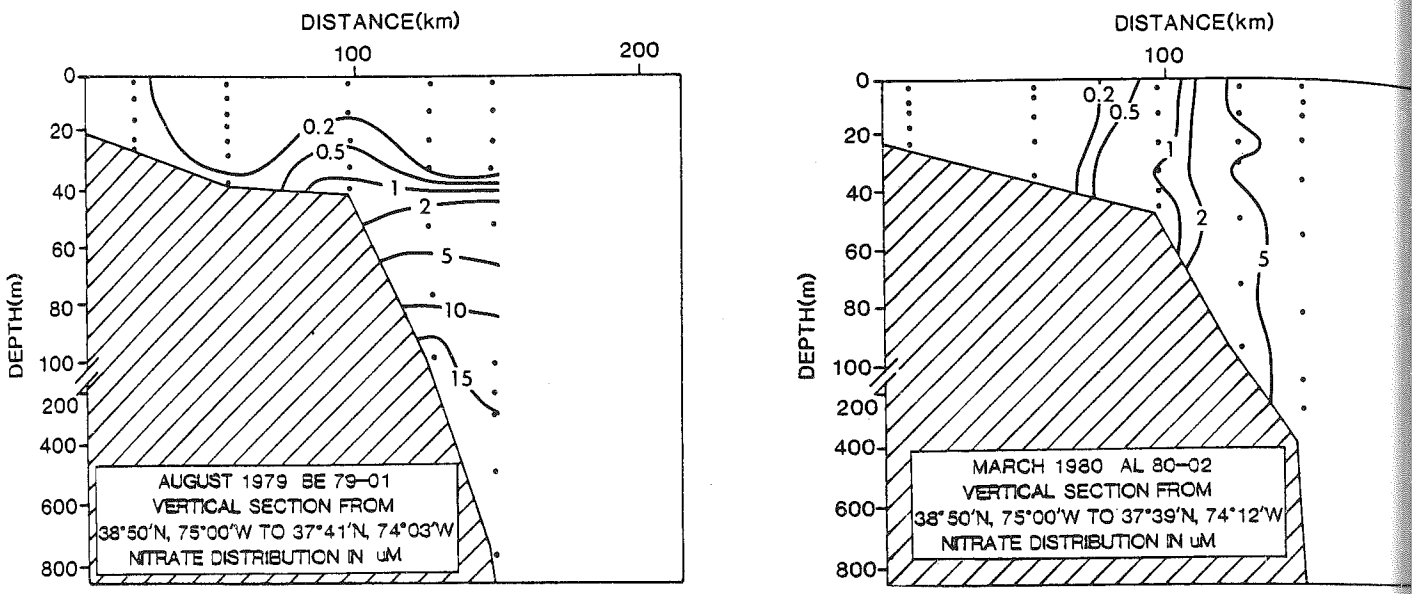


Figure 4. Cross-shelf profile of dissolved inorganic nitrate distribution along Transect 2.

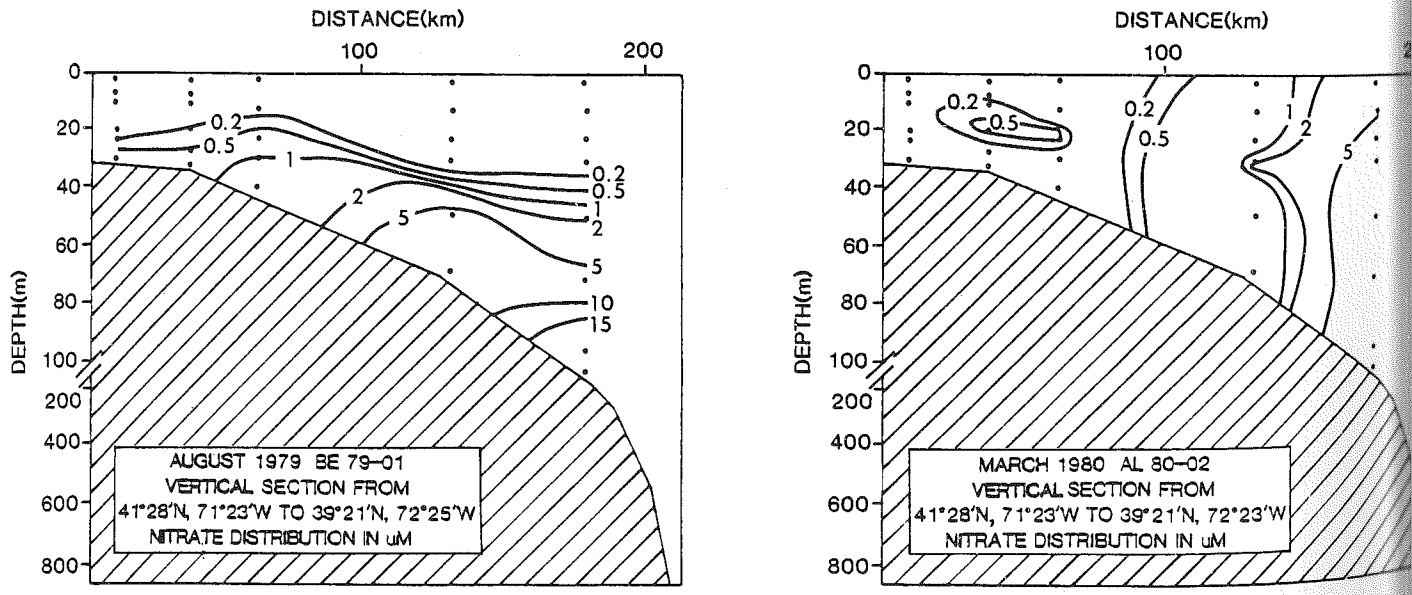


Figure 5. Cross-shelf profile of dissolved inorganic nitrate distribution along Transect 3.

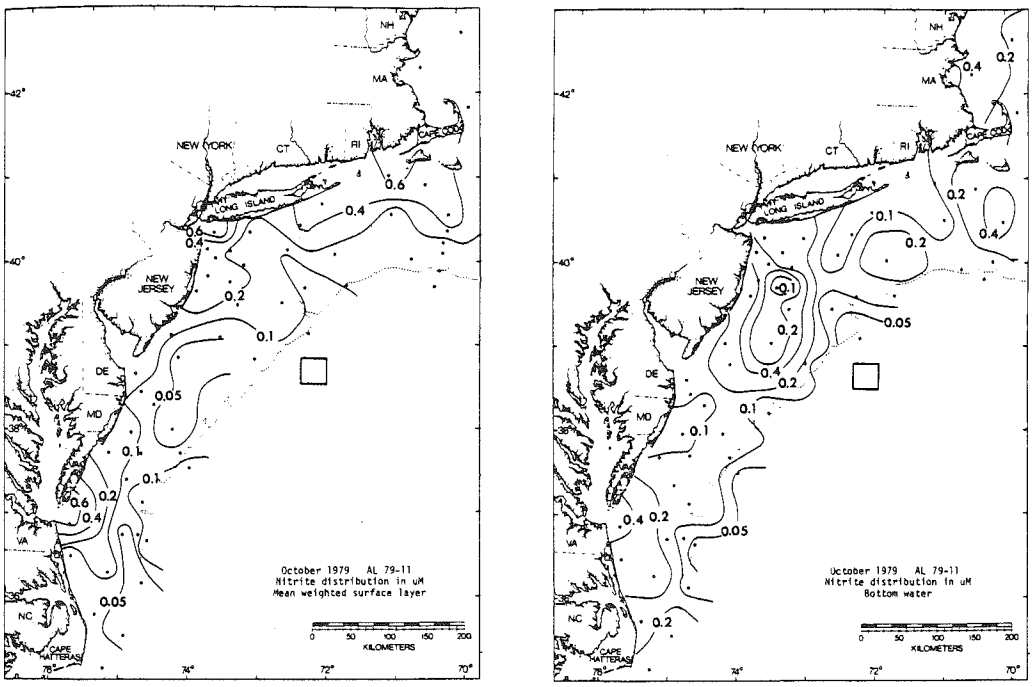


Figure 6. Distribution of dissolved inorganic nitrite in the mean weighted surface layer and bottom waters in October 1979.

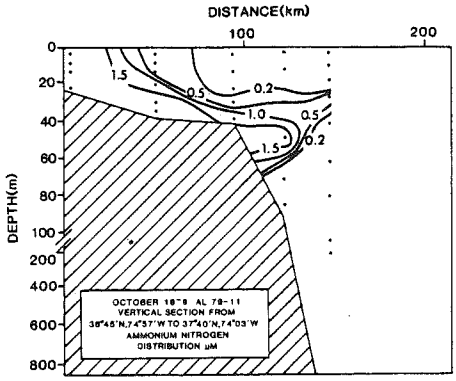


Figure 7. Cross-shelf profile of dissolved ammonium nitrogen along Transect 2, October 1979.

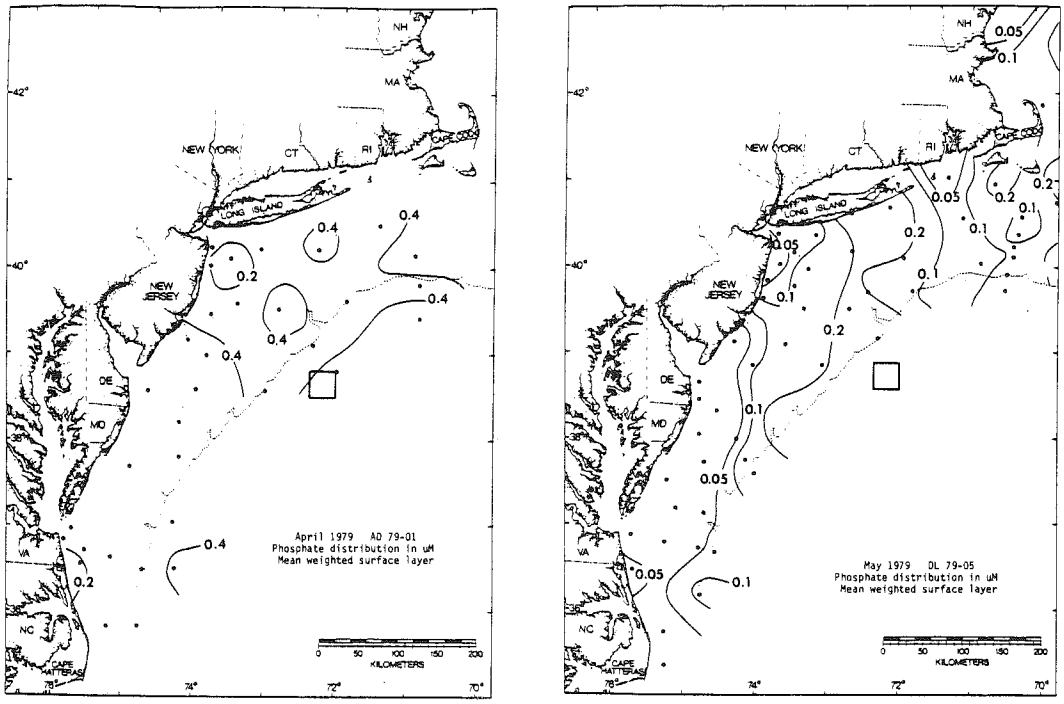


Figure 8. Distribution of dissolved inorganic phosphate in the mean weighted surface layer in April and May 1979.

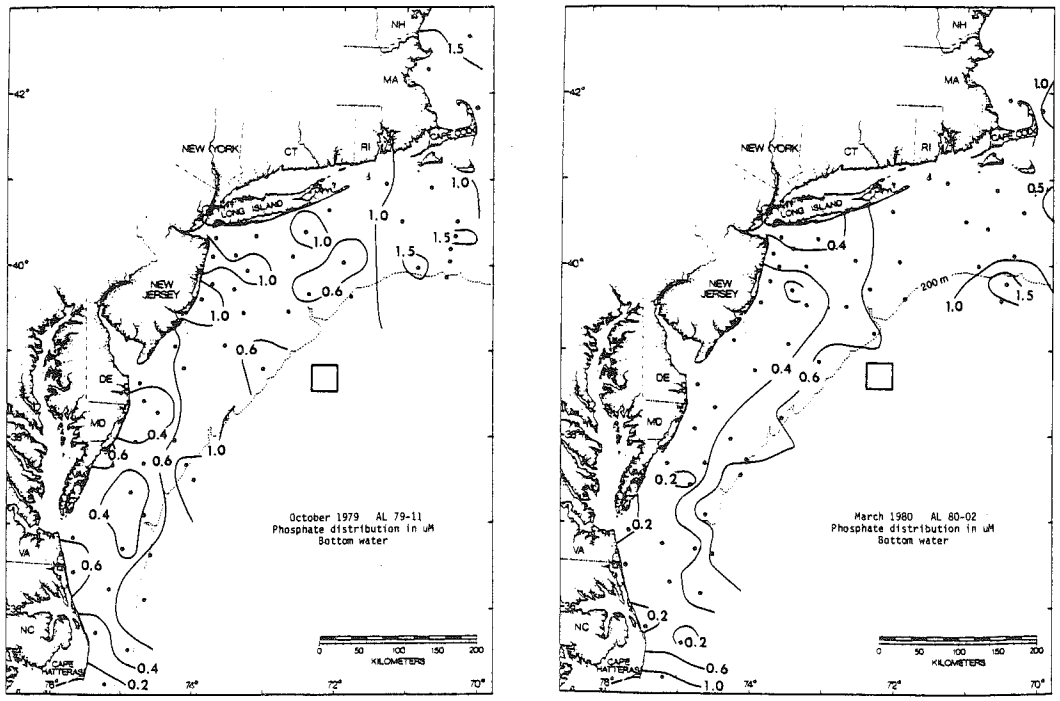


Figure 9. Distribution of dissolved inorganic phosphate in bottom waters in October 1979 and March 1980.

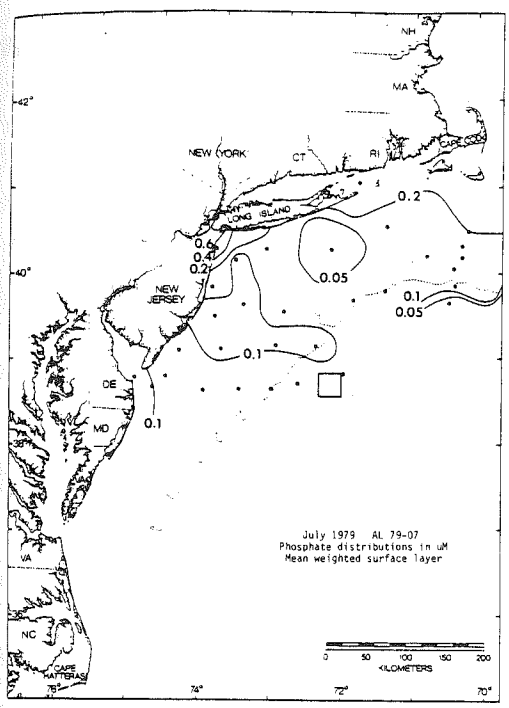
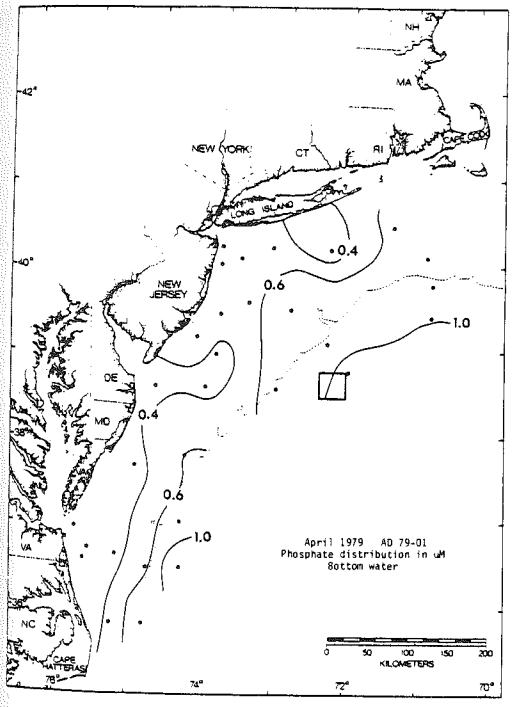


Figure 10. Distribution of dissolved inorganic phosphate in the mean weighted surface layer in July 1979.



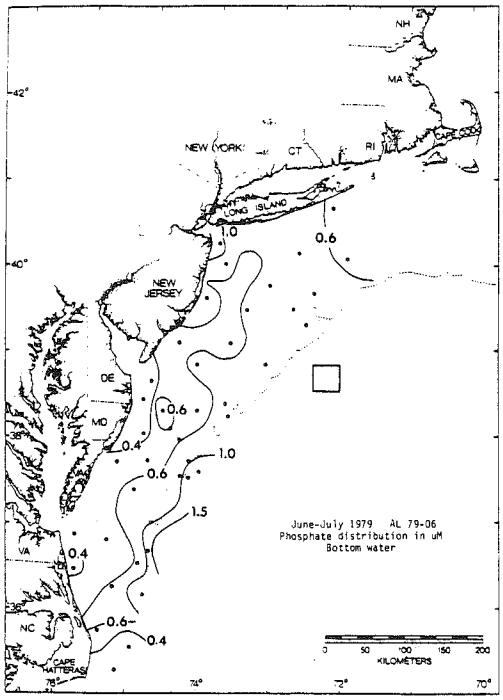
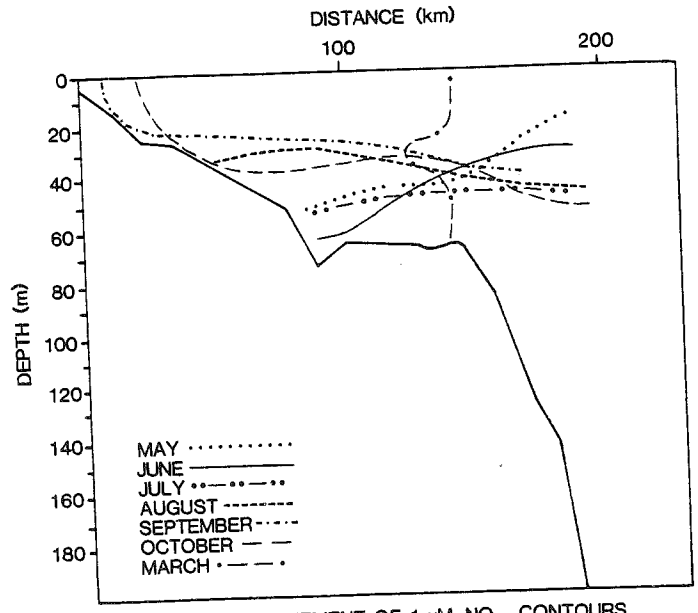
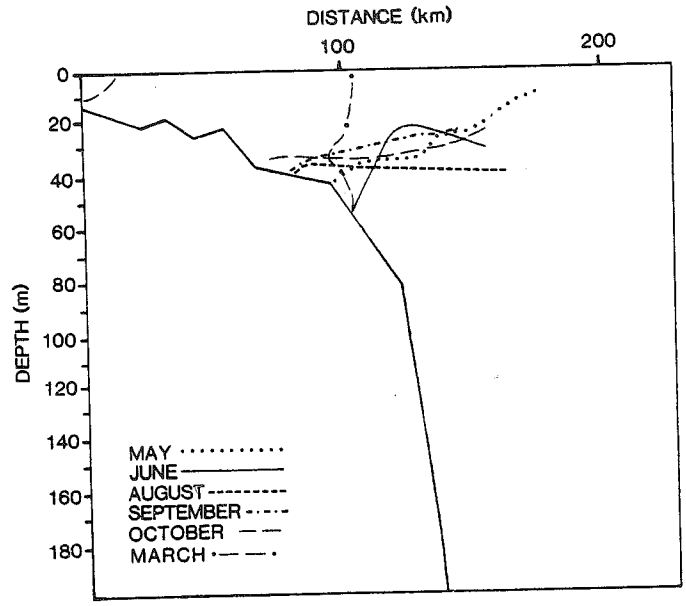


Figure 11. Distribution of dissolved inorganic phosphate in bottom waters in April and late June-early July 1979.



SEASONAL MOVEMENT OF 1 µM NO_3 CONTOURS ALONG TRANSECT 3

Figure 12.



SEASONAL MOVEMENT OF 1 µM NO_3 CONTOURS ALONG TRANSECT 2

Figure 13.

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CHAPTER 5. PHYTOPLANKTON BIOMASS AND COMMUNITY SIZE COMPOSITION

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5.1 INTRODUCTION.

The purpose of this chapter is to characterize the phytoplankton communities in slope and continental shelf water adjacent to the 106-Mile Ocean Waste Disposal Site (106-Mile Site) (Figure 1). The characterization of this site is based on chlorophyll a measurements, an index of phytoplankton biomass, made during 54 Northeast Fisheries Center surveys. Phytoplankton biomass and community size composition are examined. Phytoplankton are divided into netplankton (>20 um) and nannoplankton (<20 um) size fractions. Knowledge of the phytoplankton community size structure is "as important and probably more significant than total biomass in determining modes of transfer between trophic levels" (Steele and Frost, 1976).

Chlorophyll distribution is described for five regions which have been delinated by bathymetry. Regions 4 and 5 are within the potential area of influence (PAI) for the 106-Mile Site, with Region 4 representing the outer Middle Atlantic Bight (MAB) between 60 and 200 m, and Region 5, the slope seaward of the shelf break between 200 and 2000 m. Data collected over the MAB shelf between 0 and 60 m are also included so that trends in the PAI can be compared with trends in adjacent mid-shelf and inshore waters. The shoreward regions are designated as 1, 2, and 3, and represent the areas between 0-20, 20-40, and 40-60 m, respectively (Figure 1). No NMFS data are available for waters east and south of the dumpsite; therefore, these areas will not be described.

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5.2 METHODS.

Water samples for phytoplankton pigment analysis were collected on 54 cruises from October 1977 through March 1982 as part of an extensive ongoing monitoring and assessment program to characterize the principal biological components of the ecosystem over the northwest Atlantic continental shelf from Cape Hatteras to Nova Scotia. Generally, at each sampling location water for pigment analysis was collected from standard depths of 1, 5, 10, 15, 20, 25, 30, 35, 50 and 75 m or bottom, whichever came first. After spring 1980, 100 m sampling depth was added and routinely sampled.

Aboard the research vessel samples were size-fractionated into netplankton (>20 um) and nannoplankton (<20 um) and analyzed for chlorophyll a (chla) using the fluorometric method described in Evans and O'Reilly (in press). The chlorophyll concentration in the two size fractions was added to generate an estimate of the total chlorophyll a found at each depth sampled. The weighted water column average of total chlorophyll a (arithmetically integrated chla/deepest depth sampled) was calculated for each station sampled and then contoured using SYMAP program (version 5, Harvard Center for Environmental Design Studies, Laboratory for Computer Graphics and Spatial Analysis).

Data collected in each area from all six years sampled were pooled by month so that the general features of the annual cycle of phytoplankton abundance (chlorophyll a) could be described. (January data for Regions 3 and 5 have not been included in statistical summaries since the number of samples was small.) A weighted average chlorophyll a (mg/m^3) value was determined for each station occupied. The weighted averages for total chlorophyll a, netplankton chlorophyll a and nannoplankton chlorophyll a were arithmetically averaged by month for the entire water column for each region. The total amount of chlorophyll a found in the water column as well as the chlorophyll a (mg/m^3) in the netplankton size-fraction and in the nannoplankton size fraction for each

region were graphed by month to get an understanding of phytoplankton abundance and community structure throughout the year. The percentage of the total community chlorophyll a contributed by nannoplankton was determined by dividing chlorophyll a measured in the nannoplankton size fraction by total chlorophyll a. The coefficient of variability (standard deviation x 100) was calculated for each region.

5.3 RESULTS AND DISCUSSION.

5.3.1 Biomass Distribution over the Middle Atlantic Bight Shelf

Phytoplankton biomass (mg chla/m^3) is distributed over the shelf in a well-defined pattern. A gradient exists with high biomass concentrations inshore (Region 1) and low concentrations offshore (Region 5) (Figures 2, 3, and 4). This pattern is present throughout the year with variations occurring in the magnitude of biomass present. The estimates of the average annual biomass (excluding January in Regions 3 and 5) for Regions 1-5 are 4.37, 2.26, 1.60, 0.94, 0.63 mg chla/m^3/yr, respectively, and support the generalization that phytoplankton biomass decreases from the shallow to the deeper areas of the MAB shelf. Despite the seven-fold decrease in biomass concentration from nearshore to slope water, the overall month-to-month variability within each of the five regions was similar (coefficient of variability was 40, 42, 59, 48, and 52 for Regions 1-5, respectively).

The onshore to offshore pattern of decreasing phytoplankton biomass seen in our data set is supported by Smith (1973) and Forns (1977). Smith reported an onshore to offshore decrease in standing stocks in the Middle Atlantic Bight. Forns reported a relationship between species abundance and bottom depth when examining the shelf off Delaware.

In the Middle Atlantic Bight, the monthly distribution of biomass was bimodal with highest biomass concentrations found in the spring (all regions) and secondary maxima found between November and December (all regions). Additional maxima were seen in August and September in the inshore Regions 1 and 2. The lowest biomass concentrations were found during late spring and early summer at the onset of thermal stratification. In Regions 1 and 2, the lowest biomass concentrations occurred in May. In Regions 3, 4, and 5 biomass concentrations were relatively low from May through October.

The annual cycle of biomass reported in this study is supported by data collected over the outer shelf and slope in the New York Bight in 1957 (July, September, and November) and 1958 (January) (Yentsch, 1977). Surface biomass concentrations (highs averaging 3.25 mg chl$\underline{a}$/m^3) were measured during November and correspond to the secondary maxima observed in our data set during this time period. The lowest values averaging roughly 0.40 mg chl$\underline{a}$/m^3 were observed by Yentsch during July and correspond to low concentrations observed during the summer stratified season in the present study. Yentsch (1977) did not sample between February and April and consequently the major spring maxima was not observed. Shilling (1981) reported a primary spring bloom and secondary fall bloom when discussing the Mid-Atlantic shelf.

Netplankton strongly dominated phytoplankton biomass in all regions during the February to March spring bloom. Malone (1976) in a study of the New York Bight apex, found the nearshore area adjacent to the mouth of the Hudson-Raritan estuary in March was strongly dominated by netplankton. During the November to December secondary bloom netplankton and nannoplankton were present in near equal amounts. Netplankton slightly dominated during the November to

December secondary bloom in Regions 1-4 (shelf) while nannoplankton slightly dominated in Region 5, over the slope (Figures 2 and 4).

On an annual basis, there is an onshore to offshore trend in phytoplankton community size composition. The percentage of the annual biomass in the nannoplankton size fraction was 46, 42, 44, 52, and 63% in Regions 1 through 5, respectively. Netplankton were slightly dominant in Regions 1, 2, and 3, whereas nannoplankton were slightly dominant in the outer shelf Region 4 and clearly dominant in Regions 5, over the slope.

In general, biomass (mg chl*a*/m^3) contributed by the netplankton and total biomass paralleled each other. The percentage of nannoplankton in the community varied inversely when compared to total chlorophyll. Over the year, variability among monthly biomass averages was greater among netplankton than nannoplankton. The coefficient of variability for netplankton was 55, 60, 71, 91, and 113 for Regions 1-5, respectively. Variability among monthly averages increased with depth. In each region, the coefficient of variability for nannoplankton was lower than for netplankton. The coefficient of variability for nannoplankton in Regions 1-5 was 35, 28, 29, 14, and 28, respectively.

The general pattern of onshore to offshore decrease in total biomass is also present in the netplankton and nannoplankton data. Mean annual netplankton biomass concentrations decreased from 2.34 mg chl*a*/m^3 in Region 1 to 0.22 mg chl*a*/m^3 in Region 5. Nannoplankton concentrations decreased from 2.03 mg chl*a*/m^3 (Region 1) to 0.36 mg chl*a*/m^3 (Region 5).

5.3.2 Region 1 (0-20 m)

Distribution of biomass over the yearly cycle was bimodal. The highest biomass concentrations (7.44-7.23 mg chl*a*/m^3) were found during the January-February period in the unstratified season. Broad secondary peaks were observed during September (4.97 mg chl*a*/m^3) and during fall bloom in November and December (4.78 and 4.34 mg chl*a*/m^3, respectively). Generally, biomass concentrations exceeded 3.00 mg chl*a*/m^3 except during those months when stratification was present (May, June, and July) when the lowest values 1.75, 2.76, and 2.74 mg chl*a*/m^3 were observed. Biomass concentrations clearly reached their low point in the annual cycle in May (Figures 2, 4; Table 1).

Netplankton dominated the communities throughout most of the year. They accounted for 71% of the standing stock during the February spring bloom and for between 55 and 62% of the standing stocks the remainder of the year except during May, June, July, and September when nannoplankton were dominant and accounted for 51-67% of the community biomass. In general, netplankton were dominant during the unstratified season (strongly in February, weakly the remainder of the season) and nannoplankton dominated the stratified season. Netplankton accounted for 54% of the annual biomass and were dominant eight out of 12 months.

Biomass concentrations in Region 1 were consistently higher than those in all other regions throughout the year (Figures 2, 4). The lowest concentration (1.75 mg chl*a*/m^3) observed in this region was higher than the maximum (1.43 mg chl*a*/m^3) observed during spring bloom in Region 5 and was close to the maximum (2.12) observed in Region 4.

5.3.3 Region 2 (20-40 m)

The annual cycle of biomass in Region 2 follows the general bimodal pattern seen throughout the shelf. Averaged biomass conentrations were highest (3.84 mg chl*a*/m^3) during the February "spring bloom". During the secondary November to December fall bloom, concentrations averaged 2.96 and 3.38 mg chl*a*/m^3, respectively. A relatively high biomass conentration was also seen in August (2.10 mg chl*a*/m^3). Biomass concentrations were relatively low during late spring and summer months of April, May, June, and July with biomass concentrations averaging 1.46, 1.05, 1.34, and 1.56 mg chl*a*/m^3, respectively (Table 1).

As in Region 1, netplankton were responsible for greater than 50% of the total annual biomass. They dominated seven of the 12 months accounting for 58% of the annual biomass, and again, as in Region 1 were slightly dominant over nannoplankton on an annual basis. Spring (February), fall (November-December), and late summer (August) maxima were all dominated by netplankton. As in Region 1, netplankton were strongly dominant during the February spring bloom accounting for 77% of the biomass. During the November-December fall bloom, netplankton and nannoplankton were present in near equal amounts, although netplankton were slightly dominant accounting for 54 and 60% of the biomass, respectively. Both February and November-December peaks were associated with the unstratified season.

The "summer maxima" observed in Region 2 differed in time and size composition from the summer maxima in Region 1. In Region 2 the maxima was predominately netplankton-dominated in August, yet this was less prominent than the maxima observed during "spring" and "fall" blooms. In Region 1, the summer maxima was observed in September and nannoplankton-dominated, and was comparable in magnitude to

the November to December maxima. No summer maxima were observed in Regions 3, 4, and 5.

5.3.4 Region 3 (40-60 m)

Biomass concentrations in Region 3 were distributed in a bimodal pattern (Figure 2). The highest concentration of biomass (3.35 mg chl$\underline{a}$/m^3) was found in March during spring bloom. Again, a secondary bloom was observed in the fall during November and December with biomass concentrations averaging 1.98 and 1.76 mg chl$\underline{a}$/m^3, respectively. No peak was observed during summer.

Low concentrations of biomass were observed from May through September. The lowest concentration (0.82 mg chl$\underline{a}$/m^3) was observed in May. From June through September, biomass concentrations averaged roughly 1 mg chl$\underline{a}$/m^3.

Over the year (excluding the two observations in January), biomass concentrations in the nannoplankton size fraction did not exceed 0.83 mg chl$\underline{a}$/m^3. Netplankton concentrations exceeded 1 mg chl$\underline{a}$/m^3 only during "bloom periods" and generally remained below 0.85 mg chl$\underline{a}$/m^3 during the remainder of the year. Netplankton and nannoplankton were present in near equal quantities throughout most of the year but netplankton were often slightly more dominant than nannoplankton. In March during spring bloom, netplankton were strongly dominant and accounted for 70% of the averaged biomass. Over the annual cycle netplankton accounted for 56% of the total biomass.

5.3.5 Region 4

Total biomass concentrations were distributed bimodally in Region 4. As in Region 3, the higher standing stocks were found in March during spring bloom and during the November

to December peak. Averaged concentrations during these months were 2.12, 1.01, and 1.22 mg chl*a*/m^3, respectively (Figures 2, 4; Table 1). As in Region 3, the spring bloom was dominated by netplankton (accounting for 75% of biomass) and the fall bloom was slightly dominated by netplankton.

The lowest concentrations of biomass were present during the stratified season from May through September and in October. Nannoplankton clearly dominated the community during this time period, accounting for between 65 and 74% of the total biomass. This differs from Region 3 where netplankton and nannoplankton were present in near equal quantities during this time period.

Over the year, nannoplankton concentrations were farily consistent, ranging from 0.41-0.62 mg chl*a*/m^3. Netplankton concentrations were not as consistent over the annual cycles as those of the nannoplankton size fraction. They generally ranged between 0.14 and 0.69 mg chl*a*/m^3, with the exception of March, when netplankton concentrations reached 1.59 mg chl*a*/m^3. Concentrations less than 0.25 mg chl*a*/m^3 were observed during the summer and early fall stratified season.

Nannoplankton slightly dominated the averaged annual biomass in Region 4, accounting for 52% of the total biomass. This stands in contrast to Regions 1, 2, and 3 where netplankton were slightly dominant on an annual basis.

When averaged total biomass are considered on a monthly basis, Region 4 (outer shelf) concentrations were always lower than those observed in Region 3, and higher than those in Region 5 (slope). This pattern was also observed with monthly averages for netplankton and nannoplankton fractions.

5.3.6 Region 5

In Region 5, as in Regions 3 and 4, monthly biomass concentrations were distributed in a bimodal pattern over the year with the higher chlorophyll a concentrations occurring during March (1.43 mg chla/m^3) and November to December (0.82 and 0.76 mg chla/m^3, respectively. Over the yearly cycle, nannoplankton were dominant, accounting for 63% of the total annual biomass. However, the spring bloom, as in all other regions, was dominated by netplankton which accounted for 68% of the total average biomass. The fall bloom was slightly nannoplankton dominated (56%).

The lowest biomass concentrations were found over the slope during the stratified season from May through September, and in October. These monthly low values ranged from 0.35-0.61 mg chla/m^3 and averaged 0.54 mg chla/m^3. As in Region 4, nannoplankton dominated the stratified season accounting for 80% of the biomass during this time period.

Considering the yearly cycle, total chlorophyll a and nannoplankton chlorophyll a concentrations in Region 5 were consistently lower than those found in Region 4. Monthly nannoplankton averages ranged from 0.27 to 0.65, with an average of 0.39 mg chla/m^3. Average chlorophyll a in netplankton ranged from 0.04 to 0.36 mg chla/m^3, averaging 0.16 for all months except March when biomass concentrations reach 0.97 mg chla/m^3 during spring bloom.

5.4 CONCLUSIONS.

This chapter provides a description of the phytoplankton community in waters over the slope and continental shelf adjacent to the 106-Mile Site. Average water column chlorophyll a estimates from 54 cruises spanning the period of October 1977-March 1982 were pooled by area and month, irrespective of year, to form a synthetic year

of averaged water column biomass estimates. The area potentially affected by material dumped at the 106-Mile Site was divided into two subareas to examine chlorophyll distribution: 1) the slope, the area seaward of the shelf break between 200 and 2000 m, and 2) the outer shelf (the area approximately between 60 to 200 m). NMFS phytoplankton data are not available for the region beyond the 2000 m isobath. Additionally, to put the information for the slope and outer shelf in perspective, data collected over the remainder of the shelf were also examined. These additional subareas on the shelf were defined by bathymetry (0-20, 20-40, and 40-60 m).

The annual cycle of biomass was generally bimodal in all five regions examined. The highest biomass concentrations over the entire shelf were consistently observed during the spring bloom during February (depths <40 m) and March (depths >40 m). The lowest concentrations were consistently observed during the stratified season. This occurred in waters <60 m (Regions 1, 2, and 3). At depths >60 m (Regions 4 and 5) corresponding to outer shelf and slope, biomass concentrations were consistently low from May through October. A secondary peak in biomass was observed during November and December across the entire shelf. Additional peaks of abundance were also observed in late summer for the two nearshore regions; during September, at depths <20 m and in August at depths between 20-40 m.

A recurring gradient in biomass concentration was observed with the monthly and annual chlorophyll a averages. Highest biomass concentrations were inshore (0-20 m) and the lowest were found at depths >200 m (Region 5).

Phytoplankton community size composition varied over the year. Netplankton strongly dominated the February-March spring bloom over the entire shelf generally accounting for 70% of the standing stocks. In contrast, nannoplankton generally dominated communities during the mid-year stratified periods when biomass concentrations were at a low. During the fall bloom, netplankton and

nannoplankton contributed to the phytoplankton community biomass in near equal amounts. In waters less than 200 m (Regions 1-4) netplankton slightly dominated the fall bloom, while in water >200 m (Region 5) nannoplankton slightly dominated but these differences are probably not of statistical significance.

At depths <60 m (Regions 1-3) netplankton were slightly more abundant than nannoplankton over the annual cycle. Nannoplankton were slightly more abundant between 60-200 m and nannoplankton clearly dominated the annual biomass at depths >200 m.

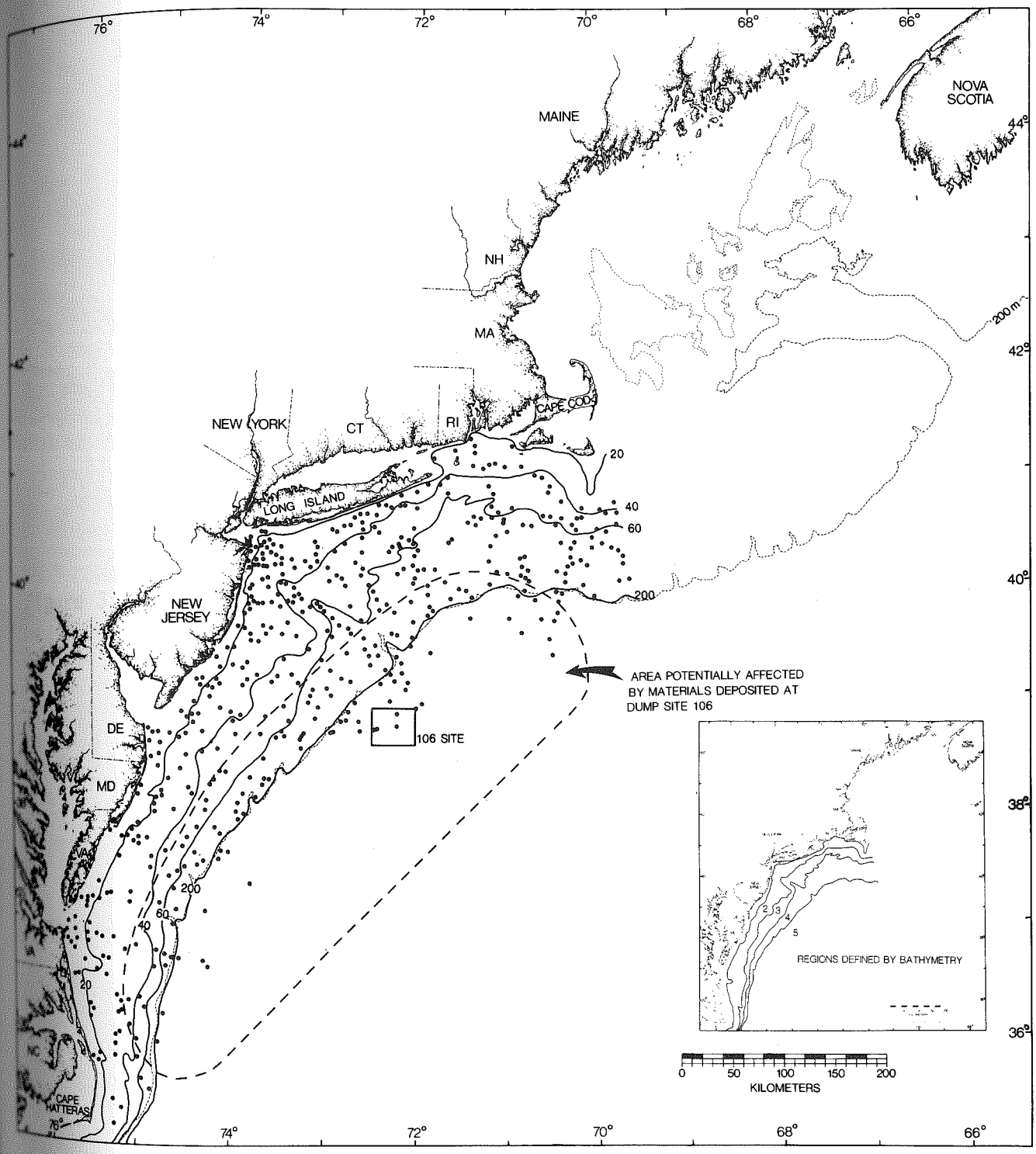


Figure 1. Sampling locations and regions defined by bathymetry.

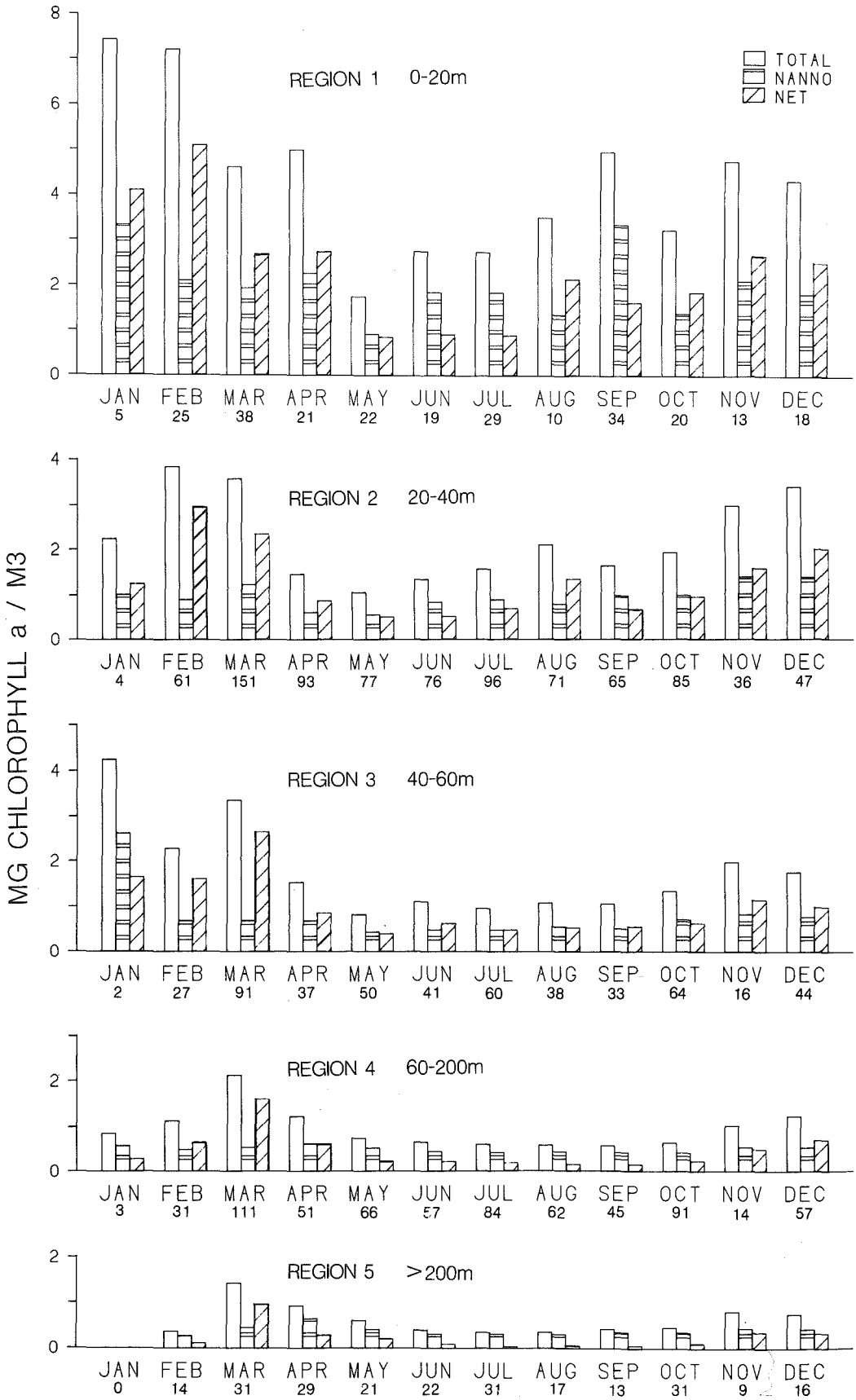
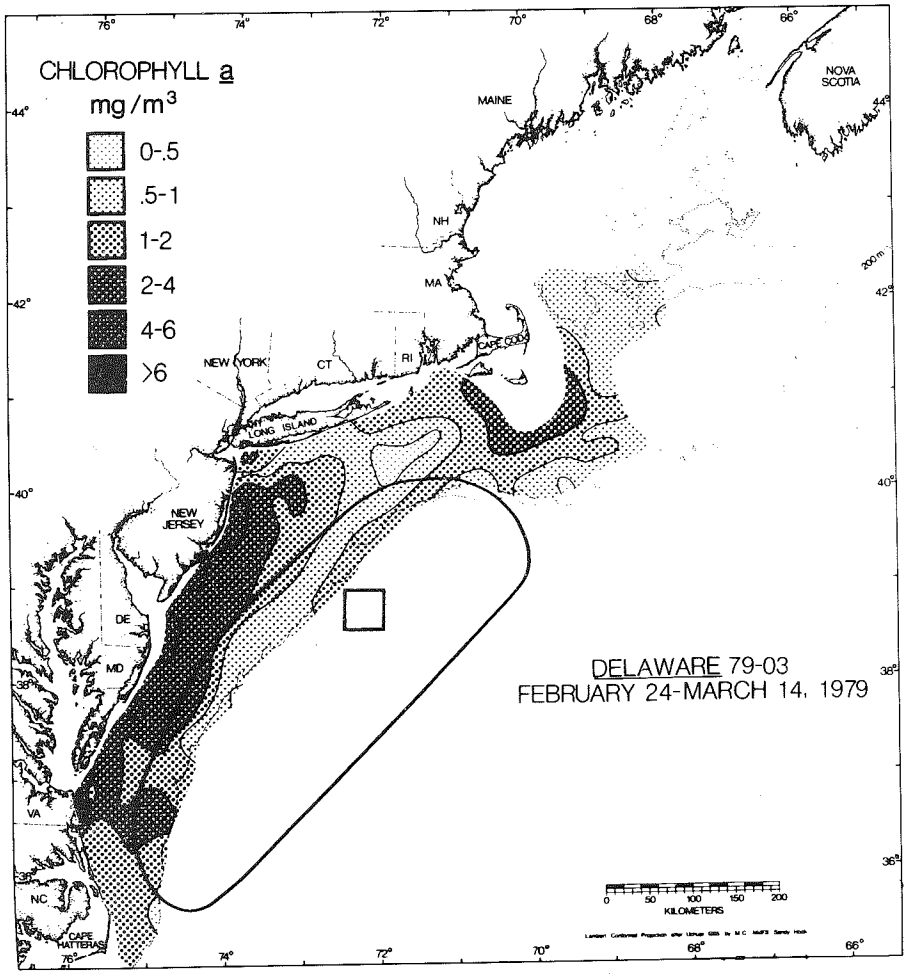


Figure 2. Average monthly chlorophyll a in five bathymetrically defined regions of the Middle Atlantic Bight.

Figure 3. Distribution of chlorophyll a (mg/m^3) during eight months of the year.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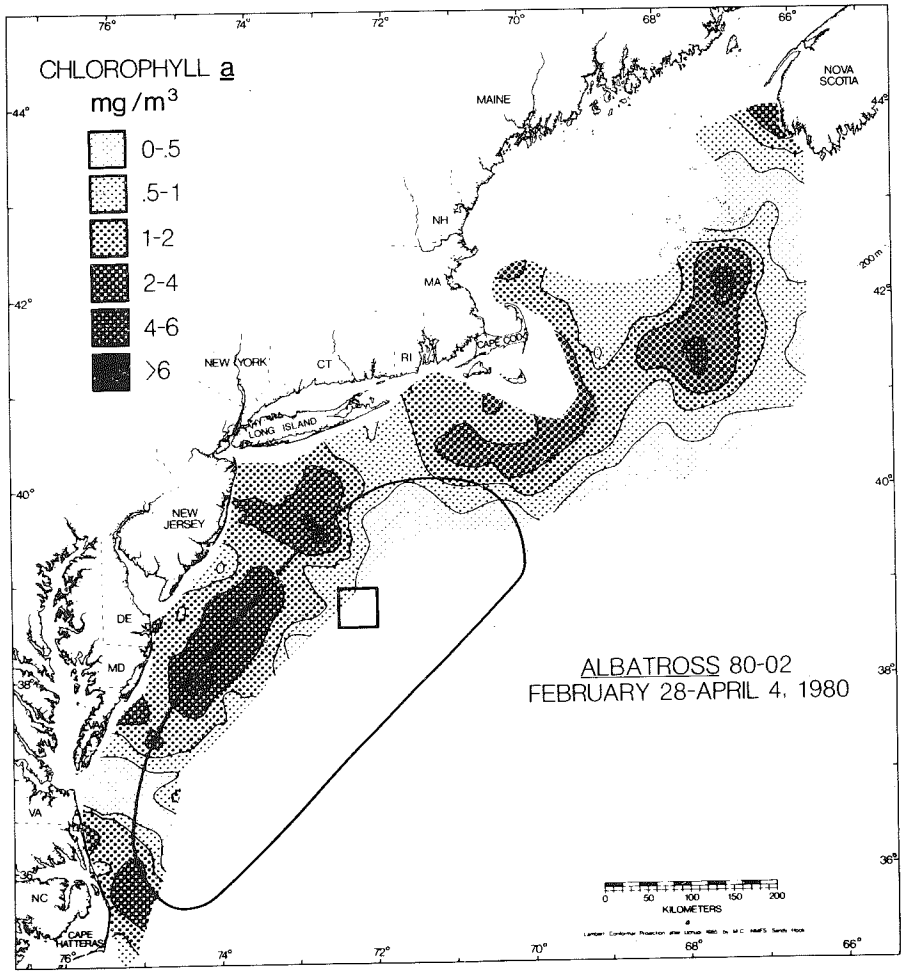
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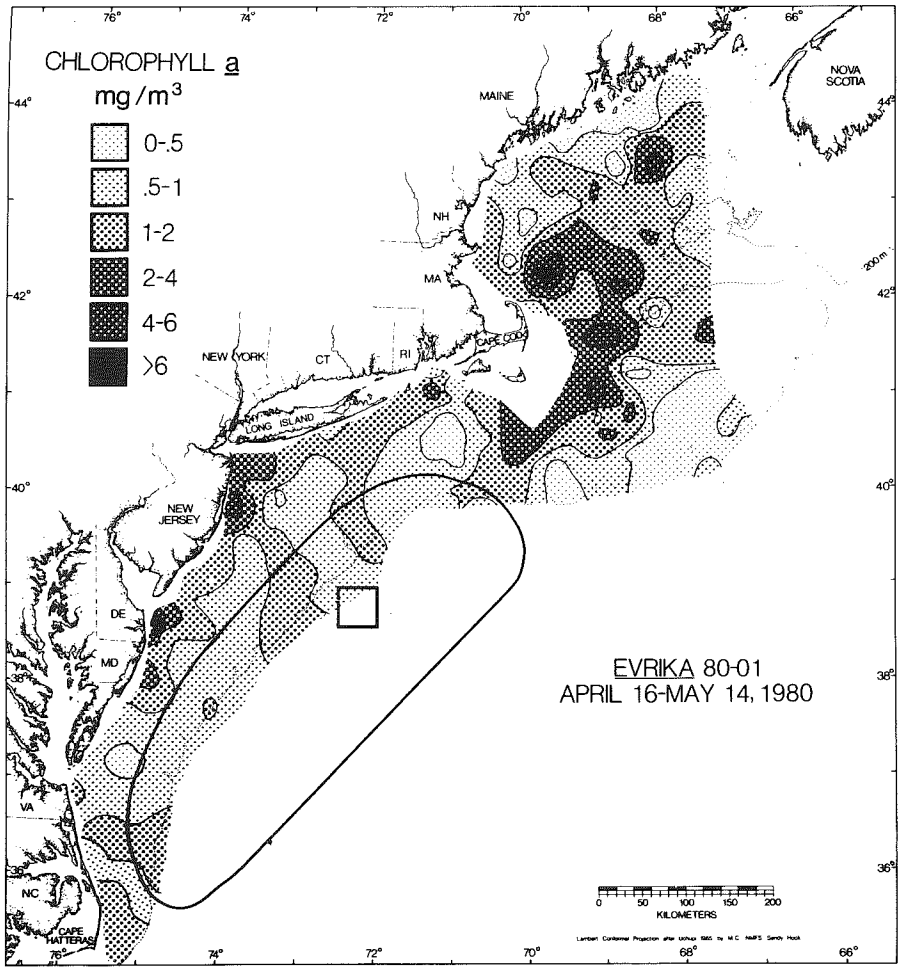
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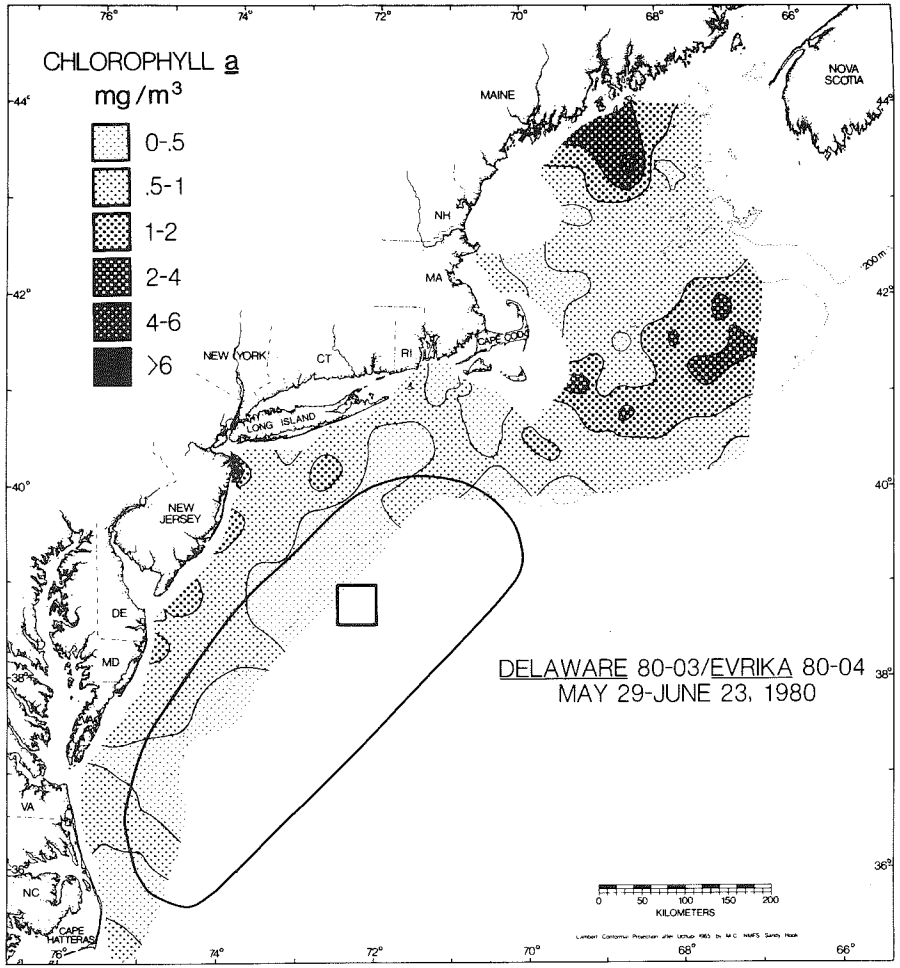
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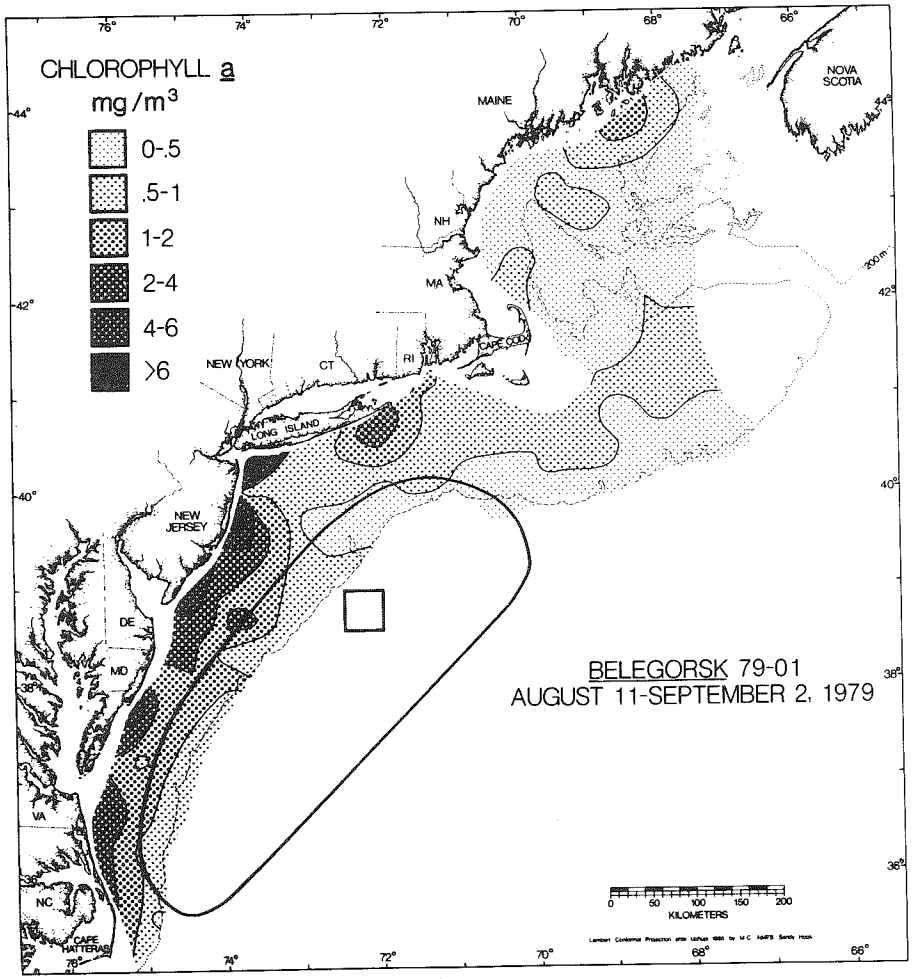
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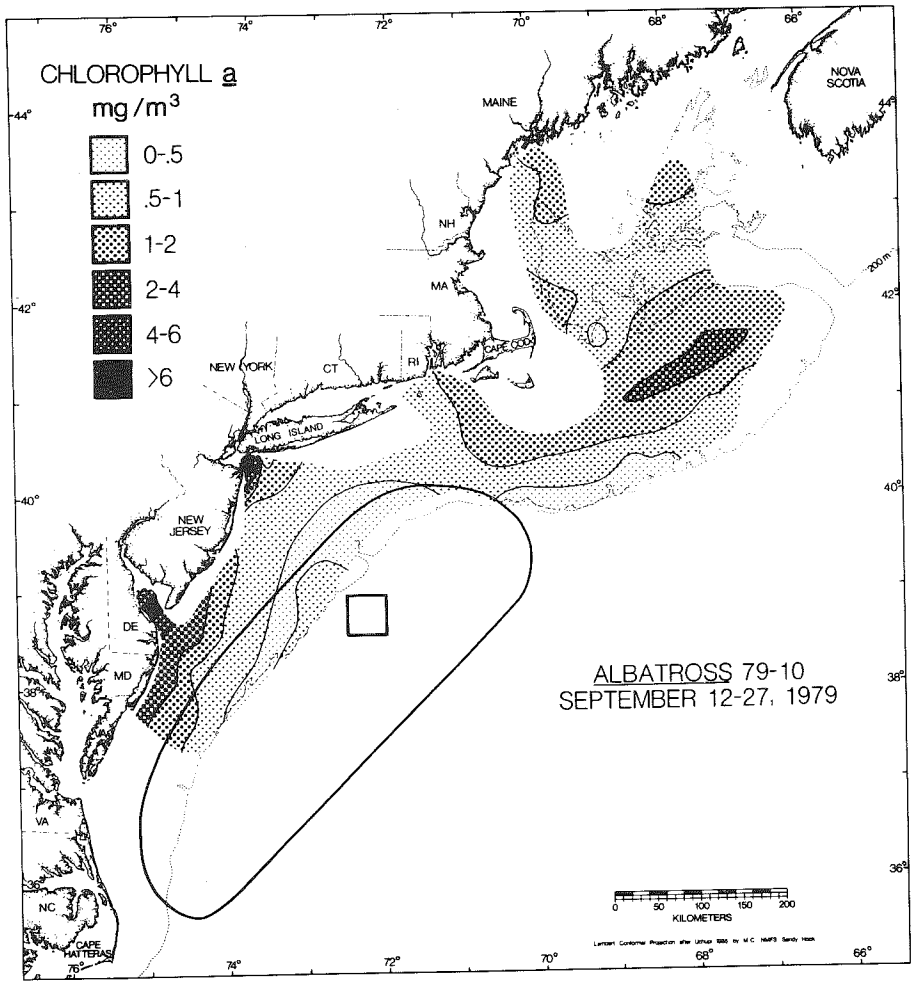
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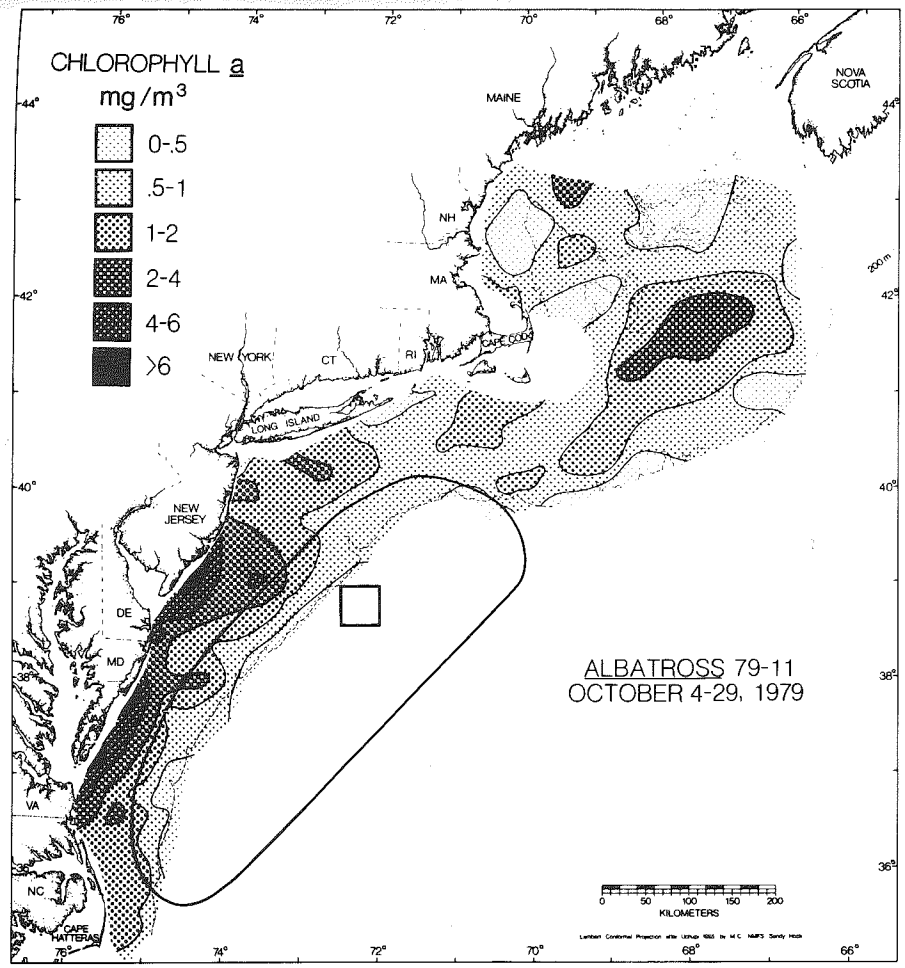
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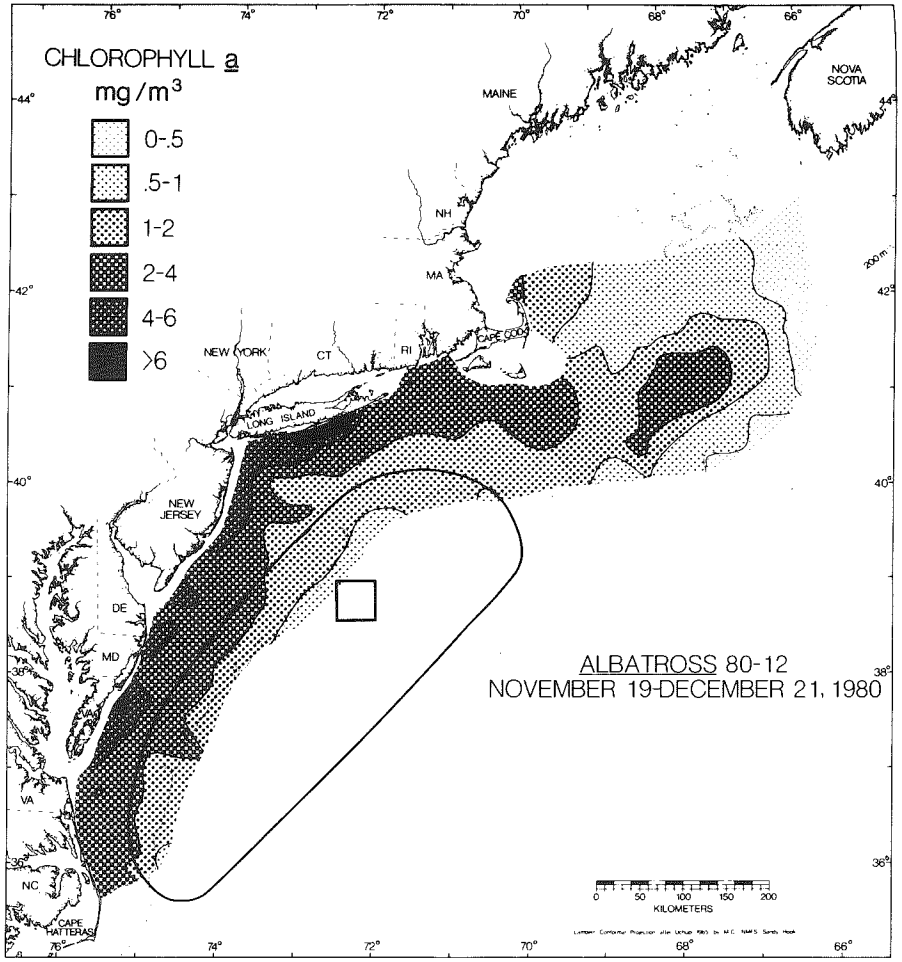
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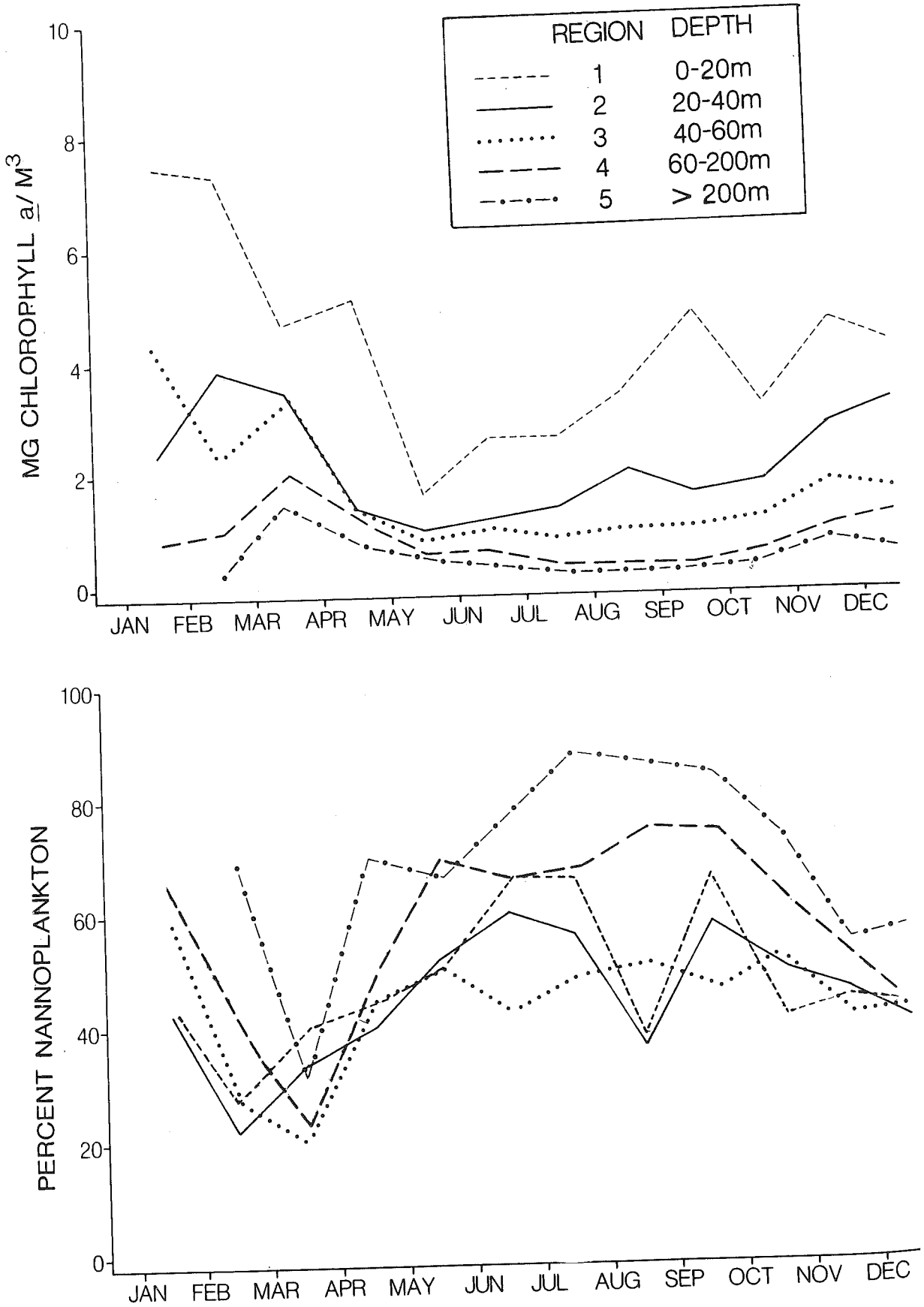

Figure 4. Averaged community biomass (mg chl$\underline{a}$/m^3) and community composition (percent nannoplankton) plotted by month for five regions of the Middle Atlantic Bight.

Table 1. Monthly average[1] chlorophyll a concentration[2] and percent nannoplankton[3] in five Middle Atlantic Bight strata adjacent to the Deepwater Dumpsite 106.

	0 - 20 M				20 - 40 M				40 - 60 M				60 - 200 M				200 - 2000 M			
MONTH	CHLA[4]	STD[5]	%NAN[6]	N[7]	CHLA	STD	%NAN	N	CHLA	STD	%NAN	N	CHLA	STD	%NAN	N	CHLA	STD	%NAN	N
JANUARY	7.44	3.34	44	5	2.24	0.86	44	4	4.25	0.88	61	2	0.83	0.02	67	3	0.00	0.00	0	0
FEBRUARY	7.23	4.28	29	25	3.84	2.81	23	61	2.28	1.49	29	27	1.11	0.73	43	31	0.37	0.20	71	14
MARCH	4.64	3.27	41	38	3.58	2.48	34	151	3.35	2.11	20	91	2.12	1.63	25	111	1.43	1.27	32	31
APRIL	5.01	5.39	45	21	1.46	1.31	40	93	1.53	1.49	44	37	1.21	1.05	50	51	0.93	0.37	70	29
MAY	1.75	1.16	51	22	1.05	0.80	52	77	0.82	0.46	52	50	0.73	0.40	70	66	0.61	0.33	67	21
JUNE	2.76	1.76	66	19	1.34	1.11	61	76	1.10	0.63	43	41	0.64	0.34	67	57	0.40	0.23	77	22
JULY	2.74	1.85	67	29	1.56	1.22	56	96	0.96	0.48	49	60	0.59	0.30	69	84	0.35	0.17	88	31
AUGUST	3.51	1.50	38	10	2.10	2.31	36	71	1.08	0.61	50	38	0.57	0.25	74	62	0.36	0.15	86	17
SEPTEMBER	4.97	4.62	67	34	1.63	1.70	59	65	1.06	0.74	47	33	0.56	0.26	74	45	0.44	0.20	85	13
OCTOBER	3.24	2.57	43	20	1.93	1.33	51	85	1.34	0.92	53	64	0.63	0.30	65	91	0.47	0.22	75	31
NOVEMBER	4.78	1.55	44	13	2.96	1.26	46	36	1.98	0.80	42	16	1.01	0.50	52	14	0.82	0.57	55	9
DECEMBER	4.34	2.09	42	18	3.38	1.98	40	47	1.76	0.87	43	44	1.22	0.59	43	57	0.76	0.46	56	16

[1]Weighted average for the upper 100 m of the water column.

[2]mg m^{-3}

[3]Nannoplankton (<20 um)

[4]CHLA = chlorophyll a

[5]STD = standard deviation

[6]%NAN = percent of total chlorophyll a in the nannoplankton size fraction

[7]N = number of stations sampled between 1977 and 1982

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Chapter 6. SEASONAL ZOOPLANKTON STANDING STOCK AND DOMINANT SPECIES

John R. Green[1]

6.1 INTRODUCTION.

A critical step in the pathway from primary producers to man is through the zooplankton which serve as a primary food source to commercially important fish species. A consideration of the effects of ocean dumping of industrial and sewage wastes must assess the potential effects on these primary consumers of particulate organic material as an integral part of the pelagic food web. Presented herein is an analysis of data from recently (1977-1981) collected zooplankton samples in the vicinity of 106-Mile Ocean Waste Disposal Site (106-Mile Site) and its potential area of influence (PAI) in terms of abundance and dominant species composition through the year. This report provides information for the portion of the shelf areas of Southern New England and the Mid-Atlantic Bight with comparisons between 50 to 200 m depth portion and the adjacent inshore areas with depths less than 50 m.

A number of previous studies of zooplankton in this same geographical area have been done but these are generally more limited in temporal and areal coverage. Sherman et al. (1977) reported on the zooplankton communities from monitoring cruises between summer 1972 and winter 1976. Their report characterizes zooplankton populations beyond the 180 m contour and in the vicinity of 106-Mile Site. Judkins et al. (1980) reported on a series of five cruises taken from September 1974 through September 1975 with stations located primarily in the waters off Southern New England. Grice and Hart (1962) sampled on five cruises over a one-year period along a transect from Montauk, Long Island to Bermuda which included four stations across the shelf. Bigelow and Sears (1939) published a volumetric study of samples collected between 1929 and 1932 from Cape Hatteras, North Carolina to Martha's Vineyard, Massachusetts. Recently, in a more process-oriented study, Cosper and Stepian (1982) looked at the linkage between phytoplankton and zooplankton and the degree to which coupling between these two trophic levels effects the residence time of water-borne pollutants in the apex of the New York Bight by incorporation of pollutants in body tissue and in the production of fecal pellets.

MARMAP (Marine Resources Monitoring, Assessment and Prediction) surveys conducted since 1977 along the entire northeast coast of the United States have made available a large body of data on primary production (^{14}C), chlorophyll a and phaeophytin a concentrations, nutrients including NO_2, NO_3, SiO_3, NH_4, and PO_4, zooplankton, ichthyoplankton, and hydrography. Briefly, the overall goals of the MARMAP surveys are to conduct a broad-scale ongoing study of the northeast shelf ecosystem which provides a source of comprehensive data on the physical and biological parameters that effect the abundance and variability of fish stocks. A detailed description of the goals of the MARMAP program is given in Sherman et al. (1980). Data collected on MARMAP surveys have shown coherent patterns of abundance, species dominance and areal distributions which when compared to previous studies indicate that the zooplankton component of the pelagic food web has remained relatively unchanged for the last 70 years (Sherman et al. 1982).

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Hydrography

The distribution of planktonic organisms within the Southern New England and Mid-Atlantic Bight areas, including the PAI, is dependent upon an assortment of hydrographic features which control the movement and suitability of the pelagic marine environment. According to Ingham et al. (1982) spring warming initiates water column stratification which lasts until mid-autumn, usually November, when seasonal mixing breaks down the stratification. The water in a band beneath the thermocline between the 40 and 100 m isobaths is referred to as the "cold pool" and extends from the eastern edge of Georges Bank down to Cape Hatteras. Temperatures in the "cold pool" remain considerably lower than adjacent shelf waters. Minimum temperatures average 2.1°C off Southern New England and 4.2°C off New York. Warming proceeds slowly until the autumn advection occurs when average maximum temperatures of 14.9°C and 12.3°C occur in Southern New England and off New York, respectively. Previous studies (Bigelow 1933; Ketchum and Corwin 1964) considered the cold pool to be remnant "winter water." However, data collected by Colton et al. (1968), Limeburner et al. (1978) and Whitcomb (1970) have shown that the feature can be traced along the entire northeast shelf to Georges Bank and the Gulf of Maine. Beardsley et al. (1976) and Hopkins and Garfield (1979) have suggested that the source of cold pool water is from the Gulf of Maine and a net southwestward flow at 1-3 cm/sec (Mayer et al. 1979) supplies water of the appropriate temperature and salinity to maintain a relatively constant source of water to Southern New England and the Mid-Atlantic Bight. The geographical location of this band of cool water as specified by the 40 - 100 m isobaths is approximately within the portion of the PAI on the continental shelf.

6.2 METHODS.

Plankton samples were collected between February 1977 and October 1981 on jointly conducted surveys with scientists and vessels from Poland, the USSR, and the German Democratic Republic. Stations considered in this study were selected from a series of 31 cruises which covered the entire northeast coast from Cape Hatteras to Nova Scotia in a network of approximately 180 stations per survey, averaging 35 km apart (Fig. 1). Coverage of the entire sample grid in some instances was not complete due to weather conditions, vessel breakdowns, etc. Surveys and sampling dates are given in Table 1. Stations from the MARMAP areal coverage corresponding with the continental shelf portion of the PAI and adjacent shallower shelf waters outside the PAI were selected for analysis. Those stations west of the 70th meridian occurring at depths greater than or equal to 50 m were considered to be located within the PAI. Seasonal zooplankton abundance and species composition were compared between this and the adjacent shelf waters at less than 50 m depth to assess the degree of difference and interaction between the PAI and the near-shore zone.

At each station zooplankton and ichthyoplankton were sampled using bongo nets of 0.333 mm and 0.505 mm mesh. These were towed obliquely through the water column from depths of a few meters off the bottom to a maximum depth of 200 m. Ship speed was maintained at 1.5 to 3 knots to provide a 45° wire angle. Volume filtered was measured by a flowmeter

mounted in the mouth of each net, and depth of tow and tow profile recorded with an attached bathykymograph. Samples were preserved in 4% buffered formalin for subsequent analysis ashore. An average of 28 samples were selected per survey for zooplankton analysis from the Southern New England and Mid-Atlantic Bight subareas. Sorting and identification of zooplankton is done at the Morski Institute Rybacki, Szczecin, Poland, under the direction of Dr. Leonard Ejsymont. Abundances of zooplankton are expressed in numbers or volume per 100 m^3. Due to skewness in the data, medians are used to indicate trends in total biomass and species abundance.

6.3 RESULTS.

Zooplankton Standing Stock

Seasonal zooplankton displacement volumes for 1977 through 1981 for Southern New England and the Mid-Atlantic Bight are shown in Fig. 2 for the offshore ($\geq$50 m) and onshore (<50 m) areas.

In Southern New England there appears to be a consistent increase in zooplankton volume in the <50 m zone generally occurring from early summer to early autumn with abundance greater than 60 cc/100 m^3 at the yearly maximum. The pattern for the development for the seasonal maximum in the PAI is more variable, in some cases occurring earlier than the inshore peak (1980 and 1981), at the same time (1977) and showing a biphasic maximum in 1979. The cycles of maxima and minima appear to be independent of one another with a similar range of variability and magnitude. The difference in mean zooplankton displacement volumes between the two areas is significant in 15 out of 33 seasonal comparisons (Table 2) but no consistent pattern is evident. No sampling occurred in late spring of 1978 in Southern New England, making the timing and magnitude of a suggested offshore peak in that year uncertain.

In the Mid-Atlantic Bight there is a consistent late summer to early autumn peak in shallower water with a much less defined maximum in the $\geq$ 50 m offshore areas during the same period. With the exception of 1977, the late winter minimum volumes were less than 20 cc/100 m^3. The inshore maximum ranged from 60 to 80 cc/100 m^3, offshore maxima were generally less than 40 cc/100 m^3. Significant differences were found between offshore and and onshore areas by season in 17 out of 27 comparisons. In 14 of the 17 significant comparisons the volume was greater at depths less than 50 m (Table 2) suggesting a tendency toward lower zooplankton abundance in the PAI. As in Southern New England, there was no sampling in late spring of 1978.

Dominant Species

The method of dominance analysis of Fager and McGowan (1963) was used to determine the patterns of abundance of zooplankton species. The dominance of a species is calculated by the formula:

$$D_j = \sum_{i-1}^{n} (d_{ji} \geq Z_i/2)$$

where

D_j = dominance of species -j

n = number of stations sampled

d_{ji} = abundance of species j at station j

Z_i = abundance of all zooplankton at station j

and

d_{ji} assumes a value of 1 when $d_{ji} > Z_i/2$

d_{ji} assumes a value of 0 when $d_{ji} \leq Z_i/2$

A listing of those taxa that were dominant for both survey areas by year and season is given in Table 3. Of the 59 seasonal survey dominance calculations, Copepoda were among the dominants in 92% (54) of the comparisons. In 48 cases (89%) the three species Calanus finmarchicus, Centropages typicus and Pseudocalanus minutus were among the dominant copepods. Other taxonomic groups that are less frequently dominant include Gammaridae, Balanidae, Sagittae, Coelenterata, Cladocera, Echinodermata, Salpidae, Ciliata, Pteropoda, Decapoda and Brachyura.

Both the developmental and mature stages of copepods are an important food source for planktonic larval and pelagic adult fishes and marine mammals and birds. Taken together the three copepod species are responsible for most of the secondary production that occurs on the entire continental shelf.

A trend toward increasing variety of dominant species is evident in a comparison of the variety of dominants (Table 3) between the Mid-Atlantic Bight and Southern New England as shown by increases in the dominance of Cladocera and other copepod species in the more southern waters of the Mid-Atlantic Bight. In the warmer months, these taxa share dominance with the major copepods, C. finmarchicus, P. minutus and C. typicus in Southern New England and in some cases replace them as dominants for short periods in the Mid-Atlantic Bight.

Seasonal Abundance of Dominant Species

The seasonal variation in total zooplankton standing stock will typically reflect the yearly cycle of abundance of the dominant species. Fig. 3 illustrates the seasonal abundances for the three dominant copepod species C. finmarchicus, C. typicus and P. minutus in the offshore and near-shore waters for the Southern New England and Mid-Atlantic Bight subareas.

Calanus finmarchicus

C. finmarchicus (Fig. 3A) maximum abundance in the Southern New England area occurs between early spring and late summer. The median abundance/100 m^3 are higher in offshore waters of the PAI and with the exception of early summer in 1981, the differences are significant at the 0.5 level (Table 4). The offshore maximum occurs in late spring with median abundance ranging from 17,000 to 85,000/100 m^3. The near-shore peak is less pronounced with median values ranging from 1,200 to 15,000/100 m^3 occurring over a wider span of time from late spring to late summer. The near-shore yearly minima are generally less than 1,000/100 m^3,

In the Mid-Atlantic Bight the seasonal distribution of C. finmarchicus shows a similar offshore peak with maximum values as high as 40,000/100 m^3 in late spring. The abundance rises rapidly from late winter to early spring and remains high until late summer. In contrast, in the inshore waters, the seasonal maximum of C. finmarchicus is in late winter. By late spring, C. finmarchicus is no longer found in the near-shore water of the Mid-Atlantic Bight. In late winter, values of 100/100 m^3 to 3,000/100 m^3 are found in both the <50 m and ≥50 m water. In late autumn the abundance in both areas returns to approximately the same levels as late winter.

Centropages typicus

The seasonal abundance distribution for C. typicus is presented in Fig. 3B. In Southern New England and the Mid-Atlantic Bight there appears to be little difference between the numbers of this species for both the near- and offshore areas of these two regions, nor are consistent differences in the timing of the yearly maximum evident. In Southern New England the yearly maximum is reached by early summer (10,000-50,000/100 m^3). The abundance in early autumn appears to be more variable than in the summer months, but is of nearly the same range as in the late spring (Table 4). In contrast the peak in the Mid-Atlantic Bight occurs generally by late spring (10,000-20,000/100 m^3) and remains high until early autumn. Centropages numbers are less variable in the Mid-Atlantic Bight than in Southern New England, with abundances remaining generally above 1,000/100 m^3 during the annual minima.

Pseudocalanus minutus

In contrast to C. finmarchicus which demonstrates a marked difference in abundance between near- and offshore areas and C. typicus which occurs generally in numbers of at least 1,000/100 m^3 throughout the year, P. minutus appears to have wide synchronous seasonal fluctuations in both the offshore and onshore areas of the Mid-Atlantic Bight and Southern New England (Fig. 3C). The yearly maximum occurs in spring (40,000 - 100,000/100 m^3) followed by a rapid drop-off in summer to very low levels in autumn (Table 4). There appears to be some evidence of recovery in late autumn in both areas, especially in Southern New England, suggesting that the population may begin to increase again with cooling of the water column. As in the case of

C. typicus there is considerable variation between years but consistent trends are visible which suggest a predictable year-to-year cycle in the abundance of this species also.

6.4 DISCUSSION.

The data presented here indicate that the offshore zone (≥50 m) corresponding to the PAI can be expected to have a standing stock of zooplankton as high as inshore areas during the early part of the year before maximum temperatures are reached in both Southern New England and the Mid-Atlantic Bight. The offshore area has some tendency to reach its maximum earlier in the year. The earlier peak may be due to the combined number of the three species of copepods which dominate the plankton. C. typicus is abundant across the shelf after late spring; however, the two cooler water species, C. finmarchicus and P. minutus, are abundant before summer temperatures are reached and more abundant in the offshore water greater than 50 m. The near-shore peak late in the year is comprised largely of C. typicus in concert with other less abundant species associated with warmer waters.

The species C. finmarchicus in the Mid-Atlantic Bight is restricted to the zone corresponding with the PAI during the warm months of the year, while P. minutus decreases to low levels across the entire shelf after the spring. Therefore, C. finmarchicus has the most disparate distribution between PAI and the adjacent inshore zone. It is associated with cool temperatures and occurs in deeper cooler waters during warm months off the northeast coast (Sherman et al. 1980; Marshall and Orr 1956). C. finmarchicus is a large copepod species and can be considered a major link between phytoplankton production and the pelagic and larval fish species, serving as a food organism for mackerel and herring, the developmental stages for larval fishes (J. Kane and R. Maurer pers. communication; Bigelow and Schroeder 1953). Although never abundant near-shore, the sustained abundance level offshore is evidence that C. finmarchicus is able to maintain itself within the cold pool during the summer months after a thermocline has formed. After the fall turnover this species appears to repopulate the shallow zone. It is likely that the population within the cold pool recruits from the northeast due to the net drift described by Ingham et al. (1982).

This is supported by the greater abundance of C. finmarchicus to the northeast in Southern New England in both the near-shore and offshore waters. It appears that the PAI off the Mid-Atlantic Bight represents the southern limit of C. finmarchicus. The cooling temperatures at the autumn turnover allow dispersal towards shallow waters.

Comparisons of near-shore (<50 m depth) and offshore (≥50 m) waters within the PAI have demonstrated that the timing of yearly zooplankton abundance increases and minima are different in the PAI from the near-shore areas. While both the shallow and deeper water zones respond to seasonal warming of the water column, the magnitude and timing of the yearly peak reflects the difference in the zooplankton community composition. The cycles of abundance of the dominant copepod species suggest that the differences in timing of the three species interact to produce the periodic changes in abundance indicated by maxima and minima in the plots of zooplankton standing stock

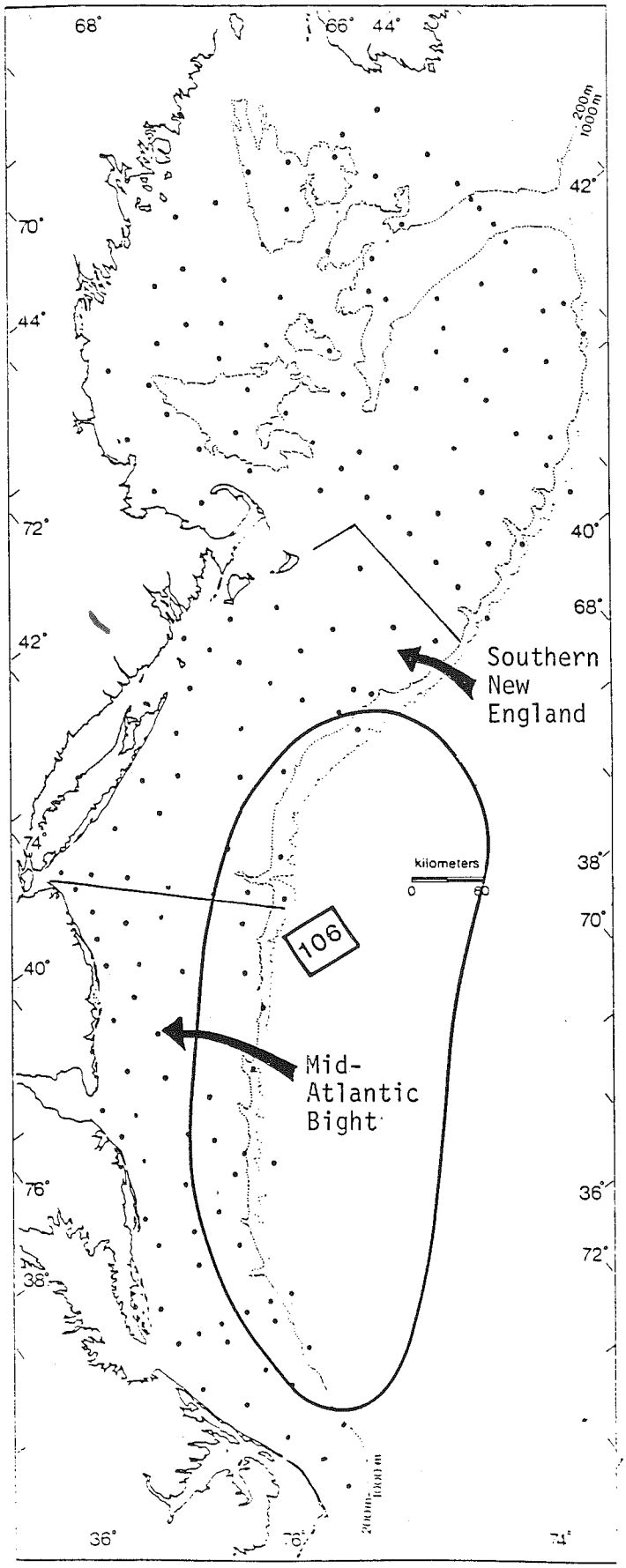
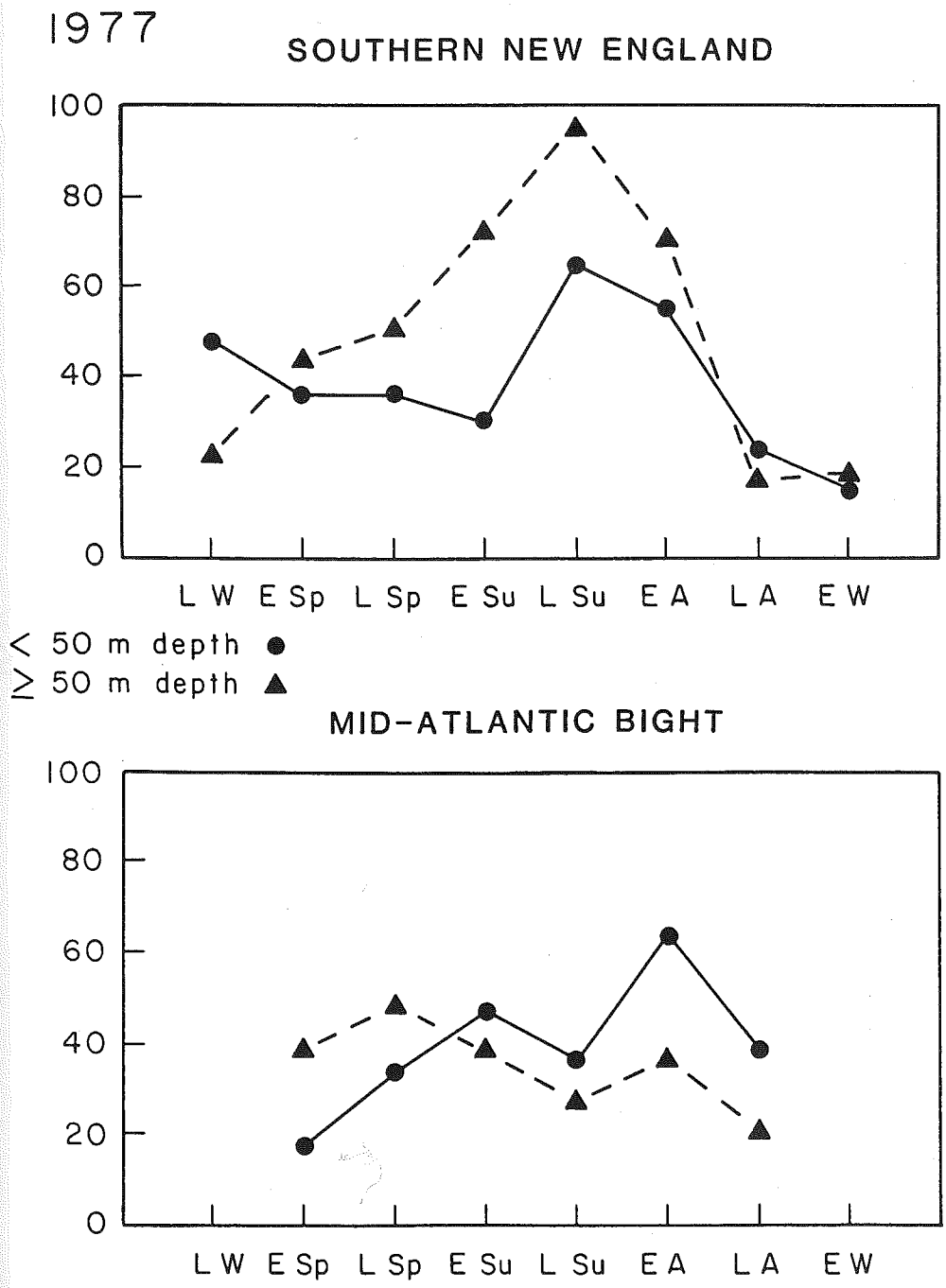
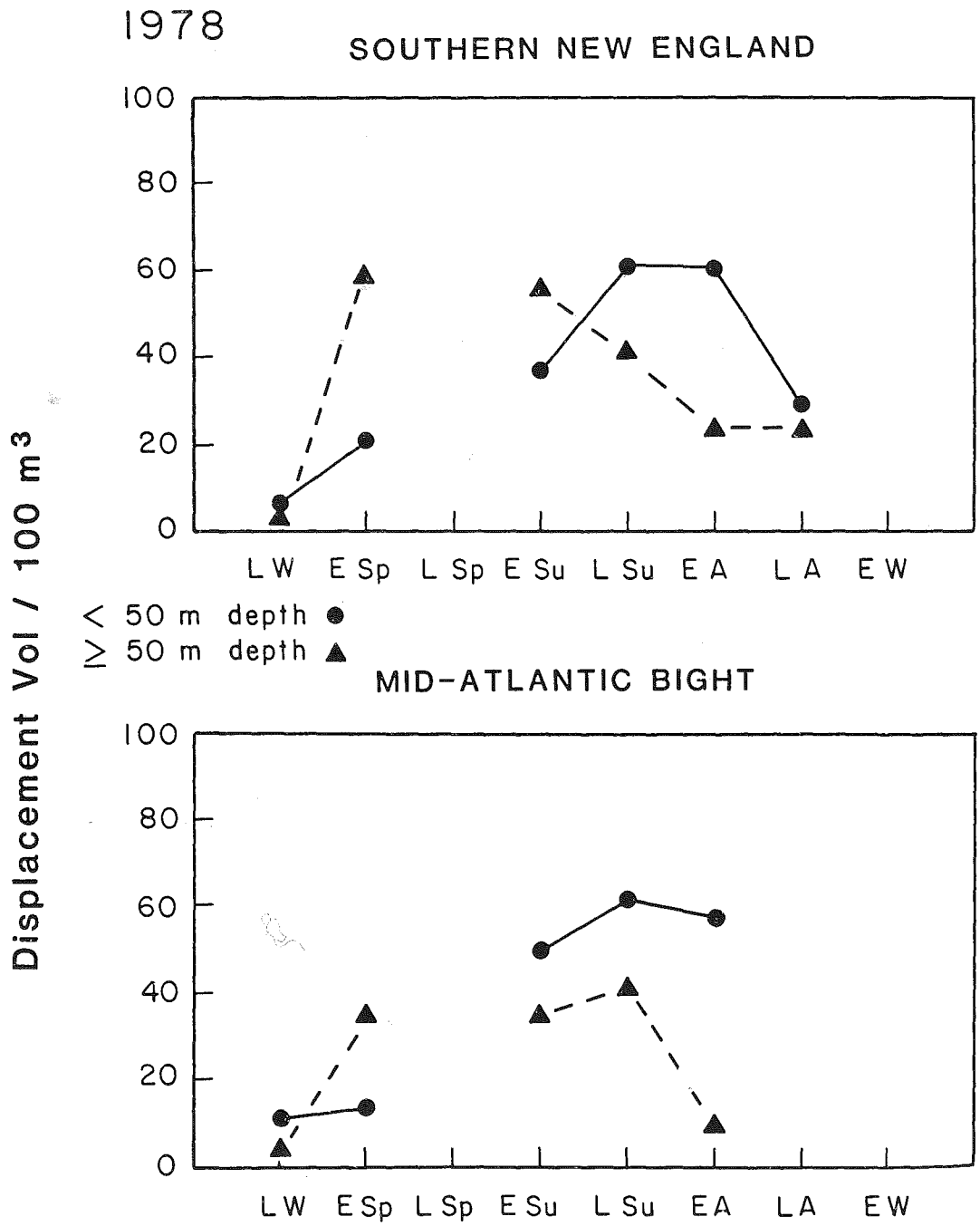
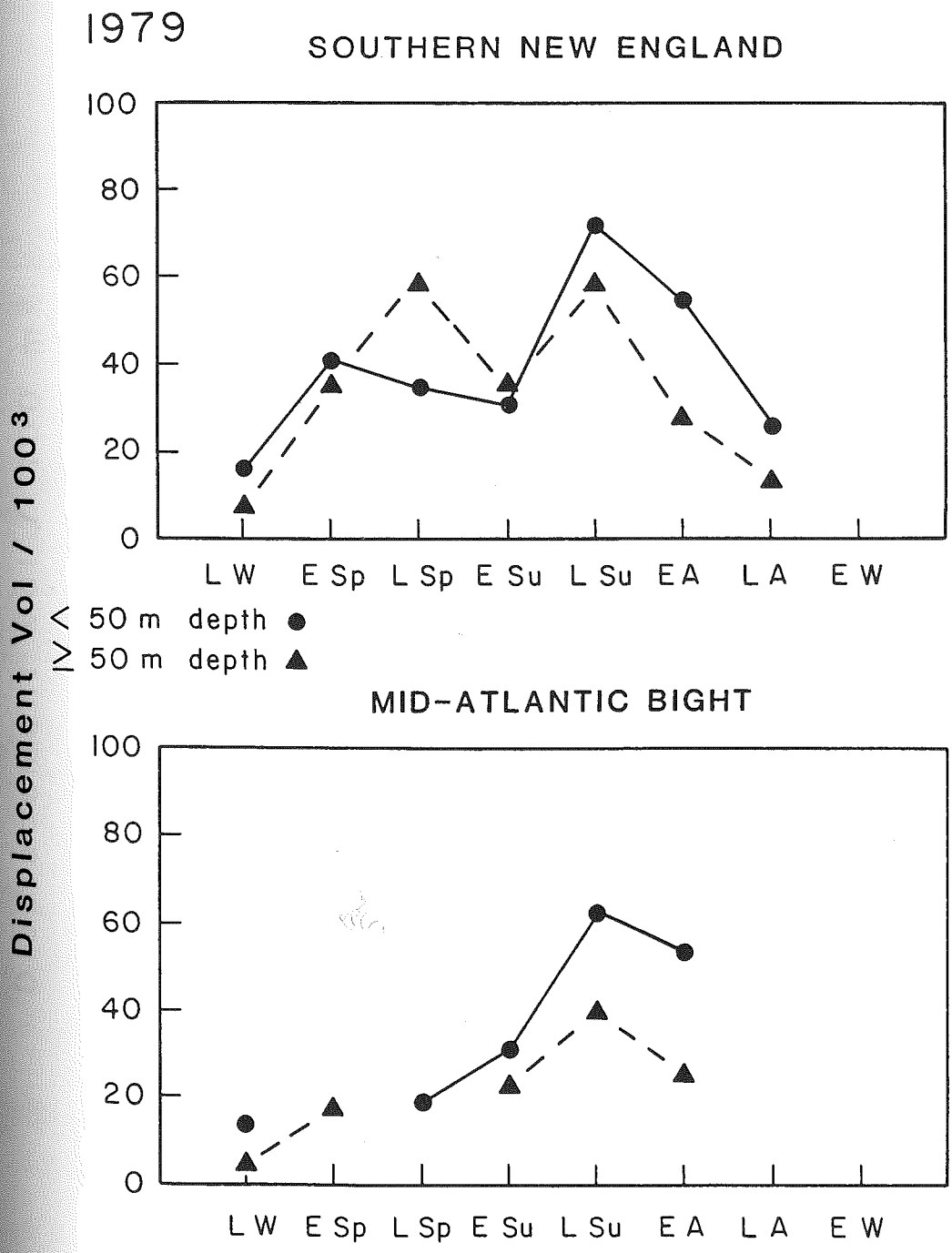


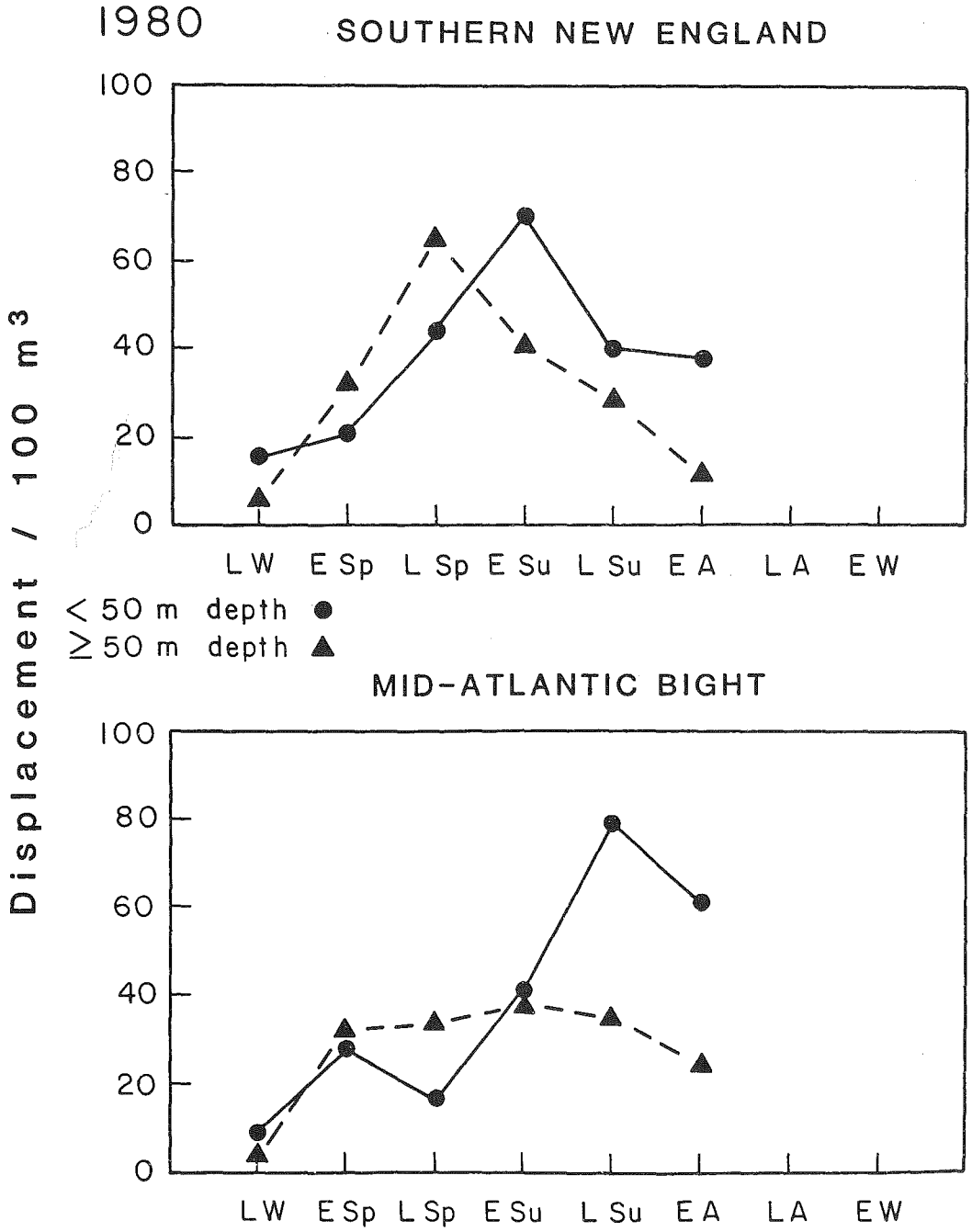
Figure 1. MARMAP plankton sampling stations off northeastern United States. DMO 106 and potential impact area in Southern New England and the Mid-Atlantic Bight are indicated. Area of coverage for analysis in this report includes all stations to west of 70° meridian.

Figure 2. Seasonal median displacement volume in cc/100 m^3 for Southern New England and the Mid-Atlantic Bight in <50 m and ≥50 m depth areas. Seasonal surveys with fewer than five observations have not been plotted.


1977
SOUTHERN NEW ENGLAND
100
80
60
40
20
0
L W E Sp L Sp E Su L Su E A L A E W
< 50 m depth ●
≥ 50 m depth ▲
MID-ATLANTIC BIGHT
100
80
60
40
20
0
L W E Sp L Sp E Su L Su E A L A E W
Displacement Vol / 100 m³


1978
SOUTHERN NEW ENGLAND
100
80
60
40
20
0
LW E Sp L Sp E Su L Su E A L A E W
< 50 m depth ●
≥ 50 m depth ▲
MID-ATLANTIC BIGHT
100
80
60
40
20
0
LW E Sp L Sp E Su L Su E A L A E W
Displacement Vol / 100 m³


1979
SOUTHERN NEW ENGLAND
100
80
60
40
20
0
L W
E Sp
L Sp
E Su
L Su
E A
L A
E W
< 50 m depth
≥ 50 m depth
MID-ATLANTIC BIGHT
Displacement Vol / 1003


1980
SOUTHERN NEW ENGLAND
100
80
60
40
20
0
LW
E Sp
L Sp
E Su
L Su
E A
L A
E W
< 50 m depth
≥ 50 m depth
MID-ATLANTIC BIGHT
Displacement / 100 m³

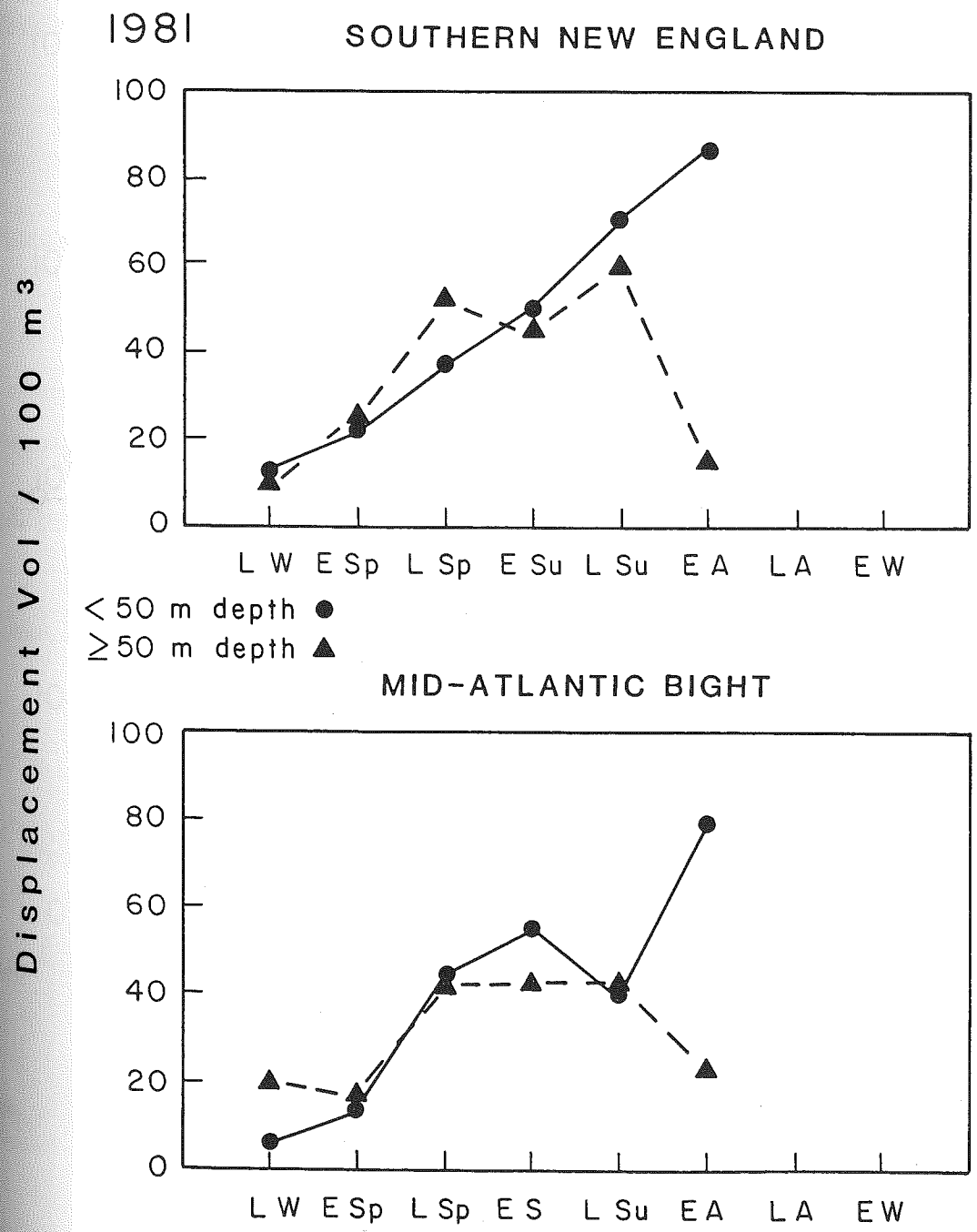
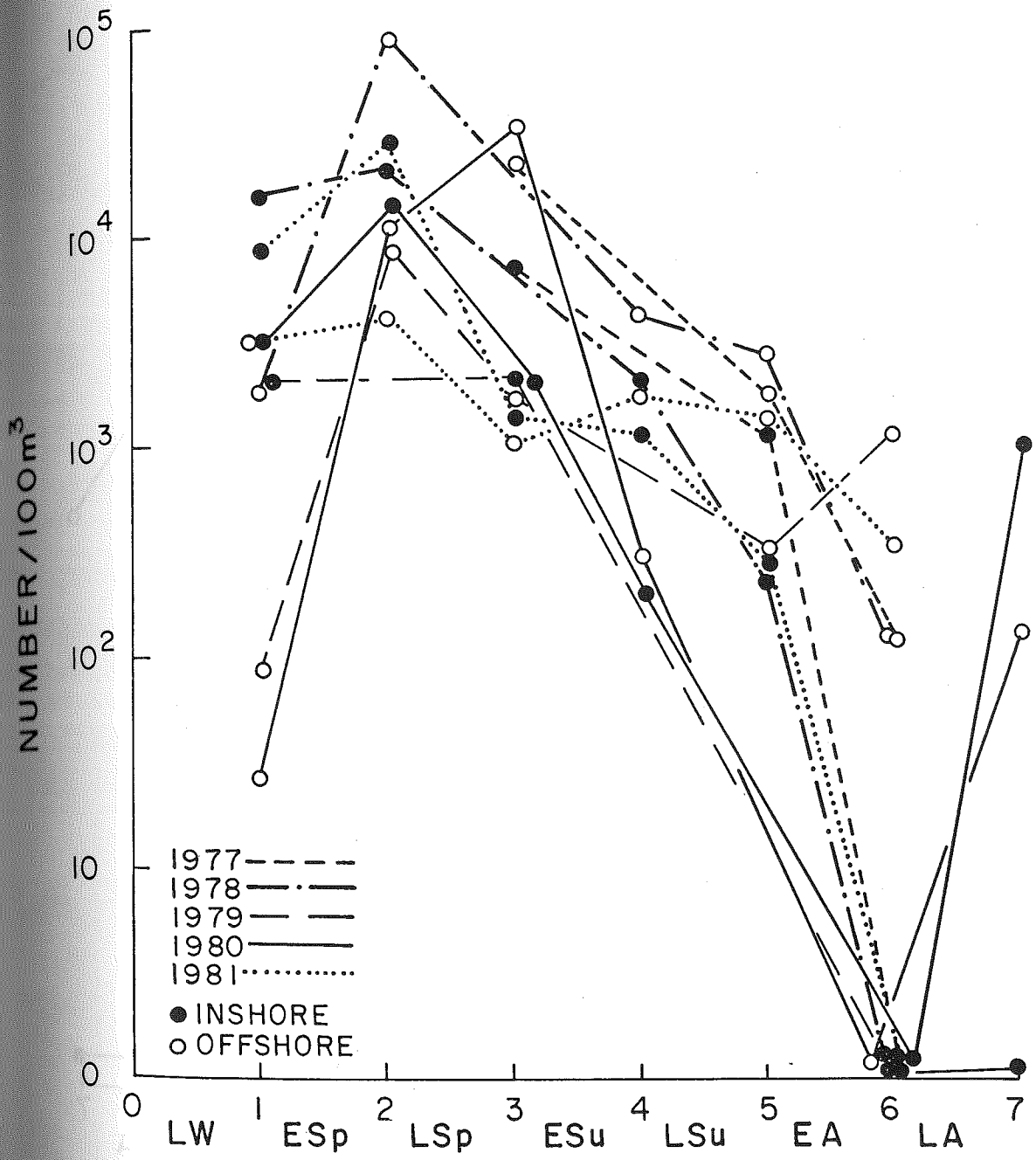
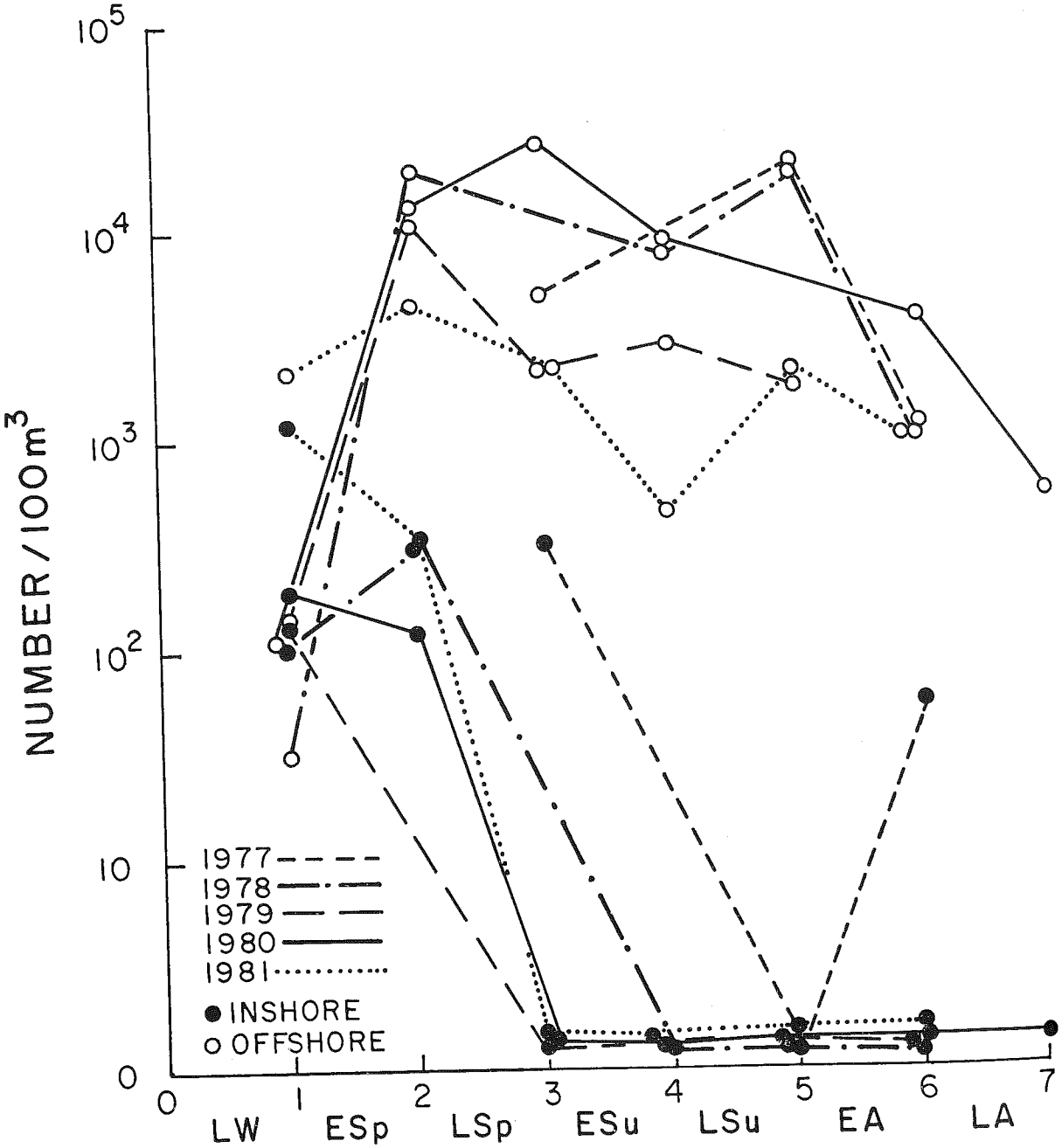

1981
SOUTHERN NEW ENGLAND
100
80
60
40
20
0
L W E Sp L Sp E Su L Su E A L A E W
< 50 m depth ●
≥ 50 m depth ▲
MID-ATLANTIC BIGHT
100
80
60
40
20
0
L W E Sp L Sp E S L Su E A L A E W
Displacement Vol / 100 m³

Figure 3A. Seasonal abundance in #/100 m^3 of Calanus finmarchicus by season for Southern New England and the Mid-Atlantic Bight for <50 m and ≥50 m depths.



Calanus finmarchicus

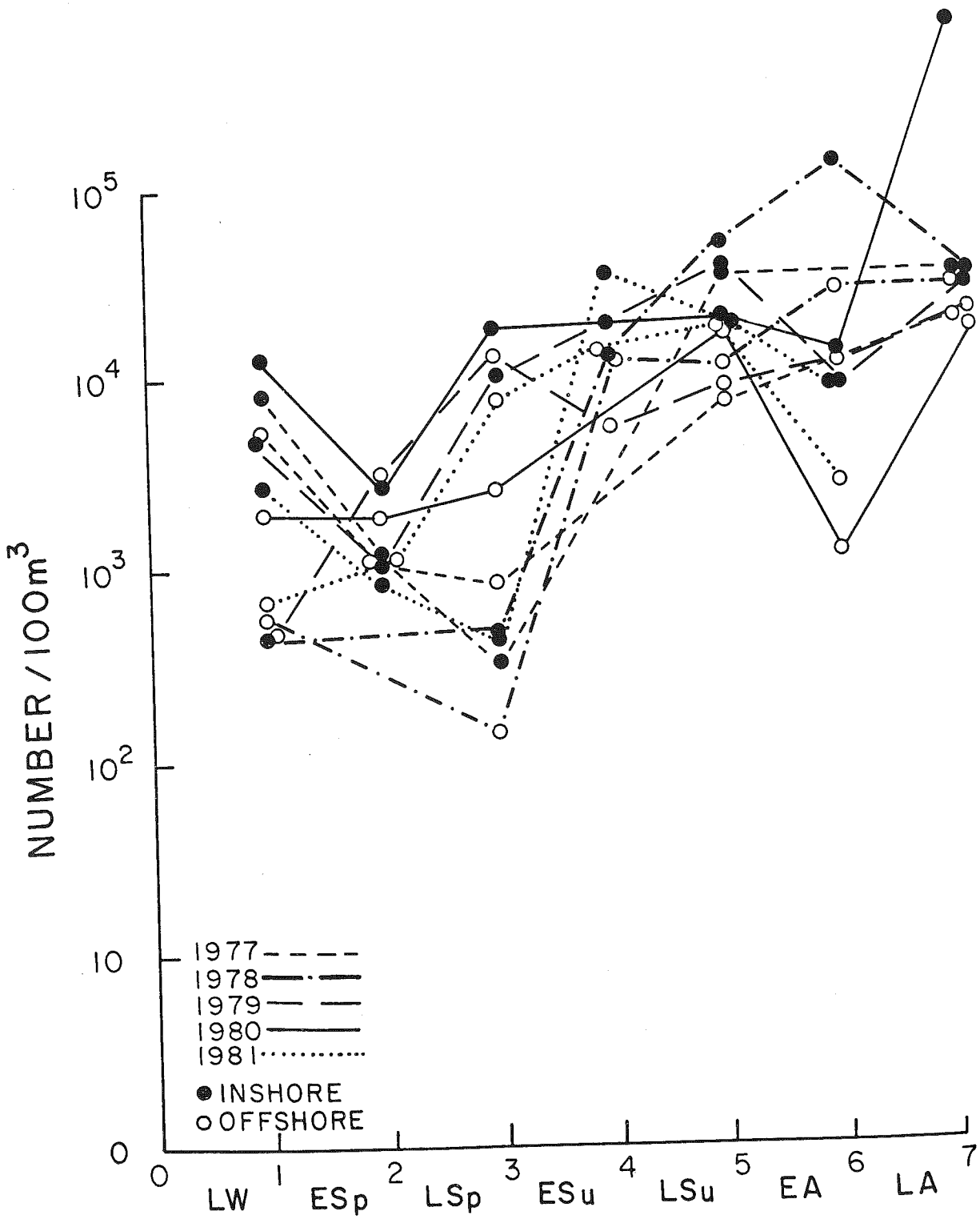
SOUTHERN NEW ENGLAND



Calanus finmarchicus

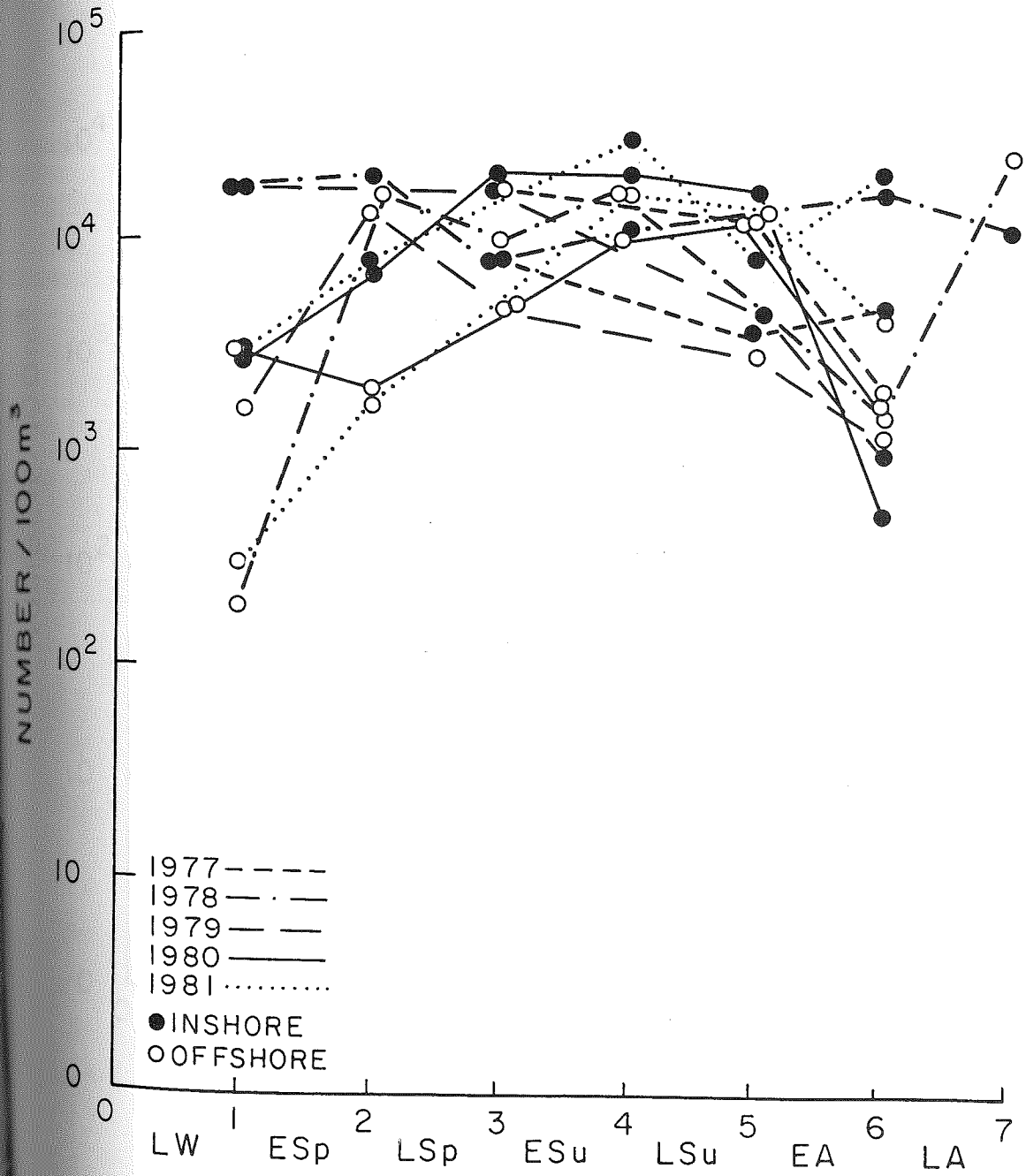
MID-ATLANTIC BIGHT

Figure 3B. Seasonal abundance in #/100 m^3 of Centropages typicus by season for Southern New England and the Mid-Atlantic Bight for <50 m and ≥50 m depths.



Centropages typicus

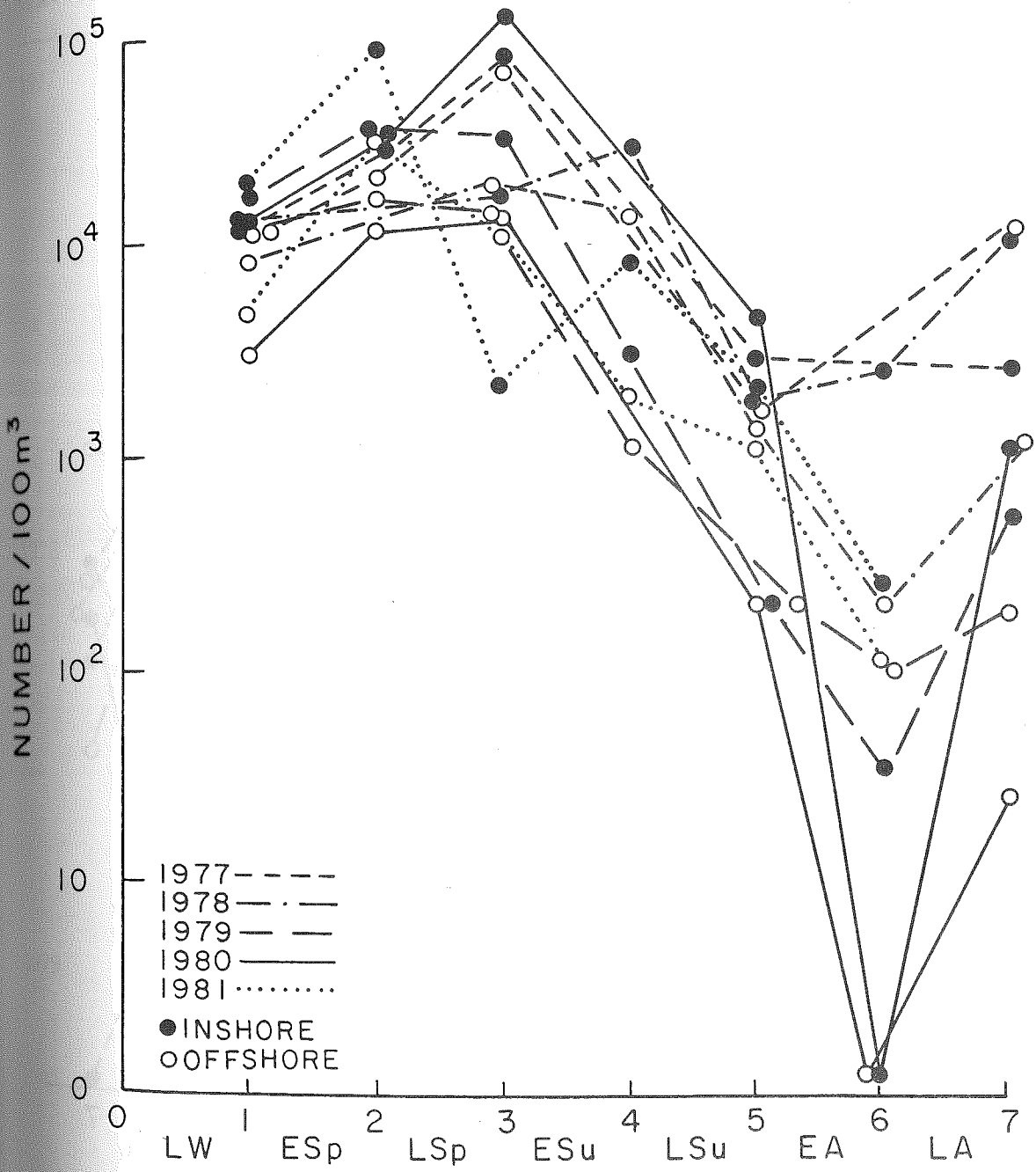
SOUTHERN NEW ENGLAND



Centropages typicus

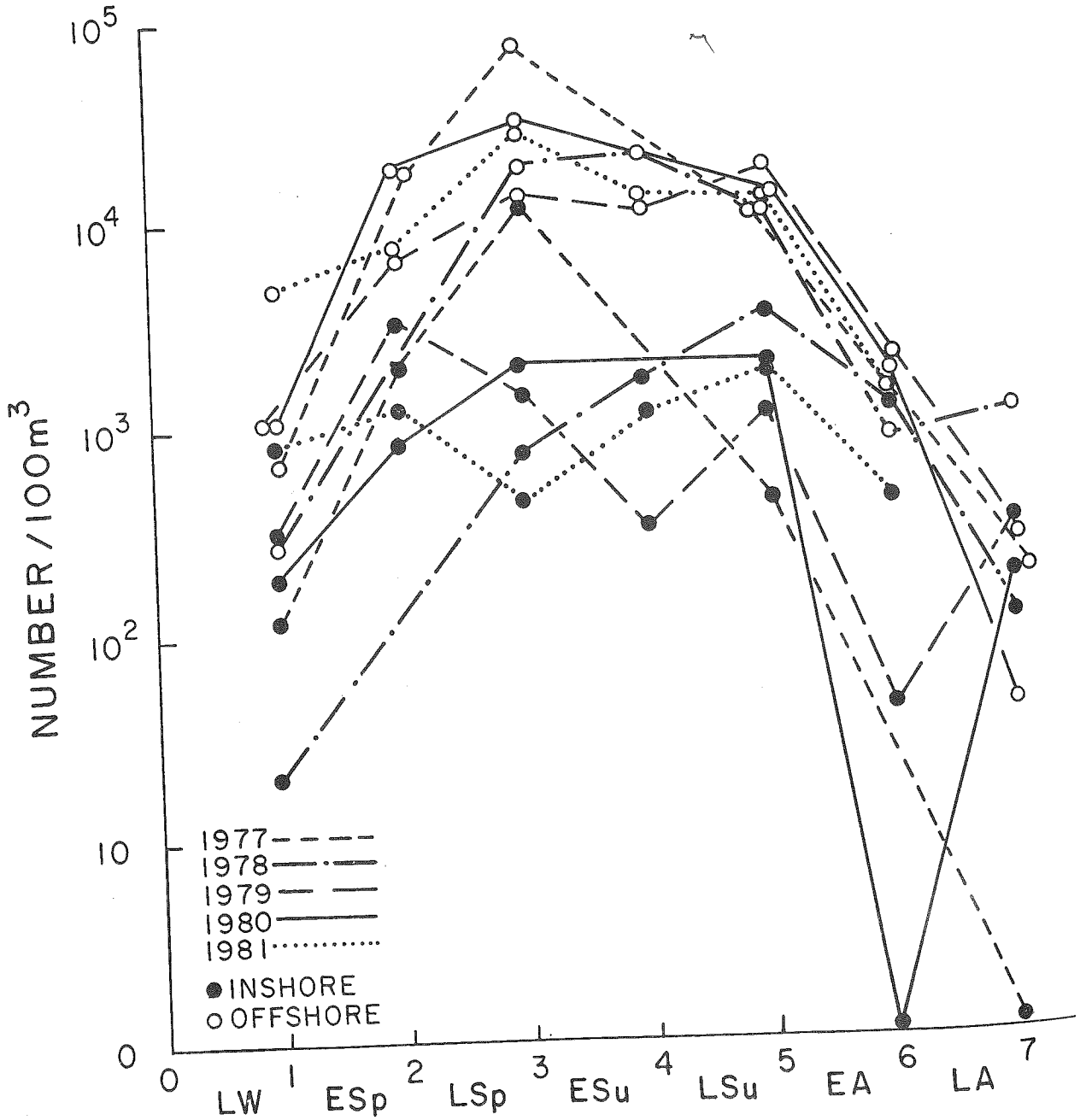
MID-ATLANTIC BIGHT

Figure 3C. Seasonal abundance in #/100 m^3 of Pseudocalanus minutus by season for Southern New England and the Mid-Atlantic Bight for <50 m and ≥50 m depths.



Pseudocalanus minutus

SOUTHERN NEW ENGLAND



Pseudocalanus minutus

MID-ATLANTIC BIGHT

Table 1. Listing of surveys, dates, cruises and numbers of stations in the Southern New England and Mid-Atlantic Bight areas falling within potentially influenced areas of DWD 106 and adjacent waters, 1977 - 1981.

YEAR	SEASON	DATE	VESSEL	CRUISE	NO. STATIONS
1977	LATE WINTER	3 MAR- 7 APR	GORLITZ	77-01	12
		13 FEB-24 FEB	MOUNT MITCHELL	77-01	10
	EARLY SPRING	13 APR-27 APR	ALBATROSS IV	77-02	3
		9 MAR- 7 APR	DELAWARE II	77-03	11
	LATE SPRING	4 MAY-24 MAY	DELAWARE II	77-05	72
		22 MAY- 6 JUN	NOGLIKI	77-02	3
	LATE SUMMER	19 AUG-29 AUG	YUBILEINLY	77-02	60
	EARLY AUTUMN	19 OCT-29 OCT	ARGUS	77-01	30
	LATE AUTUMN	2 DEC- 9 DEC	KELEZ	77-11	14
1978	LATE WINTER	16 FEB-14 MAR	DELAWARE II	78-02	52
		19 APR-12 MAY	ARGUS	78-04	52
	EARLY SUMMER	24 JUN-12 JUL	ALBATROSS IV	78-07	56
	LATE SUMMER	12 AUG- 3 SEP	BELOGORSK	78-01	56
	EARLY AUTUMN	19 OCT-27 OCT	BELOGORSK	78-03	40
		16 NOV	ANTON DOHRN	78-03	1
		14 OCT- 1 NOV	WIECZNO	78-04	6
	LATE AUTUMN	16 NOV-29 OCT	BELOGORSK	78-04	8
1979	LATE WINTER	23 FEB- 4 MAR	DELAWARE II	79-03	82
	EARLY SPRING	13 APR-14 APR	DELAWARE II	79-04	22
	LATE SPRING	17 JUN- 8 JUL	ALBATROSS IV	79-06	49
		6 MAY-18 MAY	DELAWARE II	79-05	55
	EARLY SUMMER	17 JUN- 8 JUL	ALBATROSS IV	79-06	37
	LATE SUMMER	12 AUG-22 AUG	BELOGORSK	79-01	76
	EARLY AUTUMN	4 OCT-18 OCT	ALBATROSS IV	79-11	63
	LATE AUTUMN	12 DEC-19 DEC	ALBATROSS IV	79-13	17
		13 NOV-21 NOV	WIECZNO	79-03	1

YEAR	SEASON	DATE	VESSEL	CRUISE	NO. STATI
1980	LATE WINTER	29 FEB-19 MAR	ALBATROSS IV	80-02	84
		18 FEB-11 MAR	WIECZNO	80-02	17
	EARLY SPRING	7 APR-27 APR	EVRIKA	80-01	83
	LATE SPRING	24 MAY- 6 JUN	DELAWARE II	80-03	84
	EARLY SUMMER	14 JUL-11 AUG	EVRIKA	80-06	46
	LATE SUMMER	14 JUL-11 AUG	EVRIKA	80-06	31
	EARLY AUTUMN	27 SEP- 9 OCT	ALBATROSS IV	80-10	81
	LATE AUTUMN	20 NOV- 7 DEC	ALBATROSS IV	80-12	76
1981	LATE WINTER	17 FEB-26 MAR	ALBATROSS IV	81-01	62
	EARLY SPRING	6 JAN-16 JAN	DELAWARE II	81-02	80
	LATE SPRING	I:17 MAR- 3 APR	DELAWARE II	8/-03	50
		II: 6 APR-17 APR			
		III:20 APR-29 APR			
		IV: 5 MAY-14 MAY			
	EARLY SUMMER				
		I:27 JUN- 2 JUL	DELAWARE II	81-04	44
		II: 7 JUL-24 JUL			
	LATE SUMMER	I: 3 AUG-21 AUG	DELAWARE II	81-05	71
		II:24 AUG-11 SEP			
	EARLY AUTUMN				
		I:15 SEP- 2 OCT	DELAWARE II	81-06	74
		II: 5 OCT-16 OCT			
		III:19 OCT-30 OCT			
		IV: 2 NOV-13 NOV			

*Table 2. Yearly median zooplankton displacement volumes/100 m³ for Southern New England and Mid-Atlantic Bight at <50 m and ≥50 m depths. Number of stations (N) and Kruskall Wallis probabilities (p) for test of significance of difference are given by year and season. * indicates significance at the .05 level.*

	1977					1978					1979				
	<50m		≥50m			<50m		≥50m			<50m		≥50m		
	N	Median	N	Median	p	N	Median	N	Median	p	N	Median	N	Median	p
Southern New England															
Late winter	7	49.30	12	23.10	0.0068*	19	6.10	17	5.70	0.8991	19	16.50	15	8.30	0.0587
Early spring	7	36.60	9	44.50	0.9578	12	21.10	19	59.50	0.0231*	10	41.20	11	35.70	0.8880
Late spring	37	37.40	23	51.30	0.2510						16	35.40	10	58.65	0.0398*
Early summer	17	31.10	17	72.10	0.0084*	16	36.95	18	56.15	0.3170	17	31.20	20	35.70	0.9757
Late summer	50	65.20	37	96.00	0.0142*	15	61.20	17	40.60	0.0032*	14	70.65	15	59.00	0.2752
Early autumn	16	57.30	30	71.70	0.9816	19	60.80	18	23.85	0.0007*	10	54.55	12	27.85	0.0147*
Late autumn	12	24.10	17	18.10	0.0317*	5	29.50	4	23.75	0.6242	9	25.50	15	13.60	0.1011
Early winter	7	16.20	10	19.30	0.5582										
Mid-Atlantic Bight															
Late winter						34	11.30	11	4.00	0.0462*	37	13.60	11	4.90	0.0111*
Early spring	33	18.10	17	38.90	0.0715	32	14.25	13	35.00	0.0027*				18.85	
Late spring	64	34.00	26	49.10	0.0491*										
Early summer	36	47.20	19	39.70	0.5592	33	50.00	13	35.00	0.0328*	35	31.00	14	22.75	0.0277*
Late summer	71	36.60	34	28.50	0.9863	33	61.50	15	41.30	0.0327*	33	62.20	14	39.50	0.0041*
Early autumn	28	64.30	16	37.00	0.0570*	14	57.95	5	10.10	0.0012*	21	53.20	7	25.60	0.0013*
Late autumn	30	39.15	12	21.10	0.0017*										
Early winter															

	1980					1981				
	<50m		≥50m			<50m		≥50m		
	N	Median	N	Median	p	N	Median	N	Median	p
Southern New England										
Late winter	23	14.80	27	5.70	0.0158*	17	12.40	19	11.70	0.8616
Early spring	16	21.90	19	32.00	0.1012	16	21.65	21	25.00	0.8903
Late spring	17	44.20	18	65.40	0.0294*	14	36.90	17	52.00	0.3613
Early summer	16	70.45	16	41.35	0.0317*	5	49.90	10	44.50	0.3913
Late summer	19	40.00	17	29.20	0.0410*	14	69.80	16	60.00	0.4296
Early autumn	18	38.05	18	12.40	0.0001*	15	86.40	16	15.40	0.0017*
Mid-Atlantic Bight										
Late winter	37	8.70	11	5.20	0.816	20	5.90	6	19.80	0.019*
Early spring	33	27.60	15	31.80	0.6971	28	13.70	14	14.90	0.7488
Late spring	36	17.40	12	33.50	0.0116*	15	45.60	5	43.50	0.5705
Early summer	32	41.45	13	39.50	0.2929	12	54.75	4	43.35	0.1456
Late summer	33	79.20	12	34.20	0.0001*	31	40.20	10	43.20	0.4756
Early autumn	31	61.60	9	24.50	0.0021*	27	78.60	16	22.85	0.0001*

Table 3. Summary of dominant zooplankton species by season occurring within the Southern New England and Mid-Atlantic Bight waters from 1977-1981. Species listed were dominant in at least one station. Mean rank = mean of ranking in all stations. Dom = number of stations at which species was dominant. Occur = number of stations at which species occurred. Median = abundance in number per 100 m^3.

TAXONOMIC NAME	MEAN RANK	DOM	PERCENT DOM	OCCUR	PERCENT OCCUR	MEDIAN
SNE - 1977 - Late Winter - No. Sta. 14						
Pseudocalanus minutus	1.3571	8	57.1429	14	100.000	11787.2
Centropages typicus	7.8571	4	28.5714	12	85.714	2211.0
Gammaridae	18.8214	1	7.1429	9	64.286	89.7
SNE - 1977 - Early Spring - No. Sta. 28						
Pseudocalanus minutus	1.3214	17	60.7143	28	100.000	29830.2
Calanus finmarchicus	5.8036	3	10.7143	26	92.857	1997.4
Centropages typicus	8.6071	2	7.1429	23	82.143	4230.6
Balanidae	29.2321	1	3.5714	4	14.286	0.0
SNE - 1977 - Early Summer - No. Sta. 28						
Pseudocalanus minutus	1.50000	13	46.4286	28	100.000	45472.9
Calanus finmarchicus	3.39286	7	25.0000	27	96.429	20860.9
SNE - 1977 - Late Summer - No. Sta. 28						
Pseudocalanus minutus	1.6786	5	17.8571	28	100.000	96917.9
Calanus finmarchicus	2.9286	10	35.7143	28	100.000	67850.9
Temora longicornis	17.0000	2	7.1429	15	53.571	127.6
SNE - 1977 - Early Autumn - No. Sta. 37						
Centropages typicus	4.9865	7	18.9189	35	94.5946	18560.1

Calanus finmarchicus	7.6486	5	13.5135	34	91.8919	16222.8
Acartia tonsa	35.6081	1	2.7027	16	43.2432	0.0
SNE - 1977 - Early Winter - No. Sta. 19						
Centropages typicus	1.05263	13	68.4211	19	100	32307.3
SNE - 1978 - Late Winter - No. Sta. 30						
Pseudocalanus minutus	2.1167	23	76.6667	29	96.6667	14965.5
Calanus finmarchicus	10.9833	2	6.6667	23	76.6667	291.2
Sagitta elegans	22.85	1	3.33333	10	33.3333	0
SNE - 1978 - Early Spring - No. Sta. 30						
Pseudocalanus minutus	2.0167	5	16.6667	30	100.000	26336.5
Calanus finmarchicus	4.0667	10	33.3333	29	96.667	17433.5
Balanidae	21.6167	1	3.3333	8	26.667	0.0
SNE - 1978 - Early Summer - No. Sta. 34						
Pseudocalanus minutus	2.3235	5	14.7059	34	100.000	20087.3
Calanus finmarchicus	10.2500	4	11.7647	29	85.294	14266.3
Temora longicornis	20.3529	4	11.7647	23	67.647	2154.9
SNE - 1978 - Late Summer - No. Sta. 31						
Centropages typicus	2.2258	10	32.2581	31	100.000	45441.7
Calanus finmarchicus	4.4355	2	6.4516	30	96.774	12861.5
Evadne sp.	12.7097	1	3.2258	27	87.097	1440.5
Penilia avirostris	36.8065	2	6.4516	10	32.258	0.0
Penilia sp.	40.2419	1	3.2258	8	25.806	0.0

Evadne sp.	12.7097	1	3.2258	27	[illegible]	[illegible]
Penilia avirostris	36.8065	2	6.4516	10	32.258	0.0
Penilia sp.	40.2419	1	3.2258	8	25.806	0.0
SNE - 1978 - Early Autumn - No. Sta. 51						
Centropages typicus	1.1569	30	58.8235	51	100.000	76048.6
Penilia sp.	62.6569	1	1.9608	8	15.686	0.0
Penilia avirostris	63.5294	1	1.9608	7	13.725	0.0
SNE - 1978 - Late Autumn - No. Sta. 10						
Centropages typicus	1	7	70	10	100	43046
SNE - 1979 - Late Winter - No. Sta. 40						
Pseudocalanus minutus	3.2125	19	47.5	39	97.5	13106.3
Centropages typicus	6.4000	4	10.0	38	95.0	1873.3
Balanidae	42.6000	1	2.5	15	37.5	0.0
Gammarus annulatus	61.0000	1	2.5	1	2.5	0.0
SNE - 1979 - Early Spring - No. Sta. 24						
Pseudocalanus minutus	2.9792	5	20.8333	24	100.000	20254.0
Temora longicornis	17.8333	1	4.1667	20	83.333	537.8
Oikopleura spp.	27.3958	1	4.1667	14	58.333	616.4
Balanidae	29.5208	1	4.1667	14	58.333	83.9
Gammaridea	48.1042	1	4.1667	5	20.833	0.0
SNE - 1979 - Late Spring - No. Sta. 27						
Temora longicornis	12.4630	2	7.40741	24	88.8889	2051.28
Brachyura	25.7407	1	3.70370	18	66.6667	352.94
SNE - 1979 - Early Summer - No. Sta. 44						
Centropages typicus	6.4659	5	11.3636	42	95.4545	14885.4

Calanus finmarchicus	14.6250	1	2.2727	38	86.3636	2622.7
Evadne nordmanni	41.2159	5	11.3636	22	50.0000	40.3
Clausocalanus spp.	70.5909	1	2.2727	5	11.3636	0.0
Gammaridea	72.7955	1	2.2727	4	9.0909	0.0
Scyphozoa	77.4205	1	2.2727	7	15.9091	0.0
SNE - 1979 - Late Summer - No. Sta. 36						
Centropages typicus	3.7500	5	13.8889	36	100.000	37021.3
Calanus finmarchicus	12.0556	2	5.5556	32	88.889	9178.7
Pseudocalanus minutus	30.9722	1	2.7778	24	66.667	560.8
Doliolidae	32.0000	6	16.6667	22	61.111	1874.7
Penilia avirostris	40.9167	4	11.1111	18	50.000	70.3
SNE - 1979 - Early Autumn - No. Sta. 27						
Centropages typicus	11.3889	5	18.5185	24	88.8889	19549.9
Penilia avirostris	34.9444	2	7.4074	16	59.2593	306.9
Acartia sp.	37.5000	1	3.7037	15	55.5556	87.1
Acartia spp	43.0556	2	7.4074	12	44.4444	0.0
Echinodermata	49.9444	2	7.4074	10	37.0370	0.0
SNE - 1979 - Late Autumn - No. Sta. 31						
Centropages typicus	1.06452	18	58.0645	31	100	44739.1
SNE - 1980 - Late Winter - No. Sta. 64						
Centropages typicus	3.7266	11	17.1875	63	98.4375	4542.25
Pseudocalanus minutus	4.8906	13	20.3125	62	96.8750	8713.35

Centropages typicus	3.7266	11	17.1875	63	98.4375	4542.25
Pseudocalanus minutus	4.8906	13	20.3125	62	96.8750	8713.35
Calanus finmarchicus	9.9688	2	3.1250	59	92.1875	1092.35
Metridia lucens	26.0391	1	1.5625	44	68.7500	245.76
Balanidae	38.9219	3	4.6875	32	50.0000	10.08
Appendicularia(Larvacea)	46.4063	1	1.5625	22	34.3750	0.00
Foraminifera	54.8984	1	1.5625	15	23.4375	0.00
SNE - 1980 - Early Spring - No. Sta. 43						
Pseudocalanus minutus	2.9419	2	4.6512	43	100.000	23938.6
Calanus finmarchicus	12.1628	7	16.2791	37	86.047	9846.2
Appendicularia (Larvacea)	14.8721	4	9.3023	35	81.395	2830.8
Balanidae	28.1395	2	4.6512	26	60.465	621.5
SNE - 1980 - Late Spring - No. Sta. 43						
Pseudocalanus minutus	4.7093	4	9.3023	42	97.6744	21125.3
Calanus finmarchicus	8.7093	10	23.2558	40	93.0233	9380.3
Temora longicornis	26.5814	2	4.6512	29	67.4419	1907.7
Calanus spp.	62.2093	1	2.3256	4	9.3023	0.0
SNE - 1980 - Early Summer - No. Sta. 50						
Centropages typicus	2.3875	8	20.0	40	100.0	22578.4
Calanus finmarchicus	6.9375	2	5.0	39	97.5	11454.5
Centropages hamatus	20.5875	1	2.5	33	82.5	806.7
Evadne nordmanni	47.475	1	2.5	14	35	0.0
SNE - 1980 - Late Summer - No. Sta. 43						
Penilia avirostris	42.6279	9	20.9302	26	60.4651	424.552

Echinodermata	53.2791	1	2.3256	21	48.8372	0.000
Acartia sp.	53.8140	1	2.3256	21	48.8372	0.000
Foraminifera	60.4419	1	2.3256	16	37.2093	0.000
Thaliacea (Salpa)	62.9302	1	2.3256	16	37.2093	0.000
Noemysis americana	85.9884	1	2.3256	4	9.3023	0.000
SNE - 1980 - Early Autumn - No. Sta. 44						
Centropages typicus	1.8750	20	45.4545	44	100.000	40713.2
Acartia sp.	44.3068	1	2.2727	25	56.818	56.7
Foraminifera	64.9318	2	4.5455	12	27.273	0.0
SNE - 1981 - Late Winter - No. Sta. 43						
Pseudocalanus minutus	3.6744	13	30.2326	42	97.6744	9042.88
Calanus finmarchicus	6.0465	9	20.9302	41	95.3488	1806.08
Balanidae	35.1047	1	2.3256	22	51.1628	19.20
Fritillaria sp.	54.3023	1	2.3256	6	13.9535	0.00
SNE - 1981 - Early Spring - No. Sta. 43						
Pseudocalanus minutus	2.6395	11	25.5814	43	100.000	55969.2
Calanus finmarchicus	9.7791	1	2.3256	38	88.372	6023.0
Appendicularia (Larvacea)	12.6512	5	11.6279	35	81.395	8711.9
Balanidae	28.6860	3	6.9767	24	55.814	84.5
SNE - 1981 - Early Summer - No. Sta. 35						
Calanus finmarchicus	6.0286	1	2.85714	34	97.1429	13920.6
Ctenophora	59.5143	3	8.57143	9	25.7143	0.0
SNE - 1981 - Late Summer - No. Sta. 33						

Calanus finmarchicus	6.0286	1	2.85714	34	97.1429	13920.6
Ctenophora	59.5143	3	8.57143	9	25.7143	0.0
SNE - 1981 - Late Summer - No. Sta. 33						
Centropages typicus	2.6515	8	24.2424	33	100.000	25025.6
Calanus finmarchicus	19.2273	4	12.1212	26	78.788	3654.5
Centropages hamatus	21.3636	1	3.0303	26	78.788	1207.3
Calanus spp.	65.7879	2	6.0606	3	9.091	0.0
Calanus sp.	67.9697	1	3.0303	2	6.061	0.0
SNE - 1981 - Early Autumn - No. Sta. 30						
Penilia avirostris	28.3500	1	3.33333	20	66.6667	3029.42
Acartia spp	41.1167	1	3.33333	14	46.6667	0.00
Doliolidae	46.4167	2	6.66667	11	36.66667	0.00
SNE - 1981 - Late Autumn - No. Sta. 37						
Centropages typicus	7.9595	2	5.40541	35	94.5946	9403.33
Penilia avirostris	49.1892	2	5.40541	16	43.2432	0.00
Acartia sp.	50.3243	1	2.70270	17	45.9459	0.00
Doliolidae	68.4459	2	5.40541	6	16.2162	0.00
MAB - 1977 - Late Summer - No. Sta. 30						
Centropages typicus	5.0667	2	6.6667	29	96.6667	9171.8
Pseudocalanus minutus	7.2000	3	10.0000	27	90.0000	13763.3
Temora longicornis	7.5500	3	10.0000	27	90.0000	9729.8
Centropages hamatus	13.3167	1	3.3333	24	80.0000	2190.2
Decapoda-arthropoda	31.3000	1	3.3333	11	36.6667	0.0
Hydrozoa	33.5167	2	6.6667	9	30.0000	0.0
Ovalipes ocellatus	44.6667	1	3.3333	1	3.3333	0.0

MAB - 1977 - Early Autumn - No. Sta. 30						
Penilia avirostris	6.46667	13	43.3333	28	93.3333	75107.8
MAB - 1977 - Late Autumn - No. Sta. 30						
Centropages typicus	6.76667	2	6.66667	29	96.6667	6876.62
Calanus minor	6.83333	1	3.33333	29	96.6667	5893.43
MAB - 1978 - Late Winter - No. Sta. 29						
Pseudocalanus minutus	1.48276	16	55.1724	29	100	15881.6
Centropages typicus	2.31034	4	13.7931	29	100	4548.0
MAB - 1978 - Early Spring - No. Sta. 28						
Pseudocalanus minutus	1.5000	19	67.8571	28	100.000	35229.4
Centropages typicus	2.8214	1	3.5714	28	100.000	8666.5
Calanus finmarchicus	8.2143	1	3.5714	26	92.857	1002.6
Oikopleura spp.	26.0714	1	3.5714	5	17.857	0.0
MAB - 1978 - Early Summer - No. Sta. 29						
Centropages typicus	6.0172	15	51.7241	28	96.5517	43200
Penilia avirostris	44.1207	1	3.4483	10	34.4828	0
MAB - 1978 - Late Summer - No. Sta. 31						
Penilia avirostris	1.09677	25	80.6452	31	100	263653
MAB - 1978 - Early Autumn - No. Sta. 16						
Centropages typicus	2.2188	1	6.25	16	100.00	36230.2
Penilia avirostris	14.1563	6	37.50	13	81.25	45076.9
Acartia spp	33.9063	1	6.25	6	37.50	0.0

Penilia avirostris	14.1563	6	37.50	13	81.25	[illegible]
Acartia spp	33.9063	1	6.25	6	37.50	0.0
Acartia sp.	39.1250	1	6.25	4	25.00	0.0
1980 - Late Winter - No. Sta. 48						
Centropages typicus	2.0417	22	45.8333	48	100.000	14746.6
Pseudocalanus minutus	7.6042	2	4.1667	46	95.833	2106.1
Spiratella retroversa	43.2604	1	2.0833	14	29.167	0.0
Foraminifera	46.6250	1	2.0833	13	27.083	0.0
MAB - 1979 - Late Spring - No. Sta. 30						
Temora longicornis	4.9500	4	13.3333	29	96.6667	11306.5
Brachyura	16.8500	4	13.3333	22	73.3333	3583.9
Evadne nordmanni	28.5833	1	3.3333	14	46.6667	0.0
MAB - 1979 - Early Summer - No. Sta. 49						
Centropages typicus	2.7551	11	22.4490	49	100.000	31907.8
Temora longicornis	13.8163	5	10.2041	44	89.796	3355.1
Evadne nordmanni	54.4490	3	6.1224	20	40.816	0.0
Evadne sp.	67.4694	1	2.0408	13	26.531	0.0
Acartia clausi	84.4592	1	2.0408	2	4.082	0.0
MAB - 1979 - Late Summer - No. Sta. 47						
Penilia avirostris	2.8191	29	61.7021	46	97.8723	132122
Doliolidae	38.5213	2	4.2553	24	51.0638	322
MAB - 1979 - Early Autumn - No. Sta. 31						
Penilia avirostris	22.2258	11	35.4839	23	74.1935	59251.3
Acartia spp	45.5806	3	9.6774	15	48.3871	0.0
Acartia sp.	47.2097	2	6.4516	15	48.3871	0.0
Echinodermata	63.7903	1	3.2258	7	22.5806	0.0

MAB - 1980 - Late Winter - No. Sta. 50						
Centropages typicus	1.70	19	38	50	100	12829.3
Pseudocalanus minutus	6.71	2	4	49	98	2095.4
MAB - 1980 - Early Spring - No. Sta. 47						
Centropages typicus	3.4468	10	21.2766	46	97.8723	31600.0
Pseudocalanus minutus	8.0745	1	2.1277	44	93.6170	16065.3
Centropages hamatus	23.2340	1	2.1277	37	78.7234	1080.0
MAB - 1980 - Late Spring - No. Sta. 48						
Centropages typicus	3.3646	7	14.5833	48	100.000	10191.4
Pseudocalanus minutus	6.5729	2	4.1667	47	97.917	6049.3
Brachyura	17.9688	2	4.1667	40	83.333	2026.3
Calanus finmarchicus	38.4688	2	4.1667	24	50.000	7.8
Evadne nordmanni	49.8438	3	6.2500	17	35.417	0.0
MAB - 1980 - Early Summer - No. Sta. 45						
Centropages typicus	11.6444	4	8.8889	41	91.1111	14487.2
Penilia avirostris	17.9778	17	37.7778	37	82.2222	40332.5
Temora longicornis	28.0111	1	2.2222	33	73.3333	2112.8
Thaliacea (salpa)	43.7000	3	6.6667	24	53.3333	253.2
Calanus finmarchicus	50.2556	2	4.4444	21	46.6667	0.0
Doliolidae	68.0000	2	4.4444	10	22.2222	0.00
MAB - 1980 - Late Summer - No. Sta. 45						
Penilia avirostris	2.9	5	11.1111	45	100.000	44685.4

MAB - 1980 - Late Summer - No. Sta. 45						
Penilia avirostris	2.9	5	11.1111	45	100.000	44685.4
[illegible]	54.8	1	2.2222	22	48.889	0.0
MAB - 1980 - Early Autumn - No. Sta. 40						
Centropages typicus	3.8625	16	40	39	97.5	90958
MAB - 1981 - Late Winter - No. Sta. 26						
Pseudocalanus minutus	2.40385	9	34.6154	26	100	8686.08
Centropages typicus	2.65385	1	3.8462	26	100	4772.90
MAB - 1981 - Early Spring - No. Sta. 43						
Pseudocalanus minutus	4.1977	11	25.5814	42	97.6744	31204.6
Temora longicornis	17.7326	1	2.3256	35	81.3953	1689.1
Appendicularia (Larvacea)	29.1628	3	6.9767	26	60.4651	283.9
Centropages hamatus	32.9419	1	2.3256	25	58.1395	148.5
MAB - 1981 - Early Summer - No. Sta. 20						
Centropages typicus	4.475	3	15	19	95	15173.1
Temora longicornis	7.350	3	15	19	95	7014.8
MAB - 1981 - Late Summer - No. Sta. 16						
Centropages typicus	2.0625	6	37.50	16	100.0	28757.5
Coelenterata onideria	25.8750	1	6.25	10	62.5	206.4
Calanus spp.	47.0000	1	6.25	2	12.5	0.0
MAB - 1981 - Early Autumn - No. Sta. 41						
Penilia avirostris	12.4634	13	31.7073	36	87.8049	77846.2
Siphonophora	40.7195	1	2.4390	19	46.3415	0.0
Acartia spp	47.3415	1	2.4390	16	39.0244	0.0
Evadne nordmanni	54.1585	1	2.4390	11	26.8293	0.0

MAB - 1981 - Late Autumn - No. Sta. 43

Echinodermata	28.7907	11	25.5814	33	76.7442	2496.16
Acartia sp.	70.2558	1	2.3256	15	34.8837	0.00
Acartia spp	72.0349	3	6.9767	13	30.2326	0.00
Acartia clausi	97.6163	1	2.3256	1	2.3256	0.00

*Table 4. Yearly median abundance (no./100 m³) for Calanus finmarchicus, Centropages typicus, Pseudocalanus minutus for Southern New England and the Mid-Atlantic Bight at <50 m and ≥50 m depths. Number of stations (N) and Kruskal Wallis probabilities (p) for test of significance of abundance differences are given by year and season. * indicates significance at .05 level.*

	1977					1978					1979					1980					1981				
	N	<50m Median	N	≥50m Median	p	N	<50m Median	N	≥50m Median	p	N	<50m Median	N	≥50m Median	p	N	<50m Median	N	≥50m Median	p	N	<50m Median	N	≥50m Median	p
Southern New England																									
Calanus finmarchicus																									
Late winter	9	115.0	13	807.0	0.3329	15	35.0	8	404.5	0.0185*	19	569.0	5	1091.0	0.0138*	22	296.5	29	1293.0	0.0012*	17	976.0	19	6753.0	0.0001*
Early spring	7	3508.0	7	22371.0	0.0181*						10	5465.5	10	8426.5	0.2568	17	959.0	19	27478.0	0.0005*	16	1151.5	21	9274.0	0.0003*
Late spring	22	15415.5	24	85138.5	0.0034*	12	884.5	12	35205.0	0.0032*	15	1872.0	10	17542.5	0.0005*	18	3502.0	18	42981.0	0.0247*	14	658.0	16	42869.5	0.0002*
Early summer						16	2590.0	11	34100.0	0.0019*	17	563.0	20	13120.0	0.0182*						14	1203.5	14	18663.5	0.0981
Late summer	13	631.0	17	18823.0	0.0001*	14	5745.5	11	18097.0	0.0186*	14	1364.0	15	25713.0	0.0001*	16	3488.0	16	18986.0	0.0348*	14	2361.5	16	18149.5	0.0012*
Early autumn						21	1097.0	11	960.0	0.8583	10	63.5	12	3591.5	0.0030*	19	0.0	17	2366.0	0.0002*	15	615.0	16	1883.5	0.0604
Late autumn	7	0.0	7	289.0	0.1797	5	129.0	3	1468.0	0.0253*	9	557.0	15	423.0	0.9287	18	284.5	18	61.5	0.3843					
Early winter																									
Centropages typicus																									
Late winter	9	9783.0	13	7652.0	0.9202	15	615.0	8	705.0	0.5613	19	6813.0	15	640.0	0.0098*	22	16108.0	29	3590.0	0.0149*	17	4015.0	19	923.0	0.0074*
Early spring	7	1659.0	7	1113.0	0.5229						10	1333.0	10	5052.0	0.2568	17	4373.0	19	3130.0	0.7634	16	984.5	21	1197.0	0.5197
Late spring	22	562.0	24	959.5	0.5527	12	625.0	12	186.0	0.1489	15	10634.0	10	19369.5	0.6572	18	24486.0	18	4101.0	0.0033*	14	618.5	16	8754.5	0.0159*
Early summer						16	16733.0	11	16389.0	0.5537	17	26855.0	20	7455.5	0.0161*						14	50279.0	14	17871.0	0.0101*
Late summer	13	50409.0	17	8622.0	0.2954	14	64929.0	11	14731.0	0.0018*	14	59941.0	15	9115.0	0.0001*	16	34033.0	16	26067.0	0.2744	14	35551.5	16	23670.0	0.0739
Early autumn						21	120046.0	11	40656.0	0.0203	10	9924.5	12	11983.5	0.9474	19	15893.0	17	1494.0	0.0003*	15	9403.0	16	4063.0	0.1727
Late autumn	7	51446.0	7	32307.0	0.3379	5	56882.0	3	42261.0	0.2967	9	53329.0	15	35892.0	0.5312	18	182282.0	18	23591.0	0.0001					
Early winter																									
Pseudocalanus minutus																									
Late winter	9	16056.0	13	11590.0	0.9202	15	17744.0	8	8794.5	0.1376	19	24451.0	5	11008.0	0.0042*	22	17399.0	29	5713.0	0.0043*	17	31529.0	19	6552.0	0.0025*
Early spring	7	52965.0	7	38351.0	0.4822						10	59886.5	10	21782.5	0.1509	17	53762.0	19	15317.0	0.0276*	16	88839.5	21	55969.0	0.0754
Late spring	22	92443.0	24	83749.5	0.4748	12	24238.0	12	28818.0	0.9081	15	55058.0	10	19086.0	0.0305*	18	122413.0	18	19336.0	0.0104*	14	3883.0	16	15769.0	0.4543
Early summer						16	45018.0	11	19120.0	0.2776	17	5043.0	20	1611.0	0.0771						14	9584.0	14	3571.5	0.3581
Late summer	13	5667.0	17	3192.0	0.9833	14	3458.0	11	1780.0	0.2503	14	261.5	15	389.0	0.8614	16	7387.0	16	380.0	0.0002*	14	3687.5	16	1450.5	0.0614
Early autumn						21	4164.0	11	384.0	0.0083*	10	59.5	12	103.0	0.8951	19	0.0	17	0.0	0.3835	15	407.0	16	116.5	0.0243*
Late autumn	7	4512.0	7	13872.0	0.3379	5	11510.0	3	1468.0	0.1011	9	871.0	15	303.0	0.0253*	18	1421.0	18	41.0	0.0314*					
Early winter																									

Mid-Atlantic Bight

Calanus Finmarchicus																											
Late winter						26	108.5	3	58.0	0.5667	37	133.0	11	197.0	0.1894	39	271.0	11	133.0	0.4466	20	1108.0	6	3112.5	0.0089*
Early spring						23	548.0	5	37785.0	0.0011				10379.0		32	140.5	15	16749.0	0.0003*	29	523.0	14	6014.0	0.0007*
Late spring	24	507.5	5	7284.0	0.2987						63	0.0	16	3183.0	0.0001*	36	0.0	12	40033.0	0.0001*	15	0.0	5	3294.0	0.0014*
Early summer						26	0.0	3	8966.0	0.0099*						32	0.0	13	9197.0	0.0009*	12	0.0	4	678.5	0.2751
Late summer	27	0.0	3	33136.0	0.0063*	26	0.0	5	23854.0	0.0007*	33	0.0	14	4769.0	0.0001*						31	0.0	10	2650.5	0.0001*
Early autumn	25	79.0	5	1261.0	0.0042*	13	0.0	2	1011.0	0.0894*	24	0.0	7	2440.0	0.0040*	33	0.0	12	6987.5	0.0002*	27	0.0	16	1146.0	0.0001*
Late autumn																31	0.0	9	760.0	0.0062*					
Early winter																									
Centropages typicus																											
Late winter						26	5281.0	3	599.0	0.0219*	37	25862.0	11	2328.0	0.0001*	39	24507.0	11	397.0	0.0001*	20	4500.5	6	5529.5	0.8077
Early spring						23	9231.0	5	2123.0	0.1586				18813.5		32	32371.0	15	29449.0	0.5683	29	8023.0	14	3145.5	0.0138*
Late spring	24	9172.0	5	27857.0	0.4884						63	29321.0	16	7578.0	0.1047	36	9559.0	12	10247.0	1.0000	15	25058.0	5	7142.0	0.0736
Early summer						26	50818.0	3	28528.0	0.3519						32	14454.0	13	22941.0	0.6342	12	35664.5	4	11470.0	0.1149
Late summer	27	6000.0	3	19764.0	0.3875	26	9599.0	5	19602.0	0.5020	33	6716.0	14	5085.0	0.5300						31	28923.0	10	17249.0	0.3786
Early autumn	25	7033.0	5	3176.0	0.1127	13	38501.0	2	7443.0	0.0617	24	1081.5	7	1508.0	0.5083	33	22892.0	12	3048.0	0.0006*	27	755.0	16	1015.5	0.5465
Late autumn																31	153092.0	9	22256.0	0.0004*					
Early winter																									
Pseudocalanus minutus																											
Late winter						26	20902.5	3	2296.0	0.0450*	37	3226.0	11	94.0	0.0002*	39	4988.0	11	41.0	0.0001*	20	9767.5	6	4962.5	0.3302
Early spring						23	30933.0	5	98496.0	0.1771				9846.5		32	18092.0	15	13251.0	0.5529	29	41796.0	14	6070.5	0.0128*
Late spring	24	8470.0	5	39834.0	0.4529						63	3268.0	16	2579.5	0.3932	36	3663.0	12	50990.0	0.0015*	15	1839.0	5	1111.0	0.6945
Early summer						26	3908.5	3	6706.0	0.4739						32	365.0	13	431.0	0.5150	12	1462.0	4	2453.5	1.0000
Late summer	27	1354.0	3	2523.0	0.2998	26	386.0	5	4542.0	0.0566	33	0.0	14	563.5	0.0454*						31	520.0	10	1852.0	0.2246
Early autumn	25	0.0	5	125.0	0.5590	13	0.0	2	139.5	0.3082	24	0.0	7	1114.0	0.0040*	33	0.0	12	0.0	0.9591	27	0.0	16	577.0	0.0001*
Late autumn																31	1074.0	9	164.0	0.0397*					
Early winter																									

6.5 CONCLUSIONS.

1) Three species of copepods dominante the zooplankton community, *Calanus finmarchicus*, *Centropages typicus* and *Pseudocalanus minutus*. There is an increase in the diversity of dominant zooplankton species in the more southern waters of the Mid-Atlantic Bight in comparison to Southern New England.

2) *C. finmarchicus* is more abundant in the PAI than in the shallower zone in Southern New England and is restricted to the region of the PAI in the warm months in the Mid-Atlantic Bight. *P. minutus* exhibit a similar preference for offshore waters but is not as restricted areally while *C. typicus* remain abundant throughout the warm months in both offshore and onshore waters.

3) The timing of nearshore and PAI standing stock maxima are not synchronous but of approximately the same magnitude indicating a difference in the communities which is reflected in the patterns of abundance of the dominant species.

4) The developmental and adult stages of the copepod species *C. finmarchicus*, *C. typicus* and *P. minutus* are major food organisms for pelagic species such as mackerel and herring and for larval and juvenile stages of other pelagic and demersal fish species of commercial importance. The distribution of all three zooplankters is inclusive of, or restricted to the potential area of influence of 106-Mile Site. Pollutants assimilated by primary producers which provide forage for zooplankton can therefore enter the pelagic and demersal food web which are ultimately harvested by man.

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CHAPTER 7. FISH EGGS AND LARVAE

W. Smith, W. Morse, A. Wells, and D. McMillan[1]

7.1 INTRODUCTION.

Studies of fish eggs and larvae have been an integral part of oceanographic research in continental shelf waters off northeastern United States since the turn of the century (Colton 1963). Although a wide range of study designs have contributed to the current status of knowledge of the early life history of coastal fishes, surveys of varying scope and intensity have provided the principal source of information on spawning cycles and the seasonal distribution patterns of fish eggs and larvae. Noteworthy contributions from some of these surveys include: Bigelow and Welsh (1925); Fish (1982); Walford (1938); Perlmutter (1939); Sette (1943); Colton and Temple (1961); Marak and Colton (1961); Norcross et al. (1961); Marak et al. (1962a, b); Boyar et al. (1973); Colton and St. Onge (1974); Fahay (1974); Kendall and Reintjes (1975); Smith et al. (1975); Berrien (1978); Berrien et al. (1978); Kendall and Walford (1979) and Lough et al. (1981).

Some of the above are based on short term, geographically restricted field programs that targeted a single species for investigation; others are more extensive in coverage and grandiose in their objectives. But only the pioneer study of Bigelow and Welsh (1925) continued on a year-round basis for more than two years. It was not until the mid-1970's, when the Northeast Fisheries Center initiated a broadscale fishery ecosystems study of shelf waters off northeastern United States that a temporally uninterrupted and areally exhaustive survey of fish eggs and larvae

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was put in place. This program, known as MARMAP (Marine Resources Monitoring, Assessment and Prediction), is a highly interactive research endeavor designed to measure variability in biological and environmental components of the shelf ecosystem while maintaining a constant check on the condition, status and rates of change in population levels of marine fish stocks off our northeast coast.

The MARMAP program represents the most complete ongoing study of its kind anywhere in the world and offers promising prospects for understanding the driving mechanisms in marine ecosystems (Sherman 1980). Survey measurements include: primary production (^{14}C), chlorophyll a, phaeophytin, nutrients (NO_2, NO_3, SiO_3, NH_4 and PO_4), zooplankton, ichthyoplankton, fish, benthos, observations on sea birds and marine mammals, water column temperature, salinity and circulation.

MARMAP surveys of fish eggs and larvae in that part of the Middle Atlantic Bight potentially influenced by dumping at the 106-mile site form the basis of this report. Information on the occurrence of fish larvae in adjacent slope waters that fall within the sphere of potential influence from dumping at the 106-mile site is compiled from Austin (1975); Sherman et al. (1977); McKenney (1982) and unpublished data from a MARMAP operational test phase survey by RV DELAWARE II in the summer of 1972.

7.2 METHODS.

The MARMAP survey area includes shelf and slope water from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia, an area of some 260,000 km^2. Sampling stations are spaced at 8 to 18-km intervals along five transects within the survey area. Otherwise, they were selected from a stratified-random design used for NEFC trawl surveys (Grosslein 1969; Clark and Wood 1978), with station intervals of 25 to 35 km (Figure 1 and Table 1).

Plankton samples are collected by double-oblique tows with a 61-cm bongo fitted with 0.333 and 0.505-mm mesh nets. The 0.505-mm mesh samples are used for studies of fish eggs and larvae; the 0.333-mm mesh samples for invertebrate zooplankton studies. The bongo is lowered to within a few meters of bottom or to a maximum depth of 200 m at 50 m/min, and retrieved at 20 m/min. Ship speed varies between 1 and 2 kts to maintain a 45° wire angle during a tow. A flow meter in the mouth of each net provides information for computing the amount of water filtered during a tow, and a bathykymograph records a trace of the vertical tow profile and the maximum sampling depth. Plankton samples are preserved in 4% buffered formalin.

Initial processing of MARMAP ichthyoplankton samples is completed at the Morski Instytut Rybacki, Szczecin, Poland. Larvae are identified and measured at the Institute then returned to NOAA's Sandy Hook Laboratory, along with appropriate logs and eggs. Larvae and corresponding logs are checked at Sandy Hook and that data are subsequently keypunched for entry into the MARMAP Information System (MIS). Pelagic eggs are identified and staged at Sandy Hook to map spawning areas and derive estimates of spawning stock biomass. For analytical purposes, fish eggs and larvae are converted to numbers/$10m^2$ surface area, an expression of abundance.

7.3 SPAWNING PATTERNS OF COASTAL FISHES.

Larval fishes representing >200 taxa are collected annually on MARMAP surveys. Spawning strategies vary between species but most spawn pelagic eggs which drift in the water column until hatching takes place. The incubation period requires anywhere from a few days to a few weeks, depending on water temperature and the species in question. Thereafter the developing larvae are dependent on favorable circulation patterns, water quality and food supply for a time period measured in months. It is these free-floating eggs and larvae that are the most vulnerable stages of development in the life history of marine fishes.

Although spawning goes on year-round, spawning cycles of most coastal species are seasonal and climatic changes are followed closely by changes in the species composition of the ichthyoplankton community. The role of environmental stimuli in triggering and controlling the breeding cycles of most marine fishes is poorly understood, but de Vlaming (1974) presented evidence that changing temperatures and photoperiod provoke active spawning in several temperate species. Although not substantiated, it is widely held that these two factors influence the onset of spawning in coastal fishes off northeastern United States where many species immigrate from the south with spring warming and emigrate as coastal waters cool in autumn. Eggs and larvae of these transient species are geographically limited at the onset of spawning but their distributions expand as the adult migrations advance. For example, young stages of Atlantic mackerel, *Scomber scombrus*, first occur off North Carolina and/or Virginia in April, then continue to spread northward as the adults migrate to waters off southern New England and beyond in June (Berrien 1978; Berrien et al. 1981). Conversely, the young of Atlantic menhaden, *Brevoortia tyrannus*, are found off southern New England in summer and progressively farther south during the autumn months (Kendall and Reintjes 1975). Smith et al. (1975) found similar geographic progressions in the distribution of flatfish larvae, the young of non-migratory fishes and concluded that external stimuli such as seasonal temperature cycles have a similar influence on the onset of spawning for both migratory and non-migratory species.

7.4 THE RELATIVE MAGNITUDE OF SEASONAL SPAWNING CYCLES.

Although spawning grounds are areally limited for some species, i.e., redfish (*Sebastes* spp.) in the Gulf of Maine, for others such as hakes (*Urophycis* sp.), silver hake (*Merluccius bilinearis*) and sand lance (*Ammodytes* sp.), the young are broadly distributed. Indeed, eggs and larvae representing the entire coastal fish community are so widely distributed that the entire continental shelf from Cape Hatteras to Nova Scotia must be considered important spawning and nursery grounds (Figure 2).

Species composition of the larval fish community within the MARMAP survey area is inversely proportional to increasing latitude, with the larval community most diverse in the Middle Atlantic Bight and least diverse in the Gulf of Maine. Within the Bight, the annual spawning cycle and the species composition of the larval fish community increases from a low in winter to a high in summer, then declines in autumn. Despite the disparity in the relative magnitude of seasonal spawning cycles, economically important species such as Atlantic cod (*Gadus morhua*), summer flounder (*Paralichthys dentatus*) and Atlantic menhaden (*Brevoortia tyrannus*) spawn in the Bight during the late autumn and winter months.

Survey results for the 1977-80 time period show remarkable similarity in the seasonal abundance of fish eggs in the Middle Atlantic Bight and in that part of the Bight potentially influenced by dumping at the 106-mile site. Furthermore, a comparison of the egg abundance curves for the Bight and the potentially influenced area suggests that the relative magnitude of spawning within the two areas is proportional from year to year (Figure 4). These similarities point to a remarkable level of seasonal and areal equilibrium in spawning activity in the Bight.

Fish larvae also exhibit pulses in abundance which follow seasonal trends from year to year. But the annual abundance curves for larvae differ from those of eggs, largely because of a population explosion in the mid-1970's of sand lance (*Ammodytes* sp.), a taxon that spawns demersal eggs in late autumn and winter. Whereas the abundance of eggs has a single annual peak in summer, the standing crop of larvae in the Middle Atlantic Bight peaks in winter, declines in early spring, increases in late spring to a second annual peak in summer, then declines again in autumn. As with eggs, the proportion of larvae that occurs within the Bight portion of the potentially influenced area at a given time is directly related to the overall abundance of larvae in the Bight (Figure 4).

Within the shelf part of the area subject to influence from dumping at the 106-mile site the larval fish community is a mix of shelf and slope water species that continually changes, largely because of the seasonal spawning habits of the fishes, the dynamics of coastal circulation, and the inshore-offshore movements of the shelf-slope front. During the course of a year, more than 150 of the 200+ taxa of larvae that occur annually in coastal waters off northeastern United States are found in the shelf portion of the potentially influenced area. Despite the dynamic and diverse nature of the larval fish populations in this area, numerical dominance is shared by a limited number of taxa which maintain their competitive advantage from year to year until they are directly or indirectly reduced through natural or man-induced changes such as: 1) a decline in the size of spawning stocks to a level below that required to produce enough young to maintain a competitive advantage over the developing young stages of other species; 2) shifts in spawning time and/or location which cause changes in the distribution patterns of eggs and larvae and have the potential to result in temporal or spatial mismatches between newly hatched larvae and optimal densities of their predators and/or prey; 3) changes in circulation patterns which cause mass mortality by transporting young planktonic stages away from their nursery area; and 4) increased embryonic and larval mortality imposed by the release of pollutants over principal spawning areas. In large part, it is the deviation from average conditions that influence the size of a year class.

On an annual basis, nine taxa shared the top five positions of numerical dominance in that part of the shelf potentially influenced by dumping at the 106-mile site during the 1977-80 MARMAP surveys. Three of the top five, Atlantic mackerel, hakes of the genus Urophycis and silver hake are economically important taxa that contribute to the 1.1 billion dollar fishing industry off northeastern United States. Another, sand lance, is a forage species that provides a principal part of the diet for important piscivorous species such as summer flounder, bluefish, Pomatomus

saltatrix, weakfish, Cynoscion regalis, striped bass, Morone saxatilis, Atlantic cod and bluefin tuna, Thunnus thynnus.

Sand lance, which accounted for 90 to 99.5% of the winter larval population, was the most dominant taxon within the shelf portion of the area potentially influenced by dumping at the 106-mile site. The estimated abundance of sand lance larvae within the 34,336 km^2 shelf portion of the potentially influenced area exceeded 1.8 trillion at the time of the 1979 winter survey. This extraordinary biomass is equivalent to 52 million larvae/km^2 and represents the peak abundance level for a taxon during the 4-year reporting period, although the abundance estimates of hake, Urophycis sp., and Atlantic mackerel were nearly as great in the summer of 1977 and spring of 1980, respectively. Young sand lance remained at or near the forefront of dominance during winters of the other three years when their annual abundance estimate exceeded 470 billion larvae (Table 2).

A slope water myctophid, Benthosema glaciale, was a perennial early spring dominant, although larvae were considerably less abundant than those of the other dominants. B. glaciale was succeeded by Atlantic mackerel in late spring of 1977 and 1980 but young mackerel were not abundant in the shelf portion of the potentially influenced dumping area during the intervening years. In summer hakes of the genus Urophycis dominated in 1977 and 1980, and they ranked near the top in 1978 and 1979. Silver hake, and flatfishes of the genera Citharichthys and Etropus were dominant during late summer and early autumn months of 1977, 1978 and 1979 (Table 2).

Late autumn survey coverage of the shelf portion of the potentially influenced dumping area was adequate only in 1979. Silver hake larvae dominated, although the spawning season of silver hake normally peaks in summer and tapers off to insignificant levels by late autumn. Despite the position of numerical dominance, the abundance of silver hake larvae in late autumn of 1979 was only a fraction of that for the dominant taxa during winter, spring and summer (Table 2).

7.5 FISH LARVAE IN SLOPE WATERS.

Most of the 112,657 km^2 area that falls within the realm of possible influence from ocean dumping at the 106-mile site lies east of the continental shelf, beyond the geographic scope of most United States fisheries and, therefore, in an area where fisheries research is seldom done. The MARMAP station plan shown in Figure 1 exemplifies this point. Because of the paucity of ichthyoplankton research in slope waters and the lack of standardization in collecting gears and techniques used in sampling these waters, results cannot be meaningfully compared in a quantitative sense. Larval fishes collected in slope and oceanic waters at and surrounding the 106-mile site are summarized here on the basis of monthly occurrence (Table 3). This listing contains 209 taxa which represent 73 families. Most of the taxa are slope water and/or oceanic fishes, but representatives of shelf species occur during all seasons of the year. Some of these shelf taxa originate in the Middle Atlantic Bight and are subsequently transported off the shelf by currents, while others originate south of Cape Hatteras and are transported northward by the Gulf Stream. The likelihood of these wayward larvae finding their way back onto the shelf is remote and they eventually succumb to the intolerable slope water environment.

One important species, the bluefish, does occur naturally at early stages of development in slope waters adjacent to the Middle Atlantic Bight (Austin 1975; Kendall and Walford 1979). According to Kendall and Walford (1979) these fish originate south of Cape Hatteras in spring, move northward along the shelf/slope front and ultimately move shoreward into coastal estuaries of the Middle Atlantic states where they remain for the summer. In subsequent years, they contribute to the popular summer sport fishery for bluefish off northeastern United States. Bluefish also spawn in the Middle Atlantic Bight and within that part of the Bight potentially influenced by dumping activity at the 106-mile site (see Figure 5 and Table 2). The relative contributions of bluefish

spawned north and south of Cape Hatteras to the recreational fishery remains an open question, but it is clear that both groups of fish occupy waters potentially influenced by dumping at the 106-mile site during the vulnerable early part of their life cycle.

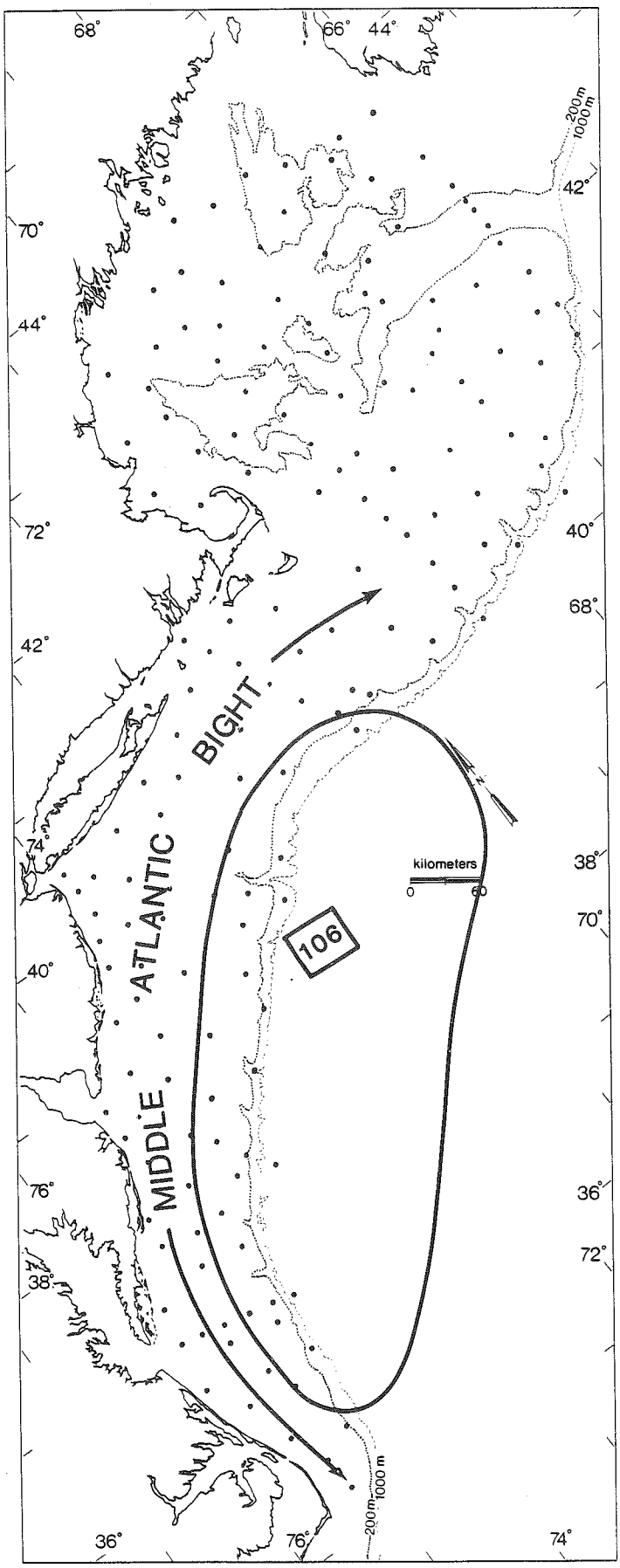


Figure 1. MARMAP (Marine Resources Monitoring Assessment and Prediction) plankton stations off northeastern United States during 1980 (see Sherman 1980 for description of MARMAP Program). DWD-106 and potential impact area from dumping at DWD-106 are shown off Middle Atlantic states.

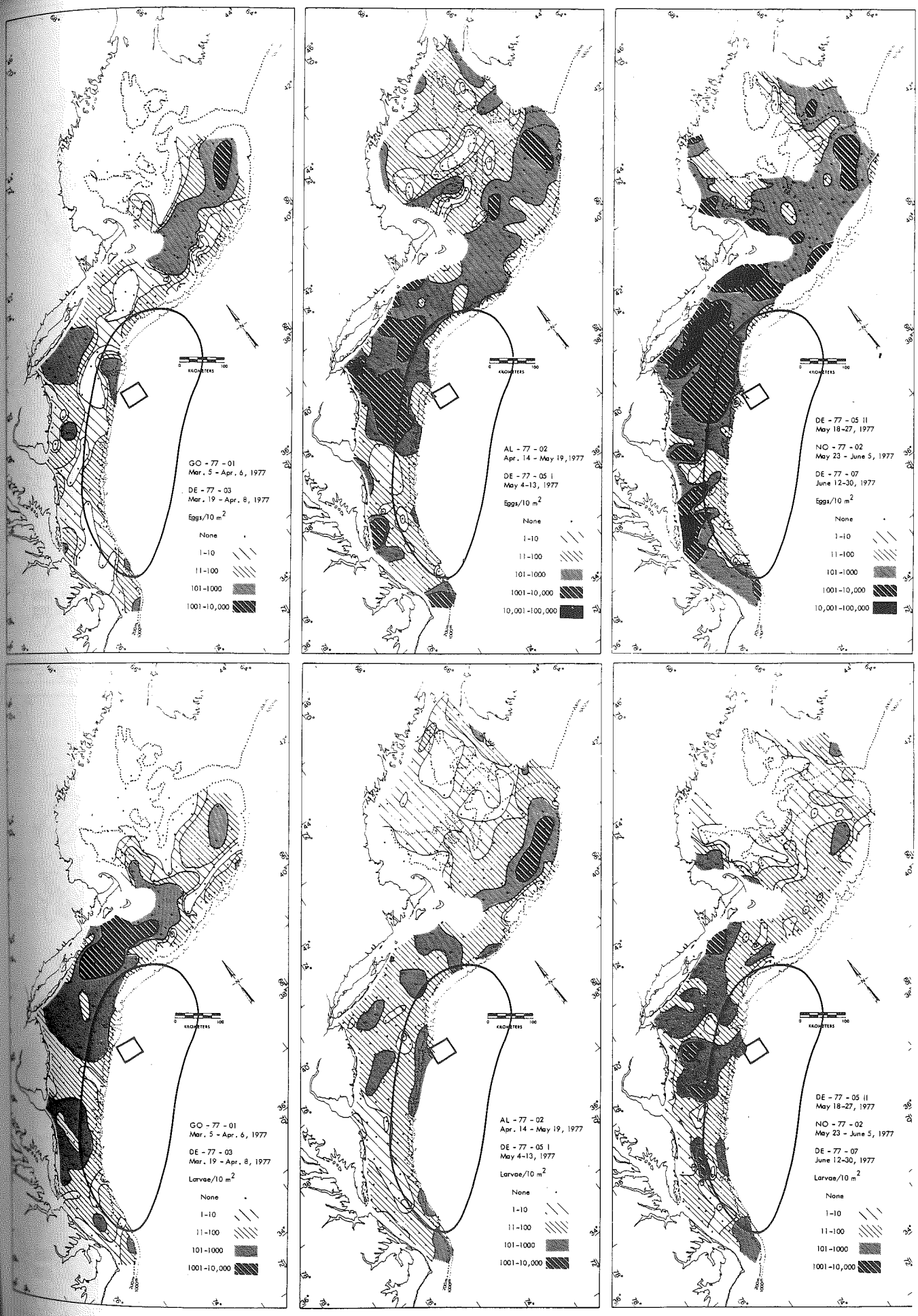


Figure 2. Distribution and abundance of fish eggs (top) and fish larvae (bottom) off northeastern United States as determined from MARMAP surveys, 1977-80.

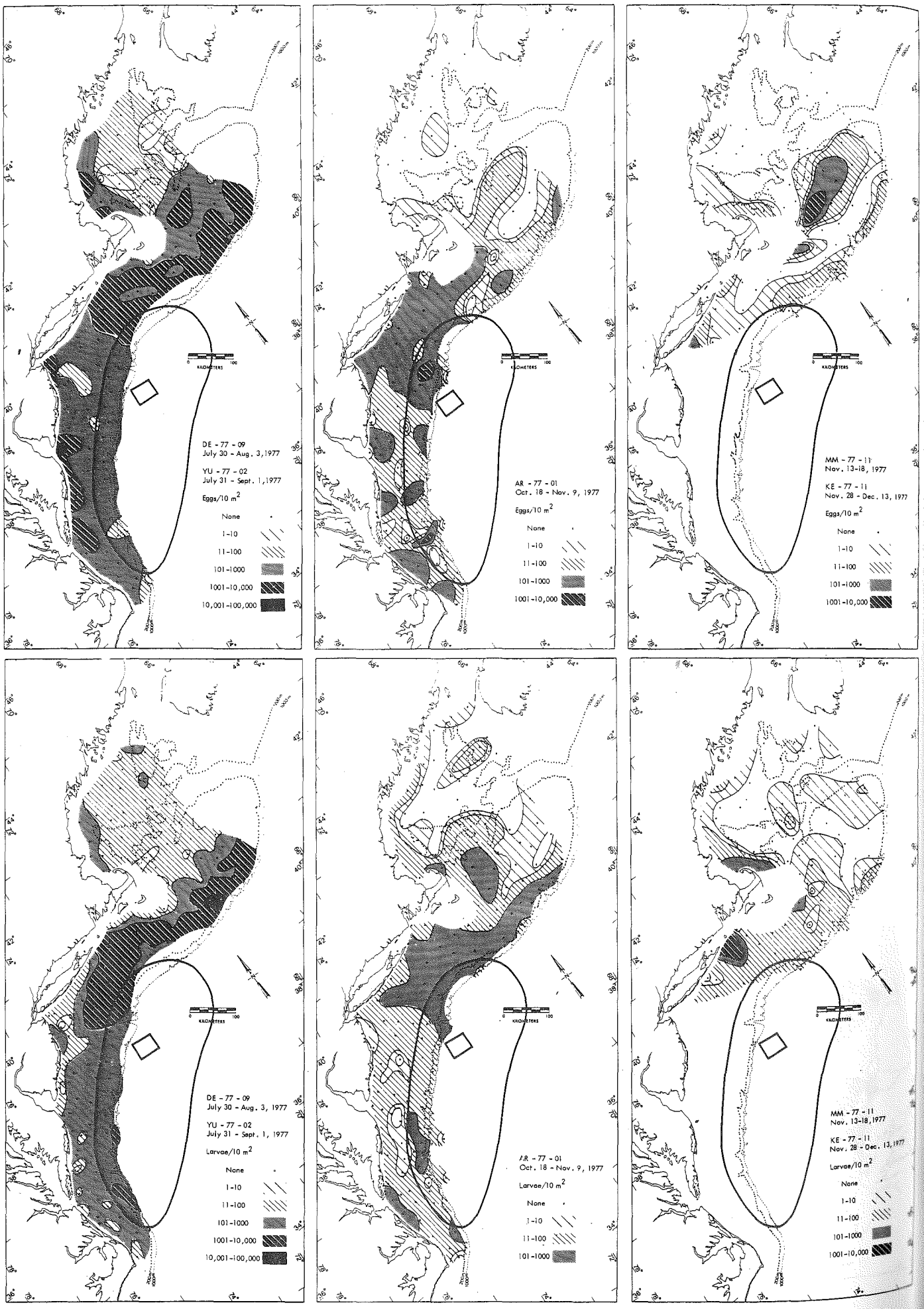
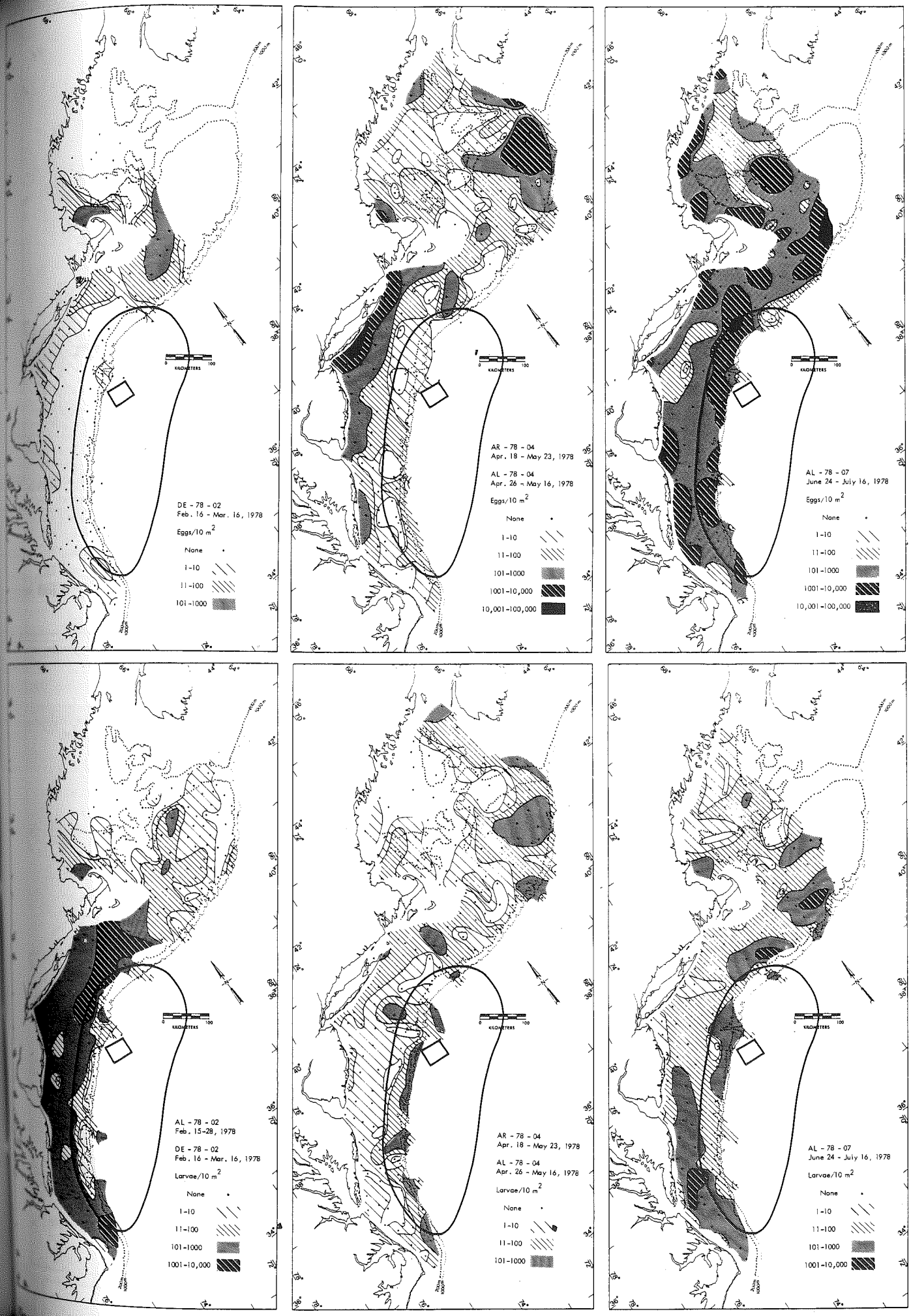


Figure 2. (continued)



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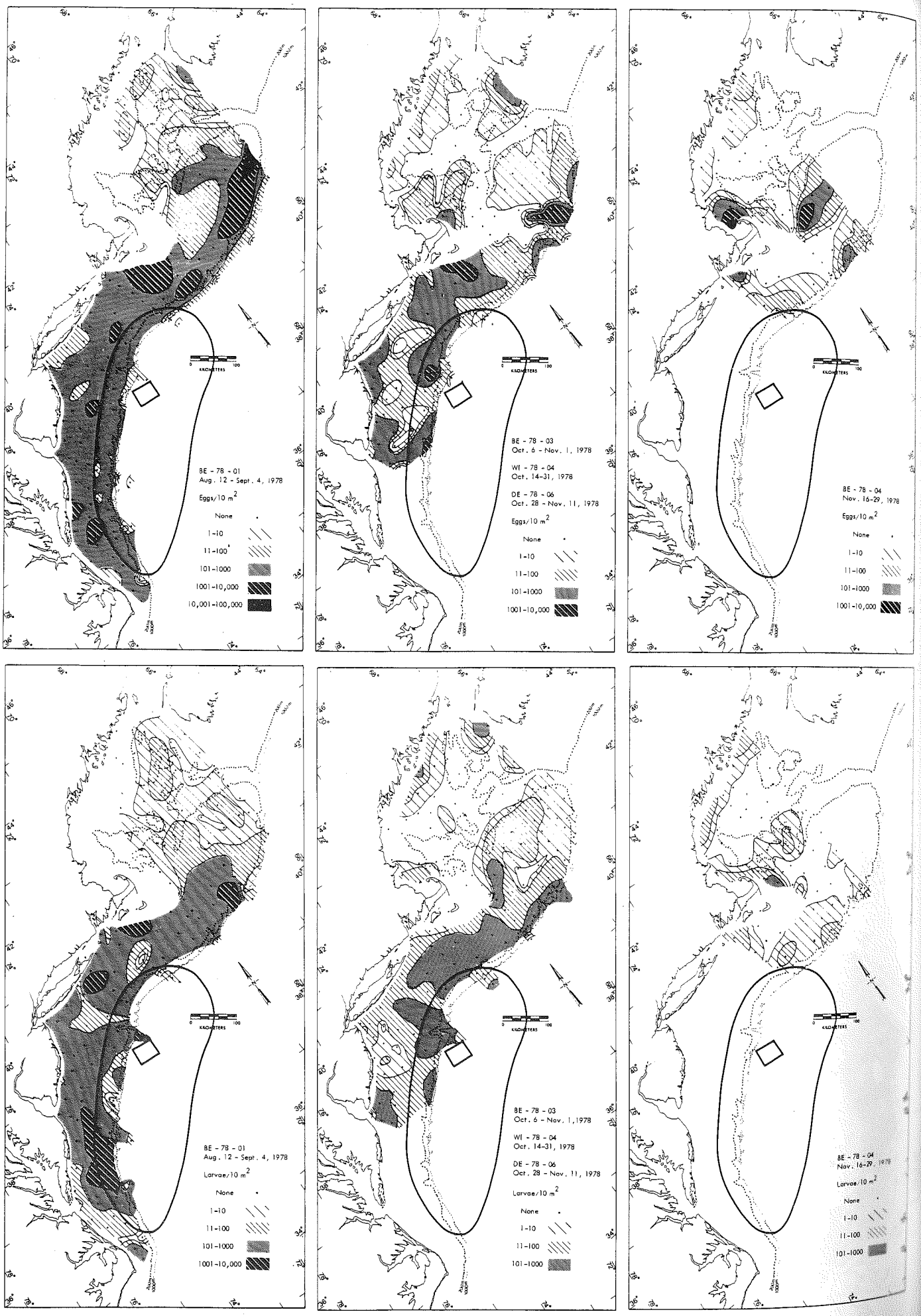


Figure 2. (continued)

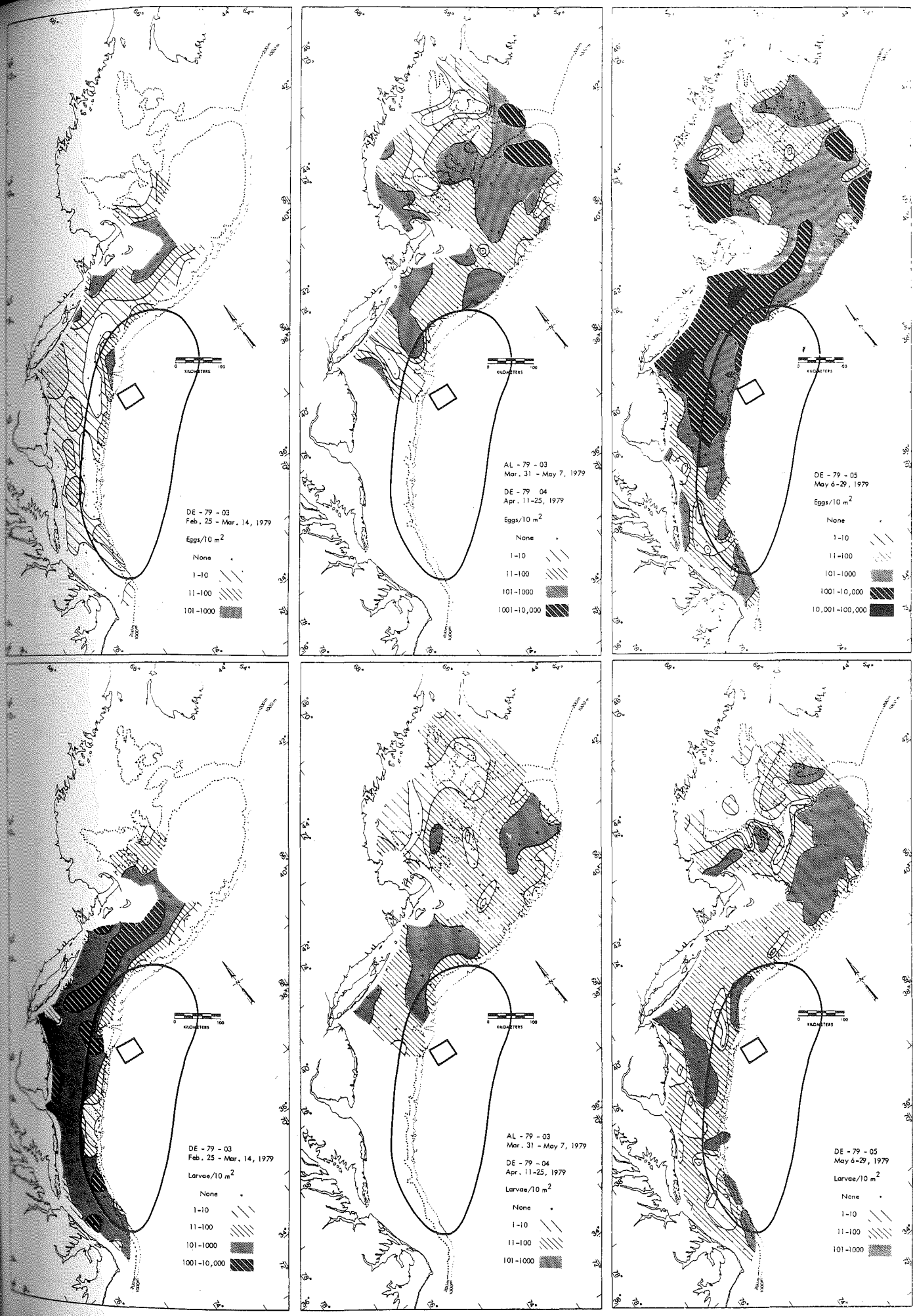


Figure 2. (continued)

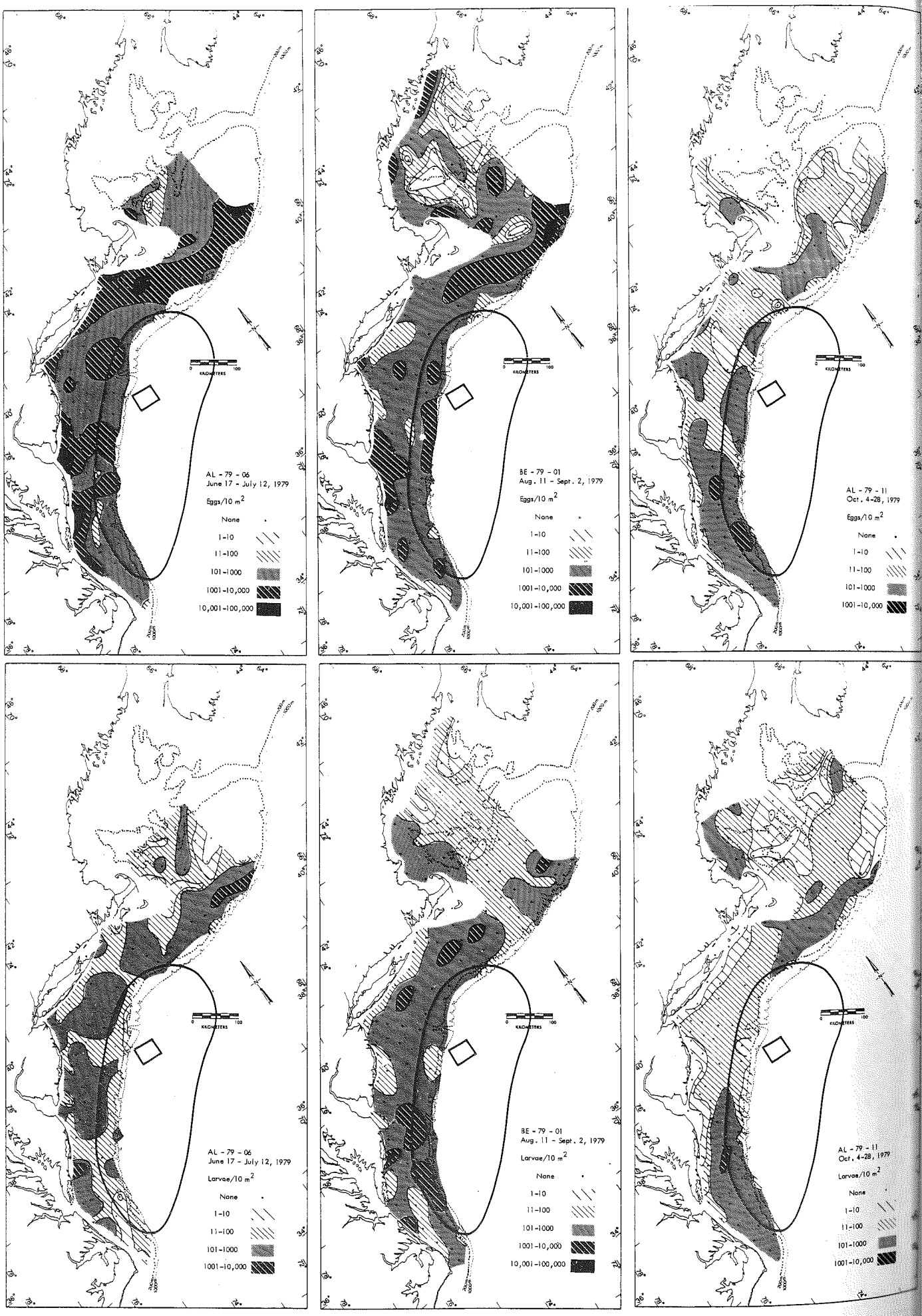
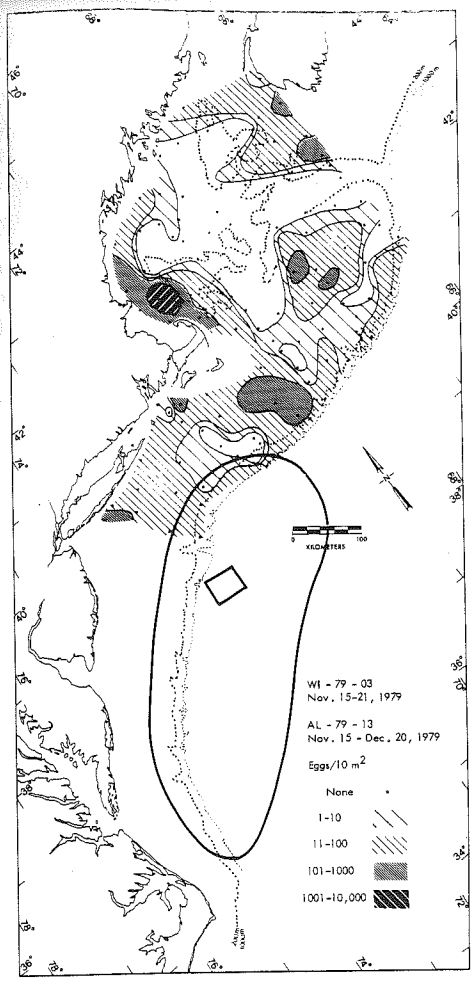


Figure 2. (continued)



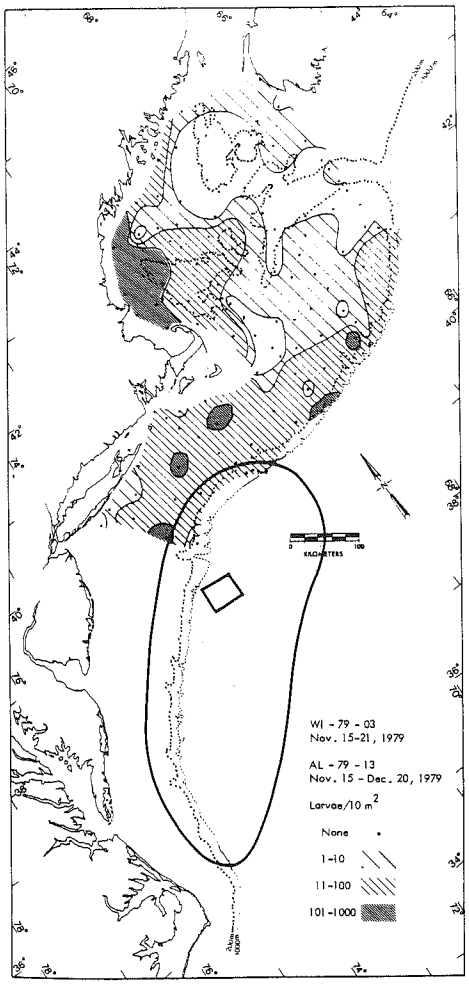


Figure 2. (continued)

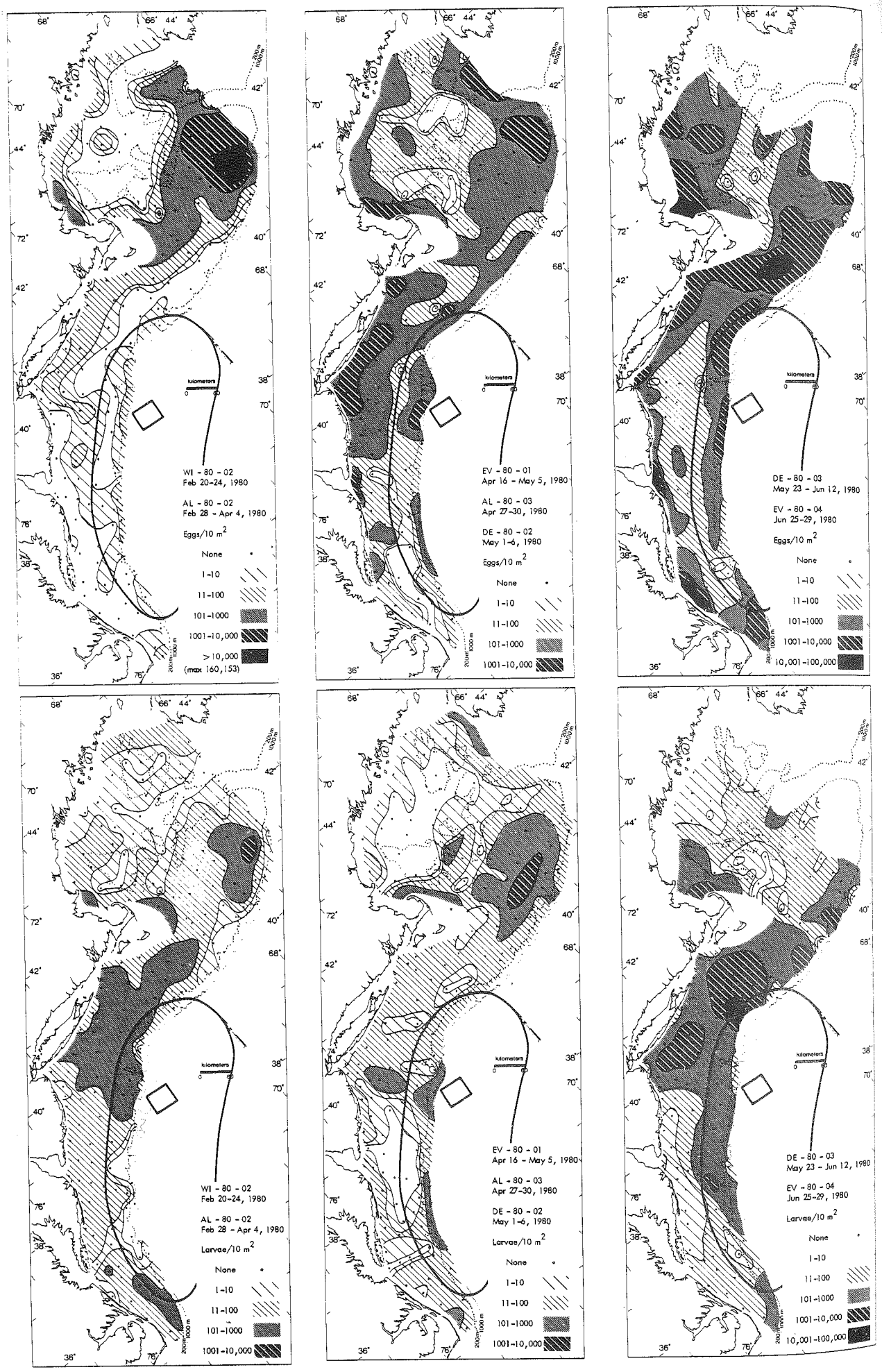


Figure 2. (continued)

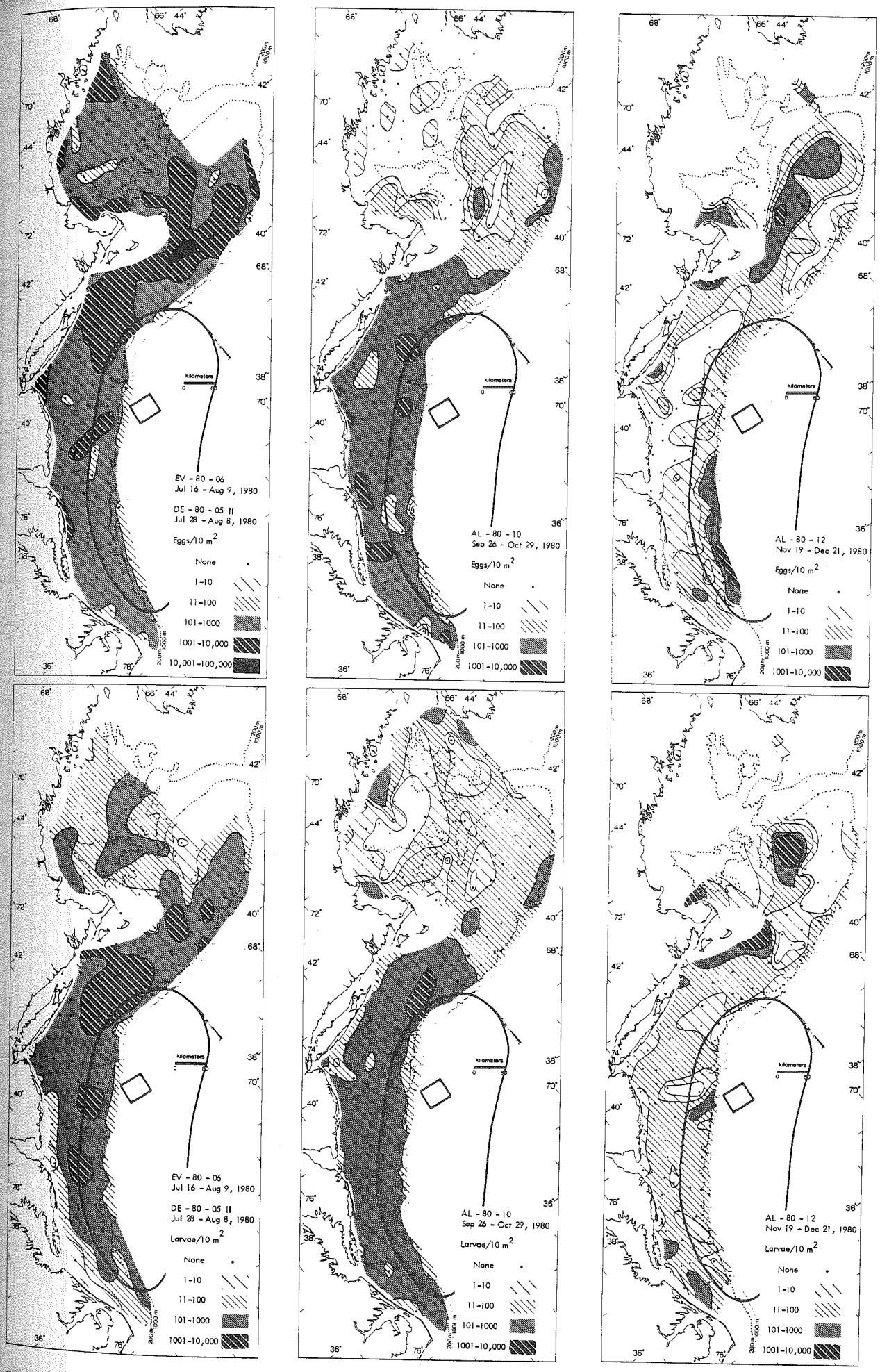
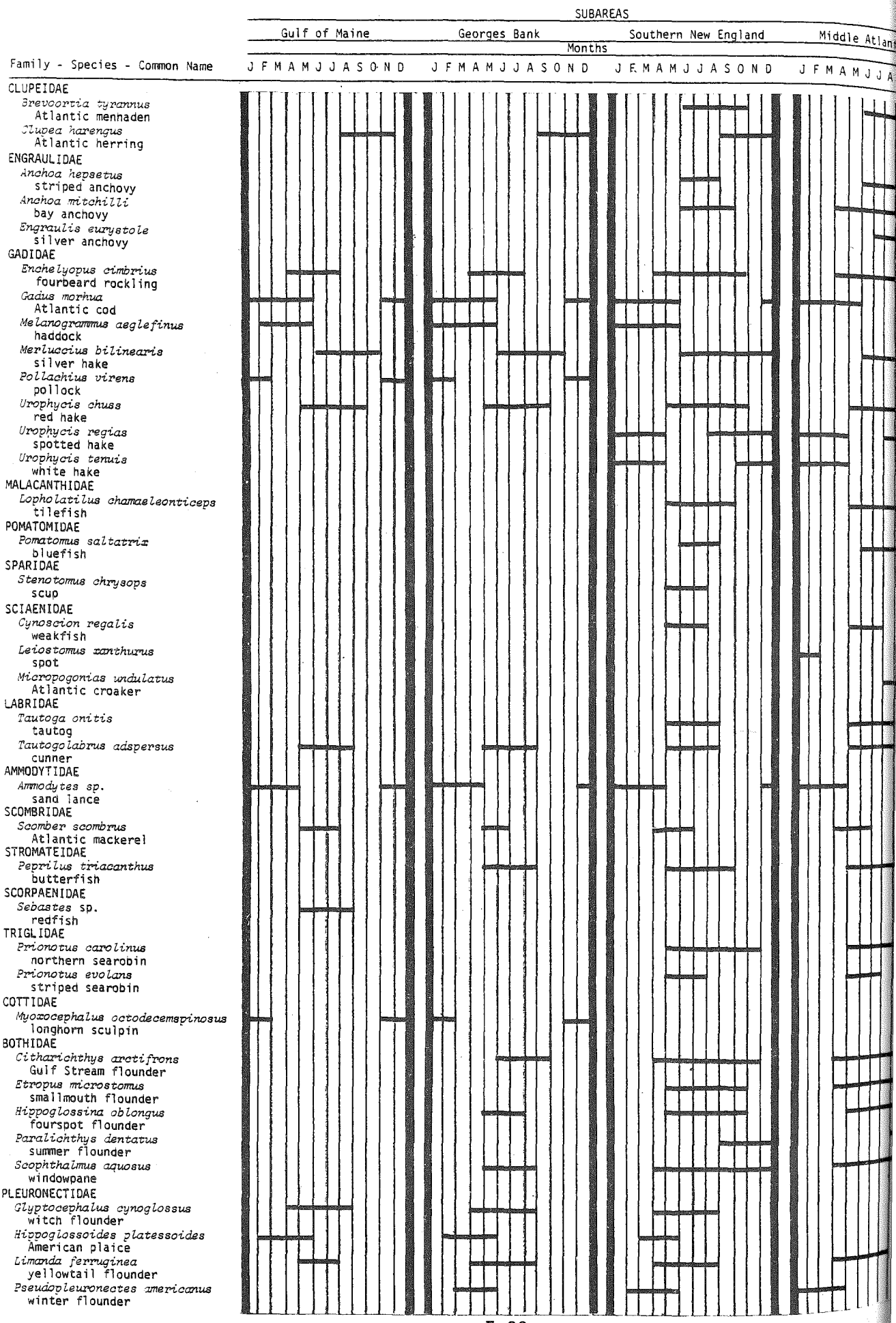


Figure 2. (continued)

Figure 3. Spawning seasons of principal species, based on larval occurrences, in four analytical subareas of northeastern United States (after Colton et al. 1979)



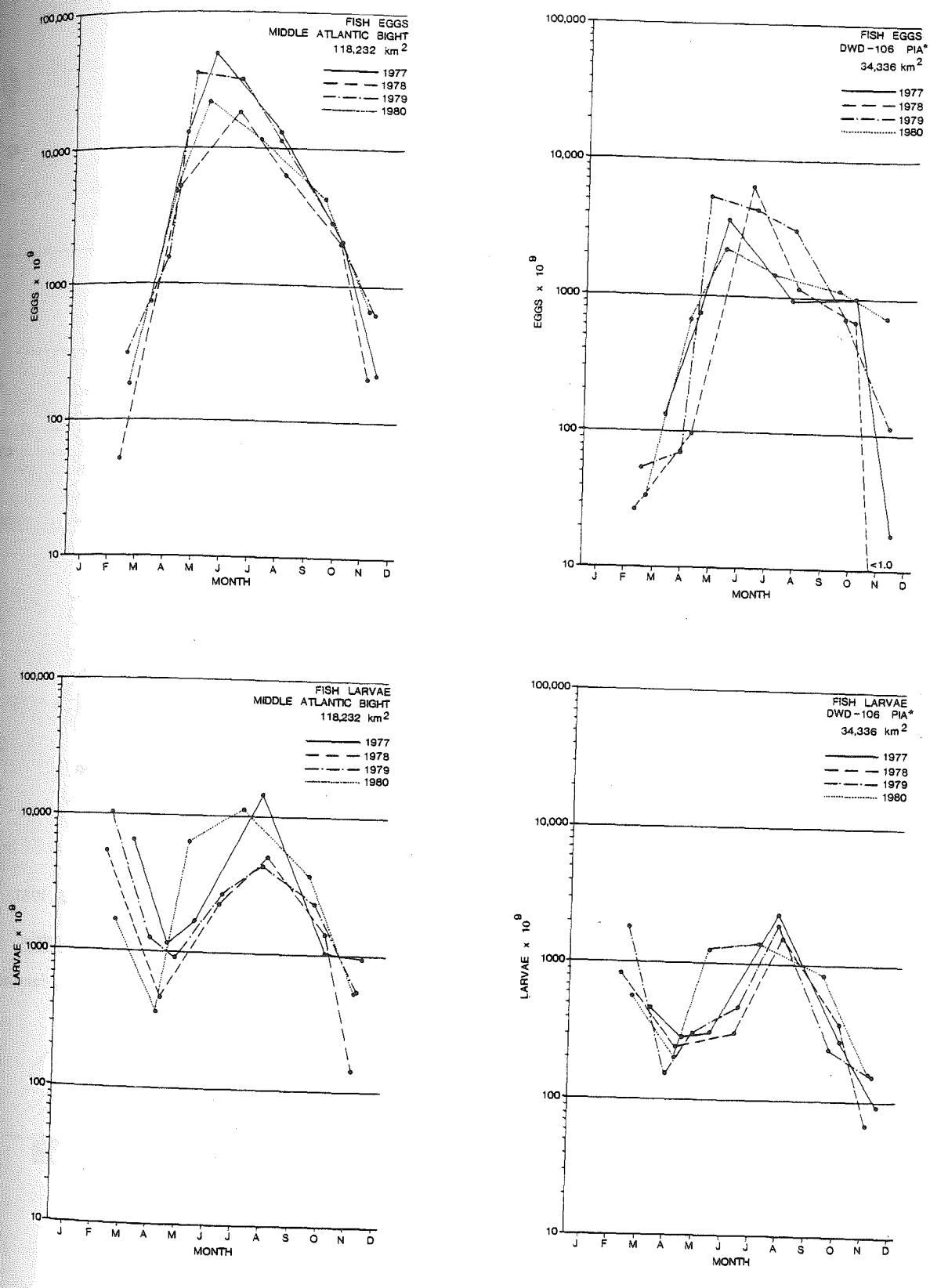


Figure 4. Seasonal changes in abundance of fish eggs in the Middle Atlantic Bight (1977-80) and in the potential impact area * of ocean dumping at DWD-106 (top). Seasonal changes in abundance of fish larvae in the Bight (1977-80) and in the potential impact area of dumping at DWD-106 (bottom).

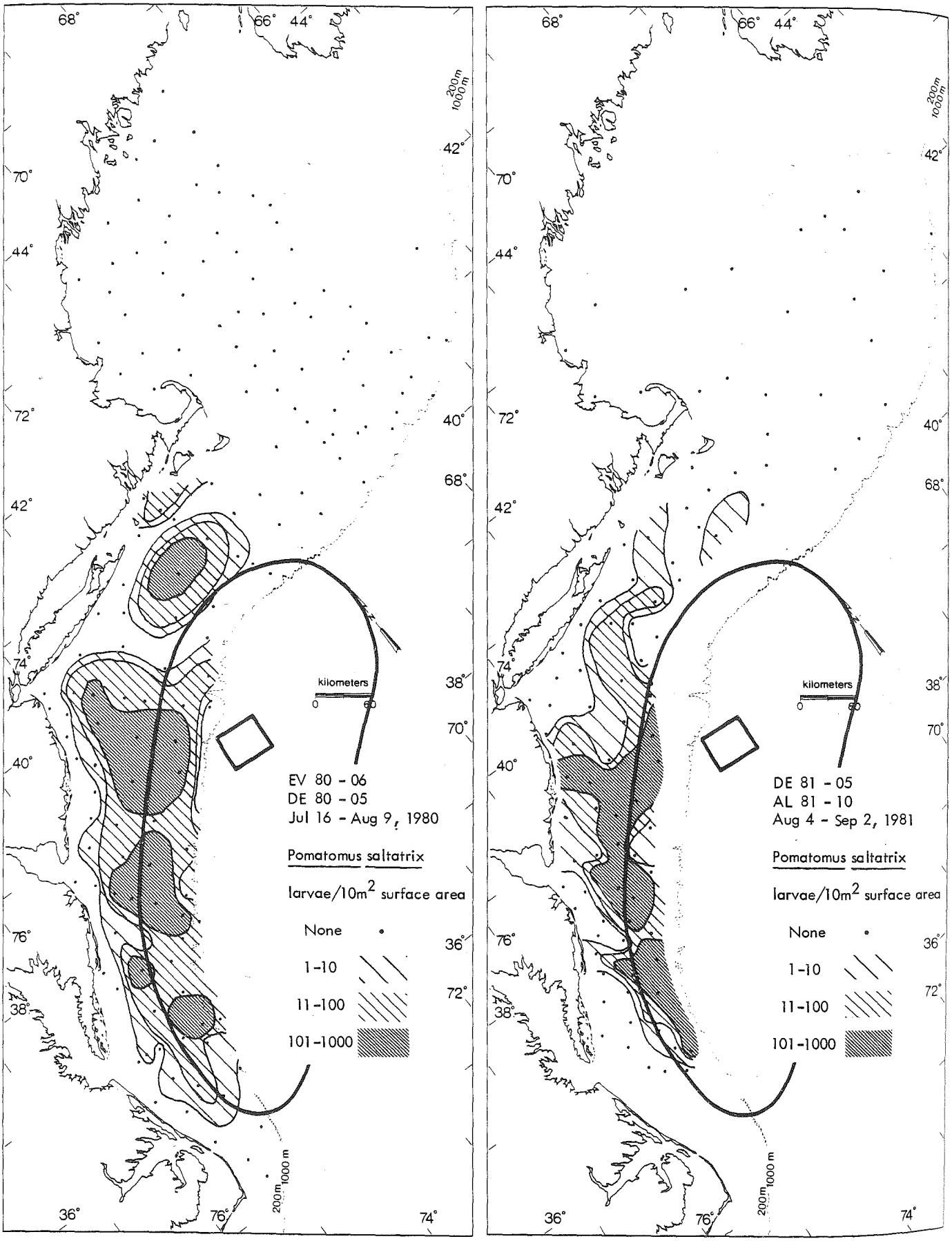


Figure 5. Distribution and abundance of bluefish larvae in Middle Atlantic Bight during summer MARMAP surveys in 1980 and 1981.

Table 1. Listing of MARMAP surveys in the Middle Atlantic Bight, 1977-80. Stations are those falling within area potentially influenced by dumping at DWD-106.

Year	Season	Date	Vessel	Cruise	No. Sta.
1977	Late winter	9 Mar-7 Apr	DELAWARE II	77-03	23
	Early spring	14 Apr-28 Apr	DELAWARE II	77-04	24
	Spring	4 May-13 May	DELAWARE II	77-05 I	27
	Spring	18 May-24 May	DELAWARE II	77-05 II	20
	Summer	19 Aug-29 Aug	YUBILEINEY	77-02	20
	Early autumn	19 Oct-29 Oct	ARGUS	77-01	22
	Late autumn	2 Dec-9 Dec	KELEZ	77-11	3
1978	Late winter	16 Feb-14 Mar	DELAWARE II	78-02	28
	Early spring	19 Apr-12 May	ARGUS	78-04	29
	Late spring	24 Jun-12 Jul	ALBATROSS IV	78-07	29
	Summer	12 Aug-3 Sep	BELOGORSK	78-01	30
	Early autumn	19 Oct-27 Oct	BELOGORSK	78-03	19
	Autumn	16 Nov	BELOGORSK	78-04	2
1979	Late winter	25 Feb-4 Mar	DELAWARE II	79-03	17
	Early spring	13 Apr-14 Apr	DELAWARE II	79-04	4
	Spring	6 May-18 May	DELAWARE II	79-05	23
	Late spring	17 June-8 Jul	ALBATROSS IV	79-06	23
	Summer	12 Aug-22 Aug	BELOGORSK	79-01	20
	Early autumn	4 Oct-18 Oct	ALBATROSS IV	79-11	18
	Autumn	12 Dec-19 Dec	ALBATROSS IV	79-13	6
1980	Late winter	29 Feb-19 Mar	ALBATROSS IV	80-02	20
	Early spring	7 Apr-27 Apr	EVRIKA	80-01	22
	Spring	24 May-6 Jun	DELAWARE II	80-03	20
	Summer	17 Jul-26 Jul	EVRIKA	80-06	22
	Early autumn	27 Sep-9 Oct	ALBATROSS IV	80-10	19
	Autumn	20 Nov-7 Dec	ALBATROSS IV	80-12	19

Table 2. Summary of fish larvae collected on MARMAP surveys (1977-80) at shelf and slope water stations (depths 55 to 2200 m) within the potential area of impact from ocean dumping at DWD-106. DOM = dominance, the number of stations where taxon accounted for >50% of all larvae; OCCUR = occurrence, the number of stations where taxon was caught; KMEAN = mean number of larvae/10m^2 surface area as determined by Δ distribution (see Berrien et al. 1981). Abundance is expansion of KMEAN to reflect the size of the area.

LARVAL ASSEMBLAGES NEAR DWD-106
CRUISES=MM7701 & DL7703

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	LATE WINTER	23	AMMODYTES	13	56.5	14	60.9	137.0	62.0	470,510,126,923	96.1
			HYGOPHUM BENOITI	3	13.0	5	21.7	3.5	1.9	11,924,947,157	2.4
			UROPHYCIS	0	0.0	2	8.7	0.6	0.4	1,910,873,043	0.4
			PARALEPIDIDAE	0	0.0	2	8.7	0.5	0.3	1,603,341,913	0.3
			CYCLOTHONE	0	0.0	1	4.3	0.3	1.4	994,251,130	0.2
			ETROPUS MICROSTOMUS	1	4.3	1	4.3	0.2	1.1	788,235,130	0.1
			CONGRIDAE	1	4.3	1	4.3	0.2	1.1	759,870,609	0.1
			BENTHOSEMA GLACIALE	0	0.0	1	4.3	0.2	1.0	707,620,174	0.1
			CERATOSCOPELUS MADERENSIS	0	0.0	1	4.3	0.1	0.5	353,810,087	<0.1
			BENTHOSEMA SIMILE	0	0.0	1	4.3	0.1	0.5	353,810,087	<0.1
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

CRUISES=GO7701 & DL7704 (STA 1-94)

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	EARLY SPRING	24	AMMODYTES	9	37.5	13	54.2	43.1	20.9	147,966,841,065	48.5
			BENTHOSEMA GLACIALE	3	12.5	8	33.3	15.0	6.8	51,514,747,595	16.9
			HYGOPHUM BENOITI	3	12.5	5	20.8	8.4	5.2	28,739,830,287	9.4
			PARALEPIDIDAE	1	4.2	5	20.8	2.1	0.9	7,126,598,698	2.3
			OPHIDIIDAE	0	0.0	2	8.3	2.1	1.7	7,061,770,667	2.3
			PEPRILUS TRIACANTHUS	0	0.0	2	8.3	1.8	1.4	6,137,560,000	2.0
			TRIGLIDAE	0	0.0	2	8.3	1.7	1.2	5,971,602,667	1.9
			MELANOGRAMMUS AEGLEFINUS	0	0.0	1	4.2	1.6	7.8	5,493,760,000	1.8
			ETRUMEUS TERES	0	0.0	2	8.3	1.4	1.1	4,645,374,667	1.5
			CENTROPRISTIS STRIATUS	0	0.0	1	4.2	1.3	6.6	4,621,053,333	1.5
			SYNODONTIDAE	0	0.0	2	8.3	1.2	0.9	4,289,138,667	1.4
			LOPHIUS AMERICANUS	0	0.0	3	12.5	1.1	0.6	3,617,581,654	1.2
			GOBIIDAE	0	0.0	2	8.3	1.0	0.8	3,530,885,333	1.1
			DIOGENICHTHYS ATLANTICUS	1	4.2	2	8.3	0.9	0.7	3,217,569,333	1.1
			EPINEPHELUS	0	0.0	1	4.2	0.9	4.3	3,033,013,333	1.0
			LIMANDA FERRUGINEA	0	0.0	1	4.2	0.5	2.6	1,828,392,000	0.6
			MYCTOPHIDAE	0	0.0	2	8.3	0.5	0.4	1,764,012,000	0.6
			MYCTOPHUM NITIDULUM	0	0.0	1	4.2	0.4	2.2	1,516,506,667	0.5
			SCORPAENIDAE	0	0.0	1	4.2	0.4	2.2	1,516,506,667	0.5
			BATHYLAGIDAE	0	0.0	2	8.3	0.4	0.3	1,460,710,667	0.5
			ETROPUS MICROSTOMUS	0	0.0	1	4.2	0.3	1.4	948,532,000	0.3
			SYMPHURUS	0	0.0	1	4.2	0.3	1.4	948,532,000	0.3
			DISINTEGRATED	0	0.0	1	4.2	0.3	1.3	944,240,000	0.3
			PARALICHTHYS DENTATUS	0	0.0	1	4.2	0.3	1.3	924,210,667	0.3
			PHOLIS GUNNELLUS	0	0.0	1	4.2	0.3	1.3	914,196,000	0.3
			ENCHELYOPUS CIMBRIUS	0	0.0	1	4.2	0.3	1.3	897,028,000	0.3
			UROPHYCIS	0	0.0	1	4.2	0.2	1.2	851,246,667	0.3
			GADIDAE	0	0.0	1	4.2	0.2	1.2	819,772,000	0.3
			CLUPEIFORMES	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
			GONOSTOMATIDAE	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
			HYGOPHUM	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
			CARAPIDAE	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
			GADUS MORHUA	0	0.0	1	4.2	0.2	1.0	705,318,667	0.2
			SYNGNATHIDAE	0	0.0	1	4.2	0.2	1.0	705,318,667	0.2
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

GUNDSTOMATIDAE	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
HYGOPHUM	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
CARAPIDAE	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
CITHARICHTHYS ARCTIFRONS	0	0.0	1	4.2	0.2	1.1	758,253,333	0.2
GADUS MORHUA	0	0.0	1	4.2	0.2	1.0	705,318,667	0.2
SYNGNATHIDAE	0	0.0	1	4.2	0.2	1.0	705,318,667	0.2
UNKNOWN	0	0.0	1	4.2	0.2	1.0	[illegible]	[illegible]

Table 8. (continued)

CRUISES=AL7702 & DL7705 (STA 1-91)

YEAR	SEASON	# STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	SPRING	27	BENTHOSEMA GLACIALE	10	37.0	15	55.6	40.6	14.0	139,280,346,837	47.0
			AMMODYTES	1	3.7	5	18.5	4.0	2.4	13,856,223,761	4.7
			SYNODONTIDAE	0	0.0	7	25.9	3.2	1.3	10,858,411,680	3.6
			OPHIDIIDAE	0	0.0	5	18.5	3.0	1.6	10,272,238,630	3.4
			MYCTOPHIDAE	1	3.7	1	3.7	2.6	13.3	8,790,016,000	2.9
			PEPRILUS TRIACANTHUS	0	0.0	3	11.1	2.5	1.8	8,741,868,289	2.9
			BOTHUS	0	0.0	3	11.1	2.5	1.4	8,456,857,277	2.8
			PARALEPIDIDAE	0	0.0	5	18.5	2.3	1.2	7,854,523,386	2.6
			LIPARIS	1	3.7	2	7.4	1.9	1.6	6,358,518,519	2.1
			UROPHYCIS	0	0.0	5	18.5	1.8	0.8	6,057,523,101	2.0
			LIMANDA FERRUGINEA	1	3.7	3	11.1	1.5	0.9	5,056,344,891	1.7
			SCOMBER SCOMBRUS	1	3.7	3	11.1	1.4	0.9	4,850,639,003	1.6
			BOTHUS	0	0.0	2	7.4	1.4	1.0	4,690,043,259	1.6
			TRIGLIDAE	0	0.0	2	7.4	1.1	0.9	3,841,816,889	1.3
			HYGOPHUM BENOITI	0	0.0	1	3.7	1.1	5.7	3,745,167,407	1.2
			ETROPUS/CITHARICHTHYS	0	0.0	1	3.7	0.9	4.7	3,092,783,407	1.0
			CENTROPRISTIS STRIATUS	0	0.0	1	3.7	0.9	4.7	3,092,783,407	1.0
			CARAPIDAE	0	0.0	1	3.7	0.9	4.7	3,092,783,407	1.0
			SYMPHURUS	0	0.0	2	7.4	0.9	0.7	3,091,511,704	1.0
			SERRANIDAE	0	0.0	3	11.1	0.9	0.5	3,036,655,232	1.0
			MELANOGRAMMUS AEGLEFINUS	2	7.4	3	11.1	0.8	0.5	2,735,965,018	0.9
			GADUS MORHUA	0	0.0	3	11.1	0.7	0.4	2,510,810,869	0.8
			PERCIFORMES	0	0.0	2	7.4	0.7	0.5	2,332,304,593	0.8
			BALISTIDAE	0	0.0	1	3.7	0.7	3.5	2,319,587,556	0.8
			SCOMBERESOX SAURUS	0	0.0	1	3.7	0.5	2.5	1,635,410,963	0.5
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	3.7	0.5	2.5	1,635,410,963	0.5
			VINCIGUERRIA	0	0.0	2	7.4	0.5	0.3	1,634,139,259	0.5
			MYCTOPHUM NITIDULUM	0	0.0	2	7.4	0.5	0.3	1,603,618,370	0.5
			DIOGENICHTHYS ATLANTICUS	0	0.0	1	3.7	0.5	2.3	1,546,391,704	0.5
			DECAPTERUS	0	0.0	1	3.7	0.5	2.3	1,546,391,704	0.5
			BLENNIIDAE	0	0.0	1	3.7	0.5	2.3	1,546,391,704	0.5
			SCORPAENIDAE	0	0.0	1	3.7	0.5	2.3	1,546,391,704	0.5
			SYACIUM	0	0.0	1	3.7	0.5	2.3	1,546,391,704	0.5
			LOPHIUS AMERICANUS	0	0.0	2	7.4	0.4	0.3	1,523,501,037	0.5
			CERATOSCOPELUS MADERENSIS	0	0.0	2	7.4	0.4	0.3	1,518,414,222	0.5
			AGONIDAE	0	0.0	1	3.7	0.3	1.4	946,147,556	0.3
			MAUROLICUS MUELLERI	0	0.0	1	3.7	0.2	1.2	817,705,481	0.3
			DIAPHUS DUMERILI	0	0.0	1	3.7	0.2	1.2	785,912,889	0.2
			GADIFORMES	0	0.0	1	3.7	0.2	1.2	785,912,889	0.2
			STOMIAS FEROX	0	0.0	1	3.7	0.2	1.2	774,467,556	0.2
			MYCTOPHUM	0	0.0	1	3.7	0.2	1.2	774,467,556	0.2
			ARIOMMA	0	0.0	1	3.7	0.2	1.2	773,195,852	0.2
			CONGRIDAE	0	0.0	1	3.7	0.2	1.2	771,924,148	0.2
			UNKNOWN	0	0.0	1	3.7	0.2	1.2	770,652,444	0.2
			MURAENIDAE	0	0.0	1	3.7	0.2	1.2	770,652,444	0.2
			PISODONOPHIS CRUENTIFER	0	0.0	1	3.7	0.2	1.1	750,305,185	0.2
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	1	3.7	0.2	1.1	750,305,185	0.2
			MERLUCCIUS BILINEARIS	0	0.0	1	3.7	0.2	1.1	749,033,481	0.2
			PSENES CYANOPHRYS	0	0.0	1	3.7	0.2	1.1	749,033,481	0.2
			POLLACHIUS VIRENS	0	0.0	1	3.7	0.2	1.1	731,229,630	0.2
			CALLIONYMIDAE	0	0.0	1	3.7	0.2	1.0	656,199,111	0.2
			CAULOPHRYNIDAE	0	0.0	1	3.7	0.2	1.0	656,199,111	0.2
			DISINTEGRATED	0	0.0	1	3.7	0.1	0.7	473,073,778	0.1
			ANGUILLA ROSTRATA	0	0.0	1	3.7	0.1	0.7	473,073,778	0.1
			ENCHELYOPUS CIMBRIUS	1	3.7	1	3.7	0.1	0.5	319,197,630	0.1

Table 2. (continued)

CRUISE=DL7705 (STA 92-180)

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	SPRING	20	SCOMBER SCOMBRUS	4	20.0	7	35.0	27.7	18.2	95,081,795,420	31.3
			BENTHOSEMA GLACIALE	3	15.0	7	35.0	10.1	4.3	34,832,234,628	11.5
			CERATOSCOPELUS MADERENSIS	0	0.0	5	25.0	10.0	7.4	34,460,100,408	11.3
			LIPARIS	1	5.0	1	5.0	5.2	23.3	17,923,392,000	5.9
			BENTHOSEMA SUBORBITALE	2	10.0	2	10.0	5.1	3.5	17,401,484,800	5.7
			HYGOPHUM HYGOMII	0	0.0	1	5.0	3.0	13.4	10,305,950,400	3.4
			UROPHYCIS	0	0.0	3	15.0	2.9	2.2	10,042,248,306	3.3
			LIMANDA FERRUGINEA	0	0.0	4	20.0	2.6	1.5	8,777,974,162	2.9
			VINCIGUERRIA	0	0.0	3	15.0	2.5	1.8	8,430,740,028	2.8
			SYACIUM PAPILLOSUM	0	0.0	1	5.0	1.7	7.5	5,725,528,000	1.9
			ENCHELYOPUS CIMBRIUS	0	0.0	3	15.0	1.4	0.9	4,788,439,260	1.5
			BOTHUS	0	0.0	2	10.0	1.3	1.0	4,441,361,600	1.4
			PARALEPIDIDAE	0	0.0	3	15.0	1.3	0.7	4,307,381,169	1.4
			COTTIDAE	0	0.0	2	10.0	1.2	1.0	4,178,691,200	1.4
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	3	15.0	1.2	0.7	4,039,665,690	1.3
			LAMPANYCTUS ALATUS	0	0.0	1	5.0	1.0	4.5	3,435,316,800	1.1
			POMATOMUS SALTATRIX	1	5.0	1	5.0	1.0	4.5	3,425,016,000	1.1
			AMMODYTES	0	0.0	2	10.0	0.9	0.6	2,935,728,000	1.0
			ARGYROPELECUS	0	0.0	1	5.0	0.7	3.0	2,290,211,200	0.7
			GOBIIDAE	0	0.0	2	10.0	0.6	0.4	2,231,840,000	0.7
			OPHICHTHIDAE	0	0.0	2	10.0	0.6	0.4	2,214,672,000	0.7
			SYNODONTIDAE	0	0.0	2	10.0	0.6	0.4	2,118,531,200	0.7
			MELANOGRAMMUS AEGLEFINUS	1	5.0	1	5.0	0.6	2.6	1,991,488,000	0.6
			LOPHIUS AMERICANUS	0	0.0	2	10.0	0.5	0.4	1,749,419,200	0.6
			DIAPHUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			DIAPHUS PROBLEMATICUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			LAMPANYCTUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			LOBIANCHIA DOFLEINI	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			DIOGENICHTHYS ATLANTICUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			CENTROPRISTIS STRIATUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			RHOMBOPLITES AURORUBENS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			OPHIDIIDAE	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			THUNNUS	0	0.0	1	5.0	0.3	1.5	1,145,105,600	0.4
			LEIOSTOMUS XANTHURUS	0	0.0	1	5.0	0.3	1.4	1,086,734,400	0.3
			STERNOPTYCHIDAE	0	0.0	1	5.0	0.3	1.4	1,069,566,400	0.3
			PSEUDOPLEURONECTES AMERICANUS	0	0.0	1	5.0	0.3	1.3	1,006,044,800	0.3
			MYCTOPHIDAE	0	0.0	1	5.0	0.3	1.3	985,443,200	0.3
			MERLUCCIUS ALBIDUS	0	0.0	1	5.0	0.3	1.3	985,443,200	0.3
			CYCLOTHONE	0	0.0	1	5.0	0.3	1.3	973,425,600	0.3
			PEPRILUS TRIACANTHUS	0	0.0	1	5.0	0.3	1.3	973,425,600	0.3
			GADUS MORHUA	0	0.0	1	5.0	0.3	1.3	969,992,000	0.3
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

Table 2. (continued)

CRUISES-YU7702 & DL7709

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	SUMMER	20	UROPHYCIS	6	30.0	17	85.0	314.2	152.2	1,078,938,525,099	46.0
			CITHARICHTHYS ARCTIFRONS	0	0.0	15	75.0	95.2	38.5	326,987,023,090	13.9
			ETROPUS MICROSTOMUS	0	0.0	3	15.0	41.5	28.4	142,570,439,458	6.1
			AUXIS	0	0.0	15	75.0	26.5	8.5	91,068,530,705	3.9
			CERATOSCOPELUS MADERENSIS	0	0.0	6	30.0	26.2	19.0	90,077,535,468	3.8
			OPHIDIIDAE	0	0.0	15	75.0	26.1	7.7	89,632,675,880	3.8
			ENGRAULIS EURYSTOLE	0	0.0	8	40.0	17.5	8.4	59,992,613,295	2.6
			LABRIDAE/SCARIDAE	0	0.0	14	70.0	15.4	6.1	52,896,215,439	2.2
			HIPPOGLOSSINA OBLONGA	0	0.0	12	60.0	14.7	4.7	50,530,984,875	2.2
			SYMPHURUS	0	0.0	3	15.0	14.5	13.3	49,839,425,201	2.1
			ETROPUS/CITHARICHTHYS	0	0.0	3	15.0	13.1	10.7	45,125,966,134	1.9
			MERLUCCIUS BILINEARIS	0	0.0	10	50.0	11.1	3.8	38,153,128,479	1.6
			POMATOMUS SALTATRIX	0	0.0	4	20.0	10.0	7.7	34,259,110,237	1.5
			BOTHUS	0	0.0	8	40.0	9.3	3.5	31,930,114,077	1.4
			SYACIUM PAPILLOSUM	0	0.0	5	25.0	4.7	2.8	16,107,063,811	0.7
			PEPRILUS TRIACANTHUS	0	0.0	7	35.0	4.1	1.7	13,962,101,355	0.6
			TRIGLIDAE	0	0.0	3	15.0	3.9	2.8	13,361,784,985	0.6
			CALLIONYMIDAE	0	0.0	4	20.0	3.6	2.3	12,263,900,307	0.5
			ENGRAULIDAE	0	0.0	2	10.0	3.0	2.8	10,458,745,600	0.4
			CENTROPRISTIS STRIATA	0	0.0	2	10.0	2.7	2.5	9,320,507,200	0.4
			SYNODONTIDAE	0	0.0	1	5.0	2.1	9.4	7,227,728,000	0.3
			UNKNOWN	0	0.0	3	15.0	2.0	1.3	6,777,985,838	0.3
			DISINTEGRATED	0	0.0	4	20.0	1.9	1.0	6,528,249,994	0.3
			CYCLOTHONE	0	0.0	2	10.0	1.7	1.5	5,763,297,600	0.2
			MERLUCCIUS ALBIDUS	0	0.0	2	10.0	1.7	1.2	5,761,580,800	0.2
			CLUPEIFORMES	0	0.0	1	5.0	1.7	7.4	5,670,590,400	0.2
			GOBIIDAE	0	0.0	5	25.0	1.5	0.6	5,217,852,640	0.2
			EUTHYNNUS ALLETTERATUS	0	0.0	1	5.0	1.5	6.7	5,177,868,800	0.2
			SERRANIDAE	0	0.0	1	5.0	1.3	5.7	4,410,459,200	0.2
			OPHICHTHIDAE	0	0.0	3	15.0	1.1	0.7	3,937,212,791	0.2
			TAUTOGOLABRUS ADSPERSUS	0	0.0	1	5.0	1.1	4.7	3,625,881,600	0.2
			ANGUILLIFORMES	0	0.0	2	10.0	0.9	0.7	3,146,894,400	0.1
			PARALEPIDIDAE	0	0.0	3	15.0	0.9	0.5	2,995,736,380	0.1
			LOPHOLATILUS CHAMAELEONTICEPS	0	0.0	3	15.0	0.9	0.5	2,930,516,363	0.1
			BOTHIDAE	0	0.0	2	10.0	0.8	0.6	2,911,692,800	0.1
			ANCHOA HEPSETUS	0	0.0	1	5.0	0.7	3.0	2,312,529,600	0.1
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	1	5.0	0.5	2.4	1,878,179,200	0.1
			OGCOCEPHALIDAE	0	0.0	1	5.0	0.5	2.2	1,661,862,400	0.1
			SCORPAENIDAE	0	0.0	2	10.0	0.4	0.3	1,481,598,400	0.1
			BALISTIDAE	0	0.0	1	5.0	0.4	1.7	1,294,467,200	0.1
			TETRAGONURIDAE	0	0.0	1	5.0	0.3	1.4	1,067,849,600	<0.1
			PISODONOPHIS CRUENTIFER	0	0.0	1	5.0	0.3	1.2	956,257,600	<0.1
			LOPHIUS AMERICANUS	0	0.0	1	5.0	0.3	1.2	935,656,000	<0.1
			NOTOLYCHNUS	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
			TETRAGONURUS ATLANTICUS	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
			VINCIGUERRIA	0	0.0	1	5.0	0.2	1.1	834,364,800	<0.1
			MURAENIDAE	0	0.0	1	5.0	0.2	1.1	834,364,800	<0.1
			ARGENTINIDAE	0	0.0	1	5.0	0.2	1.1	830,931,200	<0.1
			MYCTOPHIDAE	0	0.0	1	5.0	0.2	1.0	770,843,200	<0.1
			SARDINELLA AURITA	0	0.0	1	5.0	0.2	0.9	722,772,800	<0.1
			CARANX	0	0.0	1	5.0	0.2	0.9	722,772,800	<0.1
			LARIMUS FASCIATUS	0	0.0	1	5.0	0.2	0.9	722,772,800	<0.1
			SCOPELIFORMES	0	0.0	1	5.0	0.2	0.8	648,950,400	<0.1
			DIOGENICHTHYS ATLANTICUS	0	0.0	1	5.0	0.2	0.8	647,233,600	<0.1
			LESTIDIUM ATLANTICUM	0	0.0	1	5.0	0.2	0.8	630,065,600	<0.1
			DIAPHUS	0	0.0	1	5.0	0.2	0.8	614,614,400	<0.1

Table 2. (continued)

CRUISE=AR7701

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	EARLY AUTUMN	22	CITHARICHTHYS ARCTIFRONS	2	9.1	15	68.2	17.2	5.7	59,091,894,367	21.6
			UROPHYCIS	2	9.1	18	81.8	15.7	4.2	53,792,714,480	19.7
			MERLUCCIUS BILINEARIS	2	9.1	9	40.9	13.8	5.7	47,352,220,357	17.4
			CERATOSCOPELUS MADERENSIS	2	9.1	7	31.8	12.9	7.7	44,239,316,063	16.2
			PARALEPIDIDAE	1	4.5	9	40.9	6.4	2.3	22,122,074,961	8.1
			MERLUCCIUS ALBIDUS	0	0.0	5	22.7	3.2	1.7	10,868,870,334	3.9
			OPHIDIIDAE	0	0.0	7	31.8	2.0	0.7	6,709,995,408	2.5
			BOTHUS	0	0.0	4	18.2	1.2	0.6	4,213,268,444	1.5
			PARALICHTHYS DENTATUS	0	0.0	2	9.1	0.9	0.7	3,093,361,455	1.1
			BENTHOSEMA GLACIALE	0	0.0	1	4.5	0.9	4.1	2,991,914,182	1.1
			GOBIIDAE	0	0.0	3	13.6	0.7	0.4	2,362,227,186	0.8
			MYCTOPHIDAE	0	0.0	2	9.1	0.6	0.4	1,949,348,364	0.7
			GONOSTOMATIDAE	0	0.0	2	9.1	0.4	0.3	1,445,233,455	0.5
			LAMPANYCTUS	0	0.0	1	4.5	0.4	1.7	1,208,002,909	0.4
			LOBIANCHIA DOFLEINI	0	0.0	1	4.5	0.4	1.7	1,208,002,909	0.4
			SYACIUM PAPILLOSUM	0	0.0	1	4.5	0.3	1.4	997,304,727	0.3
			CYCLOTHONE	0	0.0	1	4.5	0.3	1.3	970,772,364	0.3
			MICROPOGONIAS UNDULATUS	1	4.5	1	4.5	0.3	1.3	927,072,000	0.3
			DIODONTIDAE	0	0.0	1	4.5	0.3	1.3	919,268,364	0.3
			VINCIGUERRIA	0	0.0	1	4.5	0.2	1.0	741,345,455	0.3
			SYMBOLOPHORUS VERANYI	0	0.0	1	4.5	0.2	1.0	741,345,455	0.3
			CARAPIDAE	0	0.0	1	4.5	0.2	1.0	741,345,455	0.3
			CALLIONYMIDAE	0	0.0	1	4.5	0.2	1.0	741,345,455	0.3
			GEMPYLIDAE	0	0.0	1	4.5	0.2	1.0	741,345,455	0.3
			UNKNOWN:FISH/EGGS	0	0.0	1	4.5	0.2	1.0	703,888,000	0.3
			ENGRAULIS EURYSTOLE	0	0.0	1	4.5	0.2	1.0	697,645,091	0.2
			SC@PHTHALMUS AQUOSUS	0	0.0	1	4.5	0.2	0.9	692,962,909	0.2
			AMMODYTES	0	0.0	1	4.5	0.2	0.9	650,823,273	0.2
			LABRIDAE/SCARIDAE	0	0.0	1	4.5	0.2	0.8	602,440,727	0.2

Table 2. (continued)

CRUISES=MM7711 & KE7711

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1977	LATE AUTUMN	3	GOBIIDAE	1	33.3	2	66.7	10.0	7.3	34,221,546,667	37.7
			PARALEPIDIDAE	0	0.0	1	33.3	4.8	8.2	16,321,045,333	18.0
			LABRIDAE/SCARIDAE	0	0.0	1	33.3	2.4	4.1	8,160,522,667	8.9
			STOMIAS	0	0.0	1	33.3	2.4	4.1	8,160,522,667	8.9
			MYCTOPHIDAE	0	0.0	1	33.3	1.9	3.3	6,638,293,333	7.3
			MERLUCCIUS ALBIDUS	0	0.0	1	33.3	1.9	3.3	6,638,293,333	7.3
			VINCIGUERRIA	0	0.0	1	33.3	1.6	2.8	5,516,650,667	6.1
			CALLIONYMIDAE	0	0.0	1	33.3	1.6	2.8	5,516,650,667	6.1

CRUISE=DL7802

YEAR	SEASON	#STA.	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	LATE WINTER	28	AMMODYTES	11	39.3	12	42.9	222.1	128.7	762,512,494,902	89.2
			PARALEPIDIDAE	4	14.3	9	32.1	11.1	5.1	37,983,661,892	4.4
			DISINTEGRATED	1	3.6	2	7.1	3.7	3.2	12,692,057,143	1.5
			UNKNOWN:FISH/EGGS	0	0.0	4	14.3	2.4	1.2	8,184,541,049	0.9
			BREVOORTIA TYRANNUS	0	0.0	3	10.7	2.1	1.5	7,167,399,176	0.8
			MYCTOPHIDAE	0	0.0	3	10.7	0.9	0.5	3,020,001,697	0.4
			GOBIIDAE	0	0.0	2	7.1	0.8	0.6	2,711,317,714	0.3
			UROPHYCIS	0	0.0	3	10.7	0.7	0.4	2,335,980,029	0.3
			HYGOPHUM	0	0.0	2	7.1	0.5	0.4	1,807,545,143	0.2
			CERATOSCOPELUS MADERENSIS	0	0.0	1	3.6	0.5	2.7	1,721,705,143	0.2
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	3.6	0.5	2.7	1,721,705,143	0.2
			SCOPHTHALMUS AQUOSUS	0	0.0	1	3.6	0.5	2.7	1,721,705,143	0.2
			SCIAENIDAE	0	0.0	1	3.6	0.4	2.2	1,449,469,714	0.2
			OPHICHTHIDAE	0	0.0	2	7.1	0.4	0.3	1,386,929,143	0.2
			ENCHELYOPUS CIMBRIUS	0	0.0	2	7.1	0.4	0.3	1,386,929,143	0.2
			CARAPIDAE	0	0.0	1	3.6	0.3	1.5	946,692,571	0.1
			CYNOGLOSSIDAE	0	0.0	1	3.6	0.3	1.3	860,852,571	0.1
			PARALICHTHYS DENTATUS	1	3.6	1	3.6	0.2	1.2	767,654,857	<0.1
			SYMPHURUS	0	0.0	1	3.6	0.2	1.1	724,734,857	<0.1
			TETRAODONTIDAE	0	0.0	1	3.6	0.2	1.1	724,734,857	<0.1
			LABRIDAE/SCARIDAE	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1
			CYCLOTHONE	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1
			DIAPHUS	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1
			BREGMACEROTIDAE	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1
			DECAPTERUS PUNCTATUS	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1
			PEPRILUS TRIACANTHUS	0	0.0	1	3.6	0.2	1.0	662,194,286	<0.1

Table 2. (continued)

CRUISES=AR7804 & AL7804

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	EARLY SPRING	29	BENTHOSEMA GLACIALE	15	51.7	16	55.2	61.1	17.8	209,776,921,462	84.2
			AMMODYTES	5	17.2	10	34.5	5.1	2.2	17,577,903,593	7.0
			MYCTOPHIDAE	3	10.3	3	10.3	3.9	3.2	13,482,161,482	5.4
			PARALEPIDIDAE	0	0.0	3	10.3	0.5	0.3	1,876,293,029	0.7
			CERATOSCOPELUS MADERENSIS	0	0.0	2	6.9	0.5	0.3	1,562,880,000	0.6
			PEPRILUS TRIACANTHUS	0	0.0	1	3.4	0.3	1.6	1,046,656,000	0.4
			ENCHELYOPUS CIMBRIUS	0	0.0	1	3.4	0.2	1.2	755,392,000	0.3
			HYGOPHUM	0	0.0	1	3.4	0.2	1.2	738,816,000	0.3
			DISINTEGRATED	0	0.0	1	3.4	0.2	1.0	636,992,000	0.2
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	3.4	0.2	0.9	555,296,000	0.2
			UNKNOWN	0	0.0	1	3.4	0.2	0.8	523,328,000	0.2
			GONOSTOMATIDAE	0	0.0	1	3.4	0.2	0.8	523,328,000	0.2
			CARAPIDAE	0	0.0	1	3.4	0.2	0.8	523,328,000	0.2

CRUISE=AL7807

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	LATE SPRING	29	MERLUCCIUS BILINEARIS	3	10.3	11	37.9	15.8	7.8	54,187,605,719	17.5
			UROPHYCIS	2	6.9	14	48.3	15.4	5.5	52,797,641,503	17.0
			PEPRILUS TRIACANTHUS	1	3.4	8	27.6	12.3	6.8	42,379,410,780	13.7
			CERATOSCOPELUS MADERENSIS	2	6.9	5	17.2	10.0	7.1	34,470,531,174	11.1
			HIPPOGLOSSINA OBLONGA	1	3.4	10	34.5	6.6	2.4	22,601,964,431	7.3
			BENTHOSEMA GLACIALE	3	10.3	11	37.9	6.3	1.9	21,585,339,573	6.9
			SCOMBER SCOMBRUS	0	0.0	5	17.2	4.2	2.5	14,346,749,887	4.6
			POMATOMUS SALTATRIX	1	3.4	1	3.4	3.1	16.9	10,755,456,000	3.5
			LIMANDA FERRUGINEA	1	3.4	4	13.8	2.2	1.4	7,652,909,817	2.5
			ENGRAULIDAE	0	0.0	2	6.9	1.7	1.5	5,708,064,000	1.8
			UNKNOWN	0	0.0	5	17.2	1.5	0.7	5,237,758,906	1.7
			LOPHIUS AMERICANUS	2	6.9	5	17.2	1.5	0.7	5,074,048,001	1.6
			MYCTOPHIDAE	0	0.0	4	13.8	1.1	0.5	3,744,854,443	1.2
			BOTHUS	0	0.0	3	10.3	1.0	0.6	3,413,720,692	1.1
			OPHIDIIDAE	0	0.0	3	10.3	0.9	0.6	3,105,949,320	1.0
			LABRIDAE/SCARIDAE	0	0.0	3	10.3	0.8	0.5	2,697,247,310	0.8
			SARDA SARDA	0	0.0	2	6.9	0.8	0.6	2,643,872,000	0.8
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	3	10.3	0.7	0.4	2,389,137,176	0.7
			SYNODONTIDAE	0	0.0	2	6.9	0.6	0.4	2,132,384,000	0.7
			MERLUCCIUS	0	0.0	1	3.4	0.4	2.3	1,477,632,000	0.5
			DISINTEGRATED	0	0.0	2	6.9	0.4	0.3	1,466,976,000	0.5
			ETROPUS MICROSTOMUS	0	0.0	2	6.9	0.4	0.3	1,451,584,000	0.5
			PARALEPIDIDAE	0	0.0	1	3.4	0.4	2.1	1,321,344,000	0.4
			DIAPHUS	0	0.0	2	6.9	0.4	0.3	1,278,720,000	0.4
			LAMPANYCTUS	0	0.0	1	3.4	0.4	1.9	1,236,096,000	0.4
			CARAPIDAE	0	0.0	1	3.4	0.2	1.1	726,976,000	0.2
			SCOMBRIDAE	0	0.0	1	3.4	0.2	1.0	660,672,000	0.2
			GONICHTHYS COCCOI	0	0.0	1	3.4	0.2	1.0	652,384,000	0.2
			HYGOPHUM	0	0.0	1	3.4	0.2	1.0	638,176,000	0.2
			GONOSTOMA ELONGATUM	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2
			CYCLOPSETTA	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2
			SYACIUM	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2

GONOSTOMA ELONGATUM	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2
CYCLOPSETTA	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2
SYACIUM	0	0.0	1	3.4	0.2	1.0	618,048,000	0.2

Table 2. (continued)

CRUISE=BE7801

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	SUMMER	30	ETROPUS MICROSTOMUS	1	3.3	9	30.0	164.8	125.7	565,832,361,762	36.2
			CITHARICHTHYS ARCTIFRONS	1	3.3	16	53.3	65.2	31.0	223,970,984,356	14.4
			LABRIDAE/SCARIDAE	0	0.0	6	20.0	27.8	18.9	95,610,206,123	6.1
			UROPHYCIS	2	6.7	20	66.7	24.9	7.0	85,515,500,716	5.5
			AUXIS	2	6.7	15	50.0	18.4	6.3	63,292,418,840	4.1
			HIPPOGLOSSINA OBLONGA	1	3.3	16	53.3	17.9	5.2	61,521,913,098	3.9
			OPHIDIIDAE	1	3.3	15	50.0	16.9	5.8	57,872,321,603	3.7
			PEPRILUS TRIACANTHUS	0	0.0	14	46.7	14.8	4.7	50,816,628,732	3.3
			ENGRAULIDAE	0	0.0	7	23.3	14.6	9.1	50,190,858,806	3.2
			TRIGLIDAE	0	0.0	5	16.7	7.9	4.9	27,066,593,267	1.7
			CENTROPRISTIS STRIATUS	0	0.0	5	16.7	7.6	4.9	26,150,241,825	1.7
			SYACIUM	0	0.0	3	10.0	7.3	4.4	25,062,792,928	1.6
			GOBIIDAE	0	0.0	5	16.7	5.8	3.4	20,009,609,794	1.3
			BOTHUS	0	0.0	7	23.3	4.4	2.2	15,091,859,761	1.0
			POMATOMUS SALTATRIX	0	0.0	7	23.3	4.4	1.9	14,960,155,684	1.0
			CALLIONYMIDAE	0	0.0	4	13.3	4.0	2.5	13,783,862,077	0.9
			SYMPHURUS	0	0.0	5	16.7	3.9	2.3	13,248,229,841	0.8
			CERATOSCOPELUS MADERENSIS	1	3.3	3	10.0	3.0	2.1	10,338,543,287	0.7
			PISODONOPHIS CRUENTIFER	0	0.0	4	13.3	3.0	1.9	10,269,830,989	0.7
			SYNODONTIDAE	0	0.0	5	16.7	2.9	1.6	9,809,585,104	0.6
			ANGUILLIFORMES	0	0.0	3	10.0	2.8	2.1	9,768,041,774	0.6
			MERLUCCIUS	0	0.0	2	6.7	2.1	1.6	7,276,942,933	0.5
			BENTHOSEMA GLACIALE	0	0.0	3	10.0	2.0	1.2	6,900,300,125	0.4
			SCORPAENIDAE	0	0.0	4	13.3	2.0	1.2	6,752,026,405	0.4
			OPHICHTHIDAE	0	0.0	6	20.0	1.8	0.7	6,257,782,295	0.4
			SERRANIDAE	0	0.0	4	13.3	1.7	1.1	5,919,483,645	0.4
			DISINTEGRATED	0	0.0	3	10.0	1.7	1.0	5,916,189,982	0.4
			MERLUCCIUS BILINEARIS	0	0.0	7	23.3	1.6	0.6	5,352,829,651	0.4
			SARDINELLA	0	0.0	1	3.3	1.5	8.2	5,136,665,600	0.4
			DECAPTERUS PUNCTATUS	0	0.0	2	6.7	1.4	1.2	4,910,048,000	0.3
			MERLUCCIUS ALBIDUS	0	0.0	3	10.0	1.3	0.8	4,402,501,808	0.3
			DIAPHUS SUBTILIS	1	3.3	1	3.3	1.2	6.7	4,217,605,333	0.3
			PARALEPIDIDAE	0	0.0	2	6.7	1.2	1.0	4,192,425,600	0.3
			EUTHYNNUS ALLETTERATUS	0	0.0	3	10.0	1.1	0.6	3,813,331,872	0.2
			MICROPOGONIAS UNDULATUS	0	0.0	1	3.3	1.0	5.5	3,424,443,733	0.2
			UNKNOWN:FISH/EGGS	0	0.0	3	10.0	0.9	0.6	3,194,066,469	0.2
			OGCOCEPHALIDAE	0	0.0	2	6.7	0.8	0.6	2,788,083,200	0.2
			MAUROLICUS MUELLERI	0	0.0	1	3.3	0.8	4.3	2,669,051,733	0.2
			CYCLOTHONE	0	0.0	2	6.7	0.7	0.5	2,379,484,800	0.1
			MYCTOPHIDAE	0	0.0	2	6.7	0.6	0.5	2,140,277,333	0.1
			LOPHIUS AMERICANUS	0	0.0	3	10.0	0.6	0.3	2,057,027,234	0.1
			SCIAENIDAE	0	0.0	1	3.3	0.5	2.9	1,812,940,800	0.1
			CERATOSCOPELUS	0	0.0	1	3.3	0.5	2.7	1,682,464,000	0.1
			MURAENIDAE	0	0.0	2	6.7	0.4	0.3	1,523,373,867	0.1
			CARAPIDAE	0	0.0	2	6.7	0.4	0.3	1,499,338,667	0.1
			MELANOCETIDAE	0	0.0	2	6.7	0.4	0.3	1,436,389,333	0.1
			DIAPHUS	0	0.0	1	3.3	0.4	2.1	1,334,525,867	0.1
			CARANGIDAE	0	0.0	2	6.7	0.3	0.2	1,184,592,000	0.1
			ARGYROPELECUS HEMIGYMNUS	0	0.0	1	3.3	0.3	1.5	965,986,133	0.1
			MENTICIRRHUS	0	0.0	1	3.3	0.3	1.5	965,986,133	0.1
			CYNOSCION REGALIS	0	0.0	1	3.3	0.3	1.4	885,868,800	0.1
			ANTHIINAE	0	0.0	1	3.3	0.2	1.4	856,110,933	0.1
			NANSENIA GROENLANDICA	0	0.0	1	3.3	0.2	1.4	856,110,933	0.1

Table 2. (continued)

CRUISE=BE7801

TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
SCOPELARCHIDAE	0	0.0	1	3.3	0.2	1.4	856,110,933	0.1
MYCTOPHUM NITIDULUM	0	0.0	1	3.3	0.2	1.4	856,110,933	0.1
TETRAODONTIDAE	0	0.0	1	3.3	0.2	1.4	856,110,933	0.1
CUBICEPS PAUCIRADIATUS	0	0.0	1	3.3	0.2	1.3	841,232,000	0.1
BRANCHIOSTEGIDAE	0	0.0	1	3.3	0.2	1.2	743,946,667	<0.1
MYCTOPHUM	0	0.0	1	3.3	0.2	1.1	667,262,933	<0.1
HYGOPHUM REINHARDT	0	0.0	1	3.3	0.2	1.1	667,262,933	<0.1
HOWELLA	0	0.0	1	3.3	0.2	1.1	667,262,933	<0.1
STOMIAS FEROX	0	0.0	1	3.3	0.1	0.8	505,883,733	<0,1
PSENES MACULATUS	0	0.0	1	3.3	0.1	0.8	505,883,733	<0.1
APOGONIDAE	0	0.0	1	3.3	0.1	0.5	302,156,800	<0.1

CRUISES=WI7804 & BE7803

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	EARLY AUTUMN	19	CERATOSCOPELUS MADERENSIS	7	36.8	15	78.9	55.6	22.5	190,993,995,969	53.1
			UROPHYCIS	2	10.5	10	52.6	11.8	4.1	40,414,965,224	11.2
			PARALEPIDIDAE	1	5.3	7	36.8	6.2	2.8	21,129,985,665	5.9
			MERLUCCIUS BILINEARIS	0	0.0	6	31.6	5.9	3.0	20,375,290,595	5.6
			BOTHUS	0	0.0	12	63.2	5.3	1.3	18,077,343,219	5.0
			GOBIIDAE	0	0.0	7	36.8	3.3	1.2	11,278,943,148	3.1
			SYACIUM	0	0.0	9	47.4	2.8	0.8	9,658,547,446	2.7
			CARAPIDAE	0	0.0	6	31.6	1.9	0.7	6,443,135,186	1.8
			MYCTOPHIDAE	0	0.0	2	10.5	1.8	1.5	6,306,981,053	1.8
			LABRIDAE/SCARIDAE	0	0.0	7	36.8	1.7	0.5	5,798,932,711	1.6
			CITHARICHTHYS ARCTIFRONS	0	0.0	4	21.1	1.2	0.6	3,981,860,928	1.0
			OPHIDIIDAE	0	0.0	4	21.1	1.1	0.6	3,766,003,573	1.0
			CERATOSCOPELUS WARMINGI	0	0.0	2	10.5	0.8	0.6	2,665,557,895	0.7
			CYCLOTHONE	0	0.0	2	10.5	0.6	0.4	2,125,217,684	0.6
			MERLUCCIUS ALBIDUS	0	0.0	2	10.5	0.6	0.5	2,063,774,316	0.6
			SYMBOLOPHORUS VERANYI	0	0.0	1	5.3	0.6	2.5	1,958,959,158	0.5
			SCORPAENIDAE	0	0.0	2	10.5	0.6	0.4	1,890,287,158	0.5
			CALLIONYMIDAE	0	0.0	2	10.5	0.5	0.3	1,711,378,526	0.5
			ICHTHYOCOCCUS OVATUS	0	0.0	1	5.3	0.3	1.3	1,051,765,895	0.3
			OGCOCEPHALIDAE	0	0.0	1	5.3	0.3	1.3	1,051,765,895	0.3
			ENGRAULIDAE	0	0.0	1	5.3	0.3	1.3	1,019,237,053	0.3
			ETROPUS/CITHARICHTHYS	0	0.0	1	5.3	0.3	1.2	954,179,368	0.3
			MAUROLICUS MUELLERI	0	0.0	1	5.3	0.3	1.2	954,179,368	0.3
			PEPRILUS TRIACANTHUS	0	0.0	1	5.3	0.3	1.2	939,722,105	0.3
			SYNODONTIDAE	0	0.0	1	5.3	0.2	1.0	751,777,684	0.2
			MURAENIDAE	0	0.0	1	5.3	0.2	1.0	751,777,684	0.2
			MICROPOGONIAS UNDULATUS	0	0.0	1	5.3	0.2	1.0	751,777,684	0.2
			SERRANIDAE	0	0.0	1	5.3	0.2	0.7	562,026,105	0.1
			SYMPHURUS	0	0.0	1	5.3	0.2	0.7	562,026,105	0.1
			CERATIOIDEA	0	0.0	1	5.3	0.2	0.7	560,218,947	0.1
			OPHICHTHIDAE	0	0.0	1	5.3	0.2	0.7	560,218,947	0.1
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

			CERATIOIDEA	0	0.0	1	5.3	0.2	0.7	560,218,947	0.1
			OPHICHTHIDAE	0	0.0	1	5.3	0.2	0.7	560,218,947	0.1
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

Table 2. (continued)

CRUISE=BE7804

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1978	AUTUMN	2	PARALEPIDIDAE	1	50.0	1	50.0	7.6	10.7	26,095,360,000	38.2
			LABRIDAE/SCARIDAE	0	0.0	1	50.0	4.1	5.8	14,026,256,000	20.6
			CARAPIDAE	0	0.0	1	50.0	4.1	5.8	14,026,256,000	20.6
			BOTHUS	0	0.0	1	50.0	4.1	5.8	14,026,256,000	20.6

CRUISE=DL7903

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	LATE WINTER	17	AMMODYTES	10	58.8	10	58.8	538.8	394.8	1,850,172,341,270	99.4
			PARALEPIDIDAE	2	11.8	3	17.6	1.0	0.6	3,479,138,476	0.2
			BENTHOSEMA GLACIALE	1	5.9	1	5.9	0.8	3.3	2,726,682,353	0.1
			DISINTEGRATED	0	0.0	2	11.8	0.7	0.5	2,393,421,176	0.1
			CRYPTACANTHODES MACULATUS	1	5.9	1	5.9	0.3	1.3	1,112,890,353	0.1
			MERLUCCIUS BILINEARIS	0	0.0	1	5.9	0.3	1.1	929,091,765	<0.1
			PARALICHTHYS DENTATUS	0	0.0	1	5.9	0.2	0.9	777,609,412	<0.1
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

CRUISES=AL7903 & DL7904

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	EARLY SPRING	4	AMMODYTES	3	75.0	3	75.0	31.4	22.9	107,699,779,541	67.7
			BENTHOSEMA GLACIALE	1	25.0	2	50.0	13.6	8.3	46,636,872,000	29.3
			MERLUCCIUS BILINEARIS	0	0.0	1	25.0	1.4	2.8	4,849,960,000	3.0

CRUISE=DL7905

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	SPRING	23	BENTHOSEMA GLACIALE	12	52.2	15	65.2	67.1	23.8	230,358,199,994	74.5
			LIMANDA FERRUGINEA	3	13.0	4	17.4	4.6	2.8	15,918,929,828	5.1
			SCOMBER SCOMBRUS	0	0.0	3	13.0	2.5	1.8	8,541,344,760	2.8
			MICROPOGONIAS UNDULATUS	0	0.0	1	4.3	2.2	10.8	7,715,149,913	2.5
			OPHIDIIDAE	0	0.0	1	4.3	1.7	8.1	5,786,362,435	1.8
			SYNODONTIDAE	0	0.0	1	4.3	1.4	6.7	4,821,968,696	1.6
			MERLUCCIUS BILINEARIS	0	0.0	2	8.7	1.2	0.9	4,248,706,783	1.4
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	3	13.0	1.1	0.7	3,923,937,645	1.3
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	4.3	1.1	5.4	3,857,574,957	1.2
			MERLUCCIUS ALBIDUS	0	0.0	3	13.0	0.8	0.4	2,737,933,781	0.9
			PARALEPIDIDAE	0	0.0	2	8.7	0.8	0.6	2,715,529,739	0.9
			MELANOGRAMMUS AEGLEFINUS	0	0.0	1	4.3	0.7	3.5	2,516,978,087	0.8
			PEPRILUS TRIACANTHUS	0	0.0	1	4.3	0.6	2.7	1,928,787,478	0.6
			SCOPHTHALMUS AQUOSUS	0	0.0	1	4.3	0.6	2.7	1,928,787,478	0.6
			UNKNOWN	0	0.0	2	8.7	0.5	0.4	1,803,386,435	0.6
			AMMODYTES	1	4.3	2	8.7	0.5	0.3	1,585,427,478	0.5
			ENCHELYOPUS CIMBRIUS	0	0.0	1	4.3	0.4	2.0	1,398,818,783	0.4
			PROTOMYCTOPHUM	0	0.0	1	4.3	0.3	1.5	1,089,794,783	0.3
			DISINTEGRATED	0	0.0	1	4.3	0.3	1.3	964,393,739	0.3
			PARALICHTHYS DENTATUS	0	0.0	1	4.3	0.3	1.3	964,393,739	0.3
			SYMPHURUS	0	0.0	1	4.3	0.3	1.3	964,393,739	0.3
			BROSME BROSME	0	0.0	1	4.3	0.3	1.3	962,900,870	0.3
			LOPHIUS AMERICANUS	0	0.0	1	4.3	0.3	1.3	900,200,348	0.3
			SEBASTES	0	0.0	1	4.3	0.2	1.2	856,907,130	0.3
			ETROPUS MICROSTOMUS	1	4.3	1	4.3	0.2	1.2	853,921,391	0.3
			CYCLOPTERIDAE	0	0.0	1	4.3	0.2	1.2	836,006,957	0.3

Table 2. (continued)

CRUISE=AL7906

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	LATE SPRING	23	MERLUCCIUS BILINEARIS	3	13.0	12	52.2	33.5	15.3	115,193,166,937	23.6
			PEPRILUS TRIACANTHUS	1	4.3	11	47.8	24.3	11.3	83,336,338,302	17.1
			UROPHYCIS	0	0.0	11	47.8	23.0	8.5	79,058,147,911	16.2
			CERATOSCOPELUS MADERENSIS	2	8.7	6	26.1	16.4	12.0	56,168,031,893	11.5
			ETROPUS/CITHARICHTHYS	0	0.0	6	26.1	6.2	3.6	21,124,107,815	4.3
			POMATOMUS SALTATRIX	0	0.0	7	30.4	5.9	2.6	20,110,221,657	4.1
			HIPPOGLOSSINA OBLONGA	0	0.0	10	43.5	5.5	1.9	18,827,709,818	3.9
			LIMANDA FERRUGINEA	0	0.0	5	21.7	5.5	2.8	18,749,875,615	3.8
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	6	26.1	2.9	1.2	9,938,166,678	2.0
			OPHIDIIDAE	1	4.3	4	17.4	2.4	1.4	8,131,244,543	1.7
			EUTHYNNUS ALLETTERATUS	0	0.0	3	13.0	2.4	1.6	8,079,196,738	1.6
			SCOMBRIDAE	0	0.0	4	17.4	2.3	1.3	7,904,966,802	1.6
			TAUTOGOLABRUS ADSPERSUS	0	0.0	4	17.4	2.1	1.1	7,188,656,025	1.5
			BENTHOSEMA GLACIALE	1	4.3	3	13.0	2.0	1.1	6,787,132,576	1.4
			DISINTEGRATED	0	0.0	3	13.0	1.8	1.1	6,204,205,804	1.3
			LOPHIUS AMERICANUS	0	0.0	4	17.4	1.6	0.8	5,501,297,083	1.1
			SCOMBER SCOMBRUS	0	0.0	3	13.0	1.0	0.6	3,298,305,079	0.7
			AUXIS	0	0.0	2	8.7	0.6	0.4	1,904,901,565	0.4
			MERLUCCIUS ALBIDUS	0	0.0	2	8.7	0.5	0.4	1,769,050,435	0.3
			ANGUILLIFORMES	0	0.0	2	8.7	0.5	0.4	1,763,078,957	0.3
			ENGRAULIDAE	0	0.0	2	8.7	0.5	0.3	1,627,227,826	0.3
			OPHICHTHIDAE	1	4.3	1	4.3	0.4	2.1	1,477,940,870	0.3
			ENGRAULIS EURYSTOLE	0	0.0	1	4.3	0.3	1.4	1,022,615,652	0.2
			LAMPANYCTUS	0	0.0	1	4.3	0.3	1.4	1,001,715,478	0.2
			BROSME BROSME	0	0.0	1	4.3	0.3	1.2	882,285,913	0.2
			MYCTOPHIDAE	0	0.0	1	4.3	0.2	1.1	821,078,261	0.2
			LAMPANYCTUS ALATUS	0	0.0	1	4.3	0.2	1.1	821,078,261	0.2
			CONGRIDAE	0	0.0	1	4.3	0.2	1.1	821,078,261	0.2
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

CRUISE=BE7901

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	SUMMER	20	ETROPUS/CITHARICHTHYS	8	40.0	18	90.0	296.5	127.3	1,017,900,975,165	53.1
			POMATOMUS SALTATRIX	0	0.0	7	35.0	47.2	30.9	161,917,985,737	8.5
			UROPHYCIS	0	0.0	14	70.0	37.0	13.8	127,042,401,100	6.6
			TRIGLIDAE	0	0.0	2	10.0	29.1	26.7	99,780,416,000	5.2
			OPHIDIIDAE	0	0.0	12	60.0	24.0	11.9	82,383,726,410	4.3
			HIPPOGLOSSINA OBLONGA	0	0.0	15	75.0	23.2	6.5	79,793,829,920	4.2
			AUXIS	0	0.0	12	60.0	20.7	8.1	70,962,214,825	3.7
			PEPRILUS TRIACANTHUS	0	0.0	17	85.0	14.9	3.8	51,326,668,080	2.7
			SCOMBRIDAE	0	0.0	4	20.0	8.0	5.1	27,447,239,887	1.4
			OPHICHTHIDAE	0	0.0	8	40.0	6.6	3.2	22,792,224,054	1.2
			TAUTOGOLABRUS ADSPERSUS	0	0.0	2	10.0	6.3	6.2	21,758,723,200	1.1
			MERLUCCIUS ALBIDUS	0	0.0	5	25.0	6.1	3.2	20,908,192,763	1.1
			ENGRAULIDAE	0	0.0	4	20.0	5.4	3.6	18,539,875,606	1.0
			LABRIDAE/SCARIDAE	1	5.0	4	20.0	4.9	3.5	16,839,092,520	0.9
			ANGUILLIFORMES	0	0.0	5	25.0	3.9	2.1	13,470,865,109	0.7
			PISODONOPHIS CRUENTIFER	0	0.0	3	15.0	3.7	2.1	12,652,800,847	0.7
			BENTHOSEMA GLACIALE	0	0.0	2	10.0	3.4	2.4	11,722,310,400	0.6
			MERLUCCIUS BILINEARIS	0	0.0	8	40.0	2.1	0.6	7,067,788,758	0.4
			DISINTEGRATED	0	0.0	6	30.0	2.0	0.9	7,028,037,667	0.4

LABRIDAE/SCARIDAE	0	0.0	4	20.0	5.4	3.6	18,539,875,606	1.0
ANGUILLIFORMES	1	5.0	4	20.0	4.9	3.5	16,839,092,520	0.9
PISODONOPHIS CRUENTIFER	0	0.0	5	25.0	3.9	2.1	13,470,865,109	0.7
BENTHOSEMA GLACIALE	0	0.0	3	15.0	3.7	2.1	12,652,800,817	0.7
MERLUCCIUS BILINEARIS	0	0.0	2	10.0	3.4	2.4	11,723,310,400	0.6
DISINTEGRATED	0	0.0	8	40.0	2.1	0.6	[illegible]	0.4
	0	0.0	4	20.0	2.0	0.5	[illegible]	0.4

CRUISE=BE7901

TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
CENTROPRISTIS STRIATUS	0	0.0	2	10.0	1.6	1.4	5,366,716,800	0.3
UNKNOWN	0	0.0	4	20.0	1.3	0.6	4,603,975,771	0.2
PEPRILUS	0	0.0	1	5.0	1.3	5.8	4,420,760,000	0.2
BOTHUS	0	0.0	3	15.0	1.1	0.6	3,899,195,319	0.2
ENCHELYOPUS CIMBRIUS	0	0.0	2	10.0	0.9	0.6	3,038,736,000	0.2
ENGRAULIS EURYSTOLE	0	0.0	1	5.0	0.8	3.4	2,642,155,200	0.1
CUBICEPS	0	0.0	1	5.0	0.8	3.4	2,642,155,200	0.1
GOBIIDAE	0	0.0	1	5.0	0.8	3.4	2,642,155,200	0.1
ETROPUS MICROSTOMUS	0	0.0	1	5.0	0.6	2.7	2,091,062,400	0.1
CARANGIDAE	0	0.0	1	5.0	0.5	2.3	1,761,436,800	0.1
URANOSCOPIDAE	0	0.0	1	5.0	0.5	2.2	1,716,800,000	0.1
BRANCHIOSTEGIDAE	0	0.0	2	10.0	0.4	0.3	1,541,686,400	0.1
SYMPHURUS	0	0.0	2	10.0	0.4	0.3	1,370,006,400	0.1
COTTIDAE	0	0.0	1	5.0	0.3	1.4	1,050,681,600	0.1
SYNODONTIDAE	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
LAMPANYCTUS	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
SERRANIDAE	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
HIMANTOLOPHIDAE	0	0.0	1	5.0	0.3	1.1	880,718,400	<0.1
SCORPAENIDAE	0	0.0	1	5.0	0.2	1.1	849,816,000	<0.1
LOPHIUS AMERICANUS	0	0.0	1	5.0	0.2	0.8	645,516,800	<0.1
TAUTOGA ONITIS	0	0.0	1	5.0	0.2	0.7	528,774,400	<0.1
BLENNIIDAE	0	0.0	1	5.0	0.1	0.6	489,288,000	<0.1
CARAPIDAE	0	0.0	1	5.0	0.1	0.6	489,288,000	<0.1
SYACIUM	0	0.0	1	5.0	0.1	0.6	489,288,000	<0.1
LIMANDA FERRUGINEA	0	0.0	1	5.0	0.1	0.6	482,420,800	<0.1
HIPPOCAMPUS	0	0.0	1	5.0	0.1	0.3	264,387,200	<0.1

CRUISE=AL7911

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	EARLY AUTUMN	18	ETROPUS/CITHARICHTHYS	3	16.7	13	72.2	18.9	7.4	64,811,970,936	27.1
			UROPHYCIS	7	38.9	15	83.3	15.1	3.8	51,971,521,151	21.7
			TRIGLIDAE	0	0.0	2	11.1	11.7	10.6	40,104,448,000	16.8
			OPHIDIIDAE	0	0.0	5	27.8	4.1	2.1	14,148,549,401	5.9
			ENGRAULIS EURYSTOLE	0	0.0	2	11.1	3.2	3.0	11,090,528,000	4.6
			ENGRAULIDAE	0	0.0	1	5.6	3.0	12.7	10,255,018,667	4.3
			MICROPOGONIAS UNDULATUS	0	0.0	2	11.1	1.5	1.1	5,207,626,667	2.2
			GOBIIDAE	0	0.0	5	27.8	1.4	0.6	4,782,719,916	2.0
			BOTHUS	0	0.0	4	22.2	1.4	0.7	4,678,731,526	1.9
			UNKNOWN	0	0.0	1	5.6	1.1	4.8	3,845,632,000	1.6
			SERRANIDAE	0	0.0	2	11.1	1.0	0.8	3,544,238,222	1.5
			CERATOSCOPELUS MADERENSIS	0	0.0	1	5.6	0.7	2.8	2,266,176,000	0.9
			OPHICHTHIDAE	0	0.0	2	11.1	0.6	0.4	2,031,546,667	0.8
			MYCTOPHIDAE	0	0.0	2	11.1	0.6	0.4	1,945,706,667	0.8
			SYNODONTIDAE	0	0.0	2	11.1	0.5	0.4	1,806,455,111	0.8
			LABRIDAE/SCARIDAE	0	0.0	2	11.1	0.5	0.3	1,644,312,889	0.7
			URANOSCOPIDAE	0	0.0	1	5.6	0.4	1.9	1,510,784,000	0.6
			HIPPOGLOSSINA OBLONGA	0	0.0	1	5.6	0.4	1.9	1,510,784,000	0.6
			PEPRILUS TRIACANTHUS	0	0.0	1	5.6	0.4	1.6	1,281,877,333	0.5
			SCOPHTHALMUS AQUOSUS	0	0.0	1	5.6	0.4	1.6	1,281,877,333	0.5
			BENTHOSEMA GLACIALE	0	0.0	1	5.6	0.3	1.4	1,155,978,667	0.5
			MURAENIDAE	0	0.0	1	5.6	0.3	1.3	1,051,063,111	0.4
			MYLIOBATIDAE	0	0.0	1	5.6	0.3	1.2	980,483,556	0.4
			DIOGENICHTHYS ATLANTICUS	0	0.0	1	5.6	0.3	1.2	980,483,556	0.4
			SCIAENIDAE	0	0.0	1	5.6	0.3	1.2	980,483,556	0.4

Table 2. (continued)

CRUISE=AL7911

TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
CARAPIDAE	0	0.0	1	5.6	0.3	1.2	980,483,556	0.4
MERLUCCIUS BILINEARIS	0	0.0	1	5.6	0.2	1.0	827,879,111	0.3
GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	1	5.6	0.2	0.9	759,207,111	0.3
CONGRIDAE	0	0.0	1	5.6	0.2	0.9	755,392,000	0.3
APOGONIDAE	0	0.0	1	5.6	0.2	0.9	755,392,000	0.3
SCORPAENIDAE	0	0.0	1	5.6	0.2	0.9	755,392,000	0.3
PARALICHTHYS DENTATUS	0	0.0	1	5.6	0.2	0.9	755,392,000	0.3
SYMPHURUS	0	0.0	1	5.6	0.2	0.8	663,829,333	0.3

CRUISES=WI7903 & AL7913

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1979	AUTUMN	6	MERLUCCIUS BILINEARIS	1	16.7	2	33.3	13.1	8.7	44,871,429,333	27.0
			PARALICHTHYS DENTATUS	0	0.0	3	50.0	9.8	6.7	33,643,463,270	20.2
			PARALEPIDIDAE	1	16.7	2	33.3	9.7	6.2	33,448,986,667	20.1
			DISINTEGRATED	0	0.0	1	16.7	2.1	5.2	7,302,122,667	4.4
			UROPHYCIS	0	0.0	1	16.7	1.8	4.3	6,077,472,000	3.6
			CERATIOIDEA	0	0.0	1	16.7	1.1	2.7	3,817,018,667	2.3
			MERLUCCIUS ALBIDUS	0	0.0	1	16.7	1.1	2.7	3,817,018,667	2.3
			GOBIIDAE	0	0.0	1	16.7	1.1	2.7	3,817,018,667	2.3
			GONOSTOMA ELONGATUM	0	0.0	1	16.7	1.1	2.6	3,651,061,333	2.2
			VINCIGUERRIA	0	0.0	1	16.7	1.1	2.6	3,651,061,333	2.2
			MICROPOGONIAS UNDULATUS	0	0.0	1	16.7	1.1	2.6	3,651,061,333	2.2
			URANOSCOPIDAE	0	0.0	1	16.7	1.1	2.6	3,651,061,333	2.2
			MERLUCCIUS	0	0.0	1	16.7	0.9	2.3	3,198,970,667	1.9
			TRIGLIDAE	0	0.0	1	16.7	0.9	2.3	3,198,970,667	1.9
			LABRIDAE/SCARIDAE	0	0.0	1	16.7	0.9	2.2	3,038,736,000	1.8
			OPHIDIIDAE	0	0.0	1	16.7	0.9	2.2	3,038,736,000	1.8
			CAULOPHRYNIDAE	0	0.0	1	16.7	0.9	2.2	3,038,736,000	1.8
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

CRUISES=AL8002 & WI8002

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	LATE WINTER	20	AMMODYTES	10	50.0	10	50.0	165.4	77.1	567,912,681,662	98.3
			PARALEPIDIDAE	0	0.0	5	25.0	1.3	0.5	4,589,035,853	0.8
			PARALICHTHYS DENTATUS	0	0.0	1	5.0	0.5	2.2	1,651,561,600	0.3
			DISINTEGRATED	0	0.0	1	5.0	0.3	1.3	999,177,600	0.2
			DIAPHUS	0	0.0	1	5.0	0.3	1.3	999,177,600	0.2
			CONGRIDAE	0	0.0	1	5.0	0.3	1.1	860,116,800	0.1
			BENTHOSEMA	1	5.0	1	5.0	0.2	1.1	854,966,400	0.1
			UNKNOWN	0	0.0	0	0.0	0.0	0.0	0	

Table 2. (continued)

CRUISES=EK8001 & AL8003 & DL8002

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	EARLY SPRING	22	BENTHOSEMA GLACIALE	9	40.9	11	50.0	46.4	23.6	159,360,522,772	76.7
			AMMODYTES	5	22.7	5	22.7	4.7	2.6	16,283,312,021	7.8
			LOPHIUS AMERICANUS	0	0.0	4	18.2	3.5	2.1	11,995,050,273	5.7
			CERATOSCOPELUS WARMINGI	1	4.5	1	4.5	1.1	5.3	3,909,621,818	1.9
			PARALEPIDIDAE	0	0.0	4	18.2	1.0	0.5	3,562,099,671	1.7
			UROPHYCIS	0	0.0	3	13.6	0.9	0.5	2,964,664,903	1.3
			CYCLOPTERIDAE	0	0.0	1	4.5	0.5	2.2	1,582,577,455	0.7
			MYCTOPHIDAE	0	0.0	1	4.5	0.3	1.6	1,162,741,818	0.5
			TRIGLIDAE	0	0.0	1	4.5	0.3	1.6	1,162,741,818	0.5
			UNKNOWN	0	0.0	1	4.5	0.3	1.4	1,019,154,909	0.5
			STOMIATIDAE	0	0.0	1	4.5	0.3	1.4	1,019,154,909	0.5
			COTTIDAE	0	0.0	1	4.5	0.3	1.3	953,604,364	0.4
			PARALEPIS ATLANTICA	0	0.0	1	4.5	0.2	1.1	777,242,182	0.3
			PARALICHTHYS DENTATUS	1	4.5	1	4.5	0.2	1.0	763,195,636	0.3
			GONOSTOMATIDAE	0	0.0	1	4.5	0.2	1.0	758,513,455	0.3
			MACROURIDAE	0	0.0	1	4.5	0.2	1.0	758,513,455	0.3
			GADUS MORHUA	1	4.5	1	4.5	0.2	0.9	653,944,727	0.3

CRUISES=DL8003 & EK8004

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	SPRING	20	SCOMBER SCOMBRUS	10	50.0	17	85.0	302.7	160.5	1,039,504,478,930	82.5
			LIMANDA FERRUGINEA	0	0.0	8	40.0	15.7	8.1	53,993,385,426	4.2
			BENTHOSEMA GLACIALE	2	10.0	7	35.0	13.6	6.3	46,707,264,745	3.7
			MERLUCCIUS BILINEARIS	0	0.0	10	50.0	11.6	5.0	39,683,144,972	3.1
			BENTHOSEMA	1	5.0	1	5.0	3.9	17.6	13,514,649,600	1.1
			MYCTOPHUM	0	0.0	1	5.0	2.6	11.7	8,968,563,200	0.7
			ENCHELYOPUS CIMBRIUS	0	0.0	6	30.0	2.5	1.0	8,467,731,190	0.6
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	8	40.0	2.3	0.7	8,066,716,072	0.6
			LOPHIUS AMERICANUS	0	0.0	5	25.0	2.1	1.0	7,361,929,204	0.5
			UROPHYCIS	0	0.0	4	20.0	2.0	1.0	6,815,451,926	0.5
			MERLUCCIUS ALBIDUS	0	0.0	3	15.0	2.0	1.2	6,790,527,052	0.2
			SYNODONTIDAE	0	0.0	3	15.0	0.9	0.5	2,994,135,166	0.2
			GADUS MORHUA	0	0.0	1	5.0	0.8	3.6	2,765,764,800	0.2
			PEPRILUS TRIACANTHUS	0	0.0	2	10.0	0.7	0.5	2,329,697,600	0.2
			CYCLOPTERIDAE	0	0.0	1	5.0	0.6	2.6	1,977,753,600	0.1
			PARALEPIDIDAE	0	0.0	1	5.0	0.4	1.8	1,345,971,200	0.1
			NETTASTOMATIDAE	0	0.0	1	5.0	0.4	1.8	1,345,971,200	0.1
			DISINTEGRATED	0	0.0	1	5.0	0.4	1.6	1,203,476,800	0.1
			CERATOSCOPELUS MADERENSIS	0	0.0	1	5.0	0.3	1.5	1,126,220,800	0.1
			UNKNOWN	0	0.0	1	5.0	0.3	1.5	1,121,070,400	0.1
			CONGRIDAE	0	0.0	1	5.0	0.3	1.5	1,121,070,400	0.1
			SYMPHURUS	0	0.0	1	5.0	0.3	1.3	1,014,628,800	0.1
			SYMBOLOPHORUS VERANYI	0	0.0	1	5.0	0.3	1.3	1,011,195,200	0.1
			CITHARICHTHYS ARCTIFRONS	0	0.0	1	5.0	0.3	1.3	1,011,195,200	0.1
			CONGER OCEANICUS	0	0.0	1	5.0	0.3	1.3	1,007,761,600	0.1

Table 2. (continued)

CRUISES=EK8006 & DL8005

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	SUMMER	22	UROPHYCIS	3	13.6	14	63.6	111.7	57.6	383,650,123,581	26.2
			POMATOMUS SALTATRIX	2	9.1	16	72.7	91.5	38.1	314,118,709,614	21.4
			PEPRILUS TRIACANTHUS	2	9.1	16	72.7	91.1	35.7	312,745,061,858	21.3
			HIPPOGLOSSINA OBLONGA	0	0.0	15	68.2	33.7	12.7	115,870,965,777	7.9
			CITHARICHTHYS ARCTIFRONS	0	0.0	14	63.6	21.0	7.7	72,037,927,627	4.9
			MERLUCCIUS BILINEARIS	0	0.0	12	54.5	16.9	5.9	58,177,433,965	3.9
			LABRIDAE/SCARIDAE	1	4.5	9	40.9	8.2	3.3	28,027,632,591	1.9
			SCOMBRIDAE	0	0.0	10	45.5	6.8	2.3	23,455,990,619	1.6
			ETROPUS MICROSTOMUS	0	0.0	5	22.7	6.3	3.6	21,703,514,783	1.5
			TAUTOGOLABRUS ADSPERSUS	0	0.0	6	27.3	5.6	3.1	19,201,270,596	1.3
			OPHICHTHIDAE	0	0.0	5	22.7	4.4	2.3	15,263,371,390	1.0
			AUXIS	0	0.0	2	9.1	4.2	3.0	14,481,988,364	1.0
			OPHIDIIDAE	0	0.0	8	36.4	2.7	0.9	9,344,176,882	0.6
			BOTHUS	0	0.0	7	31.8	2.3	0.8	7,813,670,286	0.5
			LOPHIUS AMERICANUS	0	0.0	6	27.3	2.2	0.9	7,427,493,070	0.5
			DISINTEGRATED	0	0.0	4	18.2	1.8	1.0	6,155,952,252	0.4
			BENTHOSEMA	0	0.0	1	4.5	1.4	6.4	4,719,639,273	0.3
			GLYPTOCEPHALUS CYNOGLOSSUS	0	0.0	4	18.2	1.3	0.6	4,471,168,355	0.3
			ENGRAULIDAE	0	0.0	5	22.7	1.2	0.5	3,983,160,122	0.3
			CONGRIDAE	0	0.0	3	13.6	0.9	0.5	2,994,430,674	0.2
			STERNOPTYCHIDAE	0	0.0	2	9.1	0.8	0.6	2,737,515,636	0.2
			SYACIUM	0	0.0	1	4.5	0.8	3.7	2,696,936,727	0.2
			SYNODONTIDAE	0	0.0	3	13.6	0.7	0.4	2,397,400,799	0.2
			GOBIIDAE	0	0.0	3	13.6	0.7	0.4	2,397,383,331	0.2
			UNKNOWN	0	0.0	3	13.6	0.7	0.4	2,269,342,263	0.2
			MYCTOPHIDAE	0	0.0	2	9.1	0.7	0.5	2,258,372,364	0.2
			MERLUCCIUS ALBIDUS	0	0.0	3	13.6	0.7	0.4	2,238,555,589	0.2
			LIMANDA FERRUGINEA	0	0.0	2	9.1	0.6	0.5	2,208,429,091	0.2
			SCIAENIDAE	0	0.0	2	9.1	0.5	0.4	1,724,603,636	0.1
			SCOPHTHALMUS AQUOSUS	0	0.0	1	4.5	0.4	2.1	1,513,905,455	0.1
			SERRANIDAE	0	0.0	2	9.1	0.4	0.3	1,389,047,273	0.1
			SYMBOLOPHORUS VERANYI	0	0.0	1	4.5	0.4	1.8	1,348,468,364	0.1
			TAUTOGA ONITIS	0	0.0	1	4.5	0.3	1.4	1,009,790,545	0.1
			CALLECHELYS MURAENA	0	0.0	1	4.5	0.2	1.2	849,035,636	0.1
			CENTROPRISTIS STRIATUS	0	0.0	1	4.5	0.2	1.2	849,035,636	0.1
			CYCLOTHONE	0	0.0	1	4.5	0.2	1.1	828,746,182	0.1
			HOWELLA	0	0.0	1	4.5	0.2	1.1	828,746,182	0.1
			MERLUCCIUS	0	0.0	1	4.5	0.2	1.1	817,821,091	<0.1
			PERCIFORMES	0	0.0	1	4.5	0.2	1.1	817,821,091	<0.1
			URANOSCOPIDAE	0	0.0	1	4.5	0.2	1.1	785,045,818	<0.1
			TRIGLIDAE	0	0.0	1	4.5	0.2	1.0	756,952,727	<0.1
			CERATOSCOPELUS MADERENSIS	0	0.0	1	4.5	0.2	1.0	714,813,091	<0.1
			HOLOCENTRIDAE	0	0.0	1	4.5	0.2	1.0	714,813,091	<0.1
			ARGENTINIDAE	0	0.0	1	4.5	0.2	0.9	674,234,182	<0.1
			CARANGIDAE	0	0.0	1	4.5	0.2	0.9	674,234,182	<0.1
			CALLIONYMIDAE	0	0.0	1	4.5	0.2	0.9	674,234,182	<0.1
			CYCLOPSETTA	0	0.0	1	4.5	0.2	0.9	674,234,182	<0.1
			SYMPHURUS	0	0.0	1	4.5	0.2	0.9	674,234,182	<0.1

SYMPHURUS 0 0.0 1 7.5 0.0

Table 2. (continued)

CRUISE=AL8010

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	EARLY AUTUMN	19	UROPHYCIS	7	36.8	17	89.5	147.2	64.0	505,434,083,488	60.8
			CITHARICHTHYS ARCTIFRONS	4	21.1	12	63.2	52.8	21.7	181,363,368,512	21.7
			OPHIDIIDAE	0	0.0	9	47.4	12.0	4.6	41,098,778,261	4.9
			HIPPOGLOSSINA OBLONGA	0	0.0	7	36.8	5.8	2.4	19,909,699,292	2.4
			MERLUCCIUS ALBIDUS	1	5.3	9	47.4	4.5	1.3	15,386,193,592	1.8
			CERATOSCOPELUS MADERENSIS	0	0.0	3	15.8	4.1	2.4	14,224,354,336	1.7
			MERLUCCIUS BILINEARIS	0	0.0	5	26.3	3.9	2.2	13,360,158,056	1.6
			BOTHUS	0	0.0	6	31.6	2.7	1.1	9,276,461,962	1.1
			LOPHIUS AMERICANUS	0	0.0	6	31.6	1.6	0.6	5,591,167,643	0.6
			ETROPUS MICROSTOMUS	0	0.0	3	15.8	1.3	0.8	4,353,207,575	0.5
			DISINTEGRATED	0	0.0	2	10.5	1.2	0.9	4,073,333,895	0.5
			GOBIIDAE	0	0.0	2	10.5	0.7	0.4	2,239,068,632	0.3
			BENTHOSEMA GLACIALE	0	0.0	1	5.3	0.6	2.8	2,226,418,526	0.3
			GADUS	0	0.0	1	5.3	0.6	2.5	1,969,802,105	0.2
			MERLUCCIUS	0	0.0	1	5.3	0.6	2.5	1,969,802,105	0.2
			PISODONOPHIS CRUENTIFER	0	0.0	1	5.3	0.5	2.2	1,734,871,579	0.2
			DIAPHUS	0	0.0	1	5.3	0.3	1.5	1,181,881,263	0.1
			CYNOSCION REGALIS	0	0.0	1	5.3	0.3	1.5	1,181,881,263	0.1
			POLLACHIUS VIRENS	0	0.0	1	5.3	0.3	1.5	1,154,773,895	0.1
			SYACIUM PAPILLOSUM	0	0.0	1	5.3	0.3	1.5	1,154,773,895	0.1
			CONGRIDAE	0	0.0	1	5.3	0.3	1.4	1,125,859,368	0.1
			SYACIUM	0	0.0	1	5.3	0.3	1.4	1,125,859,368	0.1
			LABRIDAE/SCARIDAE	0	0.0	1	5.3	0.3	1.3	1,013,815,579	0.1
			SYNGNATHIDAE	0	0.0	1	5.3	0.3	1.3	1,008,394,105	0.1
			PEPRILUS TRIACANTHUS	0	0.0	1	5.3	0.3	1.2	961,408,000	0.1
			BRANCHIOSTEGIDAE	0	0.0	1	5.3	0.2	0.9	713,827,368	<0.1
			ENGRAULIDAE	0	0.0	1	5.3	0.2	0.9	688,527,158	<0.1

CRUISE=AL8012

YEAR	SEASON	#STA	TXNAME	DOM	PCTDOM	OCCUR	PCTOCCUR	KMEAN	KSTDERR	TOTABUND	PCTABUND
1980	LATE AUTUMN	19	MERLUCCIUS BILINEARIS	7	36.8	11	57.9	21.8	9.0	75,008,244,396	45.8
			PARALICHTHYS DENTATUS	1	5.3	4	21.1	12.1	8.4	41,696,288,245	25.4
			UROPHYCIS	0	0.0	8	42.1	4.1	1.5	13,942,727,830	8.5
			SCOPHTHALMUS AQUOSUS	0	0.0	3	15.8	2.0	1.4	6,905,564,674	4.2
			CITHARICHTHYS ARCTIFRONS	0	0.0	3	15.8	1.3	0.8	4,530,293,787	2.8
			DISINTEGRATED	0	0.0	2	10.5	0.7	0.5	2,394,484,211	1.4
			GOBIIDAE	0	0.0	2	10.5	0.7	0.4	2,242,682,947	1.3
			PARALEPIDIDAE	1	5.3	2	10.5	0.6	0.4	2,177,625,263	1.2
			CLUPEIDAE	0	0.0	2	10.5	0.6	0.4	2,119,796,211	1.2
			ETROPUS MICROSTOMUS	0	0.0	2	10.5	0.6	0.4	2,094,496,000	1.2
			CONGRIDAE	0	0.0	2	10.5	0.6	0.4	2,074,617,263	1.2
			BOTHUS	0	0.0	2	10.5	0.6	0.4	1,935,466,105	1.2
			MERLUCCIUS ALBIDUS	0	0.0	1	5.3	0.5	2.2	1,709,571,368	1.0
			CENTROPRISTIS STRIATUS	0	0.0	1	5.3	0.3	1.4	1,140,316,632	0.7
			OPHIDIIDAE	0	0.0	1	5.3	0.3	1.4	1,084,294,737	0.6
			MYCTOPHUM	0	0.0	1	5.3	0.3	1.1	896,350,316	0.5
			HYGOPHUM	0	0.0	1	5.3	0.3	1.1	896,350,316	0.5
			DIAPHUS	0	0.0	1	5.3	0.2	1.0	820,449,684	0.5
			OPHICHTHIDAE	0	0.0	1	5.3	0.2	1.0	820,449,684	0.5
			UNKNOWN	0	0.0	0	0.0	0.0	0.0		

Table 3. Listing of larval fishes collected in slope waters off Middle Atlantic and northeastern United States, February through December. Information from Austin (1975), Sherman et al. (1977), MARMAP surveys 1977-79, and McKenney (1981). Phylogenetic sequence follows Nelson (1976).

	J	F	M	A	M	J	J	A	S	O	N	D
CLUPEIFORMES												
Unidentified					✓							
CLUPEIDAE												
Brevoortia tyrannus		✓	✓		✓							
Brevoortia sp.					✓		✓	✓				
Harengus jaquana											✓	
Unidentified							✓	✓				
ENGRAULIDAE												
Anchoa hepsetus								✓				
Anchoa sp.					✓							
Engraulis eurystole								✓	✓	✓		
Sardinella anchovia		✓	✓									
Sardinella aurita								✓				
Sardinella sp.								✓	✓			
Unidentified							✓	✓	✓			
ANGUILLIFORMES												
ANGUILLIDAE												
Anguilla rostrata		✓	✓	✓	✓					✓	✓	
Unidentified		✓	✓									
MURAENIDAE												
Unidentified					✓			✓	✓			
SYNAPHOBRANCHIDAE												
Nettodarus brevirostrus					✓							
CONGRIDAE												
Ariosoma balearicum										✓	✓	
Ariosoma sp.						✓						
Conger oceanicus							✓					
Unidentified		✓	✓	✓	✓						✓	

	J	F	M	A	M	J	J	A	S	O	N	D
NETTASTIOMATIDAE												
Saurenchelys cancrivora				✓								
Unidentified					✓							
OPHICHTHIDAE												
Myrophis punctatus		✓	✓	✓								
Ophichthus gomesii		✓	✓					✓	✓			
Ophichthus melanophorus				✓								
Ophichthus ocellatus		✓	✓		✓							
Ophichthus sp.							✓					
Pisodonophis curentifer								✓	✓			
Unidentified								✓	✓			
ARGENTINIDAE												
Nansenia groenlandica		✓						✓			✓	✓
Nansenia sp.										✓	✓	
Unidentified			✓	✓								
BATHYLAGIDAE												
Unidentified			✓	✓								
SALMONIFORMES												
GONOSTOMATIDAE												
Bonapartia pedaliota					✓							
Cycrothone sp.		✓	✓	✓	✓			✓	✓	✓	✓	
Gonastoma elongatum						✓	✓			✓	✓	✓
Ichthyococcus ovatus										✓	✓	
Maurolicus muelleri					✓			✓	✓	✓	✓	✓
Valenciennellus tripunctulatus					✓		✓	✓				
Unidentified		✓	✓	✓	✓					✓	✓	
STERNOPTYCHIDAE												
Argyropelecus hemigymnus					✓			✓	✓			
Argyropelecus sp.					✓							
Unidentified			✓	✓	✓							

Table 3. (continued)

	J	F	M	A	M	J	J	A	S	O	N	D
STOMIATIDAE												
Stomias ferox		✓	✓		✓			✓	✓			
Stomias sp.											✓	✓
Unidentified			✓	✓								
MYCTOPHIFORMES												
SYNODONTIDAE												
Saurida sp.				✓								
Trachinocephalus myops					✓			✓	✓	✓	✓	
Unidentified					✓	✓	✓	✓				
MYCTOPHIDAE												
Benthosema glaciale		✓	✓	✓	✓	✓	✓	✓	✓	✓		
Benthosema suborbitale			✓	✓	✓	✓	✓					
Centrobranchus nigro-ocellatus			✓	✓								
Centrobranchus sp.					✓							
Ceratoscopelus maderensis		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ceratoscopelus warmingi											✓	
Ceratoscopelus sp.							✓	✓				
Diaphus dumerili		✓		✓								
Diaphus holti										✓	✓	
Diaphus mollis		✓	✓									
Diaphus problematicus					✓							
Diaphus rafinesquei		✓	✓					✓	✓			
Diaphus subtilis								✓	✓		✓	
Diaphus taaningi											✓	
Diaphus sp.		✓	✓		✓	✓	✓	✓	✓			
Diogenichthys atlanticus		✓	✓	✓	✓			✓				
Gonichthys cocco						✓	✓					
Hygophum benoiti		✓	✓	✓				✓				
Hygophum hygomi					✓							
Hygophum reinhardtii								✓				
Hygophum sp.		✓	✓	✓	✓	✓	✓					
Lampanyctus alatus					✓							
Lampanyctus sp.		✓	✓	✓	✓	✓	✓					
Lepidophanes guenteri					✓	✓						
Lobianchia dolfieini					✓							
Myctophum affine		✓	✓	✓	✓		✓	✓				

	J	F	M	A	M	J	J	A	S	O	N	D
Myctophum asperum			✓									
Myctophum humboldti							✓	✓		✓	✓	
Myctophum nitidulum					✓			✓				
Myctophum punctatum								✓				
Myctophum sp.				✓	✓						✓	
Protomyctophum sp.				✓	✓							
Symbolophorus veranyi		✓	✓									
Unidentified		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PARALEPIDIDAE												
Lestidium atlanticum								✓			✓	
Notolepis rissoi		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Paralepis coregonoides		✓	✓									
Sudis hyalina											✓	
Unidentified		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
PHOTICHTHYIDAE												
Vinciguerria nimbaria											✓	
Vinciguerria powerai					✓							
Vinciguerria sp.		✓										
EVERMANNELLIDAE												
Unidentified					✓							
SCOPELARCHIDAE												
Unidentified								✓				
GADIFORMES												
Unidentified					✓							
MORIDAE												
Unidentified			✓	✓	✓							
BREGMACEROTIDAE												
Bregmaceros sp.							✓	✓				
Unidentified		✓	✓									

Table 3. (continued)

	J	F	M	A	M	J	J	A	S	O	N	D
GADIDAE												
Brosme brosme							✓					
Enchelyopus cimbrius		✓	✓	✓	✓							
Gadus morhua					✓							
Melanogrammus aeglefinus				✓	✓							
Urophycis sp.		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Unidentified		✓	✓									
MERLUCCIDAE												
Merluccius albidus				✓		✓		✓	✓		✓	✓
Merluccius bilinearis				✓		✓	✓	✓	✓	✓	✓	✓
Merluccius sp.						✓	✓	✓				
MACROURIDAE												
Unidentified				✓	✓							
OPHIDIIDAE												
Unidentified				✓	✓	✓	✓	✓	✓	✓	✓	✓
CARAPODIDAE												
Carapus bermudensis				✓				✓				
Unidentified		✓	✓					✓		✓	✓	
LOPHIIFORMES												
LOPHIDAE												
Lophius americanus				✓	✓	✓	✓	✓	✓			
ANTENNARIDAE												
Histrio histrio					✓							
Unidentified				✓								
OGCOCEPHALIDAE												
Unidentified								✓	✓	✓	✓	
CAULOPHRYNIDAE												
Caulophryne jordoni								✓				
Unidentified					✓						✓	✓

	J	F	M	A	M	J	J	A	S	O	N	D
MELANOCETIDAE												
Unidentified								✓	✓			
ATHERINIFORMES												
EXOCOETIDAE												
Unidentified					✓							
SCOMBERESOCIDAE												
Scomberesox saurus					✓	✓						
BERYCIFORMES												
MELAMPHAEIDAE												
Unidentified					✓							
HOLOCENTRIDAE												
Unidentified					✓							
CAPROIDAE												
Antogonia sp.					✓							
Unidentified				✓	✓	✓	✓	✓	✓			
SYNGNATHIFORMES												
SYNGNATHIDAE												
Syngnathus elucens					✓							
Syngnathus fuscus				✓								
SCORPAENIFORMES												
SCORPAENIDAE												
Pontinis sp.								✓	✓	✓	✓	
Scorpaena sp.								✓	✓			
Unidentified		✓	✓	✓	✓			✓	✓		✓	
TRIGLIDAE												
Prionotus sp.				✓	✓			✓	✓			
Unidentified							✓	✓				
COTTIDAE												
Unidentified							✓	✓				

Table 3. (continued)

	J	F	M	A	M	J	J	A	S	O	N	D
AGONIDAE												
Unidentified					√							
CYCLOPTERIDAE												
Unidentified							√	√				
PERCIFORMES												
Unidentified					√	√						
SERRANIDAE												
Anthiinae								√				
Anthias sp.					√			√	√	√		
Centropristis striata				√	√							
Centropristis sp.								√				
Diplectrum sp.				√								
Mycteroperca sp.					√							
Sebastes sp.			√	√	√							
Unidentified					√			√	√	√		
APOGONIDAE												
Unidentified					√					√	√	
POMATOMIDAE												
Pomatomus saltatrix					√	√	√	√				
CARANGIDAE												
Caranx sp.								√				
Decapterus punctatus		√	√					√	√			
Decapterus sp.						√						
Seriola sp.											√	
Unidentified							√	√				
CORYPHAENIDAE												
Coryphaena hippurus						√						
LUTJANIDAE												
Rhomboplites aurorubens					√							

	J	F	M	A	M	J	J	A	S	O	N	D
GERRIDAE												
Eucinstomus gula											√	
SPARIDAE												
Stenotomus chrysops					√							
SCIAENIDAE												
Cynoscion regalis								√	√			
Larimus fasciatus								√				
Leiostomus xanthurus					√							
Menticirrhus saxatilis								√				
Micropogonias undulatus								√	√		√	√
Unidentified							√	√				
MULLIDAE												
Mullus auratus											√	
POMACENTRIDAE												
Unidentified							√	√				
MUGLIDAE												
Mugil curema											√	
LABRIDAE												
Tautoga adspersus							√	√				
Unidentified		√	√		√		√	√	√	√	√	
SCARIDAE												
Unidentified							√	√	√	√		
URANOSCOPIDAE												
Unidentified											√	√
CRYTOCANTHODIDAE												
Cryptocanthoides maculatus		√	√									

Table 3. (continued)

	J	F	M	A	M	J	J	A	S	O	N	D
PHOLIDAE												
Unidentified		✓	✓									
AMMODYTIDAE												
Ammodytes sp.		✓	✓	✓	✓	✓						
GOBIIDAE												
Unidentified		✓	✓	✓	✓			✓	✓	✓	✓	✓
GEMPYLIDAE												
Unidentified					✓							
TRICHIURIDAE												
Diplospinus multistriatus											✓	
Unidentified											✓	
SCOMBRIDAE												
Auxis sp.						✓		✓	✓			
Euthynnus alletteratus								✓	✓			
Sarda sarda						✓						
Scomber scombrus					✓	✓	✓	✓				
Thunnus sp.					✓							
Unidentified		✓	✓		✓							
ISTIOPHORIDAE												
Unidentified							✓	✓				
NOMEIDAE												
Unidentified								✓				
TETRAGONURIDAE												
Unidentified								✓				
STROMATEIDAE												
Peprilus triacanthus		✓	✓	✓	✓	✓	✓	✓	✓			
Psenes maculatus								✓	✓			
Unidentified					✓		✓	✓				

	J	F	M	A	M	J	J	A	S	O	N	D
GOBIESOCIFORMES												
CALLIONYMIDAE												
Callionymus sp.											✓	
Unidentified					✓	✓		✓	✓	✓	✓	
PLEURONECTIFORMES												
BOTHIDAE												
Bothus sp.			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Citharichthys arctifrons		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Citharichthys sp.				✓	✓			✓		✓	✓	
Cyclopsetta fimbriata					✓	✓						
Cyclopsetta sp.						✓	✓					
Etropus microstomus					✓	✓						
Hippoglossina oblonga						✓	✓	✓	✓			
Paralichthys dentatus											✓	✓
Scophthalmus aquosus		✓	✓									
Syacium papillosum					✓			✓			✓	
Syacium sp.					✓	✓	✓	✓	✓	✓	✓	
Unidentified		✓	✓		✓	✓					✓	
PLEURONECTIDAE												
Glyptocephalus cynoglossus					✓	✓	✓					
Limanda ferruginea				✓	✓		✓	✓				
Pseudopleuronectes americanus					✓							
Unidentified						✓	✓					
CYNOGLOSSIDAE												
Symphurus sp.		✓	✓		✓			✓	✓		✓	
TETRAODONTIFORMES												
BALISTIDAE												
Monacanthus ciliatus					✓							
Monacanthus hispidis					✓							
Unidentified								✓				
TETRAODONTIDAE												
Unidentified		✓	✓		✓			✓				

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CHAPTER 8. BENTHIC FAUNA

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8.1 INTRODUCTION

Waste management is becoming one of man's most serious problems. As land based waste disposal sites become restricted, the ocean is often turned to for the disposal of many types of wastes. To assure that this practice will not seriously degrade marine resources, it is essential to have comprehensive information on the biological resources at risk from waste disposal activities. One group of biological resources which is at risk due to dumping, at any ocean waste disposal site, are the invertebrates that live in or on the sea bottom, the benthos. The benthos is an essential part of marine ecosystems because: 1) some species (clams, crabs, shrimp) are valued as food by man; 2) many other species are important sources of food to valuable fish; and 3) other roles, including nutrient and contaminant recycling from the seabed to the water column to be used by primary producers. Biologists and environmental managers have also looked to the benthos at shallow water disposal sites for evidence that certain waste disposal practices are or could be detrimental because benthic organisms are: 1) relatively immobile, so any response by them can be readily linked to local activities or events, and 2) they are sensitive to many types of stress and pollutants. Changes in benthic community species composition or productivity can impact fisheries by reducing the quantity or quality of food available to support fisheries or endangered species. Contaminants from wastes absorbed by benthic species can, potentially, be passed up the food web to valuable resource or endangered species.

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This chapter reviews the available information on the benthos known to occur within the 106-Mile Site potential area of impact (PAI) (Fig. 1). The estimated PAI covers a relatively large portion of the Middle Atlantic Bight, encompassing several distinct or ecological zones. The zones pertinent to benthos are, in order of their distance from land and increasing water depth (see Figs. 1 and 2): 1) the outer continental shelf, the portion of the shelf with water depths that range from approximately 50 to 200 m; 2) the shelf break, which includes the seabed at the shelf edge ranging between approximately 200 to 250 m in depth; 3) the continental slope, where the seabed drops off rapidly and extends from approximately 250 to 2,000 m in depth; and 4) the continental rise, a deep "apron" that occurs at the base of the slope, generally at depths greater than 2000 m. The 106-Mile Site per se covers the lower part of the slope and part of the upper rise (Figure 1).

Within the depth gradient covered by the PAI a major faunal change occurs in the benthos at about 250 m. This Chapter will focus on the benthic communities above this zone (the outer continental shelf and shelf break) and below it (the continental slope and rise) and discuss the major communities that are known to occur in these areas, dominant species, the influence of the environment and relationships to the fisheries resources.

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8.2 METHODS

The information on the benthos reviewed here is drawn primarily from the sources listed in Table 1. Several researchers (e.g. Boesch and Bowen, in press; Rowe et al., 1982; Haedrich et al., 1980) have reported major breaks in benthic community structure which are associated with bathymetric zones, both for smaller

organisms (infauna) living in or on the sediment and larger, surface dwelling organisms (mega- or epifauna). These two groups are, for the most part, also defined by the methods used to collect samples (or observations) of the benthos. Infaunal studies gather their data from sediment penetrating devices (grabs, dredges, corers) and generally, tend to collect smaller organisms that live in or near the sediment surface but may include larger forms that are present (e.g. Pearce et al., 1977; Wigley and Theroux, 1981; Rowe et al., 1982, Boesch and Bowen, in press). The mega- or epifaunal studies are dependent on collections from dredges, trawls, epibenthic sleds or visual observations from submersibles, such as ALVIN, and are effective in providing data on larger sediment surface-dwelling organisms which tend to be more sparsely distributed than infaunal species, which are rarely collected in these devices (e.g. Hessler and Sanders, 1967; Jones and Haedrich, 1977; Cohen and Pawson, 1977; Haedrich et al., 1980).

8.3 RESULTS: THE OUTER CONTINENTAL SHELF AND SHELF BREAK BENTHOS

The benthic infauna of this portion of the PAI can be characterized as being more diverse, with a larger number of species present, and more abundant, both in numbers of individual organisms and standing stock (biomass) per unit area, compared to the mid-shelf. Several communities have been defined on the outer shelf that are associated mostly with variations in sediment type. At the shelf break, the benthic community appears to be primarily effected by a shift in the mean bottom temperature. The outer shelf communities appear to be closely related in species composition to fauna north of Georges Bank rather than to the fauna south of Cape Hatteras. There are exceptions, however, suggesting that the benthic fauna here is partially transitional. The benthos in this area provide food to a number of important fishery species, at least seasonally. The megafauna is dominated by decapod crustaceans and echinoderms. The major environmental variables that influence the benthos, here, are sediment type, temperature and availability of food.

8.3.1 Community description.

Boesch and Bowen (in press) report that three benthic infauna communities can be separated on the outer shelf and shelf break that appear related to sediment and temperature variability. These communities are: 1) a coarse sediment, outer shelf community; 2) a fine sediment, outer shelf community; and 3) a shelf-break community. The coarse sediment community is found mostly on the upper part of sand ridges that occur across the shelf. Many of the numerically dominant species of this group (Table 2) are also common on inner shelf ridges. The major difference between the inner and outer shelf ridges is that on the outer shelf there are fewer molluscs and more burrowing polychaete worms and surface dwelling amphipod crustaceans.

The finer sediment community is usually found in swales (the depressions between ridges), and in the Hudson Shelf Valley that extends across the shelf from the mouth of New York Harbor to th Hudson Canyon. The outer shelf swale community differs from tha found on the inner shelf, principally in the increased abundance of the small polychaete, Euchone, and in that many of the same amphipods found on ridges are also present in the outer shelf swales (Table 3).

The infauna of the shelf-break is considered by Boesch and Bowen (in press) as a transitional community, although only two of the top ten dominant shelf-break species are also dominants on the shelf. The ten most abundant shelf-break species are: amphipod - Ampelisca agassizi and Unciola irrorata; polychaetes - Aricide neosuecica, Lumbrineris latreilli, Onuphis pallidula, Spiophanes wigleyi and Onuphis atlantica; brittlestars - Amphioplus macilentus; bivalves - Thyasira flexuosa; and an ostracod - Harbansus bowenae. The community structure reported by Pearce e al. (1977) generally agree in similarity of dominant species found.

Boesch and Bowen (in press) also report that the outer shelf, especially the swale habitat, has the highest number of infaunal species of all shelf bathymetric zones. The shelf-break is also richer in the number of species present than are the central and inner shelf areas but less than the outer shelf. Wigley and Theroux (1981) report that the mean whole body, wet weight benthic biomass for the Middle Atlantic Bight outer continental shelf (the PAI encompasses most of this zone) is approximately 190 g m^{-2}. This is lower than the mean biomass of the inner shelf (370 g m^{-2}), but it is higher than the mean central shelf mean biomass of 163 g m^{-2}, and the shelf break mean of 79 g m^{-2}.

The megafauna of the outer shelf and shelf-break is reported to be numerically dominanted by the echinoderms, Astropecten americanus and Amphilimna olivacea, and the decapod crustaceans, Pontophilus brevirostris, Munida valida and Cancer borealis (Haedrich et al., 1980). By weight, Cancer, Munida, Astropecten and the lobster, Homarus americanus, were dominant.

8.3.2 Community ecology and zoogeography.

The outer continental shelf is inhabited by a fish fauna that includes, at least seasonally, many recreational and commercial species as well as lobsters and Jonah crabs (see Chapter 9). Many of these fish and decapod crustaceans (e.g. black sea bass, scup, summer flounder and lobsters) use the outer continental shelf as a refuge from the colder winter temperatures inshore. Edwards and Bowman (1979) report that most of these species prey heavily or depend for food entirely upon the benthic fauna, especially small crustaceans, polychaete worms, and, to a lesser degree, molluscs and echinoderms. The outer shelf benthic community provides a major source of food at this time. Detritus, derived mostly from the biological activity in the upper water column, is the primary food source for the benthos dwelling on the shelf and upper slope (Rowe and Staresinic, 1979).

The infauna of the outer continental shelf appears to have closer zoogeographic affinities with the northern boreal fauna than it does to the southern (Carolinian) fauna, although some researchers disagree with this conclusion. Bowen et al. (1979), for example, report that the shelf infaunal benthic crustaceans, with limited larval dispersal, as well as some decapod crustaceans, are strongly boreal and the Middle Atlantic Bight often represents the southernmost range of these species. However, the shelf-break is influenced by warmer slope waters and has a mixed crustacean fauna with southern species predominating. Bowen et al. (1979) conclude that Cape Hatteras is a more effective barrier than Cape Cod or Georges Bank for boreal species. Kinner's (1977) analysis of the distribution of polychaetes notes similar affinities. However, Watling (1979) and Franz et al. (1981), in their studies of the distributions of amphipod crustaceans, molluscs and seastars, believe the Middle Atlantic Bight shelf benthic fauna may be more than just range extensions from adjacent regions and has a faunal composition that differs significantly from that north of Cape Cod (Nova Scotian) and south of Cape Hatteras (Carolinian) which they have designated as "Virginian".

8.3.3 Environmental factors.

The environmental features of the outer continental shelf and shelf break that are of primary importance to the benthos are sediment type, bottom temperatures and food supply.

The sediments are primarily silty sands, with coarser sands on the ridge crests. Topographic depressions on the shelf (e.g. swales and the Hudson Shelf Valley) accumulate finer sediments and particulate detritus. Although storms and tidal currents dominate sediment distribution on the inner shelf, only severe winter storms are thought strong enough to result in significant sediment transport and disturbance of the benthos on the outer shelf. The sediments at and below the shelf-break are not

usually influenced directly by storms, except in the vicinity of the major submarine canyons found in the PAI (e.g. Hudson Canyon) where currents are known to occur.

The benthic fauna of the outer shelf is influenced mainly by the shelf water mass, although slope water intrusions and Gulf Stream gyres also occasionally influence this zone. The location of the front between shelf and slope water masses is dynamic, changing position and form in response to currents, gyres and major weather changes. However, where it intersects with the seabed, near the shelf-break, it may be relatively constant. This could result in more stable temperature zones that are ecologically important to the benthos. On the shelf, water column stratification develops as surface waters warm in the spring, isolating cooler bottom waters that persist throughout the summer on the middle and outer shelf as a "cold pool" of less than 8°C; this produces less temperature variation than occurs in shallower continental shelf areas, reducing the role of fluctuating temperatures as a natural ecological variable and a force in benthic community structure and development. Rare seaward intrusions of colder shelf waters onto the shelf-break area may cause some stress to the benthic community, however.

The benthic fauna on the outer continental shelf, and perhaps the shelf-break, are for the most part dependent for food on the rain of detritus produced by pelagic plants and animals in the overlying water column. These pelagic communities on the outer shelf and slope-break are productive (see Chapter 5) and thus the supply of detritus is probably not a limiting factor for benthic faunal development, although more detritus may be available in the depositional areas, e.g. the swales, than in others.

8.4 RESULTS: THE CONTINENTAL SLOPE AND RISE BENTHOS

The benthic fauna on the slope and rise occur in distribution patterns related to bathymetry, although the zonation for infauna and epifauna differ somewhat. In general, the infauna decreases in numbers of species, abundance and biomass with water depth and distance from land. The dominant infaunal species found on the slope are bivalves and polychaetes, with polychaetes predominant on the rise. The epifauna is dominated overwhelmingly by echinoderms, especially brittlestars. The infauna in the major canyons transecting the slope appears to differ little from that found on the slope. There may be, however, distinct differences in the epifauna of major canyons, with some species apparently being common only in canyons and others absent from them. Detritus is also the major source of food to the deep ocean and most dominant benthic species there are deposit or detritus feeders. The availability of food appears to be a major factor in structuring the communities, i.e. determining what species or types of organisms will be present, although temperature and sediment type can be important on the upper slope. Several species of demersal fish (tilefish, graysole) and crustaceans (lobster and red crab) occurring on the upper slope support fisheries. These species depend primarily on the benthic fauna as a food source.

8.4.1 Community description.

Studies of the continental slope and rise have found the benthos to occur in distribution patterns or zones related to bathymetry; the zonation of the infauna and the epifauna, however, appear to be different.

Most infaunal studies (Pearce et al., 1977; Grassle et al., 1979; and Boesch and Bowen, in press) report a major community change at the shelf break/upper slope interface (200-250 m). Changes below this interface are believed gradual, although Rowe et al. (1982) note another major faunal break occurring at about 1,500m.

Wigley and Theroux (1981) and Rowe et al. (1982) report a general decline in mean wet weight biomass with depth, from about 35 g m^{-2} on the upper slope to 8-9 g m^{-2} at the slope-rise interface, and less than 1 g m^{-2} at 3500 m (Fig. 3). The mean number of species, however, exhibits a slightly different pattern: it drops from 120 at the upper slope to 70 at mid-slope then the number rises to 180 at the midrise, after which it declines to 60 still further offshore (Rowe et al., 1982).

There is some disagreement among researchers regarding which infaunal species are numerically dominant on the slope, especially the upper slope. Boesch and Bowen (in press) report some bivalve molluscs species (Thyasira flexuosa, Nucula tenuis) as being dominants on the upper slope, which is in partial agreement with Wigley and Theroux (1981) who report the dominance of bivalves and polychaetes and a mixed group they call "bathyl", which is an assemblage of several taxonomic groups, including the Pogonophora, Anthozoa, Sipunculida, Echiura and Holothuroidea. Rowe et al. (1982) report polychaetes as being the overwhelming dominants; however, their use of a small box corer, that has bias towards collecting smaller organisms, may explain an absence of the larger bivalves as dominants. The dominant infaunal species list (Table 4) of Rowe et al. (1982) is, however, similar to that of Pearce et al. (1977) and Sanders et al. (1965).

A number of continental slope and rise mega- epibenthic surveys (e.g. Hessler and Sanders, 1967; Jones and Haedrich, 1977; Cohen and Pawson, 1977; Haedrich et al., 1980) all generally agree in that the mega- epifauna is present in a series of bathymetrically associated zones, although the exact number of zones defined by some studies varied. Echinoderms appear to be the dominant taxa, especially the brittlestar, Ophiomusium lymani (see Table 5). Rowe et al. (1977) estimated that the biomass of the mega-epifauna per square meter was greater than that of the infauna,

contrary to the ratios on the shelf. The maximum number of megafaunal species appears to occur at the slope-rise interface (Haedrich et al., 1980).

The infauna in the major canyons that transect the continental slope and upper rise has not been found to differ significantly from that found on the adjacent slopes per se (Rowe et al., 1982). However, the megafauna of the major canyons differs in that there are species that appear to be: 1) found principally only in the canyons and 2) absent or that are rare which are common on the slopes (Rowe, 1971; Haedrich, 1980). The variables that are thought to be responsible for these differences within the major canyon are: different hydrographic conditions due to interuption of the bottom current, presence of areas of exposed consolidated sediments and higher concentrations of detritus from the outer shelf. This distinction between the slope megafaunal community and communities in smaller, minor canyons is less, often insignificant (Haedrich et al., 1975).

8.4.2 Community ecology and environmental factors.

Many authors have suggested that, in general, availability of the food structures the deep sea communities, e.g. Theil, 1979. This may be apparent from the decline in benthic biomass as one moves further from the more highly productive shelf. The food available to slope and rise benthos is mostly detritus, and occasionally, the remains of larger animals. Most of the dominant benthic fauna in this region are deposit feeders using detritus, with a few decapod carnivores omnivores on the upper slope (e.g. Homarus, Cancer, Geryon). There are, however, relatively low fluxes of carbon to the offshelf bottom; Rowe and Staresinic (1979) report inputs of 2.3-6.6 g organic carbon m^{-2} y^{-1} for the western North Atlantic. This flux, however, is not constant but varies, reflecting the seasonality of surface water primary production, with highest fluxes occurring in the spring (Billett et al., 1983).

Rowe and Staresinic (1979) also suggest that major canyons, and the tidal currents that flow down them, provide a conduit for moving organic plant and animal detritus from the shelf to the deeper slope-rise environment. Due to the limited amount of food available off the continental shelf, the deep sea benthos are thus thought to have, by necessity, a life style characterized by 1) opportunistic feeding; 2) slow growth; 3) long generation times and life spans; and, 4) possibly, high metabolic efficiencies. One example of opportunistic feeding is a report (Smith, pers. comm.)[2] that brittlestars, normally considered deposit feeders, were attracted to a fish carcass used as bait, although exact source of the attraction is unknown, possibly fecal detritus from more active feeders. Other megafaunal behavioral responses to pulses in the supply of detritus or other sources of food have also been noted, e.g. searching for detrital patches (Billett et al., 1983).

Although food availability is a major ecological factor on the continental slope and rise, temperature and sediment type can influence the composition of the benthos on the upper slope; however, below approximately 1000 m, temperature and sediment type are usually thought to be insignificant when compared to food. At least one catastrophic event causing mass mortalities to upper slope organisms is known to have occurred related to a major temperature change: the well known kill of tilefish a century ago (Freeman and Turner, 1977).

Although the continental slope and rise benthic habitats are not as productive in terms of species of interest to man, several species of demersal fish and crustaceans are common enough on the upper slope to have attracted a fishery, e.g., tilefish _Lopholatilus_ and red crab _Geryon_. Several harvestable shelf

[2]Smith, C. R. Personal communication. Scripps Institute of Oceanography, La Jolla, CA 92093.

species also occur on the upper slope, e.g., lobsters, Homarus, and the gray sole, Glyptocephalus. These species all depend on the benthic fauna for food.

8.5 DISCUSSION AND CONCLUSIONS

From this review of the information available on the benthic fauna at risk from waste dumping at the 106-Mile Site, several generalizations are apparent:

1. Within the PAI there are several distinguishable benthic communities that seem related primarily to sediment type on the outer continental shelf, to temperature on the shelf-break, and to bathymetry and/or food supply on the continental slope and rise.

2. The dominant infaunal groups within the PAI are: a) amphipods and polychaetes on the outer continental shelf and shelf break, and b) polychaetes, bivalve molluscs and minor taxa (e.g. Pogonophora) on the continental slope and rise. The dominant megafauna of the outer continental shelf, shelf break, and upper slope are echinoderms (especially brittlestars) and decapod crustaceans; in deeper waters, echinoderms, especially a brittlestar, Ophiomusium lymani, are the overwhelming dominants. Elements of the benthic fauna in major canyons transecting the slope differ somewhat in species composition from those on the adjacent slopes in species composition.

3. The benthic fauna on the shelf show strong affinities to more northern fauna, while on the shelf-break and upper slope, with constant, slightly warmer temperatures, there are species with more southern affinities.

4. The density and biomass of the infauna decreases proportionally with increasing depth within the PAI, reflecting the average rate of organic production available to the bottom. The megafauna, however, has a peak in biomass at the continental slope/rise interface; this has not been adequately explained.

5. Detritus is the primary source of food for the benthic fauna within the PAI and most of the dominant species are deposit feeders. In general, a predominately deposit feeding community is thought to be more stable than a community dominated by filter feeding organisms because filter feeders depend on suspended material that can vary seasonally in abundance; deposit feeders use 1) pulses of detritus as it reaches the seabed and 2) residual organically enriched water in the sediments, when new detritus supplies are low (Levington, 1972). Bacteria may play a crucial role in converting some of the sediment organics and detritus into food that can be used by benthic invertebrates.

6. Drastic changes in the benthic habitat within the PAI are, probably, rare but some are known. In the 1880's a movement of cold shelf waters onto the shelf-break and upper slope off southern New England is thought to have been responsible for mass mortalities of many fish species, including most tilefish in the area (Freeman and Turner, 1977); possibly some of the benthic invertebrates also experienced mortality in this zone. Periodic disruptions due to turbulent currents in deeper waters are also known, especially down major canyons.

7. The benthic fauna of the outer continental shelf, shelf-break and upper slope are used as food by several fish species and decapod crustaceans that are commercially valuable. These resource species include permanent residents such as gray sole, tilefish and red crabs, as well as seasonal residents such as black sea bass, scup, summer flounder and lobster. These, and

other species depend principally on the benthic community within the PAI should be considered for protection from degradation or contamination to maintain productive fisheries.

In addition to the above generalizations it is worth noting that the rate that benthic communities can recover from any disturbance is an important characteristic of that community; recovery rate is the time required for a community to return to a predisturbance state. Recovery rates of Middle Atlantic Bight outer continental shelf and slope macrofauna are apparently slower than for coastal, benthic communities. Two studies have examined the colonization of trays of sediments from which all life had been eliminated, set at depths of 65 and 1760 m (Grassle, 1977; Boesch and Rosenberg, 1981). The study at 65 m on the outer continental shelf found species richness in the trays exposed for nine months was still less than one-quarter that of an adjacent natural community (Boesch and Rosenberg, 1981). Rates on the lower continental slope (1760 m) were even slower; after an exposure of 26 months species richness was about one-third and density an order of magnitude lower than in adjacent natural communities (Grassle, 1977). In comparable coastal experiments, complete recovery has been reported to have occurred during the summer in less than two months (Boesch and Rosenberg, 1981).

Previous waste disposal at the 106-Mile Site does not appear to have impacted detectably the benthos. For example, data from earlier surveys (Pearce et al., 1977) were examined statistically (Table 6) by standard comparative procedures, e.g., "t" test, and no significant differences in the number of individuals in and out of the 106-Mile Site were found. It is possible that the low rate of dumping and/or the relatively high dilution and dispersal capacity of this site have reduced the concentrations of contaminants to levels that are not immediately significant to the benthos. However, our knowledge of the trajectories of the

materials dumped is still inadequate and material may be reaching the seabed elsewhere in sufficient quantities to cause some alterations or contamination.

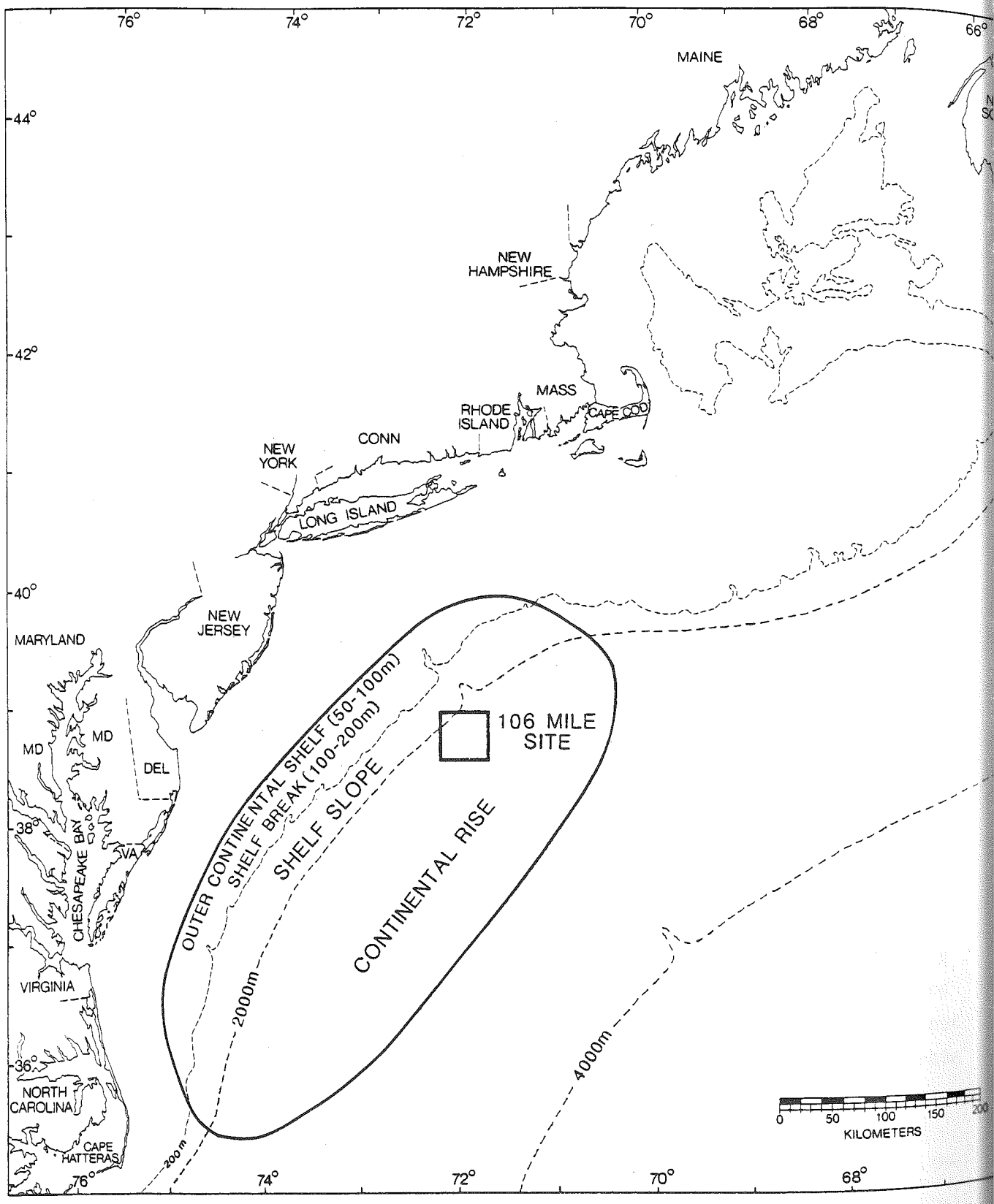

Figure 1. The 106-mile dumpsite, potential area of impact (PAI) and major bathymetri zones within.

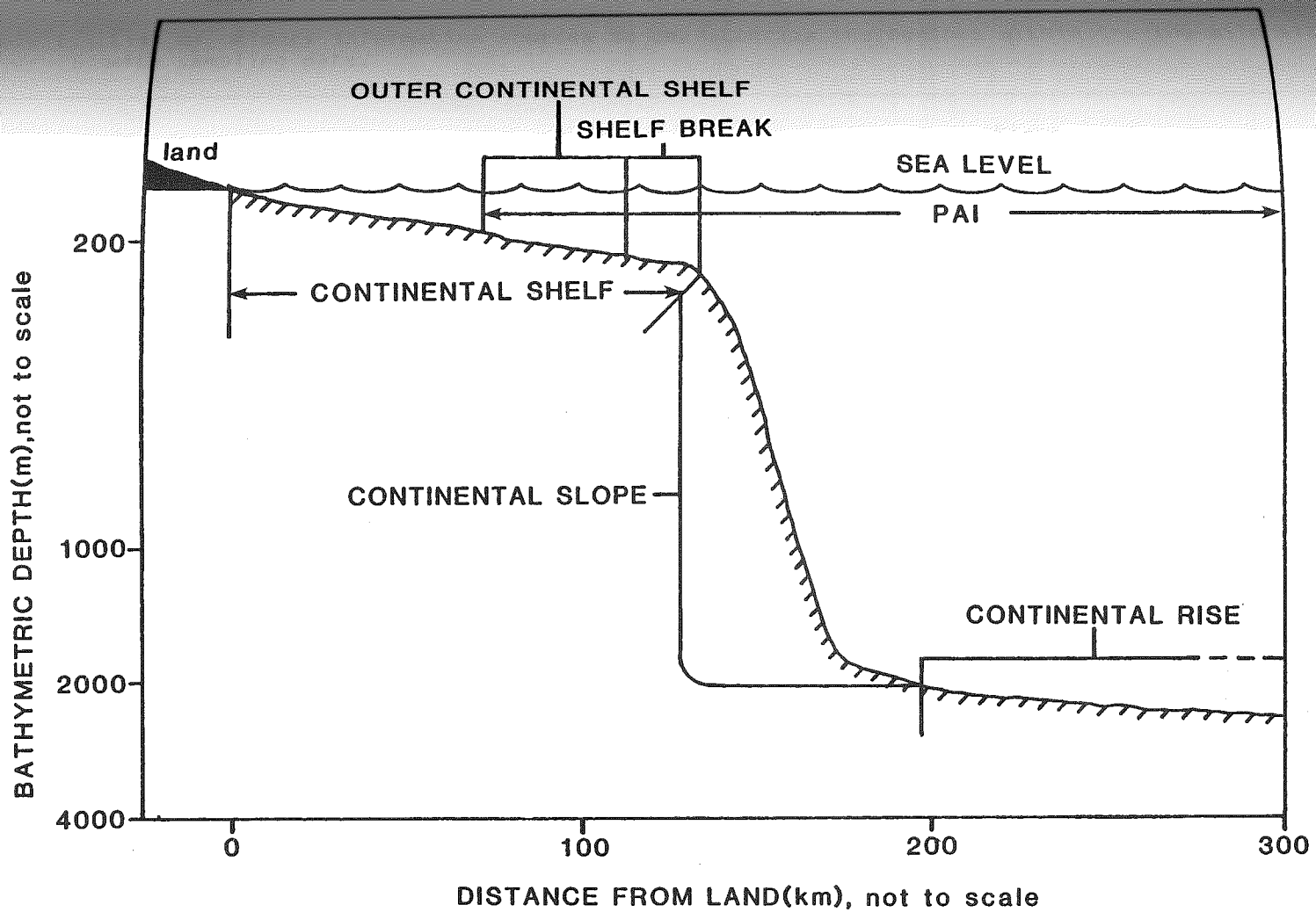

Figure 2. Approximate bathymetric contour across the center of the 106-mile site PAI, illustrating the major zones discussed; see also Figure 1.

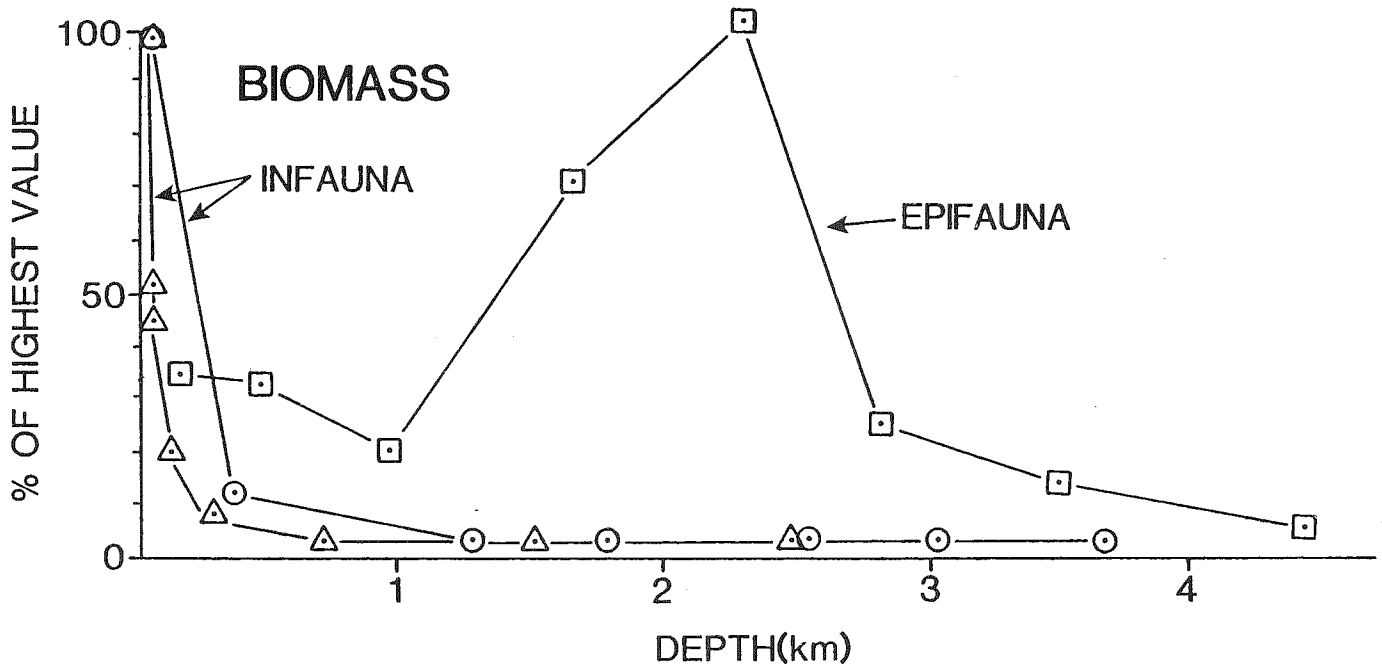

Figure 3. Biomass by depth of infauna and epifauna, each expressed as percentages of maximum values. △—△ Wigley & Theroux (1981); ⊙—⊙ Rowe, Polloni, & Haedrich (1982); ⊡—⊡ Haedrich, Rowe & Polloni (1980).

Table 1. List of primary information sources to characterize the benthos within the 106-mile site PA1, with sampling data.

Source	Sampler[1]	Sample Area(m^2)	# Replicate	Sieve Size (mm)	# of Stations[2]	Dates
A. Outer continental shelf and shelf break						
1. Wigley and Theroux (1981)	VV,SM,C	0.1-0.5	1	1.0	563A	1962-65
2. Pearce et al. (1977)	SM	0.1	1	1.0	60B	1975
3. Boesch and Bowen (in press)	SM	0.1	3-5	0.5	51C	1975-77
B. Continental slope and rise						
1. Wigley and Theroux (1981)	VV,SM,C	0.1-0.5	1	1.0	563A	1962-65
2. Pearce et al. (1977)	SM	0.1	1	1.0	60B	1975
3. Boesch and Bowen (in press)	SM	0.1	3-5	0.5	51C	1975-77
4. Haedrich et al. (1980)	T	3.2×10^6	1	-	105D	1972-76
5. Rowe et al. (1982)	BEBC	0.023-0.04	1	1.0-0.42	62E	?

[1]Codes for samplers: VV = VanVeen grab; SM = Smith-McIntyre grab; C = Campbell grab; T = trawl; BEBC = Birge-Ekman box corer

[2]Bathymetric and geographical distribution of stations: A = see Figure 2; B = shelf break and slope between Chesapeake Bay and Block Island; C = Outer continental shelf, shelf break and upper slope, off Chesapeake Bay to Long Island; D = Outer continental shelf to lower rise, Hudson Canyon and southern New England; E = Shelf break to rise, off Delaware Bay to southern New England.

Table 2. Numerically dominant infauna benthic species of the coarse sandy sediments of the Middle Atlantic Bight outer continental shelf (based on Boesch and Bowen (in press) - Table II-9).

Annelida (Polychaete worms)	Mollusca
Lumbrinerides acuta	*Mitrella dissimilis*
Goniadella gracilis	Crustacea (Amphipods)
Tharyx spp.	*Unciola inermis*
Polygordius sp.	*Byblis serrata*
Spiophanes bombyx	*Ampelisca vadorum*
Clymenella zonalis	*Erichthonius rubricornis*
Euchone elegans	*Rhepoxynius epistomus*
Exogone naidina	*Eudorella pusilla*
Scalibregma inflatum	Echinodermata
Polydora socialis	*Echinarachnius parma* (sand dollar)
Aricidea cerrutii	
Filograna implexa	

Table 3. Numerically dominant infauna benthic species of the finer sediments of the Middle Atlantic Bight outer continental shelf (based on Boesch and Bowen (in press) - Table II-10).

Cnidaria

Cerianthidae - burrowing anemone

Annelida (Polychaete worms)

Mediomastus ambiseta
Spiophanes bombyx
Tharyx spp.
Euchone rubrocincta
Euchone incolor
Euchone elegans
Chone infundibuliformis
Ampharete arctica
Ninoe nigripes
Cumbrineris impatiens
Paraonis gracilis
Clymenella torquata
Clymenella zonalis
Polydora socialis
Scalibregma inflatum
Notomastus latericeus

Mollusca

Nucula delphinodonta
Cerastoderma pinnulatum
Mitrella dissimilis

Crustacea (Amphipods)

Ampelisca agassizi
Unicola irrorata
Unicola inermis
Erichthnius rubricornis
Diastylis spp.
Photis dentata
Eudorella pusilla

Echinodermata

Echinarachnius parma (sand dollar)

Table 4. The 10 most abundant infaunal species or higher taxa (percentages in parentheses) in each of seven depth ranges (source: Rowe et al., 1982).

32 m	203-570 m	1141-1437 m	1707-1815 m	2351-2673 m	2749-3264 m	3659 m
Tharyx acutus (29.8)	Oligochaete "A" (29.9)	Cossura longocirrata (16.1)	Nucula cancellata (10.3)	Glycera capitata (5.8)	Sipuncula spp. (8.2)	Scaphopod "Spp." (7.6)
Prionospio steenstrupi (23.5)	Cossura longocirrata (5.3)	Heteromastus filiformis (10.8)	Poecilochaetus fulgoris (8.9)	Oligochaeta "Spp." (5.6)	Spionid "A" (6.0)	Ophelina abranchiata (7.6)
Nucula proxima (13.5)	Tharyx acutus (4.6)	Axinulus ferruginosus (7.7)	Glycera capitata (5.7)	Prochaetoderma sp. (A?) (5.4)	Owenid "Spp." (5.5)	Ampharete "A" (6.5)
Cossura longocirrata (8.1)	Minuspio cirrifera (4.0)	Tharyx acutus (7.1)	Nemertean "Spp." (2.8)	Leptognathia C (4.2)	Glycera capitata (4.2)	Owenid "Spp." (3.3)
Mediomastus ambiseta (8.0)	Terebellides stroemi (3.2)	Axinulus sp. (6.5)	Harpiniopsis sp. (2.8)	Notomastus latericeus (4.0)	Ophiura "A" (3.6)	Sigambra tentanculata (3.3)
Asabellides oculata (6.4)	Paraonis gracilis (3.1)	Nucula granulosa (4.7)	Polycarpa delta (2.6)	Tharyx "B" (3.3)	Ehlersia anoculata (3.3)	Sipuncula "Spp." (3.3)
Euchone incolor (1.7)	Siphonodentalium sp. (2.7)	Ceratocephale loveni (4.7)	Aricidea neosuecia (2.6)	Ophiura ljungmani (3.3)	Typhlotanais "C" (2.4)	— *
Dorvillea caeca (1.2)	Chaetozone setosa (2.6)	Glycera capitata (4.5)	Prochaetoderma sp. (A?) (2.6)	Spionid "A" (2.4)	Oligochaeta "Spp." (2.2)	—
Thracia myopsis (1.1)	Nemertean "spp."? (2.3)	Paramphinome jeffreysi (2.8)	Spionid "A" (3.0)	Sipuncula "Spp." (2.6)	Cirratulid "Spp." (1.9)	—
Aricidea jeffreysi (0.9)	Falcidens caudatus (2.0)	Falcidens caudatus (2.4)	Pholoe minuta (2.4)	Malletia estheriopsis (2.3)	Scaphopod "Spp." (1.7)	—

There were 48+ taxa among the ten most abundant species in the 7 sample sets.
* Next 14 "ranking" species at 2.2% with 2 specimens each.

Table 5. Dominant megaa-/epifaunal species for seven slope and rise depth zones (after Haedrich et al., 1980). N = numerically dominant; B = biomass dominant.

Species		Slope Depth Zones (m)				Rise Depth Zones (m)							
		283-650		653-1290		1380-1947		2116-2481		2504-3113		3244-3740		3879-4986	
Ophiura sarsi	E[1]	N	B												
Ophiura signata	E	N													
Geryon quinquedens	C		B	N	B										
Bolocera tuediae	E		B												
Psilaster florae	E		B												
Pleutonaster intermedius	E			N											
Ophiomusium lymani	E			N		N	B	N	B	N					
Hyalinoecia artifex	P			N											
Echinus affinis	E					N	B	N	B						
Paelopatides gigantea	E						B		B						
Zoroaster fulgens	E							N	B	N	B				
Pectinaster forcipatus	E							N							
Dytaster insignis	E									N	B				
Benthopecten spinosus	E									N					
Eunepththia fruticosa	E									N					
Molpadia blakei	E									N			B		
Ophiomusium armigerum	E											N	B	N	
Amphiophiura bullata	E											N	B	N	B
Parapagurus pilosimanus	C											N	B	N	B

[1]E = echinoderm; C = crustacean; P = polychaete

Table 6. Results of t tests comparing total densities of infauna in the samples of May 1974 and February-March 1976, in ad out of the boundaries of the 106-mile site (from Pearce et al. 1977).

	In	Out	Critical Value (5% level) In	Critical Value (5% level) Out
	-------Number per sample---------			
May 1974				
Number ofsamples	3	3		
Arithmetic mean of geometric means	1.687	1.406		
Standard deviation	0.194	0.278		
Normality	0.303	0.248	0.941	0.381
Skewness	0.439	0.362		
Kurtosis	-1.500	-1.465		
Variance ratio	2.054		39.2	
ts	1.483		2.571	
Probability of t_s	0.199		0.050	
February-March 1976				
Number of samples	5	8		
Arithmetic mean of geometric means	0.974	1.310		
Standard deviation	0.596	0.240		
Normality	0.318	0.250	0.337	0.285
Skewness	-0.876	0.572		
Kurtosis	-0.400	-0.744		
Variance ratio	6.169*		5.52	
ts (approximate t)	1.203		2.738	
Probability of t_s	0.322		0.050	

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Chapter 9. FISH AND FISHERIES

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9.1 INTRODUCTION

The 106-Mile Ocean Disposal Site (106-Mile Site) is located approximately 106 nm (196 km) from Ambrose Lightship; 90 nm (167 km) due east of Cape Henelopen, Delaware; and 32 nm (56 km) due south of the Hudson Submarine Canyon system. The area in question is more specifically defined as being bounded by 38°40'N, 39°00'N, 72°00'W, and 72°30'W (Figure 1). In terms of bathymetry, the 106-Mile Site can generally be described as being located over the lower continental slope and upper continental rise, and is characterized by depths between 1,500 m in the northwest of the area to approximately 2,750 m in the southwest corner. At present this area is used for the disposal of chemical wastes from the highly industrialized New York-New Jersey metropolitan area. Additional detailed information describing the bathymetry, bottom morphology, water properties, circulation, and weather conditions of the 106-Mile Site and adjacent areas can be found in U. S. Department of Commerce (1977a).

It is our intent herein to describe the fish and fisheries of an area that could be potentially influenced by dumping at the 106-Mile Site assuming a drift period of 100 days and an initial eddy diameter of 150 km. Figure 1 illustrates the approximately 116,000 km^2 area that could be permanently or temporarily influenced based on the aforementioned drift period and eddy size. The "potential area of influence" will be abbreviated as PAI throughout the remainder of this paper for the sake of brevity.

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After an extensive search for existing data or information sources applicable to defining and describing the fish and fisheries resources of this large expanse of ocean, eight rather diverse, but loosely related, data sources were identified as being germane. These sources can be separated into two distinct categories, those that are either synoptic and/or of long duration, and those that are either limited temporally and/or spatially, but nevertheless descriptive of the total area. Included in the former grouping are: 1) governmental records of U.S. commercial catch and value, 2) observed Japanese longline catch and effort, and 3) National Marine Fisheries Service (NMFS) autumn and spring research vessel surveys. Those data sources which fall into the latter grouping include: 1) bio-economic data which describe the New Jersey offshore recreational fishery, 2) tilefish fishery catch and effort information, 3) descriptive information pertinent to fishing grounds utilized by New Jersey commercial and recreational user groups, 4) governmental records of foreign landings and values for the year 1979, and 5) a review of existing literature pertinent to deep-sea fishes associated with the 106-Mile Site. These sources, although somewhat diverse in scope and nature, when combined, analyzed, and synthesized should provide the reader with a comprehensive overview of the fish and fisheries associated with the 106-Mile Site and its PAI. It should also be noted, that whenever possible and applicable, dollar and cents estimates of values are given to point out the magnitude of potential economic impact should the resources, in general, and harvesters (i.e. recreational and commercial users) specifically, be adversely affected by dumping at the 106-Mile Site.

9.2 METHODS AND MATERIALS.

The following sections give detailed descriptions of the aforementioned eight data sources with particular reference to collection methodology as well as techniques employed to present, interpret, synthesize, and analyze these data sources in a manner relative to the objectives of this endeavor.

9.2.1 U.S. Commercial Landings and Values

This data set includes 13 consecutive years (1968-1980) of landings and ex-vessel value (i.e. amount paid to fishermen) information for commercially important finfishes and invertebrates. These data are collected at a state level, on a regular and timely basis, by either NMFS Fishery Reporting Specialists or State agents under contract to NMFS. Subsequently, these data are first assigned to statistical reporting areas (i.e. capture locations) based on direct vessel interviews; and second, incorporated into a regional data management system to simplify data handling and retrieval. As a matter of reference, Figure 2 illustrates the statistical reporting areas within the scope of this paper as well as the location of the 106-Mile Site and its associated PAI.

To facilitate the use of these data as a descriptive tool, they were appropriately factored on the basis of the percent the PAI ellipse occupied a given statistical reporting area. In addition, based on first-hand working knowledge of particular fisheries, species were eliminated owing to the fact that they would not occur in the PAI, and therefore should not be included in factored tabulations for specific statistical reporting areas (e.g. surf, soft, and hard clams and menhaden). All relative data were then tabulated on a state-year, year-statistical reporting area, and year-dominant species basis to provide catch and value trends for the PAI. At this point it should be noted: 1) only the years 1972-1980 were used in the year-dominant species tabulation owing to the completeness of those data; and, 2) where given, dollar values have not been adjusted for inflationary rates.

9.2.2 Japanese Longline Fishery - Observed Data.

Four years (1978-1981) of longline catch and effort information from Fishery Reporting Zone No. 16, as recorded by U.S. Fisheries Observers stationed aboard Japanese longline vessels, comprise this data set. The particular "Reporting Zone" in question can generally be described as extending from just south of the mouth of Chesapeake Bay to approximately the 40°00'N latitude line off New Jersey, with its offshore boundary being the U.S. 200-mile Fisheries Conservation Zone (FCZ). Figure 3 illustrates the extent and location of Reporting Zone No. 16 as well as the 106-Mile Site and its PAI, which have been superimposed for purposes of this paper.

This data set was selected since it provides the most timely, quantitative, and unbiased series of information relative to tunas, billfishes, sharks, and assorted oceanic finfishes which seasonally frequent this area of the western North Atlantic. An extensive review of additional data along these lines, including research survey cruises, U.S. commercial landings, and foreign catch information, have already been collected, tabulated, analyzed, and presented in previous reports concerning the 106-Mile Site (U.S. Department of Commerce 1977b). In addition, Thompson's (1982) statistical comparison of observed versus reported Japanese longline landings and associated effort adds credence to our choice of data sets pertinent to this particular fishery.

All data were tabulated by year and species and catch-per-unit-effort (CPUE), based on 10,000 hooks fished, calculated for individual species, species groups (i.e. tunas, billfishes, sharks and rays, and other finfish), and all species combined on both a yearly and grand total basis. As a matter of information and reference, these tabulations are based on over two and one-half million hooks fished over the four years represented herein.

9.2.3 NMFS Research Survey Cruises.

NMFS, and its predecessor agencies, have conducted routine spring and autumn research vessel surveys over the continental shelf from Nantucket Shoals to Cape Hatteras since 1965. The finfish and invertebrate data collected during these synoptic bottom trawl surveys provide one of the most comprehensive records of seasonal and geographic trends in distribution and abundance, within the scope of this paper, on a species specific as well as community structure bases.

Surveys are based on a stratified random sampling design, thereby providing for; first, a statistically valid sample for population studies; and second, sampling in all trawlable areas down to 365 m and not just in those areas of known resource concentrations. Grosslein (1969, 1974) and more recently Azarovitz (1981) give detailed information and insight pertinent to the rationale, methodology, and history of this survey series.

For the purposes of this paper, cumulative plots, with the location of the 106-Mile Site and its PAI superimposed, were computer generated for spring and autumn trawl survey catches of 24 and six selected species of finfish and invertebrates, respectively. These plots illustrate the density distribution of each species and their relationship in time and space to the 106-Mile Site and its PAI. It should be noted here, only positive catches are shown in the individual species plots. The spring survey plots include nine surveys (1968-1974, 1976, and 1978) and the autumn plots include 12 surveys (1965-1975, and 1977). As points of reference, Figures 4 and 5 illustrate the cumulative station plots for spring and autumn, respectively as well as the location of the 106-Mile Site and its PAI.

9.2.4 Survey of New Jersey's Offshore Recreational Fishery.

Beginning in 1981, and continuing to the present, personnel from the New Jersey Department of Environmental Protection, Division of Fish, Game, and Wildlife, have collected information relative to the somewhat specialized offshore canyon fishery which takes place from May to October off the coast of New Jersey. The purpose of this program primarily is to estimate, and secondarily to better understand, participation, catch, effort, and value of this burgeoning offshore big-game recreational fishery. Figure 6 illustrates the extent of the survey area, which generally can be defined as the area found between the 30 (55 m) and 100 (183 m) fathom isobaths and the associated submarine canyon systems located therein.

Fisheries data were collected in the following manner; first, a list of canyon fishing boats was compiled by canvassing marinas, bait and tackle dealers, and identified canyon fishermen; second, each week a random telephone survey of canyon anglers was conducted to ascertain their catch (species and number) and effort (trips made) during the previous week; and finally, total catch was estimated by expanding the data collected from over 550 offshore trips. In addition, data concerning the economic value of the fishery were obtained by the direct mailing of questionnaires to known participants in the fishery. Figley and Long (1982) give detailed information relative to the history and background of the fishery as well as descriptions of the areas surveyed (i.e. various submarine canyons), and explanations of the collection and analysis methodology employed during this continuing project. Herein, with the objectives of this paper in mind, 1981 participation, catch, effort, and economic data are summarized and discussed.

9.2.5 Tilefish Fishery Catch and Effort.

This data set consists of nine years (1973-1981) of tilefish (*Lopholatilus chamaeleonticeps*) catch information and fishing effort projections based on preliminary interpretations and calculations of information gleened from voluntary fishermen logbooks and governmental records of total catch. These data were willingly provided to the authors by C. Grimes, K. Able, and S. Turner of Rutgers University, New Brunswick, New Jersey. It should be noted that the aforementioned have focused their research efforts to a large degree on this particular species and its fishery for the last four to six years. Additional information relative to the biology and ecology as well as the fishery for tilefish can be found in Freeman and Turner (1977), Grimes et al. (1980a, b), Able et al. (1981), and Turner et al. (1981).

All data were extracted from logbook records on a yearly basis to ascertain the total number of vessels fishing, trips made per month, amount (units) of gear fished, and catch per unit of gear (kg). The unit of gear employed in this fishery is defined as a "tub" which equals one-half mile of longline gear. Total vessel years, i.e. that percent of a year a vessel was involved in the fishery, was determined from direct interviews and/or first-hand knowledge of the fishery. Total units of gear were then calculated by multiplying vessel years x trips per month x 12 months x units of gear fished per month. All information was then tabulated along with governmental records of landings to provide the appropriate information for comparison of catch, effort, and participation trends over time.

9.2.6 Survey of New Jersey's Ocean Fishing Grounds.

This non-quantitative, but highly descriptive and informative source delineates and describes geographically, in the form of charts and text, the ocean fishing grounds utilized by New Jersey

recreational and commercial fishermen (Long and Figley 1981). Definition, location, and seasonality of individual fishing grounds are based on a direct interview survey of over 340 currently active recreational and commercial fishermen. This survey was designed and conducted by the New Jersey Department of Environmental Protection's, Division of Fish, Game, and Wildlife personnel. This collection of information, although limited spatially, provides an additional dimension to this paper; however, it must be closely scrutinized and logically extended and expanded with the seasonality and geographic range of each species kept in perspective.

Herein, using those data given in Long and Figley (1981), only those recreational and commercial fisheries which fall into the geographic scope of this paper are considered (i.e. the 106-Mile Site's PAI). Each fishery, or fishery complex, is graphically represented in the form of a chart which delineates recreational and commercial fishing grounds on a seasonal basis. At this point we would be remiss if we did not thank those members of the New Jersey Division of Fish, Game and Wildlife who provided the authors with draft materials as well as a full-size set of "fishing grounds" charts.

9.2.7 Foreign Landings and Values (1979)

This somewhat limited, but nevertheless relative, data set consists of 1979 non-U.S. landings and dollar value information for selected finfish and invertebrate species or species groups. These data, as mandated by the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA), were collected by either U.S. Foreign Fisheries Observers stationed aboard foreign vessels during fishing operations, by international reporting agreements, or by a combination of both methods. Under the auspices of MFCMA, fisheries are designated for particular species or species groups in predetermined amounts during particular fishing seasons in designated areas (i.e. "fishing

windows"). Herein we have tabulated the results of the 1979 foreign fishing season relative to six major fisheries for those "fishing windows" which fall within the purview of this paper. As a point of reference, Figure 7 illustrates the "fishing windows" in question (1-4) as well as the location of the 106-Mile Site and its PAI.

9.2.8 Deep-Sea Fish Fauna.

This section is based on a review of current pertinent literature which identifies and enumerates and/or discusses the biology and ecology of the pelagic and benthic deep-sea fish fauna generally found within the predescribed boundaries of this paper (i.e. the 106-Mile Site's PAI). With regard to terminology, "deep-sea fishes" are defined for purposes of this report as those fish which for the most part inhabit deep shelf slope and abyssal oceanic waters usually in excess of 600 m, and further have little or no direct commercial value at the present time (e.g. Myctophids (lanternfish)). Although it provides no new information, this section is included for the explicit purpose of rounding out this report by providing as complete a picture as possible relative to as many finfish species as possible which are, or potentially could be associated with the 106-Mile Site and its PAI.

9.3 RESULTS AND DISCUSSION

A simplified, but highly informative, tabular-graphic format or a somewhat cryptic narrative, or both, whichever is more applicable to the particular subject area will be employed to present our results. For purposes of clarity and continuity, the results of our tabulations and graphic interpretations, owing to the diversity of information, will be presented under the same eight headings identified in the Methods and Materials section.

9.3.1 U.S. Commercial Landings and Values

Results of our factored tabulations, i.e. the percent of the PAI ellipse occupied by the various statistical reporting areas (Figure 2), are given in the form of three tables: Table 1 gives the commercial landings and values by state and year, as well as, on a total landings and values basis for each year (1968-1980). This tabulation demonstrates the almost continuous increases in landings and values that have occurred within the limitations of these data. In addition, the dynamic nature, i.e. ebb and flow, of landings and values is obvious on both an inter- as well as intra-state basis. Table 2 summarizes catch and values by year and statistical reporting area, and identifies the percent each statistical area is occupied by the PAI ellipse. This information provides a basis for comparing the catch and value of each statistical reporting area from year to year and within years as well as providing those data necessary to compare the importance of a particular reporting area to another. Table 3 gives landings and value by year (1972-1980) on a selected species basis, thus providing information for the purpose of demonstrating which resources are the most sought after in terms of weight and/or value over time. It should be obvious from these data, that American lobster (*Homarus americanus*) and sea scallop (*Placopecten magellanicus*) represent the big "cash crops" historically in the invertebrate category, along with ocean quahog (*Arctica islandica*) in more recent years (1979-1980). Under the finfish category, summer flounder (*Paralichthys dentatus*), tilefish (*Lopholatilus chamaeleonticeps*), scup (*Stenotomus chrysops*), and swordfish (*Xiphias gladius*) dominate, in both catch and value, historically as well as at the present time.

9.3.2 Japanese Longline Fishery--Observed Data.

Table 4 gives observed Japanese longline catch-per-unit-of-effort (CPUE) from Fishery Reporting Zone No. 16 by species and species

group (i.e. tunas, billfishes, sharks, rays, and other finfish) for the years 1978-1981. The PAI ellipse is almost entirely within this particular fishing zone (Figure 3); therefore, the species composition and calculated catch rates can be termed as somewhat representative of the area considered within the context of this paper. Thus, it is interesting to note, that the big-eye tuna (Thunnus obesus), yellowfin tuna (Thunnus albacares), albacore (Thunnus alalunga), swordfish (Xiphias gladius), blue shark (Prionace glanca), and lancetfish (Alepisaurus ferox) make up, on an average, greater than 86% of the CPUE from this reporting zone. Also of interest, the first three species mentioned above are generally considered to be the target species of the Japanese longline fishery within the Mid-Atlantic area.

At present, this fishery is dominated primarily by the Japanese distant water longline fleet, with little if any U.S. participation, except in the area of swordfish fishing. However, if and when this situation begins to reverse, these valuable oceanic fishery resources will obviously become more important to domestic fishermen at which time any adverse man-induced change in abundance and/or distribution could have economic ramifications throughout the fishery. The data presented, regarding the present fishery, indicate the potential for U.S. participation, and therefore, the possibility of any man-induced change must also be taken into account (i.e. the 106-Mile Site's PAI).

9.3.3 NMFS Research Survey Cruises.

This seasonal research vessel bottom trawl survey data set, for purposes of this paper, was distilled to a series of spring (1968-1974, 1976, and 1978) and autumn (1965-1975, and 1977) computer-generated cumulative plots. Twenty-four species of finfish and six species of invertebrates were specifically

selected to illustrate seasonal and geographic trends in distribution and abundance relative to the 106-Mile Site and its PAI.

Selected finfish species are illustrated in Figures 8-31 and include the following: spiny dogfish (Squalus acanthias), little skate (Raja erinacea), blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), goosefish (Lophius americanus), offshore hake (Merlussius albidus), silver hake (Merluccius bilinearis), red hake (Urophycis chuss), spotted hake (Urophycis regalis), white hake (Urophycis tenuis), ocean pout (Macrozoarces americanus), black sea bass (Centropristis striata), scup (Stenotomus chrosops), Atlantic mackerel (Scomber scombrus), butterfish (Peprilus triacanthus), northern searobin (Prionotus carolinus), longhorned sculpin (Myoxocephalus octodecemspinosus), Gulf Stream flounder (Citharichthys arctifrons), summer flounder (Paralichthys dentatus), fourspot flounder (Paralichthys oblongus), windowpane (Scophthalmus aquosus), witch flounder (Glyptocephalus cynoglossus), yellowtail flounder (Limanda ferruginea), and winter flounder (Pseudopleuronectes americanus).

Plots of invertebrate species are given in Figures 32-37 and include: Jonah crab (Cancer borealis), rock crab (Cancer irroratus), American lobster (Homarus americanus), and long-finned squid (Loligo pealei).

Any number of conclusions can be drawn from this series of plots regarding the relationship between individual species and the PAI associcated with the 106-Mile Site, some of the most obvious include: 1) several species such as offshore hake (Figure 13), white hake (Figure 17), Gulf Stream flounder (Figure 25), American lobster (Figure 34), and sea scallops (Figure 35), tend to remain in the PAI throughout the year based on their narrow range of ecological requirements (i.e. temperature and/or depth) or sessil nature; 2) other species tend to migrate inshore and offshore seasonally and therefore are more or less abundant in

the PAI at one particular point in time and space. Included in this category are the following species: spiny dogfish (Figure 8), little skate (Figure 9), blueback herring (Figure 10), alewife (Figure 11), silver hake (Figure 14), red hake (Figure 15), spotted hake (Figure 16), black sea bass (Figure 19), scup (Figure 20), butterfish (Figure 22), northern searobin (Figure 23), summer flounder (Figure 26), fourspot flounder (Figure 27), and long-finned squid (Figure 37); 3) those species which either winter or summer in or near the PAI, and then, for all practical purposes, migrate either north or south entirely out of the area. An example of this type of relationship would be the Atlantic mackerel (Figure 21) which winters in the Mid-Atlantic and with the advent of spring moves inshore to spawn and then north and east to summer; and 4) those species which are found in relatively small numbers in the PAI, although they might be very abundant in adjacent areas. Examples of this species category include: ocean pout (Figure 18), longhorned sculpin (Figure 24), windowpane flounder (Figure 28), yellowtail flounder (Figure 30), and winter flounder (Figure 31).

9.3.4 Survey of New Jersey's Offshore Recreational Fishery.

Although this survey only deals with the big-game fishery off New Jersey (Figure 6); with a little imagination one can project and expand these results, at least as far as Cape Hatteras to the south and Rhode Island to the north and east. Results of the 1981 survey include: Participation - New Jersey's canyon fleet consisted of approximately 800 boats including 714 private-, 82 charter-, and four party-boats; Effort - 5,473 trips were made during the 1981 season, with private-boats accounting for 89% of the activity; Catch - total catch for all species was approximately 40,000 fish, with yellowfin tuna (*Thunnus albacares*) (18,200); albacore (*Thunnus alalunga*) (14,600); bigeye tuna (*Thunnus obesus*) (1,400); and white marlin (*Tetrapturus albidus*) (2,600) accounting for 92% of the total. The estimated weight of the aforementioned four species was just slightly less

a than two million pounds (907 mt); and Value - 800 boats made up the canyon fleet with an average size of 36 feet and value of slightly greater than $90 thousand. Therefore, value of the entire fleet was estimated at $73 million. In addition, boat owners participating in this fishery spent approximately $11.1 million during 1981 for the following: boats and boating equipment, $4.6 million; boat maintenance, $2.2 million; mooring and storage, $0.7 million; insurance, $0.6 million; fishing equipment, $0.7 million; fuel, $1.8 million; and bait, ice and food, $0.6 million.

The above stated facts and figures should leave the reader with little, if any, doubt as to: first, the magnitude and importance of this offshore recreational fishery; and second, the impact any adverse change in distribution and/or abundance of tunas and billfishes would have on the fishery.

9.3.5 Tilefish Fishery Catch and Effort.

Table 5 gives tilefish (*Lopholatilus chamaeleonticeps*) catch and effort data for the years 1973 to 1981 based on information extracted from fishermen logbooks and governmental records of landings. Information given in this tabulation include: number of vessels actively fishing, the part of the year they fish, number of trips made per month, quantity of gear fished per trip, quantity of gear fished per year, and average catch per unit of gear. In addition, catch in weight (mt) is given, on a yearly basis, for both the longline and total fishery.

It should be apparent from these data, that since 1978, this fishery has undergone dramatic changes as illustrated by an all but doubling of fishing effort (total "tubs"), a 50% decline in catch-per-unit-effort (CPUE), and a relatively constant harvest (longline landings). The combined simultaneous occurrence of increased effort, decreased CPUE, and stable yield over time are usually indicative of stock decline; therefore, it would be safe

to assume that the tilefish stock is probably under some type of stress (i.e. fishing pressure) at this point in time. It is then logical to ask the following question: What would be the impact on this already tenuous situation if it was complicated and compounded by environmental stress (i.e. the 106-Mile Site's PAI)?

9.3.6 Survey of New Jersey's Ocean Fishing Grounds.

This source of information was reduced to 15 charts (Figures 38-52) which graphically delineate selected recreational and commercial ocean fishing grounds for 22 species based on a one-year survey of actively involved fishermen. In addition, each chart gives the seasonality of each fishery, or fishery complex as well as the location of the 106-Mile Site and its PAI. The charts in question illustrate the ocean fishing grounds for the following: Atlantic mackerel (Figure 38); tilefish (Figure 39); summer flounder (Figure 40); scup (Figure 41); black sea bass (Figure 42); butterfish (Figure 43); silver and red hake (Figure 44); Atlantic cod and pollock (Figure 45); yellowfin tuna, albacore, and bigeye tuna (Figure 46); white and blue marlin (Figure 47); swordfish (Figure 48); ocean quahog (Figure 49); American lobster and red crab (Figure 50); sea scallop (Figure 51); and short- and long-finned squid (Figure 52).

If one logically extends and expands as well as takes into account the data presented in previous sections of this paper (e.g. commercial landings and value, recreational landings and value (big-game), and the distribution and abundance of important species), the information illustrated in the above mentioned 15 charts becomes quite relevant in terms of potential adverse impacts caused by ocean dumping at the 106-Mile Site.

9.3.7 Foreign Landings and Values (1979).

Results of our tabulations, although limited in scope (i.e. 1979 only), are given in the form of a tabular inset which is found in Figure 7. Combined data for "fishing windows" 1 through 4 have been summarized in the aforementioned table and include: 1) total catch in metric tons (mt), 2) dollar value per metric ton ($/mt), and 3) total dollar value of the catch (value $) for silver hake (*Merluccius bilinearis*), red hake (*Urophycis chuss*), Atlantic mackerel (*Scomber scombrus*), butterfish (*Peprilus triacanthus*), dogfish spp., and squid spp. This tabulation demonstrates both the amount and value of these species within the geographic limitation of the "fishing windows" associated with the 106-Mile Site and its PAI. As a point of interest these six species and/or species groups totaled approximately 21,000 mt (46.5 million pounds) worth greater than 8.7 million dollars at an average of almost 350 dollars per mt. It should be obvious from these data that first squids and second silve hake dominated the catch while butterfish commanded the highest price in the market place.

These somewhat dated data illustrate the amount and value of these resources, this information coupled with recent (1980-81) joint U.S.-foreign ventures, indicate the growing importance of these fisheries to U.S. commercial fishing interests. Therefore, any poential man-induced changes must be weighed heavily against growth potential and possible socio-economic ramifications which could be lost or accrued by this relatively new concept in the U.S. commercial fishing industry.

9.3.8 Deep-Sea Fish Fauna.

The results of our literature search are presented in the form of discussions relative to first pelagic, and second demersal deep-sea fishes which are directly or indirectly associated with the 106-Mile Site and its PAI.

The primary sources of information describing pelagic deep-sea fish in the vicinity of the 106-Mile Site are Krueger et al (1975 and 1977). For the sake of brevity, these two research endeavours can be briefly summarized as follows: 1) the pelagic fish fauna is comprised mainly of mesopelagic species which generally drift with prevailing oceanic currents; 2) 110 mesopelagic species were collected at the 106-Mile Site during baseline studies, with 108 of these species being collected in the upper 800 m; 3) Cyclothone spp. and Myctophids (lanternfish) make up 90% of the day catch below 400 m, with lanternfish accounting for 95% of the catch in the upper 200 m at night; 4) at 106-Mile Site species composition of these mesopleagic species depends on the movement of water masses in and out of the area, i.e. slope water, warm-core eddies, and even Sargasso Sea waters; 5) Cyclothone microdon and C. braveri were the first and third most abundant species; and 6) of the fifty species of lanternfish collected only Ceratoscopelus maderensis, Hygophum hygomi, Lobianchia dofleini, and Benthosema glaciale were seasonally abundant. For additional details and discussions, Krueger et al. (1975 and 1977) should be carefully reviewed.

In terms of demersal deep-sea fishes, Musick et al. (1975), based on trawl collections, describe four groupings of demersal deep-sea fishes in the depth limits of the 106-Mile Site; these are as follows: 1) "Middle slope" group (1,200-1,800 m) which is dominated by Antimora rostrata (blue hake), Synaphobranchus kaupi, Coryphaenoides carapinus, Alepocephalus agassizzi, and Diarolene intronigra; 2) "lower slope" group (1,700-2,100 m) which is dominated by A. rostrata, C. carapinus, Halsauropsis macrochir, and S. kaupi; 3) "upper rise" group (2,100-2,900) m) which is dominated by C. armatus and A. rostrata; and 4) "lower rise" group (>2,900 m) dominated by C. armatus. Additional detailed information relative to these demersal forms and their relationship to the 106-Mile Site can be found in Meade et al.

(1964), Haedrich et al. (1975), Musick (1976), Cohen and Pawson (1977), Haedrich and Rowe (1977), Wenner and Musick (1977), Sedberry and Musick (1978), Wenner (1978), Middleton (1979), and Musick and Sulak (1979).

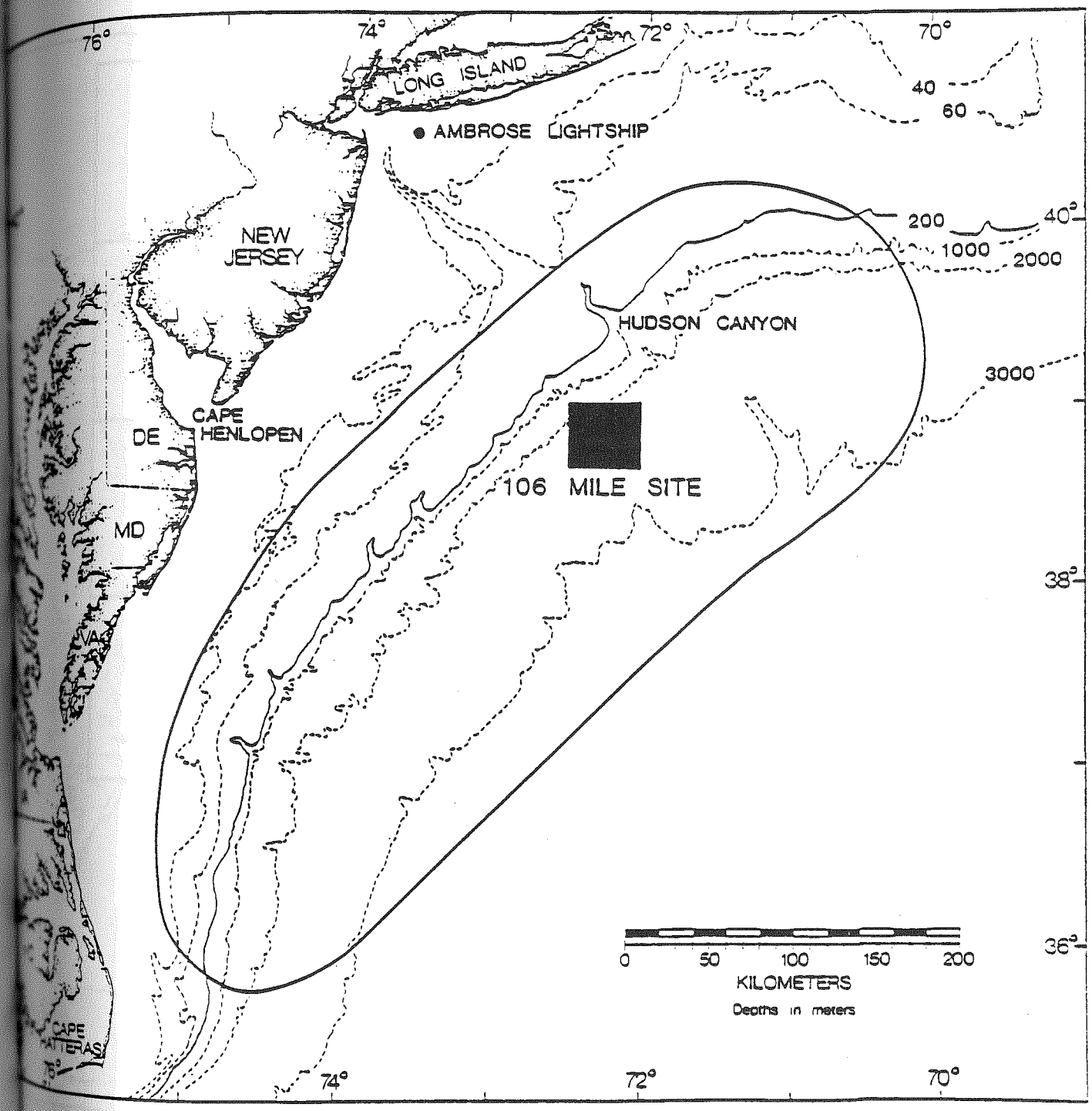


Figure 1.--Location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI) assuming a drift period of 100 days and an initial eddy diameter of 105 km.

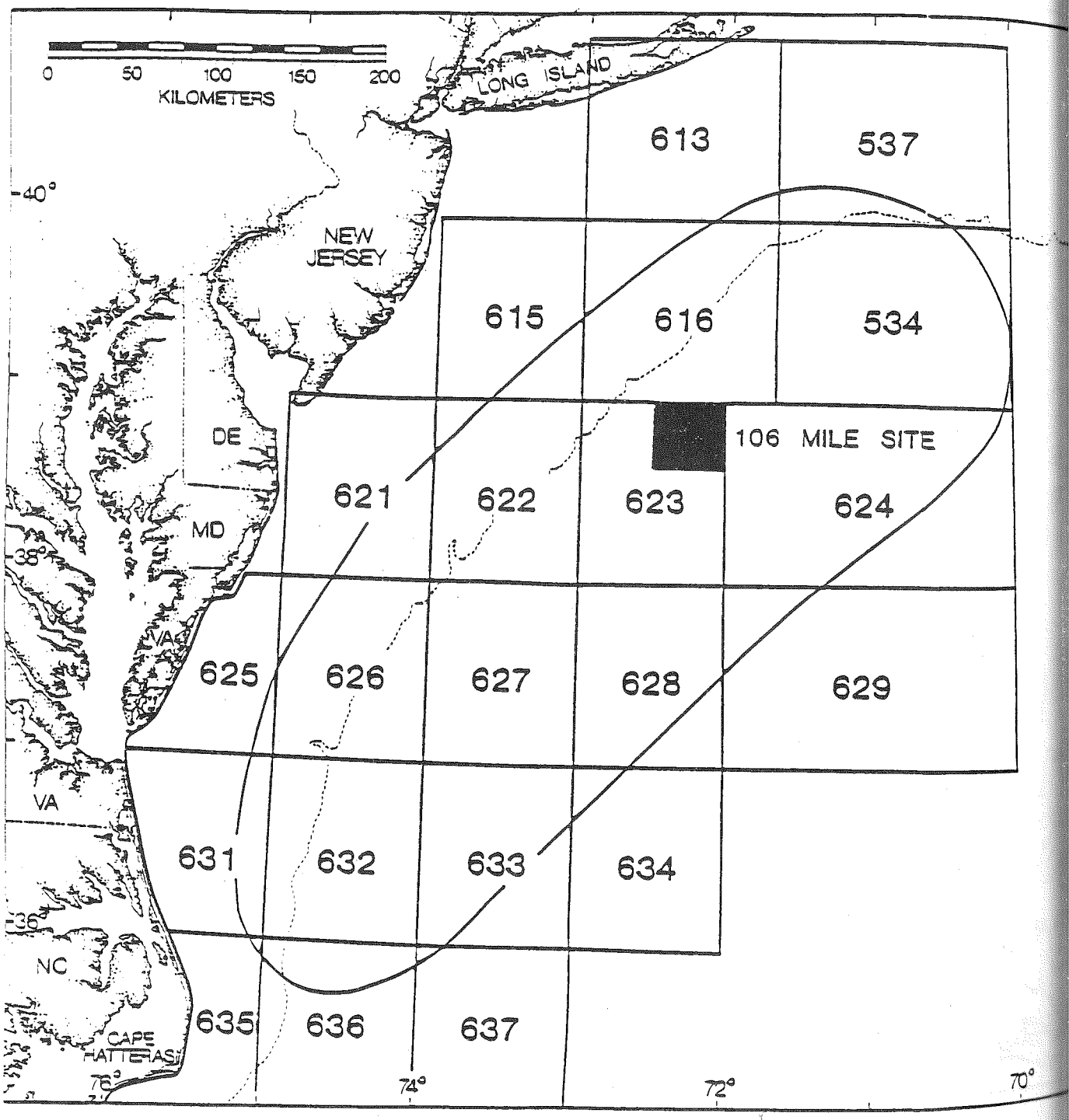


Figure 2.--Location of NMFS statistical reporting areas as well as Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

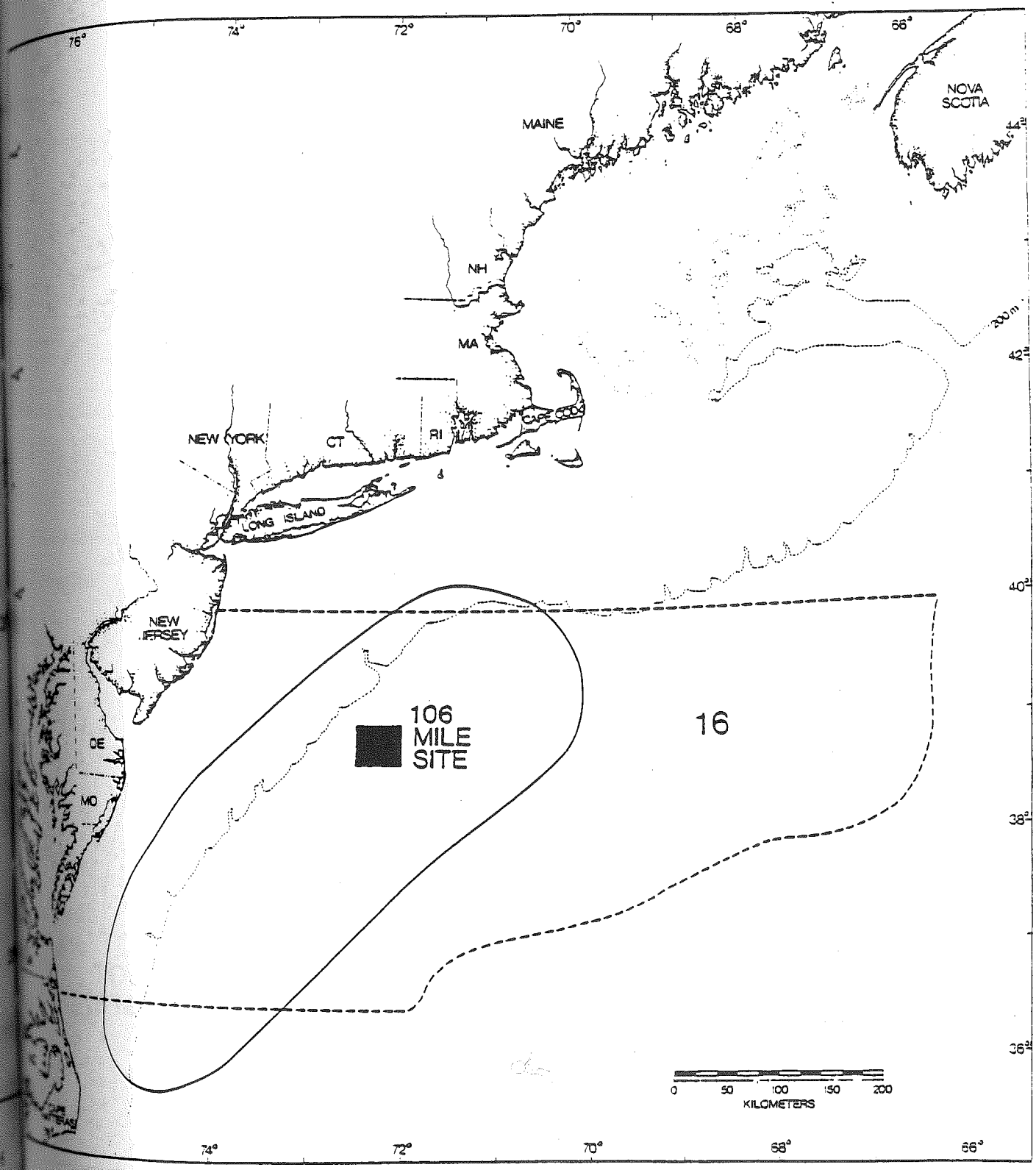


Figure 3.--Location of Fishery Reporting Zone No.16 as well as Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

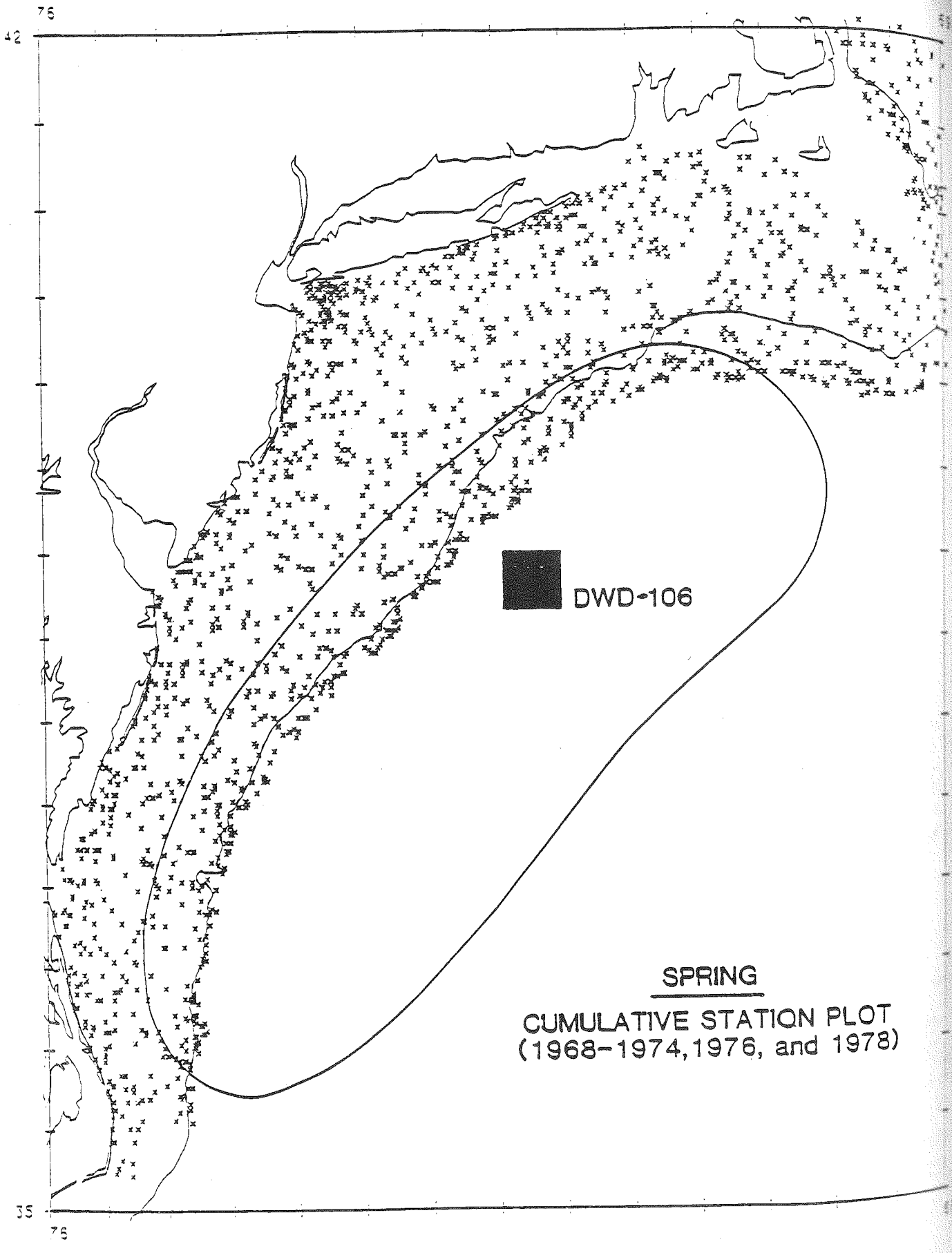


Figure 4.--Cumulative station plots of trawl sets for nine standardized NMFS spring bottom trawl surveys (1968-1974, 1976 and 1978) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

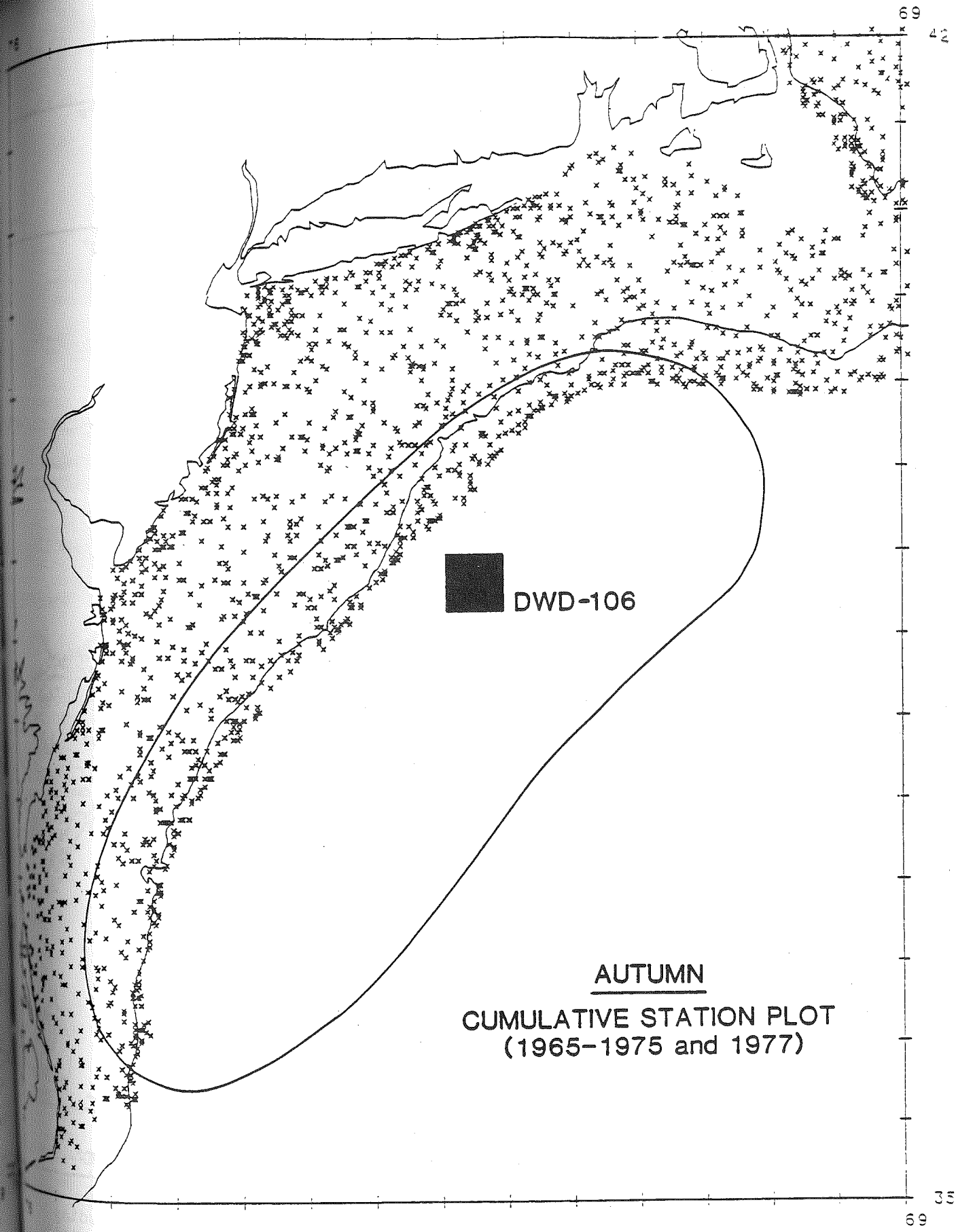


Figure 5.--Cumulative station plots of trawl sets for 12 standardized NMFS autumn bottom trawl surveys (1965-1975 and 1977) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

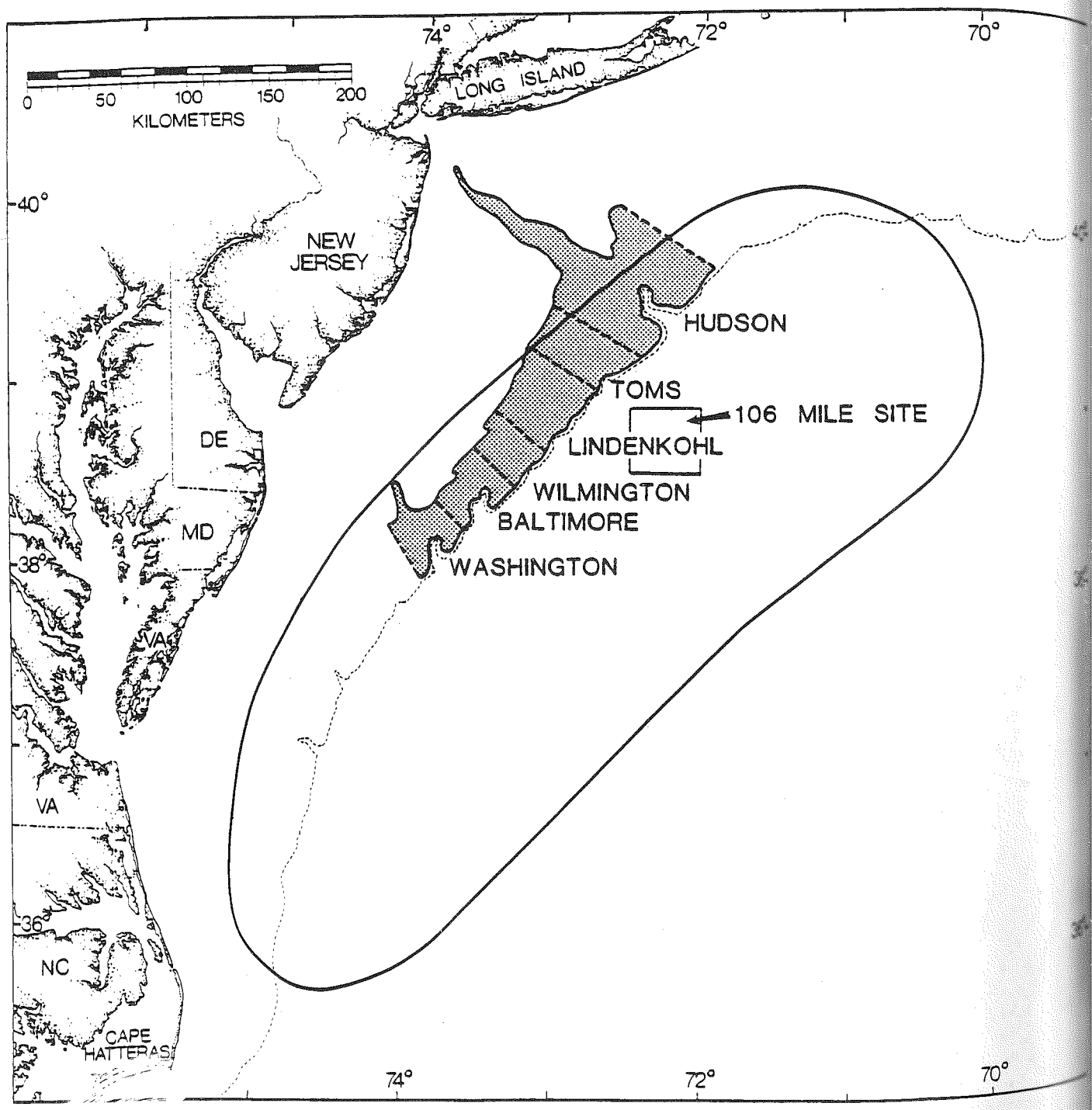
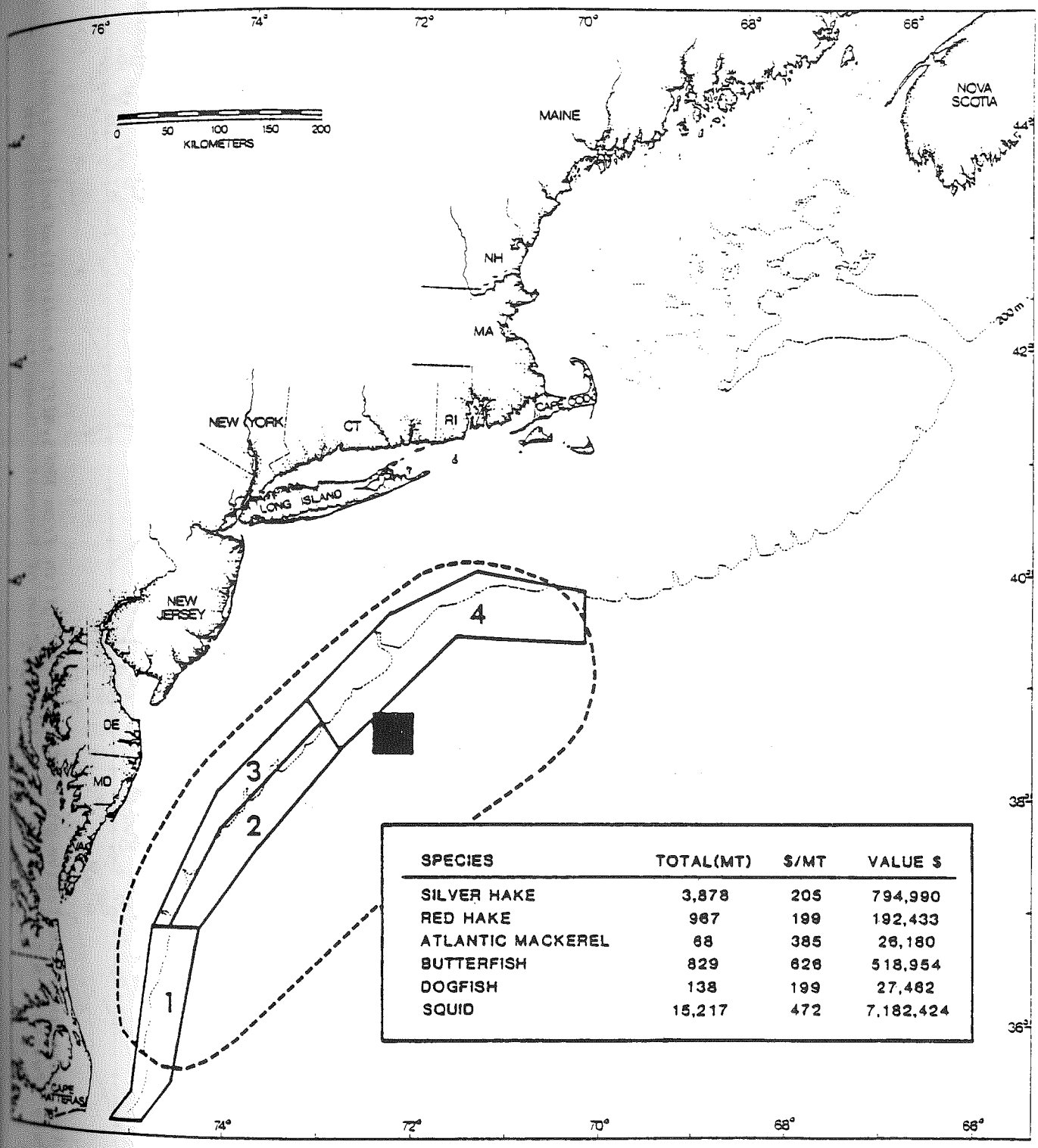


Figure 6.--New Jersey's offshore sportfishing grounds (shaded area) including locations of submarine canyons and Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).



SPECIES	TOTAL(MT)	$/MT	VALUE $
SILVER HAKE	3,878	205	794,990
RED HAKE	967	199	192,433
ATLANTIC MACKEREL	68	385	26,180
BUTTERFISH	829	626	518,954
DOGFISH	138	199	27,462
SQUID	15,217	472	7,182,424

Figure 7.--Foreign "fishing windows" (1-4) overlayed with location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI). Also included are 1979 foreign landings and values for selected finfish and invertebrate species.

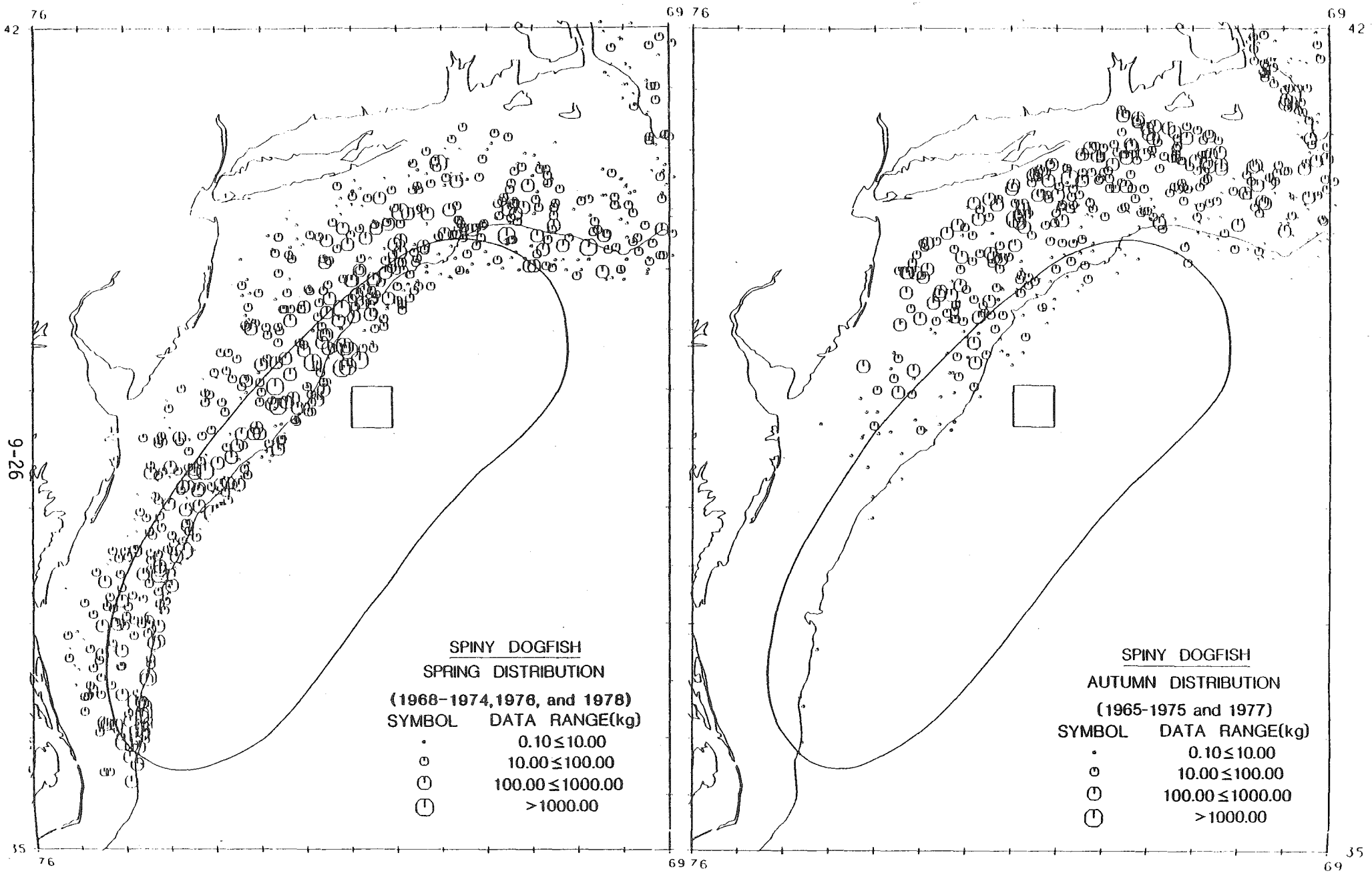


Figure 8.--Spring and autumn cumulative plots for spiny dogfish from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 8.--Spring and autumn cumulative plots for spiny dogfish from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

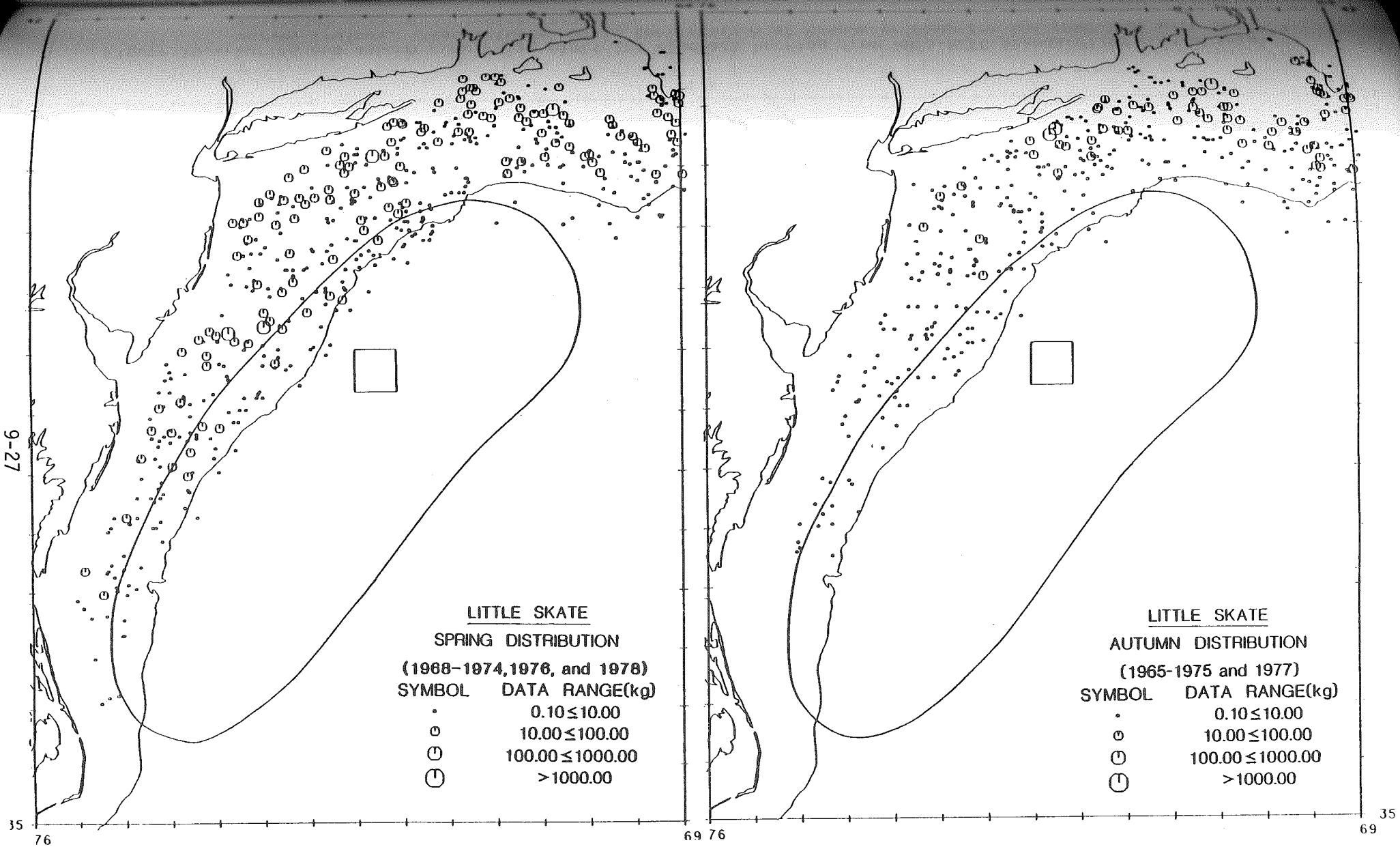


Figure 9.--Spring and autumn cumulative plots for little skate from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

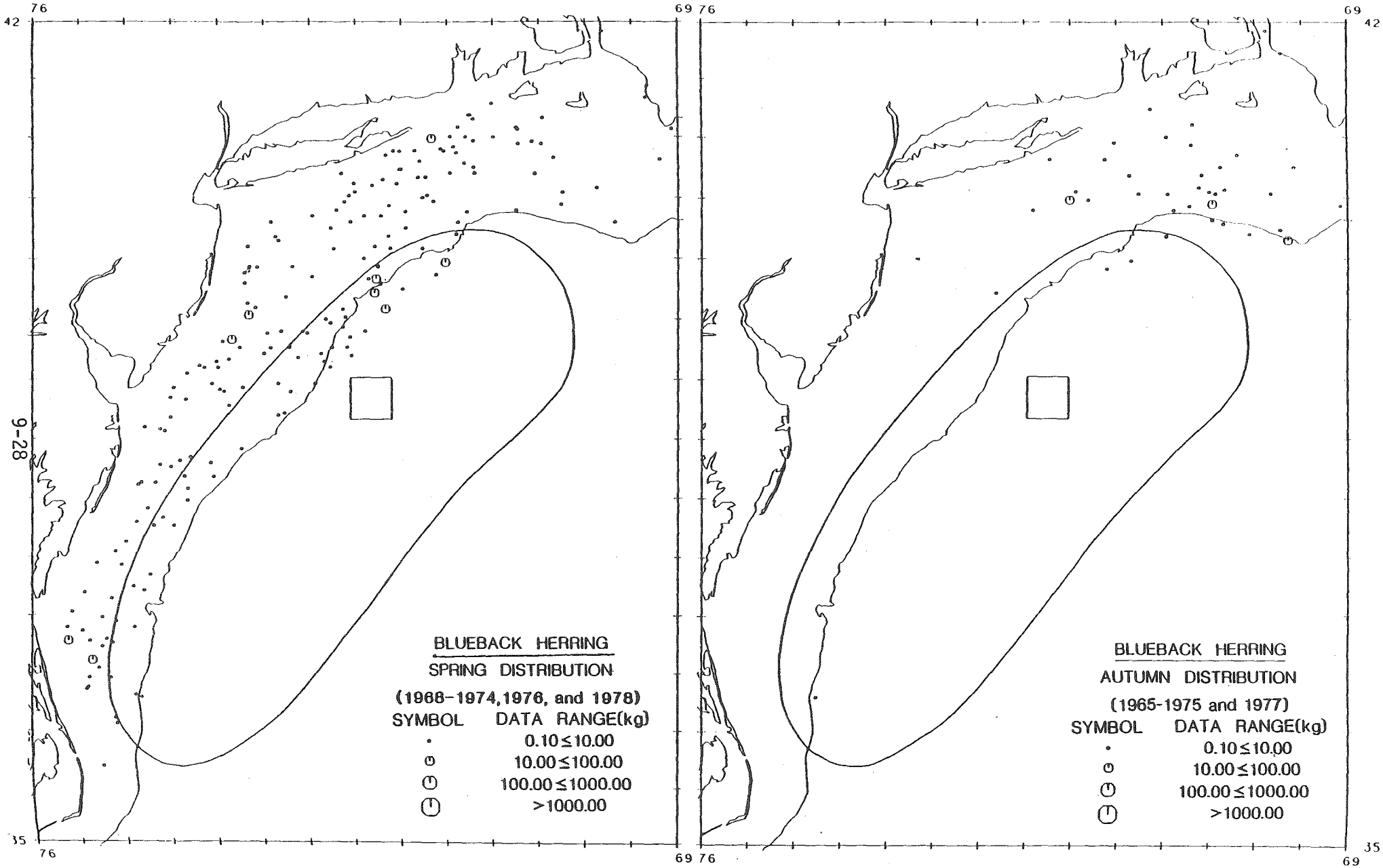


Figure 10.--Spring and autumn cumulative plots for blueback herring from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its

Figure 10.--Spring and autumn cumulative plots for blueback herring from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

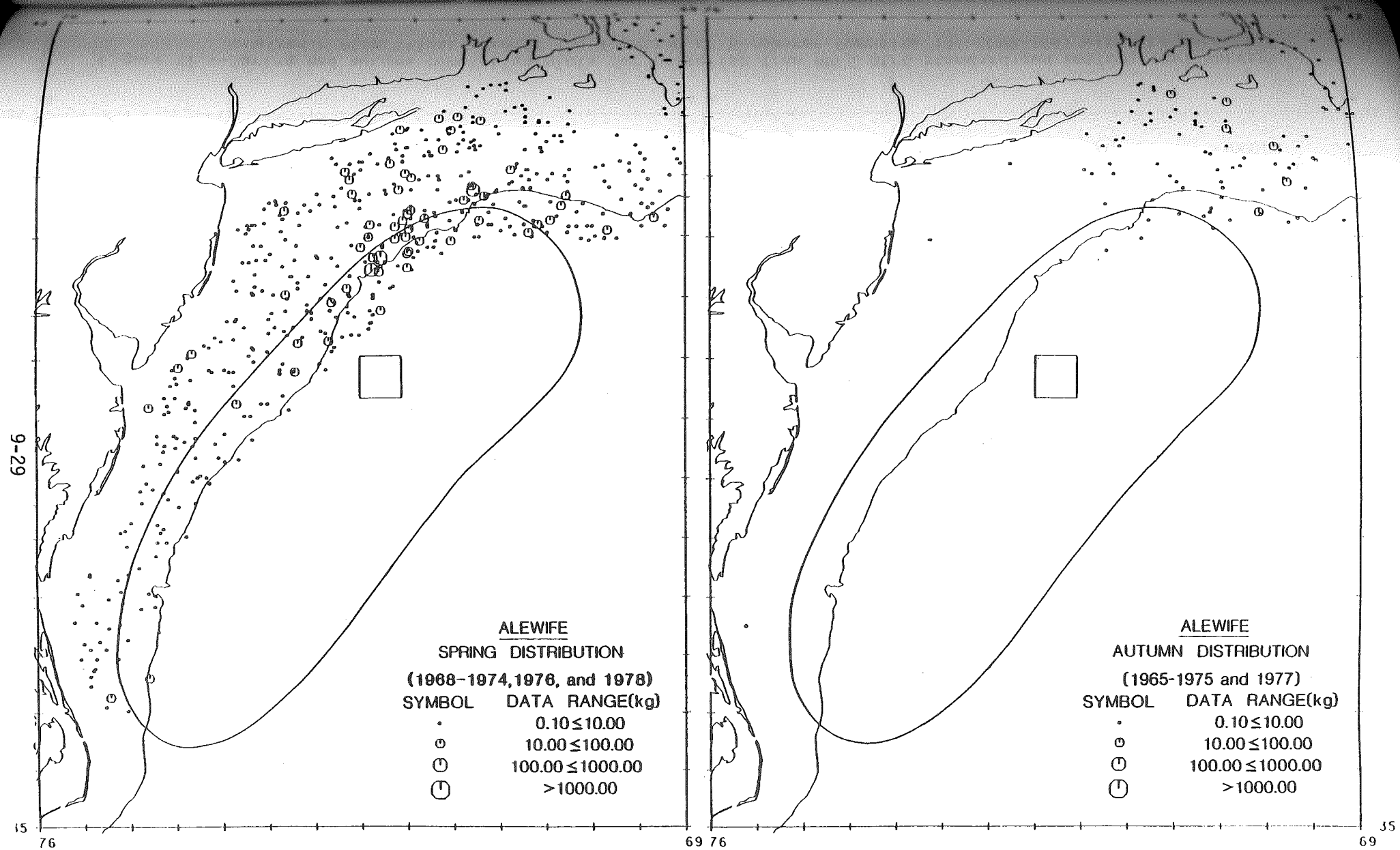


Figure 11.--Spring and autumn cumulative plots for alewife from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

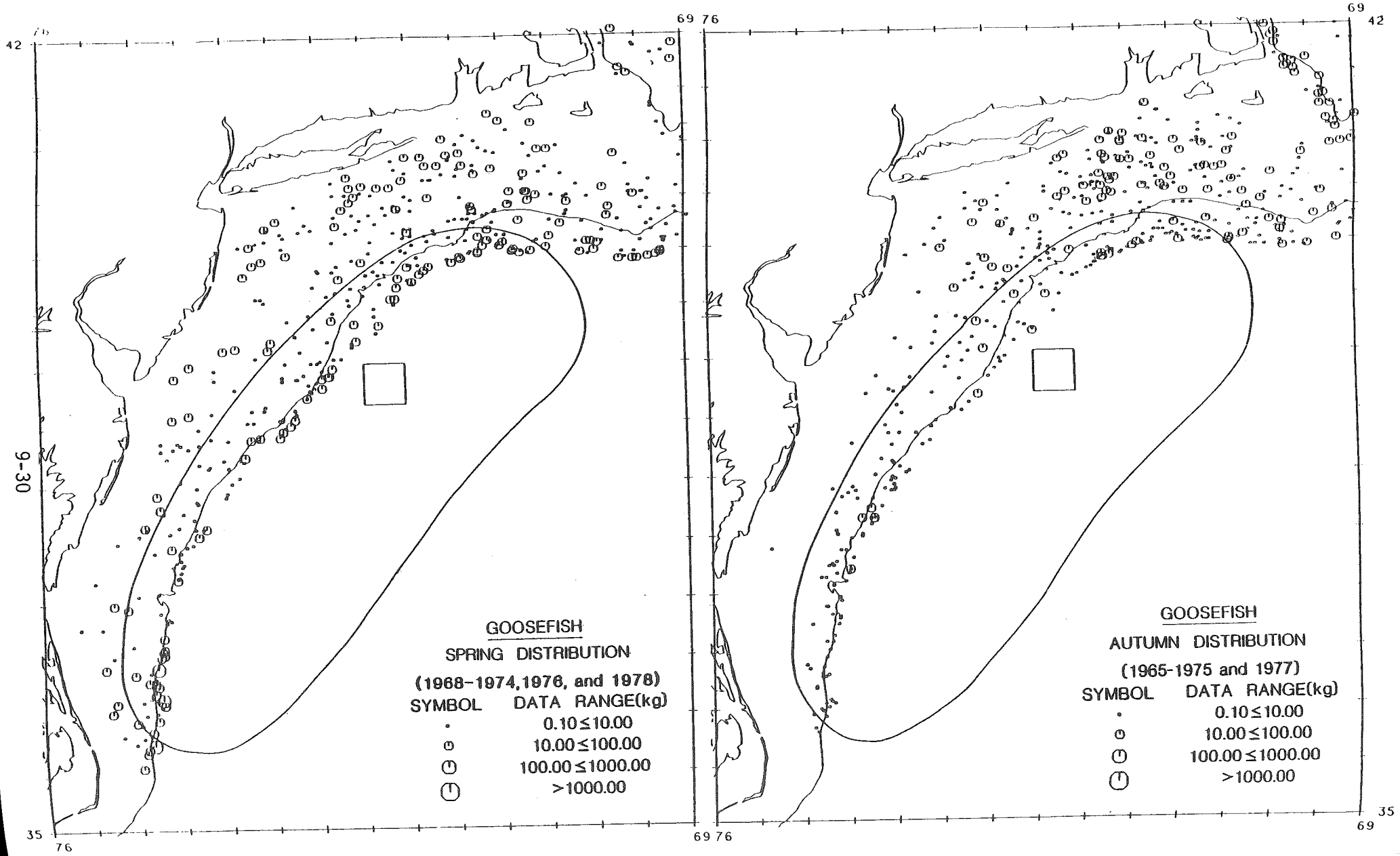


Figure 12.--Spring and autumn cumulative plots for goosefish from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

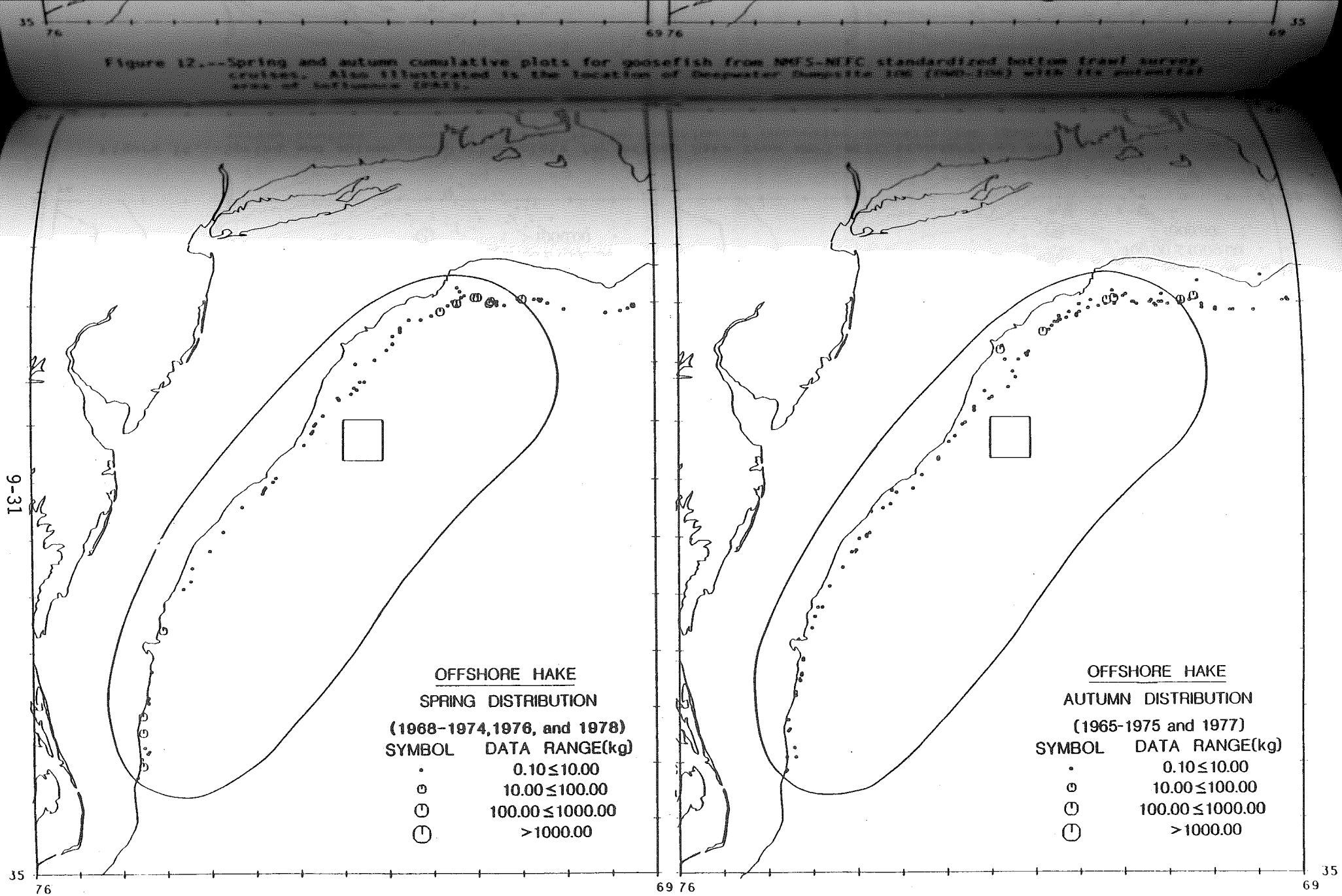


Figure 13.--Spring and autumn cumulative plots for offshore hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

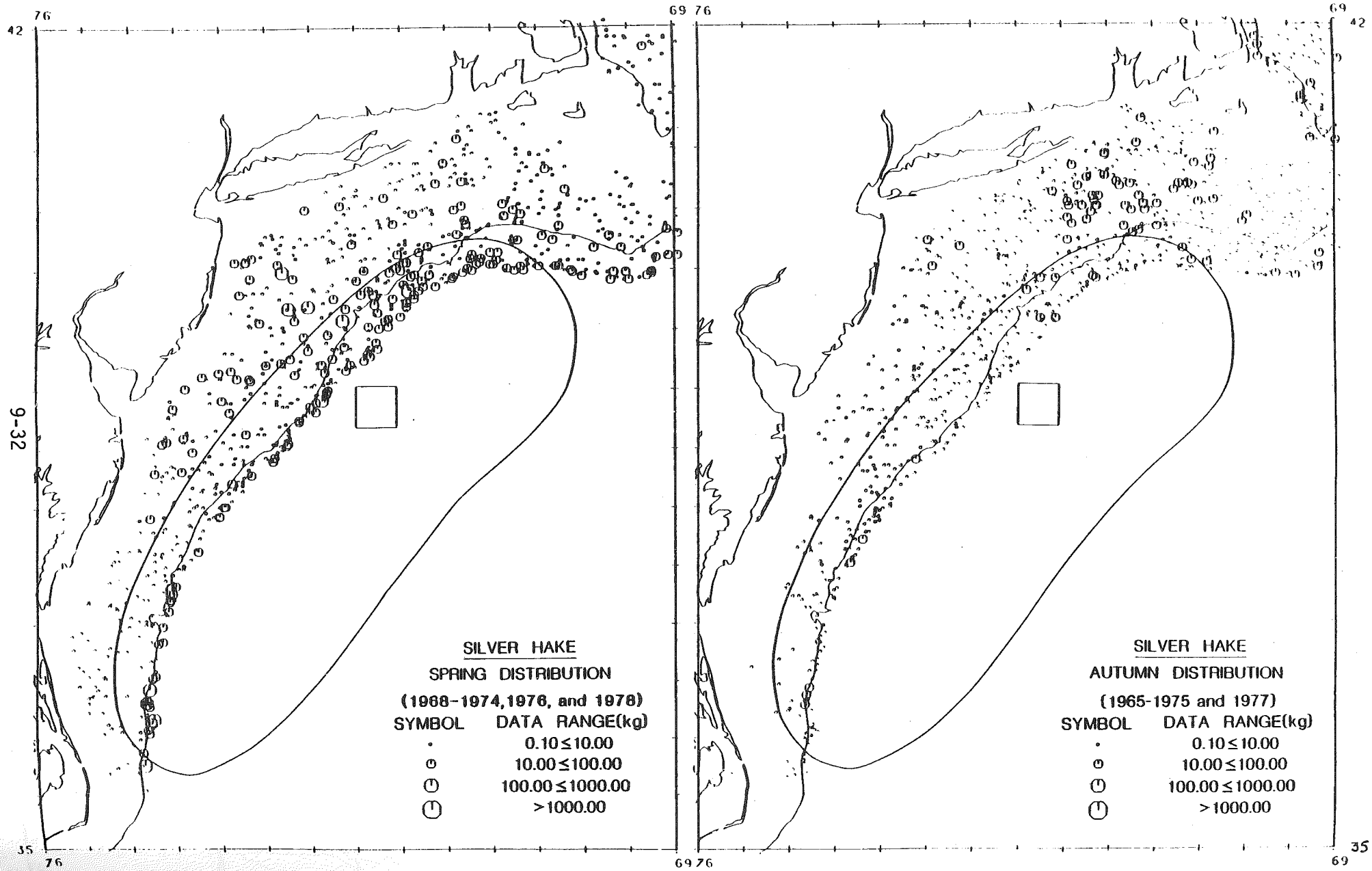


Figure 14.--Spring and autumn cumulative plots for silver hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with

Figure 14.--Spring and autumn cumulative plots for silver hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

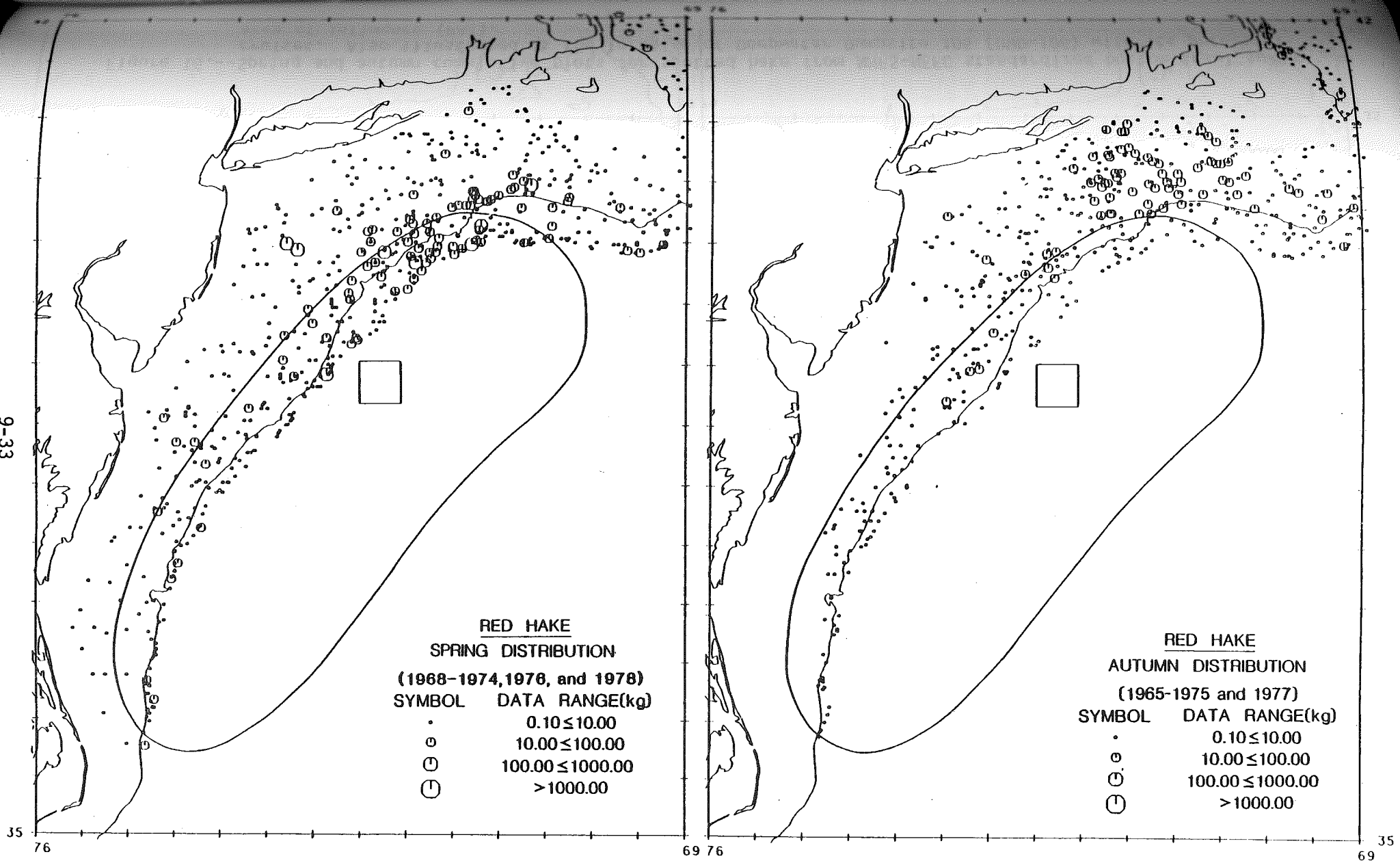


Figure 15.--Spring and autumn cumulative plots for red hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

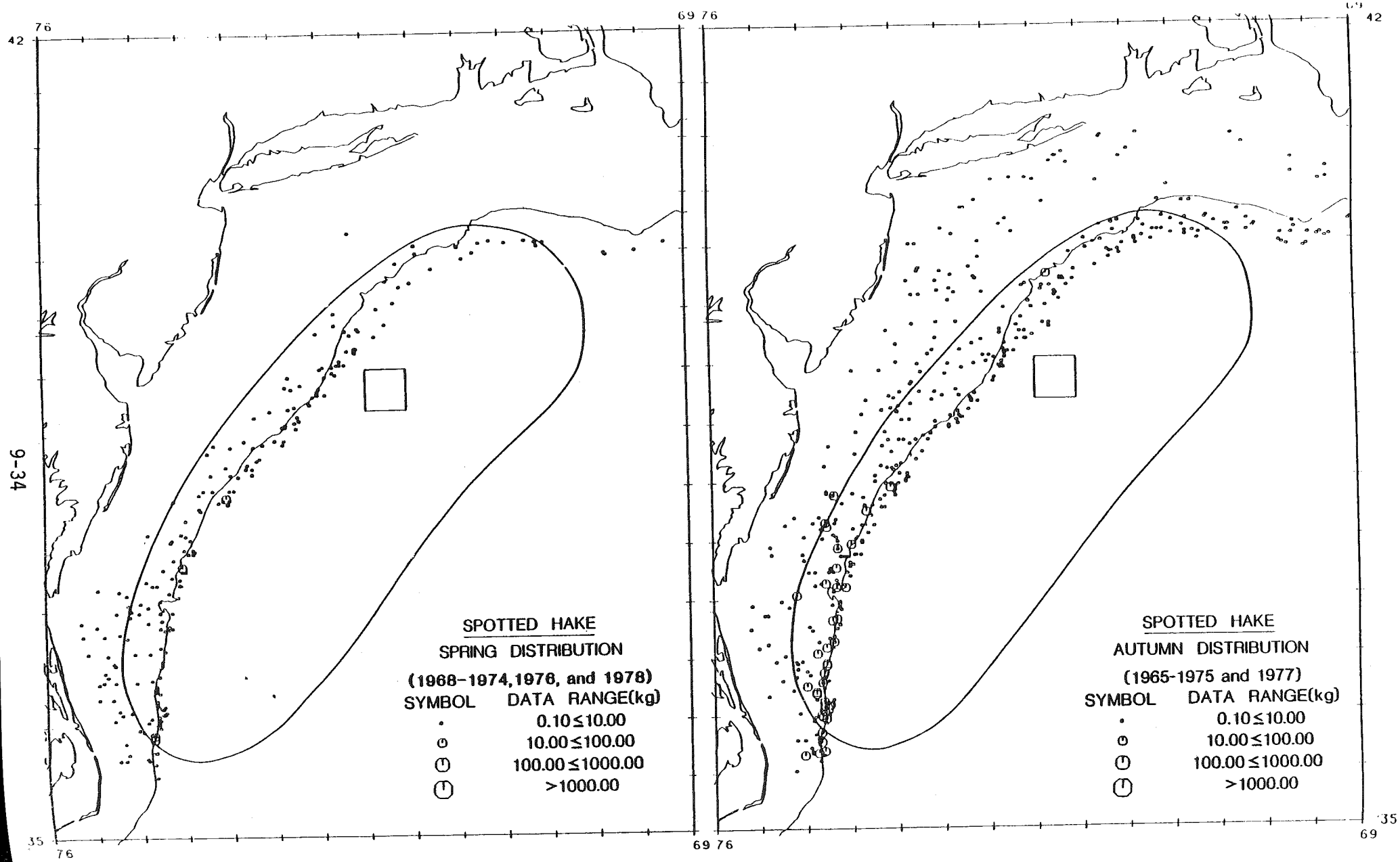


Figure 16.--Spring and autumn cumulative plots for spotted hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 16.--Spring and autumn cumulative plots for spotted hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

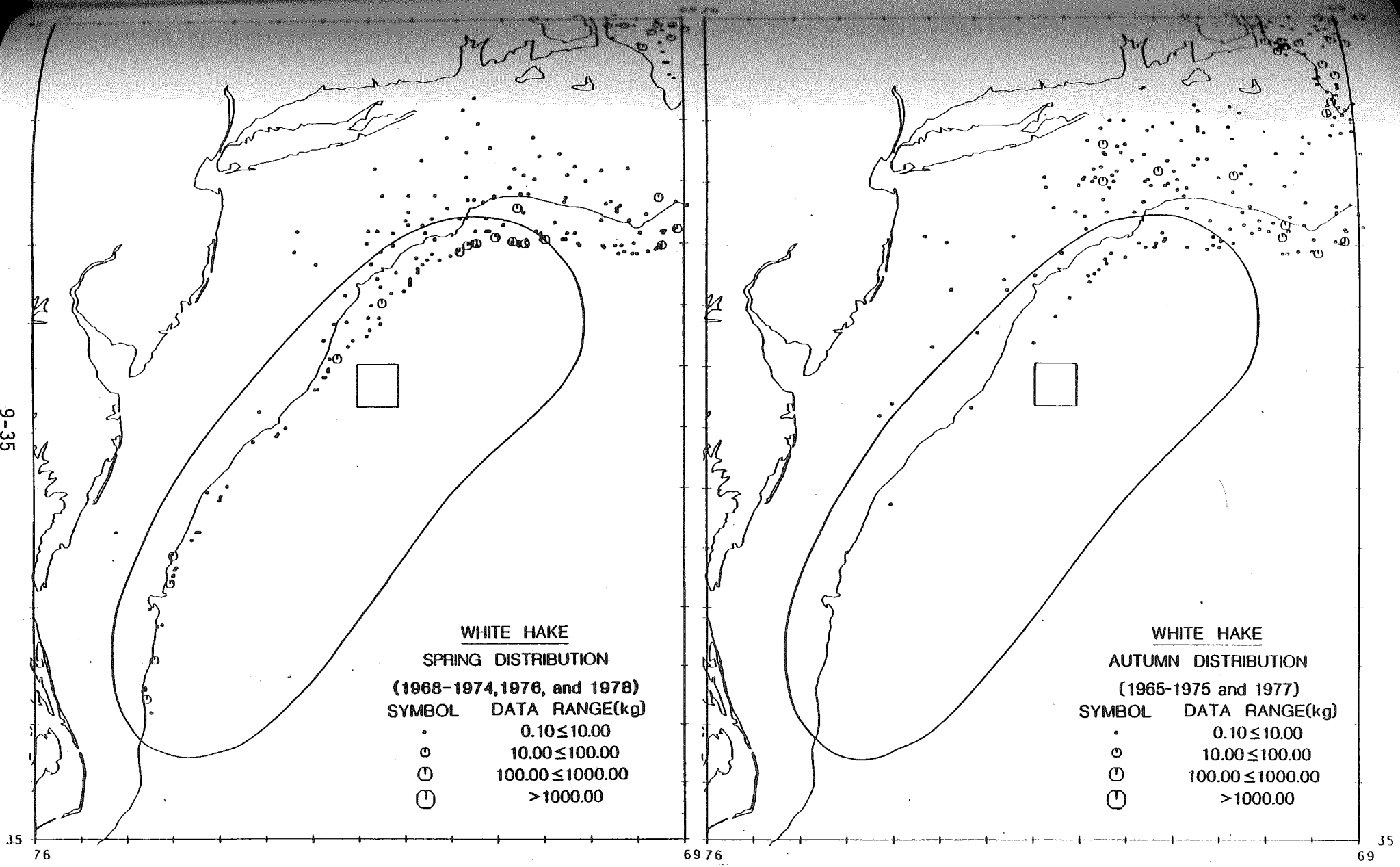


Figure 17.--Spring and autumn cumulative plots for white hake from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

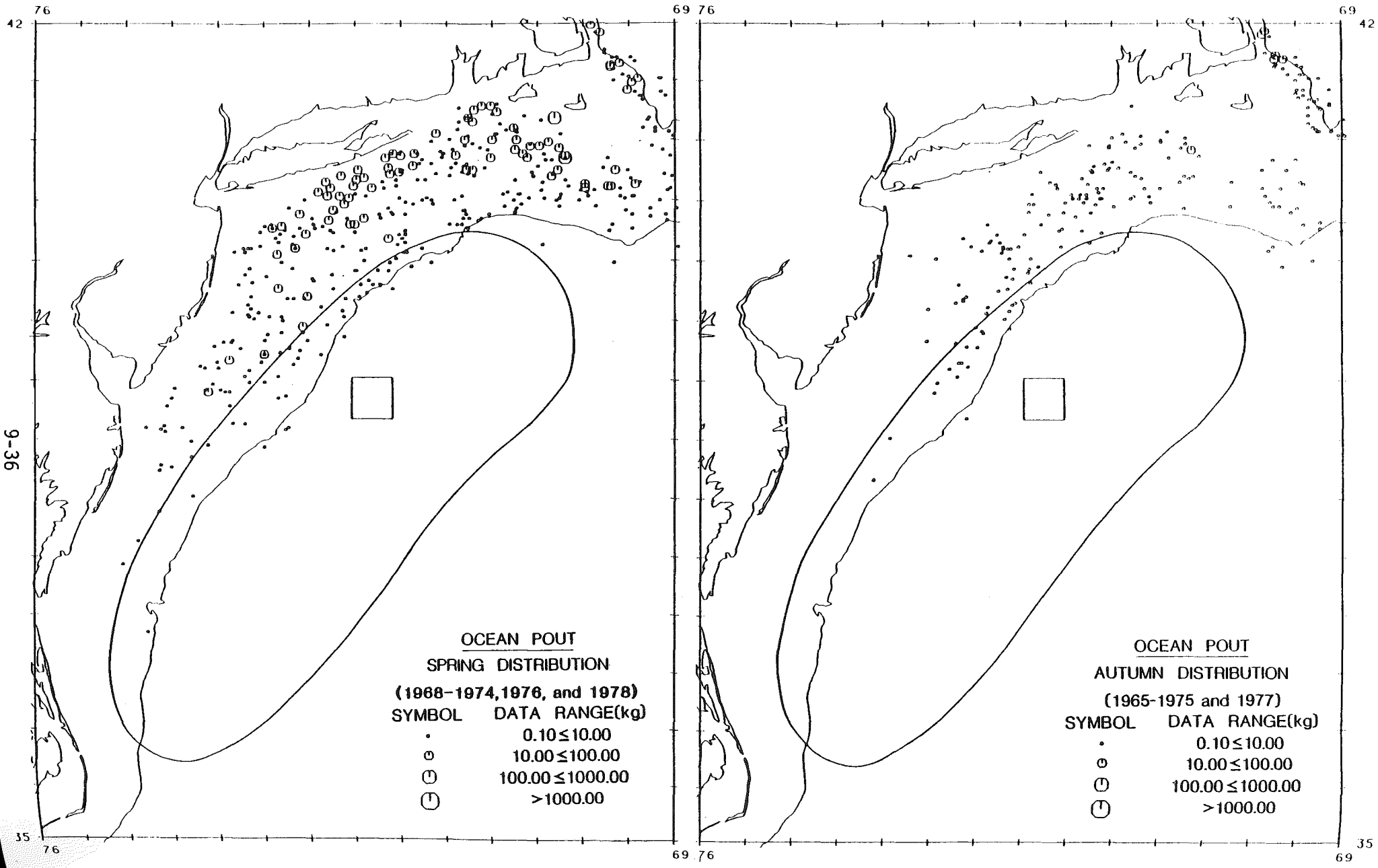


Figure 18.--Spring and autumn cumulative plots for ocean pout from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 18.--Spring and autumn cumulative plots for ocean pout from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

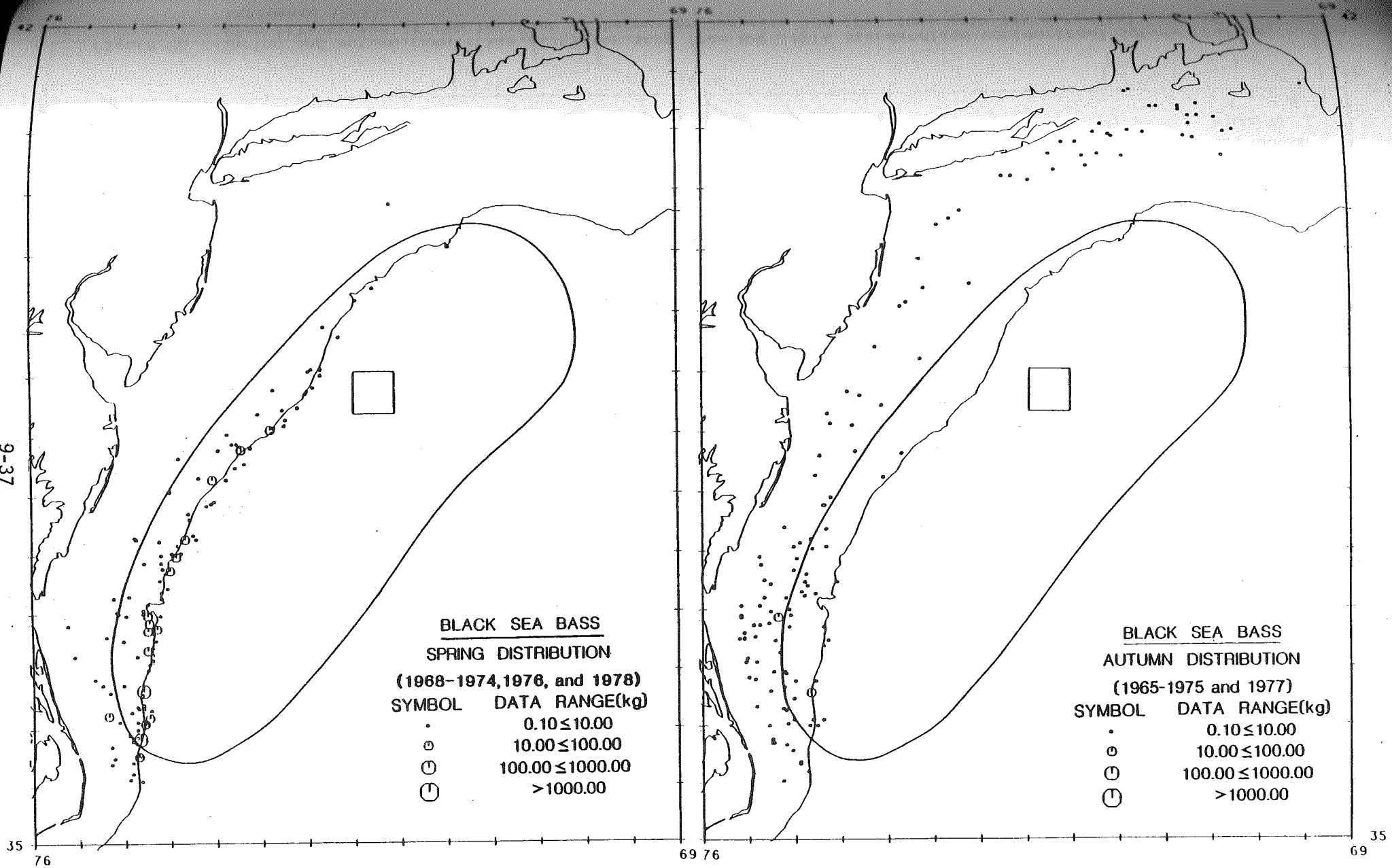


Figure 19.--Spring and autumn cumulative plots of black sea bass from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

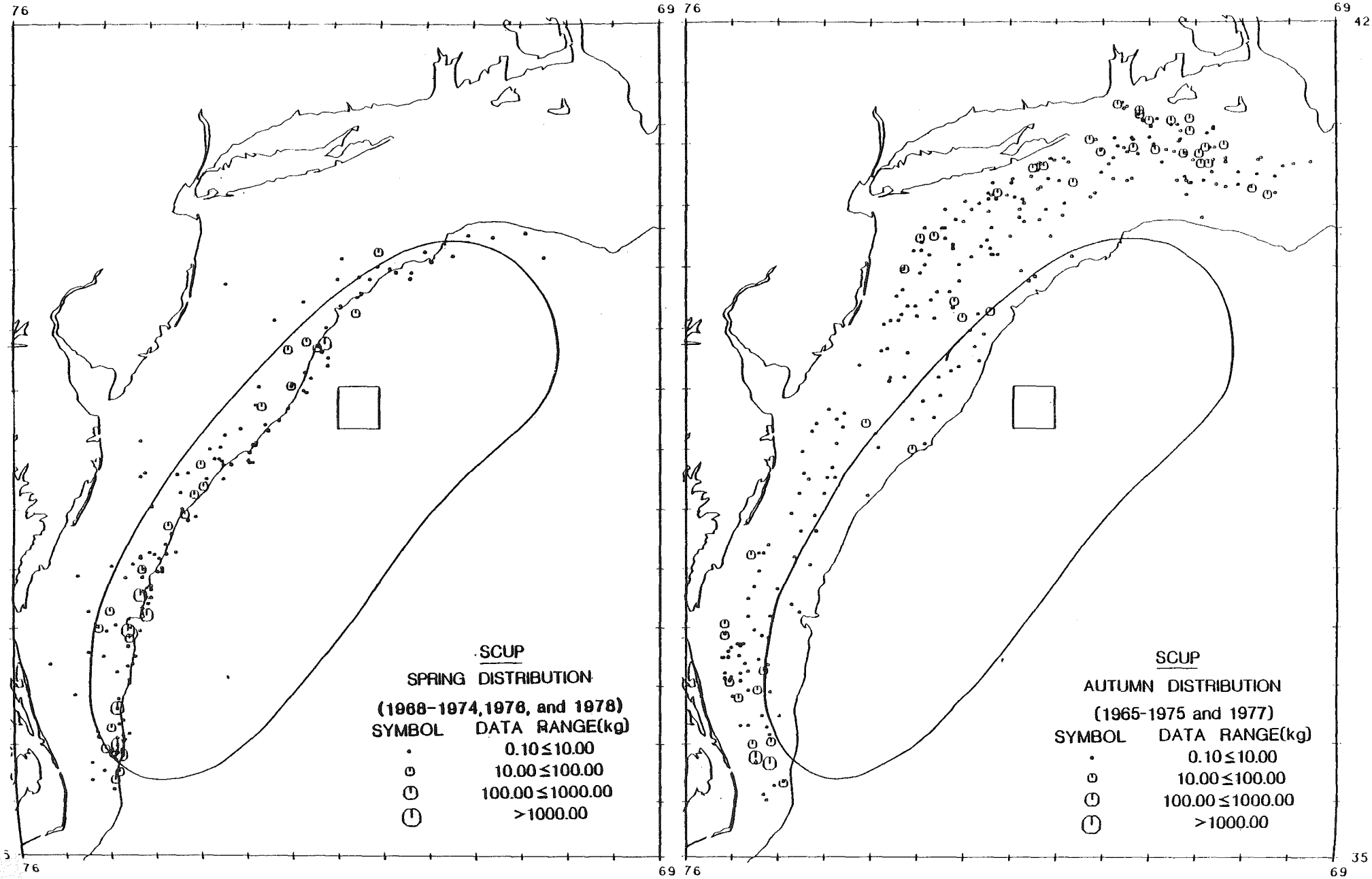


Figure 20.--Spring and autumn cumulative plots for scup from NMFS-NEFC standardized bottom trawl survey cruises.

Figure 20.--Spring and autumn cumulative plots for scup from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

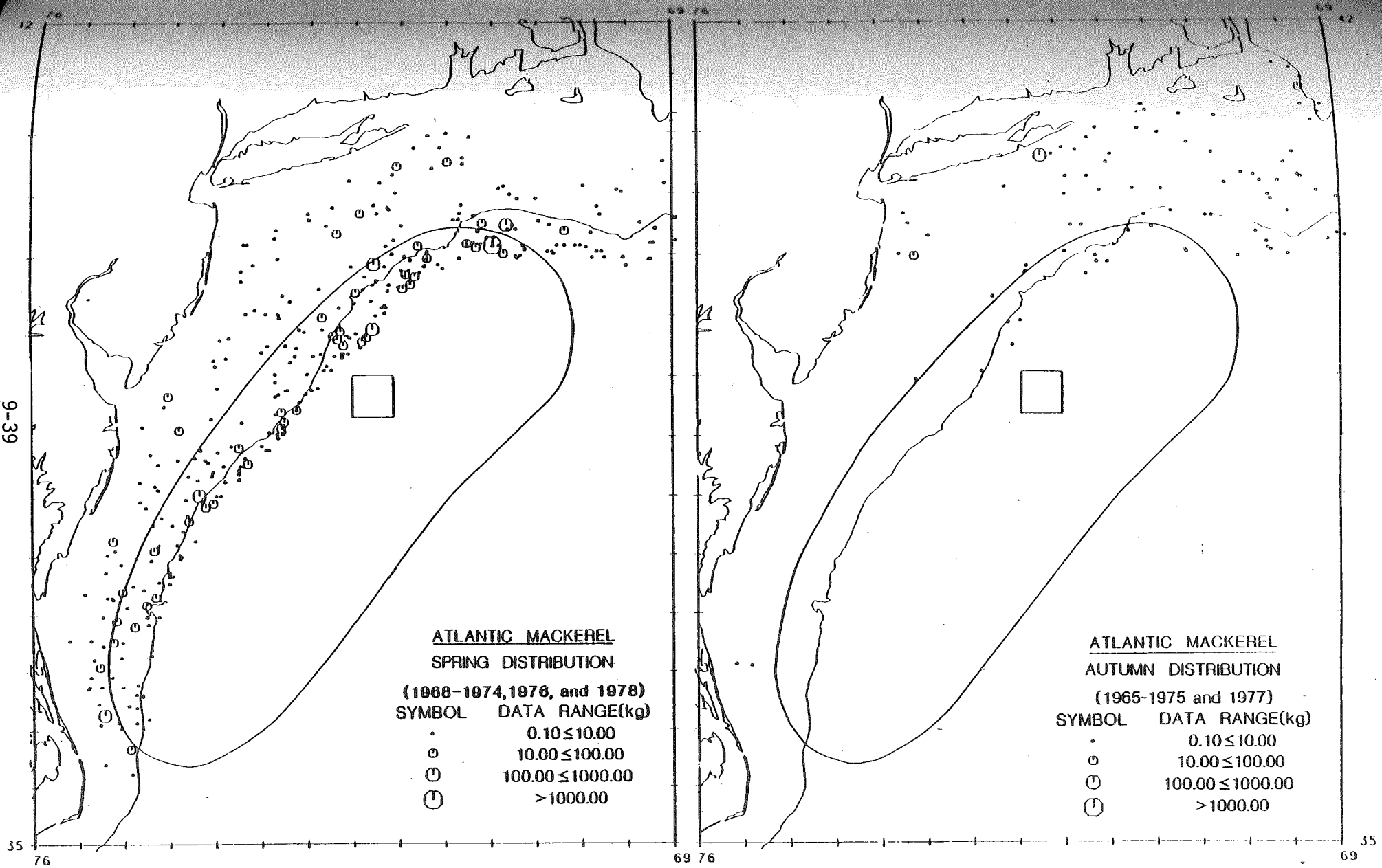


Figure 21.--Spring and autumn cumulative plots for Atlantic mackerel from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

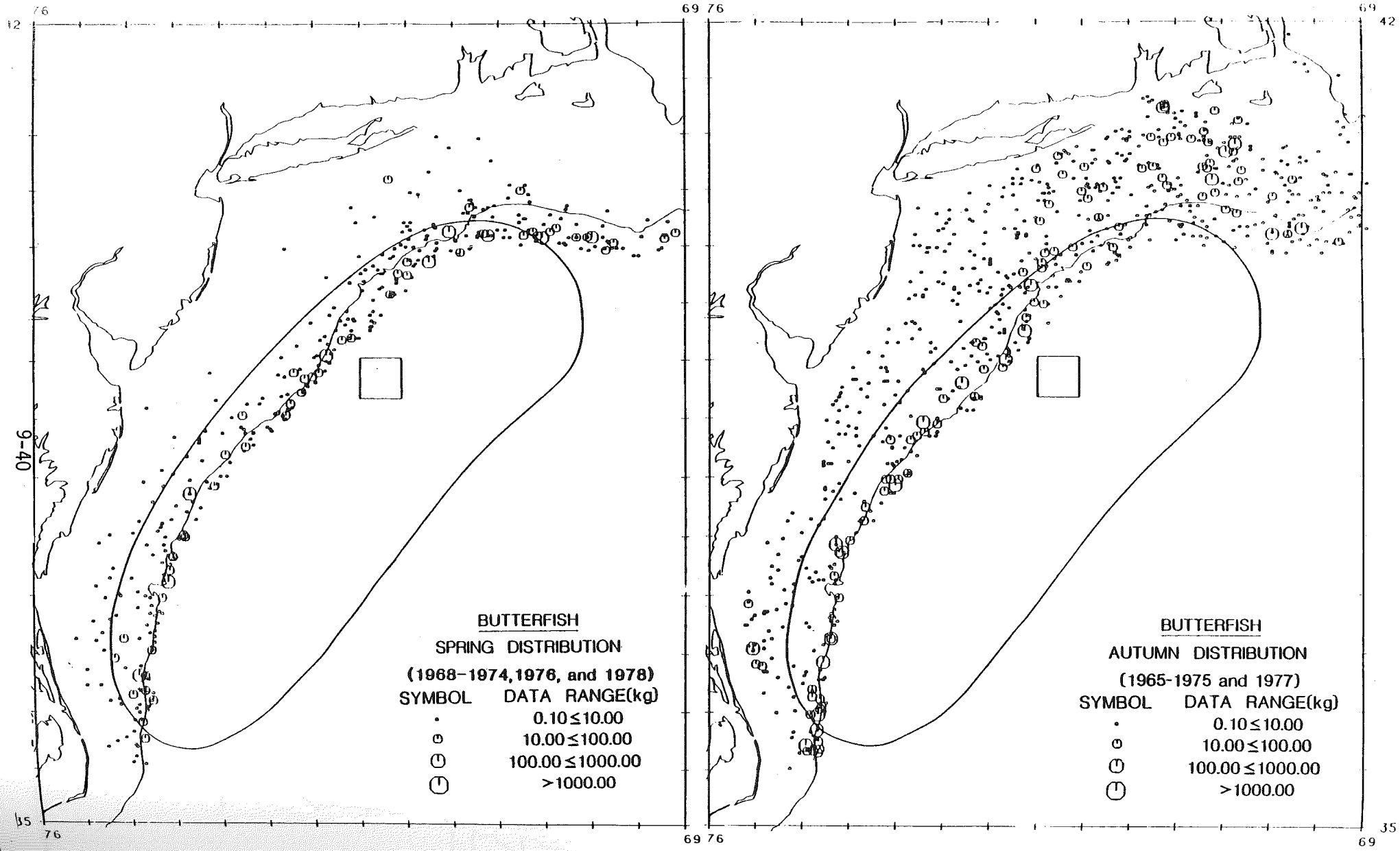


Figure 22.--Spring and autumn cumulative plots for butterfish from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 22.--Spring and autumn cumulative plots for butterfish from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

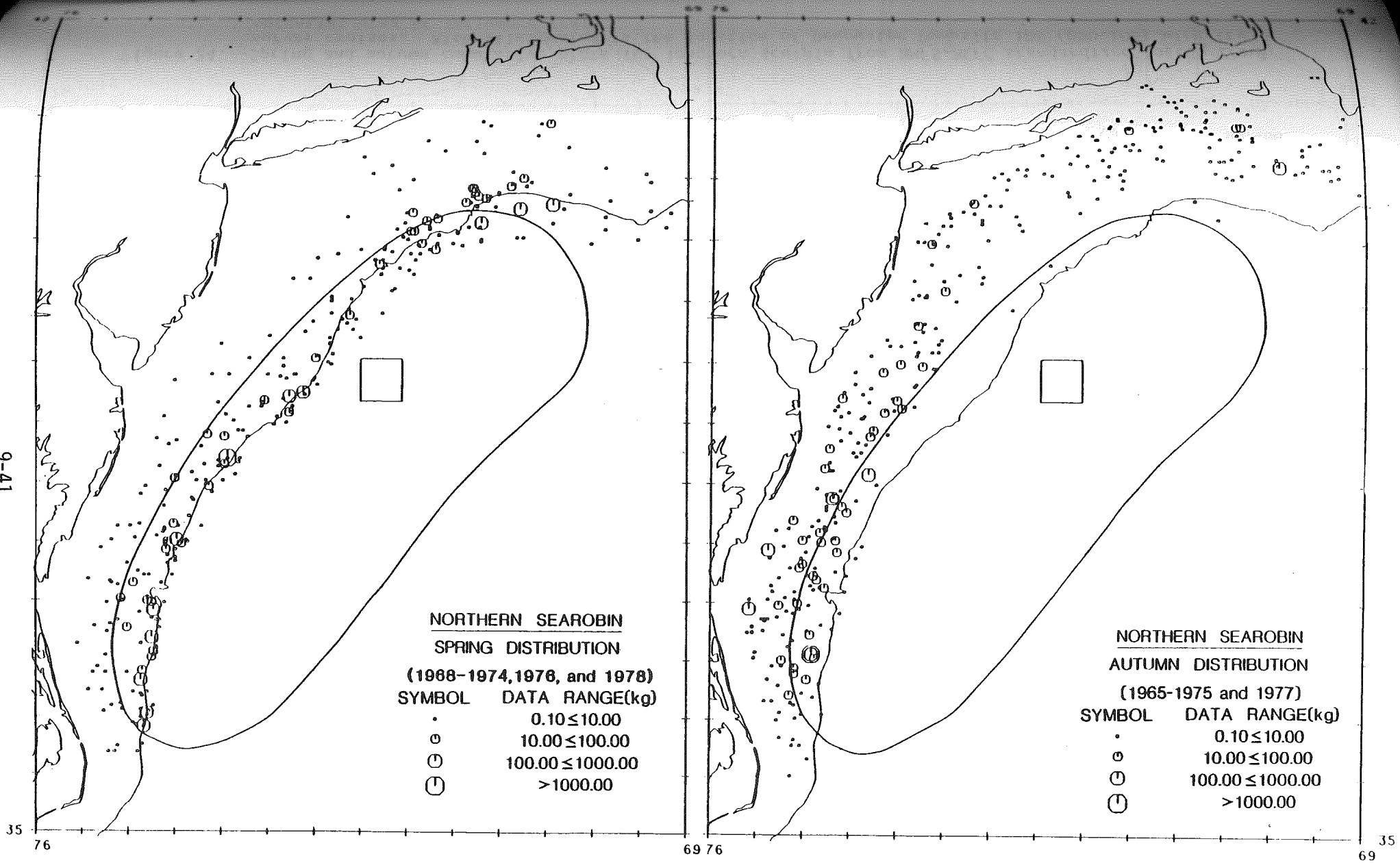


Figure 23.--Spring and autumn cumulative plots for northern searobin from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

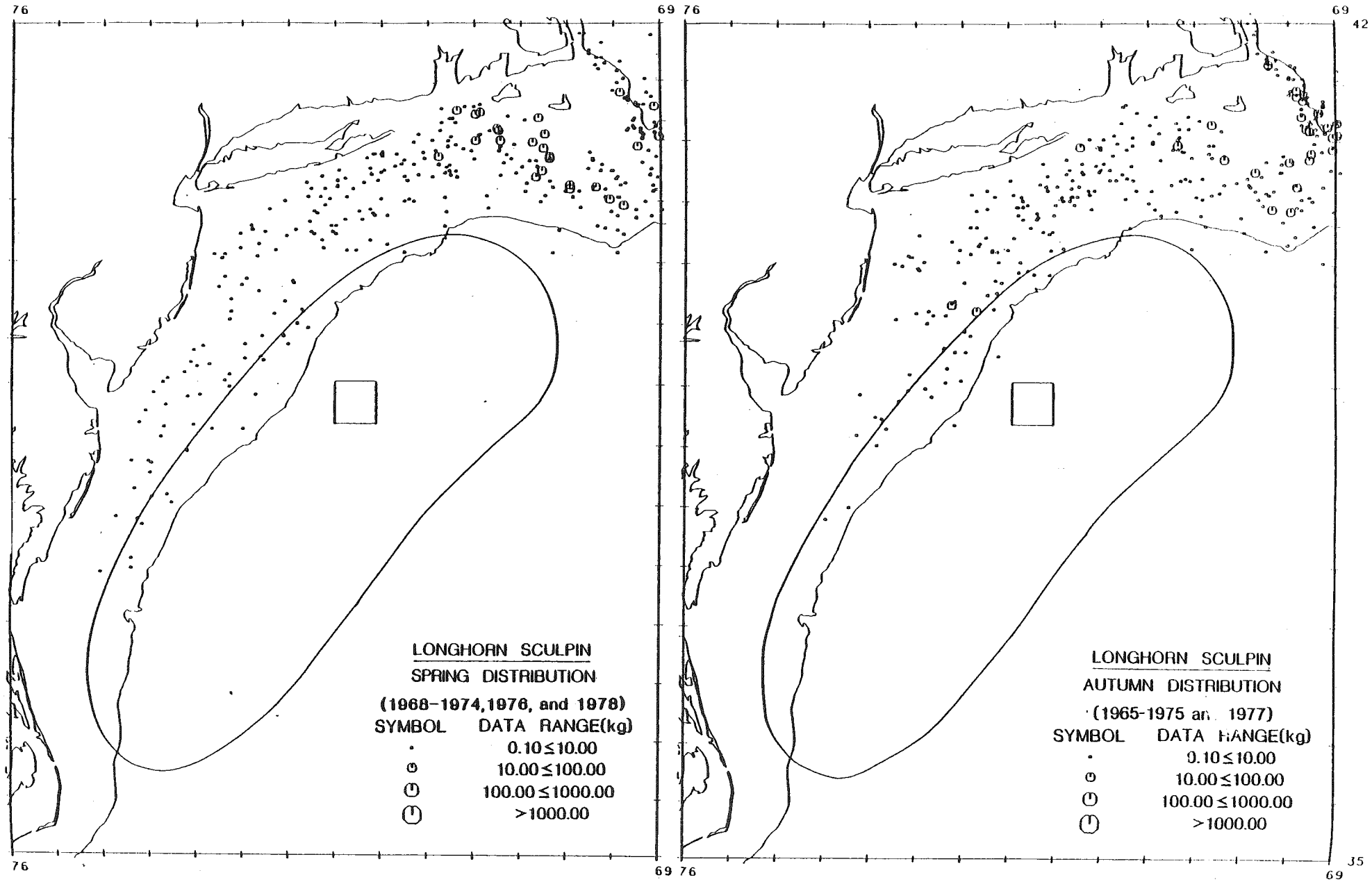


Figure 24.--Spring and autumn cumulative plots for longhorn sculpin from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 24.--Spring and autumn cumulative plots for longhorn sculpin from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

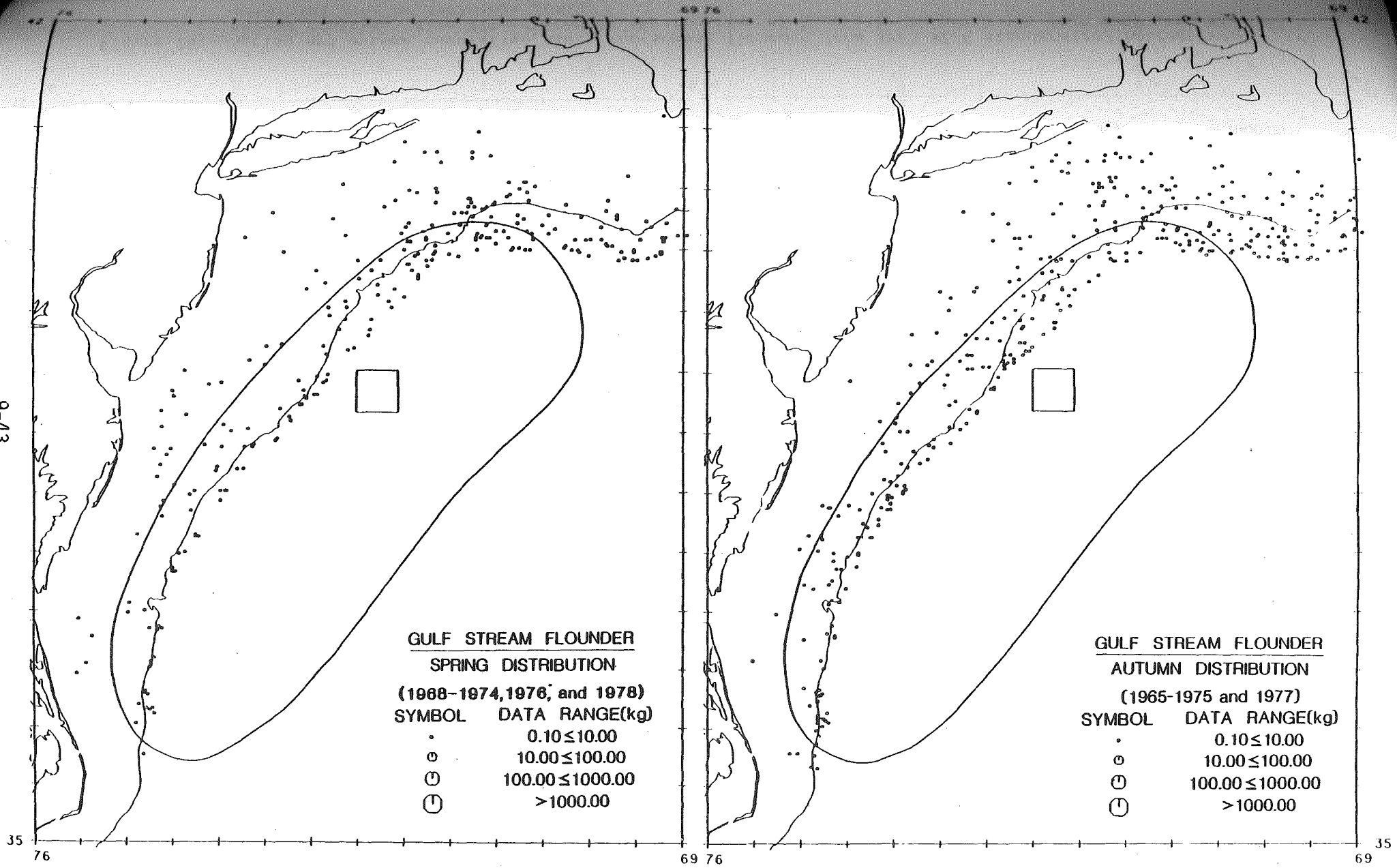


Figure 25.--Spring and autumn cumulative plots for Gulf Stream flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

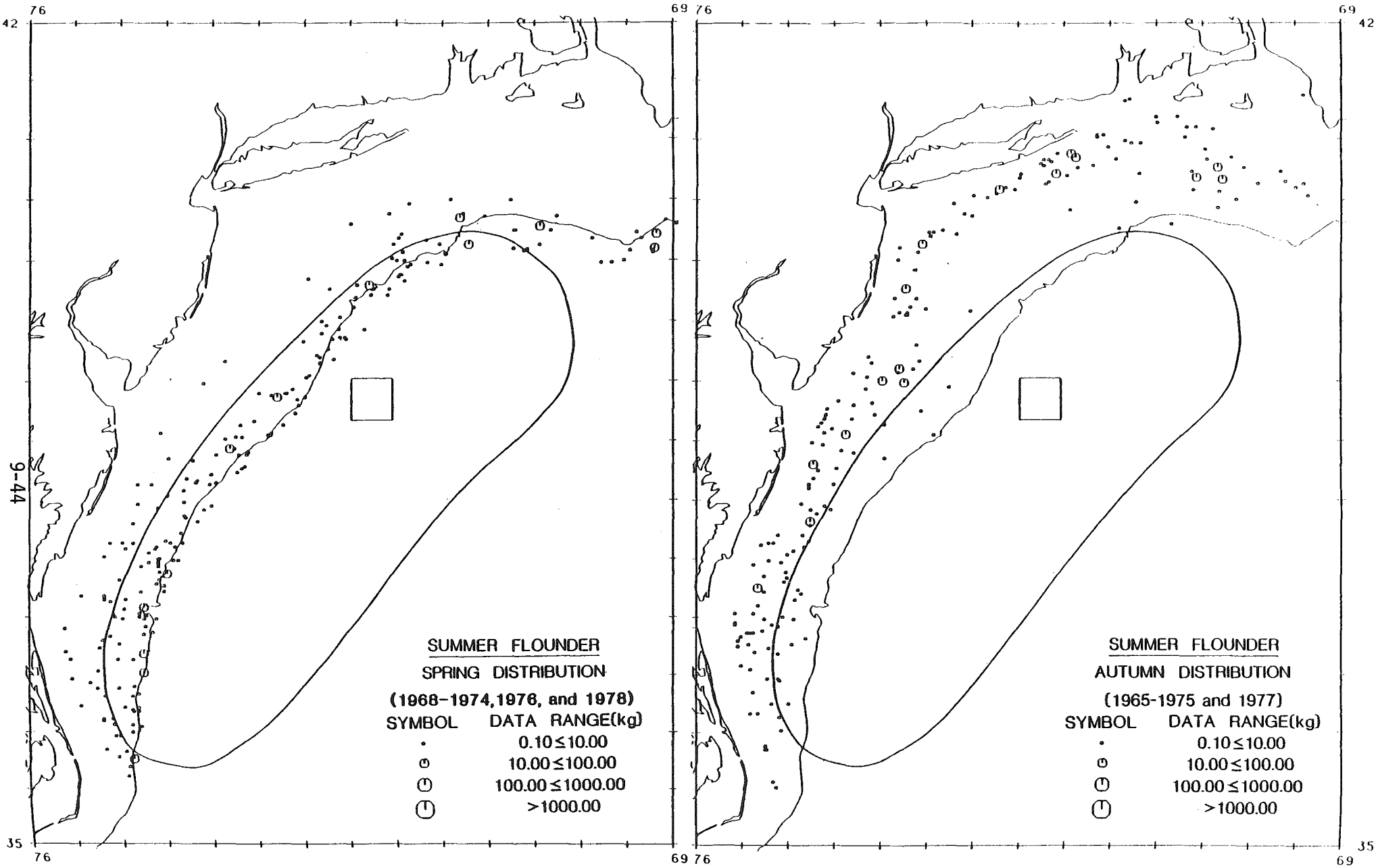


Figure 26.--Spring and autumn cumulative plots for summer flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 26.--Spring and autumn cumulative plots for summer flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

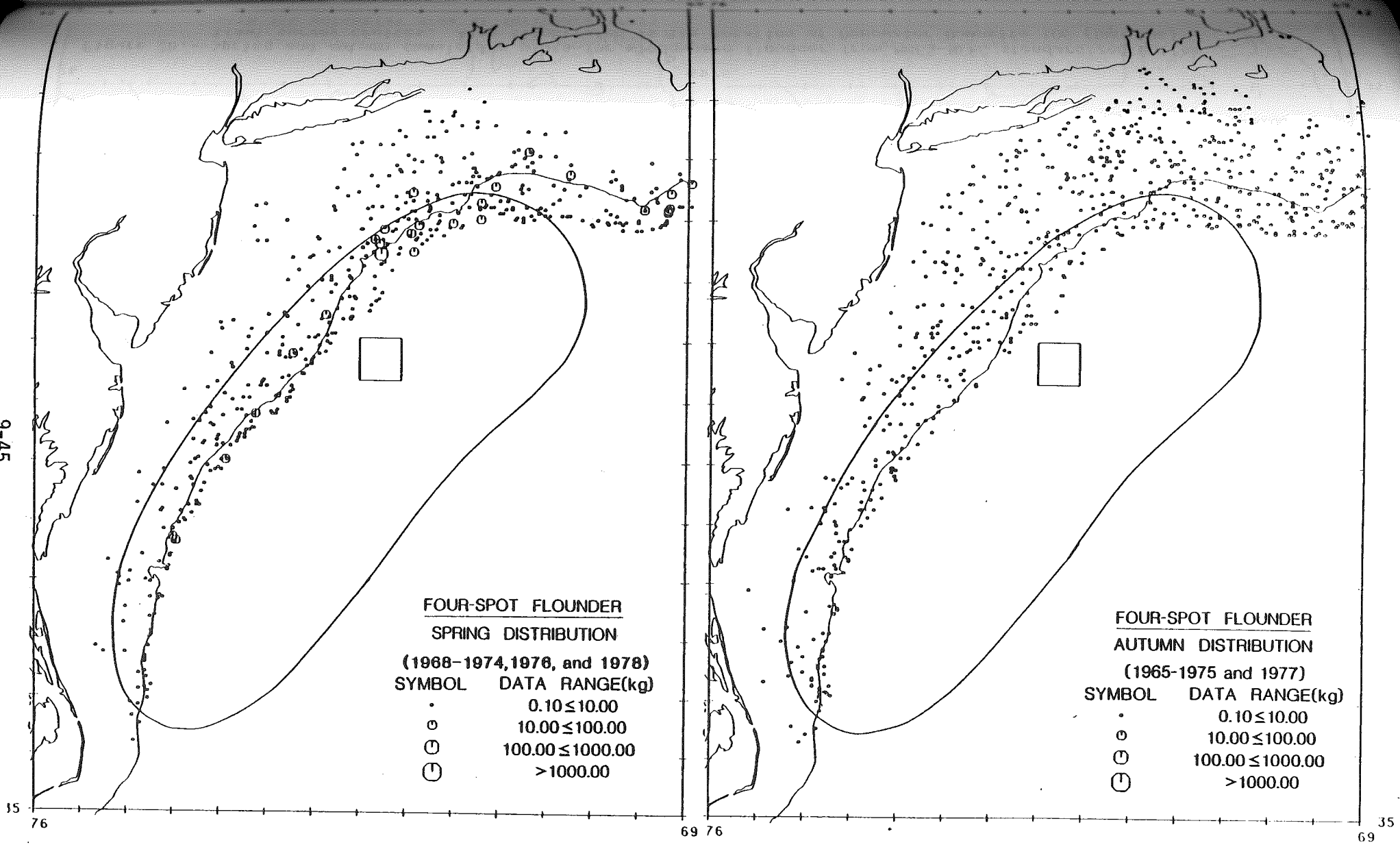


Figure 27.--Spring and autumn cumulative plots for four-spot flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

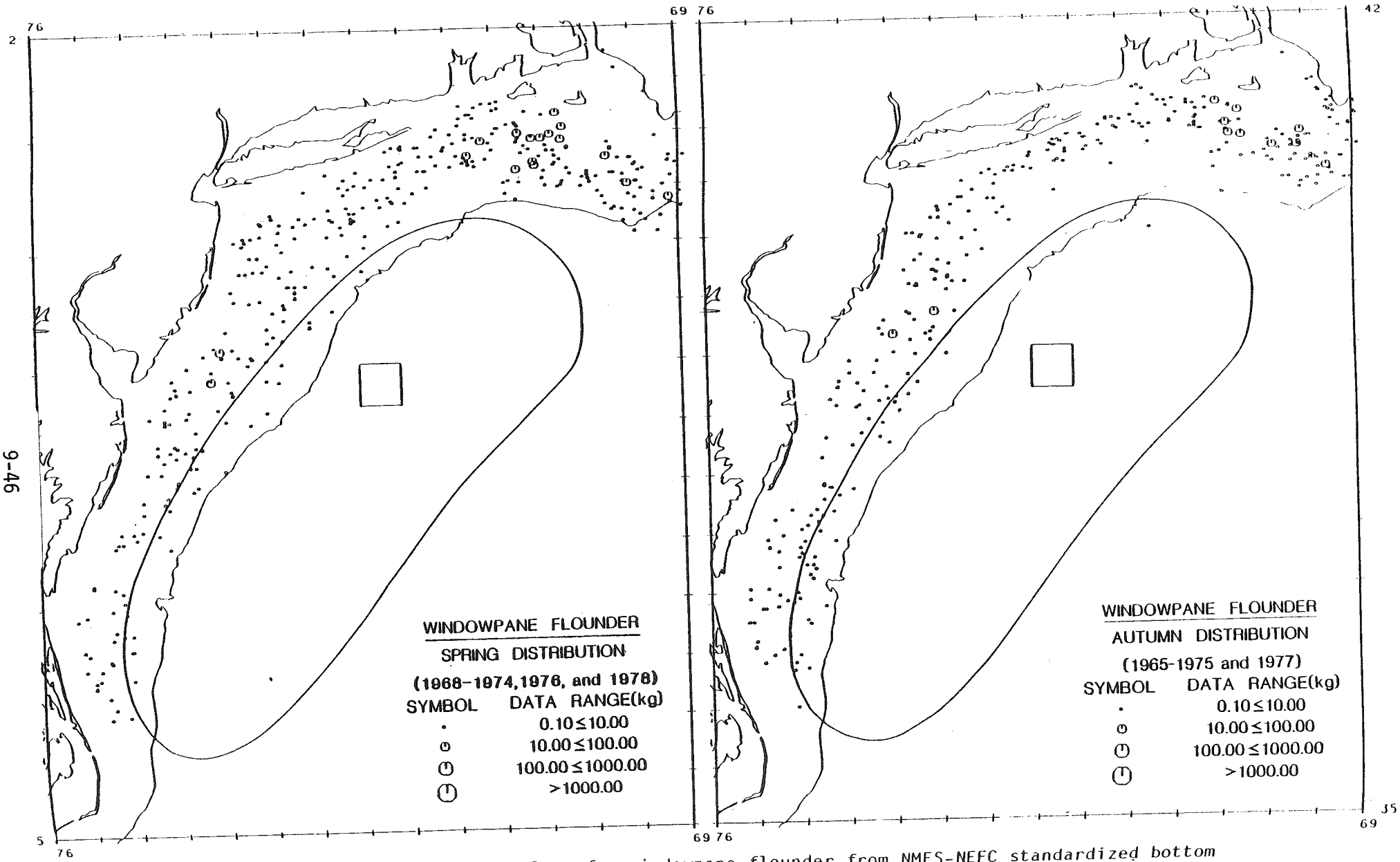


Figure 28.--Spring and autumn cumulative plots for windowpane flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 28.--Spring and autumn cumulative plots for windowpane flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

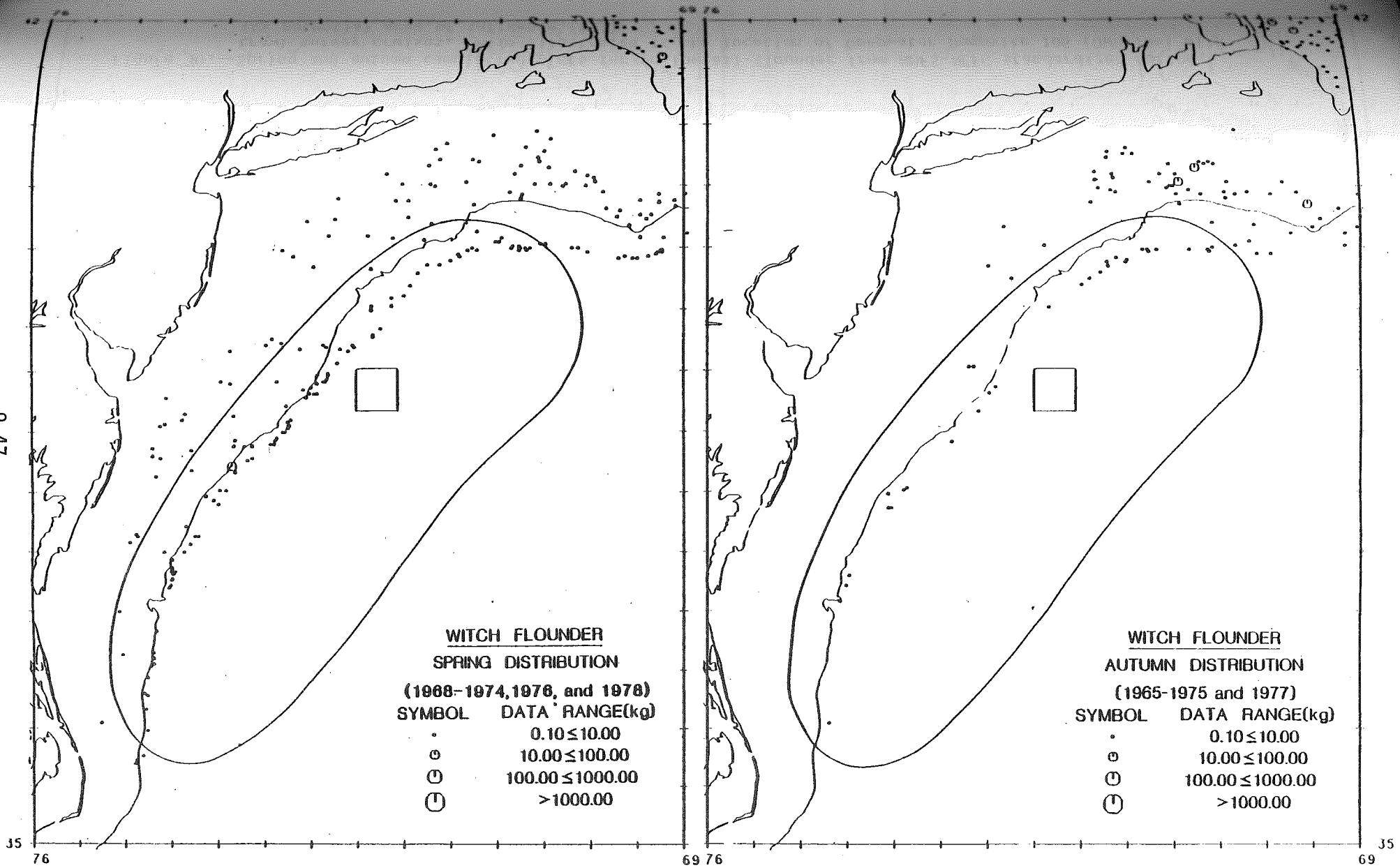


Figure 29.--Spring and autumn cumulative plots for witch flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

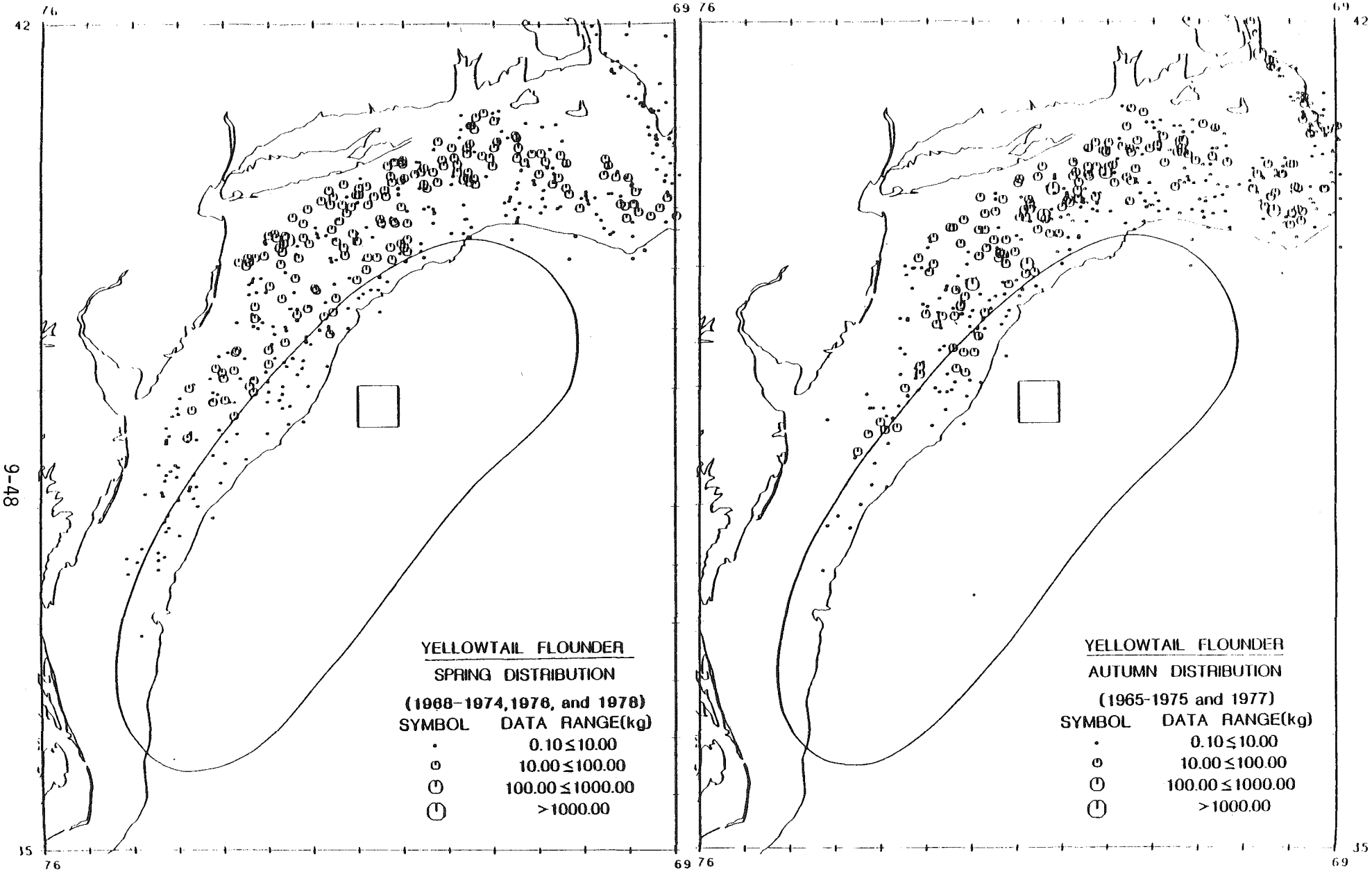


Figure 30.--Spring and autumn cumulative plots for yellowtail flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 30.--Spring and autumn cumulative plots for yellowtail flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

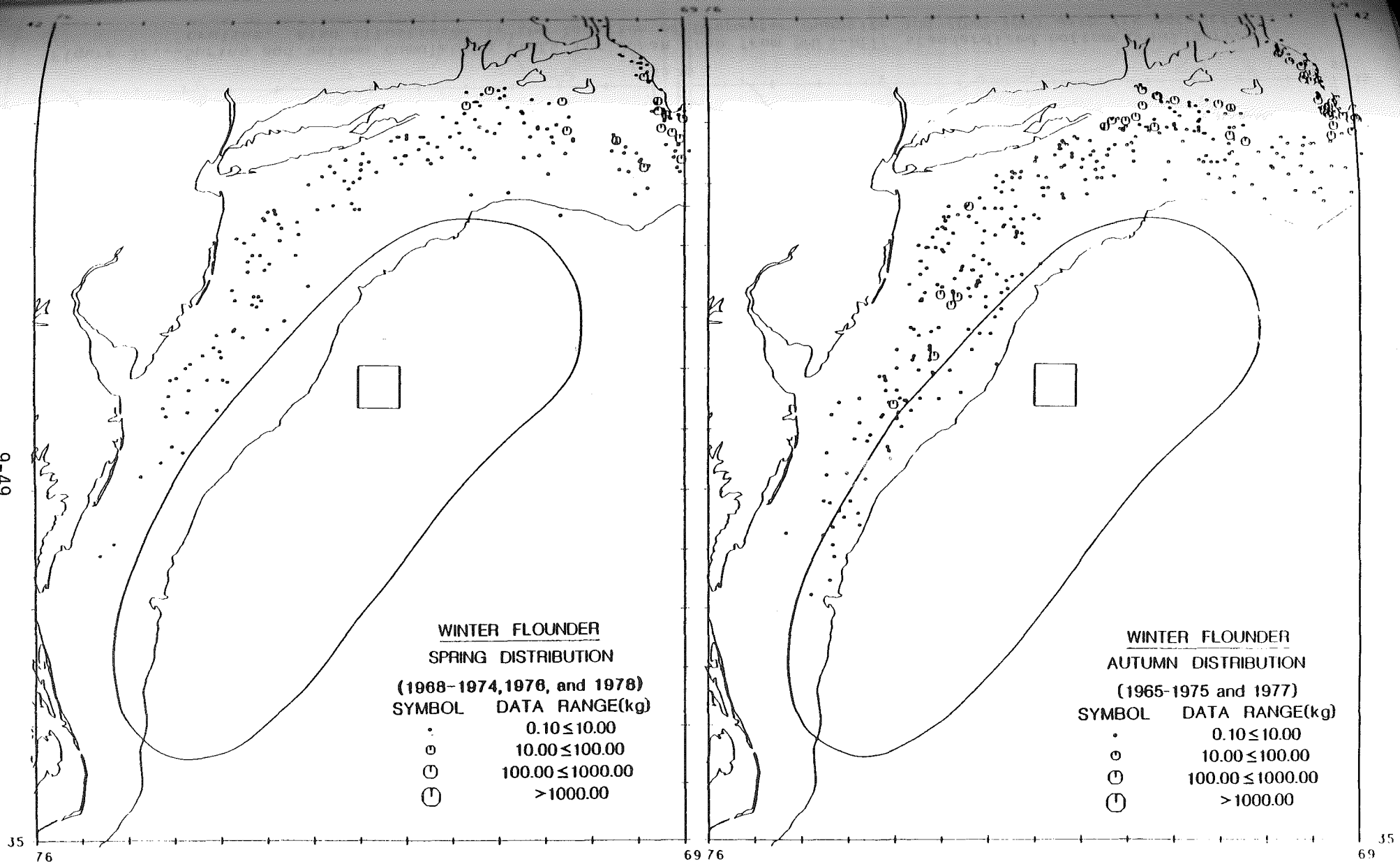


Figure 31.--Spring and autumn cumulative plots of winter flounder from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

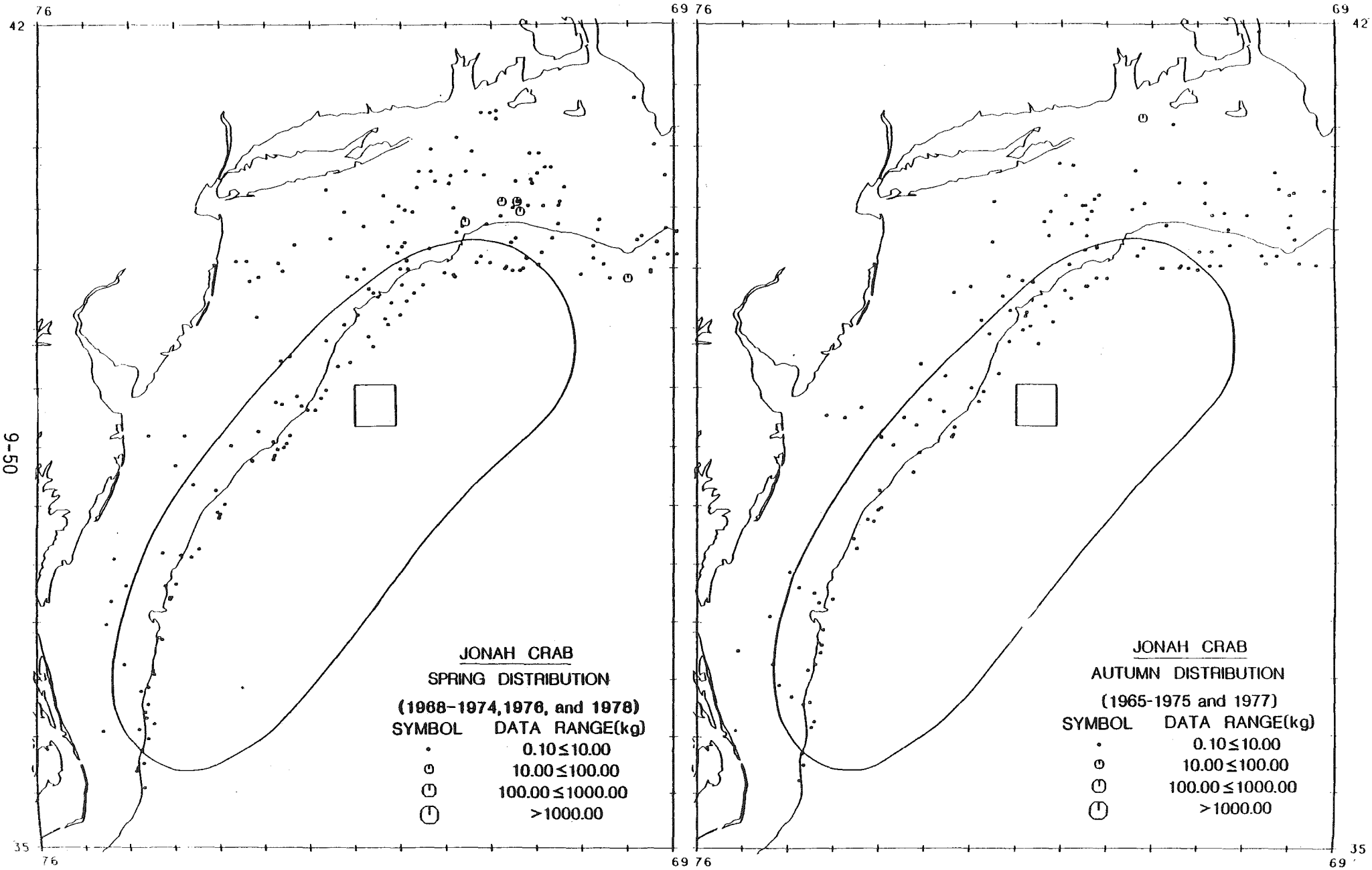


Figure 32.--Spring and autumn cumulative plots for Jonah crab from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 32.--Spring and autumn cumulative plots for Jonah crab from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

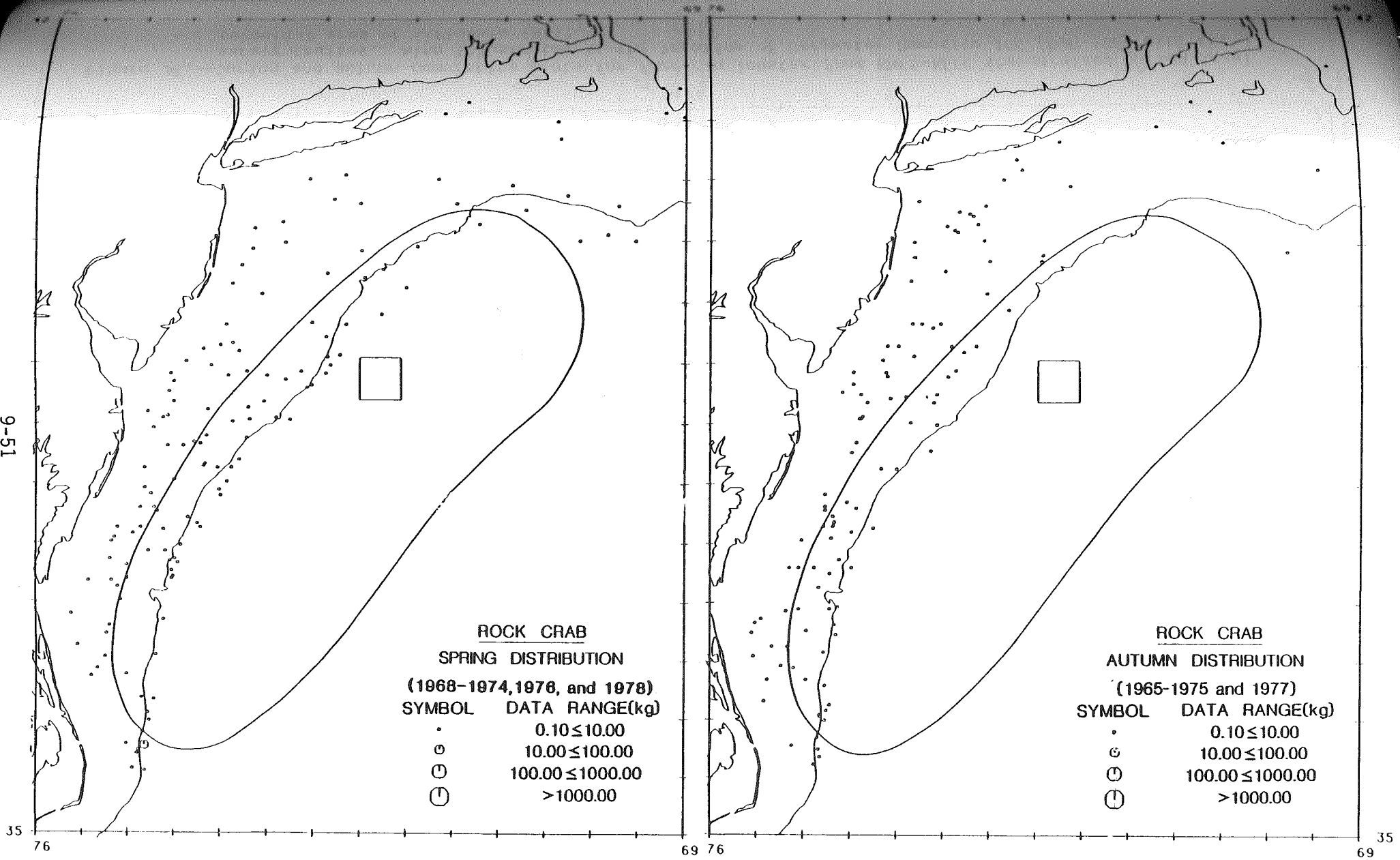


Figure 33.--Spring and autumn cumulative plots for rock crab from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

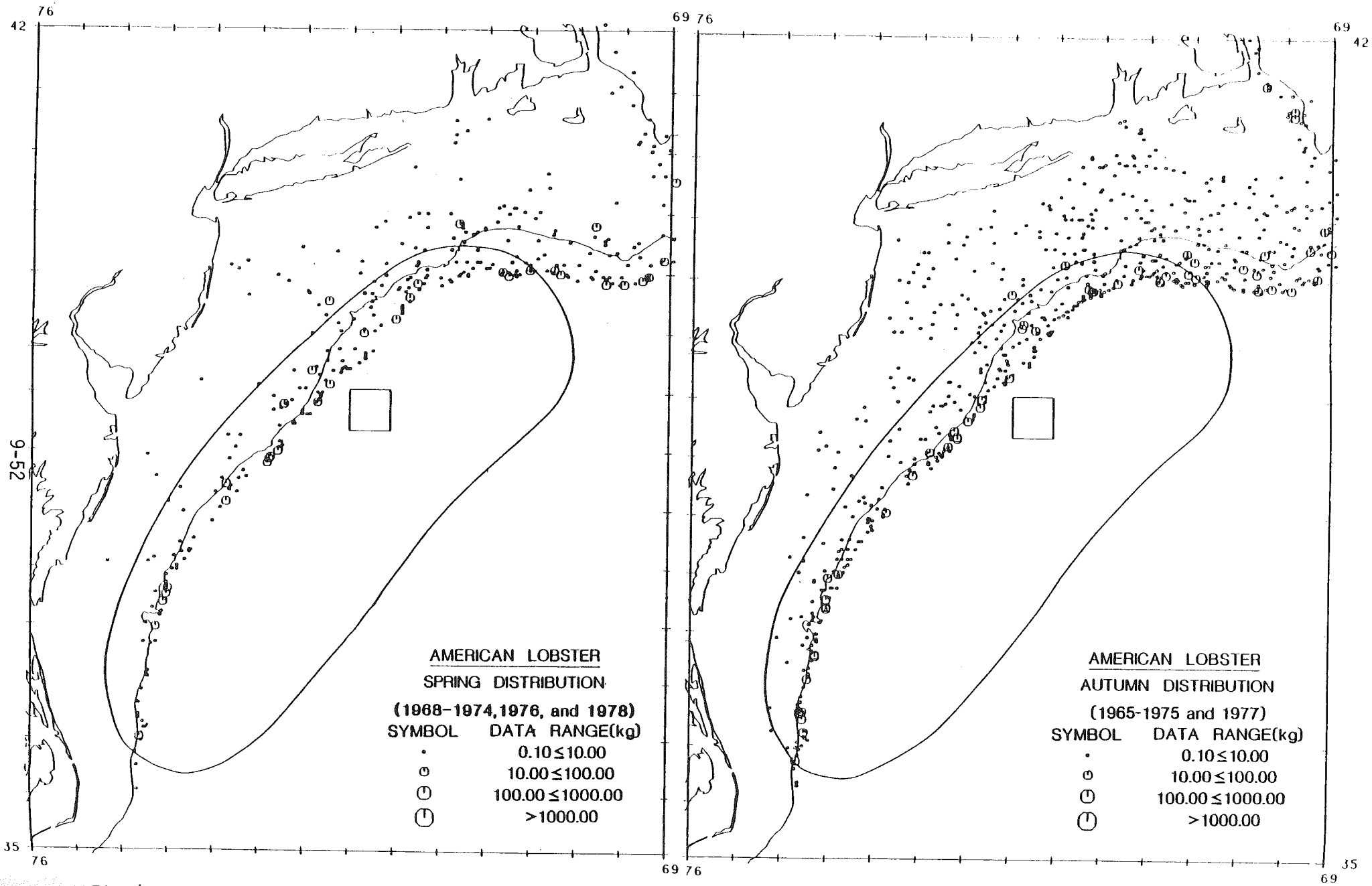


Figure 34.--Spring and autumn cumulative plots for American lobster from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD 106)

Figure 34.--Spring and autumn cumulative plots for American lobster from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

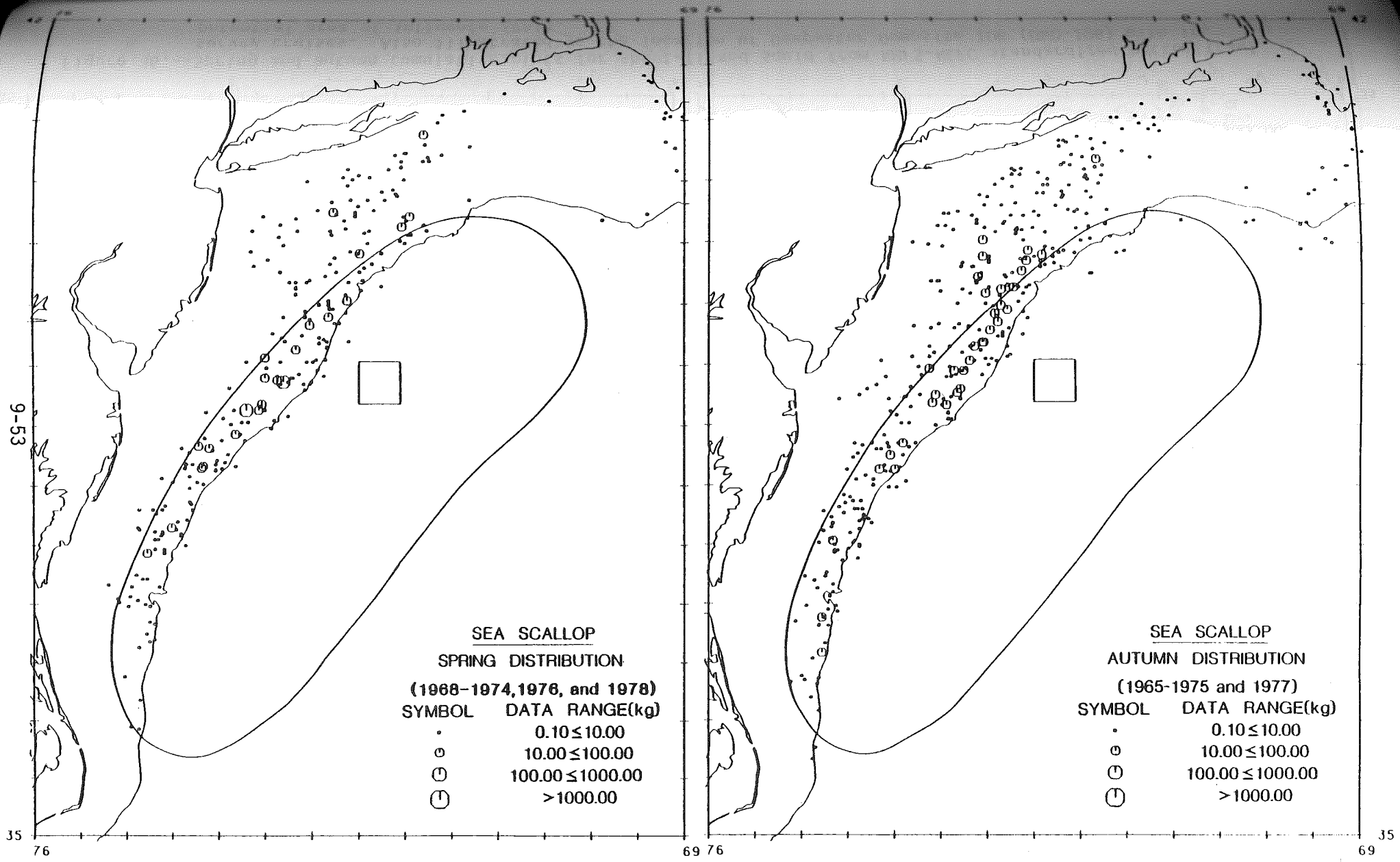


Figure 35.--Spring and autumn cumulative plots for sea scallop from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

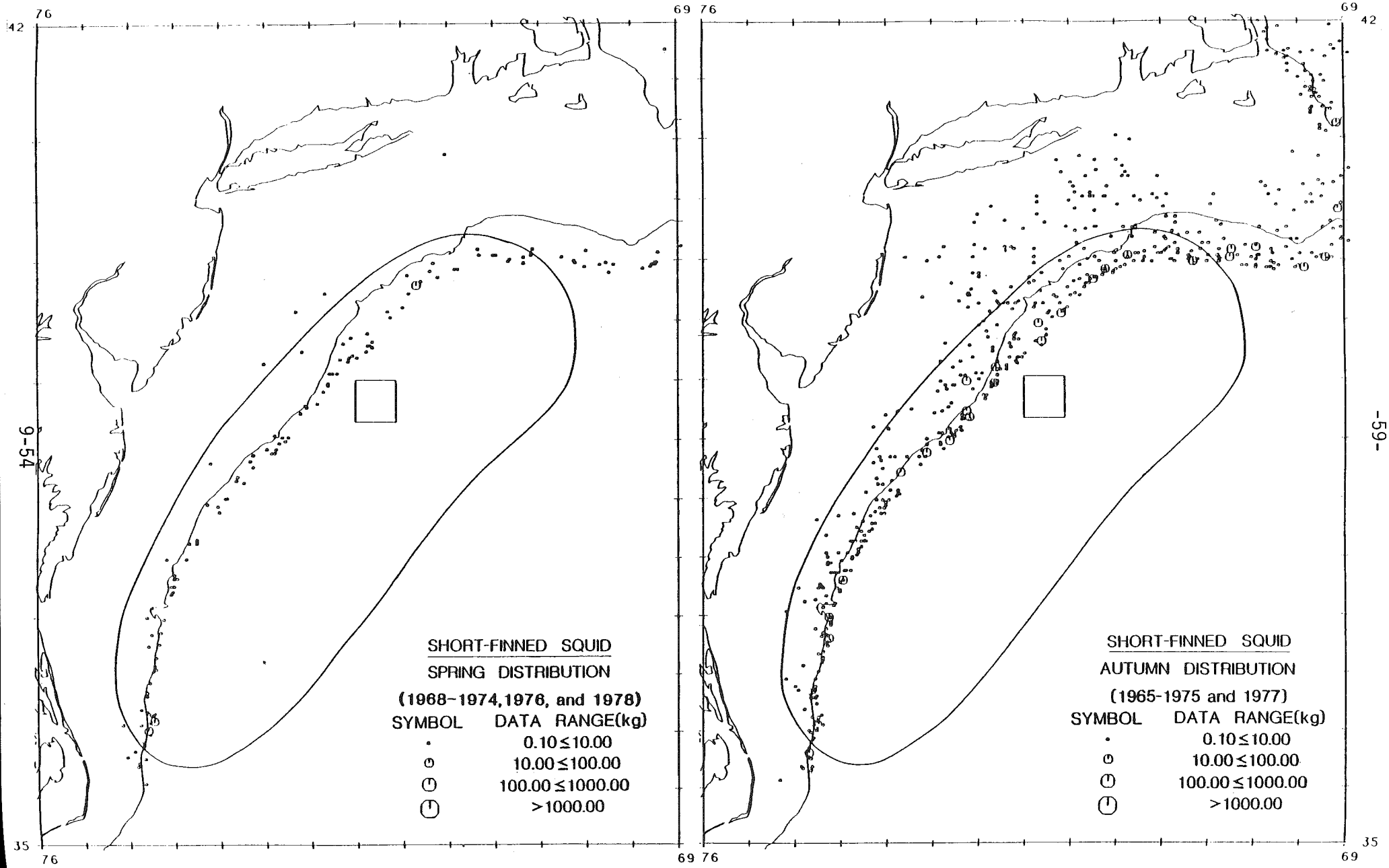


Figure 36.--Spring and autumn cumulative plots for short-finned squid from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

Figure 36.--Spring and autumn cumulative plots for short-finned squid from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

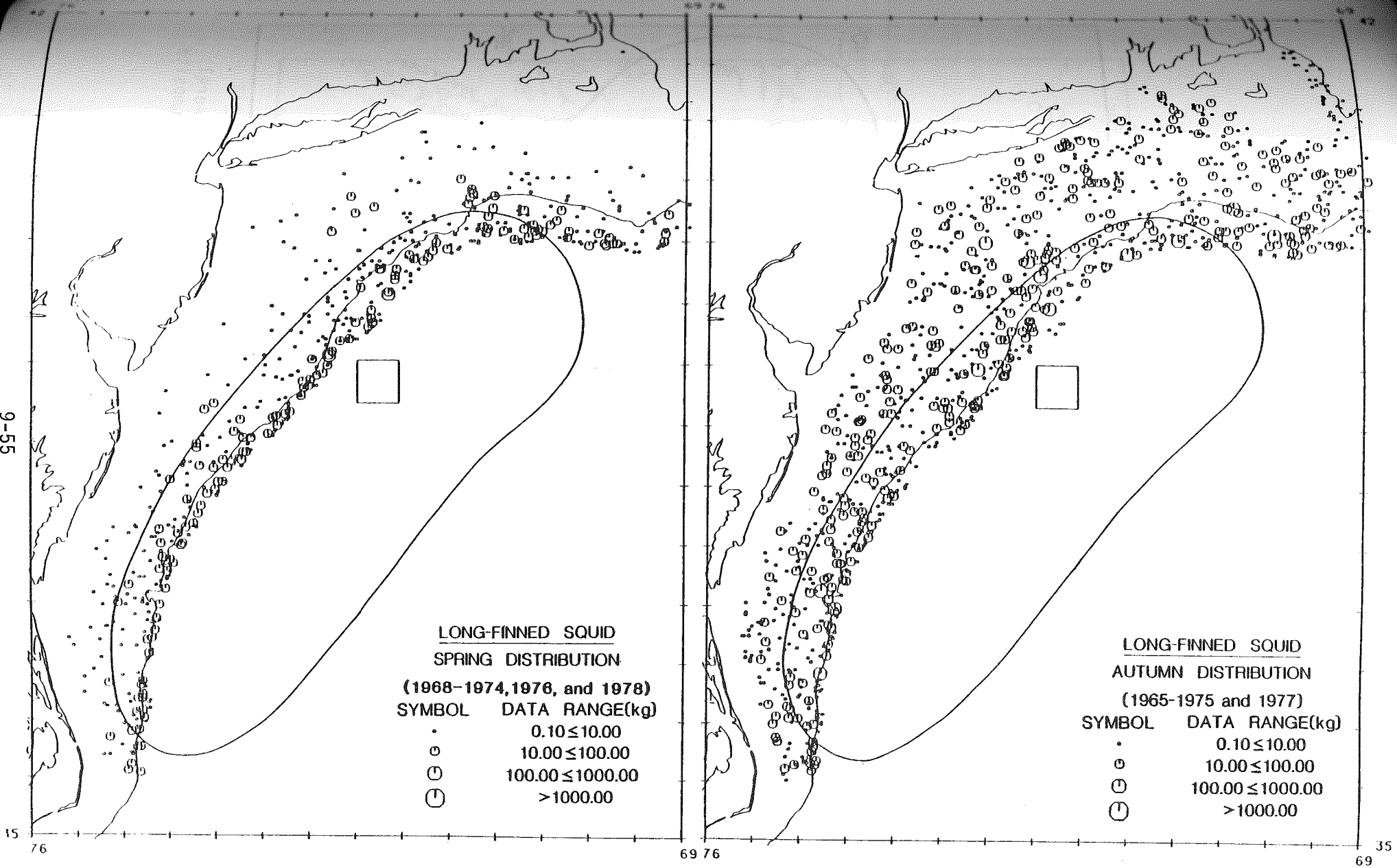


Figure 37.--Spring and autumn cumulative plots for long-finned squid from NMFS-NEFC standardized bottom trawl survey cruises. Also illustrated is the location of Deepwater Dumpsite 106 (DWD-106) with its potential area of influence (PAI).

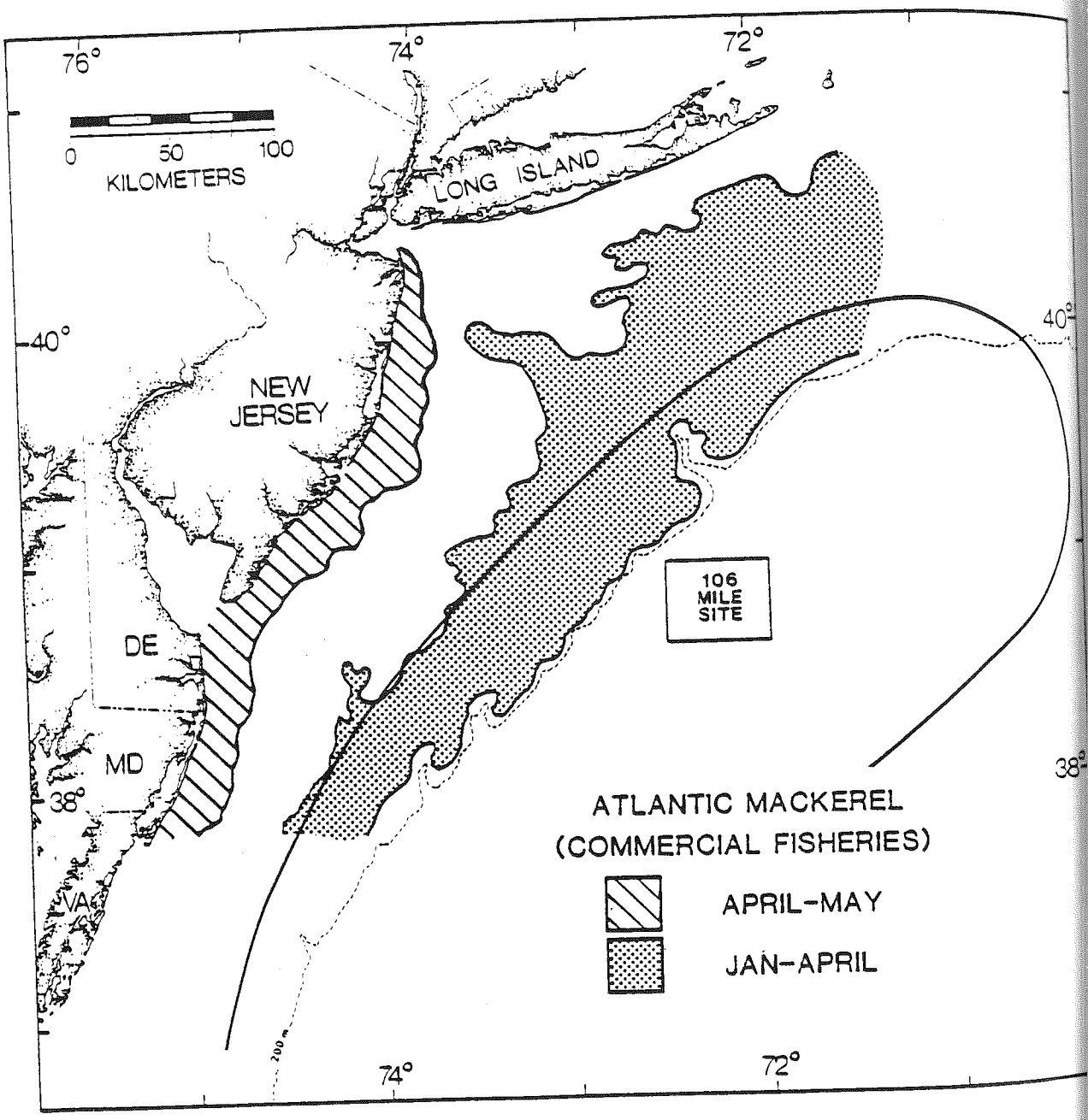


Figure 38.--New Jersey's commercial fishing grounds for Atlantic mackerel (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

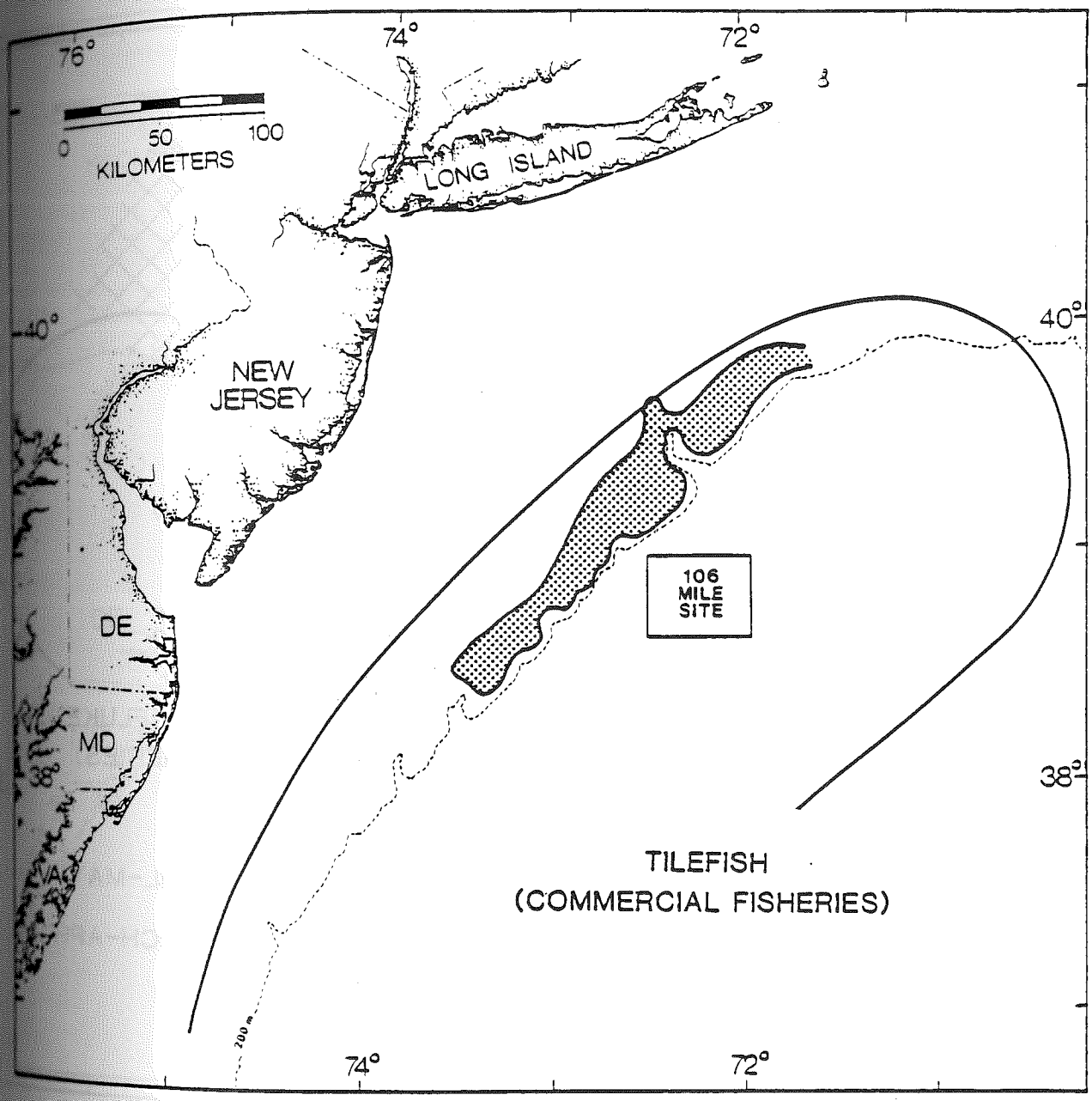


Figure 39.--New Jersey's commercial fishing grounds for tilefish (Long and Figley 1981) including location of Deepwater Dumpsite 106 and its potential area of influence (PAI).

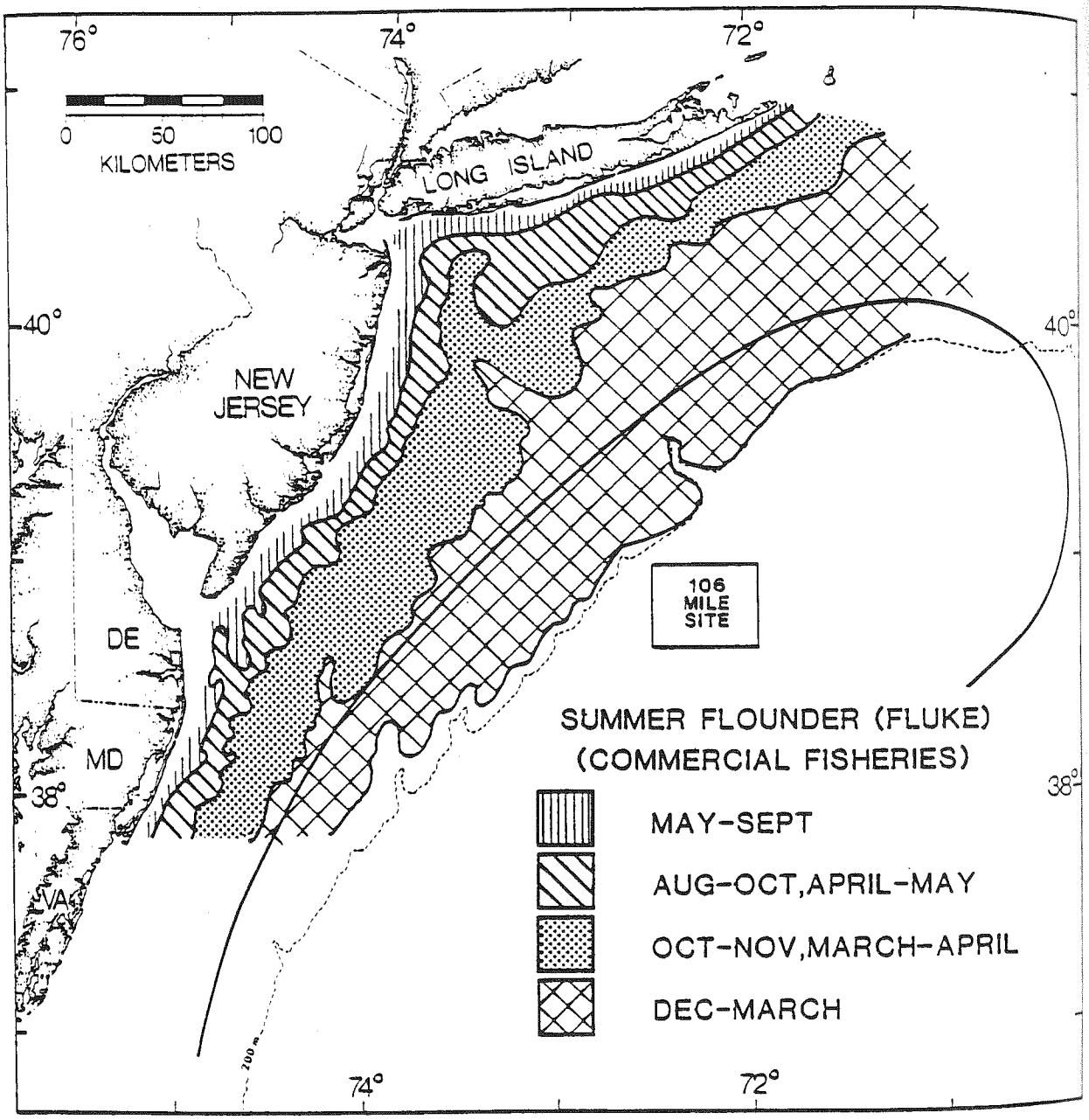


Figure 40.--New Jersey's commercial fishing grounds for summer flounder (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

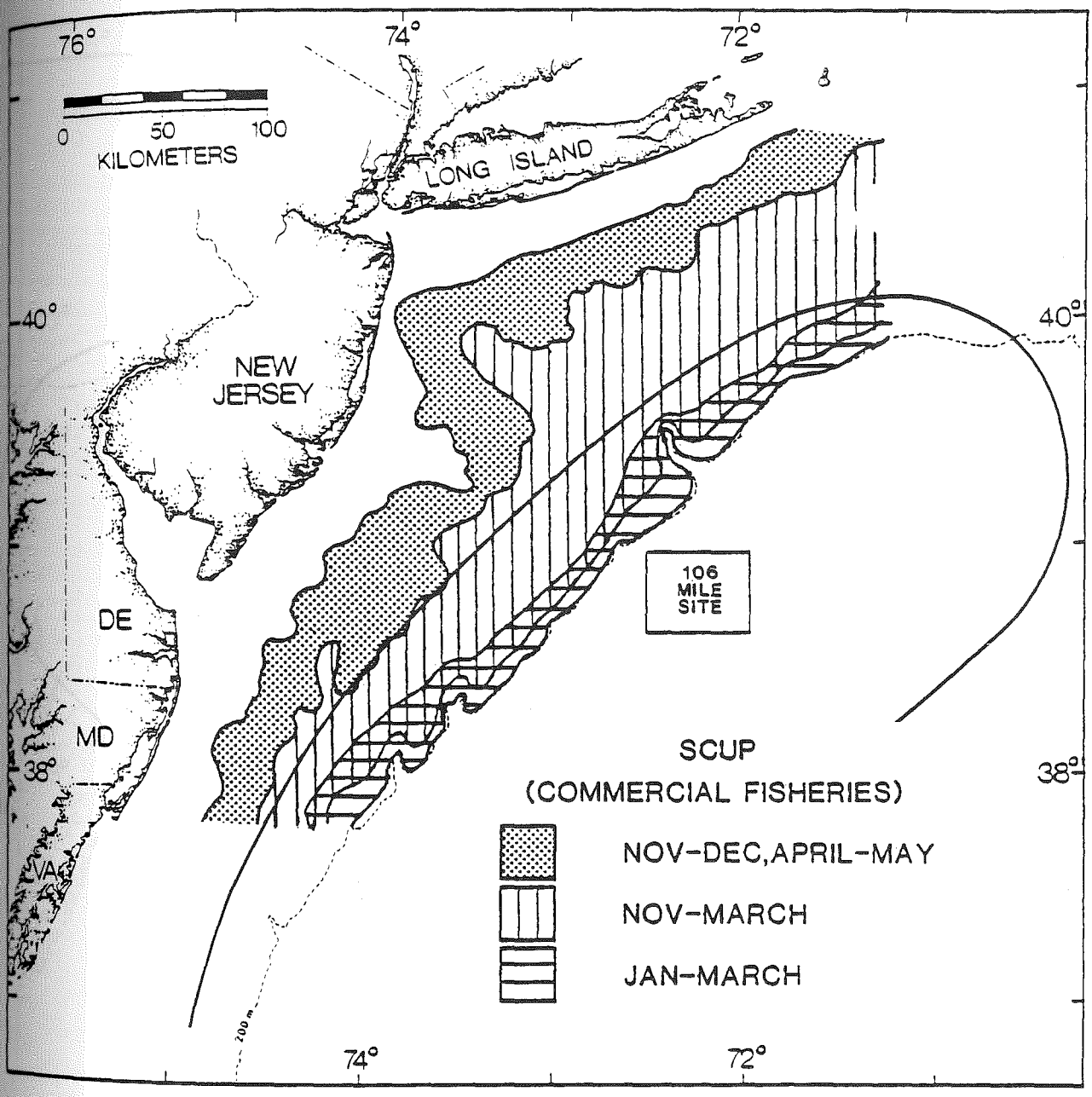


Figure 41.--New Jersey's commercial fishing grounds for scup (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

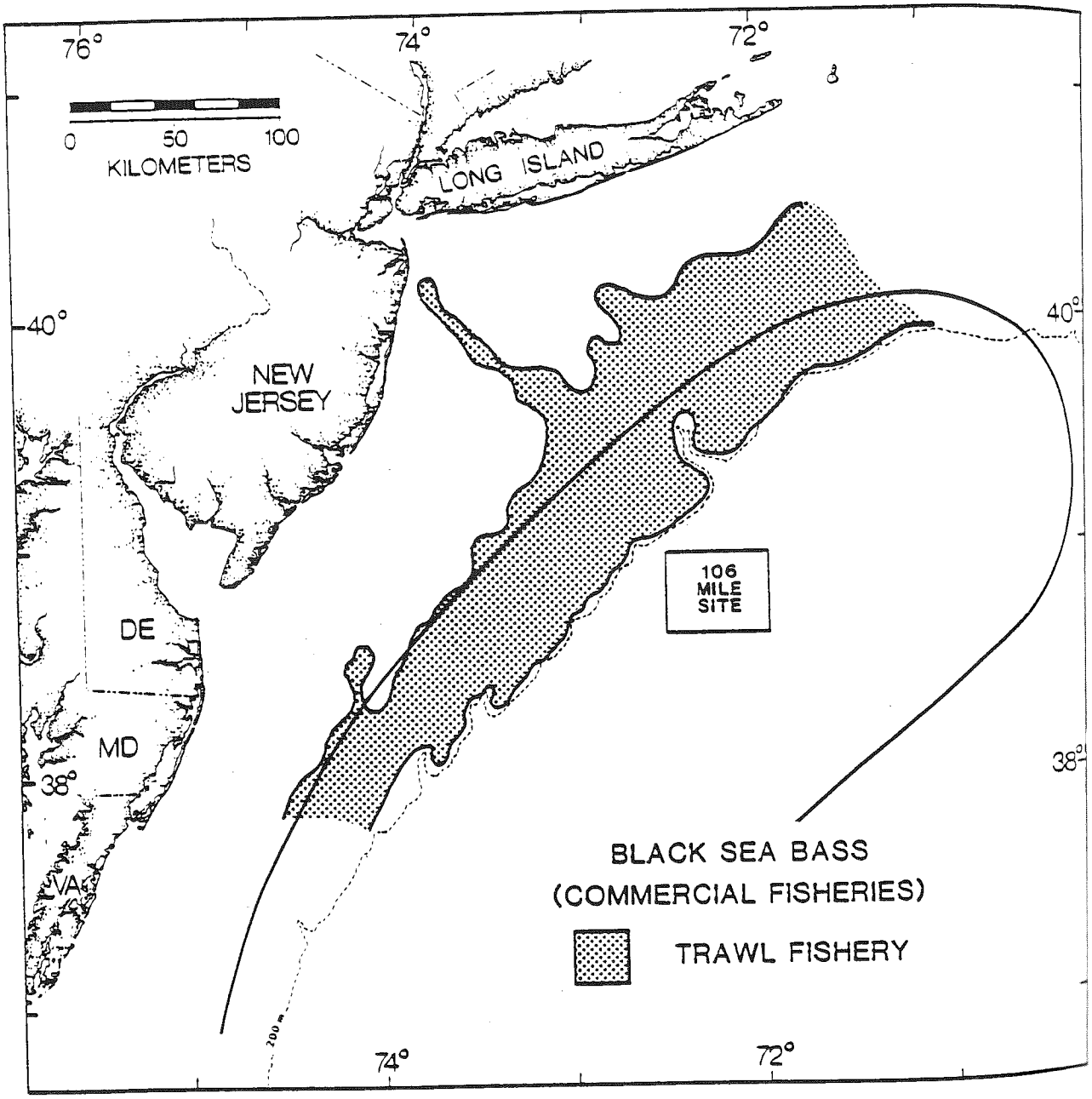


Figure 42.--New Jersey's commercial fishing grounds for black sea bass (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

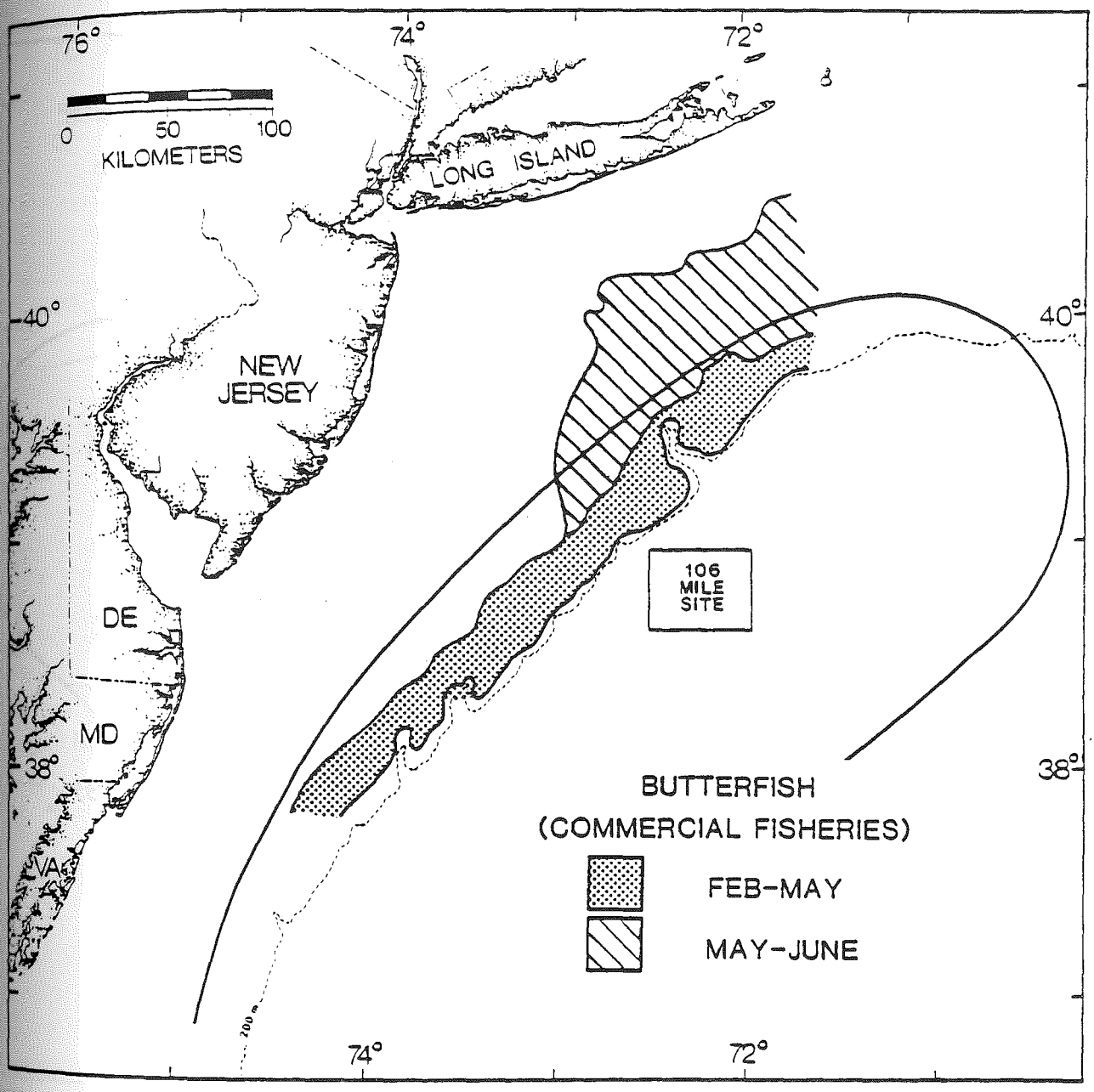


Figure 43.--New Jersey's commercial fishing grounds for butterfish (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

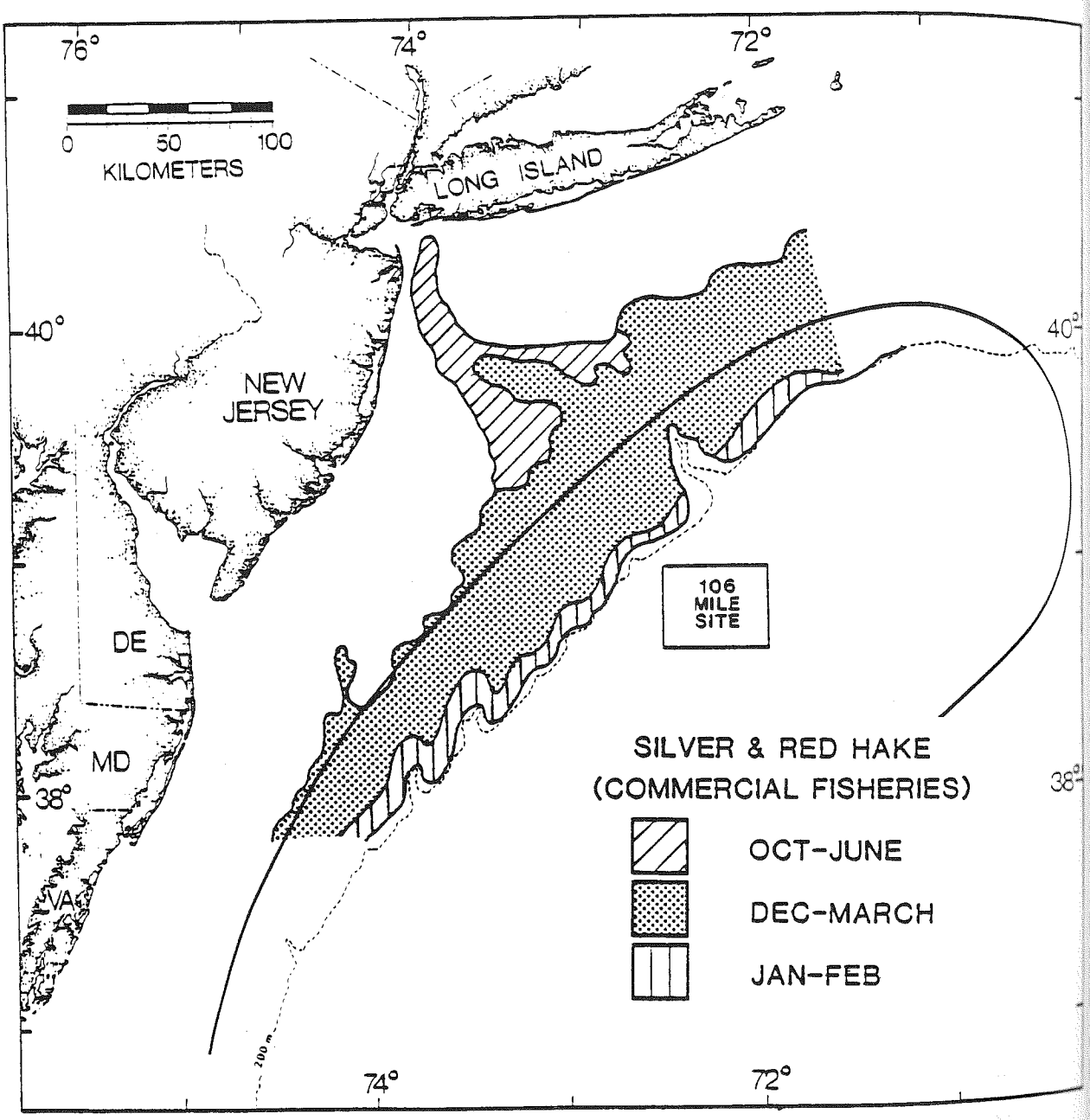


Figure 44.--New Jersey's commercial fishing grounds for silver and red hake (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

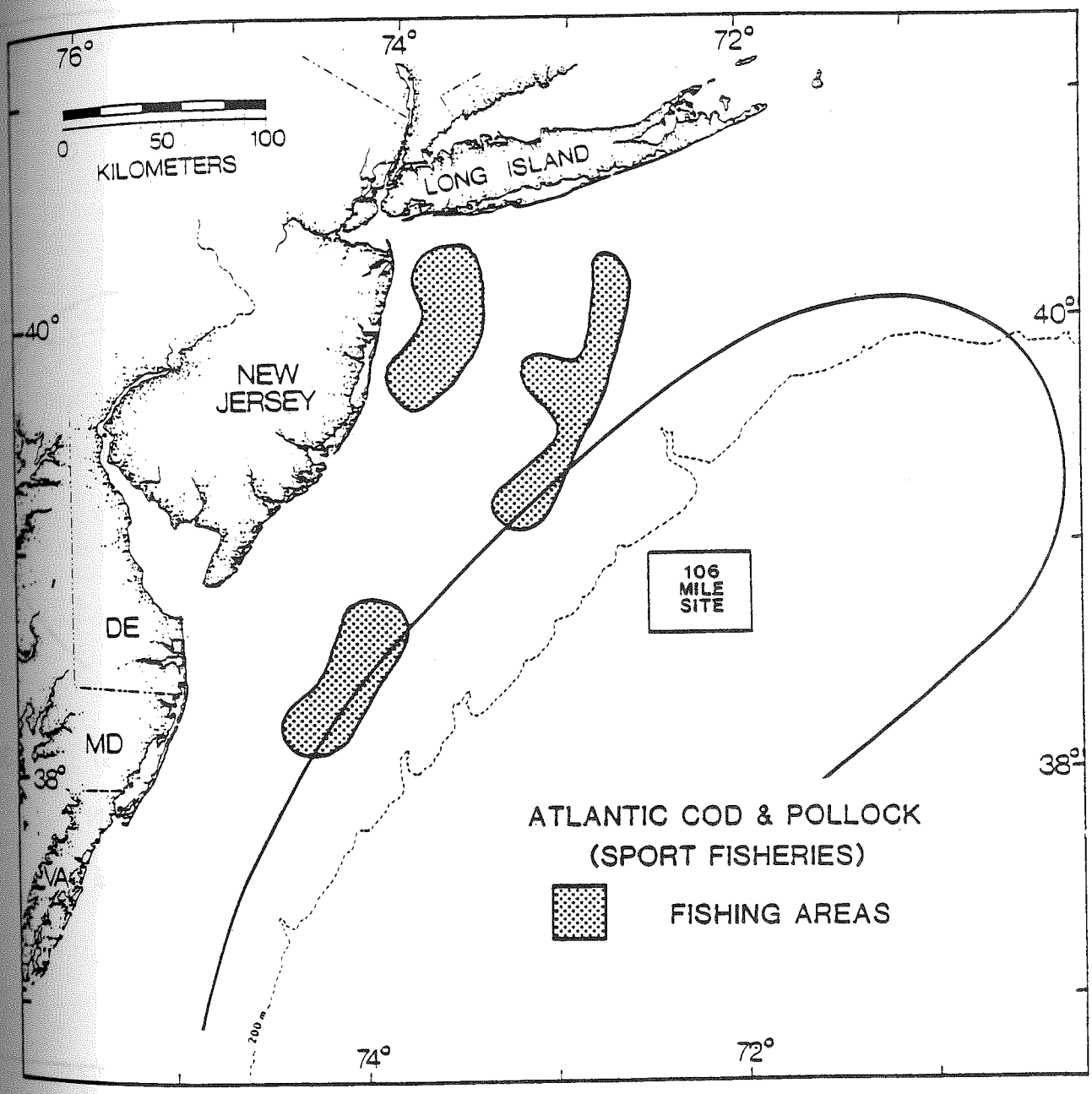


Figure 45.--New Jersey's recreational fishing grounds for Atlantic cod and pollock (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

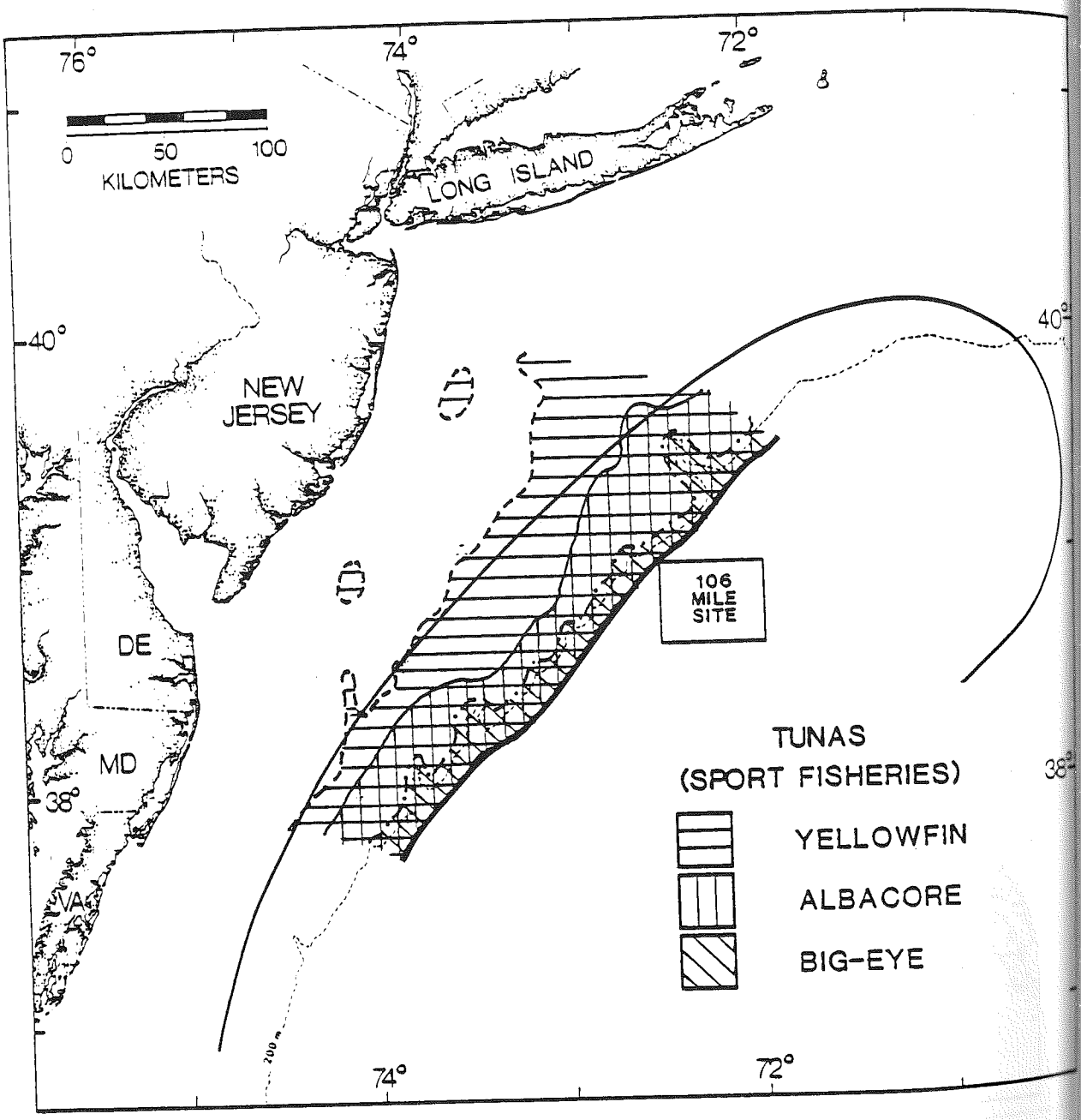


Figure 46.--New Jersey's recreational fishing grounds for tunas (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

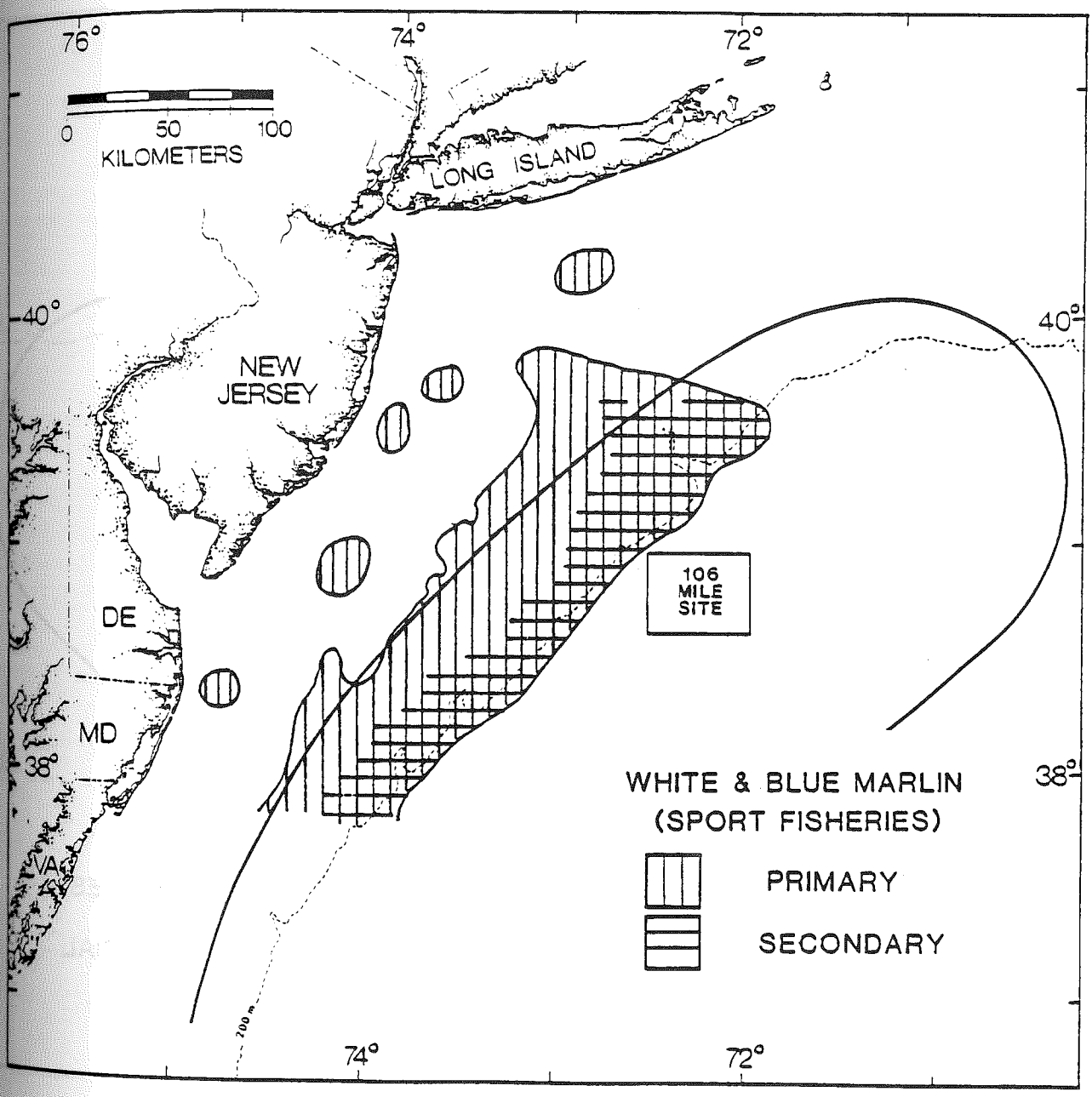


Figure 47.--New Jersey's recreational fishing grounds for white and blue marlin (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

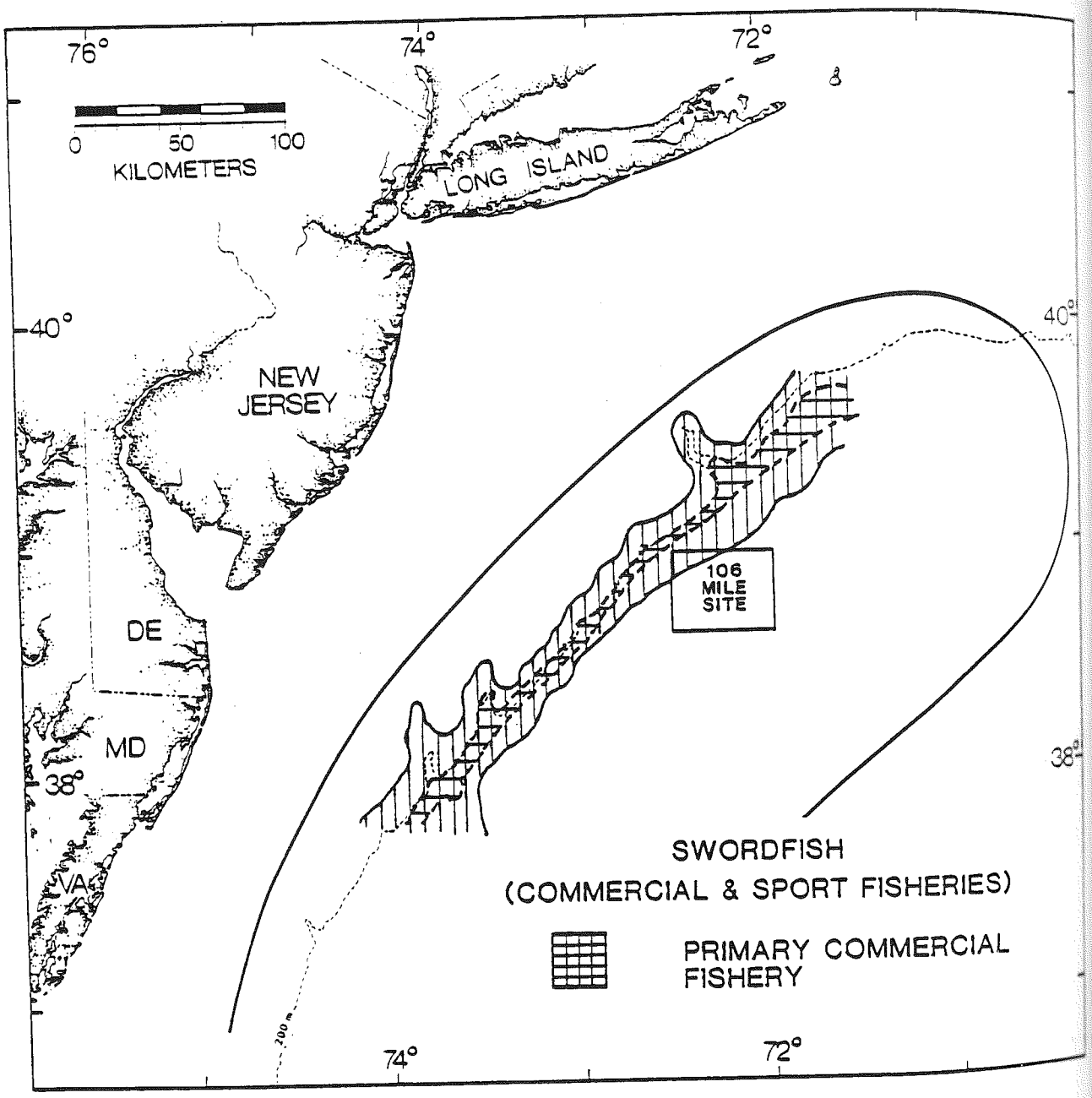


Figure 48.--New Jersey's commercial and recreational fishing grounds for swordfish (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

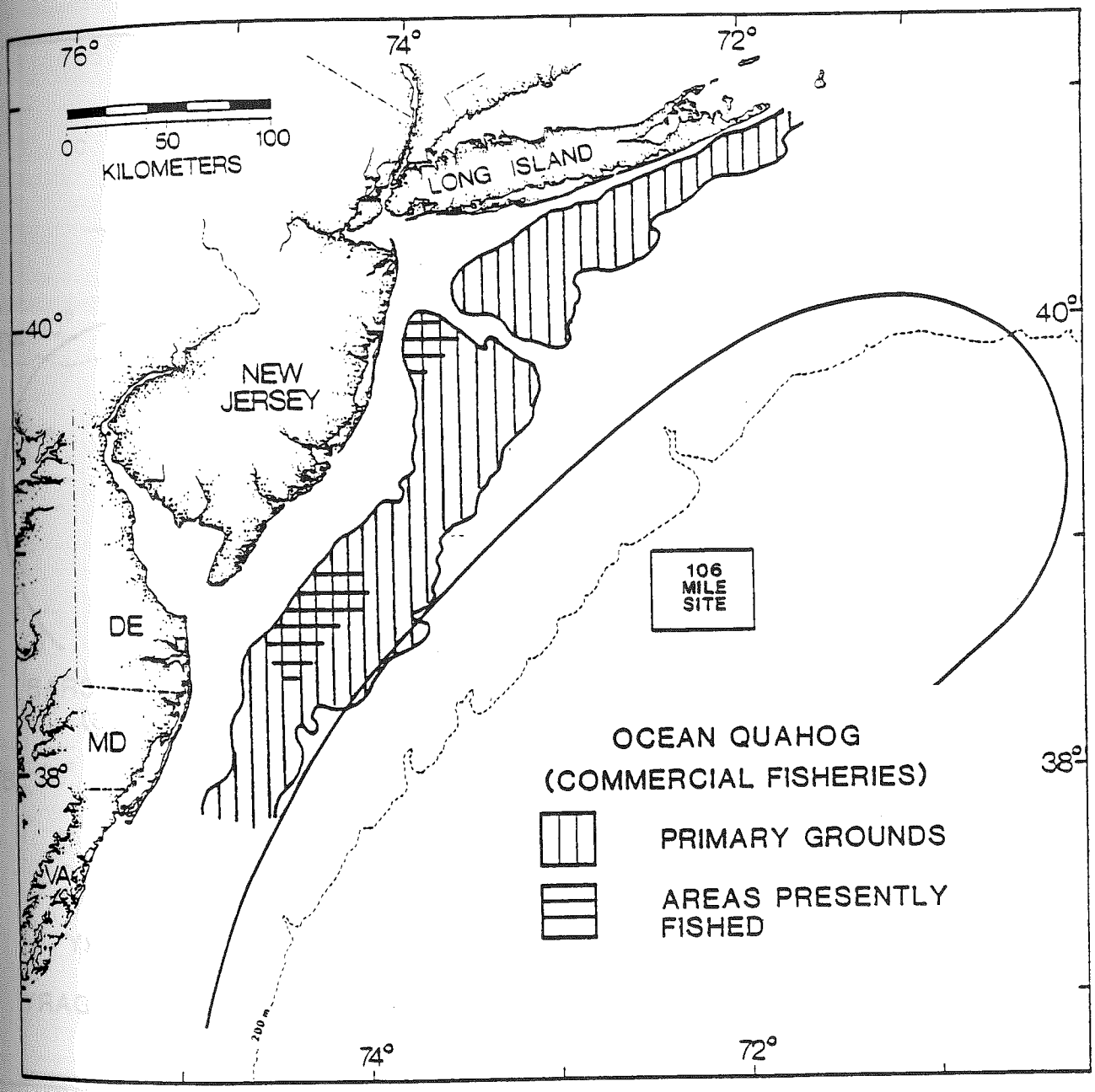


Figure 49.--New Jersey's commercial fishing grounds for ocean quahog (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

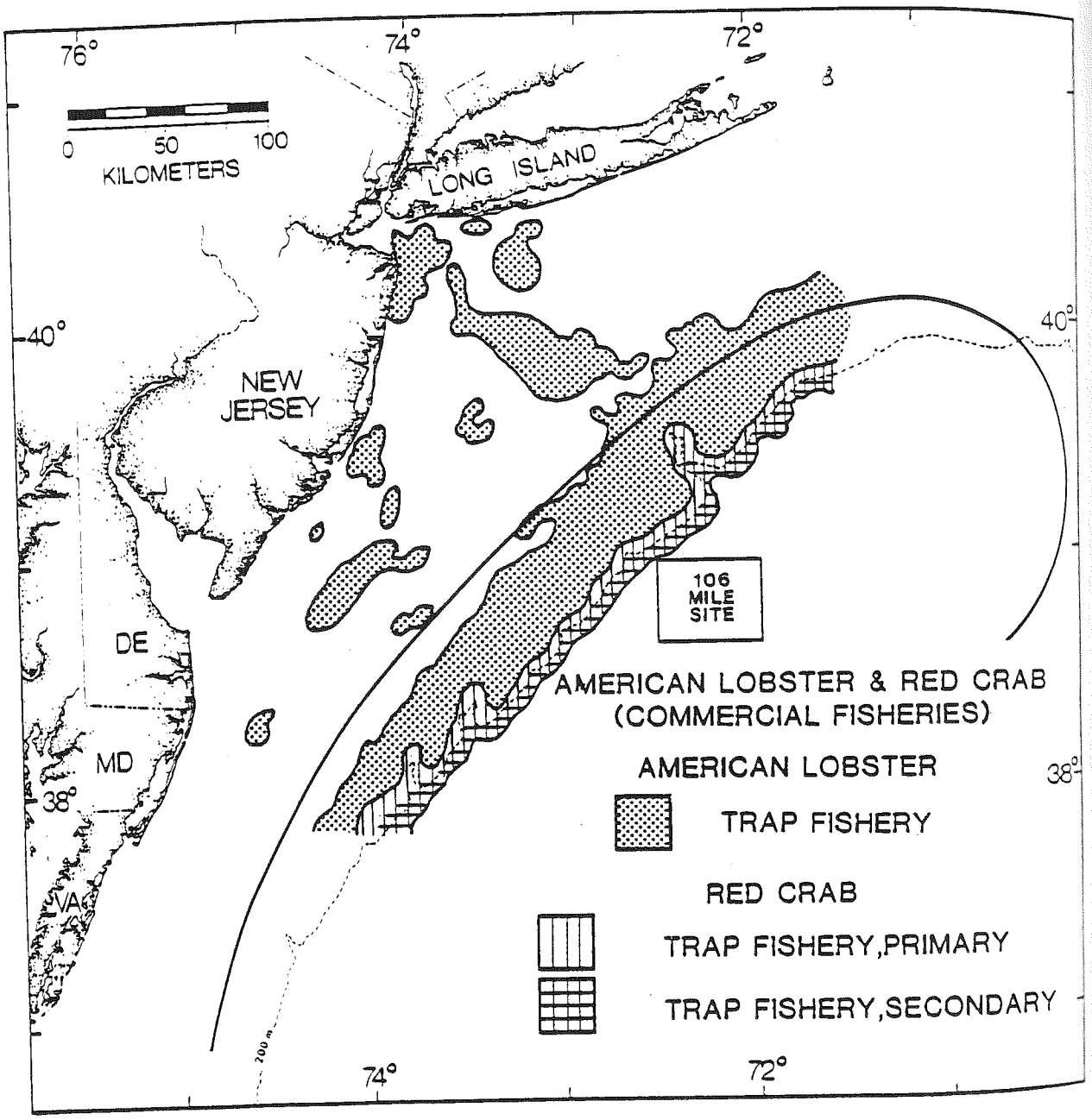


Figure 50.--New Jersey's commercial fishing grounds for American lobster and red crab (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

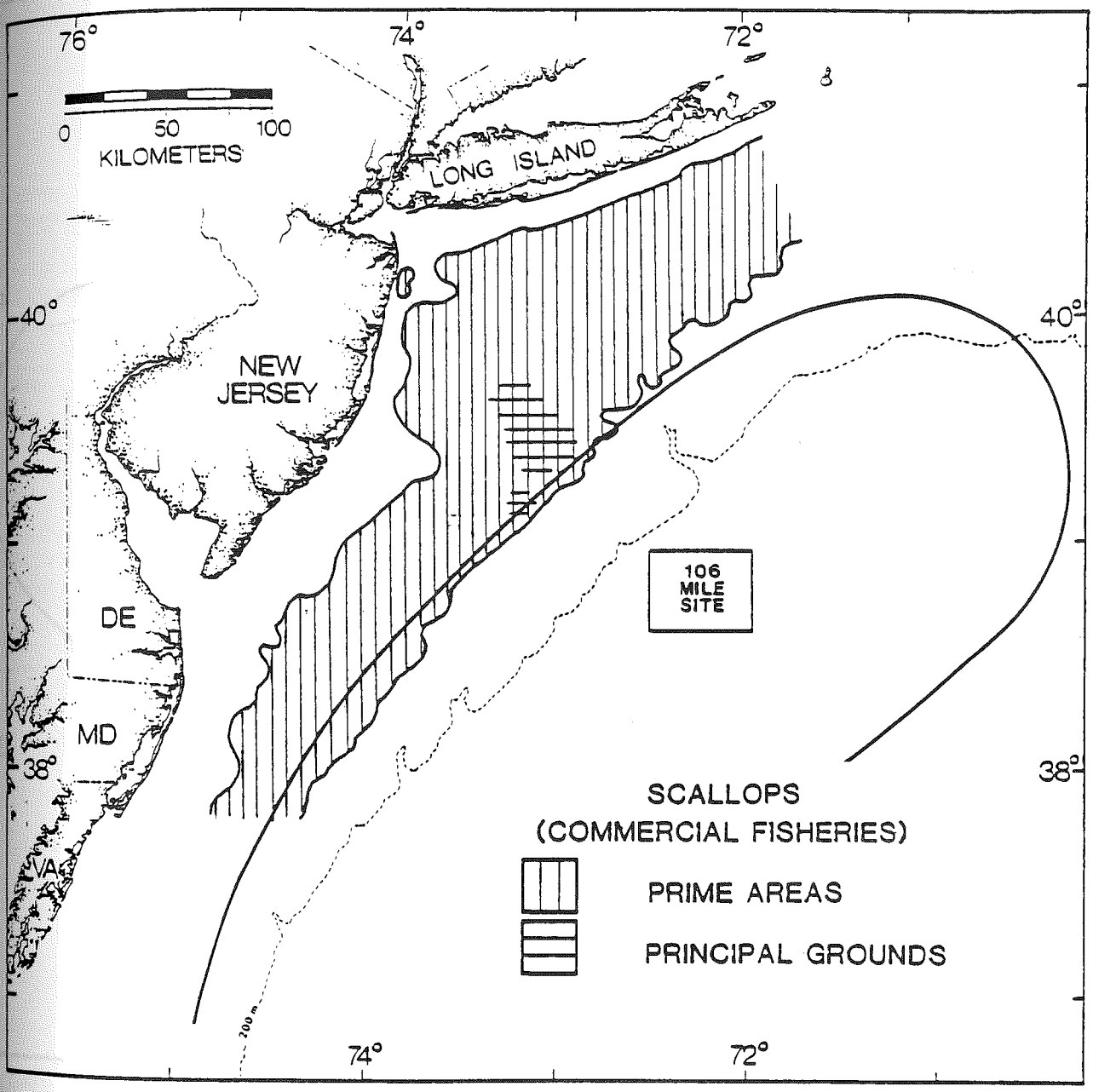


Figure 51.--New Jersey's commercial fishing grounds for scallops (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

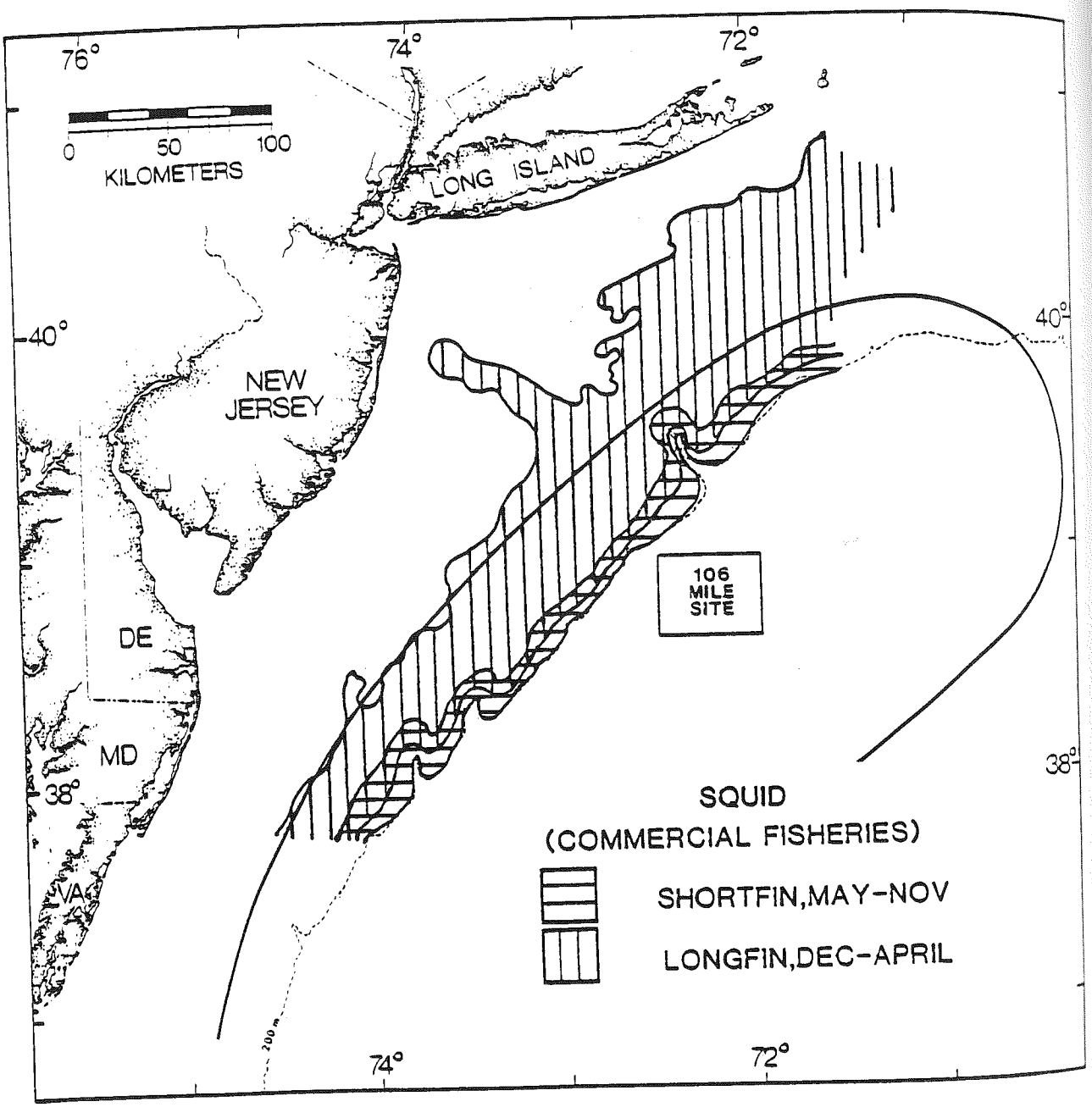


Figure 52.--New Jersey's commercial fishing grounds for squid species (Long and Figley 1981) including location of Deepwater Dumpsite 106 (DWD-106) and its potential area of influence (PAI).

Table 1.--Commercial landings and values by state and year for the potential area influenced (PAI) by Deepwater Dumpsite 106 (DWD-106), 1968-1980. Landings are expressed in weight (mt) and value in thousands of dollars. A dash (-) indicates no data reported.

Year	Massachusetts		Rhode Island		New York		New Jersey		Delaware		Maryland		Virginia		Total	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value
1968	3,451	2,971	-	-	-	-	-	-	-	-	-	-	-	-	3,451	2,971
1969	2,435	1,451	-	-	-	-	-	-	-	-	-	-	-	-	2,435	1,451
1970	1,589	746	-	-	-	-	-	-	-	-	-	-	-	-	1,589	746
1971	585	404	-	-	-	-	-	-	-	-	-	-	-	-	585	404
1972	920	1,858	1,161	668	118	412	-	-	4	3	117	66	-	-	2,319	3,007
1973	1,325	1,628	2,559	1,128	191	690	4,761	1,498	17	10	167	93	630	949	9,650	5,996
1974	932	2,642	135	78	173	707	2,439	1,778	21	15	209	111	1,366	1,885	5,275	7,216
1975	1,051	3,196	1,565	944	33	82	4,569	2,503	35	27	349	159	1,606	2,377	9,208	9,288
1976	1,909	5,856	1,828	2,070	508	1,015	3,364	5,626	64	38	383	227	1,792	3,982	9,848	18,814
1977	1,416	3,357	2,412	2,242	546	793	7,558	6,417	30	22	653	500	2,042	4,187	14,657	17,518
1978	1,547	5,832	1,924	2,062	500	1,083	7,613	9,744	26	31	1,171	793	3,562	19,636	16,343	39,181
1979	940	1,641	1,921	1,448	833	1,589	6,047	9,503	19	29	2,627	1,872	4,320	10,763	16,707	26,845
1980	1,108	1,443	1,623	1,627	641	1,372	5,640	8,195	22	43	3,698	2,482	3,737	12,394	16,469	27,556

Table 2.--Commercial landings and values by year and statistical reporting area for the potential area influenced (PAI) by Deepwater Dumpsite 106 (DWD-106), 1968-1980; including percent of each area occupied by the PAI. Landings are expressed in weight (mt) and value in thousands of dollars. A dash (-) indicates no data reported and an asterisk (*) less than 0.5 mt and/or 500 dollars.

Statistical Reporting Area	Percent of Area in PAI	1968		1969		1970		1971		1972		1973		1974		1975		1976		1977		1978		1979		1980	
		Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value
534	71	-	-	-	-	-	-	-	-	-	-	-	-	1	*	-	-	79	45			2	4	-		86	81
537	14	2,301	190	1,551	213	1,394	176	495	95	1,403	678	1,978	678	355	1,056	1,619	954	993	887	1,403	1,035	2,125	1,639	2,264	1,663	2,636	1,000
615	20	92	213	29	64	9	24	3	9	63	195	1,837	430	393	492	676	907	564	1,383	657	1,087	301	8,215	440	2,496	467	2,390
616	84	833	2,007	626	661	150	439	86	300	477	1,001	889	1,464	1,126	2,275	1,169	2,891	3,115	9,416	3,245	5,692	3,296	7,591	2,272	8,563	2,401	4,918
621	20	48	121	13	31	*	1	-	-	131	118	2,818	689	1,544	666	2,818	1,054	2,456	1,375	3,395	1,311	3,679	3,521	3,766	3,065	3,656	2,795
622	70	131	316	193	427	34	100	-	-	*	*	673	537	402	1,014	1,642	2,206	1,053	2,314	1,812	2,990	1,669	4,241	1,422	1,450	1,724	7,053
623	100	41	110	5	12	-	-	-	-	-	-	-	-	-	-	-	-	32	97	-	-	28	122	1	2	5	10
624	87	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-		
626	71	5	14	17	43	2	6	-	-	237	988	700	1,288	752	908	718	858	1,433	3,116	3,194	4,595	4,335	11,140	5,370	7,377	4,679	7,194
627	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	7	2	20	10	11	322				
628	75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
629	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
632	100	-	-	-	-	-	-	-	-	6	27	750	906	693	779	564	418	115	177	926	786	816	2,303	1,095	2,004	810	1,198
633	13	-	-	-	-	-	-	-	-	-	-	-	-	2	6	-	-	1	1	-		*	1	-	-		
636	24	-	-	-	-	-	-	-	-	-	-	6	2	6	20	-	-	*	*	5	15	2	1	68	227	6	71
TOTAL		3,451	2,971	2,434	1,451	1,589	746	584	404	2,319	3,007	9,652	5,995	5,274	7,216	9,207	9,290	9,848	18,813	14,657	17,521	16,344	39,180	16,706	26,847	16,470	27,550

Table 3.--Commercial landings and value by year and dominant species for the potential area influenced (PAI) by Deepwater Dumpsite 106 (DWD-106), 1972-1980. Landings are expressed in weight (mt) and value in thousands of dollars. A dash (-) indicates no data reported and an asterisk (*) less than 0.5 mt and/or 500 dollars.

GROUP/Species	1972		1973		1974		1975		1976		1977		1978		1979		1980	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value	Weight	Value
FINFISH																		
Dogfish	1	*	2	*	2	*	1	*	4	1	2	1	4	2	102	20	142	29
Conger eel	*	*	2	1	-	-	4	2	3	1	7	2	8	4	3	1	11	6
Atlantic herring	1	*	122	7	28	2	433	28	7	1	4	*	15	2	4	1	4	*
Goosefish	*	*	1	*	*	*	3	1	4	2	48	26	125	61	255	173	279	237
Atlantic cod	78	26	112	46	91	36	68	45	30	23	76	34	190	105	46	34	61	52
Silver hake	184	37	205	207	147	18	272	60	192	34	578	149	180	57	480	198	475	186
Red hake	12	1	43	5	22	2	37	5	44	5	37	9	53	9	104	32	78	18
White hake	13	2	21	6	18	8	15	5	12	6	5	2	4	2	-	-	3	1
Black sea bass	26	17	498	234	331	208	685	365	416	270	1,088	530	419	349	514	564	391	554
Tilefish	1	*	9	5	287	191	53	36	527	517	867	884	934	1,118	746	992	844	1,515
Bluefish	5	1	27	5	52	10	66	18	75	17	93	22	87	22	102	26	74	16
Scup	47	27	764	343	727	222	1,456	707	830	377	1,691	738	2,225	938	1,571	1,040	4,527	1,007
Weakfish	25	5	213	28	216	47	756	75	461	79	330	83	319	109	517	156	496	173
Atlantic croaker	*	*	7	3	20	6	141	24	158	34	1,331	47	120	56	28	29	2	2
Atlantic mackerel	14	12	148	44	68	17	174	36	103	25	167	33	255	54	222	91	232	46
Skipjack tuna	-	-	-	-	-	-	1	*	-	-	15	8	-	-	97	75	51	60
Bluefin tuna	28	9	*	*	97	58	*	*	211	147	185	126	86	79	2	4	3	10
Swordfish	7	20	24	68	31	94	295	287	32	114	24	100	172	504	100	351	253	1,062
Butterfish	27	7	140	62	99	34	270	136	127	86	185	89	501	1,027	354	293	601	408
Summer flounder	47	46	615	491	662	478	1,195	954	2,724	2,895	1,670	2,006	1,711	2,427	2,822	3,601	2,184	2,570
Windowpane	1	*	1	*	28	15	36	15	15	8	18	9	40	19	28	15	16	5
Witch flounder	6	3	12	6	11	6	5	3	7	4	6	4	10	7	12	8	8	5
Yellowtail flounder	524	117	459	200	183	113	135	106	58	63	153	16	121	152	310	315	201	203
Winter flounder	83	34	131	64	2	1	70	41	34	27	559	587	149	130	162	117	173	116
INVERTEBRATES																		
Ocean quahogs	-	-	-	-	-	-	-	-	217	140	665	438	2,305	453	4,364	2,728	4,570	3,025
Jonah crab	-	-	-	-	18	10	17	10	46	30	19	13	19	6	26	11	26	16
Red crab	*	*	6	1	8	2	44	26	150	92	468	332	200	165	443	334	897	798
Rock crab	2	1	45	7	120	14	24	6	25	4	4	1	22	4	22	7	2	*
American lobster	330	868	471	1,666	499	1,900	643	2,700	446	1,635	1,332	1,897	317	1,258	2,472	1,797	319	1,771
Scallops	365	1,630	453	1,579	766	2,456	978	3,947	2,613	9,736	2,584	8,783	4,100	23,204	2,083	14,420	1,576	13,421
Conch	10	4	25	16	18	11	19	10	1	*	13	10	21	23	16	11	5	4
Squid spp.	47	114	179	84	213	83	205	85	284	119	156	137	129	137	260	221	239	159
MISCELLANEOUS																		
Bait and pet food	469	8	902	32	47	2	299	6	189	5	401	13	35	*	679	21	139	5

Table 4.--Observed Japanese longline catch per unit of effort (CPUE) by species and species group expressed in numbers per 10,000 hooks from Fishing Zone 16, 1978-1981. A dash (-) indicates no data and an asterisk (*) less than 0.01 CPUE.

GROUP/Species	CPUE (no./10,000 hooks) 1978	1979	1980	1981	1978-1981
TUNAS					
Bluefin	0.27	0.84	2.43	2.73	2.24
Bigeye	91.39	52.20	84.23	66.79	71.96
Yellowfin	28.66	50.04	34.16	15.43	24.25
Skipjack	0.15	1.18	0.10	0.07	0.19
Albacore	38.94	96.75	57.16	35.05	46.21
Blackfin	0.73	-	0.02	0.26	0.23
Little	0.04	-	0.09	0.02	0.04
Atlantic bonito	-	-	0.14	0.01	0.04
Uncl. tuna	-	0.13	0.10	0.38	0.25
TOTAL	160.18	201.14	178.43	120.74	145.41
BILLFISHES					
Blue marlin	0.89	0.51	0.28	0.28	0.36
White marlin	1.47	8.74	2.60	3.07	3.33
Sailfish	0.08	0.08	-	0.01	0.02
Spearfish	0.12	0.17	0.19	0.13	0.14
Swordfish	17.11	9.84	10.60	8.42	9.93
Uncl. billfish	0.19	-	0.02	0.07	0.07
TOTAL	19.86	19.34	13.69	11.98	13.85
SHARKS AND RAYS					
Silky	0.08	-	-	0.02	0.02
Blacktip	-	0.04	-	0.01	0.01
Whitetip	0.27	0.04	0.09	0.03	0.07
Dusky	0.27	2.96	0.05	0.20	0.43
Blue	77.76	132.05	85.59	57.10	72.67
Tiger	2.59	0.04	0.10	0.01	0.29
Hammerhead	0.15	0.30	0.41	0.38	0.36
Porbeagle	0.04	-	0.10	0.13	0.11
Brown	0.12	-	0.02	-	0.02
White	-	1.39	0.38	0.12	0.29
Uncl. dogfish	0.04	-	-	-	*
Bignose	0.04	0.08	0.03	-	0.02
Lemon	0.04	-	0.03	-	0.01
Shortfin mako	0.12	-	1.89	2.03	1.62
Longfin mako	0.15	-	0.15	0.17	0.15
Uncl. mako	2.47	6.55	1.60	0.37	1.44
Bigeye thresher	0.39	-	0.15	0.78	0.05
Uncl. thresher	0.50	0.89	0.43	0.43	0.48
Atlantic sharpnose	-	-	-	-	*

Table 4.--(continued)

GROUP/Species	CPUE (no./10,000 hooks) 1978	1979	1980	1981	1978-1981
SHARKS AND RAYS (cont.)					
Bull	-	-	-	-	0.01
Seven gill	-	-	-	-	0.02
Uncl. sharks	4.48	7.52	1.53	4.61	4.17
Uncl. stingrays	29.67	36.91	25.56	4.84	15.03
Manta ray	-	0.13	-	0.11	0.08
TOTAL	119.18	188.90	118.11	71.36	97.37
OTHER FINFISH					
Uncl. dolphin	0.19	0.25	0.28	0.11	0.17
Wahoo	0.12	0.46	0.26	0.05	0.14
King mackerel	0.50	0.21	0.29	0.03	0.16
Lancetfish	27.93	61.06	74.21	65.70	63.45
Oilfish	11.24	8.87	8.43	0.68	4.27
Ocean sunfish	1.24	1.35	1.51	4.25	3.06
Multicolored opah	4.09	1.86	1.76	0.54	1.30
Barracuda	0.04	-	-	0.02	0.02
Uncl. eel	0.08	-	0.02	0.01	0.02
Amberjack	-	0.25	-	-	0.02
Bigscale pomfret	0.66	3.25	0.69	0.29	0.69
Frigate mackerel	-	-	-	0.01	*
Jack crevale	0.04	-	-	-	*
Escolar	-	0.04	-	0.01	0.01
Uncl. puffer	-	-	0.07	-	0.02
Remora	-	-	-	0.03	0.02
Uncl. finfish	1.62	3.04	4.75	1.47	2.38
TOTAL	47.75	80.64	92.27	73.20	75.75
GRAND TOTAL	346.97	490.02	402.59	277.28	332.38

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Chapter 10. DEMERSAL FISH SPECIES GROUPS

S. J. Wilk, D. E. Ralph, and A. C. Morris[1]

10.1 INTRODUCTION.

The Sandy Hook Laboratory of the National Marine Fisheries Service conducted a systematic bottom trawl survey between June 1974 and June 1975 of fishes and selected invertebrates occurring in the New York Bight. This study was designed to provide a comprehensive individual species life history as well as a community structure data base necessary for current and anticipated research needs. Herein, results relative to the identification of species groups based on recurrent group analysis of bottom trawl survey data are preliminarily summarized. The results of this endeavor, when compared with compatible historical and future data sets, will ultimately contribute a significant portion of the basic material and insight necessary to detect, interpret, and understand natural and/or man-induced changes in species associations and interactions which may occur in the New York Bight and adjacent areas.

10.2 METHODS AND MATERIALS.

10.2.1 Field Collection Methodology.

The New York Bight is herein defined, for purpose of this paper, as that portion of the Atlantic continental shelf between eastern Long Island, New York and Cape May, New Jersey (Figure 1). This study was conducted in the northern section of the New York Bight where the Long Island and New Jersey coastlines are nearly perpendicular. The designated study area was rigidly

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delineated by two sets of imaginary lines and the 28- and 366-m isobaths to facilitate sampling and data handling (Figure 2). The first set of lines extend seaward from points on Long Island and New Jersey to the 28-m isobath; the second set from the 28-m isobath to the edge of the continental shelf (366 m).

Station locations were selected by a stratified random sampling design (Grosslein, 1969, 1974). Strata boundaries were determined by depth, i.e. 0-10, 11-19, 20-28, 29-55, 56-110, 111-183, and 184-366 m (Figure 2). A minimum of two stations per stratum were randomly selected to be sampled during each collecting interval (cruise). Inshore strata (0-28 m) were sampled at a rate of approximately one station per 515 km^2 and offshore strata (29-366 m) at a rate of approximately one station per 1,030 km^2.

Research vessels used during this study were the 47.2-m DELAWARE II and 57.0-m ALBATROSS IV from the National Ocean Survey and the chartered 27.4-m ATLANTIC TWIN. LORAN-A navigation was the principal method used for station positioning. Radar, land ranges, and visual sightings of buoys were used to position vessels on some of the more inshore stations. Fish collections were made with otter trawls towed at approximately 6.5 km/h for 30 min at each station. The trawl used aboard the DELAWARE II was a Yankee No. 36 trawl with a 24.4-m footrope, 18.3-m headrope, and 9.1-m legs. The ALBATROSS IV also used the No. 36 Yankee trawl as well as a No. 41 trawl with a 30.5-m footrope, 24.4-m headrope, and 19.8-m top and 18.3-m bottom legs. The ATLANTIC TWIN used a 3/4 Yankee trawl with a 16.5-m footrope, 11.9-m headrope, 11.6-m legs, and 16.5-m ground cables. All trawls were fitted with 12.7-mm stretch mesh cod end liners. Table 1 lists dates, vessels, number of stations, and gear type for each collecting interval.

At the conclusion of each tow, the trawl was retrieved and emptied onto a sorting table where all fish species were separated and identified. All specimens of each species were weighed to the nearest whole pound and measured in centimeters. All specimens of each species were usually measured except when subsamples of very large catches were measured. In such cases, an expansion factor (weight of total catch/weight of subsample) was applied to the number and length frequency of the total catch. Additional information relative to sampling design and species abundance and distributions as well as associated hydrographic observations are given in Wilk et al. (1977).

Collected data were subsequently recorded on appropriate data processing forms, transferred to punch cards, and incorporated into a data base management system (DBMS) to simplify data recall and analysis.

10.2.2 Recurrent Group Analysis.

A package of computer programs (REGROUP, AFFIN, CONNEX, DOMIN), collectively referred to as recurrent group analysis (RGA), was employed to analyze the aforementioned 11 cruises made over 13 months for species assemblages. Program REGROUP (Fager 1957) uses only qualitative, i.e. presence-absence, data for the determination of recurrent species groups. A recurrent species group (RSG) is defined as the largest set of species in a data set (in this particular study individual cruises) in which all members show a significant degree of co-occurrence with all other members of the group (Sen Gupta and Hayes 1979). Once identified as a RSG, the member species are removed from further grouping consideration during the remainder of REGROUP execution. The next largest RSG is then determined, and its member species removed until all possible groups are so determined. During RSG selection, REGROUP also identifies associate species. Associates exhibit significant affinity,

with some, but not all, members of specified RSG's. As with RSG's, once identified as an associate, species are removed from further grouping consideration. It should be noted that not all RSG's have associates. Grouping criteria employed were devised and documented by Fager (1957).

Significant co-occurrence between all possible species pairs in a data set is determined by calculation of affinity indices (α's). Indices are then compared to a user-specified cutoff level; therefore, those indices greater than, or equal to, the predescribed cutoff level are considered significant for grouping purposes. In more technical terms, the affinity index can be described as the geometric mean of the proportion of joint occurrrences corrected for sample size. The index does not consider samples (in this particular study individual trawl tows) in which neither species of the pair considered occurred and therefore is independent of the number of empty samples (Sen Gupta and Hayes 1979). The formula as derived and given by Fager (1957) is as follows:

$$\alpha = (J/(NaNb)^{1/2}) - 1/(2(Nb)^{1/2})$$

where:

J = number of joint occurrences of species A and B,

Na = number of occurrences of species A,

Nb = number of occurrences of species B,

and $Nb \geq Na$.

Program AFFIN (Fager 1972) aids in the selection of the REGROUP α cutoff level. AFFIN utilizes a Monte Carlo technique for the selection of a cutoff level that will separate a random from a non-random association at any desired probability level (Sen Gupta and Hayes 1979). For purposes of this study, the cutoff level was set equal to 0.501 for all 11 data sets. Five iterations of AFFIN were performed for each data set, thus producing a cumulative probability curve. The probability (P) given in figures 3-13 represents the probability of a RSG of two

species with $\alpha \geq 0.501$ not being spurious, i.e. randomly grouped. The probability of any RSG of n species being spurious can be determined by: (1.0 - P) exp nC2. Properties of the program AFFIN and theoretical considerations of the α cutoff level used in RGA are further discussed in greater detail by Shulenberger (1976) and Sen Gupta and Hayes (1979).

After all RSG's and associates were identified for a particular data set (cruise), two additional analysis programs were run. REGROUP removes RSG's and associates from further grouping consideration as they are identified, and thus provides no indication of the possible interconnections between RSG's and associates. Program CONNEX (Fager 1957) determines these inter-group connections. Connections represent the number of significant affinities between species belonging to different RSG's and are reported herein as the percentage of possible significant α's actually observed. For example, the CONNEX values for an RSG of six species and an RSG of three species with nine observed significant inter-group α's is 9/18 or 50%. By considering associates as single member RSG's during a CONNEX run, the connection strength between an associate and its RSG can similarly be determined.

REGROUP identifies RSG's on the basis of presence-absence data alone. Program DOMIN (written by DER based on the computational method of Sen Gupta and Hayes (1979)) tests species dominance within a RSG by examining rank order abundance data. Significant results from DOMIN indicate that a rank order of species exists in a particular RSG and that this order is maintained over the range of samples considered.

Additional detailed statistical descriptions and case study applications of recurrent group analysis are given in the following publications: Fager (1957), Sheard (1965), Fager and Longhurst (1968), Venrick (1971), Mearns (1974), Kendall (1975),

MacDonald (1975), Renz (1976), Shulenberger (1976, 1977, 1979), Hayes (1978, 1980), Cailliet et al. (1979), Sen Gupta and Hayes (1979), Johnson and Nigrini (1980), and McGowen (1980).

10.3 PRELIMINARY RESULTS AND SUMMARY.

For purposes of simplicity as well as brevity, the preliminary results of our RGA are given in the form of figures for each of the aforementioned eleven collecting intervals (Table 1). Figures 3-13 illustrate, on a cruise by cruise basis, RSG's, associates (single species) of each RSG, interaction between RSG's and associates, ranking of species in order of dominance within each RSG, and the affinities between RSG's and associates (percentile).

This preliminary analysis can be very briefly summarized as follows: 1) recurrent group analysis proved to be an effective method in recognizing recurrent species groups and their associates (single species) on a temporal scale; 2) the most widely distributed and abundant species at any one point in time (cruise) are usually clearly identified and generally form the major (first) recurrent species group; 3) the analysis identifies and separates "deepwater" (greater than 183 m) and "shelf" (less than 183 m) species groupings; 4) the dynamics of the formation and breakdown of species groups and their interaction with other species (associates) and RSG's is demonstrated on a seasonal basis; and 5) this particular analytical technique has potential application for the detection and possible understanding of natural and/or man-induced changes in a particular geographical area on a temporal as well as spatial basis. It should be noted at this point, that additional analysis relative to the distributional aspects of each RSG in each temporal sampling universe is presently underway, and upon completion should provide even greater detail and resolution regarding the placement of RSG's both in both time as well as space.

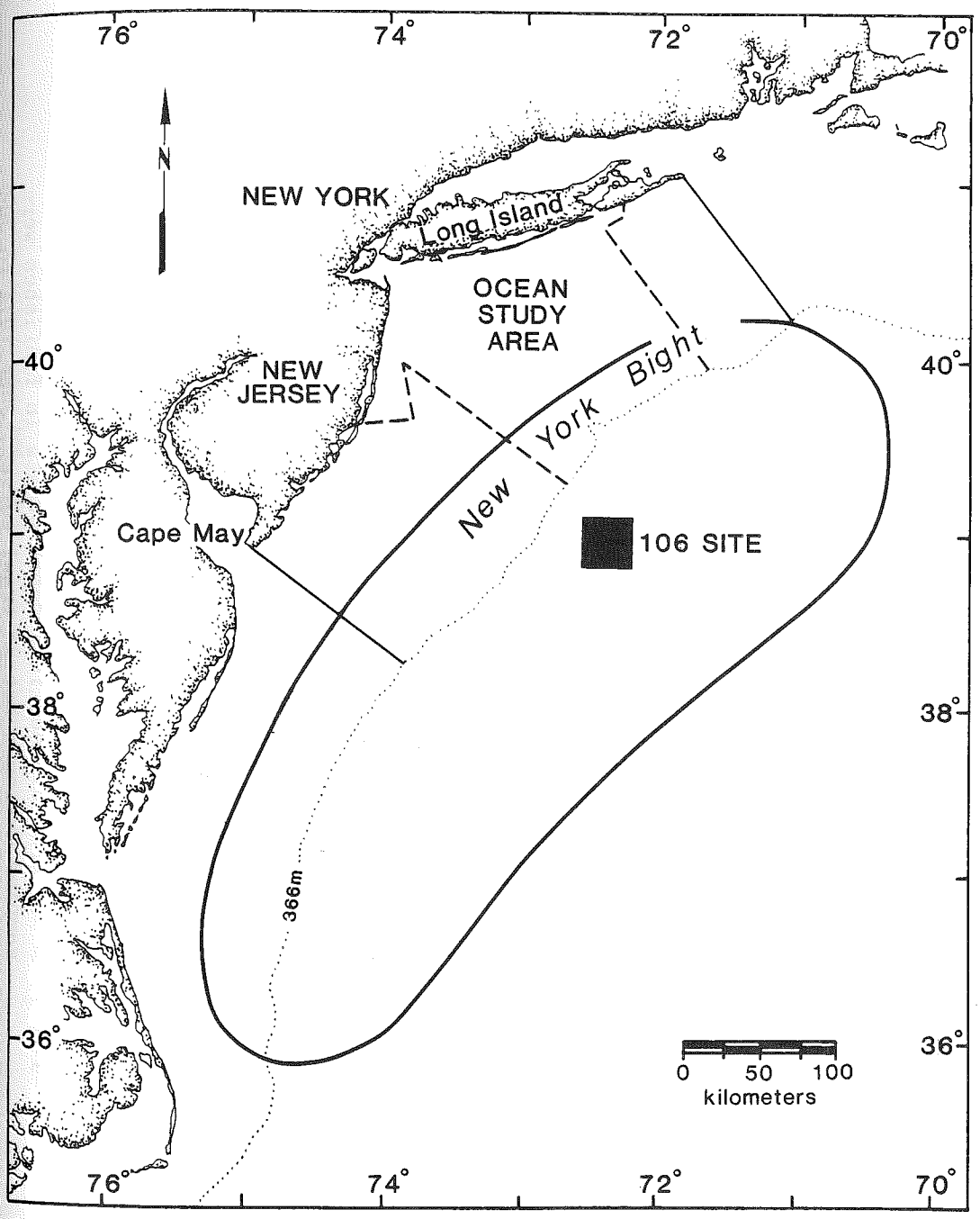

Figure 1. Middle Atlantic continental shelf with outlines of the New York Bight (solid lines) and the study area within the Bight (dashed lines). The PAI is shown as the heavily outlined oval area.

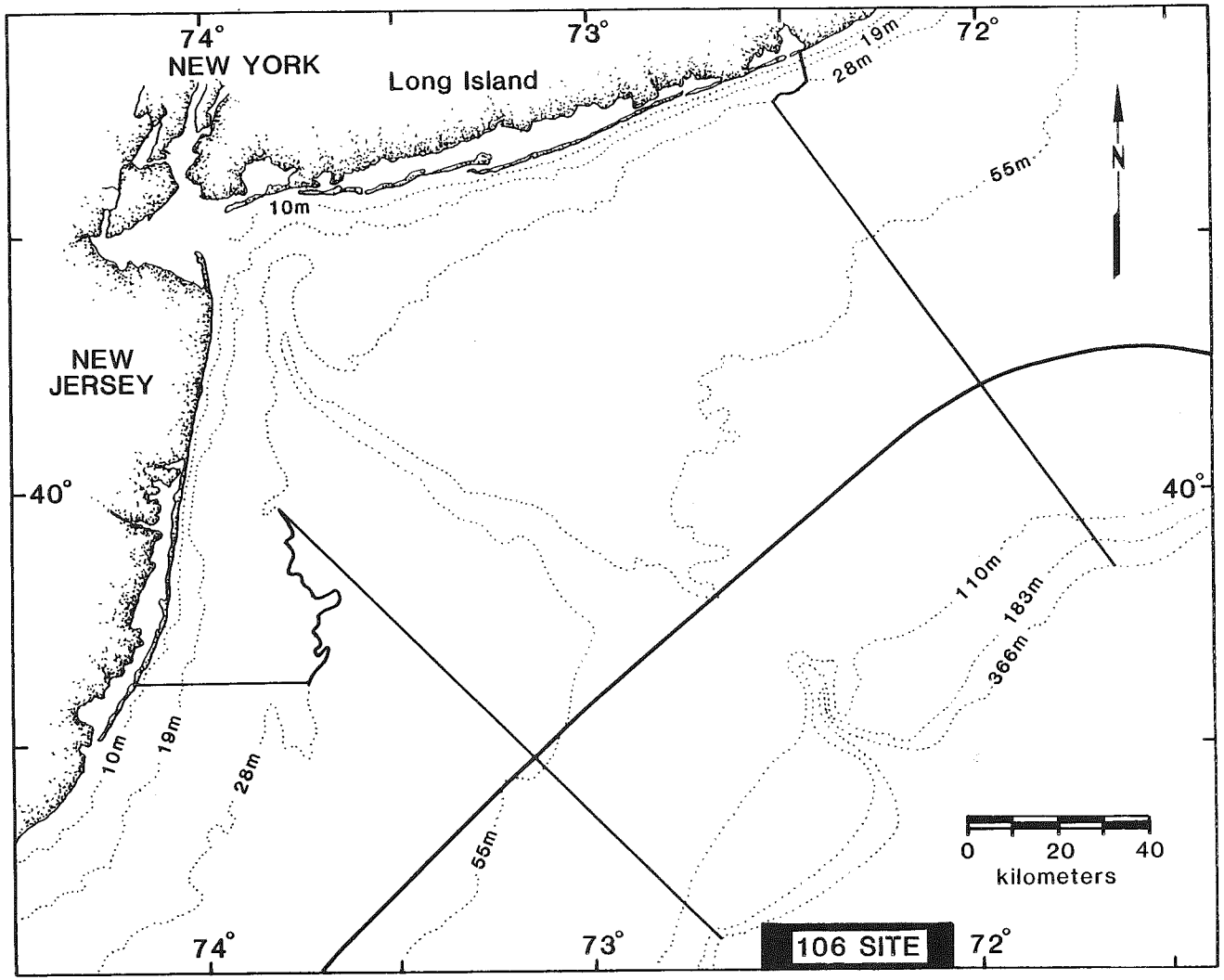

Figure 2. Study area divided into depth strata in finfishes were sampled during a bottom trawl survey, June 1974 to June 1975.

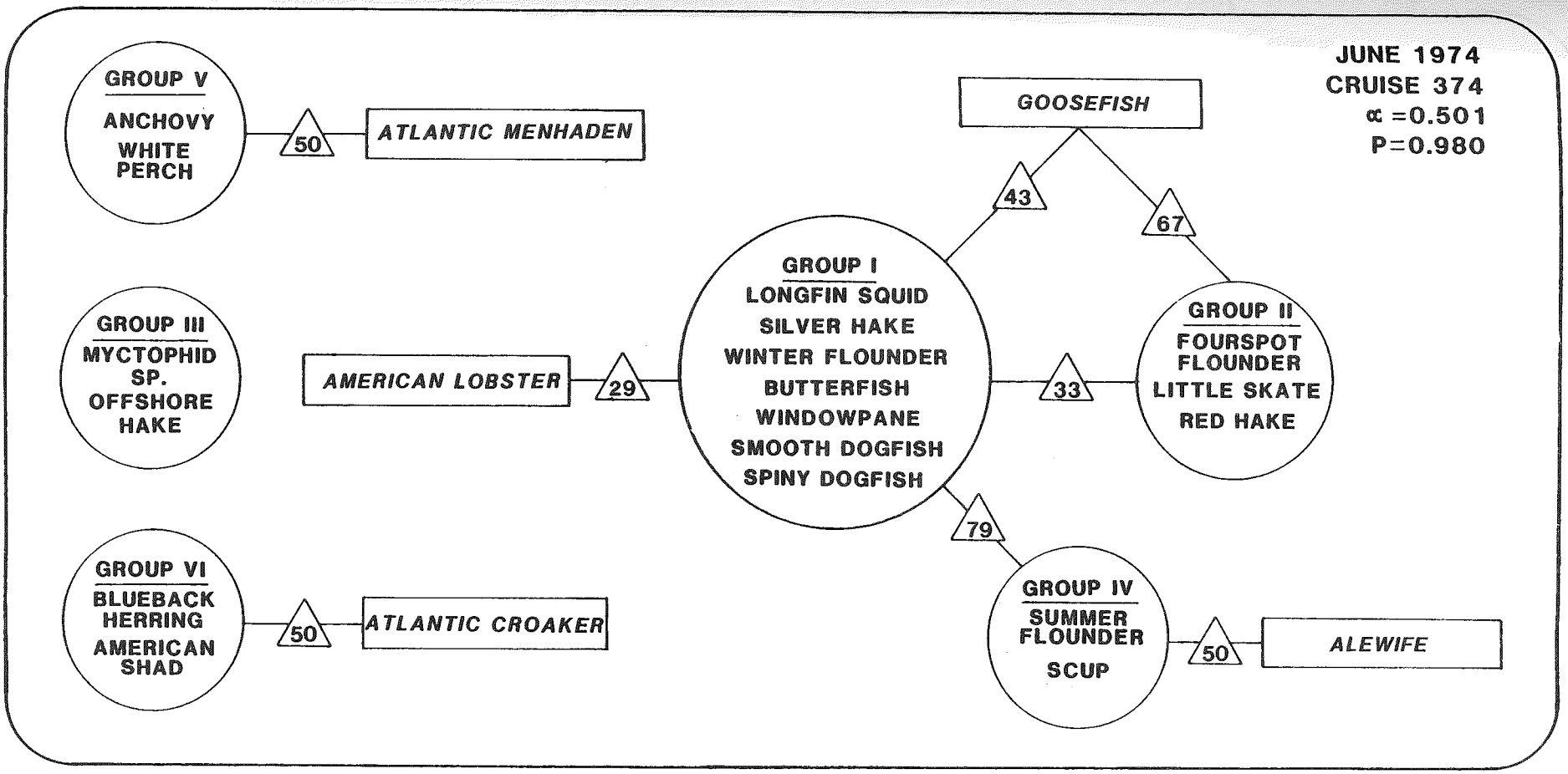

Figure 3.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during June 1974. Affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

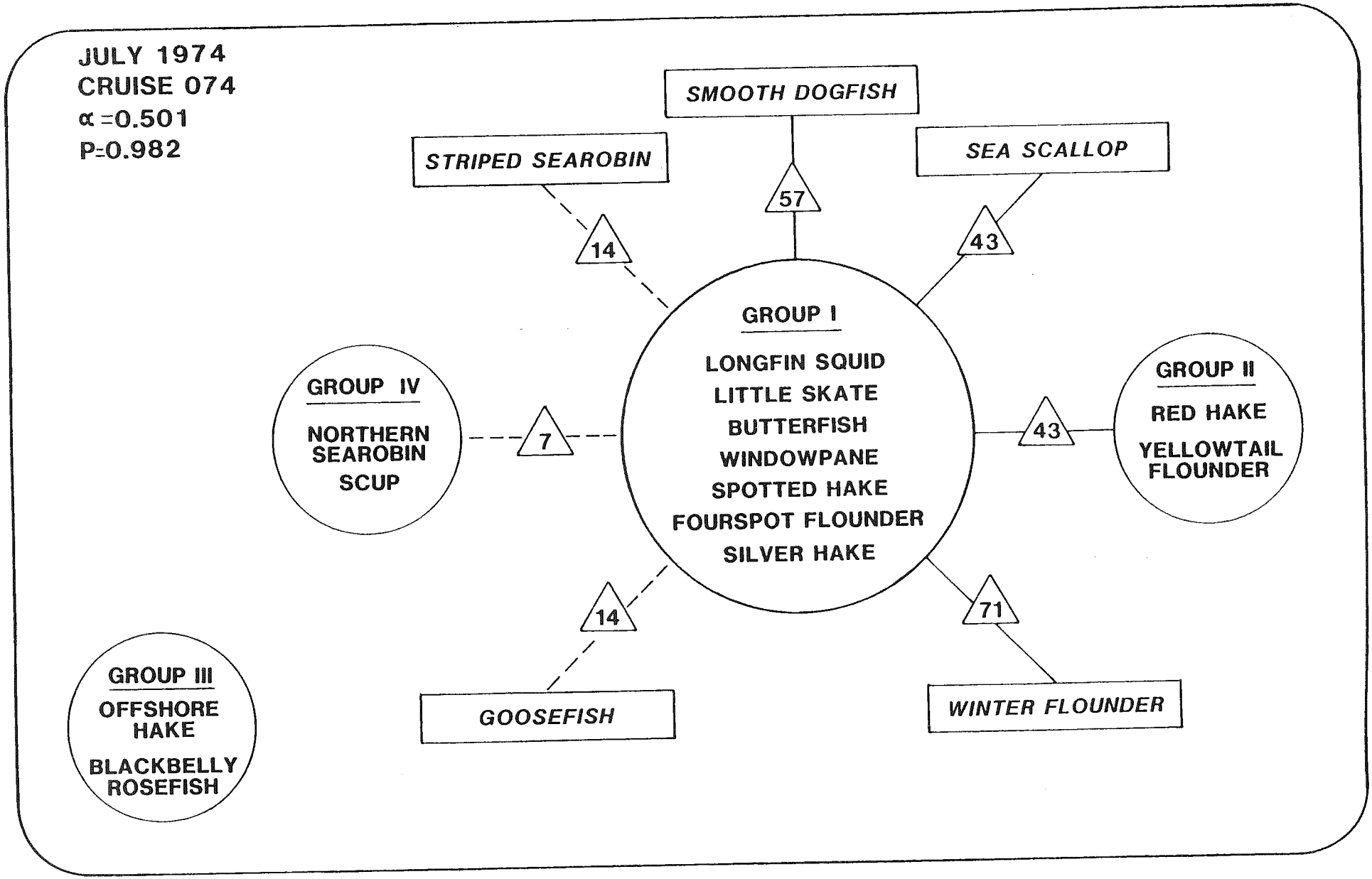

Figure 4.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during July 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

Bight during July 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

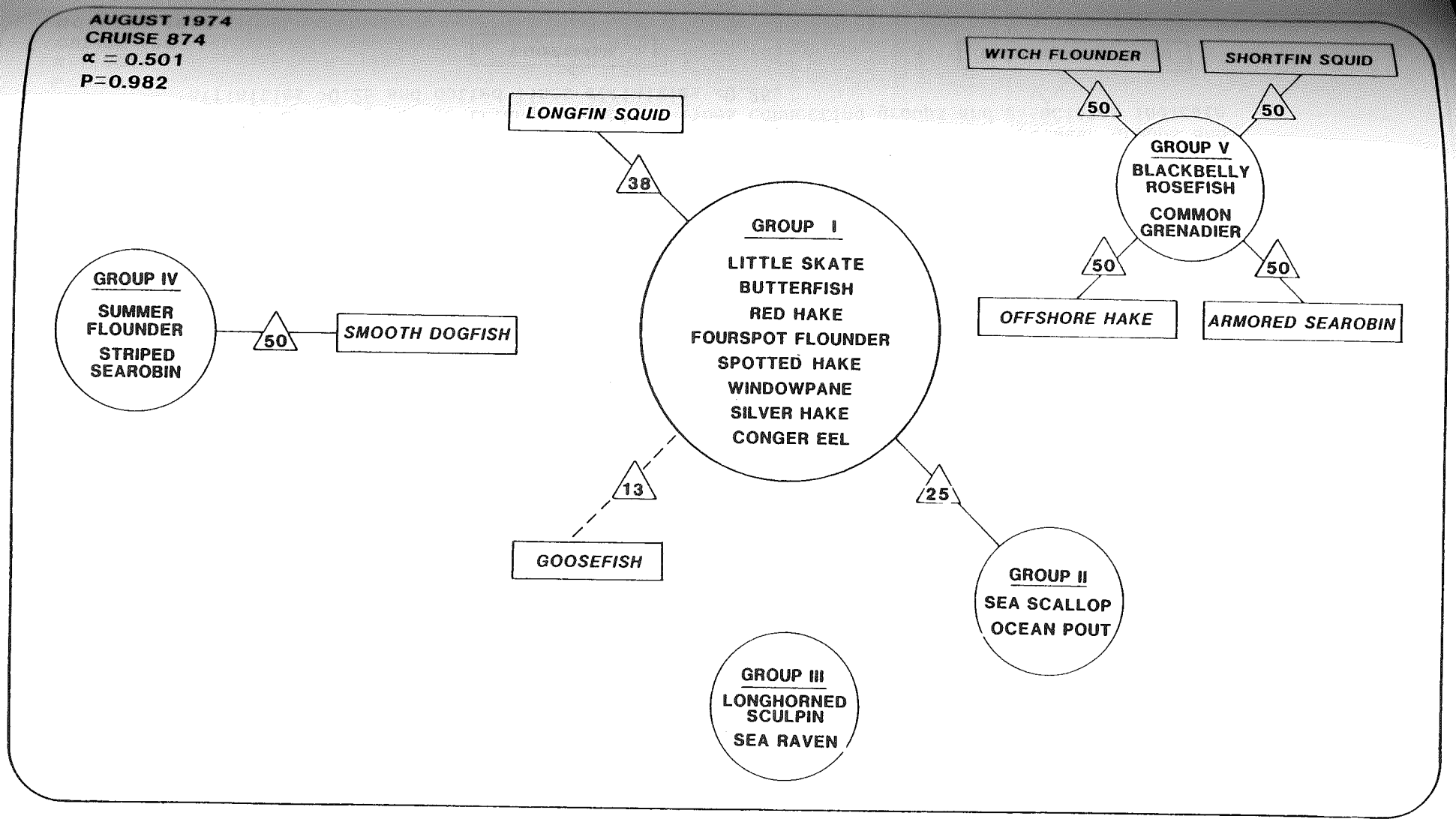

Figure 5.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during August 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

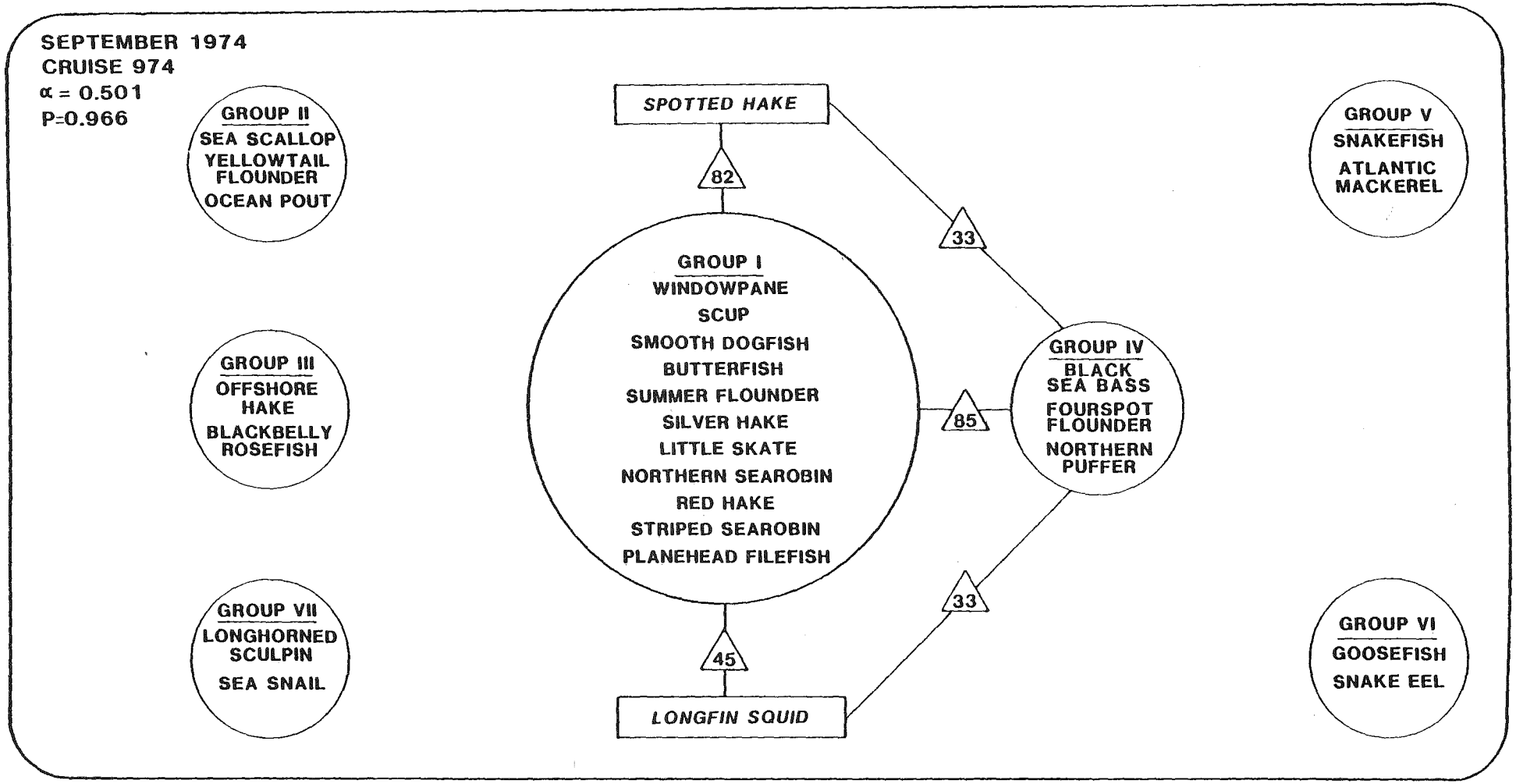

Figure 6.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during September 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

associates are given in triangles. Solid lines connecting groups and associates indicate
affinities >0.25 and dotted lines affinities <0.25.

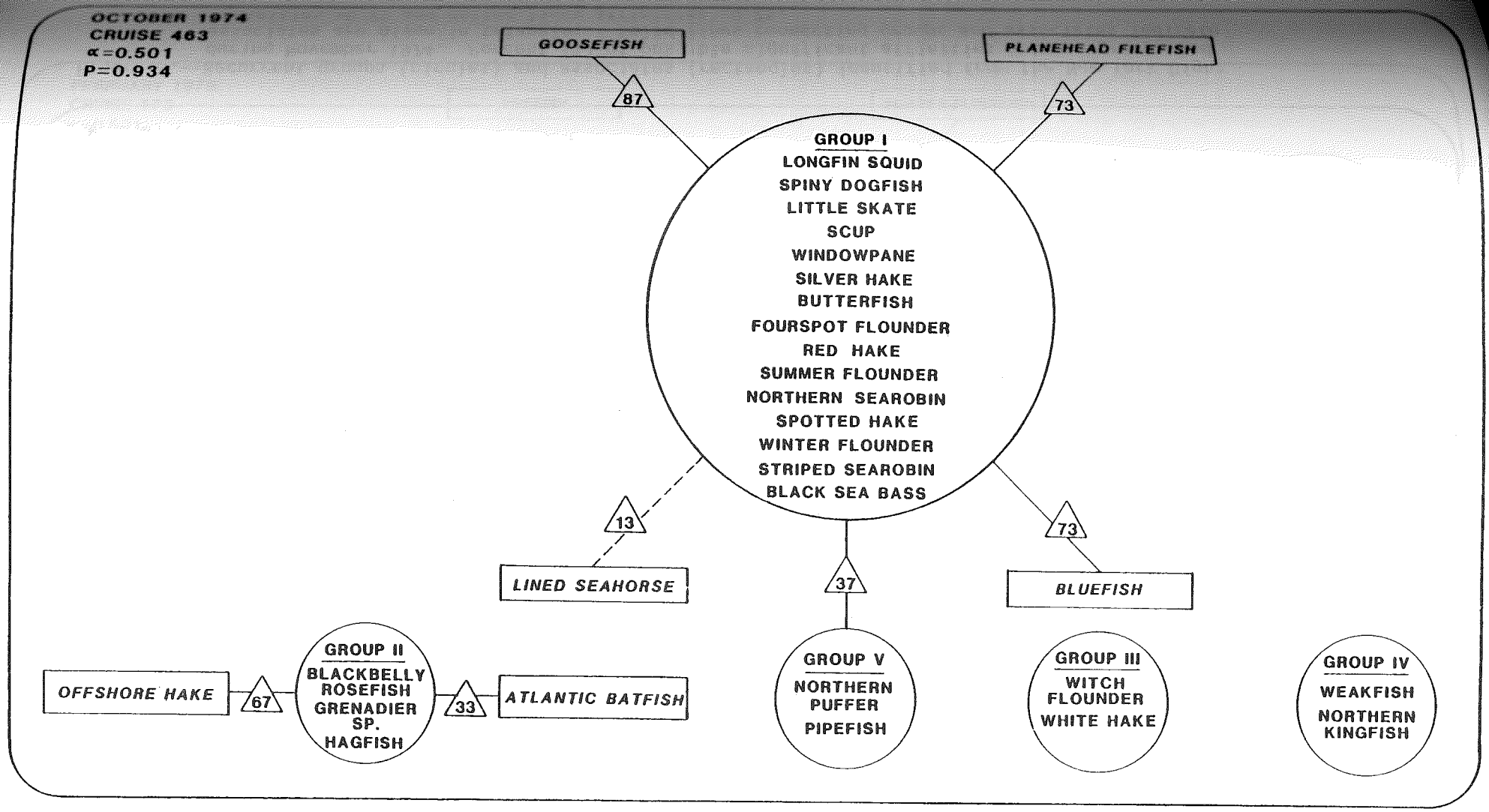

Figure 7.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during September 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

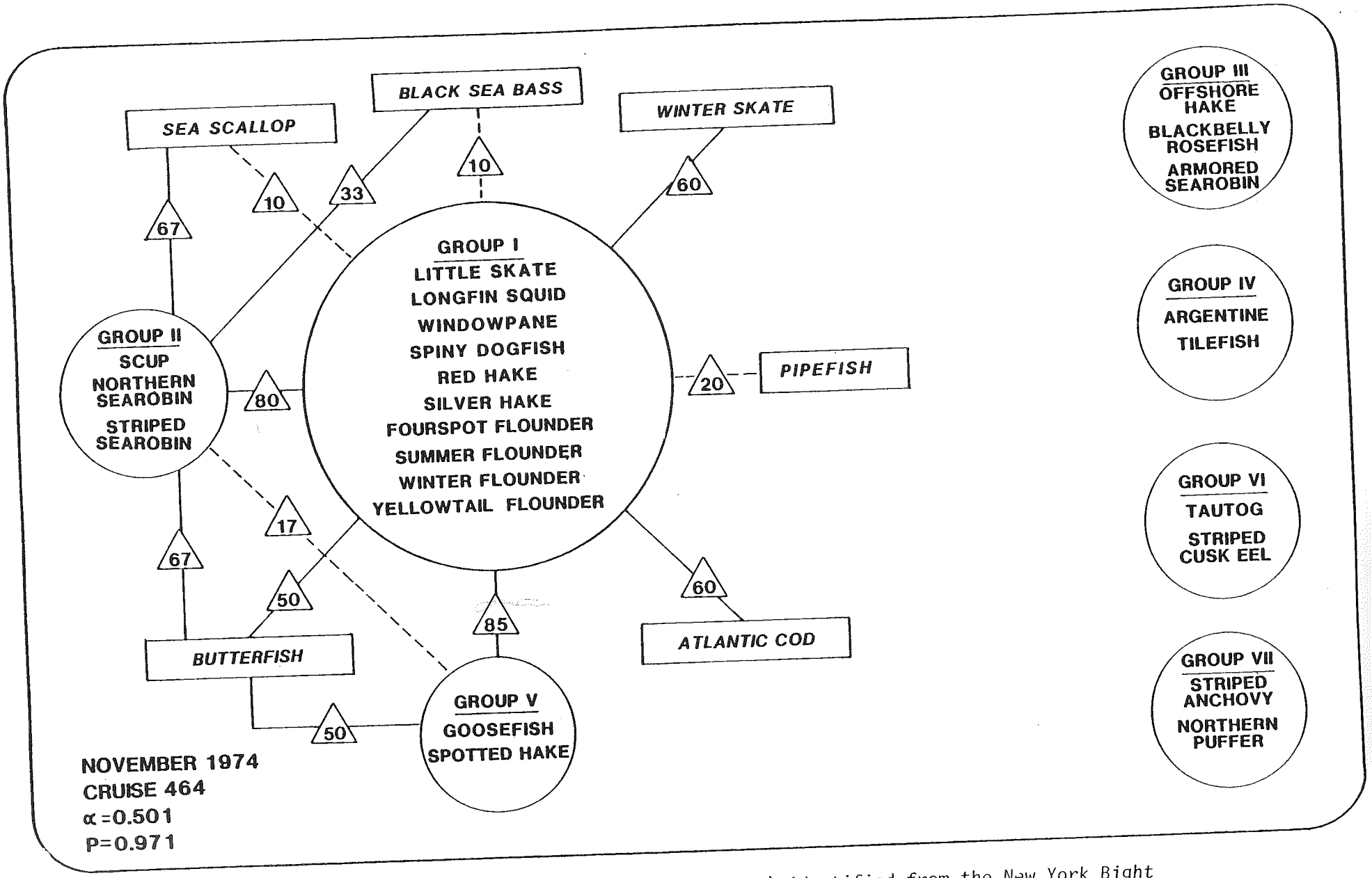

Figure 8.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during November 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

Figure 8.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during November 1974. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

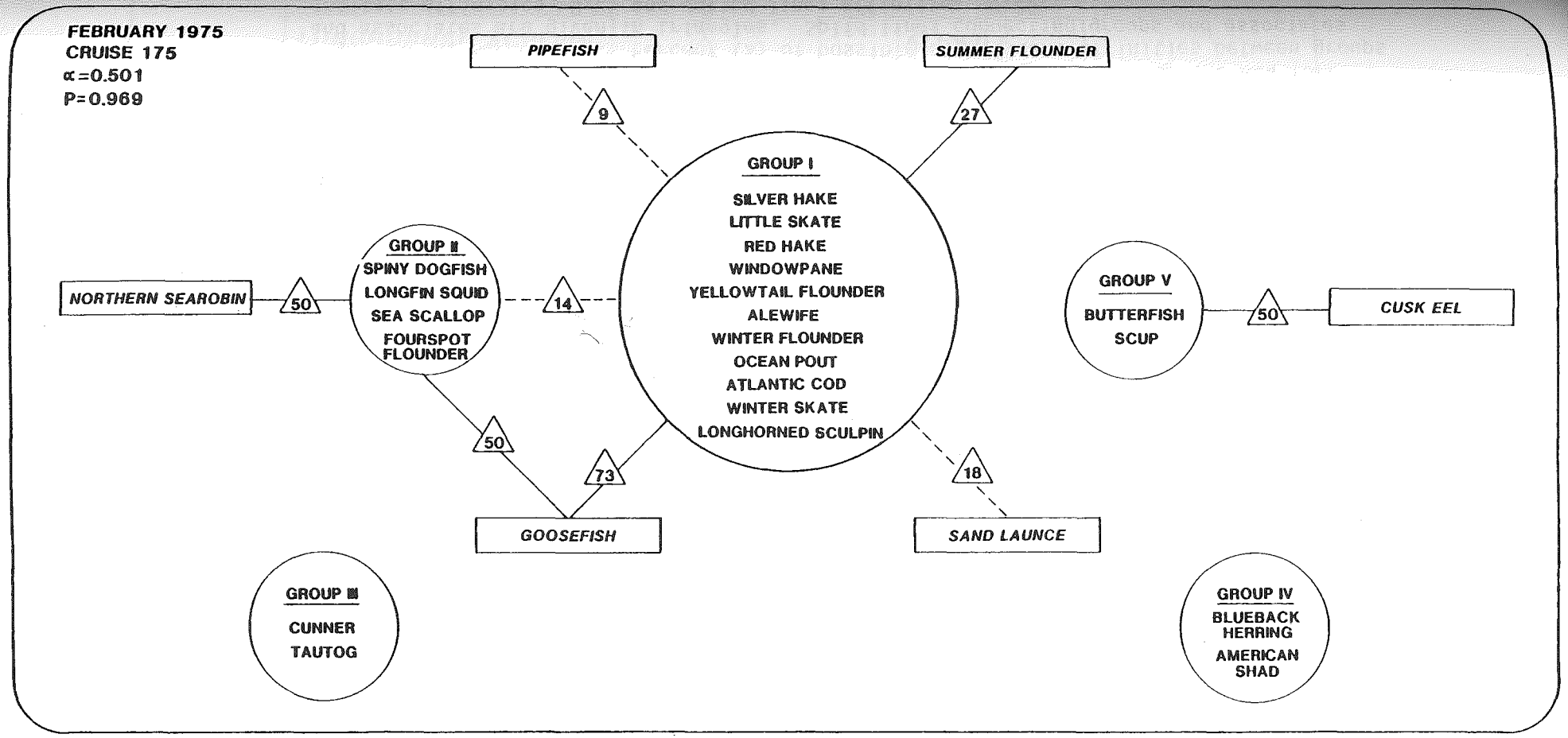

Figure 9.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during February 1975. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

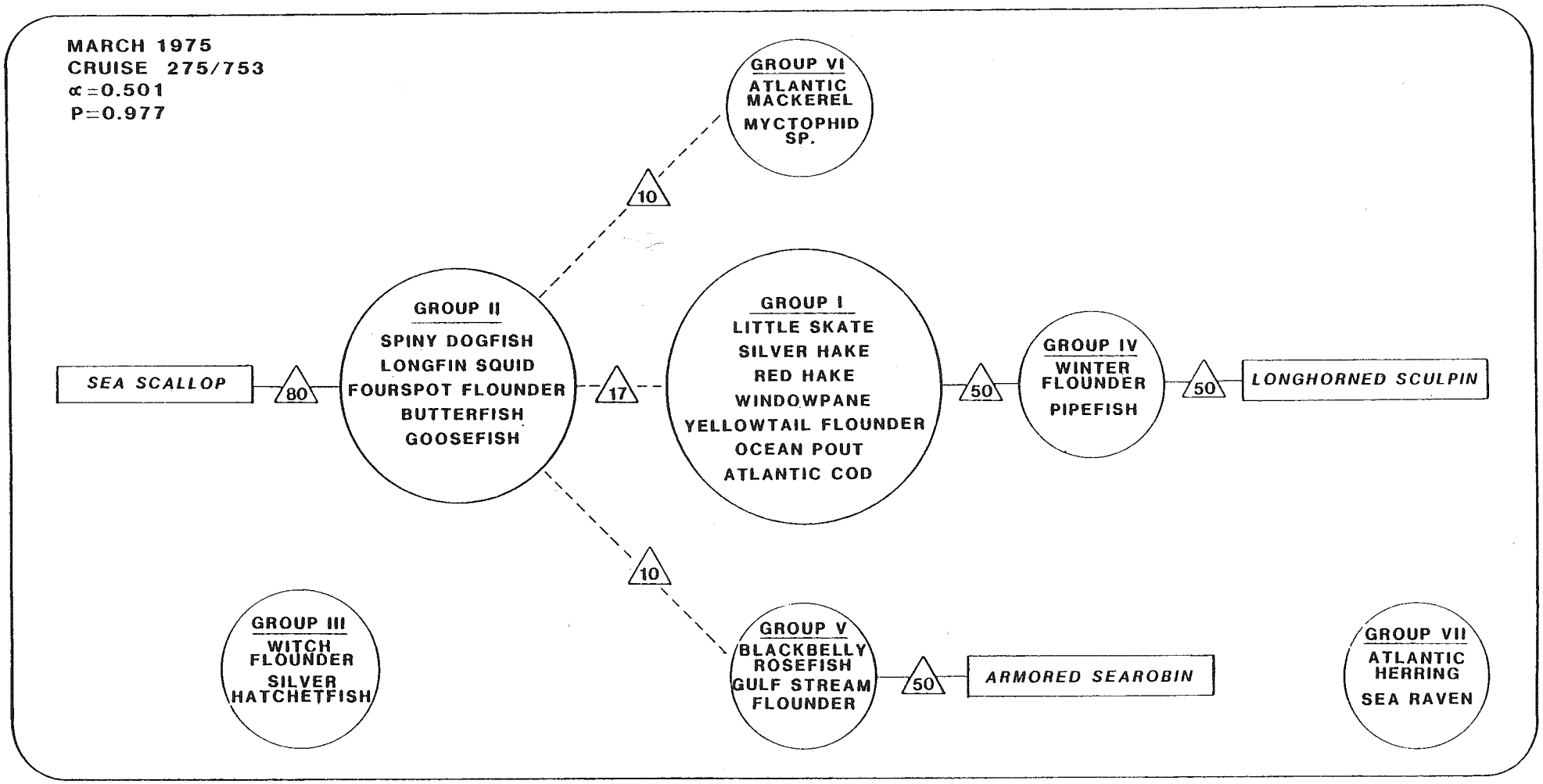

Figure 10.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during March 1975. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

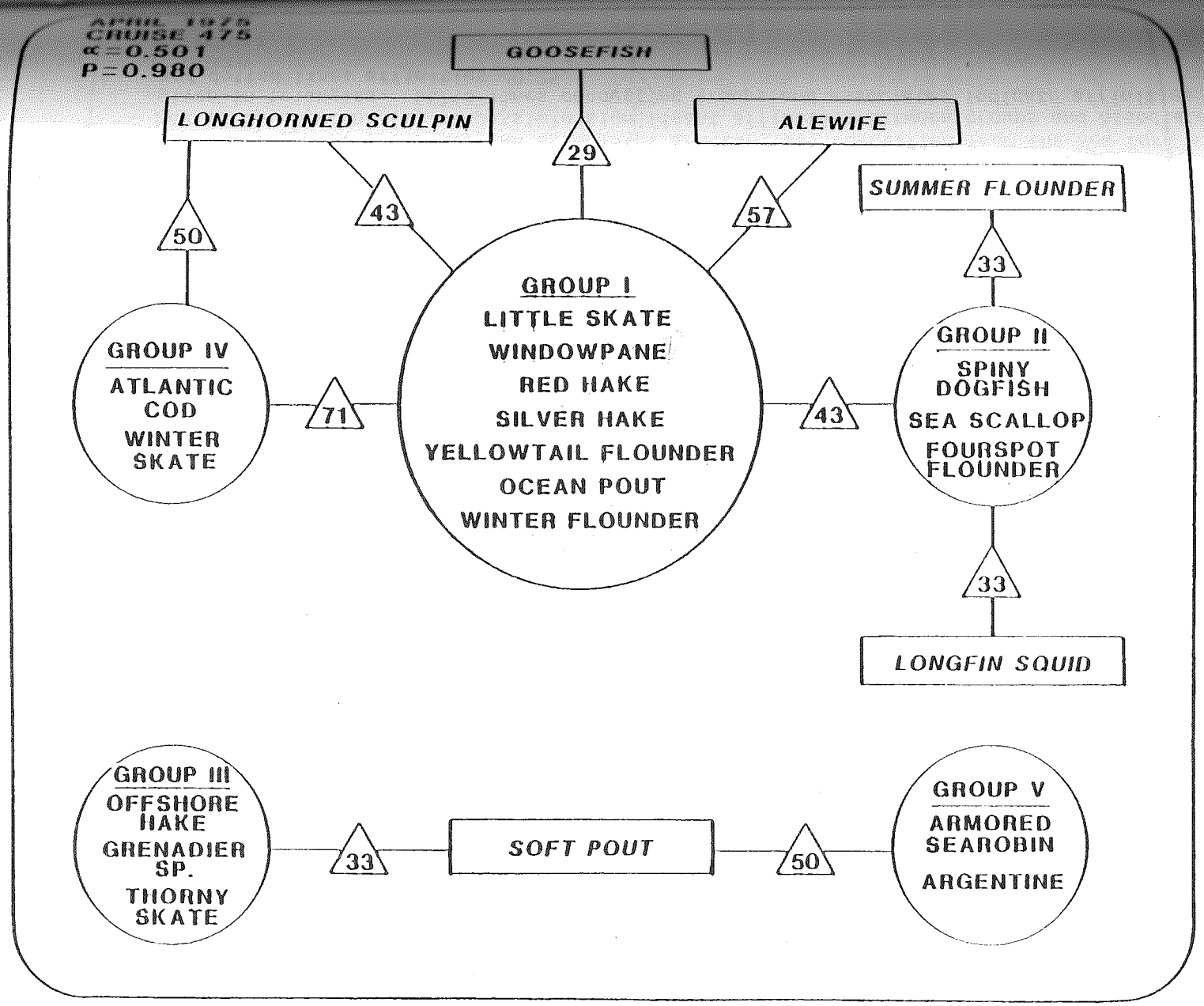

Figure 11.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during April 1975. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

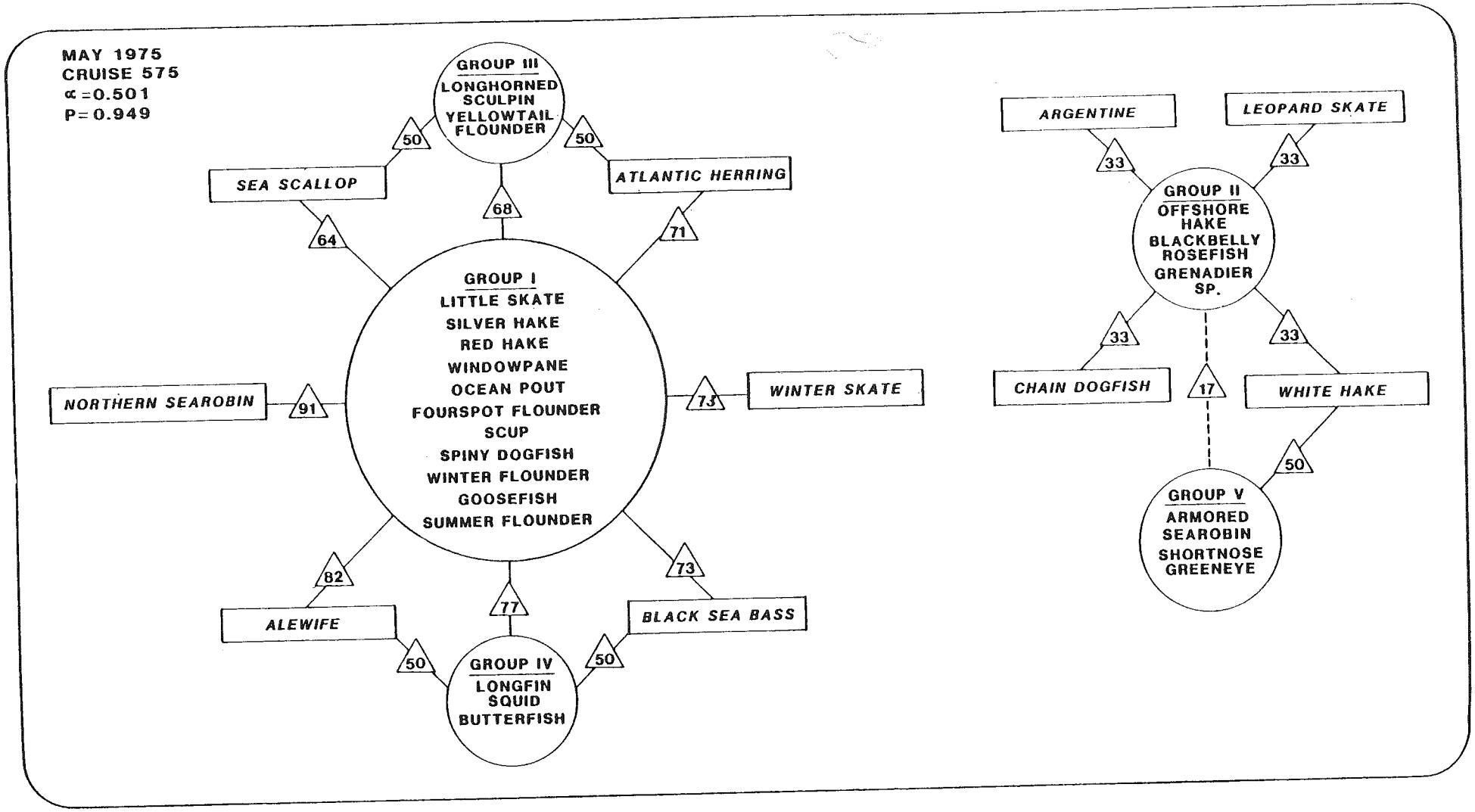

Figure 12.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during May 1975. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

and dotted lines affinities <0.25.

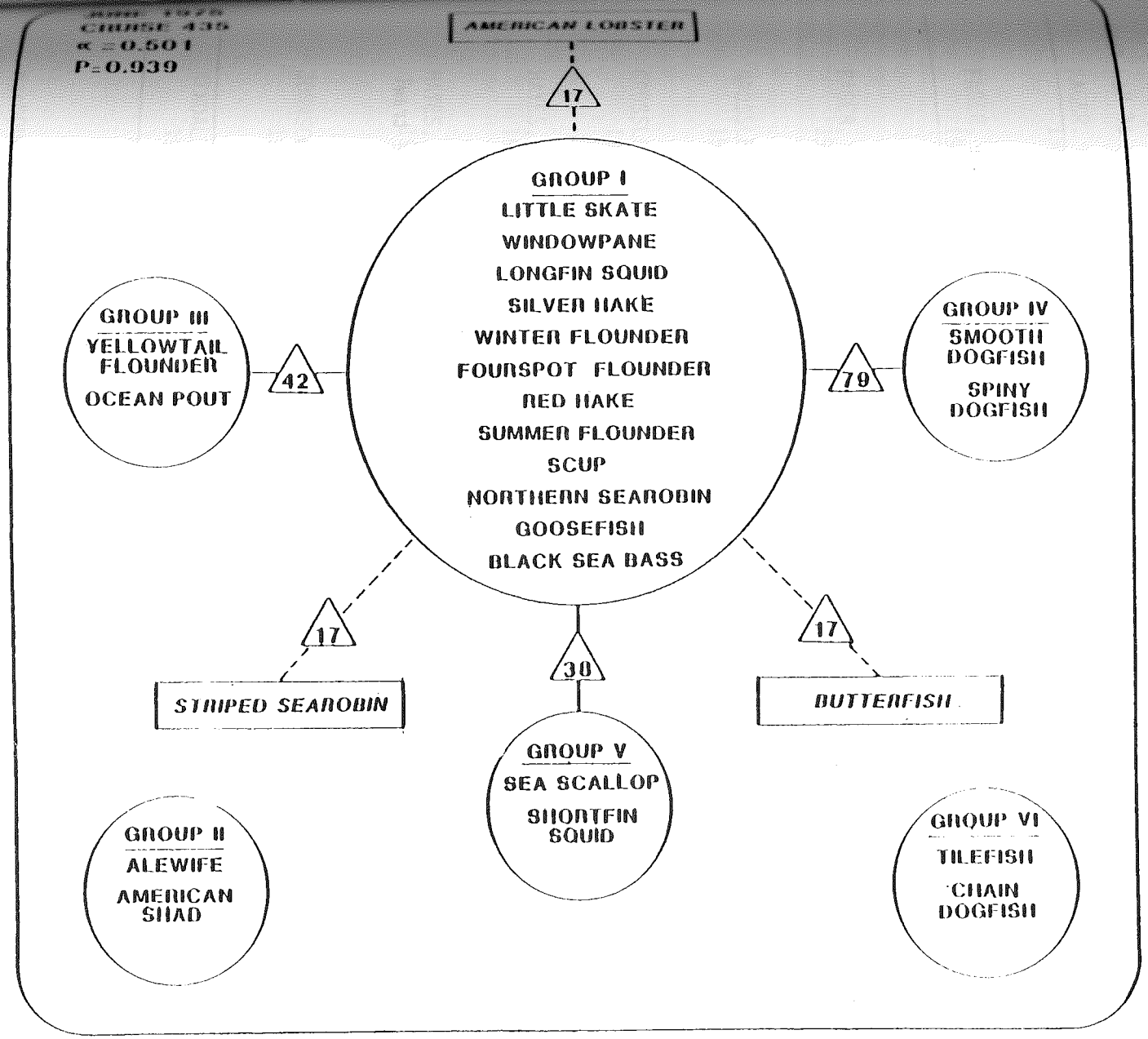

Figure 13.--Recurrent groups (circles) and associates (rectangles) identified from the New York Bight during June 1975. Percent (%) of possible significant affinities between groups and associates are given in triangles. Solid lines connecting groups and associates indicate affinities >0.25 and dotted lines affinities <0.25.

Table 1.--Summary of collecting intervals sampled during trawl survey of New York Bight, June 1974 to June 1975.

Survey Dates	Cruise Code	Vessel	No. of Stations Sampled	Gear Type
1974				
Jun 3-7	374	DELAWARE II	43	#36 trawl
Jul 24-29	074	DELAWARE II	41	#36 trawl
Aug 16-21	874	DELAWARE II	45	#36 trawl
Sep 23-28	974	DELAWARE II	40	#36 trawl
Oct 22-28	463	DELAWARE II	40	#36 trawl
Nov 18-25	464	DELAWARE II	37	#36 trawl
1975				
Jan 31; Feb 1-6	175	DELAWARE II	51	#36 trawl
Mar 6-8, 10	275/753	ALBATROSS IV	19	#41 trawl
Mar 20-24		ATLANTIC TWIN	27	3/4 Yankee trawl
Apr 1-3, 5-10	475	ALBATROSS IV	48	#36 trawl
May 5-12	575	DELAWARE II	60	#36 trawl
Jun 2-9	435	DELAWARE II	64	#36 trawl
TOTAL			515	

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Chapter 11. MAMMALS, BIRDS AND TURTLES

Kevin D. Powers and P. Michael Payne[1]

11.1 INTRODUCTION.

The 106-Mile Disposal Site (106-Mile Site) and Philadelphia disposal site (PDS) are located off the middle Atlantic states off the eastern seaboard of the United States (Figure 1). The 106-Mile Site lies in deep, slope water and PDS is located in the outer-shelf water of the Middle Atlantic Bight. An elliptical-shaped envelope (adapted from Smith et al. 1982) is indicated in Figure 1, and desscribes a potential area of impact (PAI) from materials dumped at these sites due, in part to interactions with warm-core eddies (Bisagni 1976).

Several large-scale efforts in the past decade have resulted in a better understanding of the pelagic distribution and abundance of marine mammals, birds and turtles in shelf and slope waters off the northeastern United States. Many of these studies are unpublished, existing as government reports or manuscripts in review. Reports from the Cetacean and Turtle Assessment Program (CETAP) have provided benchmark surveys for cetaceans and turtles (CETAP 1981, 1982). The Manomet Bird Observatory (MBO) has provided descriptions of mammal, bird and turtle distribution and abundance in shelf and slope waters (Powers in press; Powers and Brown in review; Powers et al. 1982) and the Canadian Wildlife Service has provided information for birds in slope and Sargasso waters (Brown 1977). Rowlett (1980) summarized bird and cetacean observations from single-day cruises to the northern Chesapeake Bight.

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Using these sources of information we describe the distribution and abundance of cetacean, turtle and bird populations in the Middle Atlantic Bight and adjacent slope water. This report does not provide a new inventory of data; but represents a synthesis of all existing data and evaluates what is known about the populations in the vicinities of the PAI and PDS. The report should assist nonspecialists in accessing and evaluating these data.

11.2 METHODS.

Seasonal distribution data for cetaceans and birds were structured into four 3-month seasons: winter (December-February), spring (March-May), summer (June-August) and fall (September-November). Sources of sighting data for cetaceans are provided in Table 1. Only sightings of cetaceans between 35°N and 40°N latitude, and west of 70°W longitude, were considered since this report emphasizes the two disposal sites and PAI in Figure 1. All sightings were plotted individually by season. The number of individuals in each sighting is not indicated, but is provided in the source reference.

Sighting data for turtles was structured around CETAP surveys (Shoop et al. 1981), and other sources of data were used (Table 1). Sightings of loggerhead turtle (*Caretta caretta*) were plotted into two survey periods (17 May-24 November and 25 November-16 May). The leatherback turtle (*Dermochelys coriacea*) is much less common than the loggerhead and all sightings were plotted into one figure; the temporal distribution of these sightings, however, is indicated.

Unlike the distribution maps of cetaceans and turtles, densities of birds were plotted using 10 x 10 blocks of latitude and longitude. These figures were extracted from Powers (in press). These distribution maps reflect densities across shelf and slope waters off the northeastern U. S. and are not restricted to data

from the Middle Atlantic Bight (MAB). Distribution plots for species seasonally common to the MAB are given.

11.3 DISTRIBUTIONS.

11.3.1 Cetaceans

Bottlenosed dolphin (*Tursiops truncatus*) occur from Cape Hatteras to at least the Northeast Channel. Two forms are recognized. A smaller inshore form is found in coastal waters of the Middle Atlantic Bight (MAB) south of Delaware Bay (Hain et al. 1981). The larger form occurs offshore along the shelf-edge from 37° to 41°N (Rowlett 1980; Hain et al. 1981; Powers et al. 1982). Their occurrence in outer-shelf waters of MAB is year round (Figures 2-5), but greatest sighting frequencies are from May to October in offshore waters (Hain et al. 1981; Powers et al. 1981). Although this species has been recorded in slope waters, sighting distribution suggests the majority of the offshore form is restricted to the shelf-break area between the 200-2,000 m isobaths. Feeding calves appearing to feed, and juveniles of this species have been recorded in the potentially impacted envelope (Figure 1) (Hain et al. 1981).

Spotted dolphin (*Stenella* spp.). Taxonomy is not clear but *S. attenuata/frontalis* and *S. plagiodon* occur in the western North Atlantic (Katona *et al* 1977; Hain et al. 1981). Spotted dolphin occur in inshore waters of the MAB only south of Chesapeake Bay; otherwise the distribution in the study area is offshore in slope water (Hain et al. 1981; Powers et al. 1982) (Figures 6-8). Spotted dolphin has not been recorded in the MAB in winter (Hain et al. 1981; CETAP 1982). The majority of sightings occur from April to October along the shelf-break and south of 38°N (Rowlett 1980; Hain et al. 1981; Powers et al. 1982).

Sightings of calves or juveniles have been made in the same areas (Hain et al. 1981).

Striped dolphin (S. coeruleoalba) occurs from the southern edge of Georges Bank southwards to Cape Hatteras and generally seaward to the 1,000 m isobath (Hain et al. 1981) (Figures 9-12). Sightings of this species north of 35°N have been made throughout the year with the majority of observations from March to August (Hain et al. 1981). Sightings are most frequent in slope water within the potential area of impact (Figure 1). Sightings of calves or juveniles have been made in the same areas (Hain et al. 1981).

Common or saddleback dolphin (Delphinus delphis) occurs in shelf and slope waters from Cape Hatteras northeastward to Georges Bank (Rowlett 1980; Hain et al. 1981; Powers et al. 1982) and Nova Scotia (Sergeant and Fisher 1957; Leatherwood et al. 1976). Its occurrence on the shelf off the northeastern United States is generally restricted to outer-shelf waters (Hain et al. 1981; Powers et al. 1982) (Figures 13-16). Greatest sighting frequencies in the MAB occur from February to May (Hain et al. 1981) and on Georges Bank from May to June and again from October to December (Hain et al. 1981; Powers et al. 1982). Thus, the common dolphin appears to be seasonally (winter-spring) common in the area of potential impact (Figure 1). Most sightings of feeding or apparent feeding calves and juveniles have been recorded on Georges Bank (Hain et al. 1981; K. D. Powers, unpubl. data) but their occurrence further south correlates with the period of poorest observer conditions for the year (winter-spring).

White-sided dolphin (Lagenorhynchus acutus) occurs in shelf waters from the Chesapeake Bight in the MAB (Testaverde and Meade 1980) (Figure 17) north-eastward to the Gulf of Maine. White-sided dolphin is found in greatest abundance and throughout the year in the southwestern Gulf of Maine (Hain et al. 1981; Powers et al. 1982) and its distribution is most widespread in October and November (Hain et al. 1981). The area of potential impact (Figure 1) includes only the marginal, southern limits of the range of this species.

Grampus (Grampus griseus) occur off the northeastern United States from Cape Hatteras to the eastern end of Georges Bank (Hain et al. 1981) (Figures 18-21). Grampus is found with greatest frequency along the outer-shelf of the MAB throughout the year, but most commonly from April to October (Hain et al. 1981; Powers et al. 1982). It is not usually found inshore of 100-m isobath or offshore of 2,000-m isobath. The PAI (Figure 1) is almost a perfect match to the distribution of Grampus. Calves or juveniles have also been sighted in the PAI (Hain et al. 1981).

Pilot whales (Globicephala spp.) occur in shelf waters from Cape Hatteras to the Gulf of Maine but principally in outer-shelf waters of the MAB and Georges Bank (Hain et al. 1982; Powers et al. 1982) (Figures 22-25). The long-finned pilot whale (G. melaena) occurs from North Carolina (Leatherwood et al. 1976) to Greenland (Mercer 1975). The short-finned pilot whale (G. macrorhynchus) occurs from North Carolina (Schmidly 1981) to the Gulf of Mexico (Fritts and Reynold 1981). These species are not separable in the field and have been combined for this report, but G. melaena is most likely the predominant species off the northeastern United States. They are most frequently recorded on Georges Bank from May to October (Hain et al. 1981; Powers et al. 1982) and possibly most

abundant in the MAB and adjacent slope water from November to May, but observer effort in this area during winter months is relatively poor. The distribution of pilot whales overlaps with the PAI (Figure 1) and feeding and calves have been observed within these waters (Hain et al. 1981).

Sperm whale (Physeter macrocephalus) is an endangered species which is widely distributed throughout the deep waters of the North Atlantic between 30° and 60°N latitude (Brown 1958). Off the northeastern United States sperm whales occur along the edge of the continental shelf and seaward into slope waters throughout the year (Hain et al. 1981) (Figures 26-29). Sighting frequencies of sperm whales in the PAI (Figure 1) are greatest from April to August (Hain et al. 1981; Powers et al. 1982) and feeding calves or juveniles have been observed in this area. The paucity of sightings in winter months may be related to poor observer effort.

Minke whale (Balaenoptera acutorostrata) is found in shelf waters from Virginia to Baffin Island (Katona et al. 1977), but sightings south of Nova Scotia are concentrated in the southwestern Gulf of Maine and on Georges Bank (Hain et al. 1981; Powers et al. 1982). They occur on the shelf in the MAB (Figures 30-33), but sightings frequency is greatest from April to October (Hain et al. 1981; Powers et al. 1982). Only the southern limit of their range overlaps with the PAI (Figure 1).

Fin whale (B. physalus) is an endangered species which is widely distributed throughout shelf waters of the North Atlantic. Fin whales are found on the shelf off the northeastern United States throughout the year (Figures 34-37), but the majority of sightings occur off in the southwestern Gulf of Maine from the Great South Channel

northwest to Cape Ann, Massachusetts from April to October (Hain et al. 1981; Powers et al. 1982). The majority of sightings in the MAB occurs in spring and summer. Rowlett (1980) observed fin whales from April to September betwen Delaware Bay and Baltimore Canyon. Leatherwood et al. (1976) suggested that most fin whales in the western North Atlantic move south and offshore during winter months. If this hypothesis is correct, the PAI (Figure 1) would overlap with the wintering range of fin whales, as well as the summer range of those animals that feed in the MAB. CETAP (1982) suggested that a portion of the fin whale population off the northeast U. S. may have a general northward shift in spring from a wintering area off the Delmarva Peninsula with a subsequent southward return in fall.

Humpback whale (Megaptera novaeangliae) is an endangered species which in the western North Atlantic breeds in the Carribean and migrates north to summer feeding grounds from Cape Cod, Massachusetts, to Iceland (Katona et al. 1980). Sightings of humpbacks are concentrated in the southwestern Gulf of Maine from the Great South Channel northwest to Cape Ann, Massachusetts from April to October (Hain et al. 1981; Powers et al. 1982). Their seasonal migration to southerly breeding areas probably passes through the PAI (Figure 38). South of Cape Hatteras humpbacks have been sighted in coastal waters of Miami, Florida (Schmidly 1981), but there is a dearth of sightings on the shelf north of Cape Hatteras until the Great South Channel is reached (Hain et al. 1981, Powers et al. 1982). This suggests an offshore route seaward of the shelf-break, which passes through the PAI (Figure 1).

Right whale (Eubalaena glacialis) is an endangered species which is known to occur throughout the temperate seas of the North Atlantic (Watson 1981). In that part of the western North Atlantic off the northeastern United States, Scott et al. (1981) estimated only 29 (±44) individuals. More recently Kraus and Prescott (1981) have identified at least 59 individual right whales in the Bay of Fundy. Right whales are seen with some regularity throughout the year north of 40°30'N with most sightings in the southwestern Gulf of Maine from April to June (Hain et. al. 1981) and in the Bay of Fundy from August through September (Kraus and Prescott 1982). Their known occurrence in the MAB is limited to a few sightings (Figure 39). During late summer and fall most right whales migrate south from the Gulf of Maine (Winn et al. 1981). Reeves et al. (1978) assumed right whales migrated offshore in fall and nearshore in spring; however, Winn et al. (1981) hypothesized that the majority of right whales migrated offshore in both spring and fall. Thus, right whales would only occur in the PAI (Figure 1) from February to April and September to November.

Beaked whales are rare in the western North Atlantic although they have been sighted in the PAI (Figure 1). Hain et al. (1981) listed three sightings of Cuvier's beaked whale (Ziphius cavirostris) and one sighting of a possible Dense beaked whale (Mesoplodon densirostris) and CETAP (1982) had ten more sightings of Mesoplodon and three sightings of Ziphius in 1980. CETAP (1982) indicated that Mesoplodon spp. are widely distributed along the shelf edge in water deeper than 1,000 m in at least two seasons, spring and summer.

11.3.2 Sea Turtles

Although five species of sea turtles occur off the northeastern United States, three species are considered very rare and will not be discussed. They are Atlantic Ridley (*Lepidochelys kempi*), Hawksbill (*Eretmochelys imbricata*) and Green Turtle (*Chelonia mydas*) (Shoop et al. 1981).

Loggerhead turtle (*Caretta caretta*) is a threatened species and is the most numerous sea turtle in shelf water off the northeastern United States (Shoop et al. 1981). In winter and early spring their range is shelf and slope waters south of 37°N (Shoop et al. 1981) (Figure 40), but from May to November they are found throughout the MAB and reach the southern edge of Georges Bank from July to August (Shoop et al. 1981; Powers et al. 1982) (Figure 41). They are also present in slope waters at this time but sightings are substantially less frequent compared to the MAB (Shoop et al. 1981). The range of loggerheads overlaps the PAI (Figure 1) from May to November and principally in the western edge of the as yet undefined PAI around the Philadelphia disposal site (PDS).

Leatherback turtle (*Dermochelys coriacea*) is an endangered species which is seasonally common in shelf waters off the northeastern United States, but is less abundant than the loggerhead (Shoop et al. 1981) (Figure 42). CETAP (1982) indicated that available data support a seasonal occurrence of leatherbacks, which may be in transit to or from waters further north, but they do not provide details on their routes or movements. However, this species occurs in the PAI (Figure 1) and sighting frequency is greatest in fall.

11.3.3 Sea Birds

Northern fulmars (Fulmarus glacialis) are found throughout boreal, subarctic and arctic waters of the North Atlantic. In the western North Atlantic fulmars occur south to at least Cape Hatteras in late winter and early spring (December to April) (Figures 43 and 44), although the majority of fulmars south of the Grand Banks off Newfoundland are found on the northern flank of Georges Bank (Powers in press). The area of potential impact (Figure 1) includes only the marginal southern limits of the pelagic range of fulmars.

Shearwaters are seasonally abundant in the western North Atlantic and five species regularly occur: Cory's shearwater (Calonectris diomedea), Greater shearwater (Puffinus gravis), Sooty shearwater (P. griseus), Manx shearwater (P. puffinus) and Audubon's shearwater (P. lherminieri). Cory's are found throughout cool subtropical waters of the North Atlantic in summer and fall (Palmer 1962; Brown 1977), but in greatest abundance on the shelf off the northeastern United States from Long Island to the Great South Channel (Figures 45 and 46). Greaters are found principally in boreal and subarctic waters of the western North Atlantic from May to November (Figures 47 to 49) (Brown et al. 1975; Powers in press). The majority of the population resides from Georges Bank north to the Grand Bank, although seasonal migrations through the area of impact may occur. The distribution of Sooties (Figures 50 and 51) is comparable to that of Greaters, except that they have a clock-wise migration through the North Atlantic and the majority of the population is in the east by August (Phillips 1963). A small population of Manx occurs in shelf waters of the western North Atlantic from April to November, although their migration routes from wintering areas of Brazil

(Spencer 1972) must pass through the PAI (Figure 1). Audubon's are found principally in slope waters from June to October (Figures 52 and 53) and their distribution coincides with the area of impact (Figure 1).

Storm-petrels seasonally occur in the western North Atlantic. Wilson's storm-petrel (Oceanites oceanicus) is a breeder in the southern hemisphere which spends the austral winter off the northeastern United States from April to November (Palmer 1962) (Figures 54 to 56). It is found in greatest abundance along the edge of the continental shelf in the MAB from April to May and Georges Bank and in the southwestern Gulf of Maine from June to August (Powers in review). Rowlett (1980) observed c. 200 Wilson's on 13 August 1974 feeding over a slick created by the dumping of sulfuric acid-iron waste at the Dupont Acid Waste Dumpsite off Delaware at 38°33'N, 74°16'W. Although the slick was visible for days, the petrels were seen feeding on parts of the slick for less than 3 h after the dumping. The attraction of Wilson's to oily slicks (Palmer 1962) and their relative abundance in the area of potential impact (Figure 1) is of concern. Leach's storm-petrel (Oceanodroma leucorhoa) breeds from Cape Cod north to Newfoundland and its pelagic distribution is centered mainly around their breeding colonies (Brown et al. 1975). Off the northeastern United States they are most common in the Gulf of Maine and slope water south of Georges Bank in summer months (Figure 57), but densities of Leach's in these waters are relatively small (<3 birds/km^2) compared to shelf waters off Nova Scotia and Newfoundland.

Northern Gannet (Sula bassanus) occurs in shelf waters off the northeastern United States from October to May (Powers in press) (Figures 58-59). They are most abundant in the MAB in winter and will aggregate around fishing vessels.

Gannets are found in greatest densities in March and April along the edge of the shelf which overlaps the PAI (Figure 1).

Phalaropes are seasonal migrants off the northeastern United States. Red Phalarope (Phalaropus fulicarius) is the most abundant species in spring (local densities 1,000 birds/km^2) (Figures 60 and 61); neither red nor red-necked phalarope (P. lobatus) are abundant in fall (Powers in press). The spring migration of phalaropes coincides in space (outer shelf) and time (April-May) with an offshore peak in zooplankton biomass (Powers and Backus 1981). The western edge of the PAI (Figure 1) coincides with the migration corridor of both phalaropes, at least in spring; and offshore dumping would be of concern to their survivability since they sit and peck at small (1-3 mm) zooplankters at the surface.

Great black-backed and Herring gulls (Larus marinus and L. argentatus) occur year-round offshore the northeastern United States, although they are found in greatest abundance from October to April (Powers in press) (Figures 62 to 67). In summer months these species are aggregated around coastal breeding colonies from the Carolinas (Portnoy et al. 1981) north to the Canadian arctic (Powers et al. 1981). Their pelagic distribution is influenced profoundly by fishing activities and they routinely follow ships. Their range extends into the PAI (Figure 1).

Black-legged Kittiwake (Rissa tridactyla) is a visitor to shelf waters south of Nova Scotia from September to March. The southern limit of their pelagic range extends south to at least Cape Hatteras (Powers in press), but the majority of kittiwakes in this area are found on Georges Bank and the southwestern Gulf of Maine (Figure 68). They

occur in the PAI (Figure 1) but this is a marginal souther limit of their range.

Alcids are generally most vulnerable to oil spills and five species have pelagic ranges in the western North Atlantic (Brown et al. 1975). Georges Bank is the southern range limit of any significant densities of Razorbill (*Alca torda*, murres (*Uria* spp.), Dovekie (*Plautus alle*) and Common puffin (*Fratercula arctica*) (Powers in press). Since the PAI is marginal range, no maps are given of this species.

11.4 DUMPSITE EVALUATION.

11.4.1 Cetaceans

The principal focus of this report is to evaluate what populations are present in the areas within and surrounding the two dumpsites, as these are locations within which the likelihood of impact is greatest. To make use of all sources of cetacean data we discussed, distribution was described separately because the methods and sampling schemes differed between the investigators as noted in Table 1. Only the location and timing of each sighting was comparable between data sources. Thus, a plot of all available sightings by season reveals locations within which each species has occurred. However, there are differences which are not reflected in the distribution plots, between seasons, in levels of observer effort. Thus, the maps are of limited quantitative value.

The aerial surveys by CETAP were experimentally adequate to allow the calculation of densities and population sizes of cetacean populations with confidence. The other data bases are based entirely on opportunistic sightings, and

methodologies have not yet been developed to derive statistically confident densities from such data. CETAP (1981) partitioned shelf and slope waters off the northeastern United States into nine areas. Those areas designated in the MAB included the entire shelf and prevent any comparisons of densities across the shelf, for which differences in the distribution of most cetaceans exist (Hain et al. 1981). Generally, baleen whales remained on the shelf and odontocetes (except Harbor porpoise and white-sided dolphin) occurred along the shelf-break. CETAP (1982) subdivided the MAB areas according to depth, which made cross-shelf comparisons possible. In this report we combined cetacean densities from CETAP stratum Y in areas G and H (CETAP 1982) to derive a representation of mean densities and minimum population sizes at the Philadelphia Dumpsite (PDS) and from stratum Z in areas F and G for the 106-Mile Site. Although the 106-Mile Site occurs further offshore than CETAP's stratum Z, these data are the most comparable statistics available for evaluating the seasonal densities of cetaceans in that area. With regard to the large elliptical envelope (PAI) for the 106-Mile Site (Figure 1) that considers warm-core eddy interactions, we indicated the seasonal occurrence of all species in Table 2, as noted by at least one documented sighting of a given species within that envelope. Again, this table is of little quantitative value, but in a qualitative sense describes what species may be present and in which season they are to be expected.

At the Philadelphia disposal site (PDS) cetacean mean densities (animals/km^2) and minimum population estimates (with a 95% confidence interval) were available for all seasons[2] using CETAP strata Y in areas G and H (CETAP 1982). Cetaceans were present in only spring and summer (Table 3). Two species of baleen whales were found, fin

Page 14, bottom--Add the footnote "[2] Seasons were based on four surveys with survey I (5 Feb - 3 Apr 1980) as spring, survey II (19 May - 19 Jul 1980) as summer, survey III (25 Aug - 17 Oct 1980) as fall, and survey IV (17 Nov 1980 - 22 Jan 1981) as winter (extracted from CETAP 1982)."

and minke whales. A high minimum population estimate was noted for fin whales in spring (252 ± 287). The minimum population estimate of fin whales for the entire shelf/slope area off the northeastern U. S. is 323 (±418) (CETAP 1982) (Table 4), so as much as 75 percent of the population south of Nova Scotia is potentially present around the PDS in spring. Fin whale is an endangered species (Table 4). Densities for three species of toothed whales were estimated for the PDS; bottlenosed and saddleback dolphins and Grampus (Table 3). Nearly 5,000 saddleback dolphins were estimated in spring and as many as 1,300 bottlenosed dolphins in summer. Minimum populations estimates of these species for the entire shelf/slope area off the northeastern U. S. are given in Table 4. No odontocetes were found in fall and winter.

At the 106-Mile Site cetacean mean densities (animals/km^2) and minimum population estimates (with 95% confidence intervals) were available for spring, summer and fall using CETAP stratum Z in areas F and G (CETAP 1982). There were no data in winter. Densities were estimated for one species of baleen whale, fin whale, and five species of toothed whale (sperm and pilot whales, bottlenosed and saddleback dolphins and Grampus) (Table 5). A low density of fin whales was found in fall. Relatively high densities of bottlenosed dolphins pilot whales, and Grampus, were noted for summer and fall, summer, and for all three seasons, respectively (Table 5). When minimum population estimates for the 106-Mile Site (Table 5) area are compared with the overall population estimates for these species in the entire shelf/slope region off the northeastern U. S. (Table 4),

we can predict that potentially a majority of these populations could be in the 106-Mile Site area in summer and fall. A minimum estimate of 69 (±52) sperm whales, an endangered species, was noted in summer (Table 5). This estimate represents approximately half of the total population estimate given in Table 4.

11.4.2 Turtles

Our quantitative evaluation of turtles in the vicinities of the PDS and 106 PAI were also based upon data from CETAP (1982). We used the same method for compiling densities of loggerhead and leatherback turtles, as was already described for cetaceans. At the PDS both species of turtles were found, but loggerhead was the most abundant (Table 3). Loggerheads, a threatened species, occurred in the PDS area in summer and fall. Using the minimum population estimate of loggerheads for summer (2871 ± 283), potentially 38 percent of the entire stock off the northeastern U. S. (Table 4) may be in the vicinity of the PDS at this time. Loggerheads were also found in the 106-Mile Site during summer and fall (Table 5), but densities were well below those recorded further inshore.

Leatherback turtle, an endangered species, was found only in fall in the area of PDS (Table 3). CETAP's (1982) minimum estimate of leatherbacks off the northeastern U.S. is 81-85 (Table 4), and it appears that of those leatherbacks found in the MAB, most occur in near and mid-shelf waters (Figure 42).

11.4.3 Birds

Quantitative bird data for the PDS and 106-Mile Site were extracted from MBO data for the period June 1980 through November 1982. MBO's bird data are stored by location and strata. The strata are the same offshore strata used in the National Marine Fisheries Service/Northeast Fisheries Center (NMFS/NEFC) groundfish trawl surveys (Grosslein et al. 1980). the PDS lies in NMFS/NEFC stratum #69 and bird densities were compiled by 3-month seasons (winter starts on 1 Dec.) for this stratum. The 106-Mile Site is in North Atlantic slope water, which is east of the NMFS/NEFC shelf strata. Powers and Brown (in review) considered slope water as a relatively uniform and rather poor habitat for birds throughout the year. Thus, we consider all bird densities derived from slope water to be indicative of what one might expect at the 106-Mile Site.

Mean densities (birds/km^2) of birds in the vicinity of the PDS by season and species are given in Table 6. There are no threatened or endangered species which regularly occur in this area. The sample sizes to compute these densities are relatively small (23-31 transects, Table 6). All densities, except Cory's Shearwater in summer, can be considered low when compared with populations further inshore in summer or on Georges Bank throughout the year (Powers in press; Powers and Brown in review; Powers et al. 1982). The mean density of Cory's Shearwater in summer was skewed upwards because of one flock of approximately 75 individuals found in one transect. Similarly to the PDS area, one might expect low densities of birds in the vicinity of the 106-Mile Site (Table 7) throughout the year. The only consideration that is not evident from Tables 6 and 7 is the spring migration of red phalaropes and Wilson's storm-petrels through the MAB in April and May. The migration of phalaropes is relatively

restricted to a corridor along the outer-edge of the shelf, 60-200 m (Figure 60). Local densities of phalaropes over a 10-100 km^2 area may be as thick as 5,000 birds/km^2 in this corridor. Storm-petrels also indicate a propensity to aggregate along the shelf-break of the MAB in April and May, before moving north to Georges Bank and the southwestern Gulf of Maine where they are most abundant from June to August (Powers in press). Local densities of storm-petrels over a 10-100 km^2 area may be as thick as 100-500 birds/km^2 in the shelf-break region. Thus, these two species are present in the warm-core eddy interaction envelope (Figure 1) in spring, and are potentially abundant in the vicinity of both dumpsites at this time.

11.5 IMPLICATIONS.

In the previous sections we presented data and discussed the seasonal distribution and abundance of cetaceans, turtles and birds in the vicinity of the PDS and the 106-Mile Site. It would also be useful to evaluate the residence time of these species in the dumpsite areas and how these animals may be affected by the dumping activities. We feel that we cannot address these questions adequately, but we can speculate on possible implications.

We know of no information on residence time for birds or turtles at sea. For marine mammals, CETAP (1982) indicated that individual humpback whales remained in one area off Cape Cod for a maximum of 24 days and groups of individuals for up to 8 days, but this species would only pass through the dumpsite area during spring and fall migration.

We assume that food availability and the competitive interactions between these and other predators are the most important factors controlling the distribution of all these groups of animals,

unless they are breeding or in migration to or from breeding to wintering areas. Predation is not a major factor in regard to these populations, since man is the only potential predator in this area; the killer whale (Orca orcinus) is another but it is rare off the northeastern United States (CETAP 1982).

A better understanding of food habits in relation to prey availability is needed for a thorough evaluation of residence time and food chain related effects caused by excessive burdens of pollutants from dumping. For example, the spring migration of phalaropes and storm-petrels along the seaward edge of the MAB correlates with an offshore (>50 m) maximum of zooplankton on the shelf (Judkins et al. 1980). These birds feed on various zooplankton (fish eggs, barnacle cyprids, copepods, euphausiids) at the surface. Concentrations of toxic chemicals great enough to destroy or affect these zooplankton would probably cause birds to forage elsewhere. However, sublethal doses of pollutants, which can be entrained into the food web but still allow these prey populations to remain at optimum abundance, represent the most damaging effect, other than direct physical contact with the toxic wastes. The accumulation of pollutants in individual predators (secondary and tertiary carnivores) could impair breeding performance and survival in the long-term.

Another implication may be related to seasonal mixing regimes in the MAB and adjacent slope water. The vertical structure of the water column in the MAB is well-mixed in winter and early spring, and well-stratified in summer and early fall (Bumpus 1973). In spring, productivity maxima occur in near-surface waters, whereas in summer these maxima are found at depths closer to the thermocline where nutrients are more available (Walsh et al. 1978). Consequently, one might predict a pelagic food web under mixed conditions, and a demersal or benthic energy transferral under stratified conditions. The feeding strategies of mammals, birds and turtles would change according to these oceanographic regimes. In well-mixed conditions food may be available

throughout the water column, but in stratified conditions feeding may be limited to depths at or below the thermocline. Therefore, knowledge of the fate of various chemicals dumped at these sites may provide an insight into potential damage to cetacean, turtle and bird populations.

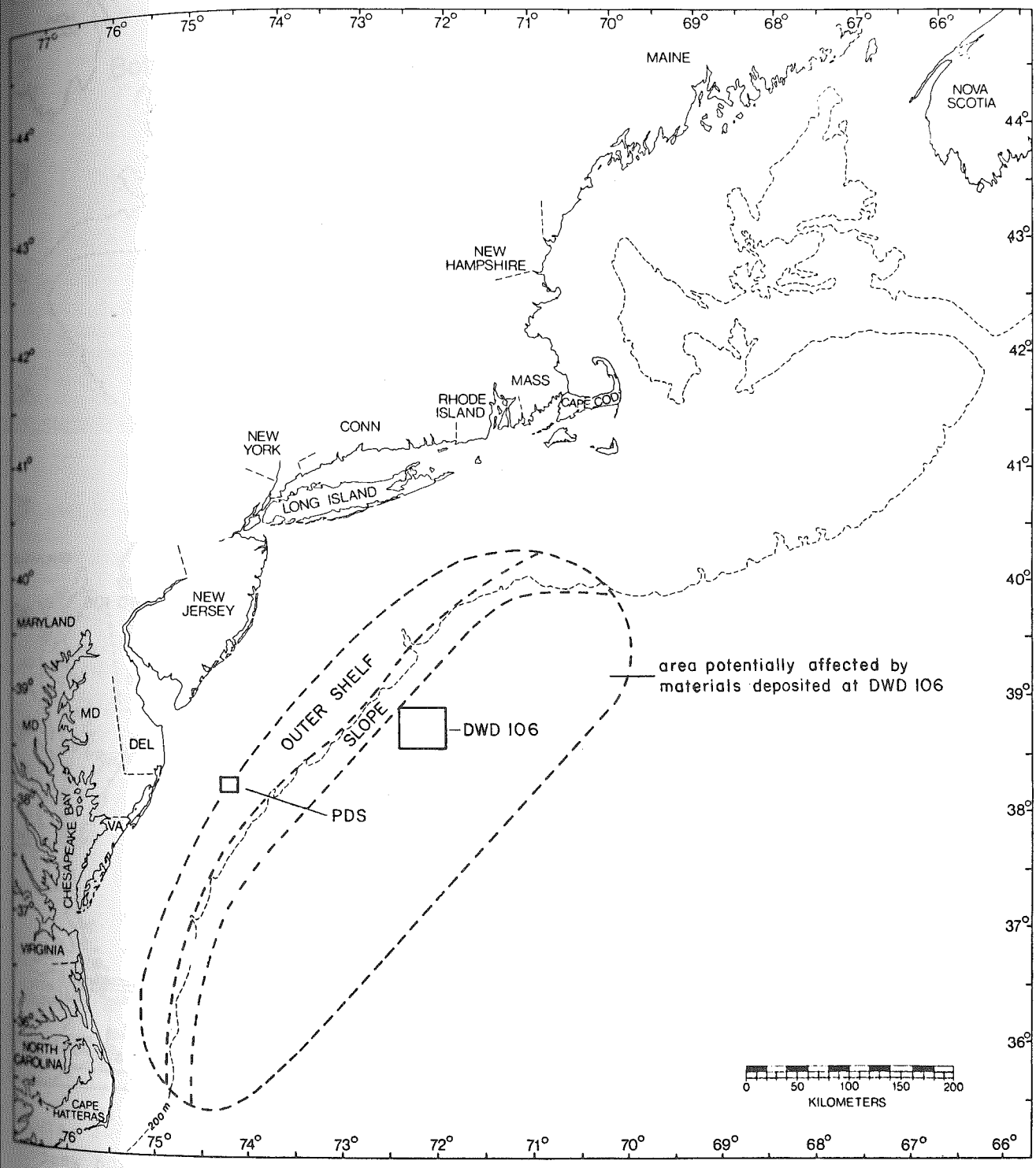


Figure 1. Location of study area, Philadelphia Dumpsite (PDS), Deepwater Dumpsite 106 (DWD-106) and limits of warm-core eddy interaction envelope (adapted from Smith et al. 1982).

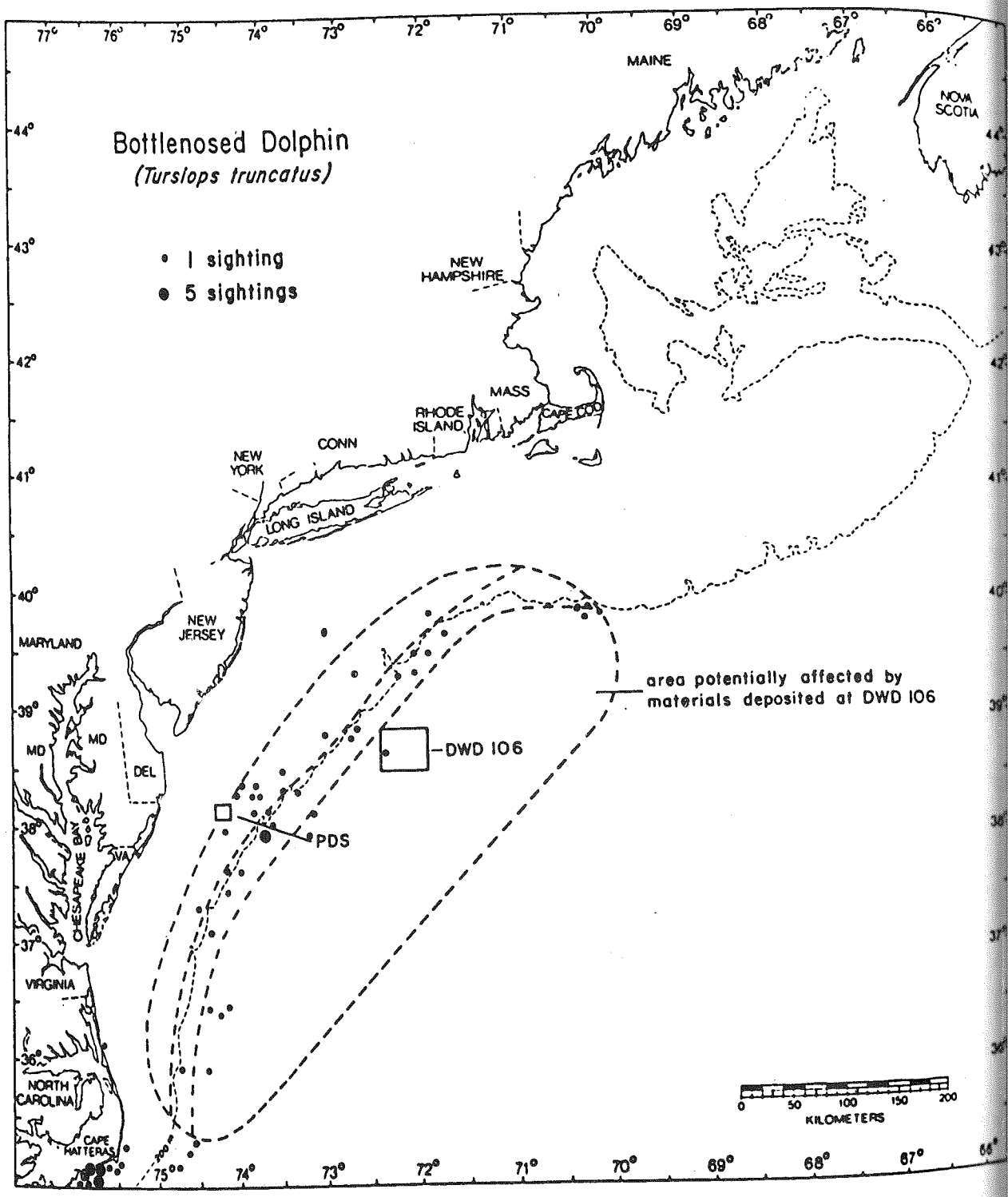


Figure 2. Known sightings of Bottlenosed Dolphin (Tursiops truncatus) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

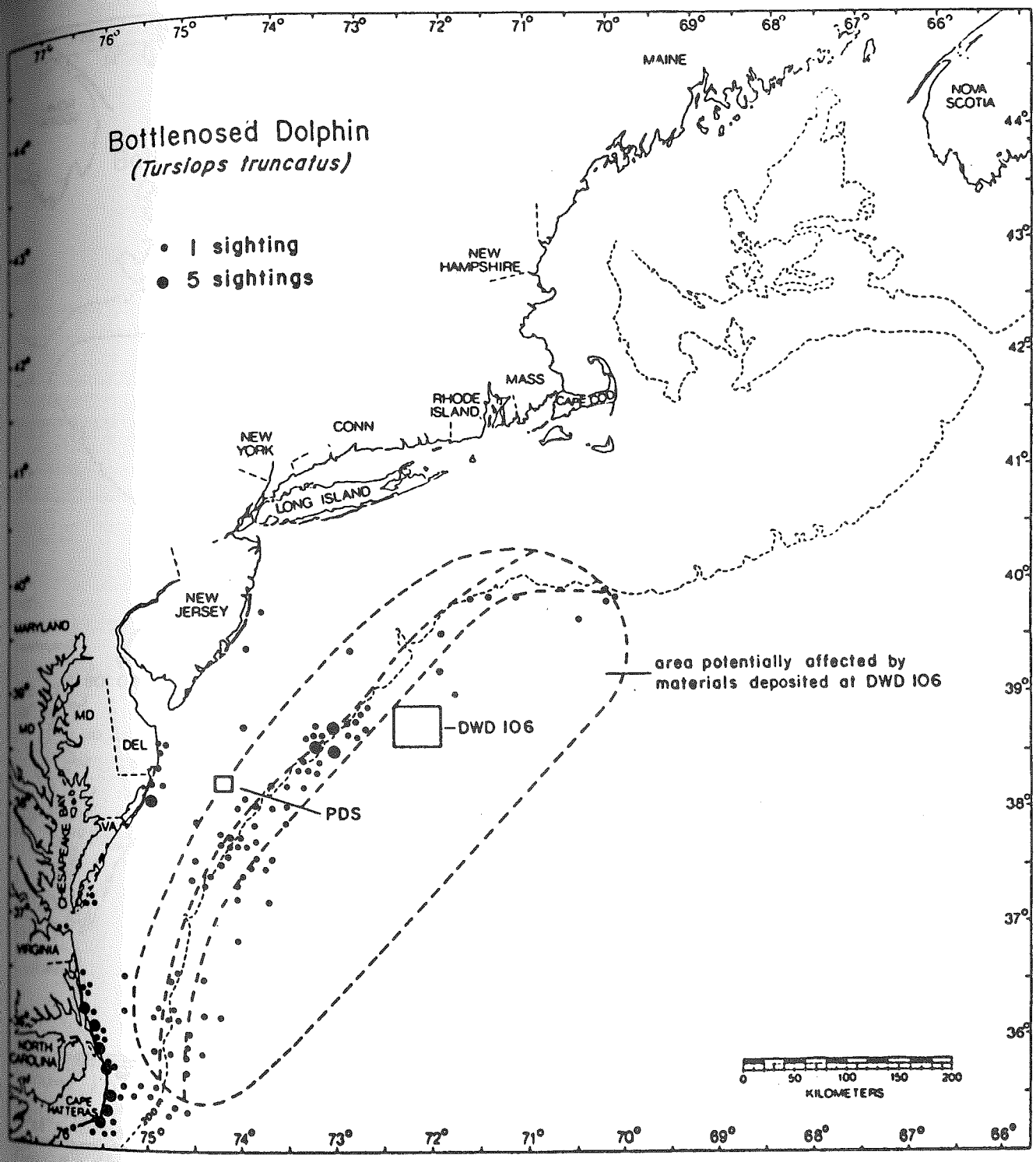


Figure 3. Known sightings of Bottlenosed Dolphin (Tursiops truncatus) in summer (June to August) between 35°00′ and 40°00′N latitude and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

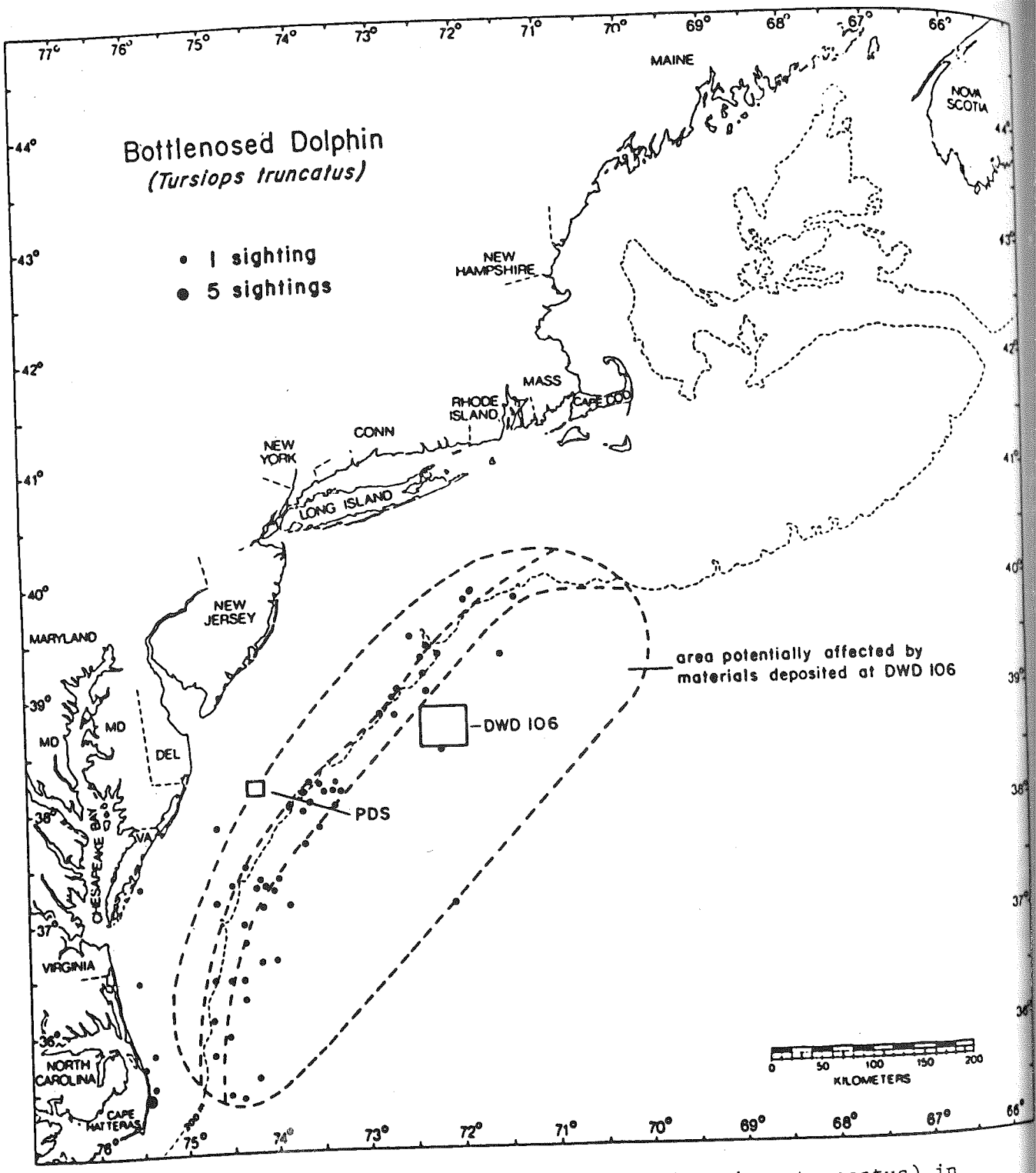


Figure 4. Known sightings of Bottlenosed Dolphin (Tursiops truncatus) in in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

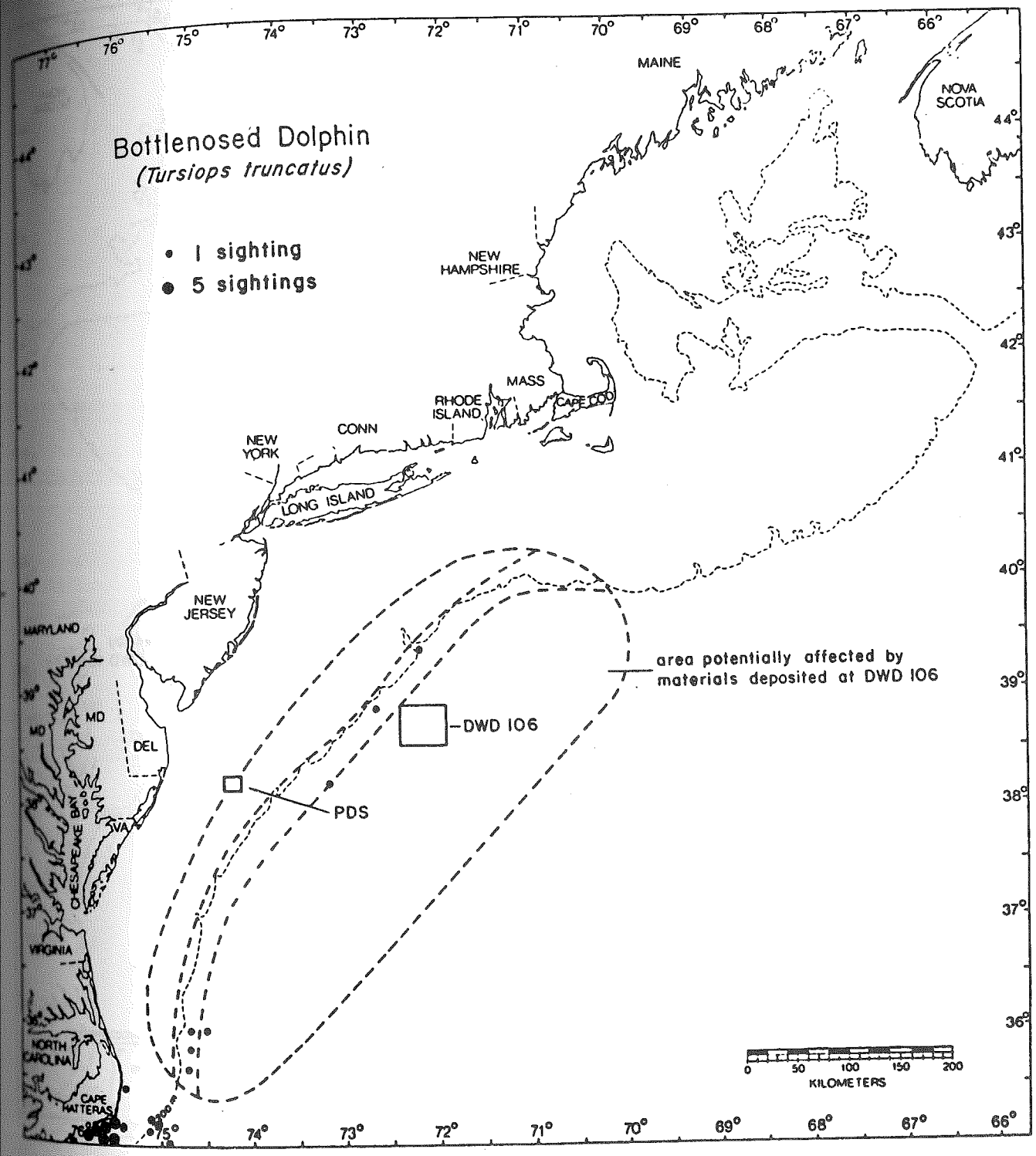


Figure 5. Known sightings of Bottlenosed Dolphin (Tursiops truncatus) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

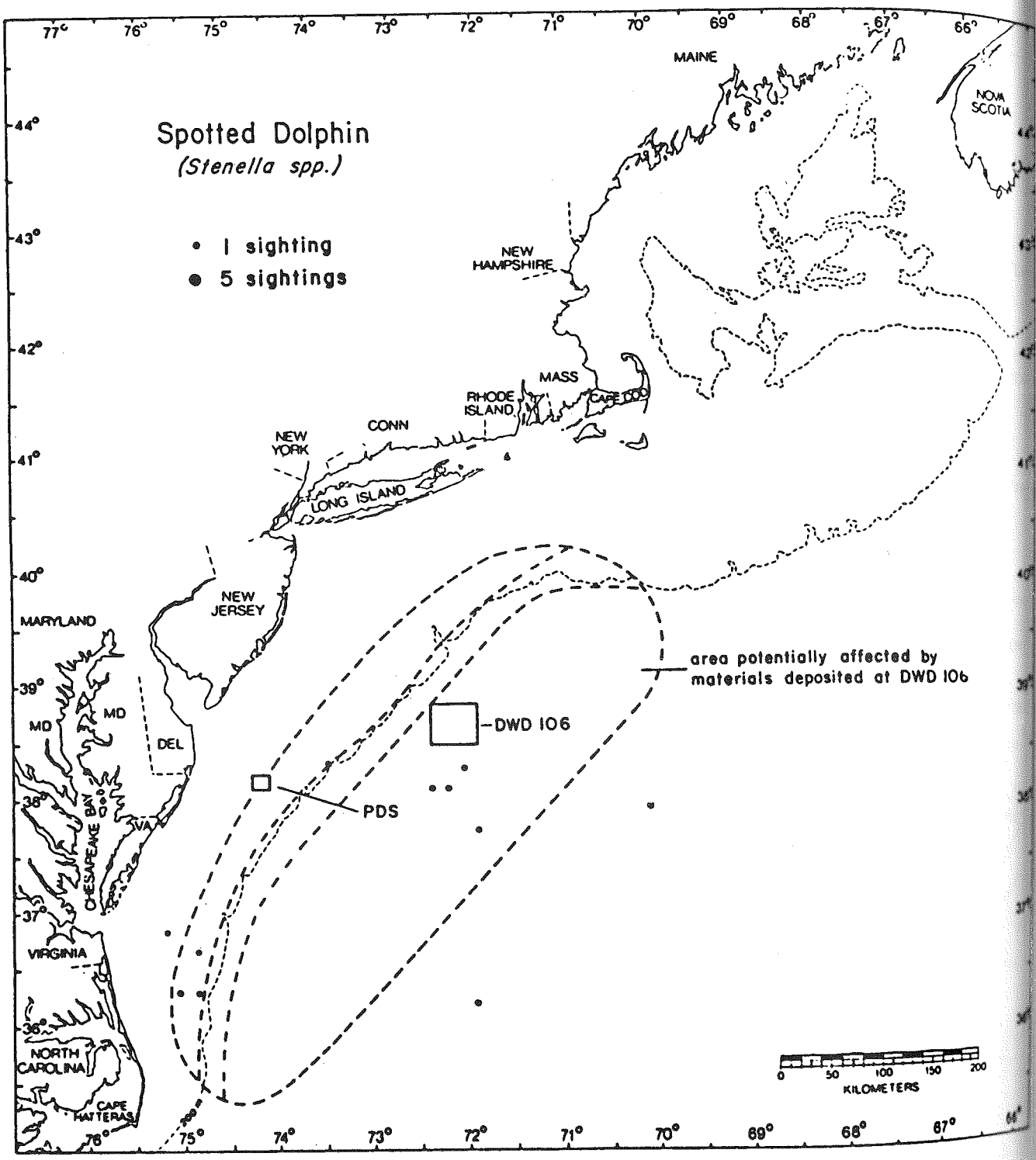


Figure 6. Known sightings of spotted dolphins (Stenella spp.) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

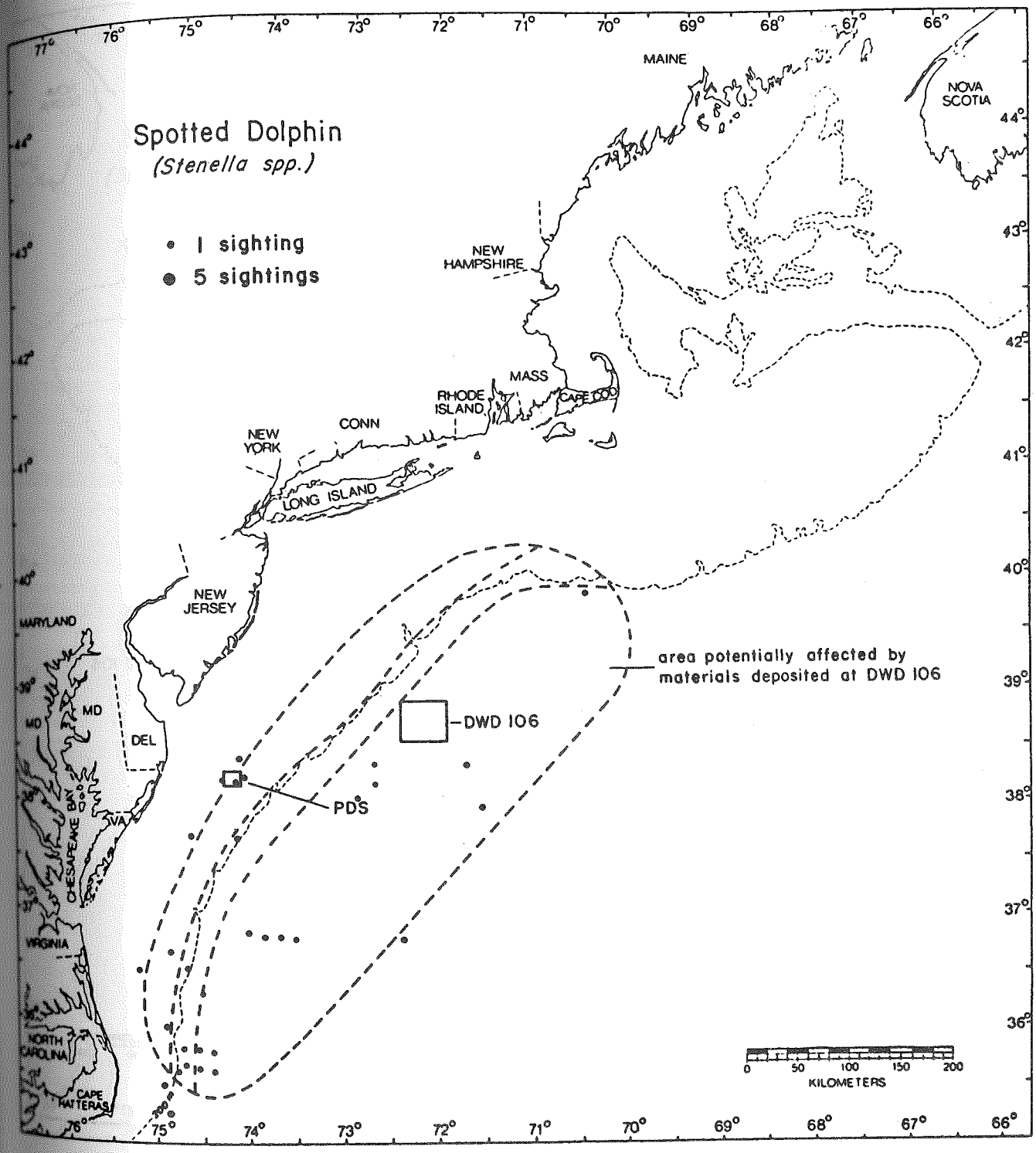


Figure 7. Known sightings of spotted dolphins (Stenella spp.) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

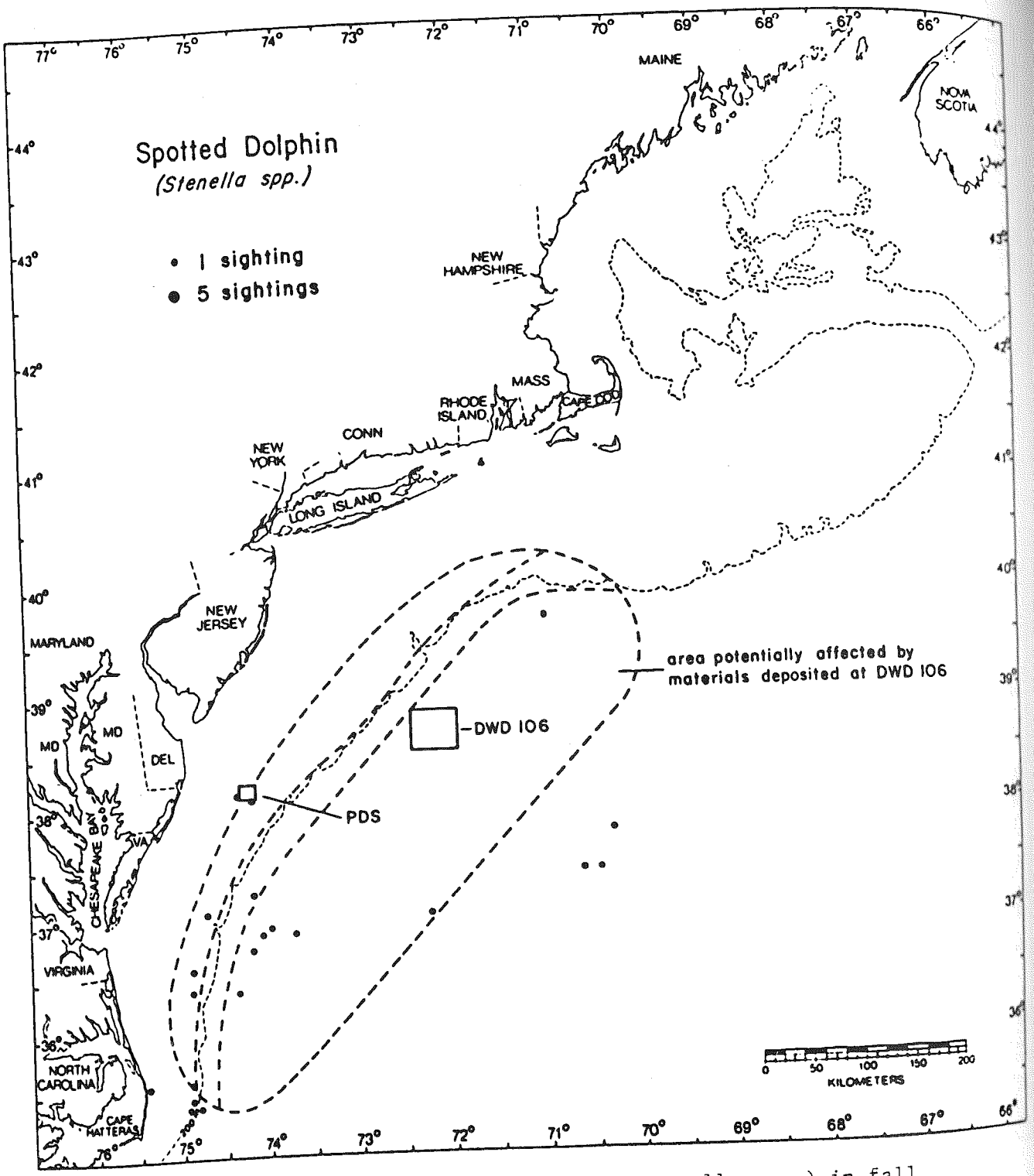


Figure 8. Known sightings of spotted dolphins (Stenella spp.) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

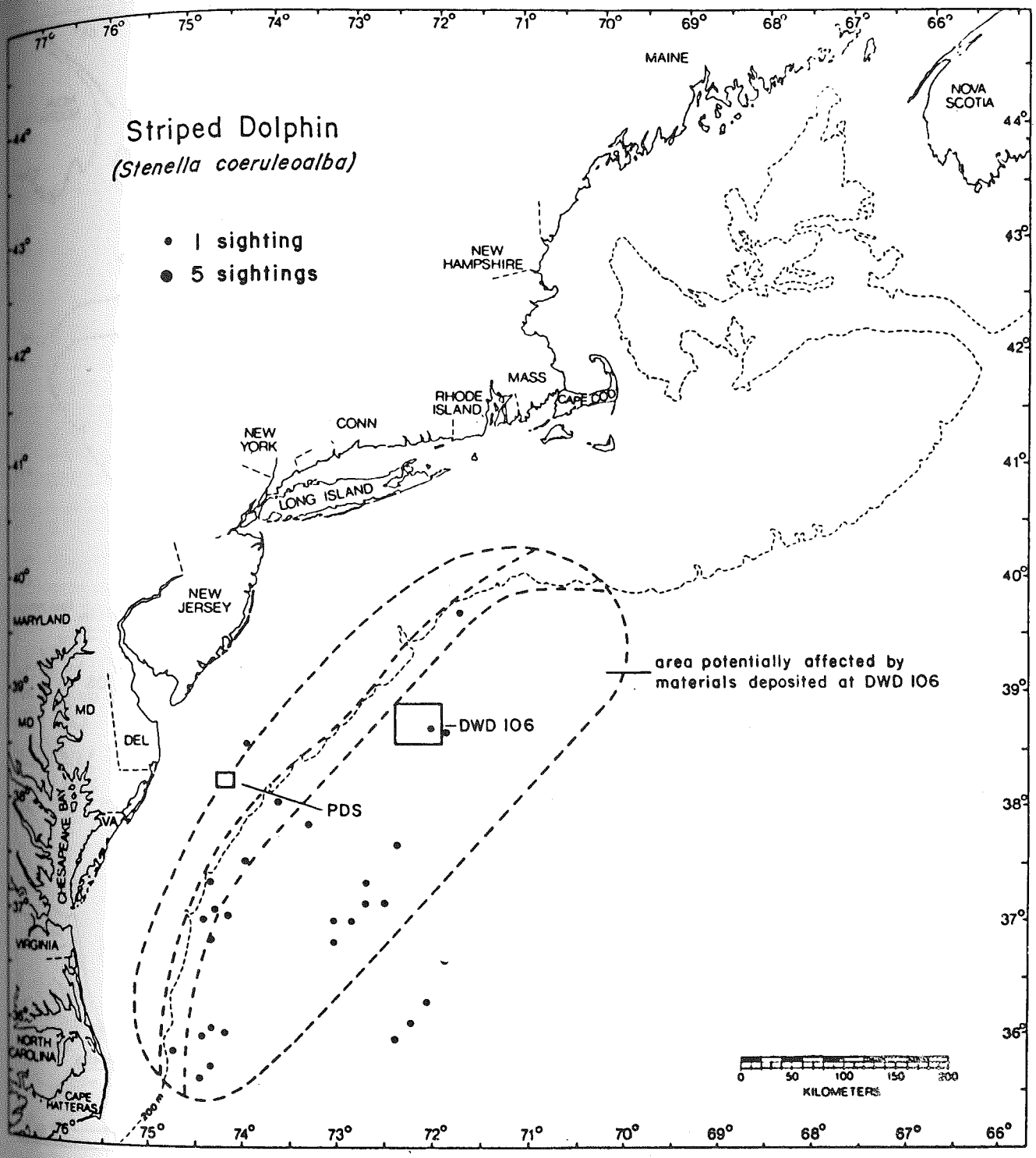


Figure 9. Known sightings of Striped Dolphin (Stenella coeruleoalba) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

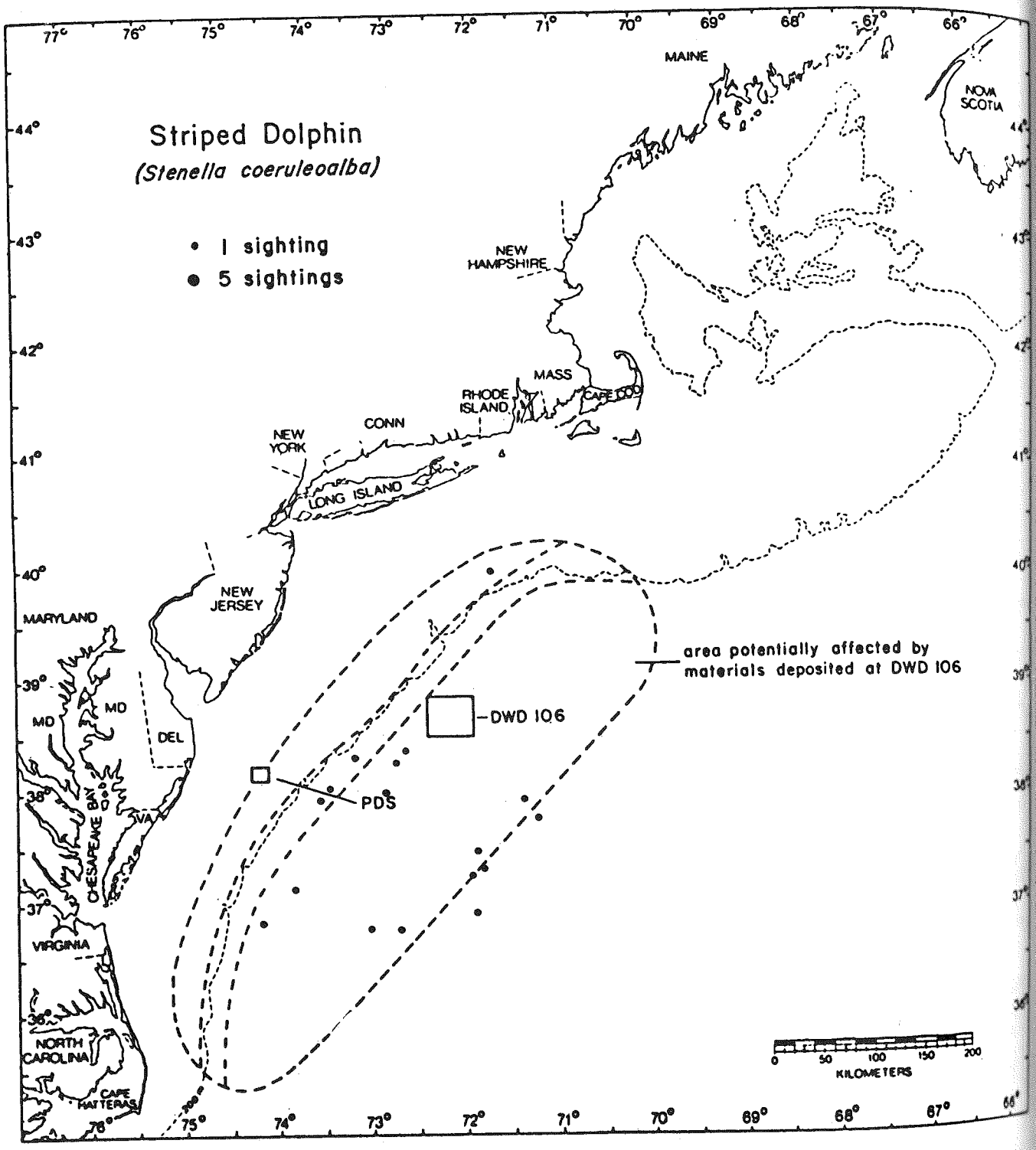


Figure 10. Known sightings of Striped Dolphin (Stenella coeruleoalba) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

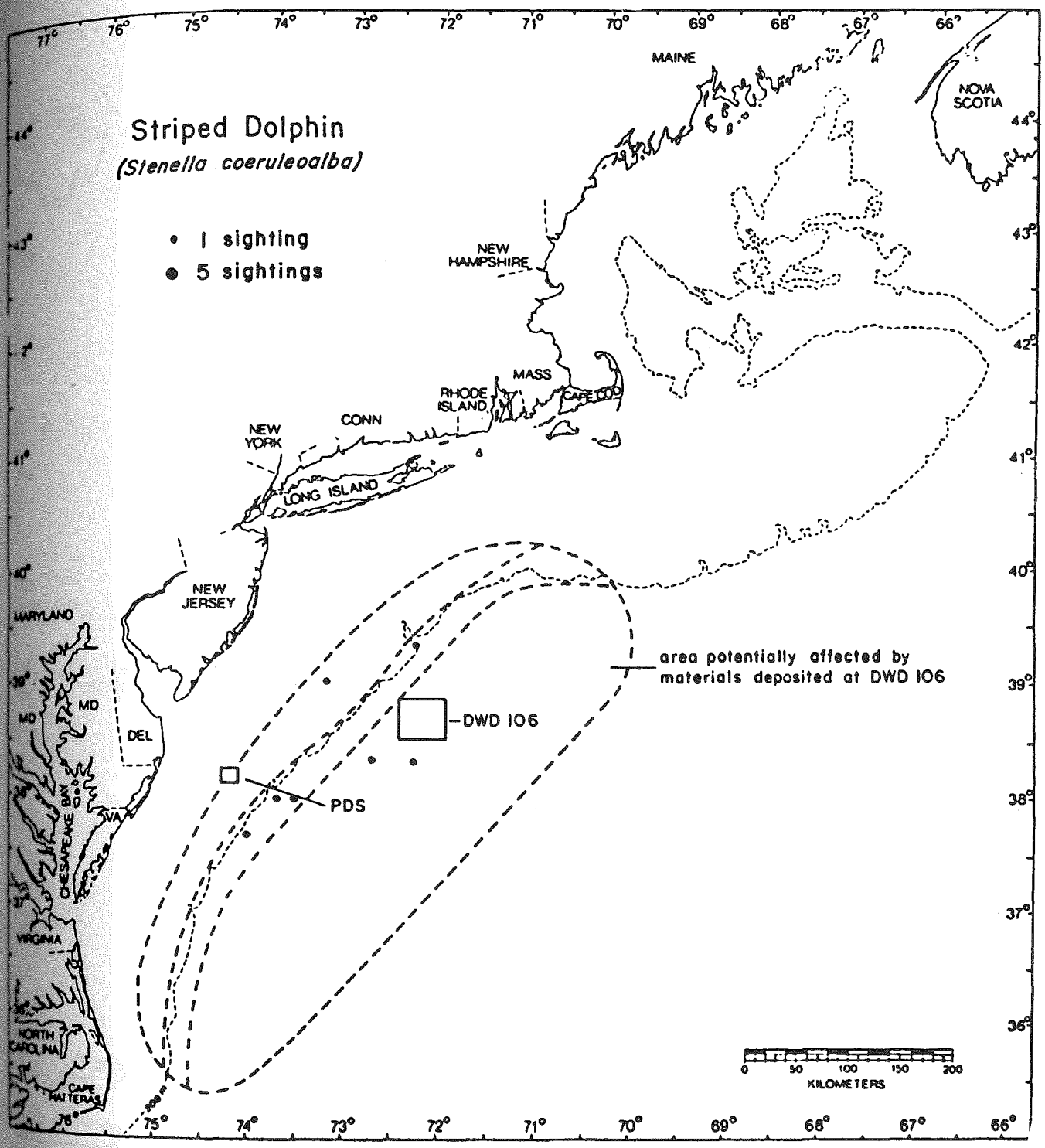


Figure 11. Known sightings of Striped Dolphin (Stenella coeruleoalba) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

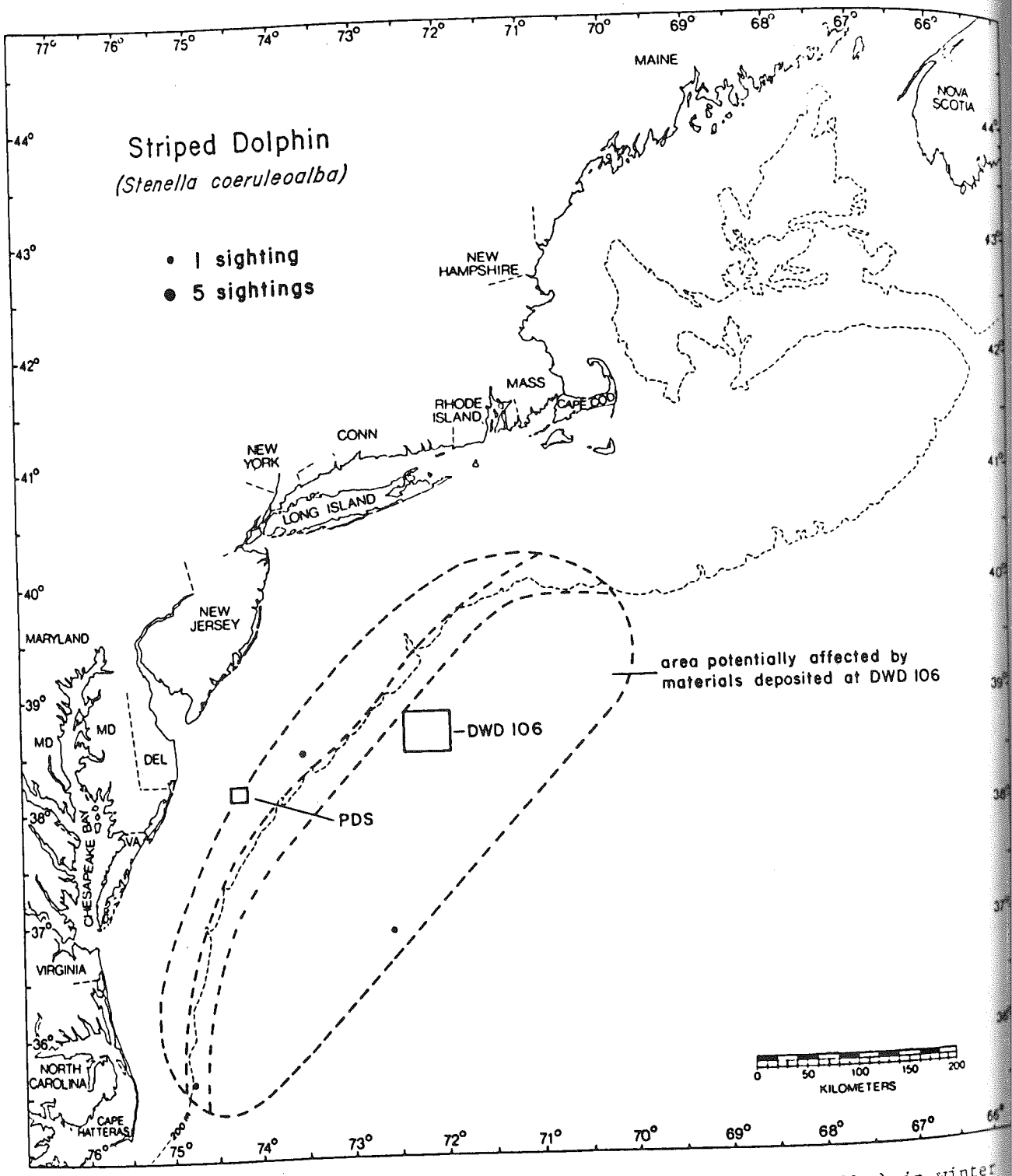


Figure 12. Known sightings of Striped Dolphin (Stenella coerueoalba) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

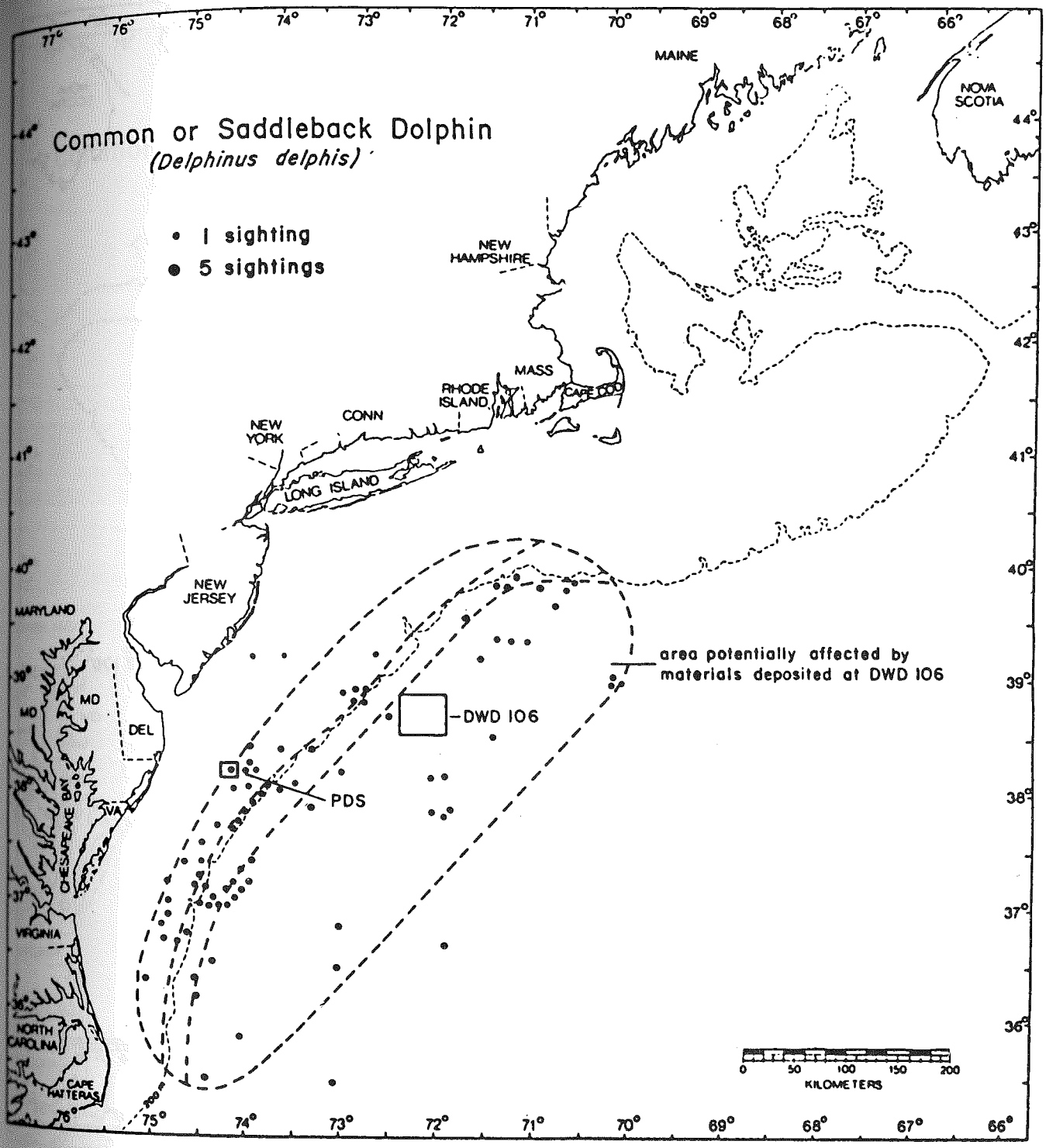


Figure 13. Known sightings of Common Dolphin (Delphinus delphis) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

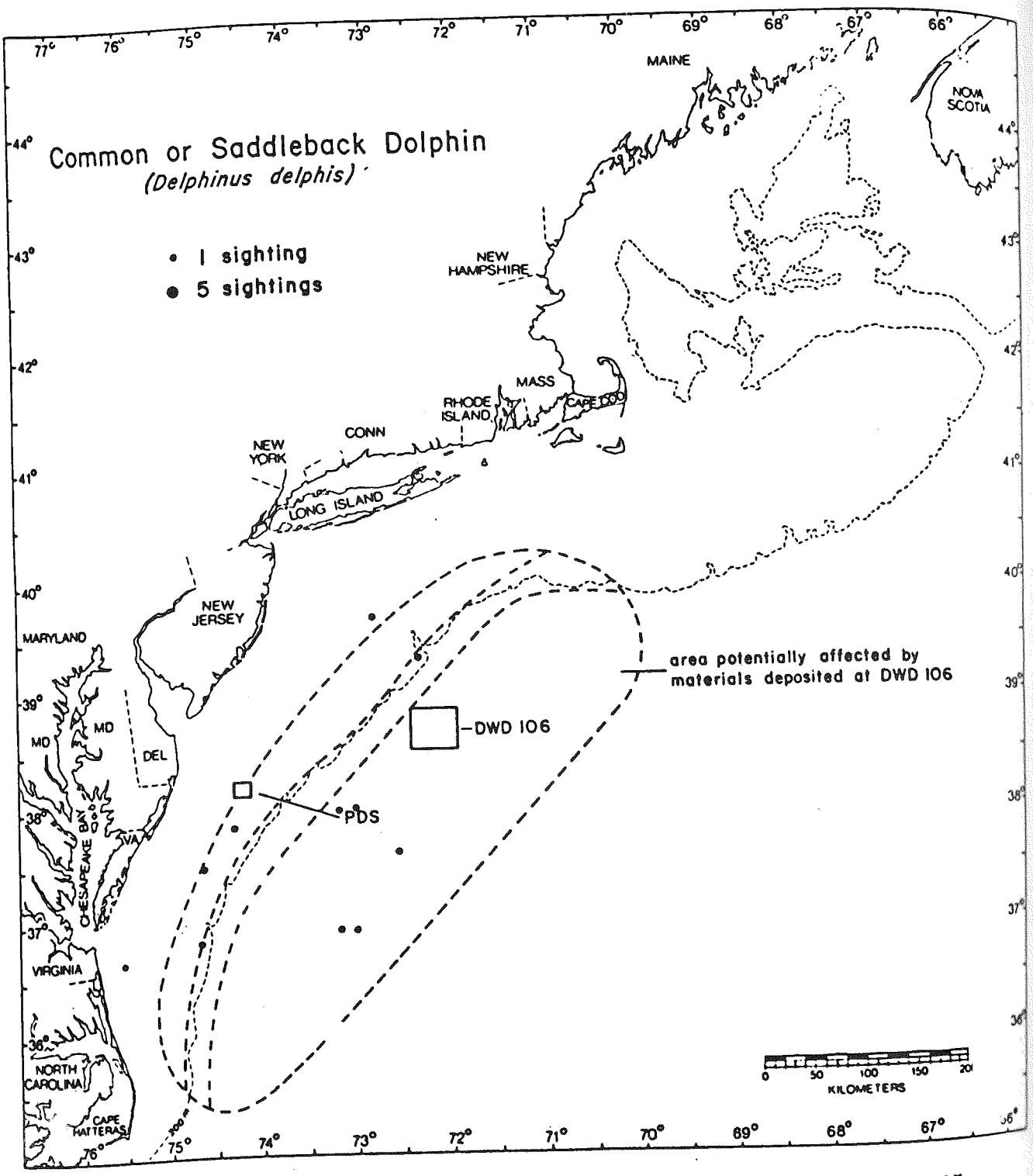


Figure 14. Known sightings of Common Dolphin (Delphinus delphis) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

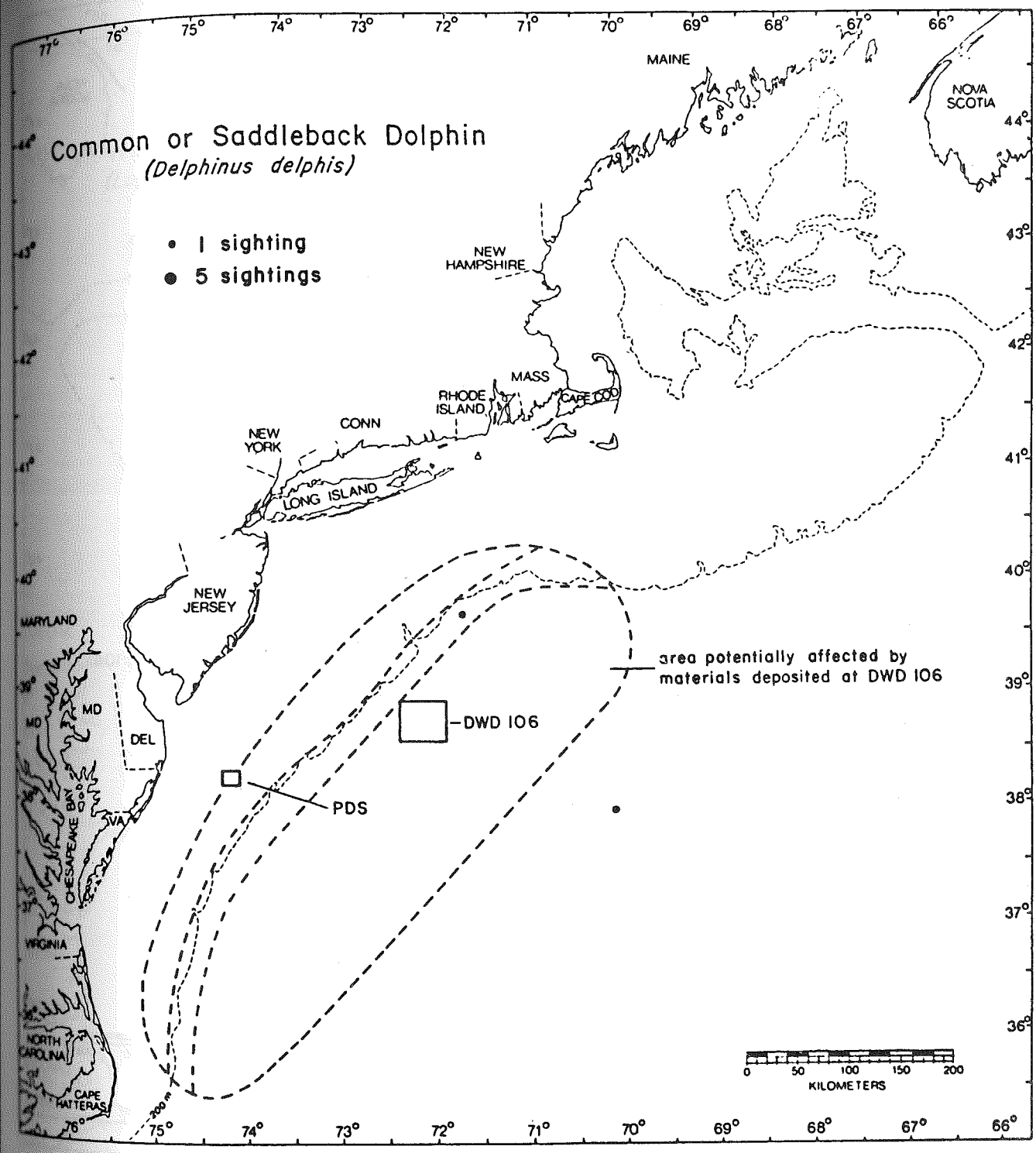


Figure 15. Known sightings of Common Dolphin (Delphinus delphis) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

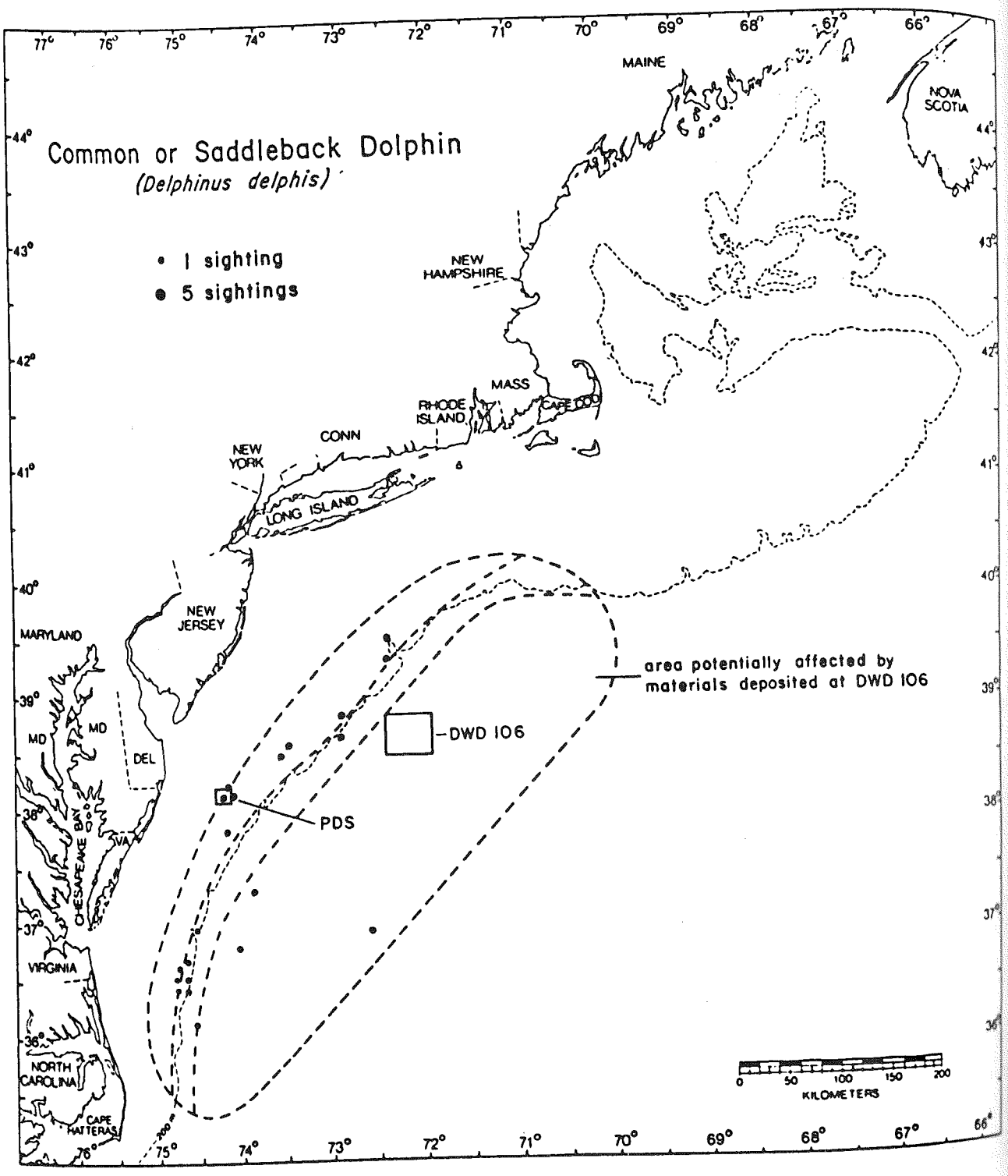
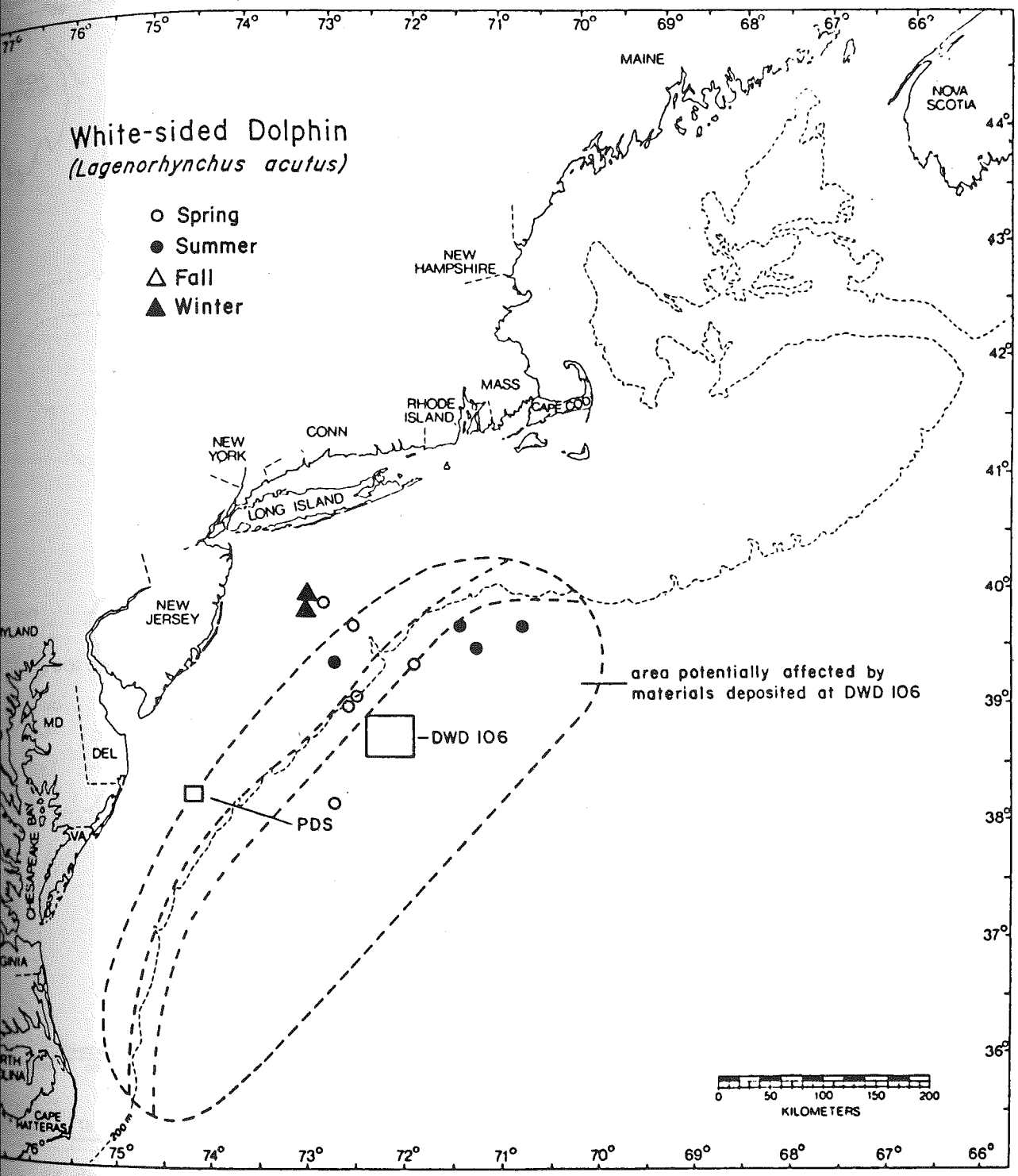


Figure 16. Known sightings of Common Dolphin (Delphinus delphis) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.



ure 17. Known sightings of White-sided Dolphin (Lagenorhynchus acutus) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

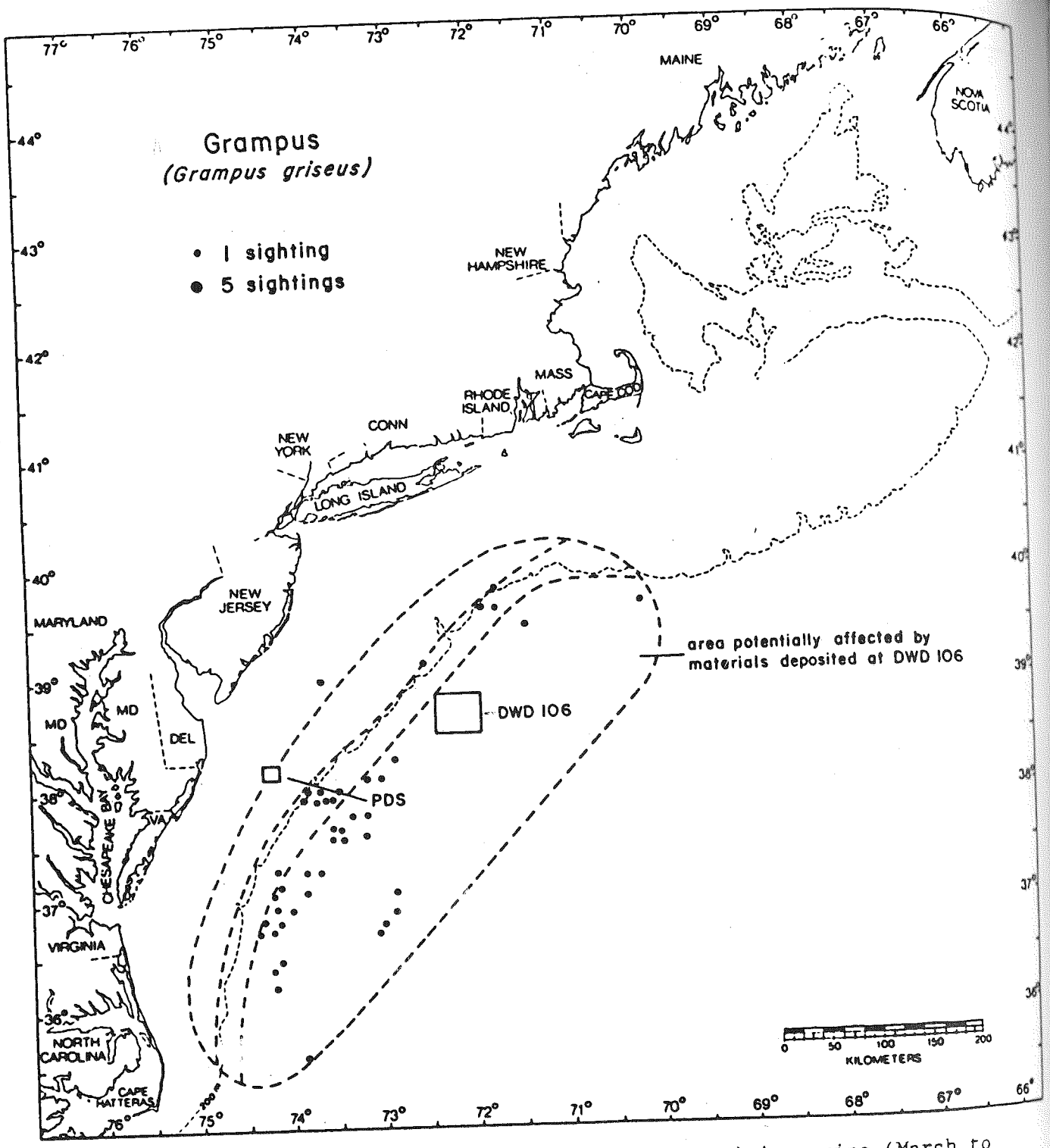
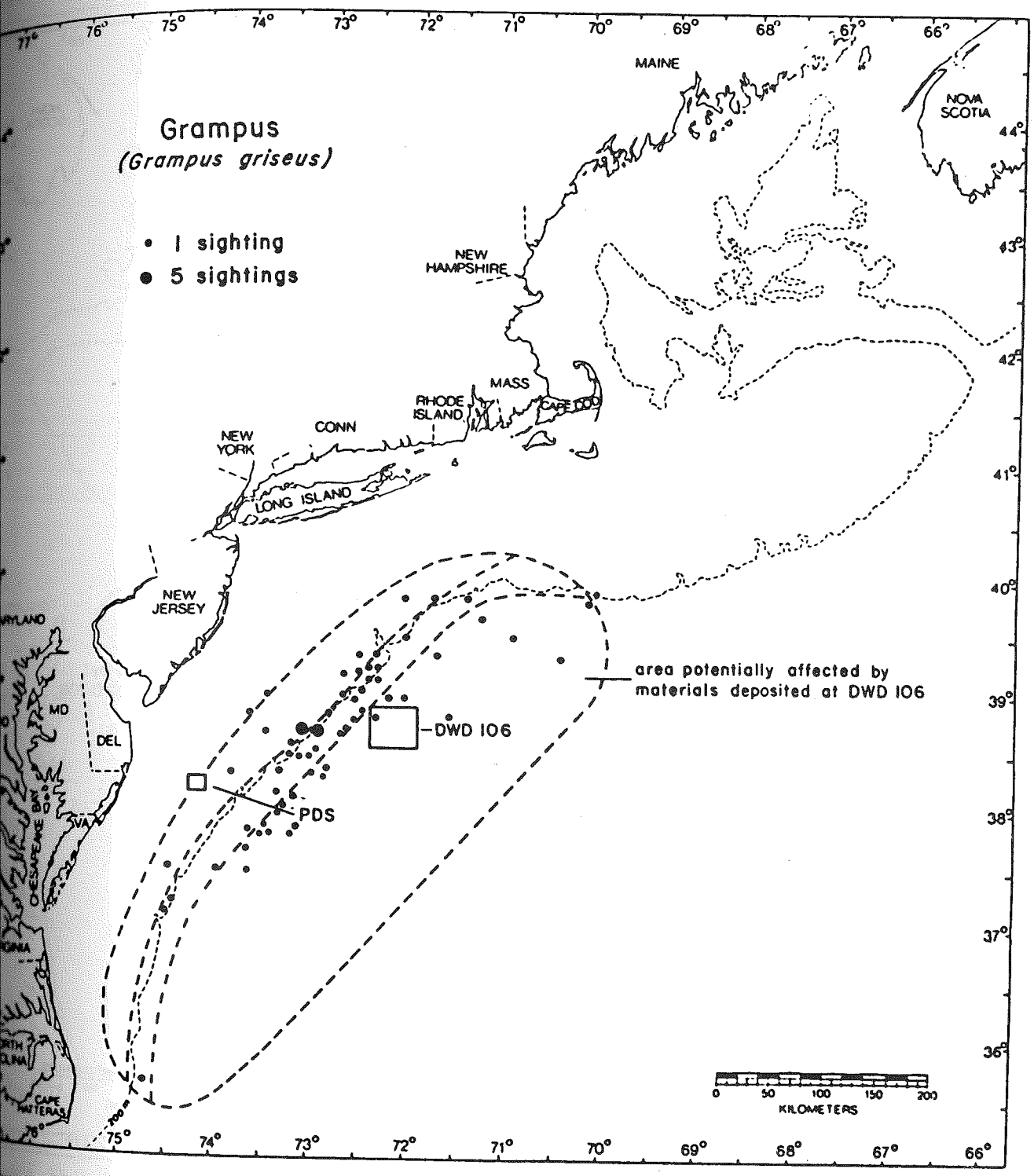


Figure 18. Known sightings of Grampus (Grampus griseus) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.



ure 19. Known sightings of Grampus (Grampus griseus) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

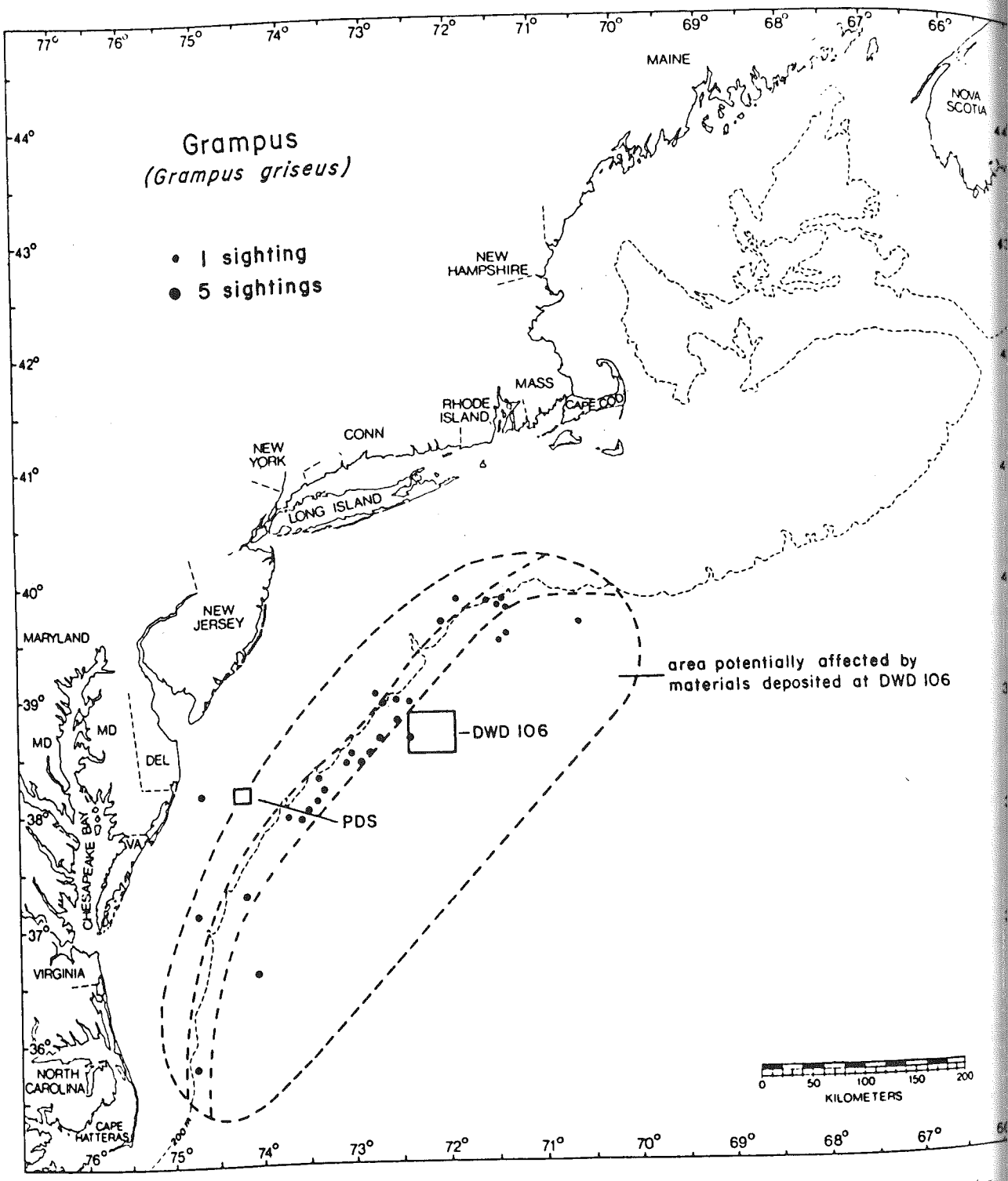


Figure 20. Known sightings of Grampus (Grampus griseus) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

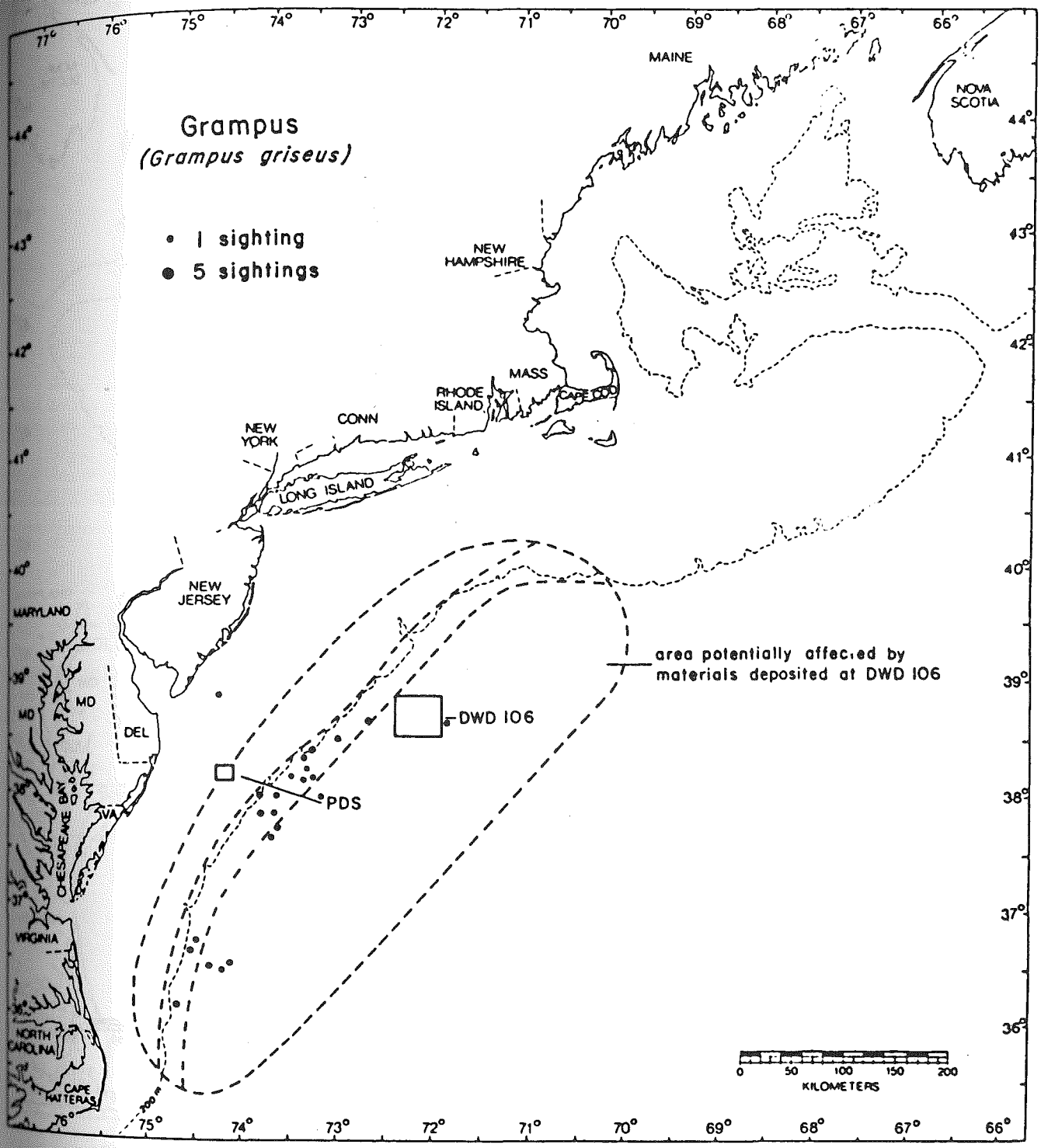


Figure 21. Known sightings of Grampus (Grampus griseus) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

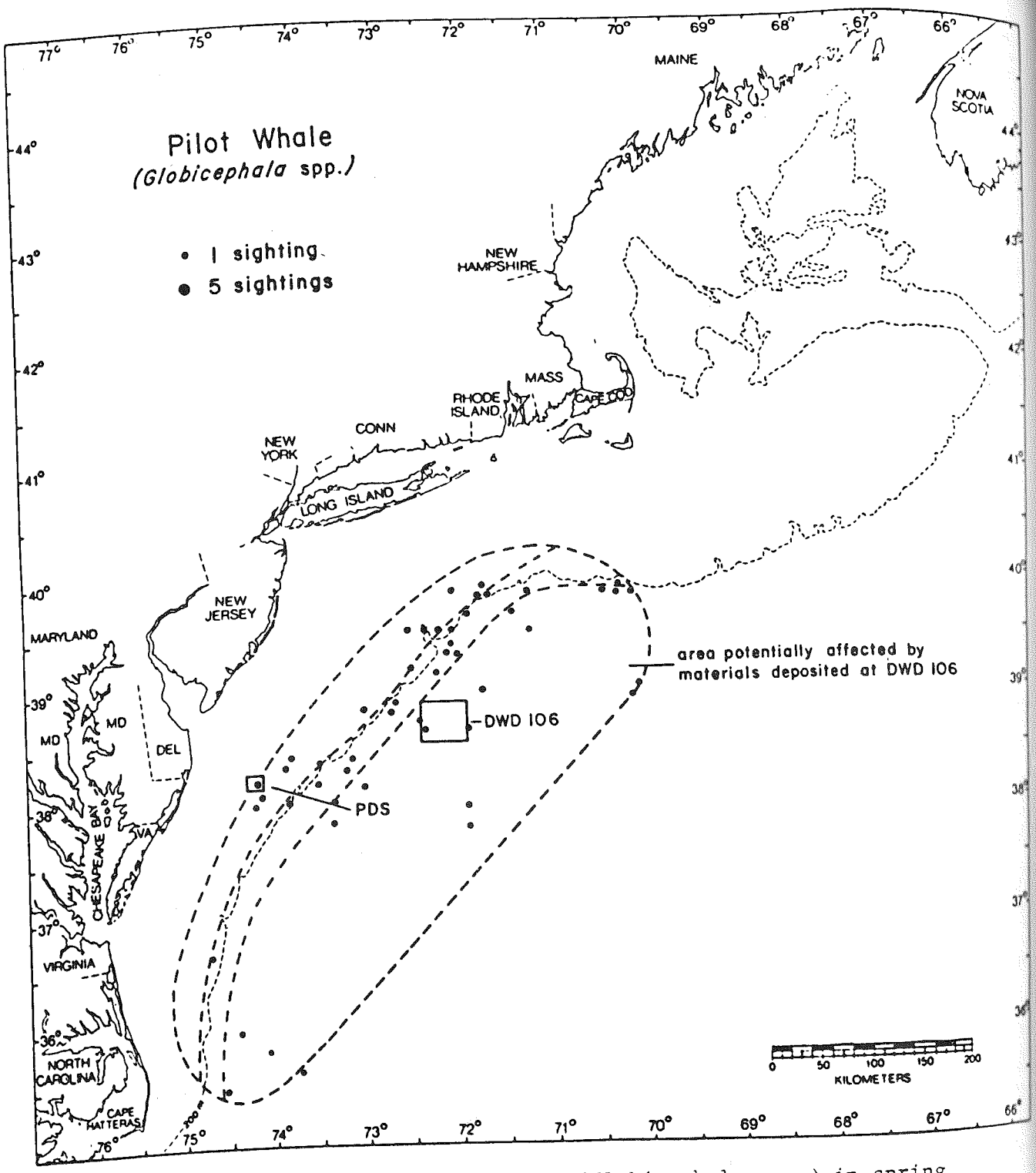


Figure 22. Known sightings of pilot whales (Globicephala spp.) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

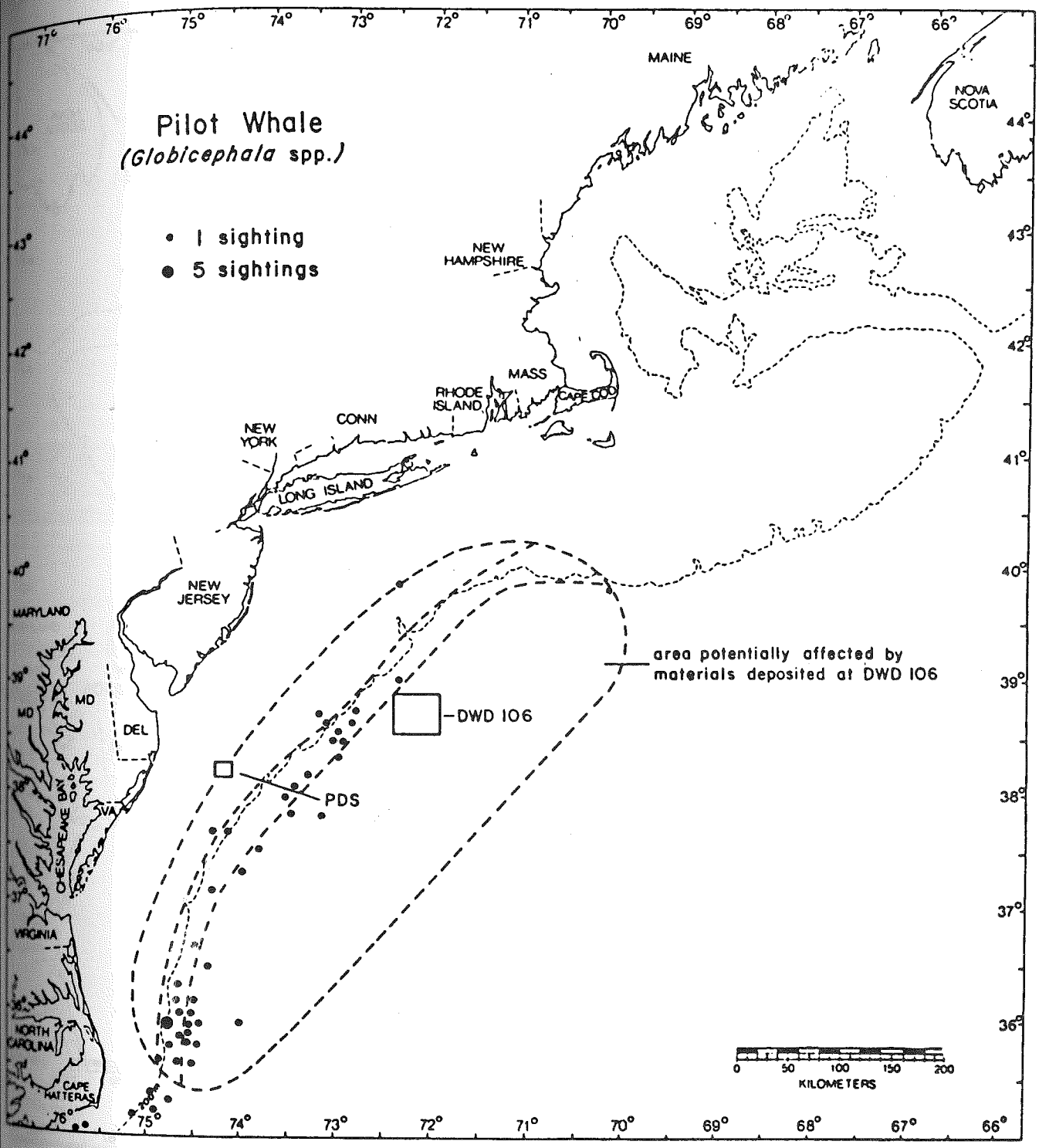


Figure 23. Known sightings of pilot whales (Globicephala spp.) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

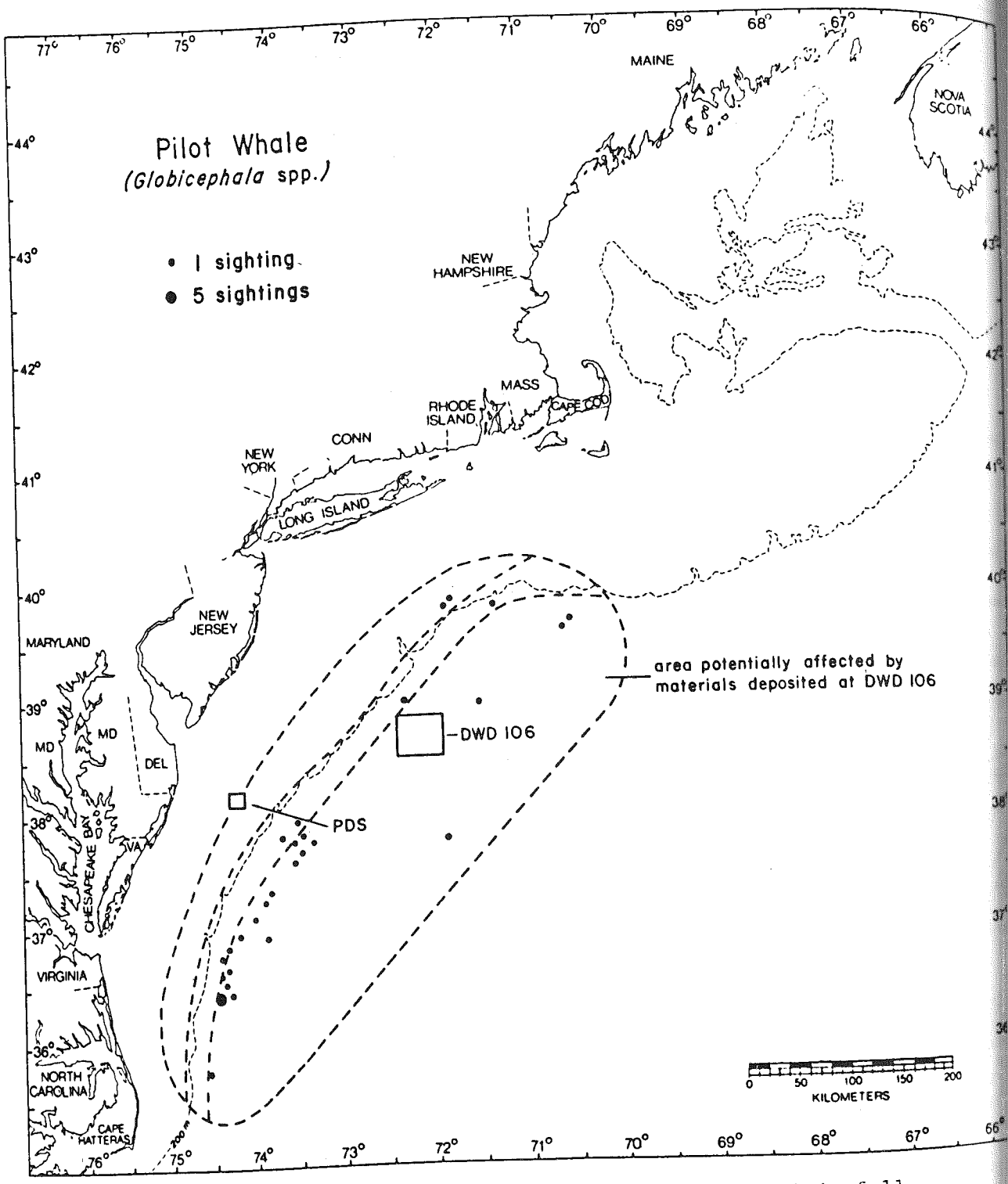


Figure 24. Known sightings of pilot whales (Globicephala spp.) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

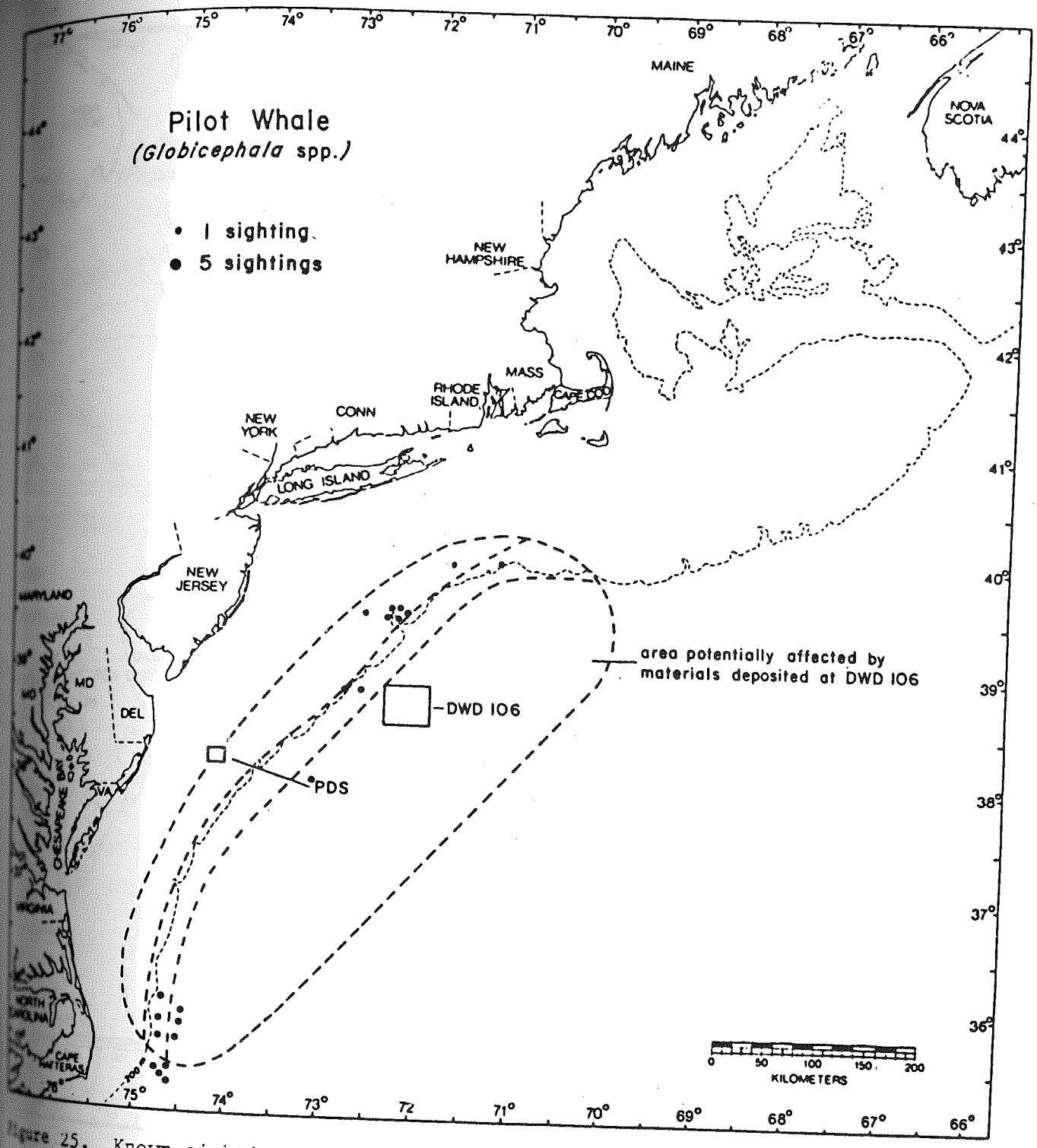


Figure 25. Known sightings of pilot whales (Globicephala spp.) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

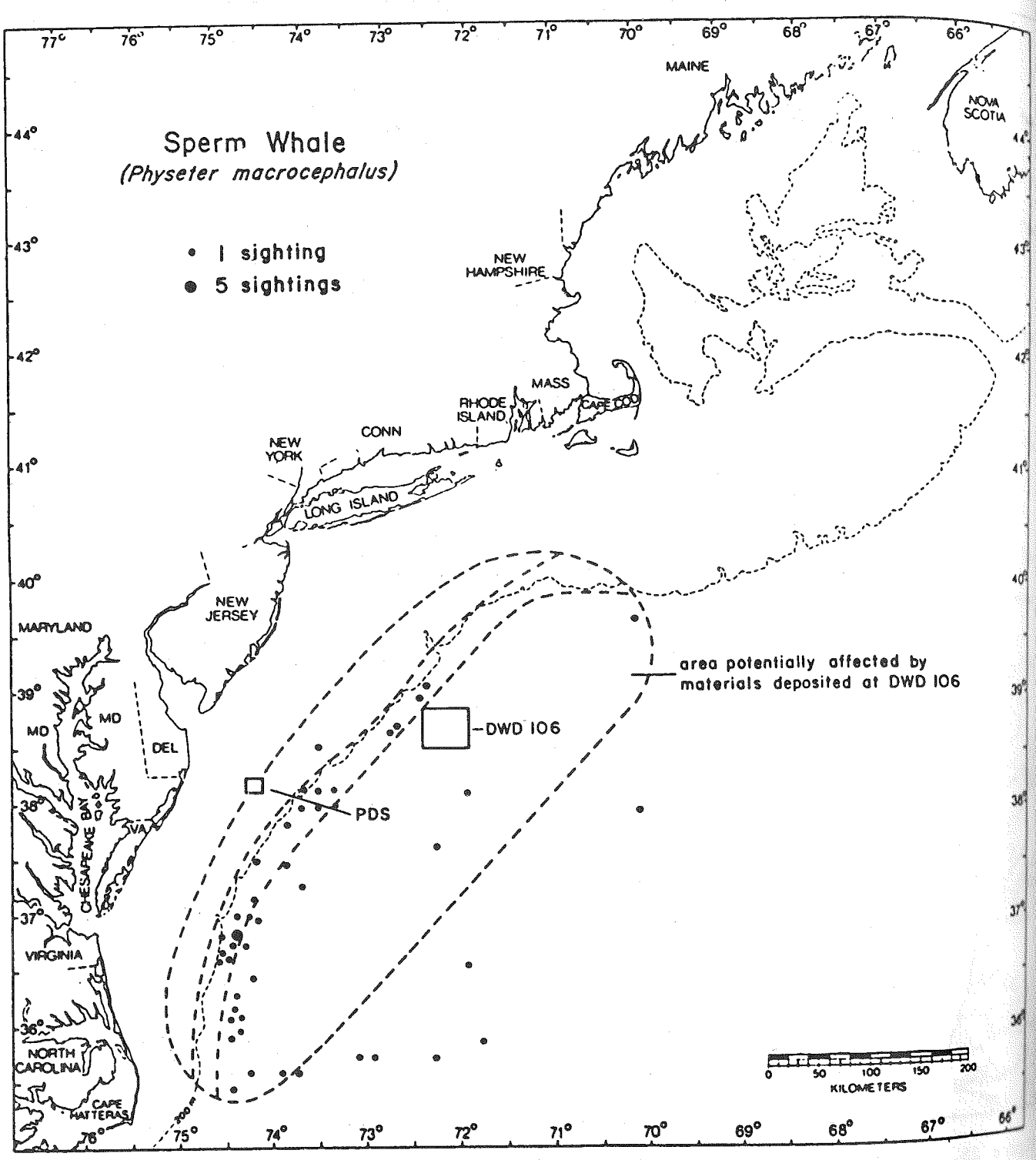


Figure 26. Known sightings of Sperm Whale (Physeter macrocephalus) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

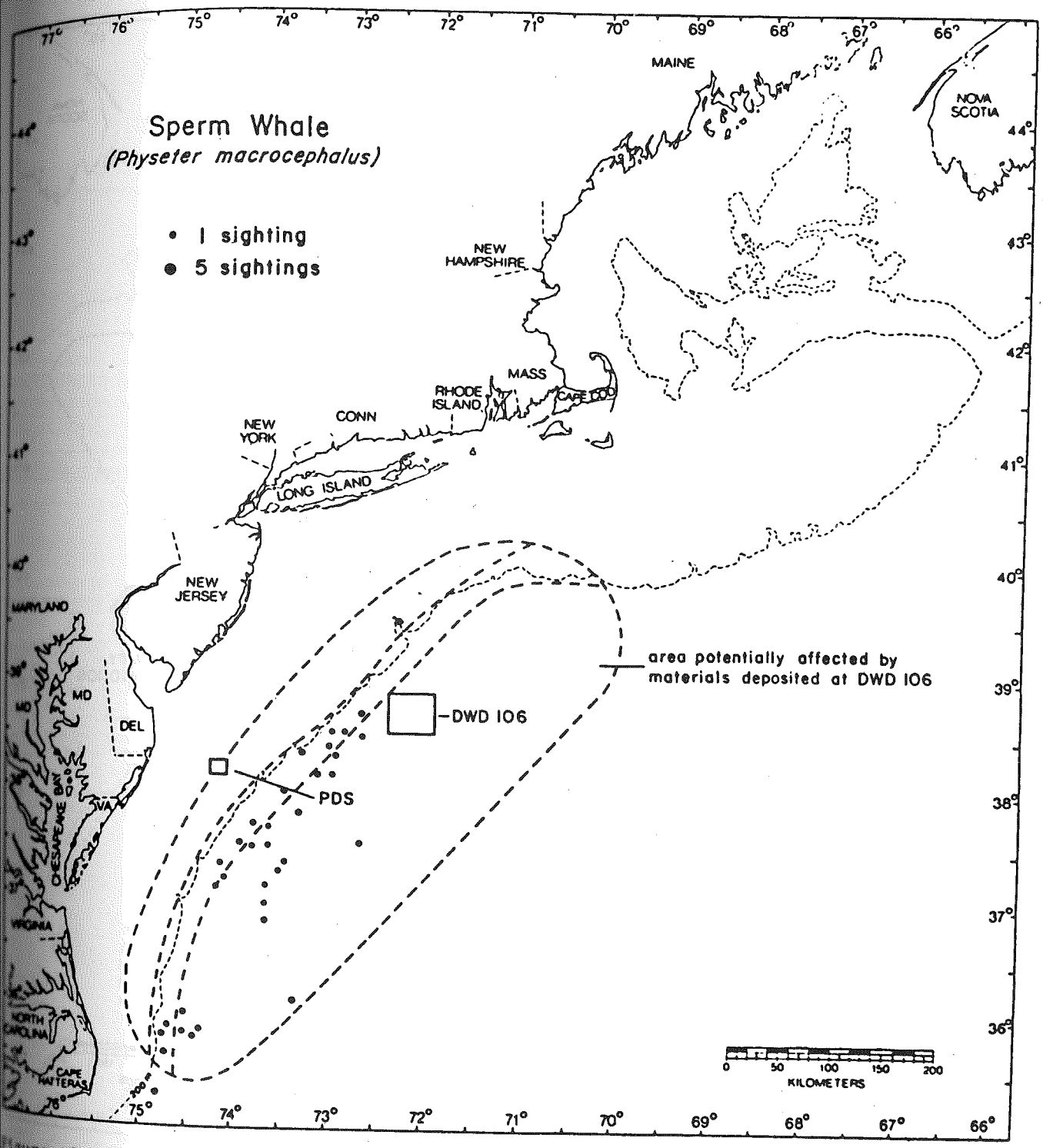


Figure 27. Known sightings of Sperm Whale (Physeter macrocephalus) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

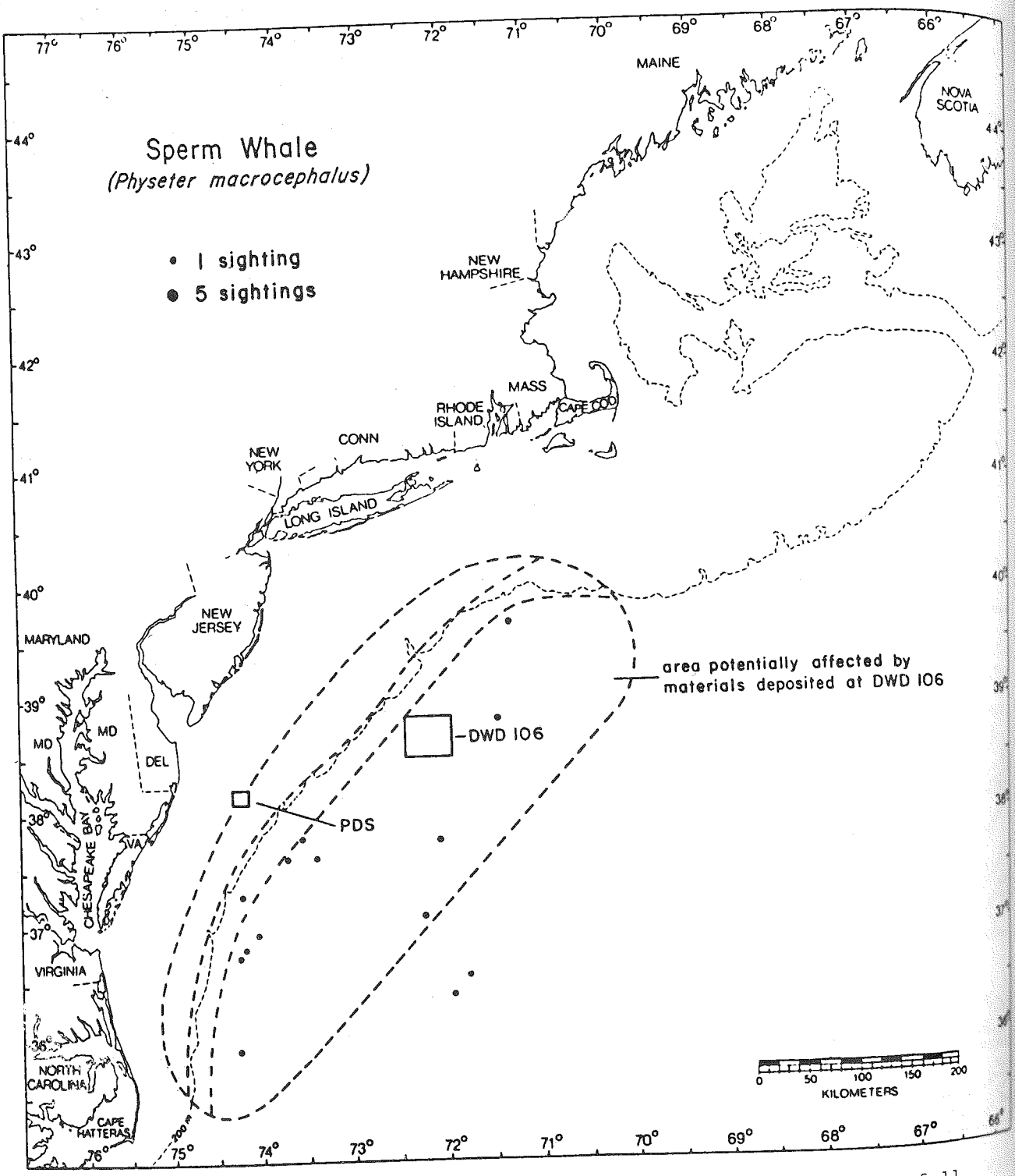


Figure 28. Known sightings of Sperm Whale (Physeter macrocephalus) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

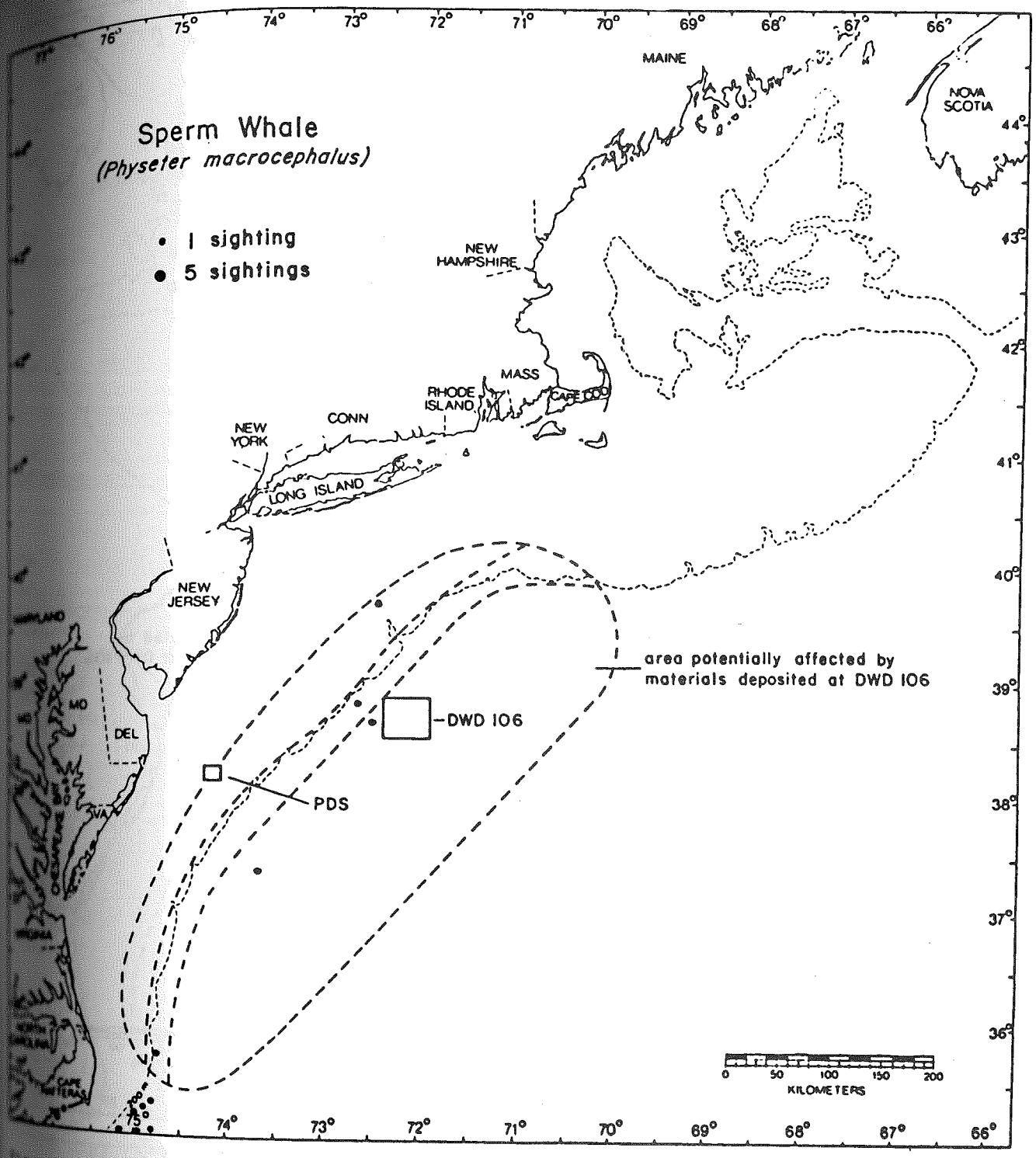


Figure 29. Known sightings of Sperm Whale (Physeter macrocephalus) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

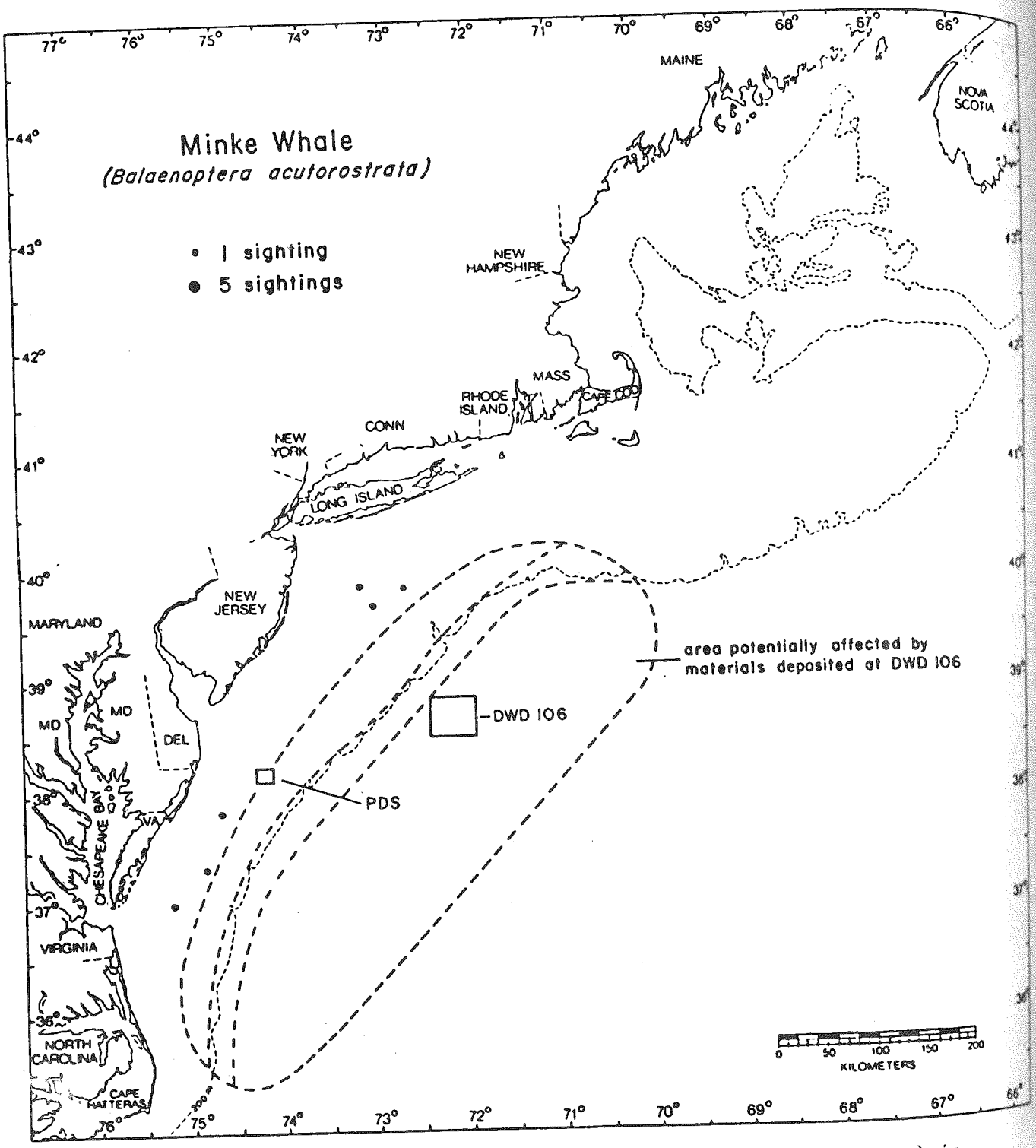


Figure 30. Known sightings of Minke Whale (Balaenoptera acutorostrata) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

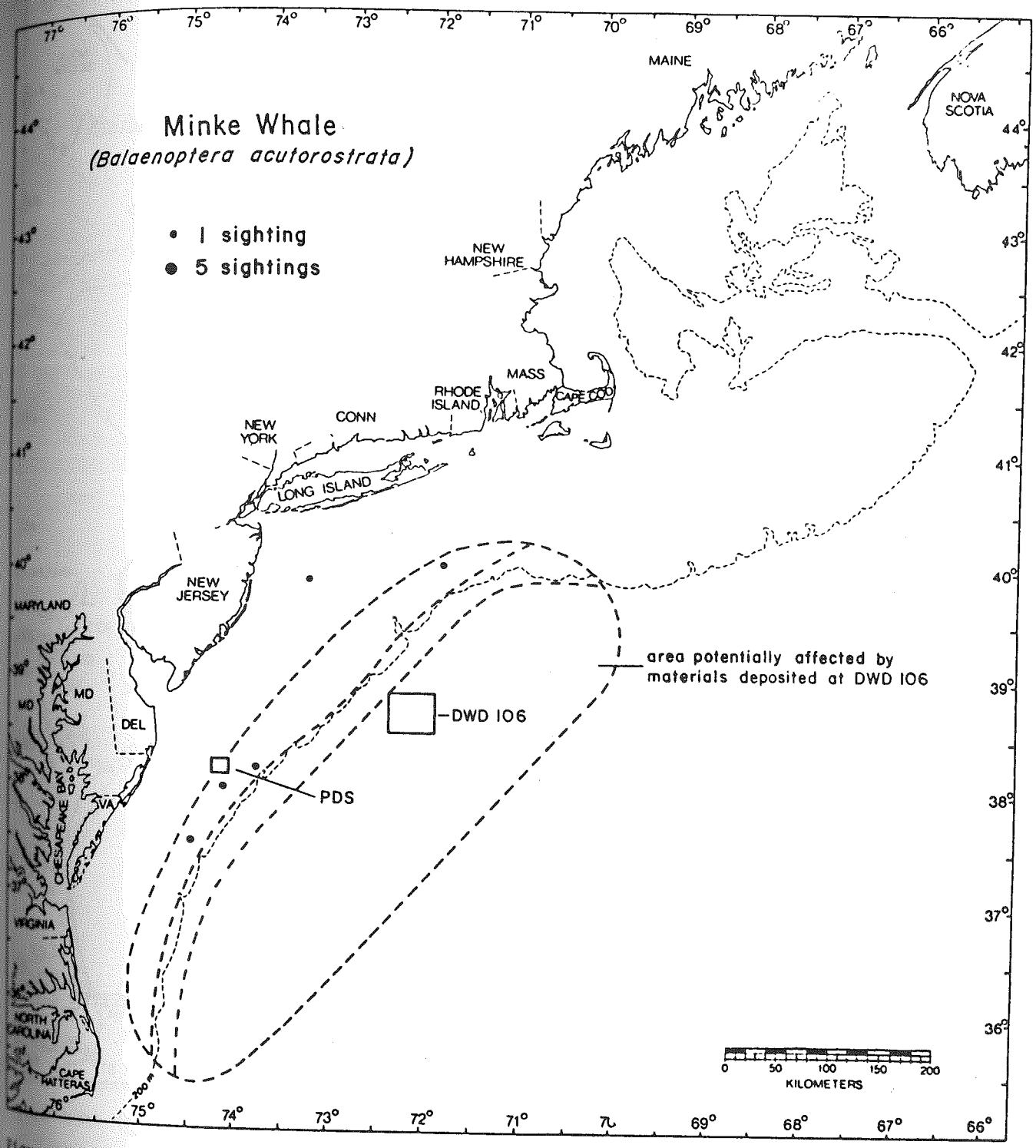


Figure 31. Known sightings of Minke Whale (Balaenoptera acutorostrata) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

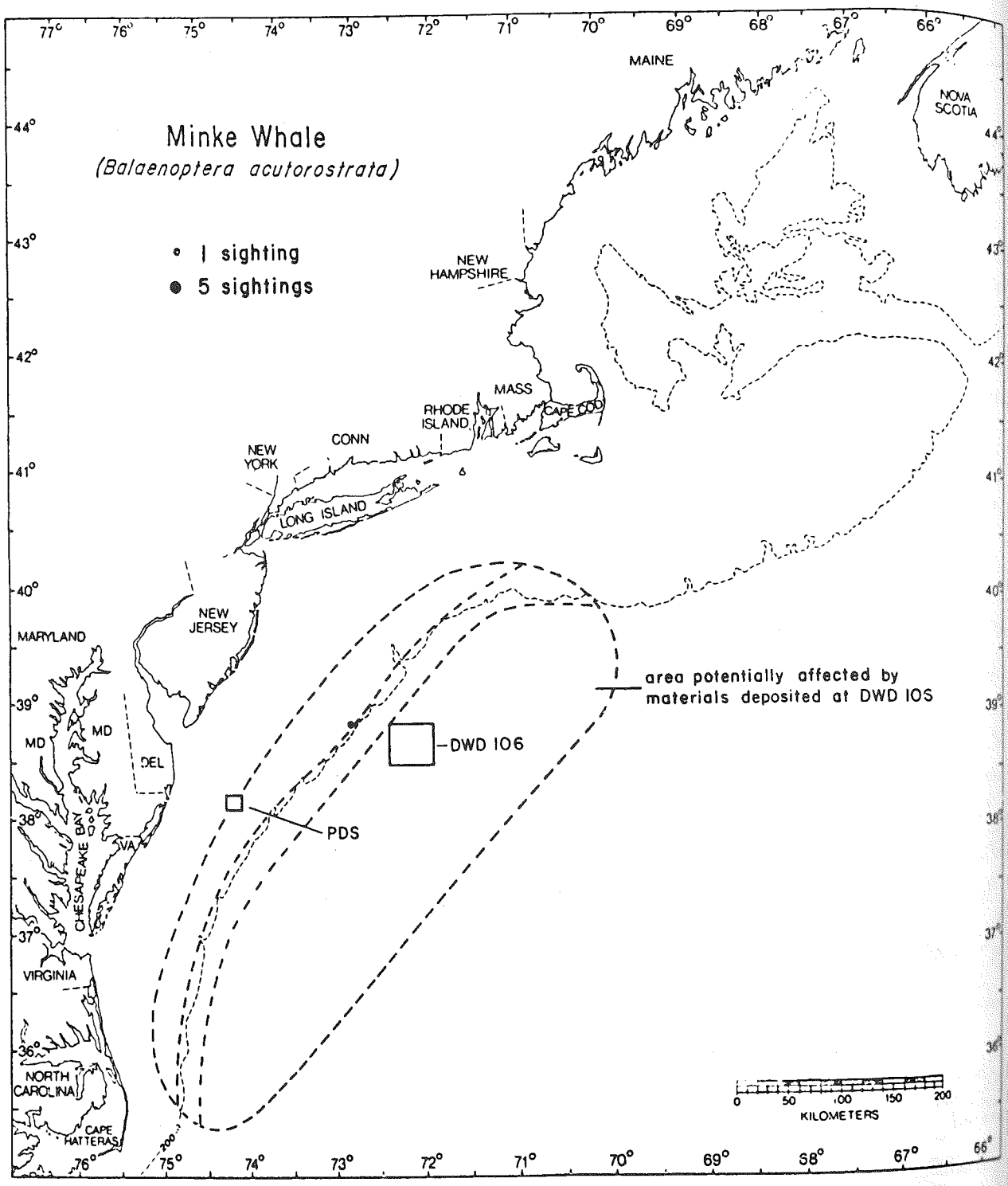


Figure 32. Known sightings of Minke Whale (Balaenoptera acutorostrata) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

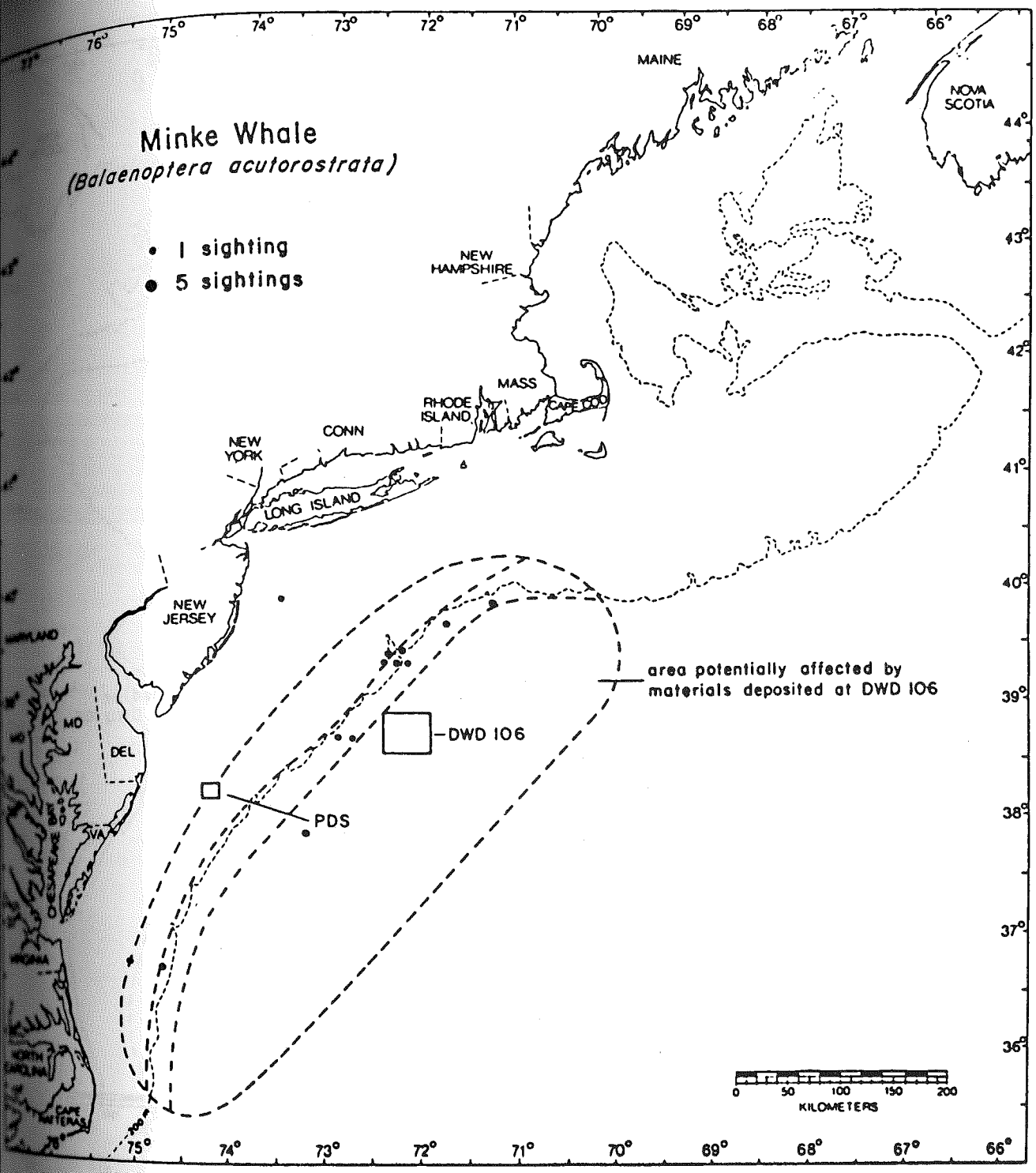


Figure 33. Known sightings of Minke Whale (Balaenoptera acutorostrata) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

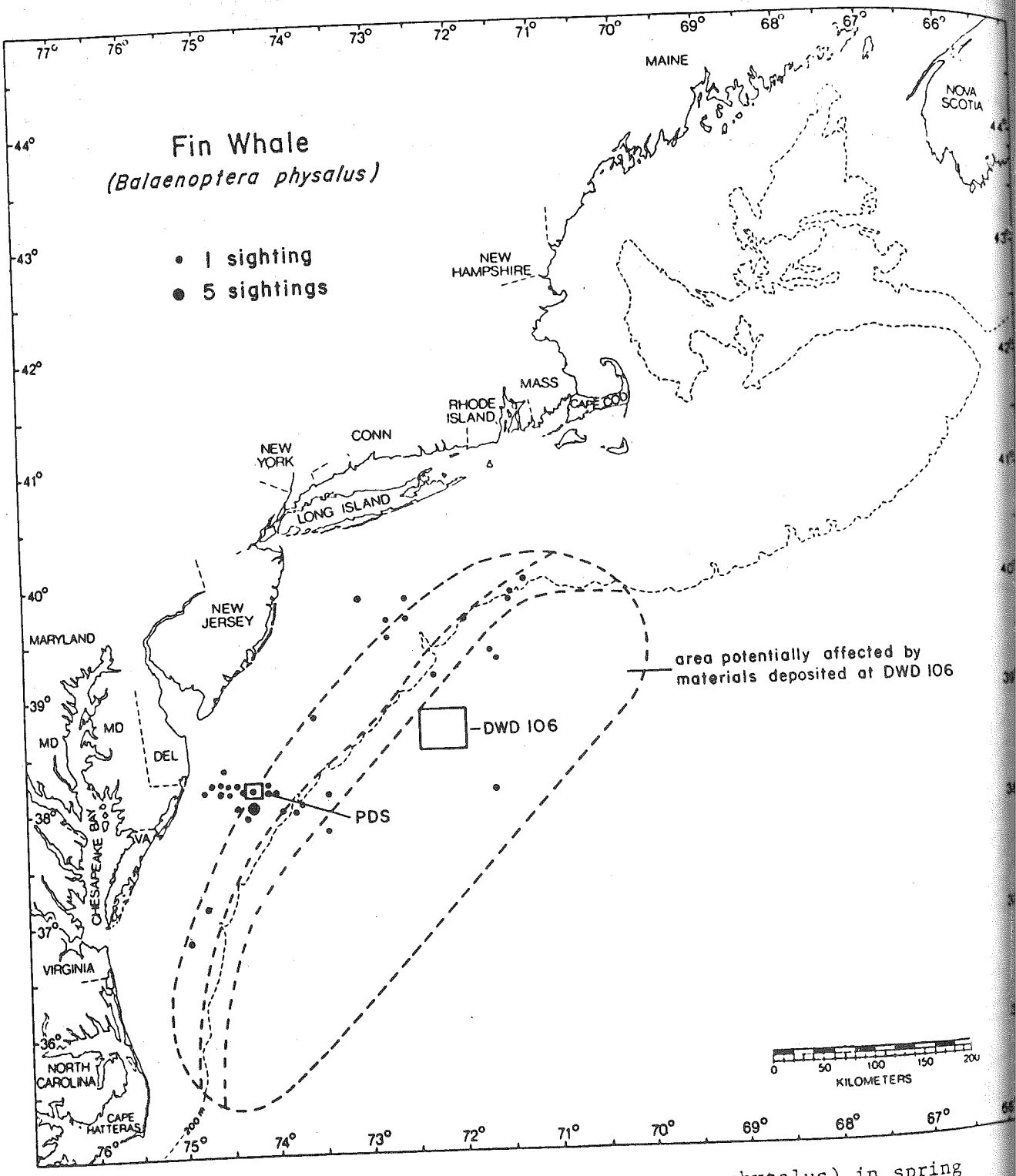


Figure 34. Known sightings of Fin Whale (Balaenoptera physalus) in spring (March to May) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

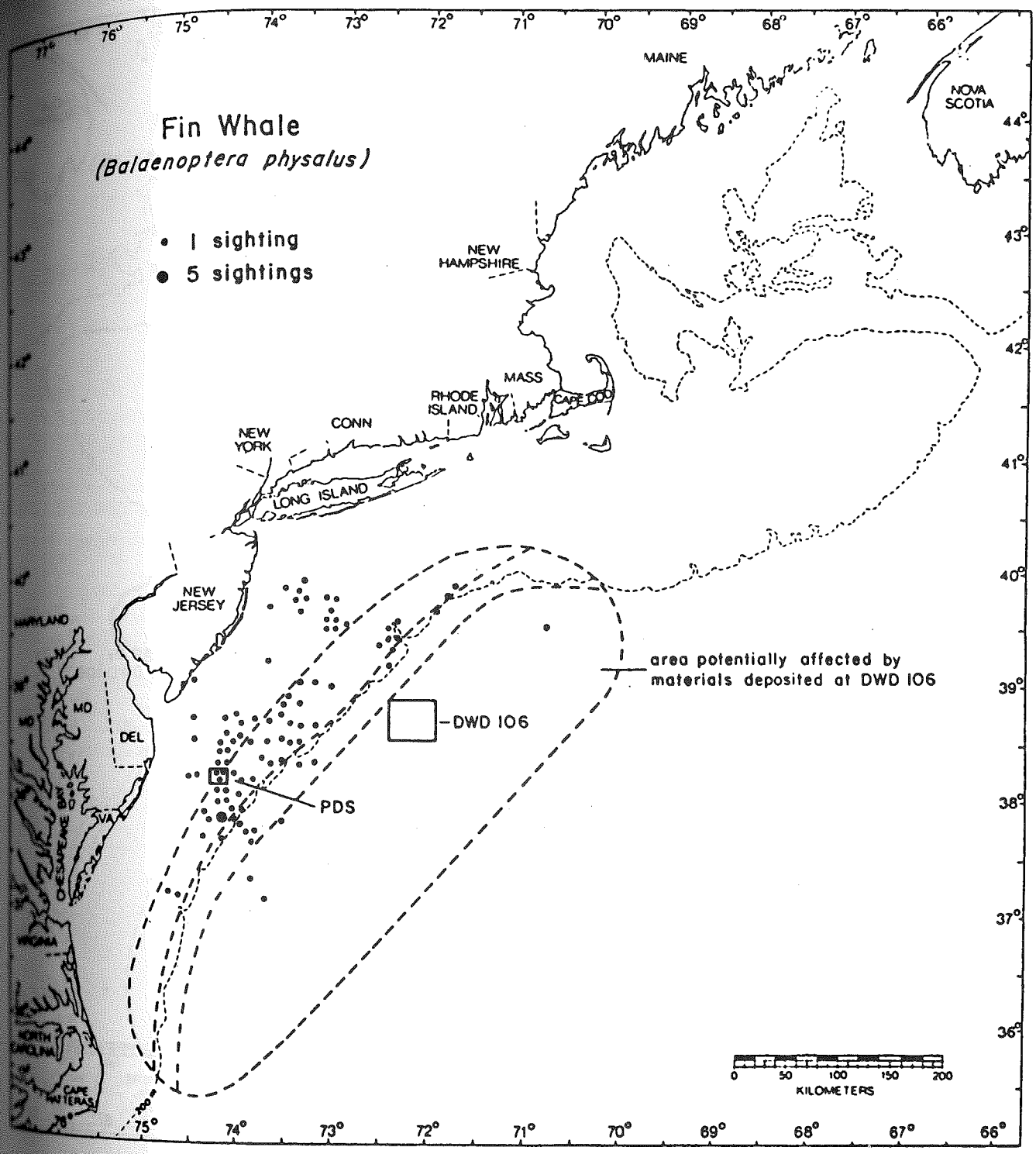


Figure 35. Known sightings of Fin Whale (Balaenoptera physalus) in summer (June to August) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

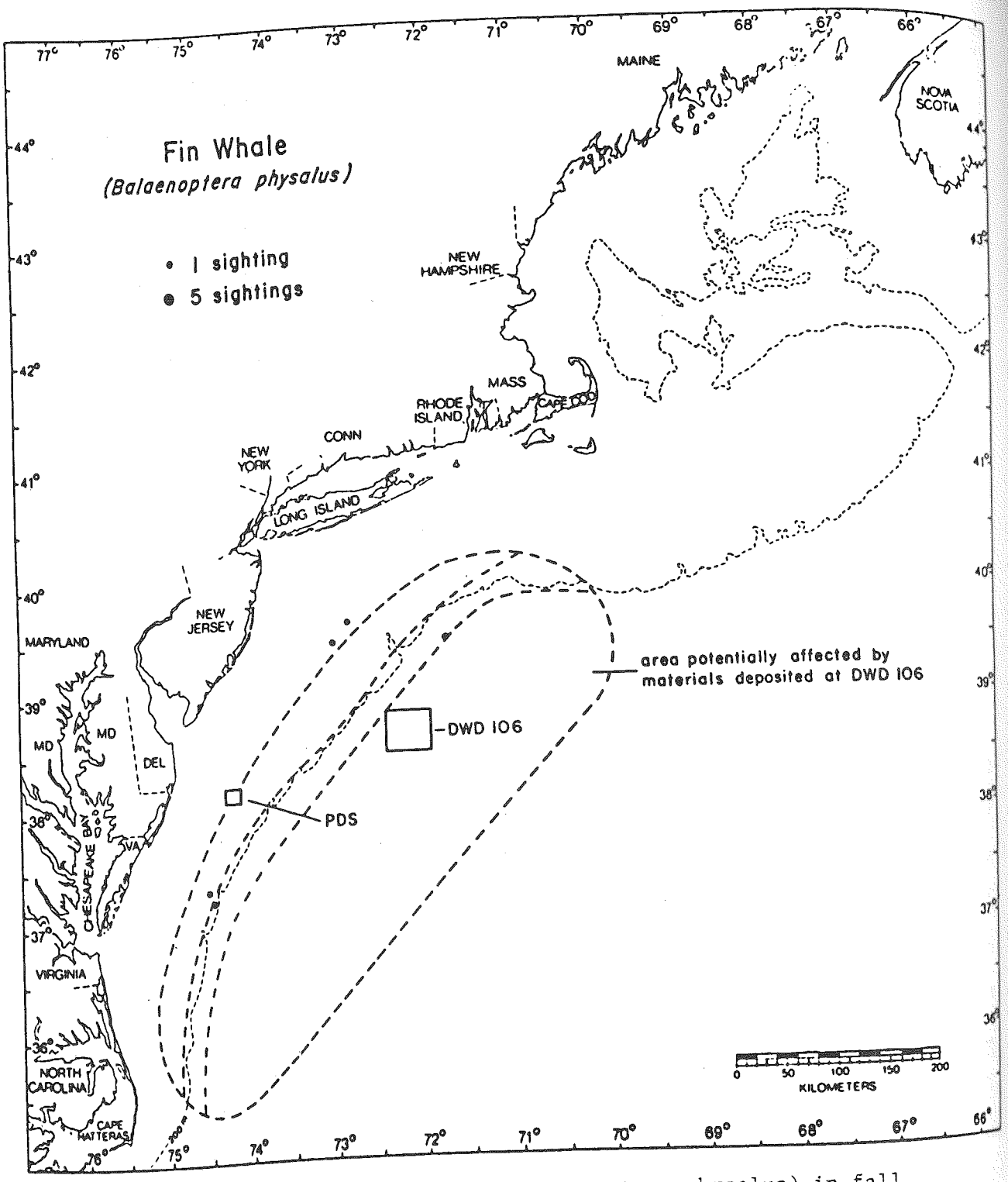


Figure 36. Known sightings of Fin Whale (Balaenoptera physalus) in fall (September to November) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

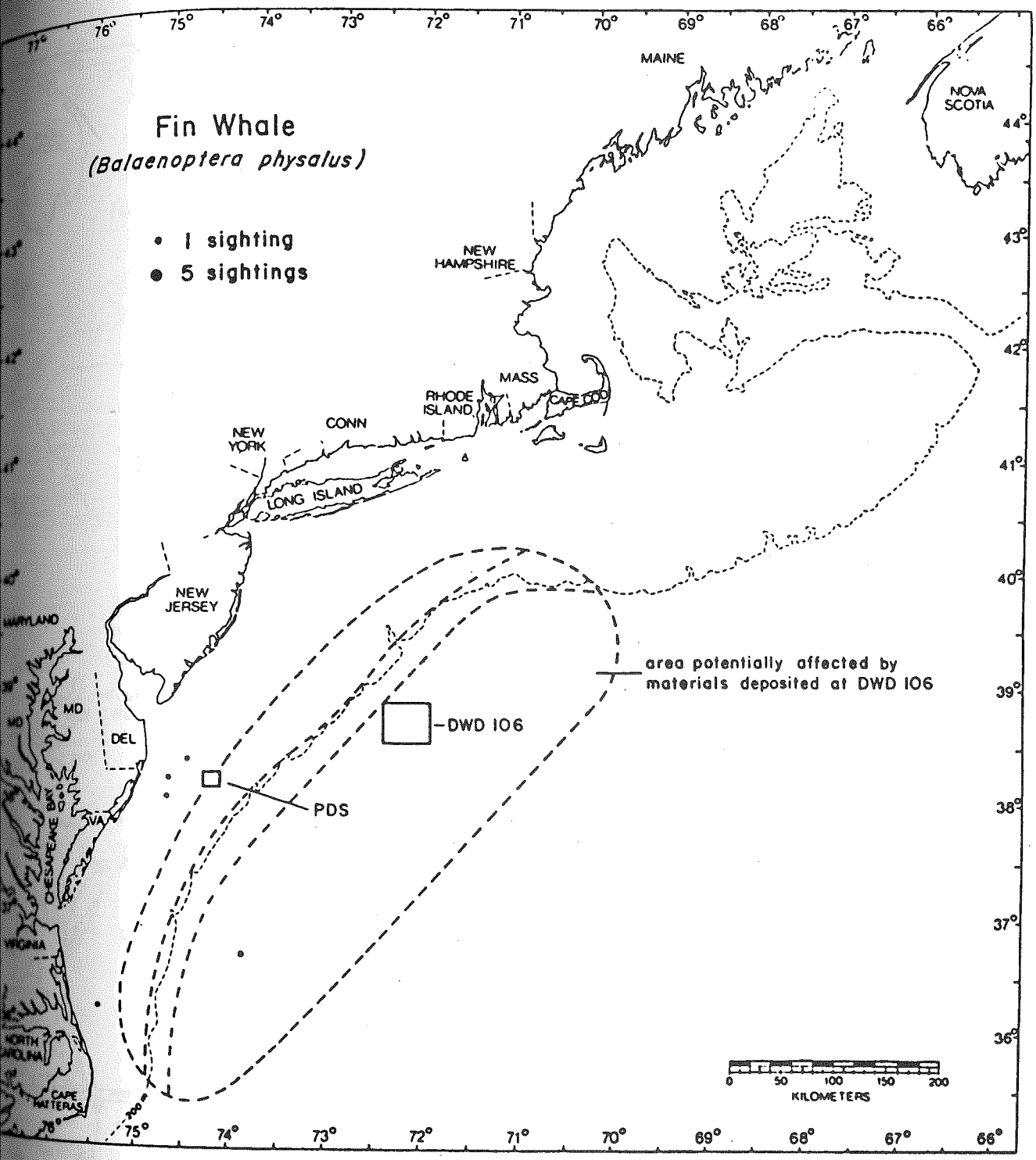


Figure 37. Known sightings of Fin Whale (Balaenoptera physalus) in winter (December to February) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

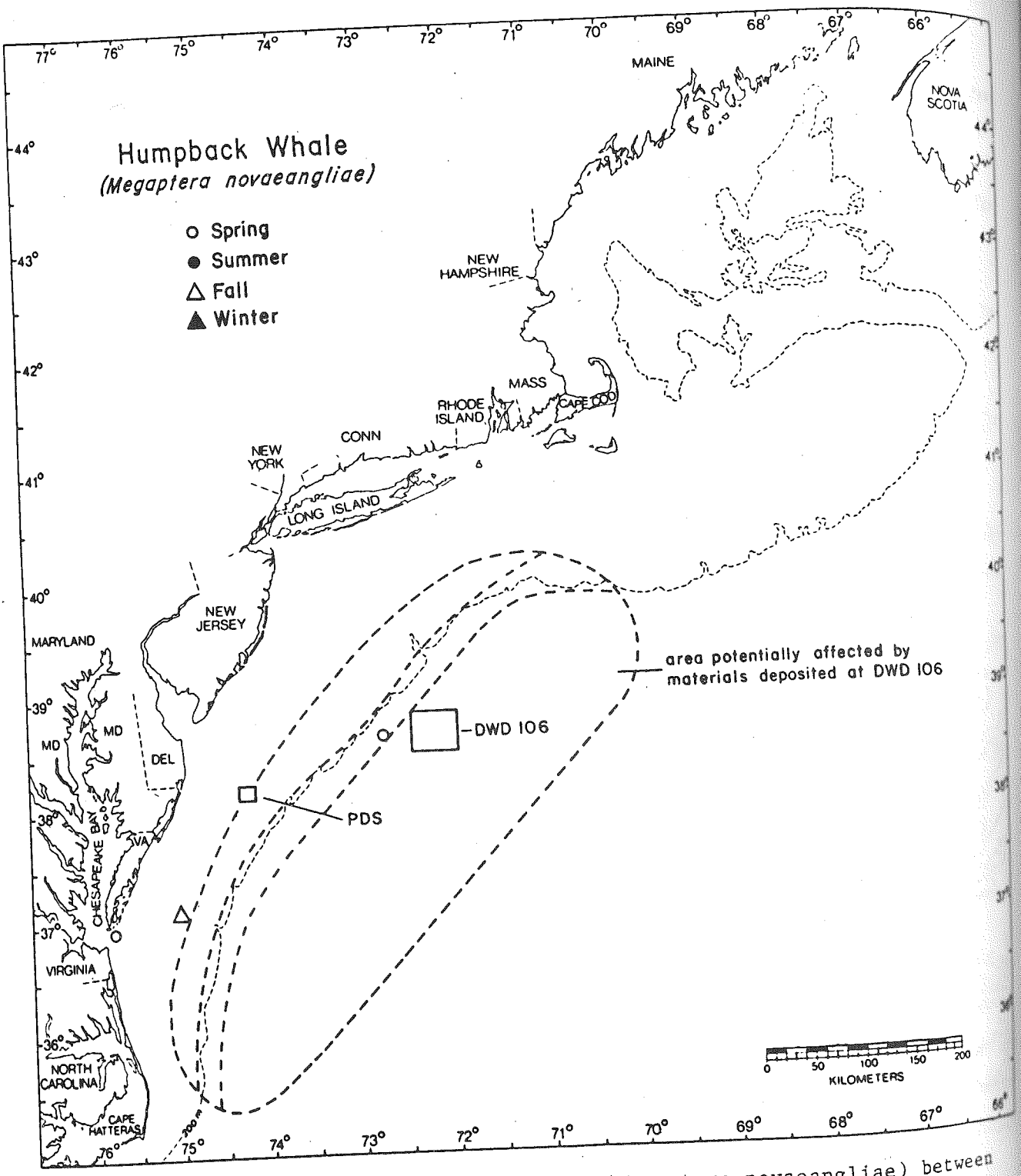


Figure 38. Known sightings of Humpback Whale (Megaptera novaeangliae) between 35°00′ and 40°00′N latitudes and west f 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

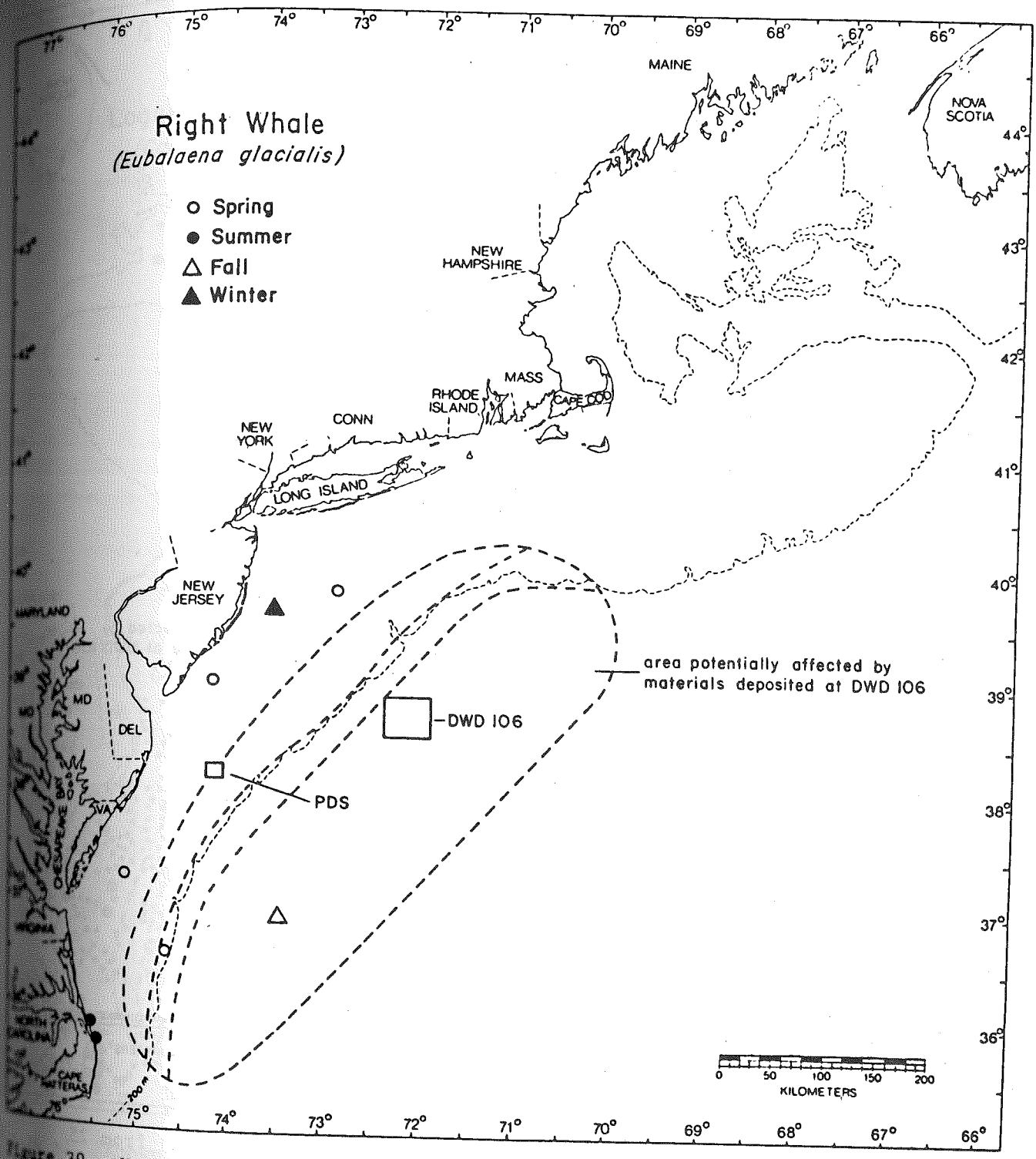


Figure 39. Known sightings of Right Whale (Eubalaena glacialis) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

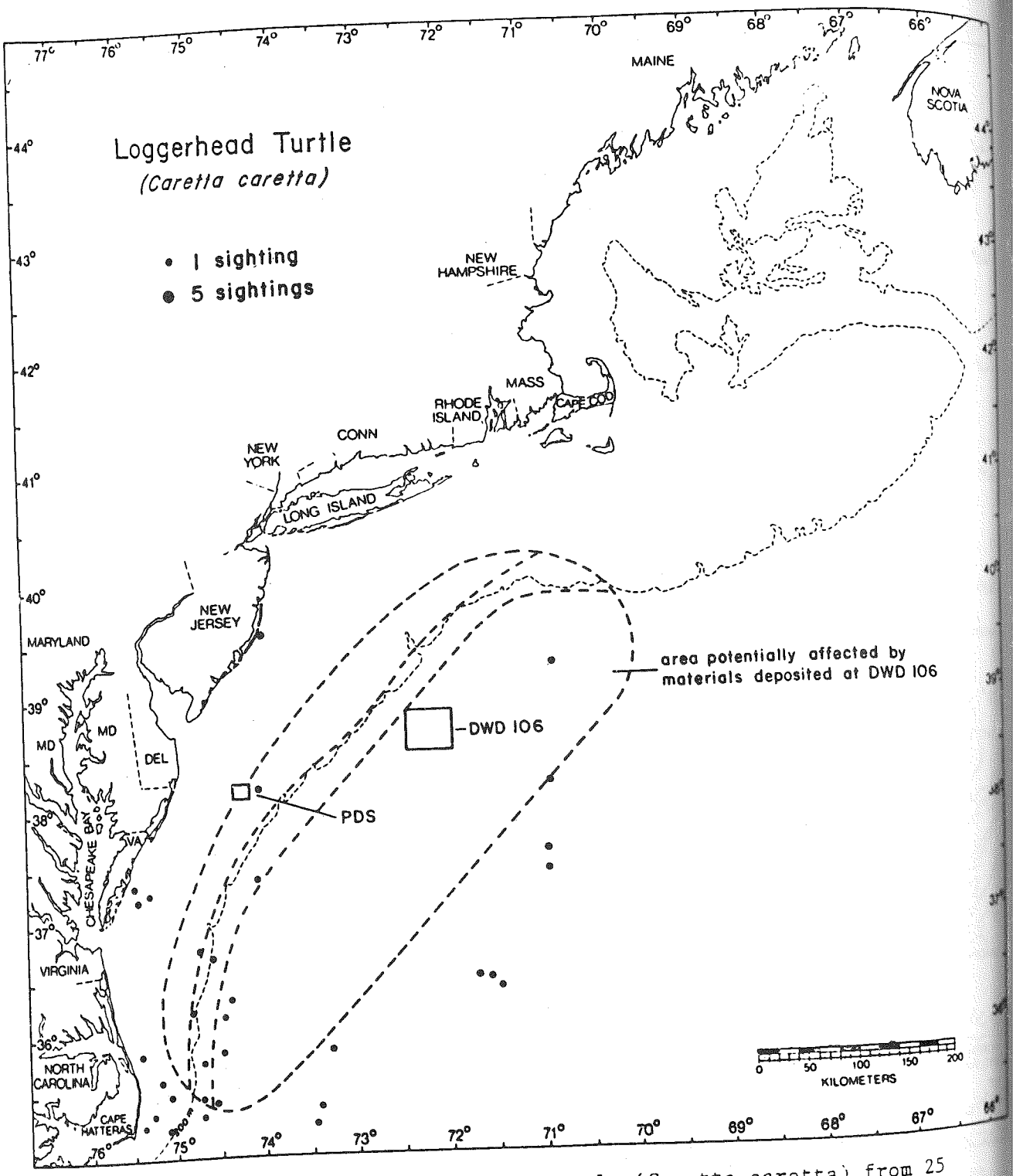


Figure 40. Known sightings of Loggerhead Turtle (Caretta caretta) from 25 November to 16 May between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

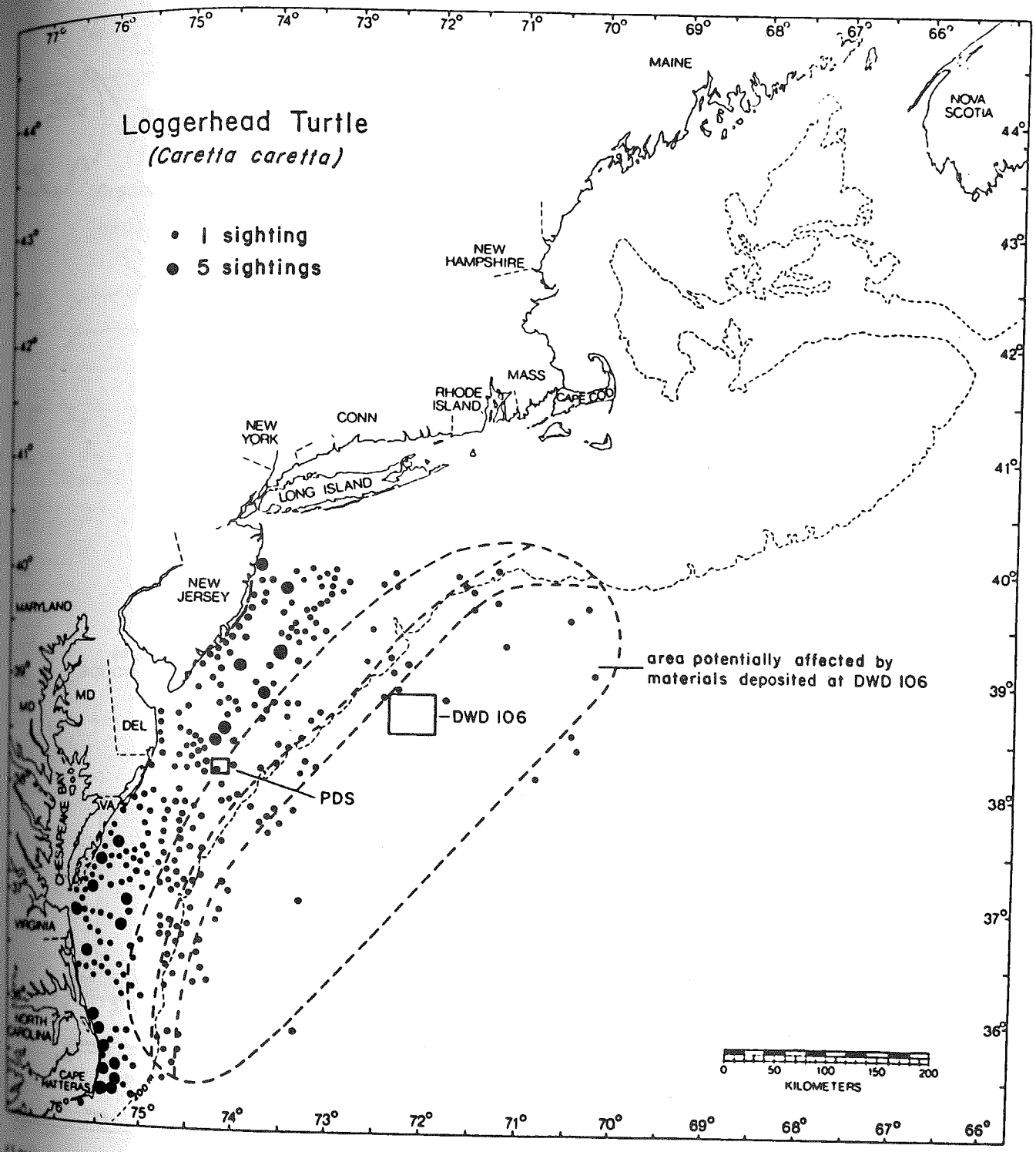


Figure 41. Known sightings of Loggerhead Turtle (Caretta caretta) from 17 May to 24 November between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

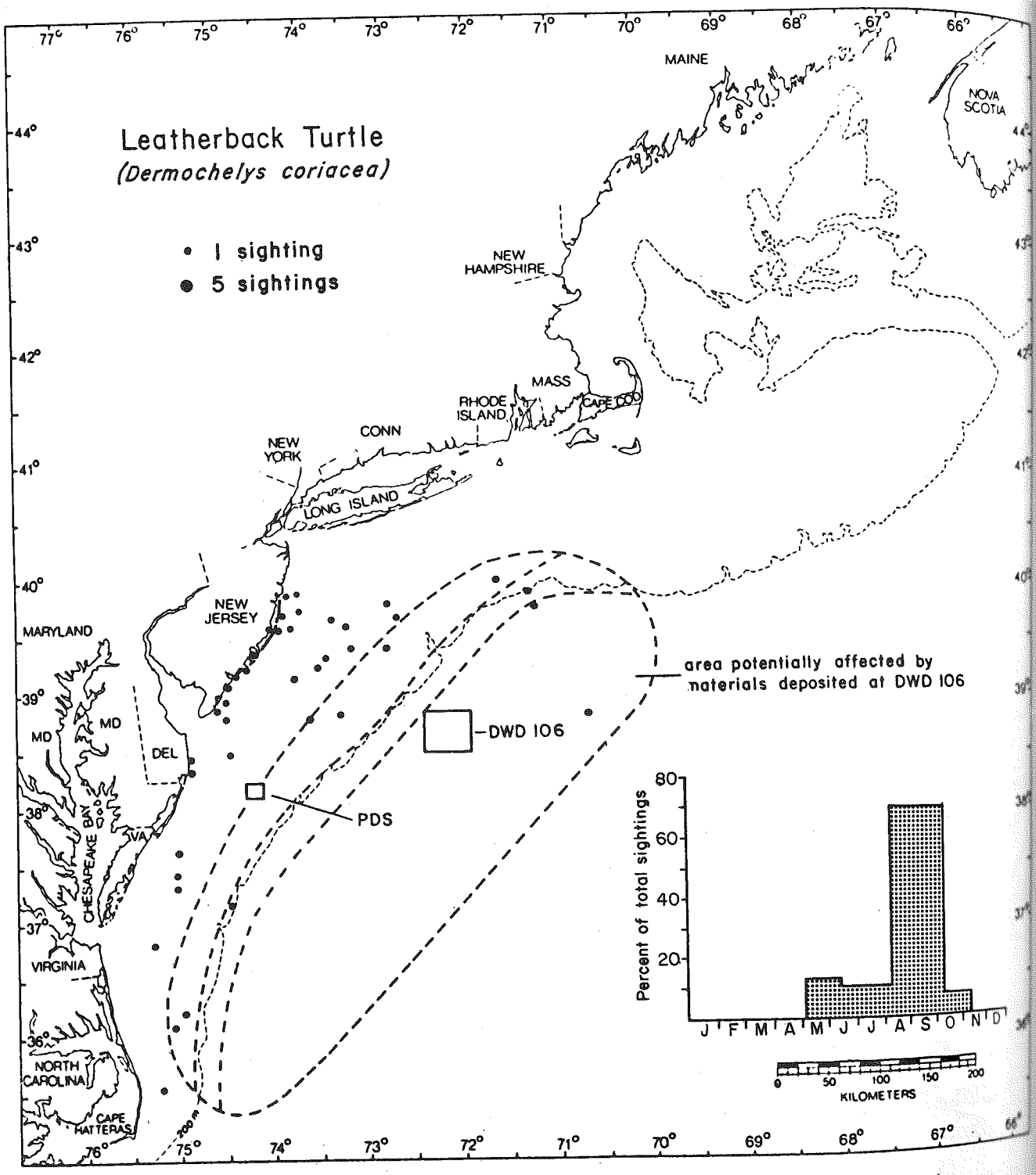


Figure 42. Known sightings of Leatherback Turtle (Dermochelys coriacea) between 35°00′ and 40°00′N latitudes and west of 70°00′W longitude. PDS, DWD-106, and warm-core eddy interaction envelope are indicated.

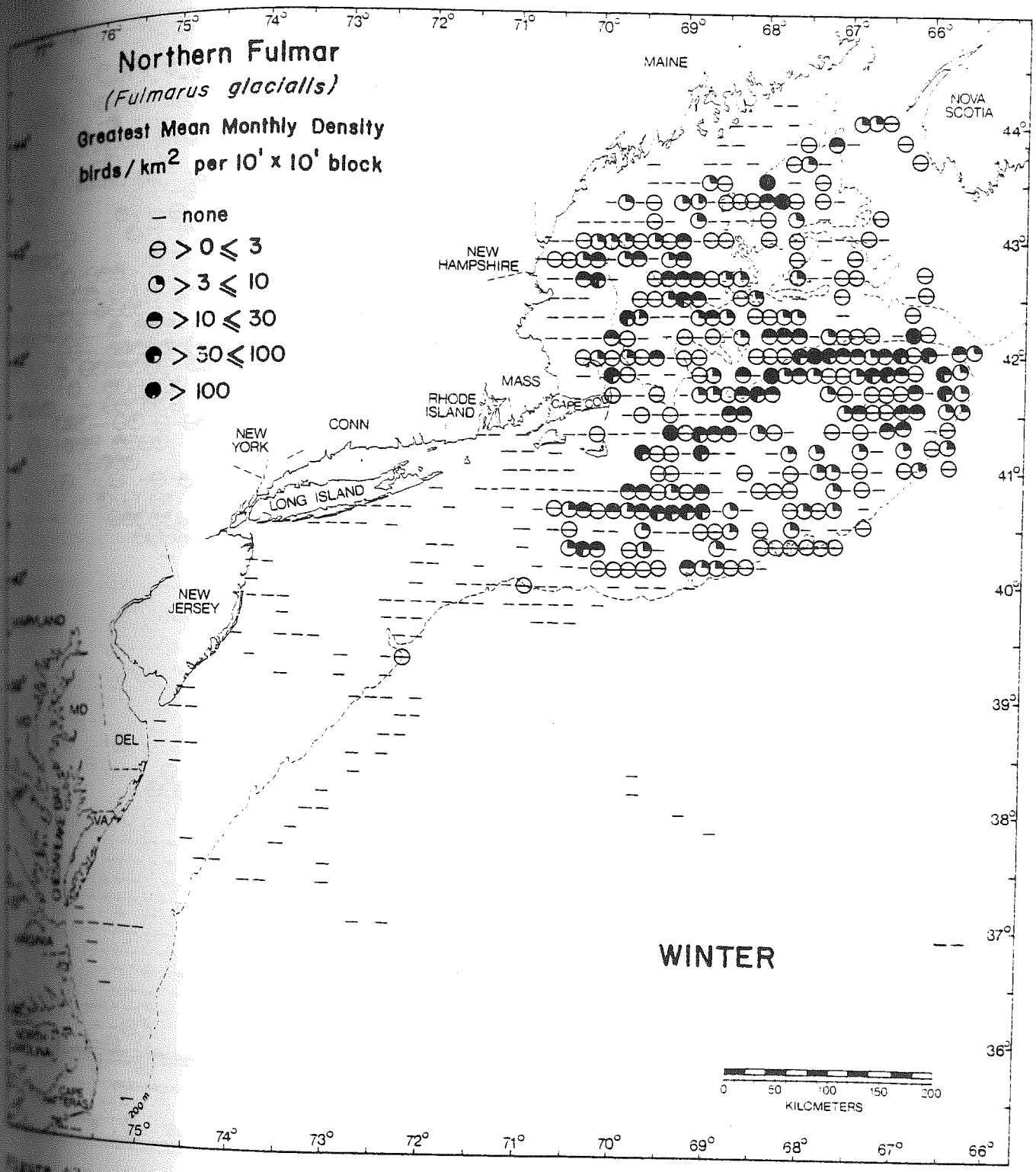


Figure 43. Relative distribution and abundance of Northern Fulmar (Fulmarus glacialis) in winter (December to February) off the northeastern United States.

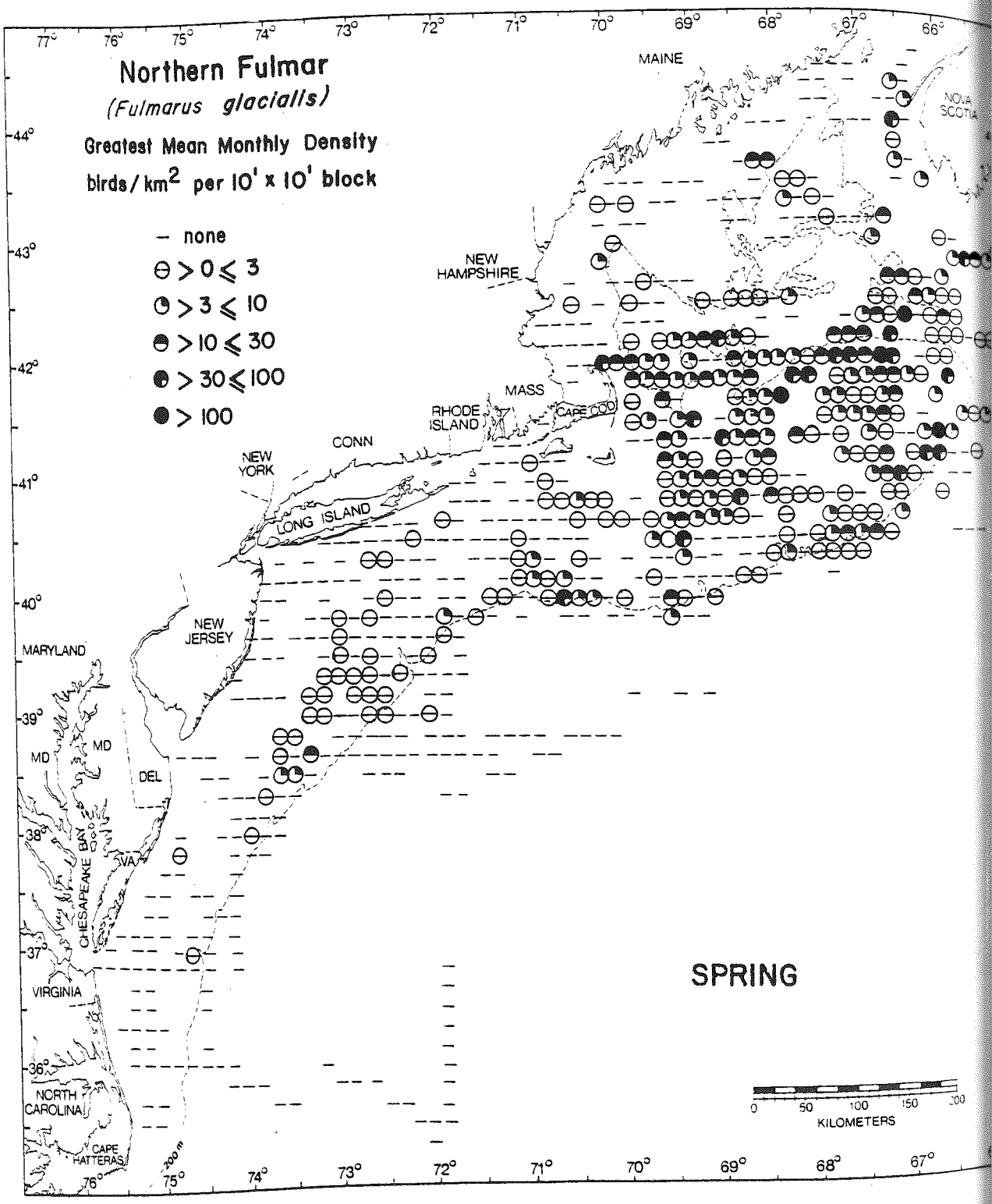


Figure 44. Relative distribution and abundance of Northern Fulmar (Fulmarus glacialis) in spring (March to May) off the northeastern United States.

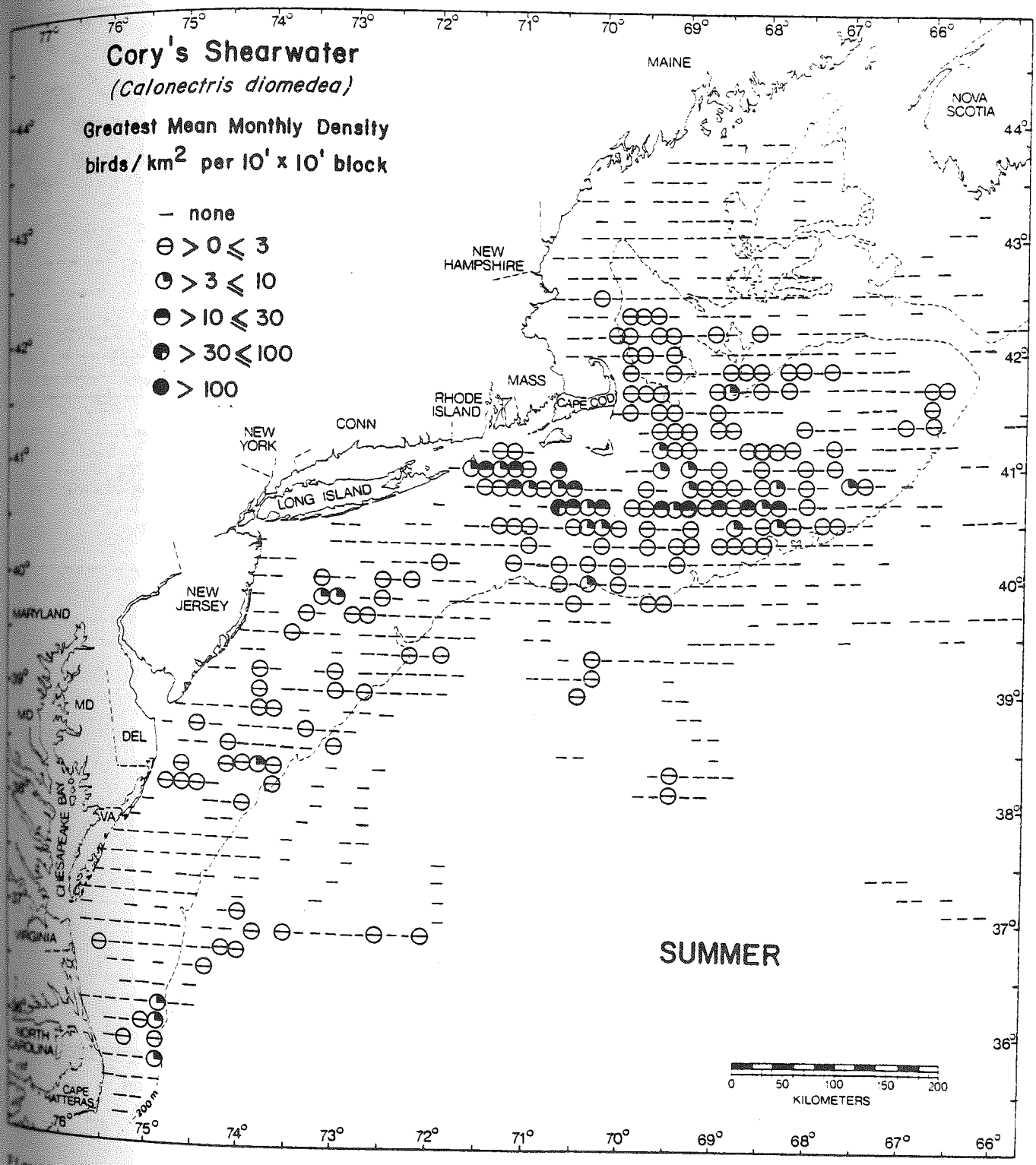


Figure 45. Relative distribution and abundance of Cory's Shearwater (Calonectris diomedea) in summer (June to August) off the northeastern United States.

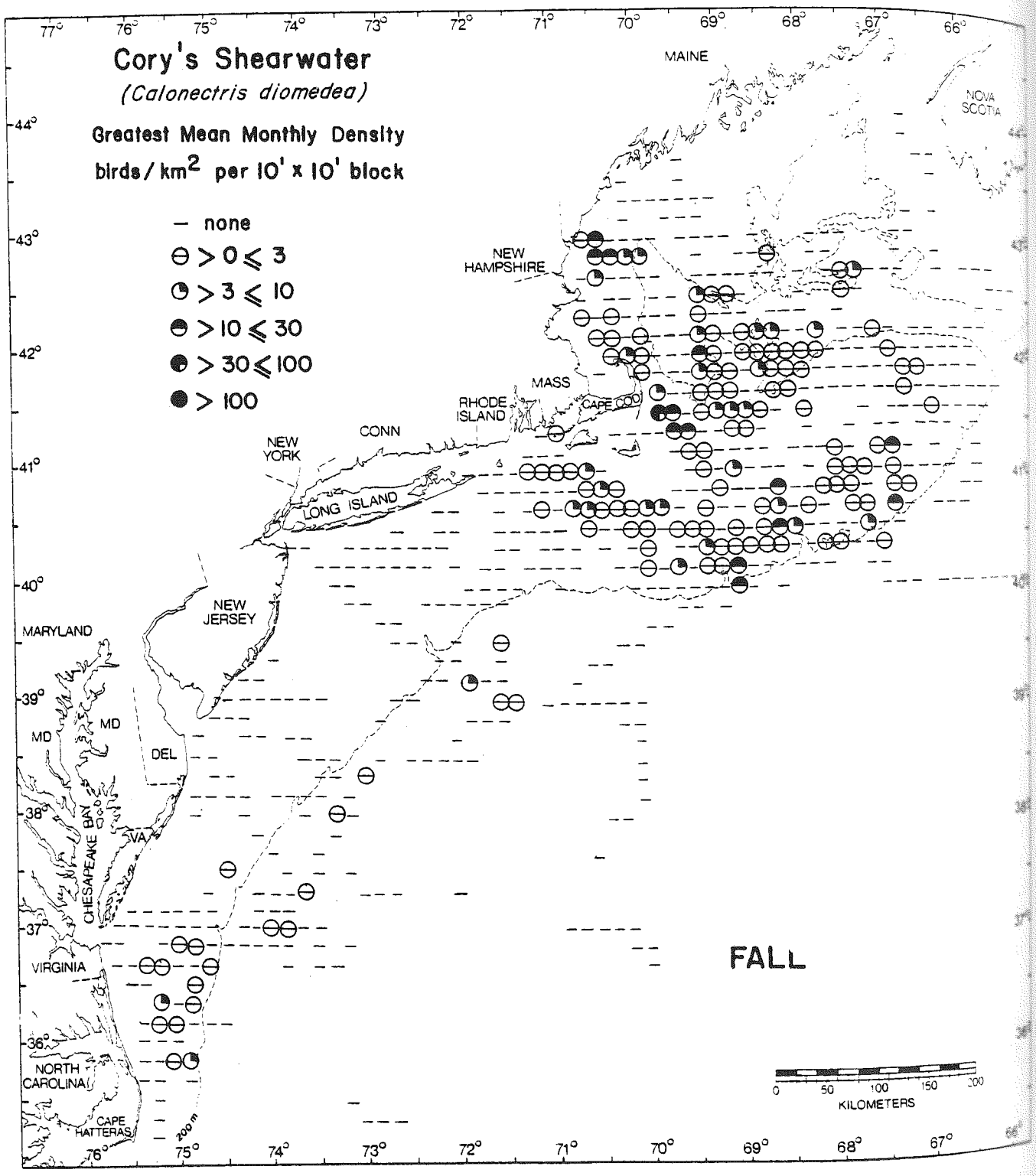


Figure 46. Relative distribution and abundance of Cory's Shearwater (Calonectris diomedea) in fall (September to November) off the northeastern United States.

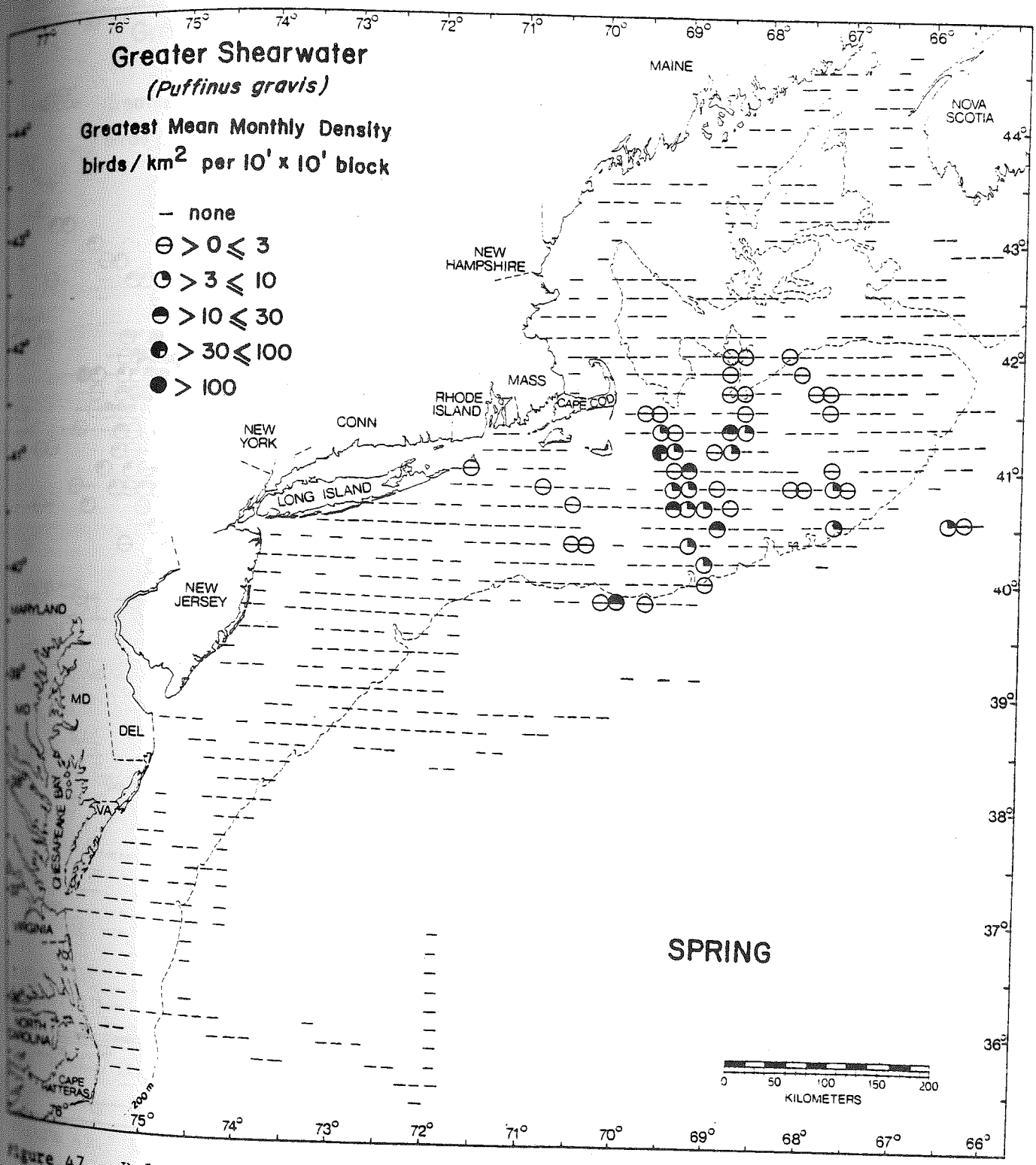


Figure 47. Relative distribution and abundance of Greater Shearwater (Puffinus gravis) in spring (March to May) off the northeastern United States.

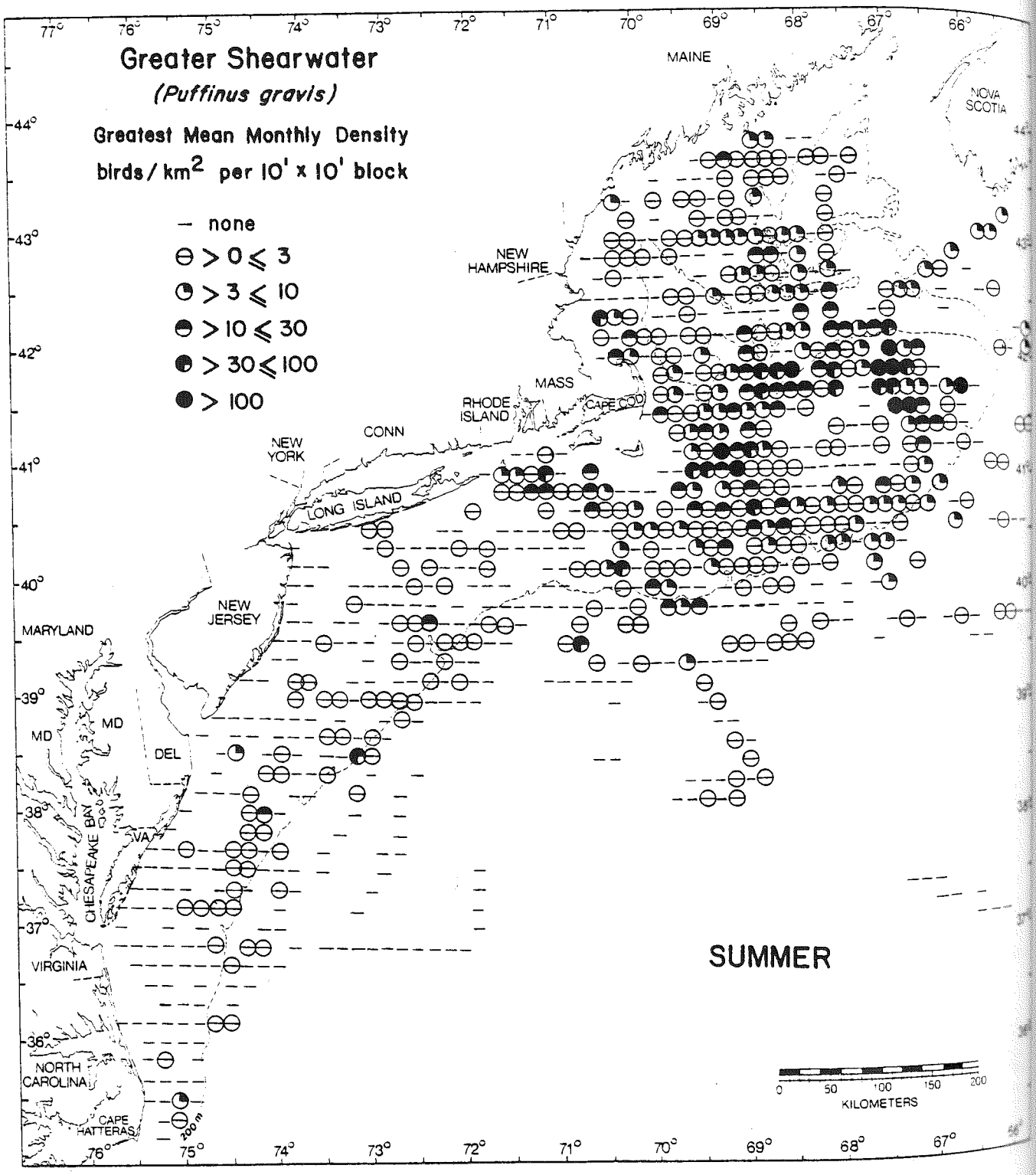


Figure 48. Relative distribution and abundance of Greater Shearwater (Puffinus gravis) in summer (June to August) off the northeastern United States.

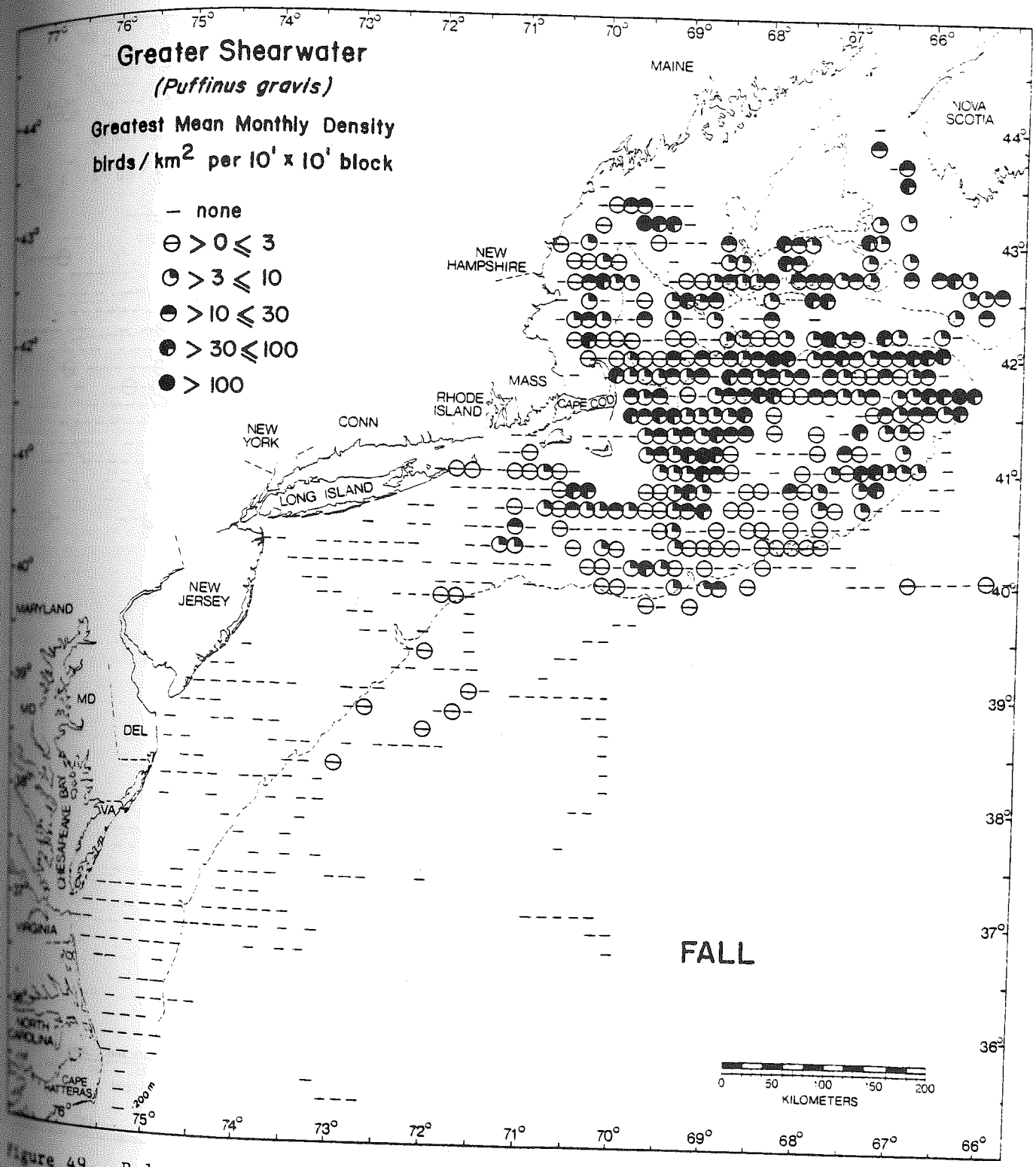


Figure 49. Relative distribution and abundance of Greater Shearwater (Puffinus gravis) in fall (September to November) off the northeastern United States.

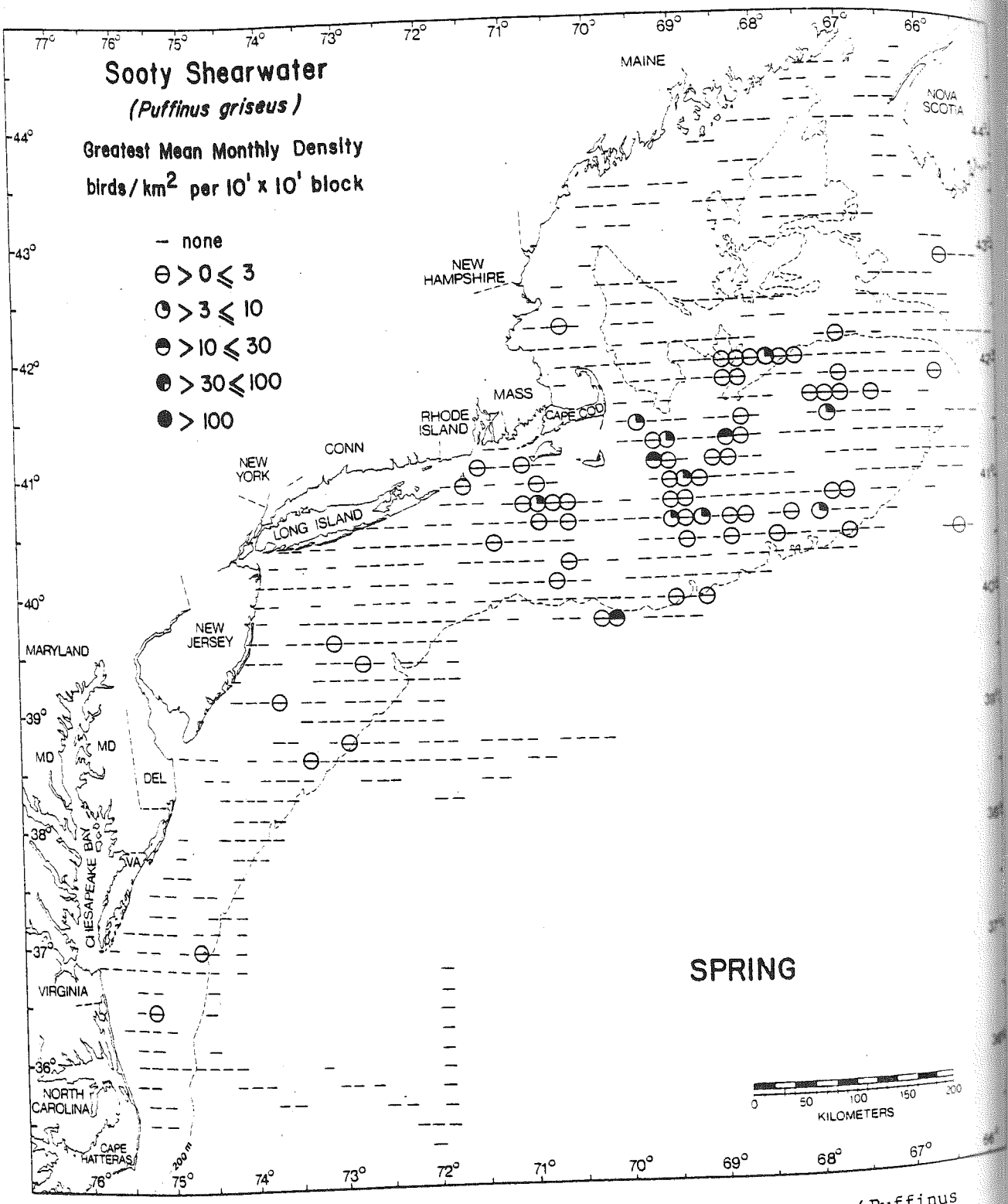


Figure 50. Relative distribution and abundance of Sooty Shearwater (Puffinus griseus) in spring (March to May) off the northeastern United States.

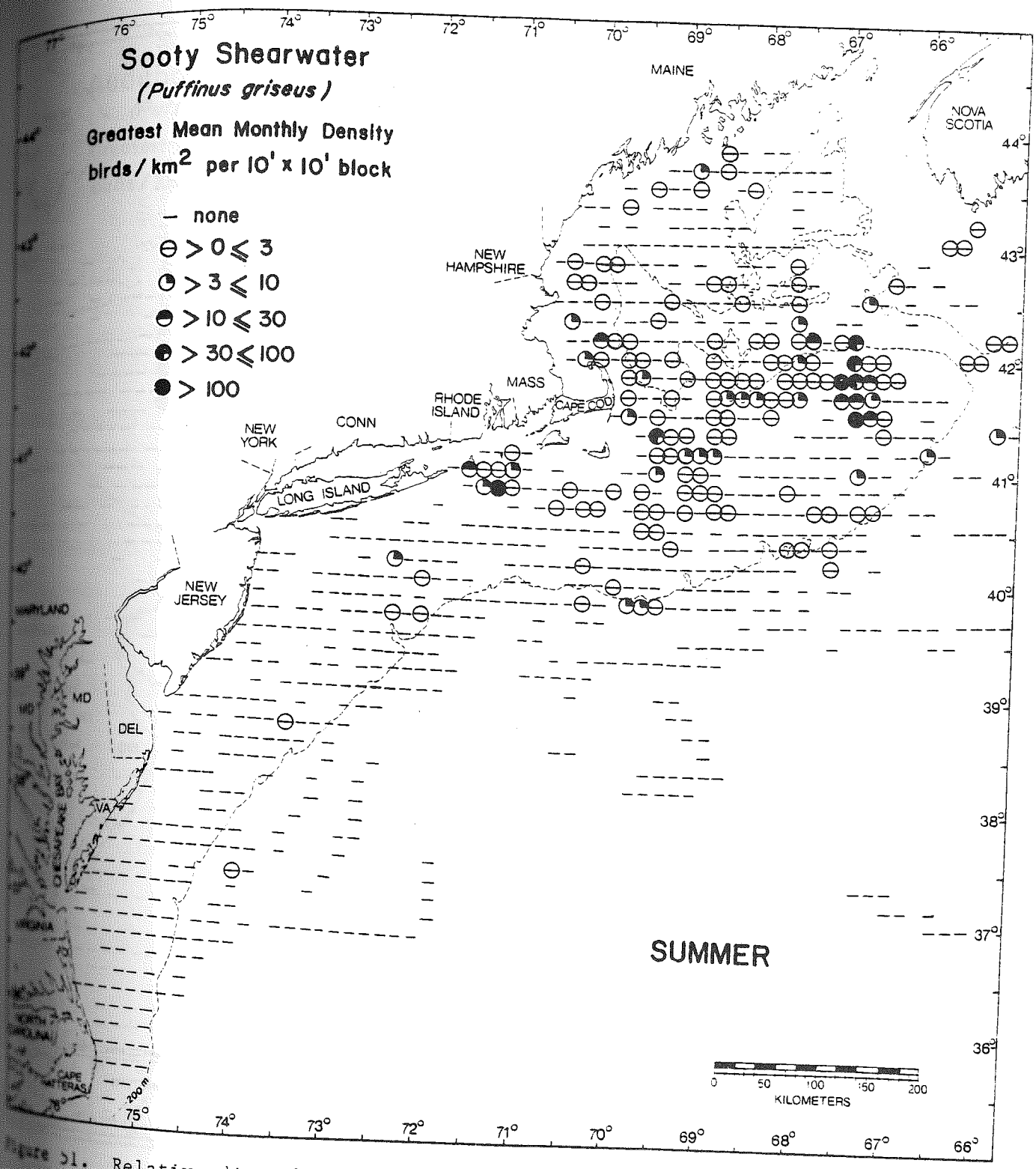


Figure 51. Relative distribution and abundance of Sooty Shearwater (Puffinus griseus) in summer (June to August) off the northeastern United States.

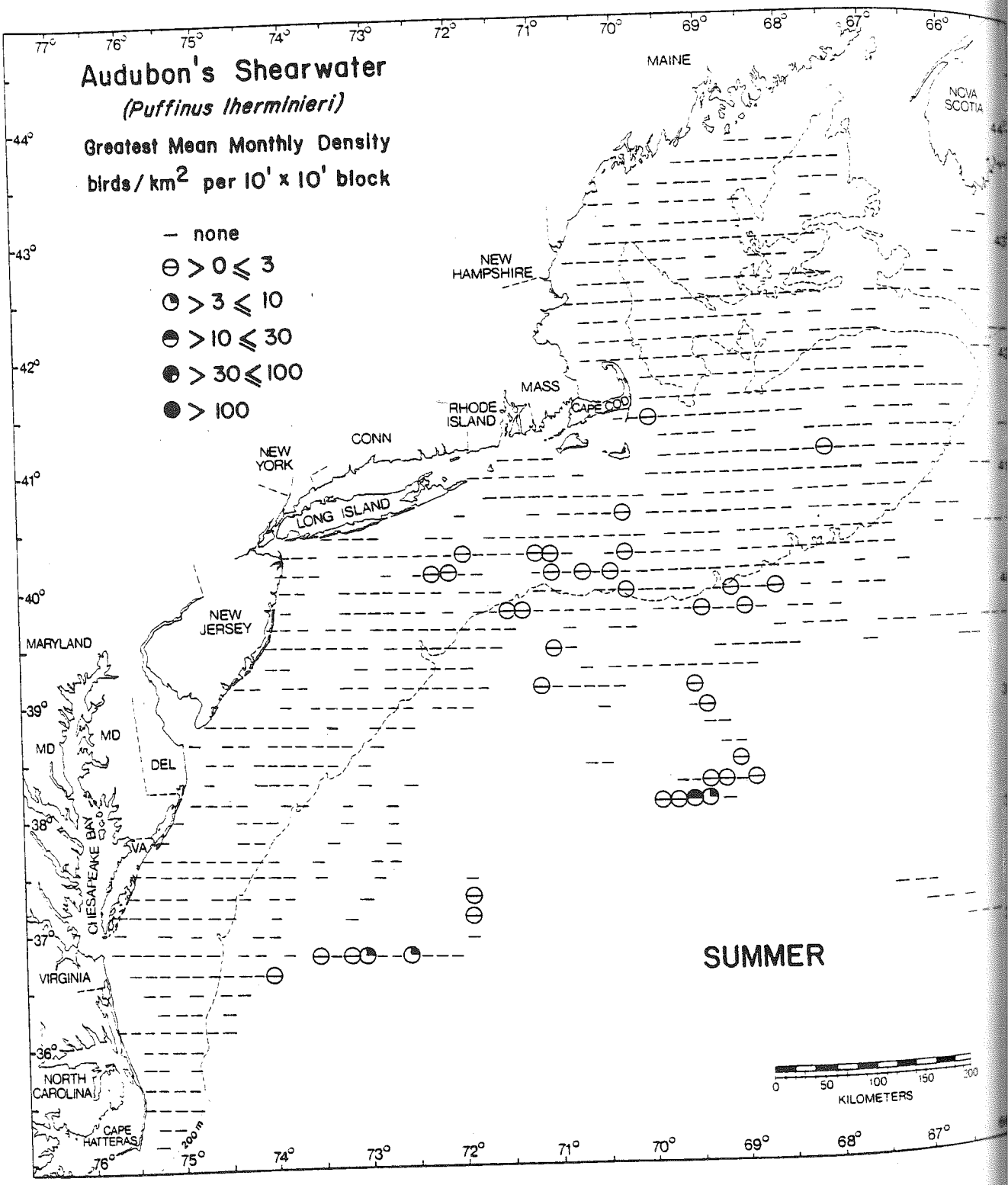


Figure 52. Relative distribution and abundance of Audubon's Shearwater (Puffinus lherminieri) in summer (June to August) off the northeastern United States.

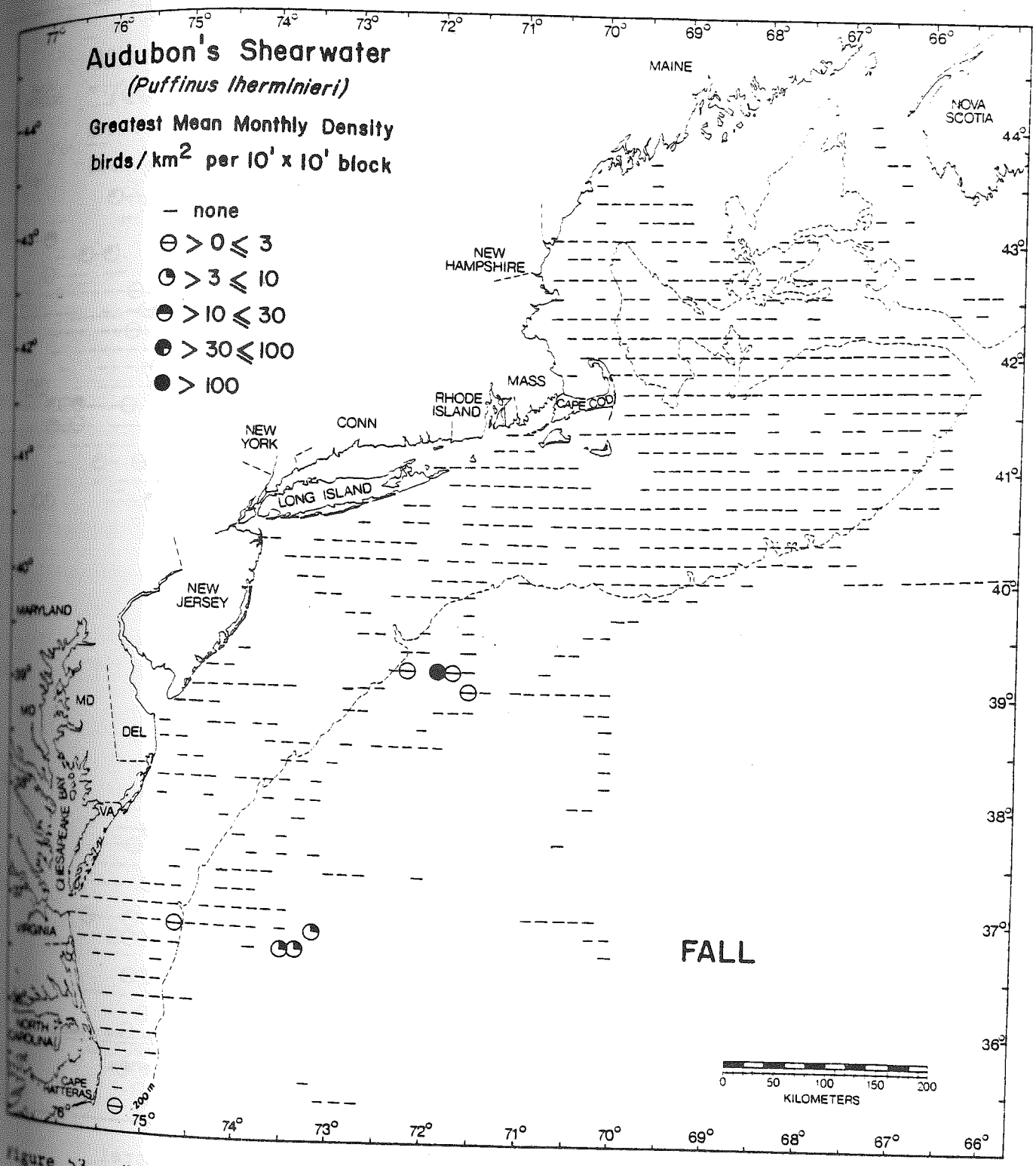


Figure 53. Relative distribution and abundance of Audubon's Shearwater (Puffinus lherminieri) in fall (September to November) off the northeastern United States.

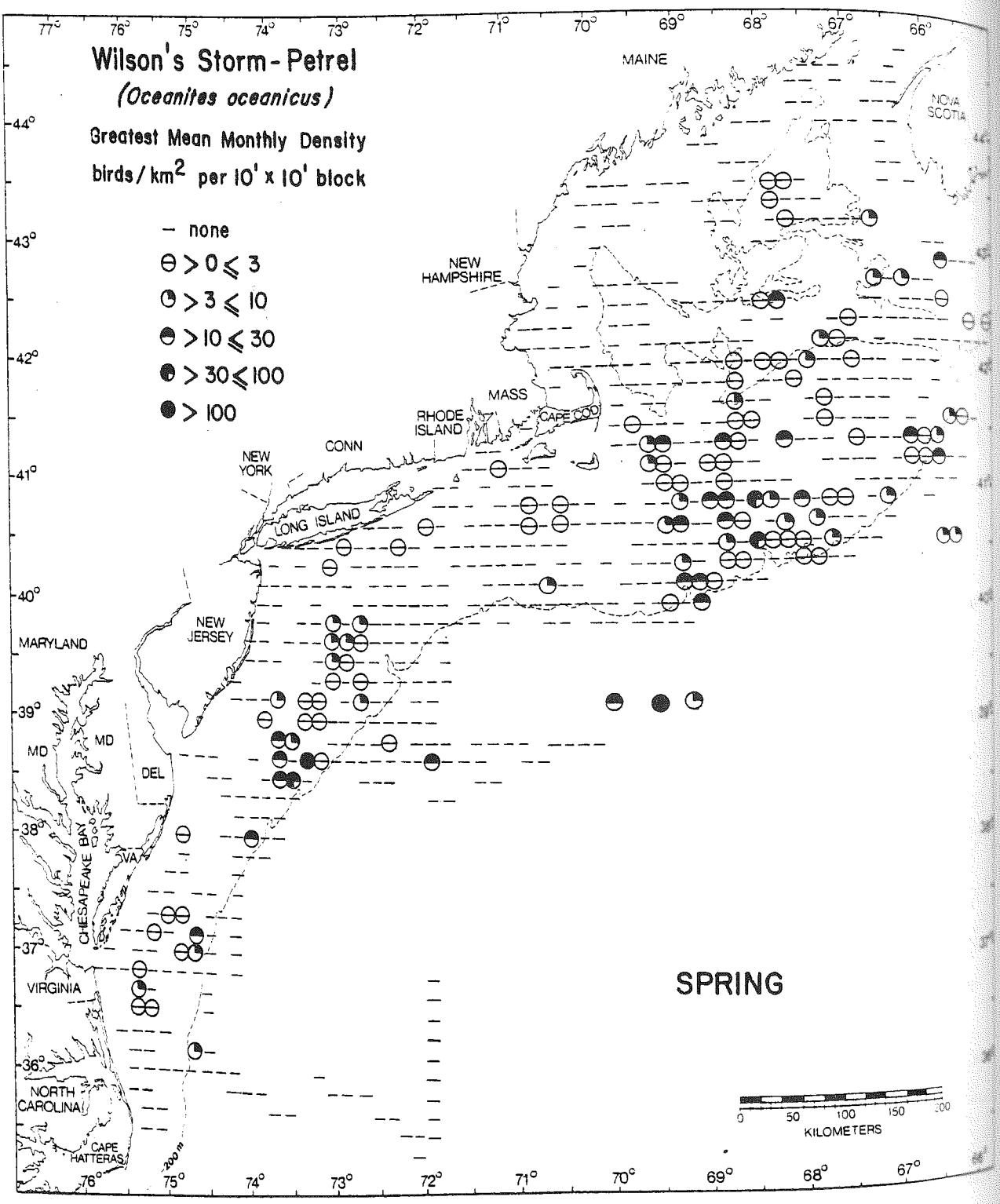


Figure 54. Relative distribution and abundance of Wilson's Storm-Petrel (Oceanites oceanicus) in spring (March to May) off the northeastern United States.

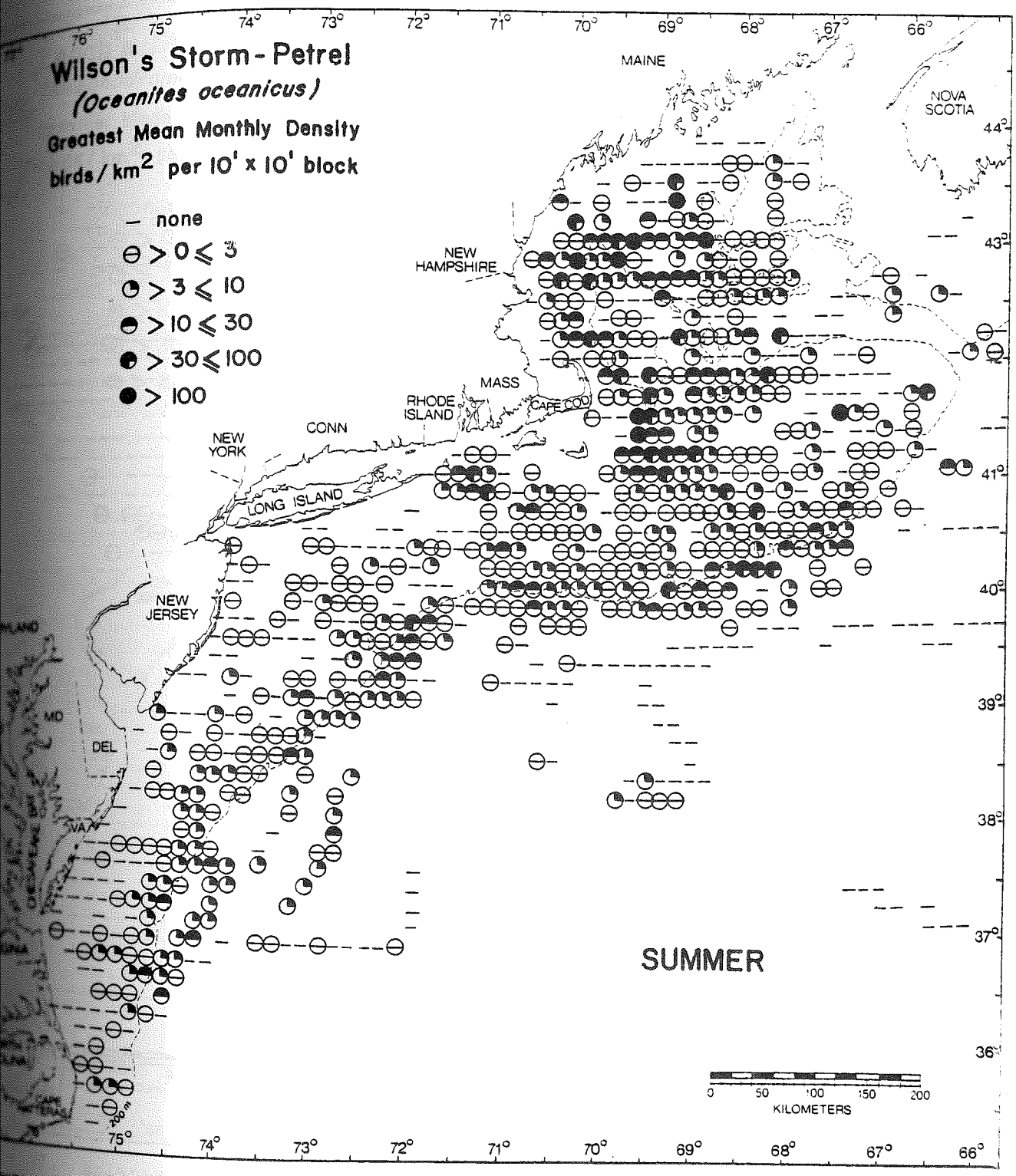


Figure 55. Relative distribution and abundance of Wilson's Storm-Petrel (Oceanites oceanicus) in summer (June to August) off the northeastern United States.

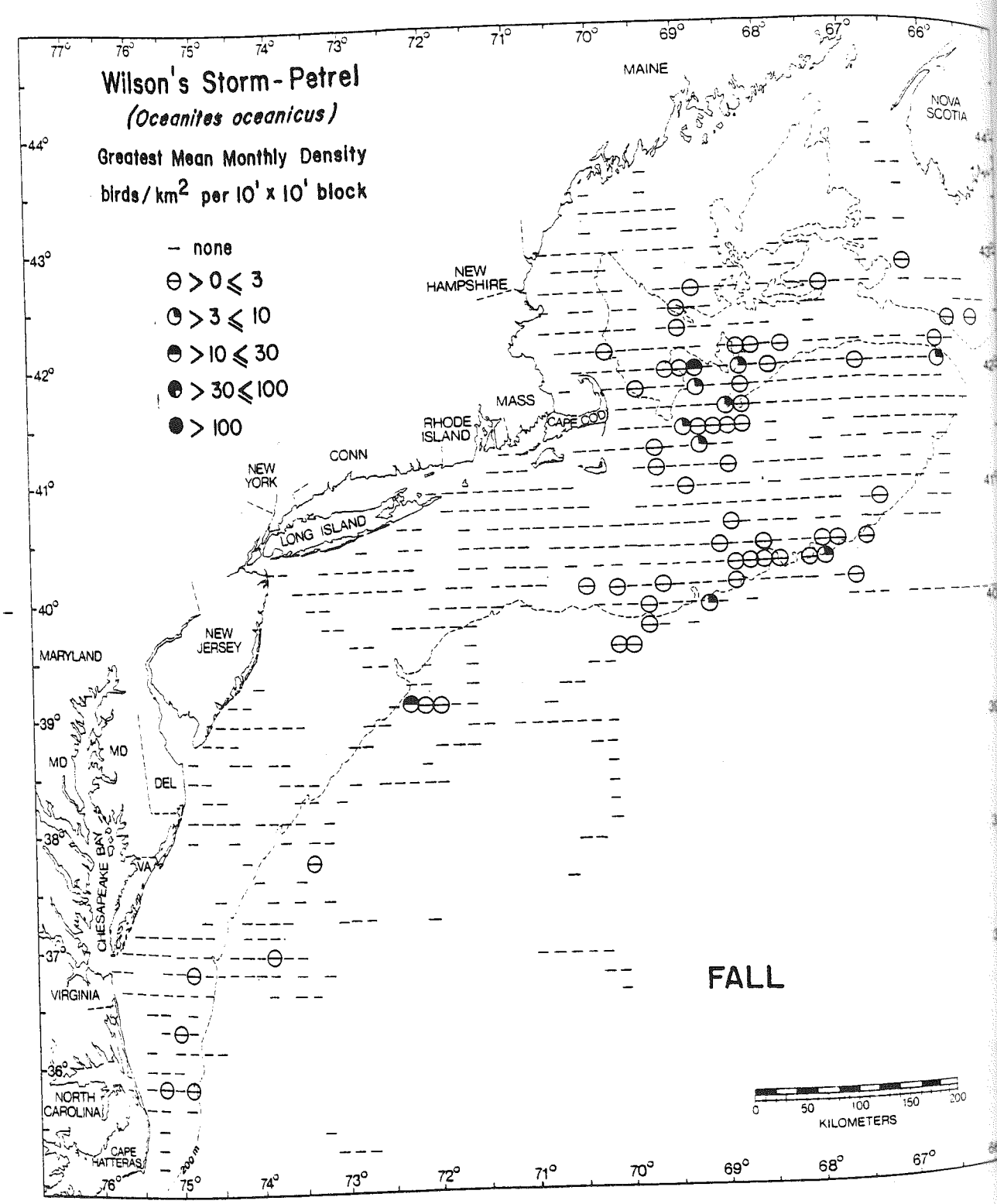


Figure 56. Relative distribution and abundance of Wilson's Storm-Petrel (Oceanites oceanicus) in fall (September to November) off the northeastern United States.

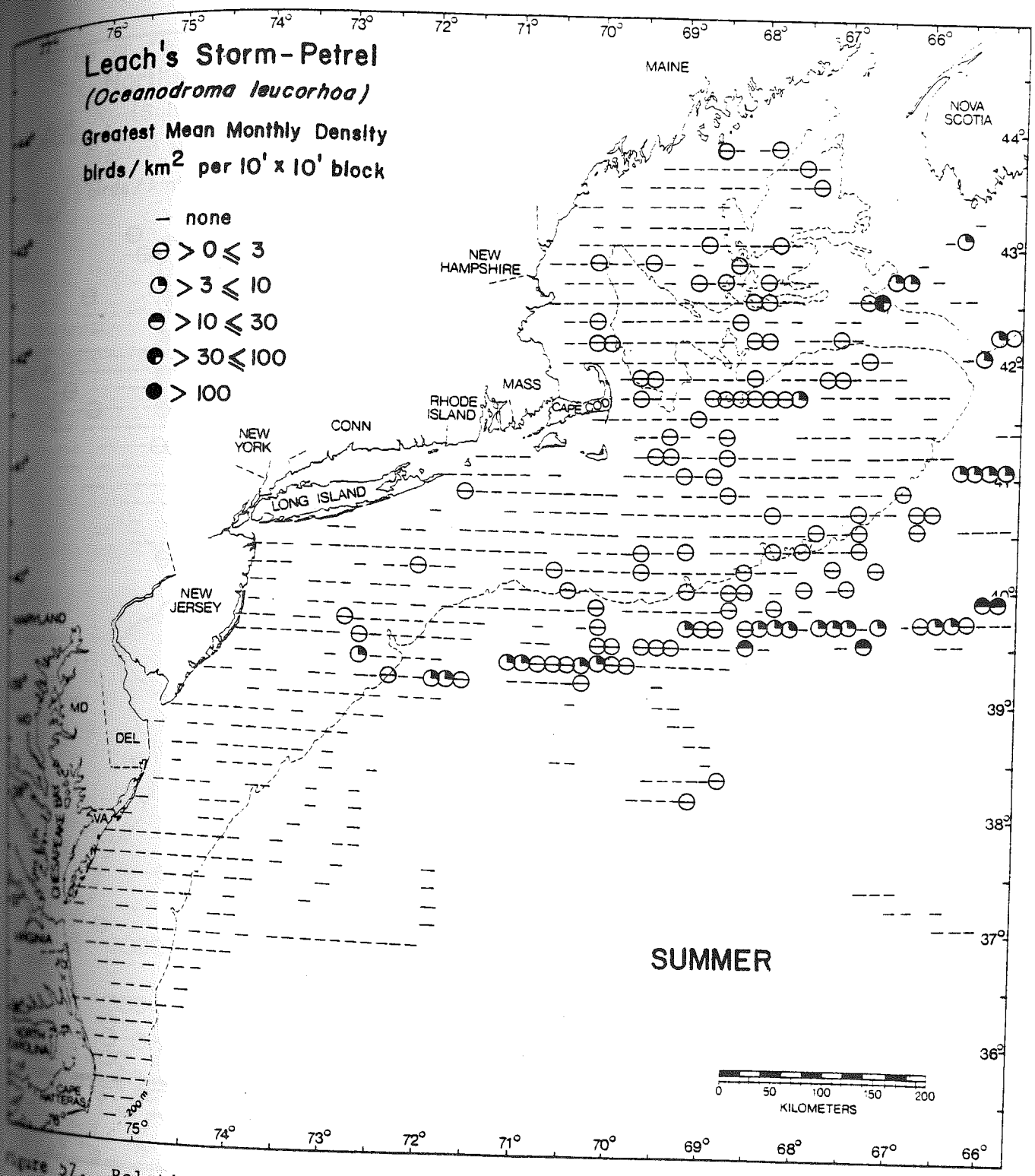


Figure 57. Relative distribution and abundance of Leach's Storm-Petrel (Oceanodroma leucorhoa) in summer (June to August) off the northeastern United States.

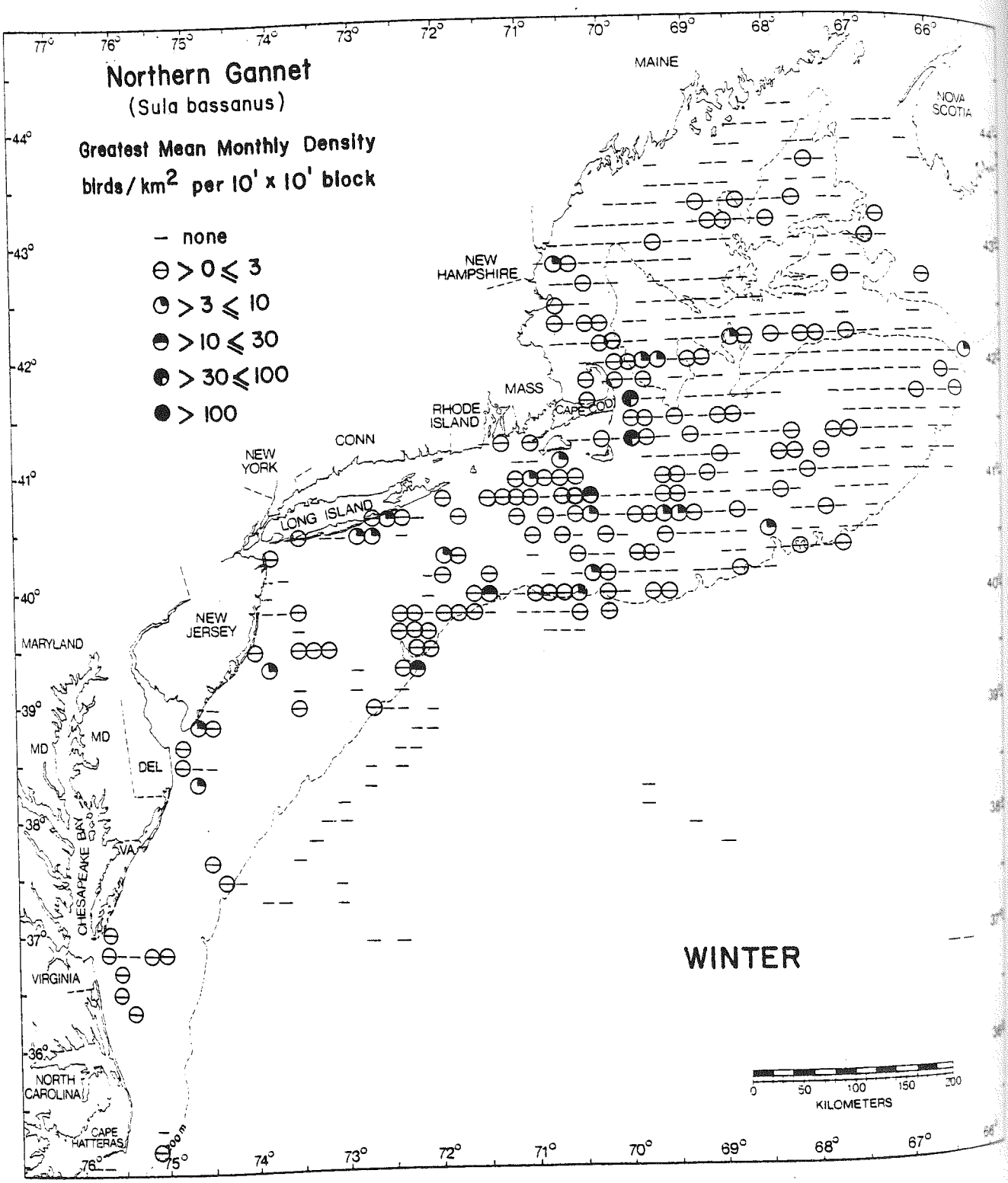


Figure 58. Relative distribution and abundance of Gannet (Morus bassana) in winter (December to February) off the northeastern United States.

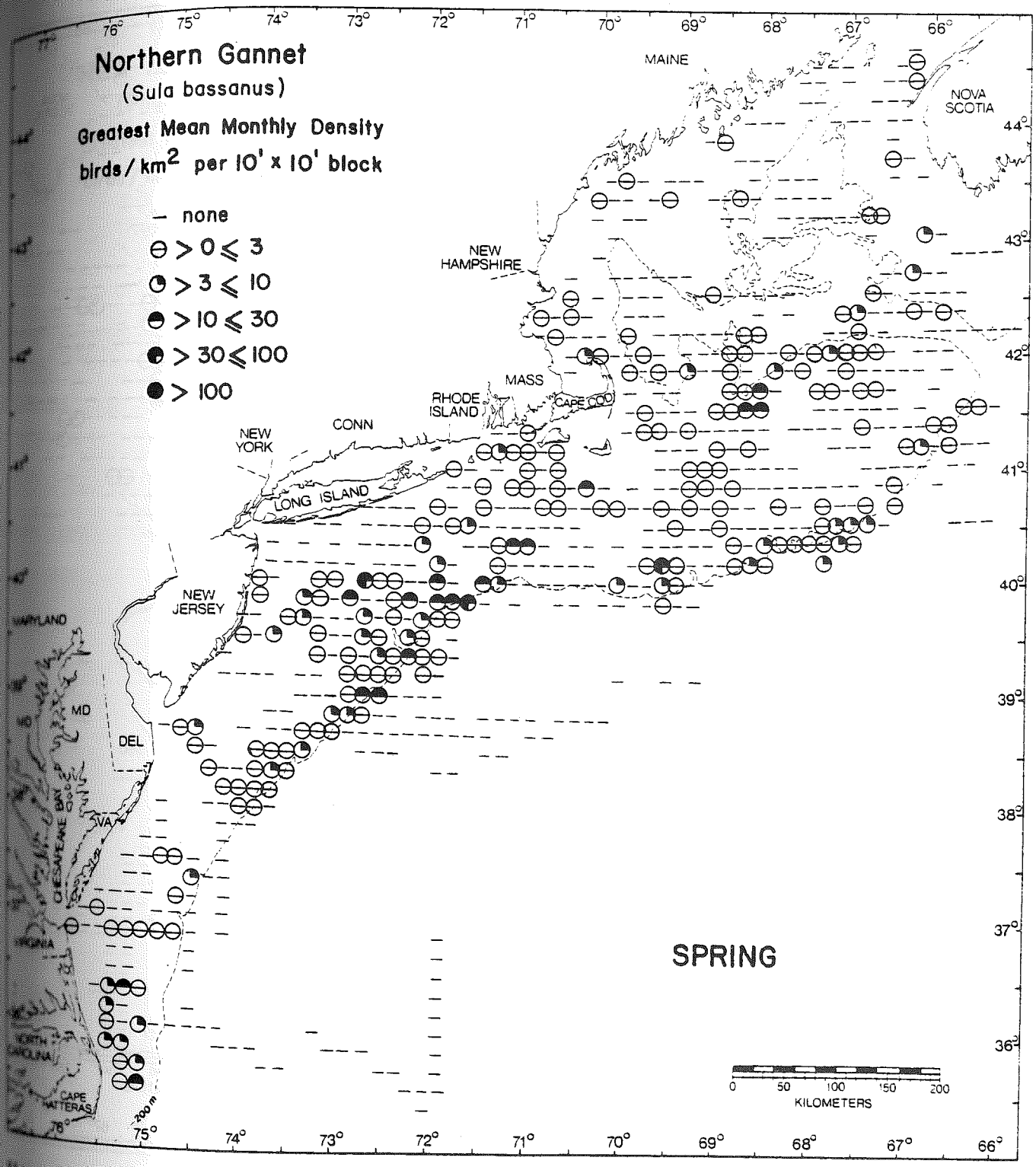


Figure 59. Relative distribution and abundance of Gannet (Morus bassana) in spring (March to May) off the northeastern United States.

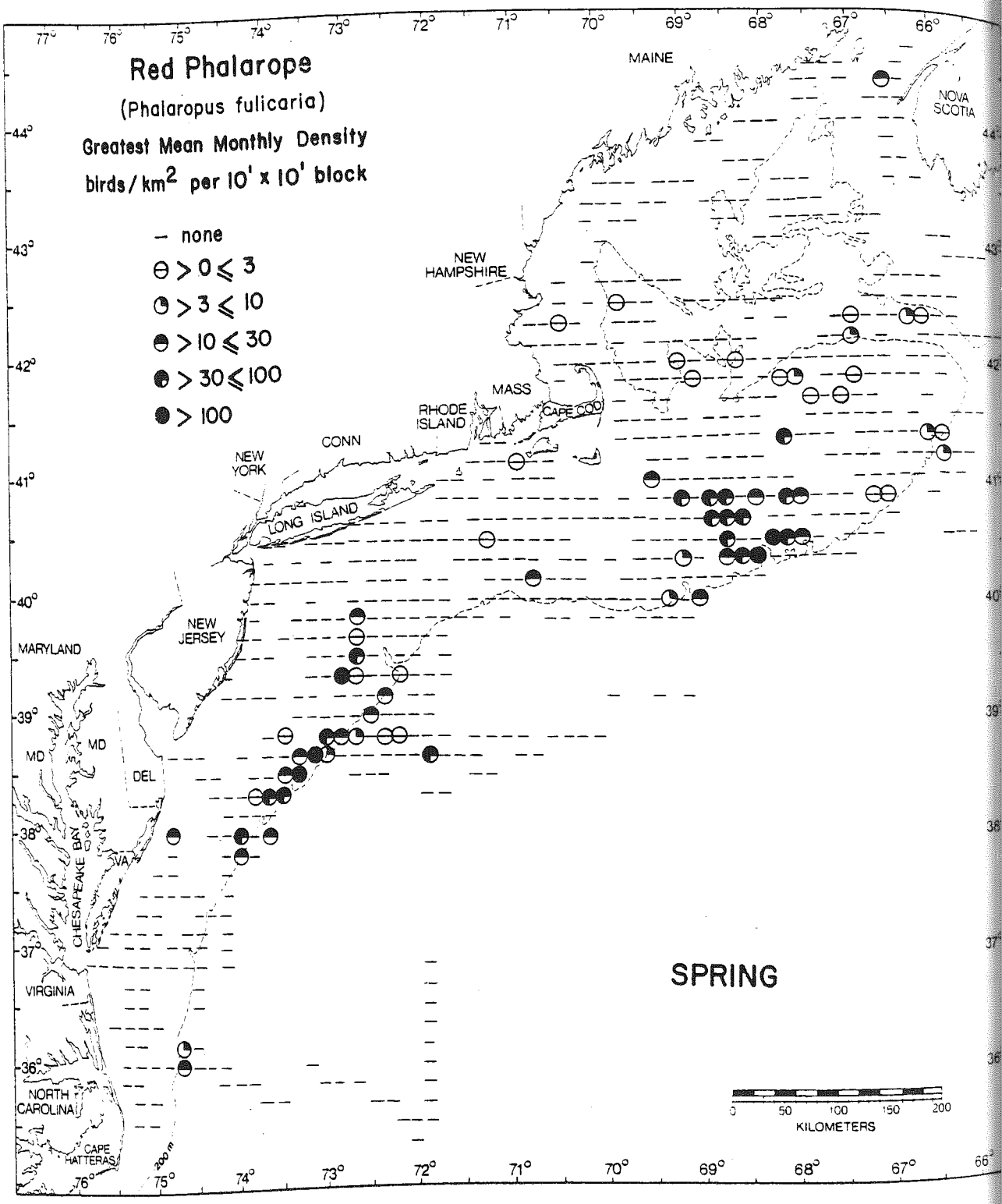


Figure 60. Relative distribution and abundance of Red Phalarope (Phalaropus fulicarius) in spring (March to May) off the northeastern United States.

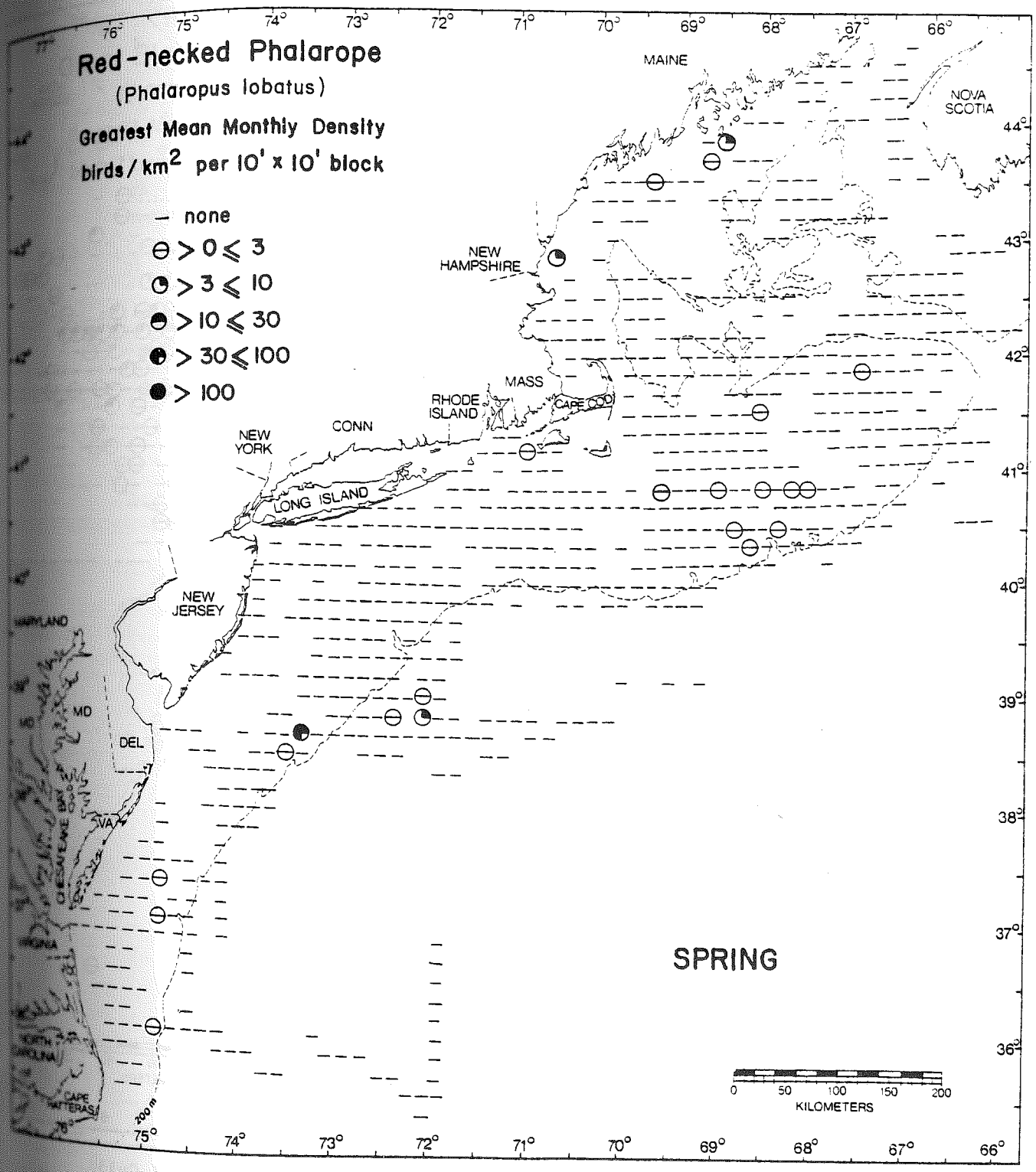


Figure 61. Relative distribution and abundance of Northern Phalarope (Lobipes lobatus) in spring (March to May) off the northeastern United States.

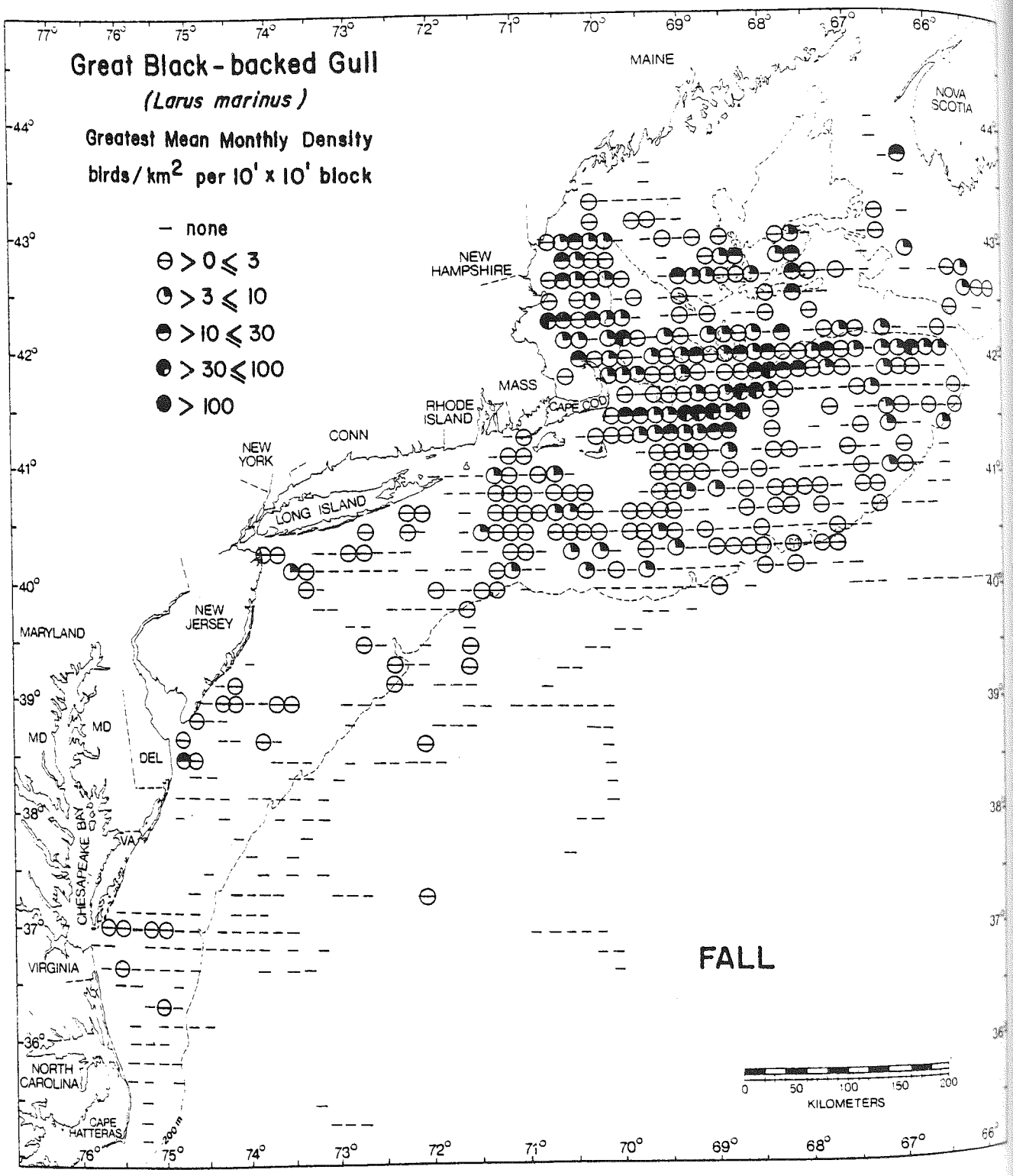


Figure 62. Relative distribution and abundance of Great Black-backed Gull (Larus marinus) in fall (September to Novmeber) off the northeastern United States.

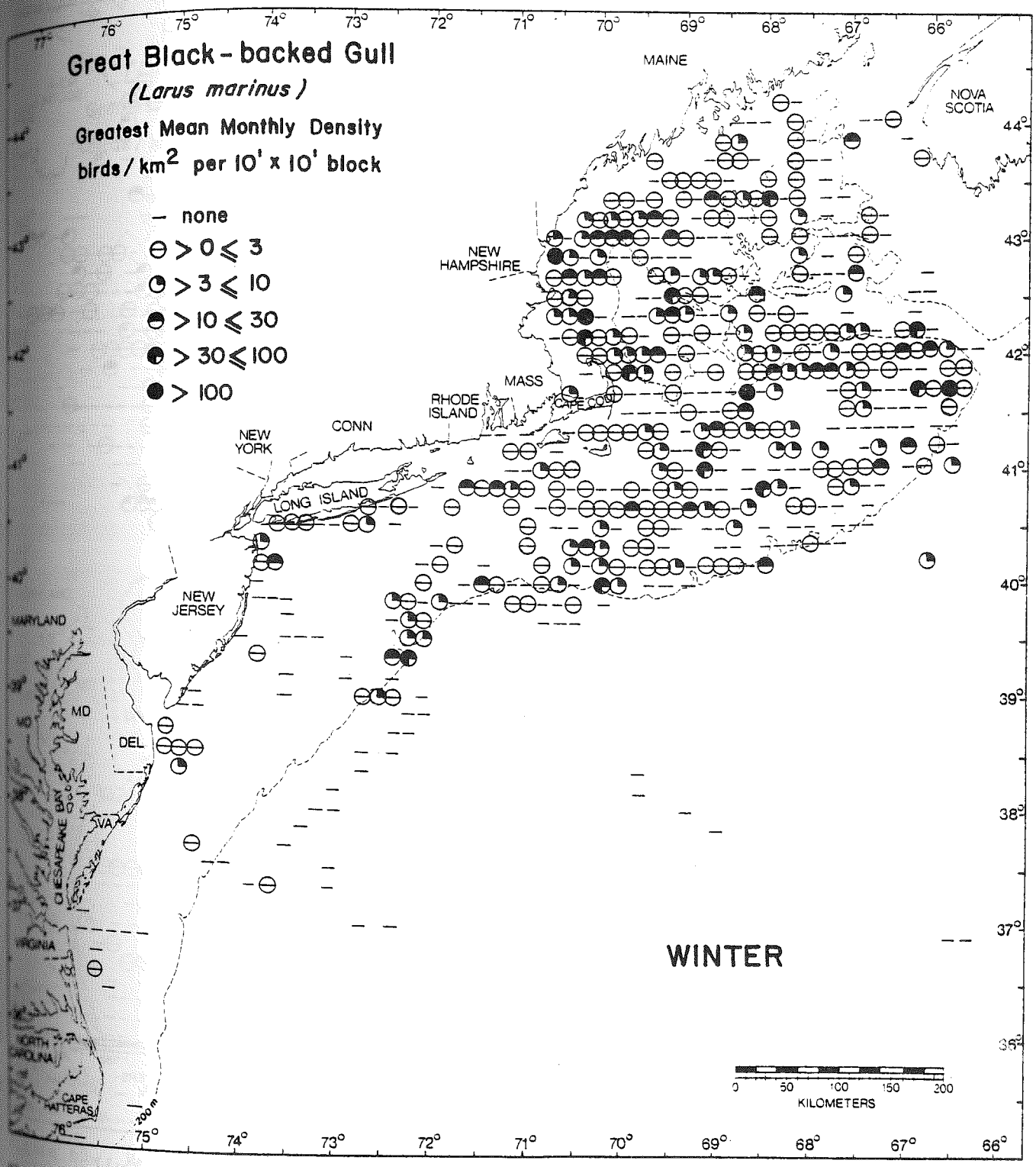


Figure 63. Relative distribution and abundance of Great Black-backed Gull (Larus marinus) in winter (December to February) off the northeastern United States.

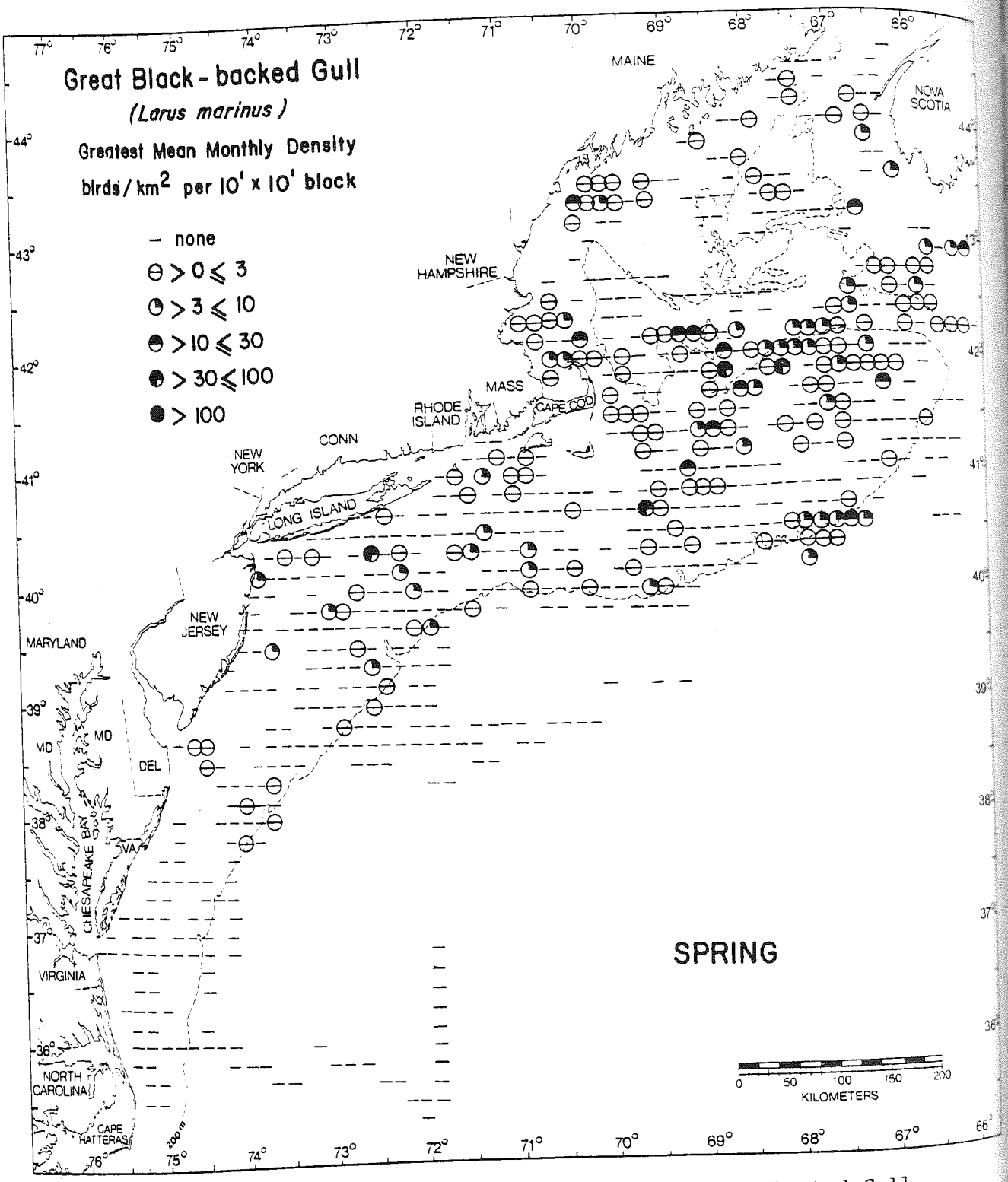


Figure 64. Relative distribution and abundance of Great Black-backed Gull (Larus marinus) spring (March to May) off the northeastern United States.

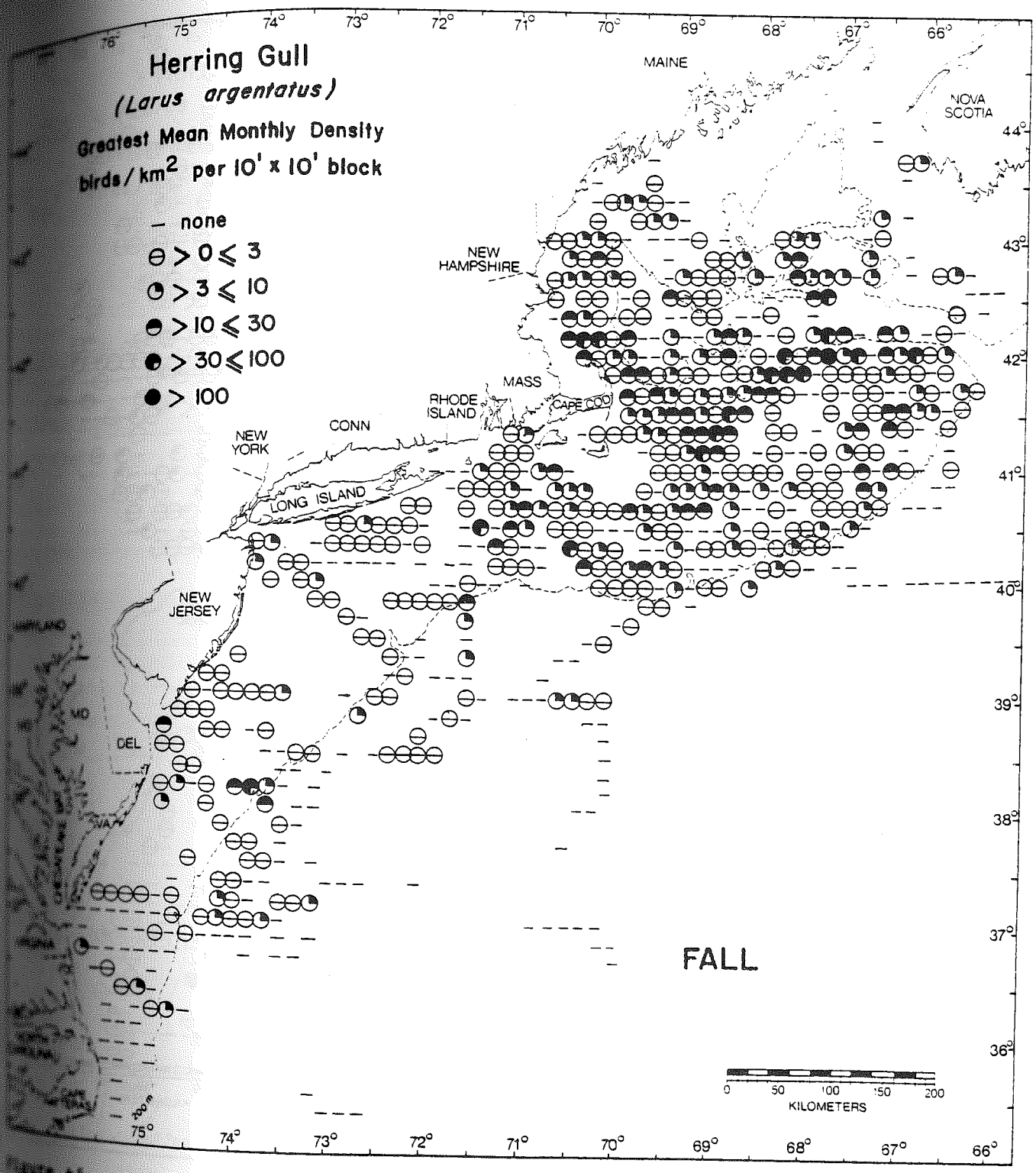


Figure 63. Relative distribution and abundance of Herring Gull (Larus argentatus) in fall (September to November) off the northeastern United States.

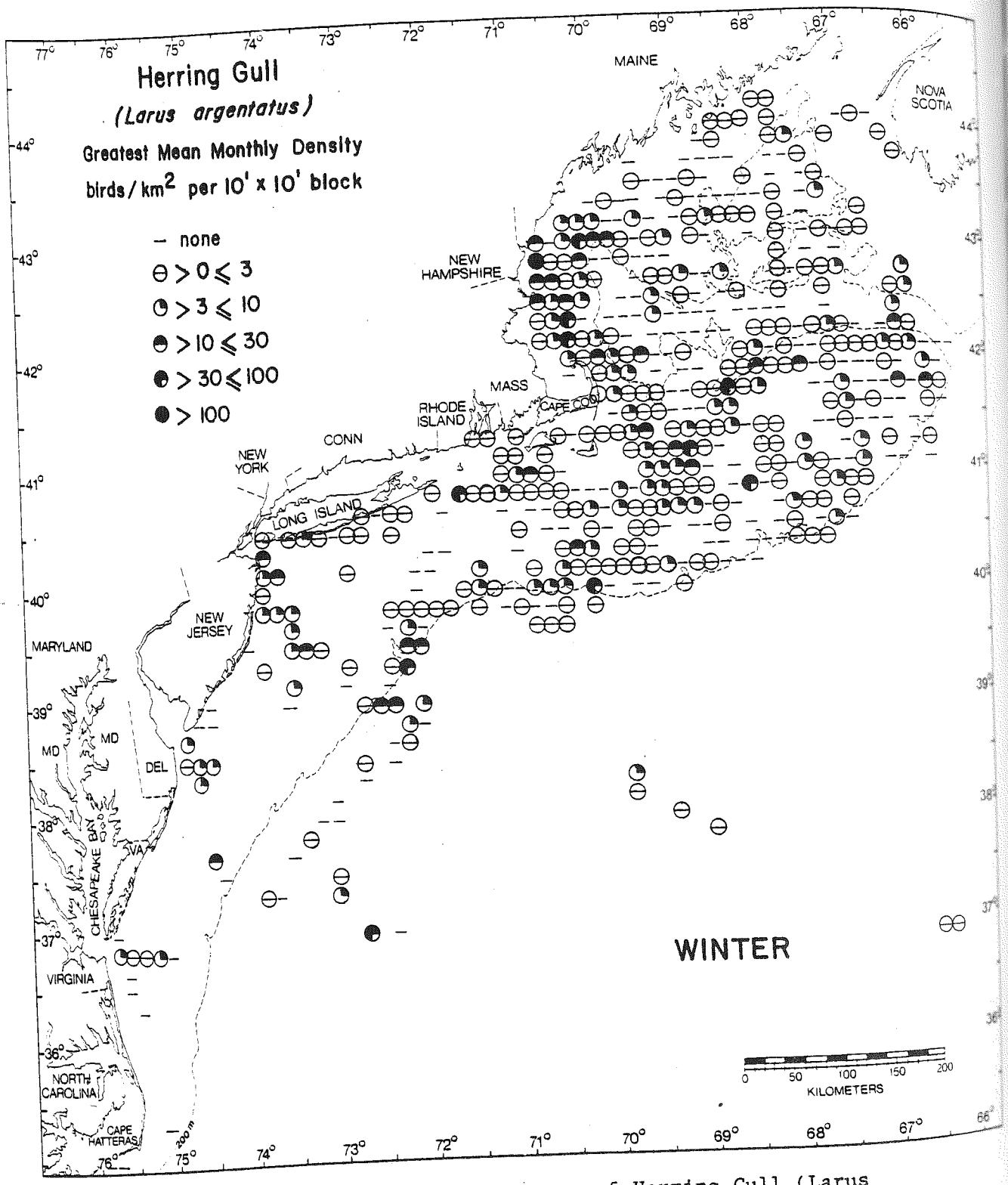


Figure 66. Relative distribution and abundance of Herring Gull (Larus argentatus) in winter (December to February) off the northeastern United States.

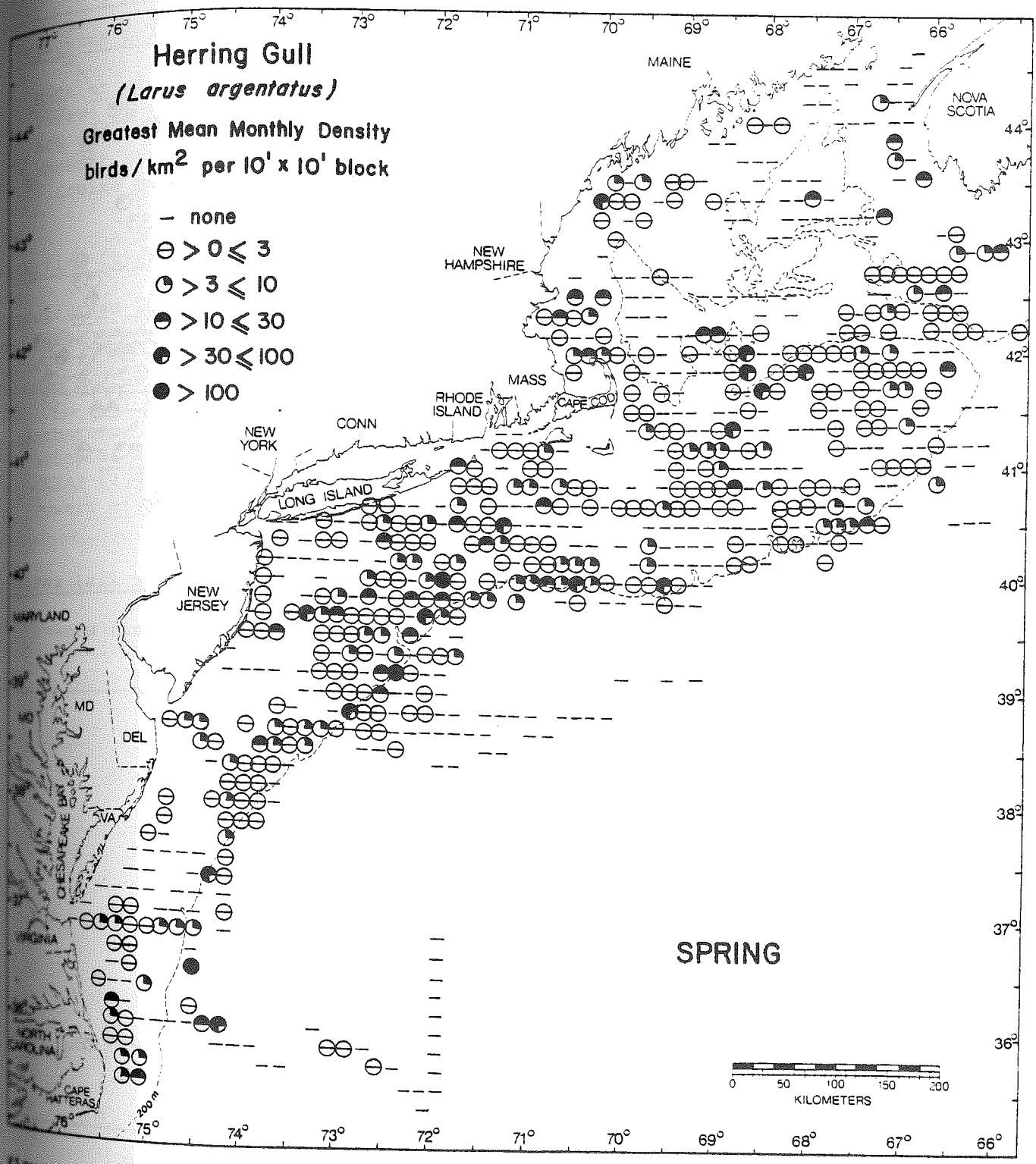


Figure 67. Relative distribution and abundance of Herring Gull (Larus argentatus) in spring (March to May) off the northeastern United States.

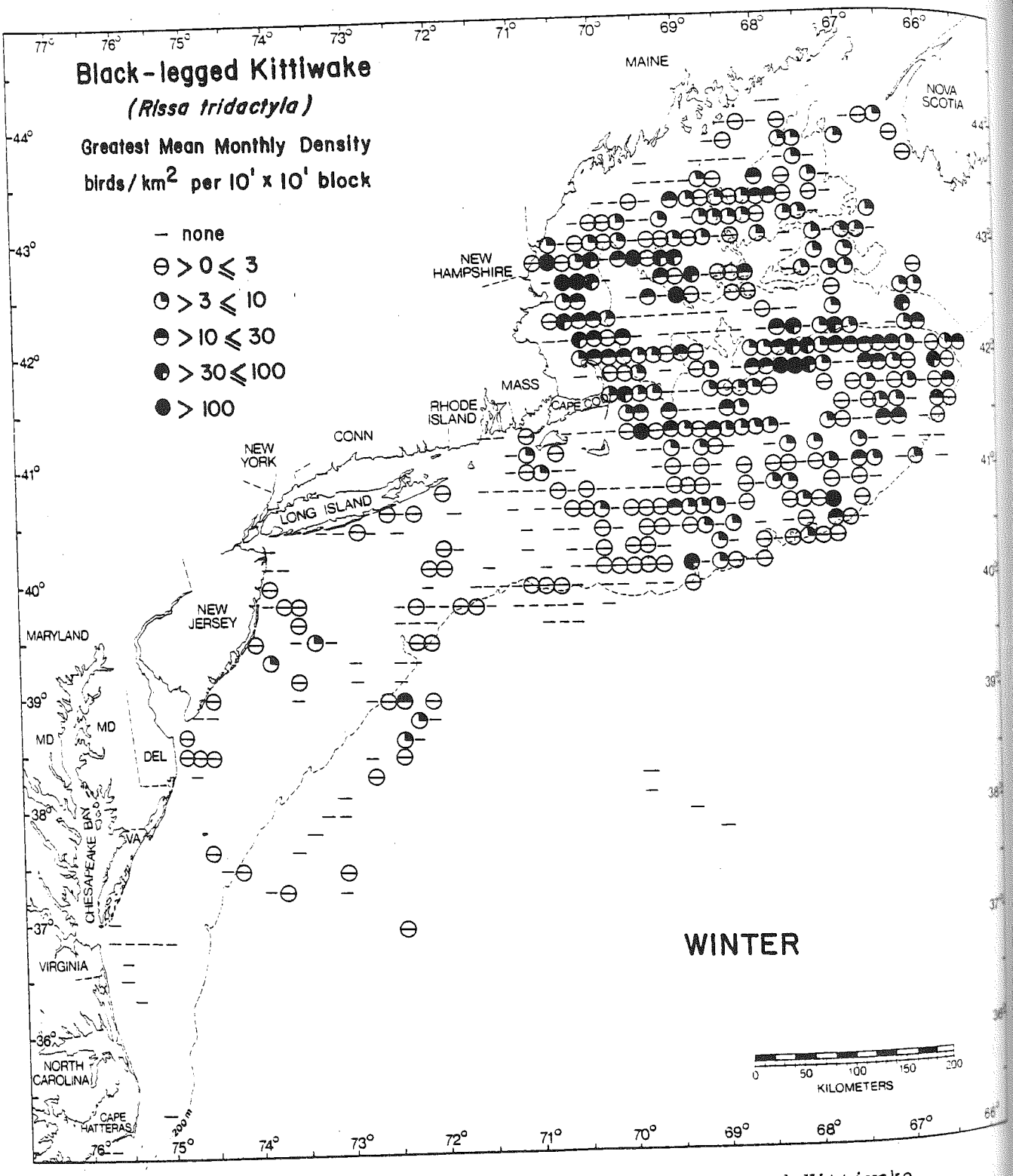


Figure 68. Relative distribution and abundance of Black-legged Kittiwake (Rissa tridactyla) in winter (December to February) off the northeastern United States.

Table 1. Sources of cetacean and turtle sighting data included in this report.

Cetaceans (all species)	Survey Period
Main *et al.* (1981), Appendix II	01 Nov 1979 - 09 Jan 1980
Powers *et al.* (1982), Appendix I	01 Jun 1980 - 31 Dec 1981
Rowlett (1980)	1971 - 1977
Manomet Bird Observatory (MBO) Cruise Reports (unpublished)	01 Jan - 11 Dec 1982
Turtles (by species)	
Loggerhead Turtle	
Shoop *et al.* (1981)	01 Oct 1978 - 09 Jan 1980
Powers *et al.* (1982), Appendix 2)	01 Jun 1980 - 31 Oct 1981
MBO Cruise Reports (unpublished)	01 Jan - 01 Dec 1982
Leatherback Turtle	
Shoop *et al.* (1981)	01 Oct 1978 - 09 Jan 1980
CETAP (1982)	10 Jan 1980 - 22 Jan 1981
Powers *et al.* (1982), Appendix 2	Jun 1980 - Dec 1981
Birds (all species)	
Powers (in review)	01 Jan 1978 - 31 May 1980

Table 2. List of species known to occur in the warm-core eddy interaction envelope given in figure 1. An 'x' designates at least one sighting of that species in that season.

Species	Season			
	Spring	Summer	Fall	Winter
Bottlenosed dolphin	x	x	x	x
Spotted dolphin	x	x	x	
Striped dolphin	x	x	x	x
Common dolphin	x	x	x	x
White-sided dolphin	x	x		x
White-beaked dolphin		x		
Grampus	x	x	x	x
Pilot whales	x	x	x	x
Sperm whale	x	x	x	x
Minke whale	x	x	x	x
Fin whale	x	x	x	x
Sei whale		x		
Humpback whale	x		x	
Mesoplodon spp.	x			
Ziphius cavirostris		x		
Kogia breviceps		x		
Loggerhead turtle	x	x	x	
Leatherback turtle		x	x	

Table 3. Cetacean and turtle densities (animals/km^2) and minimum population estimates (with 95% confidence interval) by season for Philadelphia Dumpsite (PDS) from CETAP (1982), stratum Y in areas G and H.

Species	Season			
	Spring	Summer	Fall	Winter
Fin Whale				
Density	0.0221	0.0010	0	0
Population estimate	252(± 287)	18(± 11)	0	0
Minke Whale				
Density	0	0.0005	0	0
Population estimate	0	9(± 6)	0	0
Bottlenosed Dolphin				
Density	0	0.0745	0	0
Population estimate	0	1301(± 583)	0	0
Grampus				
Density	0	0.0070	0	0
Population estimate	0	123(± 52)	0	0
Common Dolphin				
Density	0.4266	0.0052	0	0
Population estimate	4877(±6971)	91(± 69)	0	0
Loggerhead Turtle				
Density	0	0.1643	0.1538	0
Population estimate	0	2871(± 283)	1677(± 513)	0
Leatherback Turtle				
Density	0	0	0.0028	0
Population estimate	0	0	49(± 23)	0

Table 4. Minimum population estimates (with 95% confidence intervals) of cetaceans and turtles off the northeastern U. S. as derived by CETAP (1982). Species status, if any, is also given.

Species	Population Estimate	Status
Pilot Whale	45 (± 35)	Endangered
Humpback Whale	193 (± 481)	Endangered
Fin Whale	323 (± 418)	Endangered
Sei Whale	270 (± 146)	Endangered
Minke Whale	84 (± 68)	
Sperm Whale	135 (± 78)	Endangered
Bottlenosed Dolphin	5,653 (± 2,761)	
White-sided Dolphin	29,954 (± 16,413)	
White-beaked Dolphin	no estimate	
Pilot Whales	3,352 (± 3,878)	
Grampus	3,709 (± 2,302)	
Common Dolphin	14,525 (± 9,335)	
Spotted dolphins	no estimate	
Striped Dolphin	3,511 (± 3,517)	
Harbor Porpoise	3,342 (± 818)	
Loggerhead Turtle	7,495	Threatened
Leatherback Turtle	81-85 (May - Sep)	Endangered

Table 5. Cetacean and turtle densities (animals/km^2) and minimum population estimates (with 95% confidence interval) by season for Deepwater Dumpsite 106 (DWD-106) from CETAP (1982), stratum Z in areas F and G. No data were available for winter.

Species	Season		
	Spring	Summer	Fall
Fin Whale			
Density	0	0	0.0044
Population estimate	0	0	54 (± 24)
Sperm Whale			
Density	0.0013	0.0035	0*
Population estimate	10 (± 3)	69 (± 52)	0
Bottlenosed Dolphin			
Density	0.0846	0.1601	0.0968
Population estimate	630(± 167)	3177(±1375)	1199(± 909)
Pilot whales			
Density	0.0452	0.1299	0
Population estimate	337(± 126)	2577(±1089)	0
Grampus			
Density	0.1662	0.2024	0.2922
Population estimate	1238(± 269)	4014(±1582)	3619(±1100)
Saddleback Dolphin			
Density	0.0525	0.0292	0
Population estimate	391(± 163)	435(± 388)	0
Loggerhead Turtle			
Density	0	0.0065	0.0030
Population estimate	0	97(± 40)	37(± 27)

Table 6. Sesonal densities of birds (birds/km^2) in the vicinity of the Philadelphia Dumpsite (PDS).

Species	Season			
	Spring	Summer	Fall	Winter
Northern Fulmar	0.05(±0.28)	---	---	---
Common Loon	0.60(±1.70)	---	---	0.35(± 1.15)
Cory's Shearwater	---	8.30(±35.77)	0.05(±0.20)	---
Greater Shearwater	---	0.04(± 0.24)	---	---
Sooty Shearwater	---	0.02(± 0.13)	---	---
Manx Shearwater	0.01(±0.13)	---	---	---
Audubon's Shearwater	---	---	0.03(±0.13)	---
Wilson's Storm-Petrel	---	0.64(± 1.69)	---	---
Gannet	1.84(±5.35)	---	---	1.09(± 1.61)
Phalaropes	---	---	0.03(±0.15)	---
Great Skua	---	---	---	0.03(± 0.17)
Great Black-backed Gull	0.16(±0.96)	---	0.08(±0.32)	1.21(± 3.17)
Herring Gull	4.13(±9.22)	---	0.51(±1.20)	4.99(±13.77)
Bonaparte's Gull	0.22(±1.03)	---	---	0.04(± 0.19)
Laughing Gull	0.13(±0.51)	0.75(± 1.29)	0.05(±0.18)	---
Black-legged Kittiwake	---	---	---	2.50(± 4.75)
King-billed Gull	0.01(±0.12)	---	---	---
Common Tern	---	0.37(± 1.94)	0.21(±0.69)	---
Razorbill	0.18(±1.24)	---	---	0.24(± 0.88)
No. of transects (effort)	71	35	30	23

Table 7. Seasonal densities of birds (birds/km^2) in slope water off the northeastern United States. Densities should represent those in area of Deepwater Dumpsite 106 (DWD-106).

Species	Season			
	Spring	Summer	Fall	Winter
Northern Fulmar	1.64(±1.93)	0.01(±0.01)	0.12(±0.12)	0.22(±0.38)
Cory's Shearwater	0.01(±0.01)	0.05(±0.03)	0.25(±0.31)	---
Greater Shearwater	0.12(±0.24)	0.35(±0.35)	0.71(±0.97)	---
Sooty Shearwater	0.03(±0.05)	0.02(±0.03)	---	---
Audubon's Shearwater	---	0.12(±0.15)	0.26(±0.51)	---
Manx Shearwater	0.03(±0.05)	---	---	---
Wilson's Storm-petrel	1.30(±1.61)	3.39(±1.76)	0.73(±0.41)	---
Leach's Storm-petrel	0.08(±0.09)	0.52(±0.83)	0.02(±0.02)	---
White-faced Storm-petrel	---	---	0.01(±0.01)	---
Gannet	0.81(±0.79)	---	0.01(±0.01)	0.01(±0.01)
Red Phalarope	1.78(±0.74)	0.02(±0.05)	0.02(±0.02)	---
Great Skua	---	---	---	0.03(±0.05)
Great Black-backed Gull	0.52(±0.76)	0.01(±0.01)	0.05(±0.09)	0.10(±0.10)
Herring Gull	1.97(±1.21)	0.01(±0.01)	0.48(±0.42)	0.86(±0.89)
Black-legged Kittiwakes	0.14(±0.13)	---	0.35(±0.41)	0.27(±0.42)
Parasitic Jaeger	0.01(±0.01)	---	0.01(±0.02)	---
Pomarine Jaeger	0.02(±0.04)	---	0.05(±0.08)	---
Unid. tern	0.01(±0.01)	---	0.01(±0.01)	---
Dovekie	0.39(±0.78)	---	---	0.31(±0.63)
Murres	0.07(±0.14)	---	---	0.01(±0.02)
No. of transects (effort)	282	530	272	112

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CHAPTER 12. CONTAMINANT INPUTS, FATE AND EFFECTS

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12.1 INPUT.

12.1.1 Waste Sources

The 106-Mile Chemical Waste Disposal Site (Figure 1), established by the U.S. Army Corps of Engineers in 1965 (Anderson and Dewling, 1981), is the closest location to New York harbor which is beyond the edge of the continental shelf. While it had been used to some extent since 1961 (EPA, 1979), its establishment was requested by New Jersey industries whose chemical wastes were precluded by the State from being placed in landfills or discharged to inland waters. It encompasses a formerly used munitions disposal site (NOAA nautical chart 13003) and is about 20 km north of a location where cannisters of low-level radioactive waste were dumped between 1951 and 1962 (Dyer, 1976).

Except for the radioactive waste, I am unaware of documentation on types and amounts of waste dumped at or near the 106-mile site before 1973. Anderson and Dewling (1981) have determined that prior to 1973 most ocean dumped industrial wastes which could have gone to the 106-mile site were dumped at the sewage sludge site in the New York Bight. The year 1973 was a turning point in ocean waste disposal because it marked the beginning of implementation of the Marine Protection Research and Sanctuaries Act designed to prevent degradation of the marine environment through ocean dumping. Because of the Act, dumping of a large volume waste, that from the duPont-Grasselli plant,

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was moved from a New York Bight Site to the 106-mile site. Prior to 1973, without that law, it is unlikely that a large volume of waste would have been transported to the 106-mile site.

Since ocean dumping has been regulated it has also been routinely documented. As part of permit conditions dumpers submit logs of their activities and periodic summaries to the U.S. Environmental Protection Agency (EPA). The data in Table 1 listing permittees and quantities dumped at the 106-mile site from 1973 through 1981 has, therefore, been obtained from the EPA.

Nine permittees have used the site. Three of them; American Cyanamid, the duPont-Grasselli plant and the duPont-Edge Moor plant, have accounted for 65 percent to 95 percent (depending on the year) of the total annual inputs. The other inputs have been small by comparison. Modern Transportation Company is a waste hauler which, by permit, dumped wastes collected from several relatively small sources. The largest of those, a Merck and Co. plant, disposed of 35,000 metric tons in 1978 (Anderson and Dewling, 1981) about half the total dumped by Modern Transportation Co. General Marine dumped small amounts in 1976 and 1979 which were also comprised of contributions from a number of sources. The City of Camden, N.J. used the site for about twelve month period over the years 1977 and 1978 to discard sewage sludge which was deemed unsuitable for dumping over the continental shelf. Prior to 1977 that city's sludge was dumped at the same location used by the City of Philadelphia. It was ruled unsuitable because of its cadmium concentration and sent to the 106-mile site until a land-based disposal became available. It has been disposed of on land since mid-1978. Chevron Oil Co. disposed of sulfite containing wastes generated in a petroleum refining plant until 1975. Hess Oil ceased ocean disposal in 1973. Sludges generated by cleaning out sewage sludge digestors are dumped periodically as cleanout is required (P. Anderson, personal communication, 1982). Lastly, Consolidated Edison of New York dumped one barge load of fly ash in 1980 as part of permitted research into a possible routine disposal technique.

The Consolidated Edison dump is significant in the sense that it was the only waste dumped at the 106-mile site, or any ocean site, which was not already being ocean dumped prior to enactment of the Marine Protection Research and Sanctuaries Act. Waste from the duPont-Edge Moor plant and Camden sewage sludge were dumped at the 106-mile site only after 1977 but prior to that year they were dumped closer to shore off the Delaware coast. The sewage sludge was briefly forced to the 106-mile site. DuPont requested and was granted a revision of its dumping permit in 1977. The diminution of waste quantities over the 1973 to 1981 period evident in Table 1 is the result of EPA policy, as mandated by Congress, to discourage ocean dumping. Permits were issued with the provision that feasible land based waste disposal be implemented. Those alternatives will have been implemented for all wastes in Table 1 except duPont-Grasselli and digestor cleanout by 1982. Those two wastes were the only contaminant sources to the 106-mile site by the latter part of 1981.

New inputs have been suggested which would increase quantities dumped at the 106-mile site. The single dump of fly-bottom ash was part of a study to secure disposal space for approximately 750,000 annual metric tons of ash anticipated when two power plants are converted from oil to coal (Consolidated Edison, 1980). The U.S. Department of Energy is required to remove soil from up to 35 sites formerly used during the Manhattan Project. The first site being considered is in Middlesex, N.J. where uranium ores had been handled. Kupferman et al. (1982) have discussed the feasibility of dumping the 100,000 metric tons of soil from that site at the 106-mile site. The City of New York and municipalities in nearby New York and New Jersey have dumped sewage sludge at a site 12 nmi offshore in the New York Bight since the 1920s. Suggestions have been made that, in lieu of cessation of ocean dumping, the sludge be discarded at the 106-mile site. The quantity of that sludge in

1980 was 7,300,000 tons (EPA, 1981) or about ten times the largest annual total volume ever dumped at the 106-mile site.

In anticipation of increased pressure to use the 106-mile site for waste disposal this document has been prepared to summarize experience and knowledge gained from studies of the site, wastes, and waste dumping. Decisions on future use of the site should be based on that and accumulating knowledge.

12.1.2 General Waste Characteristics

In general it is the physical properties of wastes which, along with their method of disposal, determine their distribution at a given dumpsite. Aside from digestor cleanout and coal ash the wastes dumped at the 106-mile site have all been aqueous suspensions with bulk densities in the range of 1.0 to 1.15 g cm^{-3}. Since 1977 they have been discharged from moving barges at relatively slow rates of about 80 m^3 km^{-1} so that they are highly diluted immediately behind the barge (O'Connor and Park, 1982). Their dispersion occurs in the surface mixed layer except for very slow vertical mixing across seasonal or permanent pycnoclines, gravitation descent of waste particles and incorporation of waste components in sinking biological matter. The single coal ash dump was almost a spot dump during which a load of nominally dry ash was released from a hopper barge in about 10 minutes (ERCO, 1981). This slug of ash particles apparently and not unexpectedly descended quickly below at least 100 m (ERCO, 1981). The physical properties of digestor cleanout have not been described. The material comes from those sewage treatment plants which, by permit, send sludge to the New York Bight sewage dumpsite. The digestors are cleaned by being emptied and dried so that residue can be scraped from the surfaces. The scrapings are then mobilized by powerful streams of water and loaded onto dumping vessels. They are dumped at the same rate and under the same permit which applies to sewage

sludge in the New York Bight (P. Anderson, personal communication). In 1981 that rate was about 500 m^3 km^{-1}. It is not known if this digestor cleanout behaves like sewage sludge in the water column. Nominally it is an aqueous suspension but the solids having been dried probably causes them to be considerably larger than those in conventional sewage sludge. The one dump of sewage sludge observed at the 106-mile site centered on Camden sludge which was dumped at the relatively rapid rate of 700 m^3 km^{-1}. It behaved basically like industrial wastes in being dispersed primarily in the surface mixed layer (O'Connor et al., 1983). Digestor cleanout could possibly consist of relatively large particles which sink through the mixed layer.

It is possible to list chemical compositions of all wastes, except digestor cleanout, dumped at the 106-mile site since 1973. Granting of permits required dumpers to submit analyses of waste giving concentrations of selected elements, total organic carbon, total solids, total suspended solids, pH and specific gravity. In addition, results of acute bioassays were provided. These data are on file with Region II EPA. Information only on the three major waste sources, Camden sludge, and Modern Transportation Company wastes will be presented. Of these, only the three major wastes will be discussed in detail.

A number of reasons limit discussion to these wastes. First, since 1976 when studies of waste distributions and effects began, these five wastes have accounted for well over 90 percent of the total annual waste volumes. Secondly, chemical and biological examinations of wastes in laboratories were made to estimate expected effects in the ocean. Testing those expectations required coordination of oceanographic ship schedules with dumping events. This could only be done with wastes that were generated continuously and dumped frequently. The three major wastes were dumped at least weekly and were therefore subjects of those studies. One dump of sewage sludge, which

was transported to the 106-mile site about twice per month for twelve months, was made to coincide with an oceanographic cruise. Modern Transportation Company dumped industrial wastes from barges with 7,200 metric ton capacities, about twice that of other waste barges (American Cyanamid and duPont-Grasselli wastes were usually carried in separate compartments on the same 3,800 metric ton barge). Division of the 7,200 metric ton barge load into the annual Modern Transportation Co. quantities in Table 1 indicates that such dumps occurred less than monthly. Digestor cleanout annual volumes were not only usually low, indicating few dumps, but the waste was irregularly generated. When a digestor needed cleaning a number of sequential dumps would be made, otherwise long times elapsed between dumps (P. Anderson, personal communication).

Chemical and physical properties of wastes as defined in dumping permittee reports are summarized and compared in Table 2, along with results of acute toxicity tests. Year-to-year variations in characteristics of both duPont wastes and within-year variations of those and American Cyanamid waste are detailed in Table 3. Table 3 was constructed to emphasize that the averages of Table 2, while being reasonable values for later calculations, are from data sets where standard deviations often exceed means and ranges of values sometimes span more than an order of magnitude. Wastes can only be described in general terms they are not amenable to the precise consistency sought in the processes that generate waste.

Combining data from Tables 1 and 2 yields total masses of waste components contributed by each source. This has been done for the year 1978 (Table 4) to reveal some useful relationships among those sources. For example, duPont-Edge Moor waste has been by far the major source of elemental contamination. It is an inorganic waste. The other four wastes have been or are all

significant sources of organic matter, though they differ in terms of compounds comprising their organic contents. Sewage sludge, even though its 1978 volume was a fraction of any of the three major wastes, was a non-trivial source of both organic and inorganic contamination. It was a major source of suspended solids (as will be discussed, due to reactions with seawater both duPont wastes are much larger sources of suspended matter than their initial analyses portray). If New York/New Jersey sewage sludges, whose average composition is similar to that of Camden sludge, are dumped at the 106-mile site in annual volumes of the order of $10^6 m^3$ as discussed by O'Connor et al. (1983), they would overwhelmingly dominate chemical inputs except for iron and probably titanium even if industrial wastes were dumped at their 1978 volumes. (The 164 g l^{-1} TSS concentration in Table 2 for Modern Transportation Company waste was calculated by Murray [1981] from quarterly summaries submitted to EPA. This is ten times higher than TSS concentrations reported for Merck and Co., Reheis, and Crompton-Knowles waste [Hydroscience, 1979]. Since these are the major sources of industrial wastes carried by Modern Transportation Company the origin of the 164 g l^{-1} average is obscure. Conversely, half the Modern Transportation Company. waste was from Merck and Co. which contained about 30 g l^{-1} TOC [Hydroscience, 1979; Anderson and Dewling, 1981] so the average concentration of 1.8 g l^{-1} in Table 2 may be ten times too low).

12.1.3 Major Individual Wastes

The duPont plant in Edge Moor, Delaware extracts titanium from ores to produce titanium dioxide pigment. The chlorine based process generates an hydrochloric acid waste and a similarly acidic waste containing impurities from the ore. The major impurity is iron but vanadium and chromium which are chemically similar to titanium are significant components of this waste

stream along with fugitive titanium. The two acid wastes are mixed to create the ocean dumped waste. Since 1977 duPont has sought to market the ferric chloride waste as a flocculant to waste water treatment plants. The difference in average iron concentrations between 1977 and 1979 (Table 2) is to some extent a reflection of that marketing effort, though it is also a function of the quality of ore available to the plant. The very low 1981 volume of this waste indicates success with marketing it as a useful substance and recycling the acid waste stream.

Only two additional pieces of information complete the description of duPont-Edge Moor waste given in Tables 2 and 3. First, the anion corresponding to the list of mostly cationic elements is chloride. Secondly, the concentration of acid is about 2 molal. A pH electrode cannot sense so high an acidity other than its being less than 0.1 on a pH scale. However, equivalents of acid were routinely determined and averaged 4.4 and 3.0 eq. l^{-1} in 1977 and 1979, respectively. In an acidity measurement, each mole of ferric ion would appear as three acid equivalents. So, discounting for the average iron concentrations in 1977 and 1979, 2.4 and 2.2 moles of HCl per liter, respectively, would remain.

The duPont-Grasselli plant in Linden, New Jersey produces N,O-dimethyl hydroxyl amine (DMHA) continuously and anisole (methyl phenyl ether) for three to four months per year. Both production processes utilize dimethyl sulfate under alkaline conditions, to provide methyl and methoxy groups. The DMHA production also requires an initial reduced form of nitrogen which is probably ammonia. Anisole production requires phenol in addition to dimethyl sulfate. The waste is a very basic solution of sodium sulfate with some organics. It also contains nitrogen which as total Kjeldahl nitrogen (TKN) averaged 778 and 602 mg $(N)l^{-1}$ in 1976 and 1979. (TKN and total phosphorus,

conventionally regarded nutrients, have not been included in Table 2. They have been reported only for duPont-Grasselli and Modern Transportation Co. waste. In both cases the total phosphorus concentrations were less than 3 mg l^{-1}. A 1976 Modern Transportation Co. waste analysis used in Table 2 included a TKN concentration of 1493 mg N l^{-1}. Both these wastes have been similar to sewage sludge in TKN, 1500 mg l^{-1} [Mueller et al., 1976] but much less concentrated sources of total phosphorus, 500 mg l^{-1} in sludge).

Discussions with plant personnel in 1979 indicated that the organic content of duPont-Grasselli waste would be 50 percent in the form of methyl sulfate, 20 percent as methanol, 1 percent as the product DMHA and other amines with the remaining 29 percent as anisole, phenol or other unspecified compounds. The average concentrations in mg $l^{-1}$of phenol, DMHA and anisole were 2, 86, and less than 5 in 1976 and 1248, 58, and 7 in 1979, respectively, for six barge samples of each year. The high phenol concentrations correspond to, at least, detectable anisole concentrations indicating that the 1979 analyses were probably of wastes generated while anisole was being produced. Nevertheless, the high phenol concentrations are suspect because phenol is 76 percent carbon and over the two sample sets where average phenol concentrations increased from 2 to 1248 mg l^{-1} TOC concentrations decreased from 4765 to 3495 mg l^{-1}.

Boehm (1981) analyzed a duPont-Grasselli sample in terms of its volatile, acid-extractable and base-neutral extractable fractions. Nothing was found via the conventional purging technique where volatile compounds are transferred to the gas phase. Direct injection of waste onto a glass capillary column subsequently revealed methanol at a concentration of approximately 100,000 mg l^{-1}. Since this corresponds to a TOC concentration of 38,000 mg l^{-1} or about ten times reported TOC concentrations

(Table 3), it may be an overestimate of the methanol concentration. Acid or base-neutral extractions found phthalates and unidentified compounds in the low 1 to 50 ug l^{-1} range and several halogenated compounds at the ng l^{-1} level. Essentially, Boehm (1981) found trace organics with the TOC consisting almost entirely of methanol. Application of the purging technique to extract volatizable organic compounds by Kennicutt and Brooks (1982) yielded 499 and 316 mg l^{-1} of organic compounds in two samples of duPont-Grasselle waste. In each case five or fewer compounds were extracted and a single compound, methoxy methylamine, accounted for 70 to 75 percent of total compound concentrations. These observations are at variance with those of Boehm (1981) in that purgeable compounds were identified. However, the conclusion of Boehm (1981) that the major waste compound is methanol is still valid.

Because waste from the duPont-Grasselli plant displayed a low toxicity and because no reasonable (environmentally or economically) alternative to its disposal in the ocean has been identified, this waste may be the only waste dumped at the 106-mile site in 1982. It could be joined to some extent by waste from the duPont-Edge Moor plant if not all of that waste can be recycled or marketed.

Chemical characterizations of both duPont wastes are not simple but they pale in complexity relative to American Cyanamid waste. This waste from the Warners plant in Linden New Jersey is generated from production of thirty separate products. Discussions with plant personnel indicated that in 1978, 37 percent of the waste was expected to result from organophosphorus insecticide production, 35 percent from production of water treatment chemicals, 24 percent from production of intermediates for the rubber, paper, mining and chemical industries and 4 percent from production of surfactants. Within these broad catagories of products a number of

individual chemicals are produced on a varying schedule. Over thirty different organic chemicals were indicated as reagents employed at the Warners plant.

Monthly analyses of this waste as reported to EPA included measures of malathion and a series of other organophosphorous insecticides with the trademarked names Thimet, Counter, Cynthion, Abate, Cygon, Cytrolane, and Warbex. In 1976 the concentrations of these compounds in waste were in the 20 to 400 mg l^{-1} range. Not all compounds were produced during each month. Interesting unquantified waste chemicals were mercaptans required in producing these compounds. While not routinely monitored, the presence of these foul (rotten-egg) smelling compounds was immediately obvious and the source of a unique logistic problem. In being transported from Linden to the ocean, this waste was carried by Staten Island. Until the transporting vessels were fitted with gas locks over their waste compartments, their contents were periodically responsible for tripping natural gas-leak alarms at Island storage tanks (natural gas is spiked with mercaptans to reveal its presence).

Boehm (1981) performed detailed chemical analyses of four samples of American Cyanamid waste and found over 150 compounds. Table 5 is a compilation of the "volatile" compounds extracted by purging the waste and/or directly injecting waste into a column and the fifteen most concentrated compounds extracted in base-neutral media. Compounds which appeared only in the acidic extracts in the concentration range of 1 to 3 mg l^{-1} were 2,3,4 trithiapentane, cresol, toluol and other phenol compounds. Concentrations and even presences of compounds varied widely among the samples analyzed. Of the compounds listed in Table 5 only cyclohexanone, the diene compounds and the phosphate pesticides (compound numbers 2, 3, 4, 5, 8, 9, 10, 12, 13, and 14) were in each of four samples.

Presumably methanol which was highly concentrated in the one sample directly injected to a glass capillary chromatographic column would have been found if other samples were similarly injected.

Wiesenburg and Brooks (1983) using the purge-trap technique found only four compounds in samples of American Cyanamid waste. Methanol and toluene were identified, two compounds which eluted from the column prior to toluene were not. However the same technique when applied to seawater samples collected from a plume of only American Cyanamid waste yielded about 60 distinct chromatographic peaks. Nine of those were identified with varying degrees of confidence. Positively identified were; dichloromethane, toluene and two isomers of trichlorobenzene.

Three compounds of fairly certain identity were a C_6-aldehyde, formaldehyde diethyl mercaptan and O,O,S-trimethyl dithiophosphate. Tentatively identified were 1,3 dithiane and bis-2-chloroprophyl ether. In terms of concentrations in seawater within thirty minutes of being dumped and therefore diluted by a factor of about 5000; toluene was about 1 mg l^{-1}, trichlorobenzene at 0.1 mg l^{-1}, 1,3 dithiane and bis-2-chloropropyl ether at 0.02 mg l^{-1} the other compounds were less concentrated. Wiesenburg and Brooks (1983) attribute the absence of an array of volatile compounds in waste samples sent to their laboratory to the large headspaces in glass shipping bottles. Very volatile compounds could have essentially become totally gaseous and lost when the bottles were opened for analysis. One of their nine identified compounds, trimethyl dithiophasphate, is a breakdown product of organophosphate pesticides. Their breakdown is enhanced at the pH of seawater.

Among the volatile organic compounds identified in the work of Boehm (1981) and Wiesenburg and Brooks (1983) there are similarities and differences. Both found methanol, toluene and trichlorobenzene (it appeared as a base-neutral extract in Boehm's analysis) and, while they were different compounds, low molecular weight mercaptans. The hexanones were found only by Boehm and only Wiesenburg and Brooks report chloropropyl ether. This cannot be attributed to differing techniques or expertise but simply to the fact that different waste samples were analyzed. The American Cyanamid waste is a very inconsistent entity. It is derived from diverse processes which vary in their relative intensity. Another example of variation is in the surface activity of American Cyanamid waste. Kester et al. (1981a) found that 10 percent mixtures of waste (collected in 1976) lowered the surface tension of seawater by 33 percent. This could be expected of a waste from a plant producing surfactants and is consistent with the observation that plumes of thiswaste sometimes include a surface slick. However in a study designed to address this behavior, Goupil (1980) found a distinct absence of surface activity or compounds in the upper 200 Angstroms of the water column in the area of the 106-mile site or a waste plume. A 50 percent v/v seawater solution of the waste dumped at that time (same dump yielding the volatile analyses of Wiesenburg and Brooks, 1983) was lowered in surface tension by only 1 percent.

American Cyanamid waste dumping continued into 1981 under an EPA (Region II) enforced phase out schedule. In 1975 the first major change in waste handling occurred when a strongly organic waste (not included or existing during the analyses discussed here) was subjected to a toluene extraction with the extract subsequently incinerated. Later the production process was modified to preclude creation of this highly organic waste (P. Anderson, personal communication). Ocean dumping ceased in 1981 when the waste streams, previously combined and dumped,

were divided into three parts. One part is now transported through a sewer line to a sewage treatment plant. The other two are trucked to an American Cyanamid plant in Bound Brook, New Jersey where, along with other American Cyanamid wastes, one part is incinerated and the other subject to physical/chemical treatment with the effluent discharged to a river.

12.2 FATE.

12.2.1 Waste-Specific Reactions and Chemical Signals

Knowledge of the physical fate of wastes dumped at the 106-mile site is useful in predicting environmental consequences of those and other possible wastes. Information evolved from studies of waste dispersion is discussed later in the context of small- and large-scale oceanographic processes controlling dispersion. Prior to that discussion it is appropriate to indicate aspects of the fate of the three major industrial wastes which are unique to each.

12.2.2 DuPont-Edge Moor Waste

DuPont-Edge Moor waste is essentially a very acidic solution of iron. The high pH cannot persist in seawater. While the alkalinity of seawater (2.4 milliequivalents per liter, Skirrow, 1965) is about 2000 times less than the acidity of the waste, the waste is diluted by a factor of 5000 upon being dumped. This should reduce oceanic alkalinity to 1.5 $meq.l^{-1}$. As Park (1957) has demonstrated, so long as equilibrium with atmosphere CO_2 is maintained decreasing alkalinity to that level will decrease the pH of seawater from its normal value of 8.2 to about 8.0. Seawater is a well buffered medium. A dramatic change in pH to, say, less than 7.0 would require an alkalinity decrease to about 0.1 $meq.l^{-1}$ corresponding to a duPont-Edge Moor waste dilution factor of only about 1800. If the waste

were dumped more quickly acidic conditions could prevail in fresh plumes. As dilution proceeded through oceanic mixing pH values would rise to normal.

At oceanic pH the iron in duPont-Edge Moor waste is in the form of a hydrous ferric hydroxide floc (Kester et al., 1981b). Ignoring water of hydration associated with the floc, each mole of ferric ion becomes a mole of ferric hydroxide ($Fe[OH]_3$). The annual 5665 metric tons of iron (Table 4) from this waste was therefore more than 10,000 metric tons of a particulate floc and has been the largest waste source of particulate matter introduced at the 106-mile site.

The creation of this floc provides three waste characteristics not evident from its initial analysis. One, the suspended floc is eminently amenable to remote sensing. Two, the floc provides surfaces for adsorption of other waste components. Three, the settling behavior of them provides some insight into possible settling of other particulate wastes.

The visibly green color of dumped waste is readily sensed by elements within the multi-spectral scanner of the Landsat satellite. Landsat images of waste plumes have been used by Klemas and Philpot (1981), Ohlhorst (1981) and O'Connor and Park (1982) to estimate plume sizes as functions of time since dumps, rates of plume dispersion and advection of water containing plumes. The particles can also be indirectly sensed by their reflection of high frequency acoustic signals (Orr and Baxter, 1983). Such accoustic sensing has been done to measure the vertical and horizontal distribution of acid-iron waste. Both types of remote sensing, by definition, do not directly measure waste. The first, based on reflection of visual light, yields an almost unambiguous signal. The long and thin ribbon-like images can only be plumes of waste or clouds. Since clouds generally appear in clusters and have unique spectral

characteristics they can be distinguished from waste plumes. The second, based on the intensity of acoustic reflection, yields a signal that without corresponding chemical analysis cannot be unequivocally related to waste particles.

Hydrous ferric hydroxide has long been known to provide sites for the adsorption of water-borne substances (e.g. Jenne, 1968). Kester et al. (1981b) concluded that correlations among Fe, Pb, Cu, and Cd concentrations in a dispersing plume of acid-iron waste indicated that Fe and Pb were migrating together but that Cu and Cd were dispensing separately and less rapidly. This would happen if all the Pb were adsorbed by the floc and the floc slowly sank out of the surface mixed layer while Cu and Cd remained in the dissolved phase.

Sinking of acid-iron waste flocs has never been observed in the ocean. Profiles of iron concentrations (Brown et al., in press) show iron to be well mixed in the surface layer and to be at background concentrations below the pycnocline. Mukherji and Kester (1980) have used vertical profiles of iron concentration to indicate the enhanced dispersion experienced by wastes in winter over summer due to the absence of a seasonal pycnocline. Gravitational settling of waste flocs will be insignificant so long as the inherent settling rate of particles due to their size and density is too low to overwhelm the tendency of turbulence in the mixed layer to homogenize vertical concentrations. Iron distributions in waste plumes have been used by Csanady (1981) and Spaulding (1983) to generalize measured distributions of iron in waste plumes to apply to all non-sinking wastes.

Brown and Kester (1983) have recently tested the time-stability of acid-iron waste in a surface mixed layer. In a large controlled tank (horizontal mixing precluded) a stratified water column was created and acid-iron waste introduced to the

upper layer to achieve a waste dilution of 10^5. This dilution factor is a reasonable simulation of waste plumes under calm sea conditions (later discussion). The flocs of ferric hydroxide did sink into the deeper layer. Their rate of removal from the upper layer was dependent on iron concentration and, therefore, was consistent with floc growth preceding descent. At the dilution used the half-life of iron in the mixed layer was about 30 hours. This is approximately the maximum time scale over which acid-iron plumes have been successfully studied at the 106-mile site (Kester et al., 1981 and Brown et al., in press). Rather than plumes having been horizontally dispersed to background concentrations or plumes having simply been lost, it may have been that vertical dispersion of iron made its detection impossible beyond that time scale. However, since the rate of loss of iron from the upper layer in large tanks increased with iron concentration and horizontal dispersion of iron in the ocean would decrease concentrations, the effect of flocculation on sinking may be less in the ocean than observed in tanks.

Since there are no components in an inorganic waste which are not also naturally present in seawater, detection of acid-iron waste was based on concentration differences. O'Connor et al. (1983) have summarized available information on concentrations of a number of trace constituents in the open (not coastal) ocean. Some of that data (total suspended solids, total organic carbon, Cu, Cd, and Fe) was obtained from work at the 106-mile site. Comparison of those concentrations with the average composition of duPont-Edge Moor waste (1979, Table 2) yields estimates of dilution factors beyond which waste constituent concentrations would become indistinguishable from ambient seawater. At dilutions of 10^4, As, Hg, and TOC would be at ambient levels, between 10^4 and 10^5 Cd, Cu, Ni, V, and TSS (allowing it to be twice the iron concentration in waste)

would become too dilute, in the dilution range of 10^6 to 10^7 Cr, Pb, and Zn would become enmeshed in background, Fe could remain as a signal of waste at dilutions of 3×10^7. Only Cu, Cd, and Fe have been reliably measured at the 106-mile site (Kester et al., 1981). Within plumes, where its concentration is relatively high, Pb has also been an indicator of waste. The most sensitive of these waste tracers is iron and it has not been observed above its ambient level of about 0.5 ug l^{-1} except in discreet plumes. DuPont-Edge Moor waste has not demonstrably been a source of widespread general contamination in the area of the 106-mile site. O'Connor et al. (1983) conservatively estimated the flux of ocean water through the surface layer of the 106-mile site to be $10^{10} m^3 d^{-1}$. The largest annual volume of duPont-Edge Moor waste ($3.79 \times 10^5 m^3$ in 1977, Table 1) corresponds to a daily flux of $1 \times 10^3 m^3 d^{-1}$. The waste could therefore have been diluted by a factor of 10^7 (later discussion) which would make its detection through iron analysis marginal. Not having detected elevated iron is due to either extensive horizontal dispersion or sinking of waste-derived particles. The relative importance of the two processes cannot be determined from field data.

12.2.3 DuPont-Grasselli Waste

The alkalinity of duPont-Grasselli waste corresponding to its being 0.1 M in NaOH (pH 13) is 100 meq. l^{-1}. At a dilution of 5000 this has no significant effect on the alkalinity or pH of seawater. However, Kester et al. (1978) found that 1:10 mixtures of this waste with seawater contained a magnesium hydroxide floc, the Mg having been supplied by seawater. Such a floc forms in the wake of barges dumping this waste. Most probably Mg is precipitated immediately at the waste discharge ports.

Kester et al. (1981a) found the precipitate, in laboratory mixtures, to be 74 percent $Mg(OH)_2$, 10 percent $MgCO_3$, 5 percent $MgSO_4$, 5 percent $NaSO_4$, 6 percent H_2O and less than 1 percent $CaCO_3$. Unlike the $Fe(OH)_3$ formed from acid-iron waste, this solid should not be a permanent addition to the ocean. It should dissolve in seawater at pH 8. Nevertheless, Orr and Hess (1978) acoustically detected the presence of duPont-Grasselli waste plumes so particles must have persisted for at least as long as their approximately 20 hour observations (assuming acoustic returns to have been due to $Mg(OH)_2$ for the entire period). Kester et al. (1981a) examined the formation and history of this precipitate under various dilutions (dilution factors of 25 to 700) and times. They observed both dissolution and enhanced precipitation. They hypothesized that increased precipitation, when it occurred, could be due to deposition of $CaCO_3$ over the initial $Mg(OH)_2$ particle. $CaCO_3$ is near saturation in surface ocean waters so would allow the particles to remain intact for extended periods.

As an indicator of waste the concentrations of suspended matter in duPont-Grasselli waste plumes proved too low (Hausknecht and Kester, 1981). Under laboratory conditions Kester et al. (1981a) found the precipitate to incorporate essentially all the waste's Pb, 40 percent of its Cd, 20 percent of the Cu and 1 to 3 percent of its TOC. The sequestering of Cd at the 40 percent level was unexpected since this element is not readily adsorbed into solids from seawater. It may have been that, rather than being adsorbed, the Cd was trapped within the precipitate. The lack of TOC adsorption is consistent with the organic compounds in duPont-Grasselli waste being highly soluble (e.g. methanol, methy sulfate). There are no inorganic constituents in the duPont-Grasselli waste at sufficiently high concentrations to be useful indicators of the waste in the ocean. Measurements of TOC would reflect its presence only at dilutions of less than about 4000 (compare average waste

concentrations of TOC in Table 2 with ambient seawater TOC concentration of 1 mg l^{-1}). So, unless waste loads are spiked with dye for special studies, this waste can only be detected in the sea through identification of specific organic compounds. Organic chemical analyses using the purge-trap technique with gas chromatography have found compounds of waste origin in the area of the 106-mile site (Wiesenburg and Brooks, 1983; G. Harvey, NOAA Atlantic Oceanographic and Meteorological Laboratory, personal communication, 1979). However, since that technique is ill-suited to extraction of the very soluble compounds in duPont-Grasselli waste and since chromatographic spectra which have been generated with this waste are very simple, the organic contamination which has been detected has been attributed to American Cyanamid waste. If the ambient, background, concentration of methanol is low and its stability in seawater is high (neither attribute yet quantified), chemical analyses specific for methanol may yield the data on oceanic distributions of duPont-Grasselli waste.

12.2.4 American Cyanamid Waste

American Cyanamid waste was near neutral in pH and did not produce a solid phase upon being dumped. Except for dissolved phase reactions of its constituents with seawater it was the major waste subject to simple dilution. Reactions of note were hydrolysis of organophosphorus pesticides. Boehm (1981) examined changes in waste composition which occurred over 24 hours with waste diluted 500-fold in sterile or non-sterile seawater. Sterilization had no effect on results. Although many minor constituents appeared or disappeared, the results with the major base-neutral extractable compounds (Table 5) can be readily summarized. The carbamates (compounds 9 and 12, Table 5), the phosphorodiathionate compounds (compounds 19 and 20) and one of the phosphate pesticides (compound 13) were lost within five minutes. Hydrolysis of organophosphates is a

significant route of their degradation under alkaline conditions. Wolfe et al. (1977) report a half-life of malathion at pH 8 of about 40 hours, however, which is much slower than the Boehm (1981) result. Wade (1978) found the half-lives of parathion and methy parathion (organophosphorus pesticides not among those in American Cyanamid waste) to have half-lives in seawater at 25°C of 50 and 20 days respectively. As Wade (1978) points out the structure of the original compound has considerable influence on its rate of hydrolysis so one would expect the relative proportion of organophosphates in a given batch of waste to vary over time. While the loss of compounds in Boehm's (1981) experiment was faster than expected it is the case that none of those "lost" compounds were found in zooplankton collected within a plume of American Cyanamid waste. On the other hand, the phosphate pesticide (compound 14) which did not disappear was found in zooplankton samples along with cyclohexanone and two of its derivatives (compounds 2, 8, and 10).

The presence of cyclohexanone compounds in the samples analyzed by Boehm (1981) led him to suggest their use for seeking contamination derived from American Cyanamid waste. On the other hand they are not among those found by Wiesenburg and Brooks (1983) in a waste plume. Given wide variability in the specific compounds and concentrations in American Cyanamid waste it was impossible to select distinct chemical tracers of it.

The purge and trap technique has indicated that some seawater samples on some occasions contained arrays of organic compounds which are not normally in seawater (G. Harvey, personal communication, 1979; Brooks, 1982; Wiesenburg and Brooks, 1983). Most probably, American Cyanamid waste was the source of those compounds. However, regardless of the source, the

contamination evident in those samples is the only contamination ever found at and near the 106-mile site which was not in discreet, and therefore fresh, waste plumes.

12.2.5 Waste Dispersion (Small-Scale)

Csanady (1981) has analyzed results of dispersion studies with both duPont wastes to indicate that dumping initially distributes waste into volumes which are as long as the dumping track with cross-sectional areas about four times that defined by the draft and width of the discharging vessel. Wastes dumped at the 106-mile site are (and were) dumped at a rate of about 80 m^3 km^{-1} so that the usual 4000 m^3(one million gallon) loads are discharged over 50 km. Given average barge dimensions the initial volumes are about 10 m deep, 40 m wide and 50 km long or 2 x 10^7 m^3 (O'Connor and Park, 1982). So 4000 m^3 of waste is initially diluted by a factor of 5000 into a long, thin ribbon of contamination. This extensive initial dilution is sufficient to nullify density differences between seawater and industrial wastes (specific gravities 1.02 to 1.14, Table 2), so subsequent dilution is due to passive oceanic mixing.

Mixing to deeper than the initial 10 m is limited by the depth of the surface mixed layer which varies from about 20 m in summer to 150 m (the permanent pycnocline) in winter. Vertical profiles of iron, in acid-iron waste plumes, show distinct limits to vertical mixing in summer (Brown et al., 1983) and much deep mixing in winter (Mukherji and Kester, 1980). Waste dispersion rates are therefore, smaller in summer than in winter. A useful and simplifying assumption is to consider the initial 10 m to be the extent of vertical mixing. This is almost correct during the warmer months.

With waste unable to be diluted in the vertical direction, diffusion occurs only along horizontal concentration gradients

and such gradients exist only perpendicular (normal) to the plume. So essentially the fate of initial plumes is to migrate with the current while becoming wider. Csanady et al. (1979) have described this process as occurring on average at about 1 cm s^{-1}. That useful "diffusion velocity" proposed by Pritchard and Okubo (1969) approximately describes the short-term history of plumes as observed at the 106-mile site (O'Connor and Park, 1982) and the Puerto Rico dumpsite (O'Connor, 1983) where liquid wastes were also dumped from moving barges. Any individual plume will have its own unique history since diffusion rates will vary with oceanographic conditions being low when the sea is calm and large under strong winds (Csanady, 1981). However the 1 cm s^{-1} approximation leads to useful predictions which have been found to apply in plume studies.

An initially 40 m-wide plume, widening at 1 cm s^{-1} will be about 400 m wide in 10 hours, 1 km wide in 24 hours, and so forth increasing at 1 km d^{-1}. The corresponding maximum concentrations of waste in the plume will be 200 ppm initially, 20 ppm after 10 hours, 8 ppm after 24 hours, 4 ppm after 2 days and so forth. After 10 days the plume would be 10 km wide with a maximum concentration of about 1 ppm, a dilution factor of 10^6. However, actual observations of plumes whether from ship board (O'Connor and Park, 1982) or satellite (Ohlhurst, 1981) do not exceed a period of 40 hours after a dump. Csanady (1981) has indicated that the simple diffusion model cannot proceed <u>ad infinitum</u>. Episodic events such as storms or strong temperature induced mixing will rapidly disperse waste plumes. They will be broken into small patches so that diffusion along, as well as normal to, plumes will contribute to dilution and diffusion rates will increase. Storms are expected on at least a ten day frequency so it is likely that waste will be dispersed over a larger area and be more dilute than predicted

by extrapolation of the 1 cm s^{-1} diffusion velocity. O'Connor and Park (1982) and O'Connor (1983) have noted that waste dispersion studies under stormy conditions have lead to waste being "lost" in less than one hour.

This consideration of short-term plume dispersion has been deliberately brief. It is acknowledged that total understanding turbulent diffusion is an outstanding goal of physical oceanography and that studies of waste plume behavior can have contributed to that understanding. However, there are four basic points that should be appreciated. First, the small scale history of a waste plume is independent of dumpsite location so long as physical boundaries such as shorelines or the seafloor do not inhibit mixing. Second, the initial dilution can be considerable and is determined by the dumping rate. Third, waste dilution is a relatively slow process until episodic events such as storms rapidly destroy plumes. Fourth, vertical mixing is inhibited by pycnoclines and is therefore greater in winter than in summer.

Dumpsites are not distinguished on the basis of short-term waste dispersion, but on the water volume they can provide for longer-term mixing.

12.2.5 Waste Dispersion (Large-Scale)

Regardless of how extensively an individual waste plume is diluted the concentrations of contaminants are ultimately determined by the total waste input relative to the rate of water renewal through the area of the dumpsite. Consider, for example, a totally stagnant ocean. If there were no flow through the 106-mile site, all the waste ever dumped there, more than 4.7×10^6 m^3 (Table 1), could still be there. If it were mixed throughout the dumpsite area, 1500 km^2, to the depth of the permanent pycnocline, 150 m, or a volume of 2.25×10^{10} m^3,

its concentration would be 5 ppm, the equivalent of two days of plume dispersion. It is the nature of ocean waste disposal to exploit the fact that water is continually renewed, and the rate of renewal is an important characteristic of a site. O'Connor et al. (1983) have described this aspect of the 106-mile site as follows:

> "Water column characteristics for the 106-mile site are representative of the slope water regime of the northwest Atlantic, between the edge of the continental shelf and the Gulf Stream. There is a permanent pycnocline at about 100 m and a seasonal pycnocline at about 20 m during May through September (Ingham et al., 1977). Long-term current meter records from Woods Hole Oceanographic Institution's Site-D (39°20'N, 70°00' W) about 190 km northeast of the 106-mile site have been analyzed by Webster (1969) and summarized by Ingham et al. (1977) to indicate an average slope water flow to the west along the contour of the continental shelf. Flow along that same contour at the 106-mile site would be toward the southwest. Satellite-tracked buoys drogued at 10 m have been shown to migrate through the 106-mile site in a southwestward direction (Bisagni, 1981). Two buoys deployed at the 106-mile site in September 1980 and three which entered the slope water flow in January 1979 after having earlier been deployed over Georges Bank all moved in conformance to the contour of the continental shelf. They migrated southwest from the 106-mile site at 10 to 20 cm/sec and became entrained within the Gulf Stream off Cape Hatteras within about 30 days of passing through the dumpsite. These data reinforce the contention of Ingham et al. (1977) that the Site-D current meter data also describe average flow at the 106-mile site with the exception that flow is directed toward the southwest.
>
> "Except for relatively fast sinking particles, wastes dumped at the 106-mile site are constrained to the upper mixed layer. The flux of water in that layer occurs over a cross-section 20 m deep, in summer, and, conservatively, 60 km wide, which is the distance across the dumpsite perpendicular to the average flow direction. With an average surface current velocity of 11 cm/sec (Ingham et al., 1977) the flux of water available for dilution of dumped wastes is 1×10^{10} m^3/day.
>
> "The major deviation from this average river-like flow occurs with the passage of warm-core Gulf Stream eddies

through the slope water regime (Bisagni, 1976). If they do not recombine with the Gulf Stream before nearing the continental shelf these eddies migrate along a path which parallels the shelf contour and eventually are reabsorbed into the Gulf Stream north of Cape Hatteras. When the 106-mile site is within an eddy it remains so for about 3 weeks (Bisagni, 1976). The volume of water available in the upper 20 m of a 100-km diameter eddy is about 2×10^{11} m^3. This corresponds to a volume per day of about 1×10^{10} m^3, the same as that flowing through the dumpsite in the absence of eddies. The overall effect of eddies is therefore to alter the short-term flow structure at the dumpsite, but not to significantly change its long-term dispersive characteristics.

"In this discussion, we will use the flux of 1×10^{10} m^3/day as the rate of renewal of water above the seasonal pycnocline at the 106-mile site. Once water has passed through the site it will be assumed to be subsequently entrained into the Gulf Stream. Theoretically the southwest flow along the contour of the continental shelf could be part of the western leg of a slope water gyre (Sverdrup et al., 1942; Csanady, 1979). The existence of this gyre, if demonstrated, would imply that some fraction of the water flowing through the dumpsite had previously been there about one year earlier (Csanady et al., 1979). While it does not disprove a gyre's existence, none of the satellite-tracked buoys discussed by Bisagni (1981) returned to the slope water region after being entrained within the Gulf Stream.

"Restricting flow from the dumpsite to the Gulf Stream over a 60 km wide path precludes advection eastward into slope water or westward over the continental shelf. The front (Figure 1 [not shown]) between shelf water and slope water is not static. On the basis of satellite imagery of sea surface temperature Ingham (1981) has estimated that for 32 percent of the time between October 1979 and September 1980 part of the 106-mile site was occupied by shelf water. Such shelf water does not necessarily return westward to the continental shelf. A major mechanism, seen in satellite imagery, for shelf water migration is its entrainment around anticyclonic warm-core Gulf Stream eddies. Such water appears to be mixed, eventually, into slope water (Fischer, 1980). Csanady (1983) has pointed out that the general seaward salinity gradient implies a net eastward movement of cold, fresh shelf water to the warm, salty Sargasso Sea. Therefore, while the details of flow in the area of the 106-mile site are complex,

our assumption of a 60 km wide path leading to the Gulf Stream is a reasonable, conservative, estimate."

The estimate is conservative because it does not include water deeper than 20 m and restricts flow to a 60 km width. During winter, wastes mix to about 150 m so the appropriate water flux is larger. Flierl and Dewar (1983) have considered the effect of warm-core Gulf Stream eddies on slope water flow. They concluded that water outside of, but within about 100 km of an eddy will be subjected to anti-cyclonic flow. So, under the influence of eddies there will be a swath about 300 km wide, centered on a 100 km-diameter eddy, over which water is translated westward in front of the eddy path and eastward behind the eddy. This is similar to the portrayal of Ingham (1983) where the Potential Area of Influence for wastes dumped at the 106-mile site is an oval, overlapping the continental shelf, defined by the size and assumed effect of eddies. If that type of eddy influence were included in an estimate of water flux through the 106-mile site, the estimate would have to increase.

It is acknowledged that flow through and away from the dumpsite is not simply described. However, it is useful to use a water flux of 10^{10} m^3 d^{-1} as being characteristic of the 106-mile site. During winter and under the influence of an eddy the flux could be ten times larger. Each m^3 d^{-1} of waste dumped at the site is therefore subject to dilution by a factor of 10^{10}. During 1978, the year of most dumping (Table 1), the daily flux of waste was about 2×10^3 m^3. So, prior to eventual entrainment into the Gulf Stream this waste could have been diluted by a factor of at least 5×10^6 (to a concentration of 0.2 ppm), This extensive possible dilution probably contributes to the fact that, with few exceptions, no dumping-induced chemical contamination has been found except in waste plumes. Wiesenburg and Brooks (1983) found no volatile organic chemical waste

over a station grid encompassing about 1.5 x 10^4 km^2 around the dumpsite except for one sample taken along the northern edge of the site. They discuss an earlier study by G. Harvey (personal communication, 1979) where a volatile organic signal indicative of waste was found at a number of stations within the dumpsite in the absence of specific waste plumes. Brooks (1982) notes that of about 20 samples supplied to him by others who collected water near the site, 4 displayed evidence of volatile organic waste contamination. Three of those samples were taken along the eastern edge of the site and the fourth was taken about 50 km to the southwest.

In principle, the positions of these sporadic observations of waste can be reconciled with the respective dumping histories at the site prior to sampling and satellite or shipboard observations of flow structure. However, the only positive observation outside the site was to the southwest where its occurrence could be expected on the basis of already discussed physical oceanographic information. Other observations, within the site, are results of local, time variable flow on a scale larger than plumes but smaller than considered in deriving an estimate of water flux through the site. The 106-mile site has not received wastes in sufficient volumes (or the best possible indicators of waste have not been identified) to generate a consistent signal of dumping downstream of the site. If, in the future, wastes are dumped in larger volumes such a signal may be detectable.

12.3 EFFECTS.

12.3.1 Exposed Organisms

The amount and frequency of waste dumping at the 106-mile site has created independent, discreet patches of contamination in the surface mixed layer. Within a day of a dump

these patches cover about 50 km^2 (ca. 3 percent of the dumpsite) with waste diluted by a factor of about 10^5 in summer. In the absence of storms, these patches should, theoretically, disperse only very slowly. Biological responses to dumping are therefore more likely to be observed among plankton entrained into zones of contamination than among free-swimming organisms.

It is possible to calculate the level of wide-spread contamination that dumping could have caused. Combining the conservatively estimated flushing capacity of the mixed layer at the dumpsite (10^{10} m^3 d^{-1}, O'Connor et al., 1983) with the maximum rate of waste input (2×10^3 m^3 d^{-1}, daily equivalent of 1978 annual volume, Table 1) yields a wide-spread waste dilution factor of about 10^7 which would only diminish upon mixing into the Gulf Stream. Permanent pelagic residents of slope water could be exposed to this level of waste, as they would not readily avoid waste simply via their normal swimming. However, the only fishes which have been routinely collected in the mixed layer are mesopelagic myctophids which vertically migrate into the mixed layer at night. Their exposure to even wide spread waste would be limited to about twelve-hour intervals.

Sessile benthic organisms are ideal sentinels of contaminant effects when they are permanent inhabitants of contaminated zones. Most information on effects of waste disposal in shallow water relates to benthic organisms. However, there is no evidence that major wastes dumped at the 106-mile site reach the seafloor in detectable amounts. The hydrous iron floc from the duPont-Edge Moor waste may sink slowly but it receives considerable dispersion in the mixed layer and should be further dispersed over the time required to settle over 2000 m to the seafloor.

For scientific and practical reasons, effects of waste disposal at the 106-mile site have been sought only in organisms collectable in plankton nets or bottles. The effects sought are evidence for pathogenic damage in whatever organisms are collected, changes in the species composition of phytoplankton communities and reduced fecundity among copepods. The possible phytoplankton and copepod responses were hypothesized on the basis of laboratory studies. Those studies will be briefly reviewed prior to discussion of field investigations.

12.3.2 Phytoplankton

Murphy et al. (1981) have demonstrated that ascribing a level of toxicity to any waste on the basis of its effect on phytoplankton must be done cautiously. The response is at least as dependent on the species of phytoplankton, and especially its origin, as it is on the waste. Results of tests of duPont-Grasselli waste on fifteen separate phytoplankton isolates (Table 6) showed growth rate decreases varying from none to as much as 84 percent relative to controls. Generally, those isolates obtained from areas commonly considered to be "polluted" were least affected by waste, while those from clean coastal or oceanic areas were most sensitive. This same wide variation in response among clones of a given species and over a wide array of species has been further demonstrated using waste that was dumped at sea north of Puerto Rico (Murphy et al., 1983). The tolerance of organisms from "polluted" areas is probably due to natural selection for resistance and, for the Puerto Rico waste, has been induced by continuously culturing an originally sensitive isolate in the presence of waste.

So long as the same isolates of the same species are used, results of phytotoxicity tests among wastes can yield relative toxicities. Four isolates of the diatom Thalassisira pseudonanna have been tested against each of the three major wastes dumped at the 106-mile site. The results (Table 7) show that at a concentration of 1000 ppm the order of decreasing toxicity is American Cyanamid >duPont-Edge Moor > duPont-Grasselli no matter which test organism is considered. At 100 ppm, the duPont-Edge Moor waste stimulated growth of all isolates (most probably supplying nutritive trace metals). The other two wastes were inhibitory (only toward oceanic clones for duPont-Grasselli) with American Cyanamid waste being the more toxic.

The permittee supplied data on waste toxicity toward the diatom Skeletonema costatom show, on the basis of average EC50's (Table 2), an order of decreasing toxicity as American Cyanamid > duPont-Grasselli > duPont-Edge Moor. The relative order for the two duPont wastes, though it differs from Table 7 results, is probably valid for the isolate of S. costatum used since both wastes were routinely tested by the same laboratory. The results with American Cyanamid waste may not be comparable to the others for two reasons. First, the S. costatum isolate may have been a different one. Secondly, it appears from texts accompanying toxicity reports that EC50's for American Cyanamid waste are those which decrease growth rates by 50 percent while those for duPont wastes correspond to 50 percent fewer cells than in controls after 96 hours. Using a typical growth rate of $0.058h^{-1}$ corresponding to a 12h generation time, a 50 percent decrease in the rate over 96 hours (assuming log-phase growth for the entire period) would yield a cell concentration of only 6 percent that in the control system. The apparent extreme relative toxicity of American Cyanamid waste in Table 2 may be more a function of the measured parameter than a characteristic of the waste. Nevertheless, both the permittee data and that

of Murphy et al. (1983a) show American Cyanamid to be the most toxic of the major 106-mile site wastes.

No waste has been shown by L. Murphy (Bigelow Laboratory for Ocean Science, personal communications, 1982) to reproducibly affect phytoplankton growth at a concentration of 10 ppm. The lack of precision at these low levels is due to the effects, if any, being small and within the "noise" of growth rates in the absence of wastes. It is probable that wastes dumped at the 106-mile site have not affected phytoplankton. However, oceanic phytoplankton are more sensitive to contamination than those in heavily utilized coastal areas and responses vary widely among species. It is possible that, within patches of contamination, the composition of phytoplankton communities could change as less sensitive organisms thrive at the expense of their sensitive cousins.

Changes at the level of phytoplankton community structure have been observed to be manifestations of low level contamination (e.g. Thomas and Siebert, 1977). Ecologially such a change can be of consequence if the revised structure favors organisms which are not used as food by higher organisms. In the case of the 106-mile site the major predator of phytoplankton is probably copepods. As will be discussed, the consequence of dumping on copepods is more direct than through changes in their food supply.

12.3.3 Copepods

The only zooplankton organism routinely used in permit required toxicity tests has been the copepod *Arcatia tonsa*. The average 96 hour LC50's for duPont-Grasselli and American Cyanamid wastes towards it were both about 200 ppm (Table 2).

DuPont-Edge Moor waste was not tested against zooplankton. Capuzzo and Lancaster (1983) have used four species of copepods to test the lethal toxicity of each major waste. The results (Table 8) conform to the permittee test results. The LC50s for all wastes against all copepods were within a factor of 2 of 200 ppm.

Unlike toxicity work with phytoplankton Capuzzo and Lancaster (1983) did find measurable lethality of copepods with wastes in the concentration range of 1 to 10 ppm. For example, 10 percent of C. typicus and T. longicornus died with duPont-Grasselli waste at a concentration of 1 ppm. In the presence of duPont-Edge Moor waste at 1 ppm, 10 to 20 percent of A. tonsa, C. typicus and Pseudocalanus sp. died. Only A. tonsa was exposed to American Cyanamid waste at a 1 ppm level, no deaths were recorded. In terms of LC50's the three major wastes do not appear very different. At the level of 1 ppm the two duPont wastes may be of similar toxicity and more toxic than American Cyanamid waste.

However, lethal responses at low concentrations, while measurable, were small. They would be undetectable in the ocean, because the appropriate measure would be density of the organisms. A 10 to 20 percent loss in density would be within the normal variations. (Measures of phytoplankton species composition, it should be noted, do not rely on total densities of organisms for manifestations of change).

As a practical and ecologically meaningful measure of copepod response to low level contamination, scope for growth and reproduction were tested for their sensitivity to 106-mile site wastes. Capuzzo and Lancaster (1983) measured decreases in feeding, respiration, and fecal pellet production rates as functions of waste concentration. These data were combined to calculate the energy available for growth and

reproduction (scope for growth). Concomitantly, direct determinations of egg production were made. The results (Table 9) indicate that egg production and scope for growth were measurably decreased at waste concentrations as low as 1 ppm. The magnitude of the decreases for both parameters were similar and, moreover, the components of scope for growth (i.e. feeding, respiration and fecal pellet production rates) decreased by similar amounts.

Reduced egg production has obvious implications for copepod populations. However, while copepods displayed decreased egg production during 96 hour exposures to waste and did not recover to normal production even after a week in uncontaminated water, the progeny which these animals did produce exhibited normal rates of egg production. Hence, waste induced losses of reproductive capacity would not be compounded through succeeding generations.

The sub-lethal responses to waste measured by Capuzzo and Lancaster (1983) are manifest at the level of the individual animal. Copepods collected at the 106-mile site have therefore been examined for evidence of decreased rates of egg production, fecal pellet production and respiration. While they do not relate to copepods, other experiments on sub-lethal responses to 106-mile site wastes should be mentioned. They were done with each duPont waste in the context of applications for special dumping permits. In each case two test organisms; sheepshead minnow *Cyprinodon variegatus* and mysid shrimp *Mysidopsis bahia* were continuously exposed to waste through reproduction and initial growth of the subsequent generation. The *C. variegatus* tests ran for 170 days with duPont-Grasselli waste (EG&G, 1977a) and 200 days with the duPont-Edge Moor waste (EG&G, 1977b). The *M. bahia* tests ran for 28 days in each case.

Briefly, the C. variegatus was unaffected by duPont-Grasselli waste at concentrations of 750 ppm or less. They grew from fry, hatched from eggs and survived as well in the presence of waste as in its absence. The only exception was in egg production. At waste concentrations in the range of 188 to 750 ppm egg production was decreased to about 75 percent of controls. At 3000 ppm the initial fry did not survive to the reproduction stage. At 1500 ppm results were like those at lower concentrations except for a 10 percent decrease in hatching success of eggs. The same test with duPont-Edge Moor waste yielded similar results but the critical concentrations were much lower. Life-cycle success, except for reduced egg production, was basically equal to that of controls with waste at concentrations of 100 ppm or less. Egg production was decreased to 65 percent of its control value. At 200 ppm there was significant loss of initial fry, decrease in hatching success and decreased survival of second generation fry.

Tests with M. bahia did not include measures of egg production but did quantify numbers of offspring. DuPont-Grasselli waste had no effect on survival of initial organisms, their number of offspring or survival of offspring at concentrations of 750 ppm or less. Some decreased survival was evident at 1500 ppm. Only at concentrations of 38 ppm or less were the shrimp unaffected by duPont-Edge Moor waste. There was some mortality at 75 ppm and total mortality (over the life cycle) at a concentration of 150 ppm.

The more than 10-fold difference in toxicities between the two wastes towards both organisms could have been due to pH. The duPont-Grasselli waste was treated with concentrated sulfuric acid so that it did not affect the pH of seawater in which it was later diluted. The duPont-Edge Moor waste was not modified prior to testing. The pH values of 150 and

300 ppm dilutions were 6.5 and 5.5, respectively. The 75 ppm dilution was at pH 7.0 and the lower concentrations were in the pH range of 7.5 to 8.2.

It is difficult to separate the effects of acid-iron waste due to pH changes from those due to its constituents. Vacarro and Dennett (1981), using heterotrophic uptake of glucose by bacteria as the biological measure, found the metal content of duPont-Edge Moor waste to account for 2 to 4 times more of the toxicity than hydrochloric acid alone. Since the waste can be detoxified with metal chelating agents (Vaccaro and Dennett, 1981), the metal content is a source of toxicity. However, metal toxicity, being dependent on chemical speciation (Sunda and Guillard, 1976), is itself pH dependent.

At the rate it is dumped, duPont-Edge Moor waste does not create zones of high acidity in the surface ocean mixed layer. Hence, laboratory toxicity data derived from acidic systems is irrelevant to the oceanic situation. Similarly, although duPont-Grasselli waste can make seawater more basic than normal, it does not do so at the rate it is dumped. With the exception of life-cycle tests with acid-iron waste none of the toxicity data discussed above is meaningfully biased by pH alterations.

Capuzzo and Lancaster (1983) found that their sample of duPont-Edge Moor waste, when present at 100ppm, caused a pH decrease from 8.0 to 7.4. This should be insufficient to attribute the measured lethality to acidity. At 10 ppm, where sub-lethal effects were measured, the pH was 7.9. The Murphy et al. (1983) phytotoxicity work with this waste at 100 ppm was at pH 7.8, while at 1000 ppm pH was adjusted to 8.1 with sodium hydroxide. In both sets of studies, pH changes due to duPont-Grasselli waste were insignificant.

Capuzzo and Lancaster found 1000 ppm solutions of that waste to increase pH by 0.15 units, while in Murphy et al. case the increase was 0.4 pH units.

The acute toxicity data reported for duPont wastes by permittees (Table 2) is from pH adjusted systems where dilutions of waste at the requisite concentrations were modified with acid or base. That adjustment is trivial for duPont-Grasselli waste at concentrations in the range of reported EC or LC50's. For duPont-Edge Moor waste, on the other had, reported critical concentrations exceed 1000 ppm and considerable pH ajdustment must have been necessary. While adjusting pH fairly simulates oceanic conditions, the size and surface activity of the iron flocs produced may not be similar to oceanic flocs. No tests of toxicity as a function of floc characteristics have been made. However, the method of pH adjustment and, therefore, floc characteristics probably does influence toxicity test results. The highest LC50 values for duPont-Edge Moor waste were those for C. variegatus and M. bahia reported by EG&G (1977b) in cases where the raw waste was neutralized with sodium hydroxide pellets so that the "mixture became chocolate-brown and very think, similar to mud". The LC50 values exceeded 30,000 ppm, but their relevance to oceanic conditions is questionable.

12.3.4 Biological Responses to Waste Dumping at 106-Mile Site

The single unequivocal demonstrated biological response to dumping at the 106-mile site was with copepods. During the July 1980 cruise (on which Wiesenburg and Brooks [1983] sought organic chemical evidence for the presence of waste and found it only within a fresh plume of American Cyanamid waste [previous discussion]), Capuzzo and Lancaster (1983) collected and cultured copepods to measure their rates of

fecal pellet production, respiration and egg production. The dominant copepod at all stations was Temora stylifera. Those collected at four stations occupied prior to a dump displayed fecal pellet and egg production rates in the ranges of 5.8 to 8.6 and 2.2 to 2.5 copepod^{-1} d^{-1}, respectively. Those collected 3 and 24 hours after the dump showed no egg production and generated fecal pellets at the rate of 2.5 and 3.4 copepod^{-1} d^{-1}. The spacially discreet nature of this response, its occurrence only within a fresh plume, make it ecologically insignificant. No other field studies of copepod responses have been conducted at the 106-mile site. Using respiration rate as the indicator of response, similarly discreet copepod effects have been observed in the context of waste dumping north of Puerto Rico (Capuzzo, 1981).

Phytoplankton samples were collected on the same July 1980 cruise to the 106-mile site. Of twelve total samples, nine were collected before the dump, two within 24 hours after the dump and one 40 hours later over 200 km west of the dump location. Murphy et al. (1982a) found phytoplankton cell concentrations over the nine pre-dump stations to vary from (0.4 to 1.6) x 10^5 cells l^{-1}. Those cells were mainly dinoflagellates and pennate diatoms with the relative proportion of occurrence among them varying widely. In some samples the cells would be about 80 percent dinoflagellates and 20 percent pennate diatoms, in another the proportions would reverse. Since no waste was detected at any of these pre-dump stations (Wiesenburg and Brooks, 1983), the variations in phytoplankton concentrations and composition cannot be attributed to prior dumping. The dumpsite was within the influence of a warm-core Gulf Stream eddy during this cruise. Surface salinities at the nine pre-dump stations varied from 35.33 to 36.39 o/oo due presumably to intermixing of shelf, slope and Gulf Stream waters. There

was generally a direct relationship between salinity and cell concentrations and a weak correspondence between high dinoflagellate proportions and low salinity. The variation among phytoplankton samples was therefore, due to natural causes. This hardly presented a good experimental matrix in which to observe a phytoplankton response to waste.

The cell concentrations at the two post-dump stations were 0.7 and 1.0 x 10^4 cells l^{-1} and pennate diatoms were 50 and 20 percent of the populations. The sample taken 24 hours after the dump had fewer total cells and relatively fewer pennate diatoms than the earlier sample. Conceivably the population was adjusting to waste and, in the absence of waste, would have had more cells and a higher proportion of pennate diatoms. However, the observed population sizes and compositions were well within the range defined by the pre-dump samples. The last sample, taken well to the west in lower salinity (35.12 o/oo) water had only 0.4 x 10^4 cells l^{-1} and a dinoflagellate/pennate diatom ratio of ca. 70/10.

Phytoplankton samples were also collected at the 106-mile site in August 1980 during a cruise which included observation of a dump of duPont-Edge Moor waste (Murphy et al., 1982b). There was no eddy influence at the time and variation among samples was more systematic than observed during the July 1980 cruise. Ten samples were collected between the time of the dump and about 60 hours later. With the exception of a sample taken 50 hours after the dump, cell concentrations were in the range of (1.0 to 1.6) x 10^5 cells. The exceptional sample contained 2.4 x 10^5 cells l^{-1}. Species composition among the ten samples differed between those collected within 48 hours of the dump and those collected later. Earlier samples displayed a dominance of pennate diatoms, about 40 percent dinoflagellates and less than

10 percent monads (small unidentified cells). Later samples showed dinoflagellate and monad dominance with about 20 percent pennate diatoms. The very last sample again indicated pennate diatom dominance. The differences which appeared in the 48 to 60 hour post-dump period relative to earlier samples and one later sample, could be related to a response to waste. However, for two reasons, this cannot be demonstrated. First, iron analyses of seawater did not indicate the presence of waste beyond about 24 hours after the dump (a strong wind began about 18 hours after the dump and probably hastened plume dispersion). Secondly, a possible non-waste cause for the phytoplankton shift may be contained in the observation that during the time of the later samples surface waters were underlain by a wedge of cold water not present during the earlier sampling. This may have been a source of nutrients to phytoplankton and caused a species shift. So, as with the July 1980 sampling, phytoplankton speciation at the 106-mile site may be strongly dependent on small scale hydrographic variations which masks any effect due to waste. In a less hydrographically variable area, north of Puerto Rico, Murphy et al. (1983) have documented phytoplankton community changes in fresh waste plumes which were distinct enough to attribute to waste disposal.

Two sets of observations based on microscopic examination of animals or their eggs did, at one time, suggest effects from waste disposal at the 106-mile site. On five occasions between 1977 and 1980 a total of 5712 euphausids were collected from the mixed layer at the 106-mile site and surrounding areas (MacLean, 1981). In all, 15.8 percent (904/5712) of the organisms displayed melanization (blackening) of their gills. Since this condition has been experimentally induced in crustaceans by exposure to chemical contaminants and because it was rarely observed (7 percent or less) in animals collected elsewhere, it was suspected to

be a consequence of waste disposal. However, MacLean (1981) has observed that the relative proportions of two euphausid species in individual samples, regardless of their location, seemed to explain the observations. The species Meganyctiphanes norvegica almost never had melanized gills, while samples dominated by the species Euphausia krohnii often had a 40 percent frequency of this condition. Samples taken near one another at almost identical times would differ in their frequency of melanization in proportion to their species composition. Samples well away from the dumpsite would display a high frequency of melanization if they contained E. krohnii. It was concluded, therefore, that the high-occurrence of gill melanization found at and near the dumpsite was a reflection of the high-occurrence of E. krohnii in slope waters and a natural propensity of this species for the condition.

Crosby-Longwell (1980) cytologically examined fish eggs collected at the 106-mile site in 1977 and from a warm-core eddy northeast of the site. The eddy was chosen for control sampling because at the time the dumpsite was also within an eddy. Of 363 eggs taken in the control eddy, only 1.9 percent showed evidence of being moribund (i.e. fertilized but incapable of developing to a healthy fry), while 7.8 percent of the 446 eggs taken at the dumpsite were moribund. Moreover, within the dumpsite the frequency of damaged eggs was as high as 19.8 percent in waste plumes. All this data suggested a response to waste disposal but, given the low number of examined eggs, more samples were required to establish firm conclusions. Unfortunately, on succeeding cruises in 1978 and 1979 either no or very few fish eggs were found in plankton nets (McKenney, NOAA National Marine Fisheries Service, personal communication, 1979). The consequence of waste disposal on fish eggs remains undetermined except for there being few eggs at the 106-mile site.

All observed planktonic responses to waste dumping at deep ocean sites have been over limited temporal and spacial scales. There is value in documenting these observations but they are of no consequence to ocean resources. The lack of observed wide-spread, steady-state effects is due to either not having made the correct measurements or, more likely, the rates of waste input having been small enough relative to flushing rates to avoid reaching waste concentrations that affect organisms. If, for example, the 1978 dumping at the 106-mile site occurred in a weakly flushed estuary there could have been higher levels of contamination and corresponding biological responses.

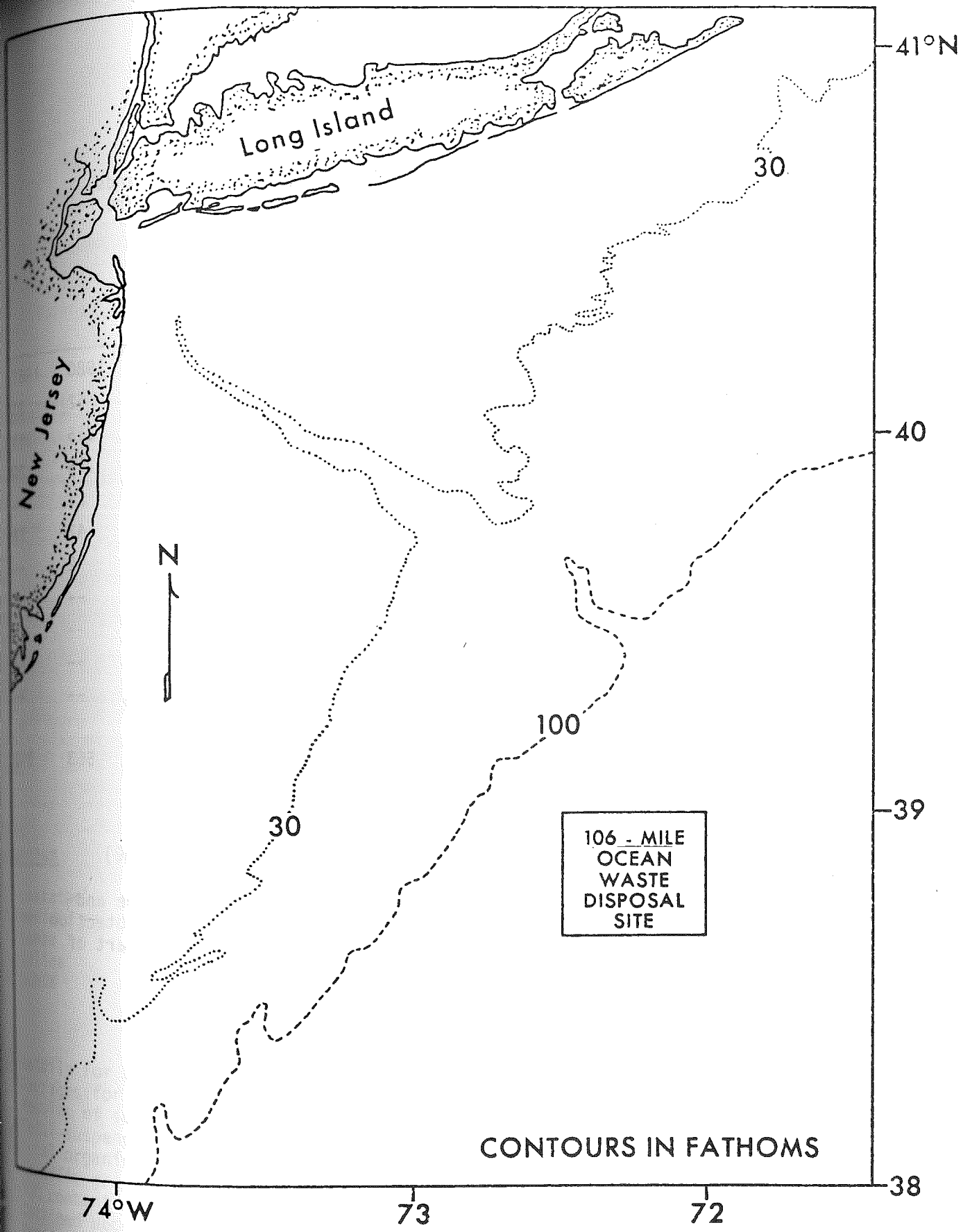

Figure 1. Location of the 106-Mile Ocean Waste Disposal Site

Table 1

Annual quantities of waste dumped at 106-Mile Site over the period 1973 through 1981[a]. Numbers represent thousands of metric tons (which at waste densities of 1.0 g cm^{-3} are equivalent to cubic meters).

Permittee	Year								
	1973	1974	1975	1976	1977	1978	1979	1980	1981
American Cyanamid	118	137	116	119	130	111	92	62	23
duPont-Grasselli	115	154	263	163	107	171	141	215	181
duPont-Edge Moor	--	--	--	--	379	371	279	216	20
Modern Trans. Co.	34	35	78	63	83	72	42	21	--
Digestor Cleanout	41	93	96	24	16	16	82	47	18
Consolidated Edison	--	--	--	--	--	--	--	2	--
General Marine	--	--	--	5	--	--	4	--	--
Camden Sewage Sludge	--	--	--	--	48	54	--	--	--
Chevron Oil Co.	24	26	22	--	--	--	--	--	--
Hess Oil Co.	7	--	--	--	--	--	--	--	--
TOTAL	339	445	575	374	763	795	640	563	242

[a] Data summarized and provided by P. Anderson, Chief of Marine and Wetlands Protection Branch, Region II U.S. Environmental Protection Agency. This data is updated and also issued annually as part of EPA Reports to Congress on Ocean Dumping.

Table 2

Average Characteristics of Wastes Dumped at 106-Mile Site

	Waste Sources (averaging year)						
	duPont-Edge Moor		duPont-Grasselli		Am. Cyan.	Camden	Mod. Tr.
	(1977)[a]	(1979)[a]	(1976)[a]	(1979)[a]	(1979)[a]	(1976)[b]	(1976)[c]
	(Chemical and Physical Characteristics, Concentrations mg l^{-1} or g l^{-1} where "g" indicated)						
	0.1	0.1	--	0.002	0.4	0.3	0.007
	0.3	0.4	0.2	0.07	0.004	4.6	0.07
	205	77	0.1	0.2	0.6	19	2.4
	3.1	1.3	0.3	0.3	1.0	25	8.0
	38g	15g	--	--	--	--	--
	0.01	0.01	0.004	0.005	0.003	0.03	0.1
	19	16	0.4	0.6	0.5	4.1	5.5
	40	23	0.3	0.6	0.2	48	13
	2.0g	0.8g	--	--	--	--	--
	133	37	--	--	0.1	0.9	--
	73	62	0.3	0.2	0.2	99	53
	<0.1	<0.1	13.1	12.6	6.0	5.6	6.0[j]
	208	844	134	488	145	76.5g	164[g]
	59	100	4.8g	3.5g	20.4g	9.2g[h]	1.8[g]
	1.14	1.09	1.12	1.09	1.02	1.01	0.99[j]
	(96 Hour LC or EC50 Concentrations, ppm v/v, waste/seawater)						
costatum	1910	3757	534	1053	49(103)[k]	808	12500[j]
menidia	5000	5000	1328	2527	681(31)	5567	19000[j]
tonsa	--	--	182	--	--(223)	1155	470[j]
salina	--	--	100,000	--	--(9741)	--	15250[j]
bahia	--	--	--	--	26 --	--	--

Details for both duPont wastes and American Cyanamid waste averages in Table 3.
Averages for period of November 1975 to June 1976 given in 1977 EPA permit notice.
Results of summary by Murray (1981).
Total suspended solids.
Total organic carbon.
Specific gravity.
TOC content of average sludge dumped in New York Bight (Mueller et al, 1976).
Obtained upon analysis of a single barge load in 1976.
Concentration in parentheses are 1976 averages.

Table 3

Detailed summaries of monthly analyses of three largest waste volumes annually dumped at 106-Mile Site.

duPont-Edge Moor

	six(n=6) 1977 analyses				six(n=6) 1979 analyses			
Component	mean[a]	s.d.[b]	min.	max.	mean	s.d.	min.	max.
As	128	94	33	300	101	67	26	225
Cd	297	333	20[c]	903	405	120	250	580
Cr	205	88	120	180	77	75	53	290
Cu	3053	1077	7670	3700	1298	1379	3	3500
Fe	37533	13340	23000	54800	15350	11542	3800	27700
Hg	14	22	0.5	59	12	23	0.2	58
Ni	19273	16533	180	42000	16095	9469	2070	27000
Pb	39766	26916	2700	70000	22700	19609	6200	53000
Ti	1965	903	900	3550	830	659	69	1800
V	133	64	50	199	37	49	3	130
Zn	72767	27061	37800	100000	61667	91029	6000	240000
pH			<0.1	<0.1			0.1	0.1
TSS	208	174	53	441	844	683	619	1940
TOC	59	52	25	130		157(1)	100(5)	
S.G.	1.137	0.031	1.106	1.174	1.091	0.025	1.065	1.125
Test organism								
S. costatum 1910[d]	547		1100	2690	3757	2890	950	8950
M. menidia			5000	5000			5000	5000

[a] Concentrations in units of ug l^{-1} except for the following components where units are mg l^{-1}; Cr, Fe, Ti, V, TSS, TOC.

[b] Standard deviation.

[c] Where "less than" values apply they have been included, as the value shown, in averages.

[d] 96 hr EC or LC 50 concentrations in units of ul waste per l seawater (ppm, v/v).

Table 3 (cont.)

American Cyanamid

ten(n=10) analyses from March 1979 to February 1980

Component	mean[a]	s.d.	min.	max.
As	437	345	14	1146
Cd	4.3	2.3	1.5	7.9
Cr	630	608	275	2050
Cu	1042	1021	0.6	2289
Hg	3.2	3.0	0.6	31
Ni	500	586	1.4	1870
Pb	185	140	120	450
V	109	129	360	7
Zn	158	149	0.7	420
pH	6.0	1.5	8.0	4.2
TSS	145	109	748	40
TOC	20400	14486	3500	22500
S.G.	1.019	0.004	1.012	1.024
Test organism				
S. costatum	49	27	16	100
S. costatum[b]	103	105	31	300
M. menidia	681	802	20	1950
M. menidia[b]	31	21	8	57
M. bahia	26	24	2	76
M. bahia[b]	223	336	26	900
A. tonsa	9741	8300	950	21000
A. tonsa[b]				
A. salina				
A. salina[b]				

[a] Concentrations in units of ug l^{-1} except for the following components where units are mg l^{-1}; TSS and TOC.

[b] Acute toxicity data from six(n=6) 1976 analyses.

Table 3 (cont.)

duPont-Grasselli

Component	six(n=6) 1976 analyses mean[a]	s.d.	min.	max.	six(n=6) 1979 analyses mean	s.d.	min.	max.
					2(4), 5(1), 3(1)			
As	--	--	--	--	71	55	23	141
Cd	222	85	163	358	180	114	53	326
Cr	95	32	89	234	303	145	100	483
Cu	276	183	25	534	5.3	2.1	3	8
Hg	3.5	2.3	2	8	633	700	15	1864
Ni	412	321	179	2011	556	534	56	1471
Pb	341	345	63	2529	201	145	100	483
Zn	275	114	152	431	12.6	0.3	12.2[b]	13.0
pH	13.1	0.3	12.7	13.4	488	630	66	1540[c]
TSS	134	114	15	1336	3495	746	2484	4178
TOC	4765	1853	2598	6892	1.092	0.028	1.038	1.117
S.G.	1.116	0.059	1.060	1.210				
Test organism								
S. costatum	534	257	305	960	1053	1362	220	3800
M. menidia	1328	576	750	2400	2527	970	860	3600
A. tonsa	182	47	105	238	--	--	--	--
A. salina	--	--	100,000		--	--	--	--

a Concentrations in units of ug l^{-1} except for the following components where units are mg l^{-1}; TSS, TOC.

b Excluding a reported value of 10.2.

c Excluding a reported value of 18979 mg l^{-1}.

Table 4

Total masses (metric tons) of waste components dumped at 106-Mile Site in 1978 due to each waste source[a,b]

Sources				
duPont-Edge Moor	duPont-Grasselli	American Cyanamid	Camden Sludge	Modern Trans. Co.
0.04	0.0003	0.04	0.02	0.0005
0.15	0.01	0.0004	0.25	0.005
29	0.03	0.06	1.0	0.2
4.8	0.05	0.1	1.4	0.6
5665	--	--	--	--
0.003	0.0009	0.0003	0.002	0.007
5.9	0.01	0.06	0.22	0.4
8.5	0.01	0.02	2.6	0.9
296	--	--	--	--
14	--	0.01	0.05	--
23	0.03	0.02	5.3	3.9
313	83	16	4131	11808
37	598	2264	496	130

[a] Masses calculated by multiplying 1978 volumes in Table 1 by average concentrations in Table 2 (1979 concentrations used for both duPont wastes).

[b] Underlined values are the maxima for a given waste component or within a factor of ten of the maxima.

Table 5

Volatile organic compounds and most concentrated base-neutral extractable compounds in American Cyanamid waste (Boehm, 1981).

Volatile Compounds

No.	Compound	Approximate Concentration ($mg\ l^{-1}$)	
1.	dimethyl sulfide	10	(purge-trap)[a]
2.	cyclohexanone	5/500	(purge-trap/direct injectio
3.	S-methoxy cyclohexanone-diene sulfide	20/80	(purge-trap/direct injectio
4.	methyl cyclohexanone-diene disulfide	15/1000	(purge-trap/direct injectio
		3000	(direct injection)
5.	methanol	0.5	(purge-trap)
6.	acrylonitrile	2	(purge-trap)
7.	toluene		

Base-neutral extractable compounds

(Compounds 2, 3 and 4 from volatile compd. list not repeated)

8.	methyl cyclopentanonediene	2
9.	carbamate (R-CH3)	100
10.	S,S-methyl cyclohexanonediene disulfide	100
11.	trichlorobenzene	10
12.	carbamate ($R=C_2H_5$)	100
13.	phosphate pesticide	50
14.	phosphate pesticide	5
15.	S-ethyl methoxycyclohexene sulfoxide	5
16.	acetyl cyclohexanonedienethiol	2
17.	unidentified compound	1
18.	unidentified compound	1
19.	phosphorodithioate pesticide	0-100
20.	malathion	

[a] Purge-trap extractions not corrected for efficiency of purge.

Table 6. Growth rates relative to controls of fifteen distinct phytoplankton monocultures in the presence of duPont-Grasselli waste at a concentration of 1000 ppm (waste/seawater, v/v)[a].

Species	Clone (source)[b]	Growth rate, test/ Growth rate, control
Thalassiosira pseudonanna	3H (pn)	0.93 ± 0.07
	W (pn)	1.00 ± 0.02
	58-102 (o)	0.60 ± 0.03
	13-1 (o)	0.72 ± 0.02
	C5 (n)	0.80 ± 0.08
	STX-97 (n)	0.74 ± 0.04
	Swan-1 (n)	0.69 ± 0.02
Skeletonema costatum	Ske1 (pn)	0.96 ± 0.01
	35-24a (o)	0.16 ± 0.004
	G44S (o)	0.82 ± 0.01
	Fry-2 (n)	0.86 ± 0.06
	FhS21 (n)	0.51 ± 0.06
	FH-1 (n)	0.93 ± 0.05
Emiliania huxleyi	BT6	0.25[c]
	451B	0.75

[a] Murphy et al (1981).

[b] Details of clonal designation and source in Murphy et al (1981). Areas from where clones were isolated divided into being polluted-neritic (pn), oceanic (o) and neritic (n) by Murphy et al (1982a).

[c] Estimated from graphic representation in Murphy et al. (1981).

Table 7. Growth rates relative to controls of four distinct *T. pseudonanna* monocultures in the presence of major wastes (dumped at the 106-Mile Site) at concentrations of 100 and 1000 ppm (waste/seawater, v/v)[a].

	Relative Growth Rate					
	duPont-Grasselli		duPont-Edge Moor		American Cyanamid	
T. pseudonanna clone[b]	100 ppm	1000 ppm	100 ppm	1000 ppm	100 ppm	1000 ppm
3H (pn)	1.01	0.98	1.13	0.68	0.97	0.44
W (pn)	1.01	1.01	1.08	0.63	0.65	0.01
58-102 (o)	0.82	0.62	1.16	0.22	0.82	died
13-1 (o)	0.95	0.73	1.13	0.45	0.76	died

[a] Murphy et al (1983).

[b] Same designations as in Table 6. Specific locations and years of isolation for these four clones were:
3H from Great South Bay, Long Island, NY in 1958
W from Wumme River Estuary, Bremmen, Germany in 1973
58-102 from Continental Slope (39°of'N, 71°56'W) in 1976
13-1 from Sargasso Sea (33°11'N, 65°15'W) in 1958

Table 8. Lethal toxicities[a] (96 hour LC50) of three major wastes toward copepods.

Species	96 hour LD50 (ppm, v/v)[b] duPont-Grasselli	duPont-Edge Moor	American Cyanamid
Centropages typicus	273 ± 2	104 ± 2	—[c]
Pseudocalanus sp	200 ± 2	121 ± 2	—[c]
Temora longicornis	225 ± 2	no data	no data
Arcatia tunsa	no data	171 ± 2	232 ± 2

[a] Capuzzo and Lancaster (1983).

[b] At 10°C LC50's were 106 ppm for duPont-Grasselli with *C. typicus* and 97 and 91 ppm for duPont-Edge Moor with *C. typicus* and *Pseudcalanus sp.*, respectively.

[c] Data for tests of these species against American Cyanamid waste were insufficient to calculate LC50's. The responses were reported to be similar to that of *A. tonsa*. relative to concentration.

Table 9. Rates of egg production and scope for growth relative to controls in the presence of major 106-Mile Site wastes[a].

	Relative egg production/relative scope for growth						
	duPont-Grasselli			duPont-Edge Moor	American Cyanamid		
Species	1 ppm	10 ppm	100 ppm	10 ppm	1 ppm	10 ppm	100 ppm
C. typicus	-/-	-/-	-/0.27	0.55/0.55	-/-	-/-	-/-
Pseudocalanus sp.	0.44/-	0.44/0.56	0.24/0.43	0.64/0.54	-/-	-/-	-/-
T. longicornis	0.76/-	0.76/0.77	0.59/0.59	-/-	-/-	-/	-/-
A. tonsa	-/-	-/-	-/-	-/-	0.67/-	0.58/-	0.46/-

[a] Source, Capuzzo and Lancaster (1983).

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APPENDIX A

PROBABILISTIC APPROACH FOR THE DETERMINATION OF THE POTENTIAL AREA OF INFLUENCE FOR WASTE DISPOSAL AT THE 106-MILE OCEAN DISPOSAL SITE

John F. Paul, Henry A. Walker, and Victor J. Bierman, Jr.[1]

The Potential Area of Influence (PAI) used by the National Marine Fisheries Service for the preparation of this 106-Mile Site Characterization Report (Chapter 1) is based primarily upon the fact that the main perturbation in the circulation in the slope water is the aperiodic passage of warm core rings. The typical diameter (170 km) and passage time (100 days) of the warm core rings were used. The approximate PAI was generated by successively plotting typical warm core ring positions through the slope water area from the point of first contact with the dumpsite until encounter with the Gulf Stream. The rotary currents (clockwise) of the warm core rings are vigorous enough to pull shelf water into the slope water area and push slope water along the bottom onto the continental shelf as far as the 50 meter isobath. This PAI contains no information regarding probability of occurrence or concentration of the waste materials; rather, it merely states possible occurrence of wastes disposed at the 106-Mile Site.

For a quantitative determination of a potential area of influence, a probabilistic approach is used to determine the dispersion of waste material disposed at the 106-Mile Site (Paul et al. 1983). The dominant transport processes that affect the dispersion of waste in the upper mixed layer are incorporated in this analysis. From this information, the time-averaged relative concentration fields for the disposed waste are determined.

We estimate the dispersion of the waste by

$$x = ut \quad \text{and} \qquad \text{(A-1)}$$

$$y = vt, \qquad \text{(A-2)}$$

where x and y are cartesian coordinates in the horizontal for the trajectory of the waste; u and v are velocities for the x and y directions, respectively; and t is time. These equations are a result of using Taylor's hypothesis for relating point measurements in time to fixed-time measurements over space (Taylor 1921) and assuming a limiting form for the autocorrelation function for each velocity component (Csanady 1971). We assume that u and v are functions of time, but the realized, or observed, values for any given time are random and are specified in terms of a bivariate probability distribution. Over a long period of observation, the velocities are approximated quite well by the bivariate normal probability distribution, as will be shown below. As a consequence of this approximation, equations (A-1) and (A-2), which relate position to velocities, imply that the mass distribution of the waste at a prescribed time is described as a multiple of the bivariate normal probability distribution which describe the velocities.

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The information necessary to estimate the parameters that determine the probability distribution for the velocities can be obtained by using long-term current meter mooring records. Unfortunately, no such current meter records are available for the upper water column at the 106-Mile Site. Woods Hole Oceanographic Institution (WHOI) has maintained long-term current meter moorings since the mid 1960s at Site D (39 20' N, 70 0' W), located approximately 200 km east-northeast of the 106-Mile Site and in a similar bathymetric regime as the 106-Mile Site (Fig. A-1). In the present analysis, it is assumed that the currents at Site D would continue to follow the bathymetry into and beyond the vicinity of the 106-Mile Site (Ingham, Bisagni, and Mizenko 1977). Thus the characteristics of the currents would be similar over the whole area that would be influenced by the wastes disposed at the 106-Mile Site.

Under the assumption that the two components of the current are described by bivariate normal probability distributions, the currents are completely described by the mean vector and the variance-covariance matrix. Table A-1 details the velocity characteristics used for the present calculation. The variances and covariance exactly as reported in the WHOI report (Tarbel and Whitlatch 1977) are indicated in the table. These variances and covariance include the effects of all the physical process, including storms, that influenced mixing during the 83-day period of observation. Note that the skewness and kurtosis for the observed distributions of the velocities are quite close to the expected values for normal distributions. The values used for the determination of the potential area of influence represent the observed variances and covariance that have been modified to remove the effect of the periodic motions in the current meter record. These large scale periodic motions are organized back-and-forth movements that do not produce net, or bulk, dispersion. The periodic motions increase the variances and covariance but do not directly produce any dispersion of the waste material (G.T. Csanady, personal communication). For our analysis, we used a 40 percent reduction in the coefficient of variation for the observed record to remove the effect of the periodic motion.

For the calculation, the physical oceanographic conditions at the 106-Mile Site are taken to include a permanent pycnocline at 100 meters and variations in currents which encompass the major transport processes. The average relative concentration field is calculated based upon the following simplifying assumptions: first, no explicit distinction is made between dissolved and particulate phases of the waste; and second, the total waste is transported with the local fluid flow field. As a consequence, the disperison of the waste is by dilution and the actual waste mass is treated as conservative. By the latter, we mean that there is no vertical flux of waste that would be associated with gravitational settling out of the upper mixed layer. A consequence of these assumptions is that there is uniform mixing in the vertical down to the permanent pycnocline. The vertical mixing of liquid wastes disposed at the 106-Mile Site has been observed to occur quite rapidly, and the pycnocline has been observed to act as a barrier to mixing across it (Orr et al. 1980, Kohn and Rowe 1981).

The concentration distribution for the steady-state limit of continuous daily disposal of waste at the 106-Mile Site is calculated in order to quantitatively determine the potential area of influence for disposed waste. This procedure is operationally accomplished by superimposing a series of 100 individual daily dumps of waste material. The time-averaged mass distribution reaches the steady-state limit within 100 days for the region of interest. The time-averaged mass distribution is obtained directly by this superposition and is the sum of the 100 individual bivariate normal probability distributions. The time-averaged concentration field is obtained directly from the mass distribution by multiplying the time-averaged mass in a given volume by a daily mass loading rate, and dividing by the volume. The concentration field is transformed to relative waste dilution by normalizing with respect to the initial dilution, i.e., with respect to the diluting volume into which the waste material is discharged when disposed from a barge. The initial diluting volume for the 106-Mile Site is taken to be 2×10^7 cubic meters (O'Connor et al. 1983). Fig. A-2 shows the time-averaged relative waste dilutions that result assuming a permanent pycnocline at 100 meters.

Comparing the calculated potential area of influence (Fig. A-2) with the PAI used in the prepartion of this report (Fig. A-3), one sees an almost identical match between the relative waste dilution contour of 40000 and the NMFS PAI downstream of the disposal site. The major difference between the two is the region upstream of the site; this is a result of the NMFS PAI being extended upstream of the site by the point of first contact with a warm core ring, and our calculation not including any upstream effects due to warm core rings. It should be noted that Fig. A-2 was computed assuming an upper mixed layer of 100 meters. For application when a seasonal thermocline would be at 20 meters, the relative dilution factors in Fig. A-2 should be reduced by a factor of 5.

Our analysis indicates that the NMFS PAI is a good operational estimate of the potential area of influence for waste disposed at the 106-Mile Site because it is consistent with results obtained using an independent, quantitative approach and existing current meters records. Based on our results, a waste dilution factor of 10^4 to 10^5 relative to the initial dilution can be used for an order-of-magnitude estimate of the dilution at the boundary of the potential area of influence for disposal at this site.

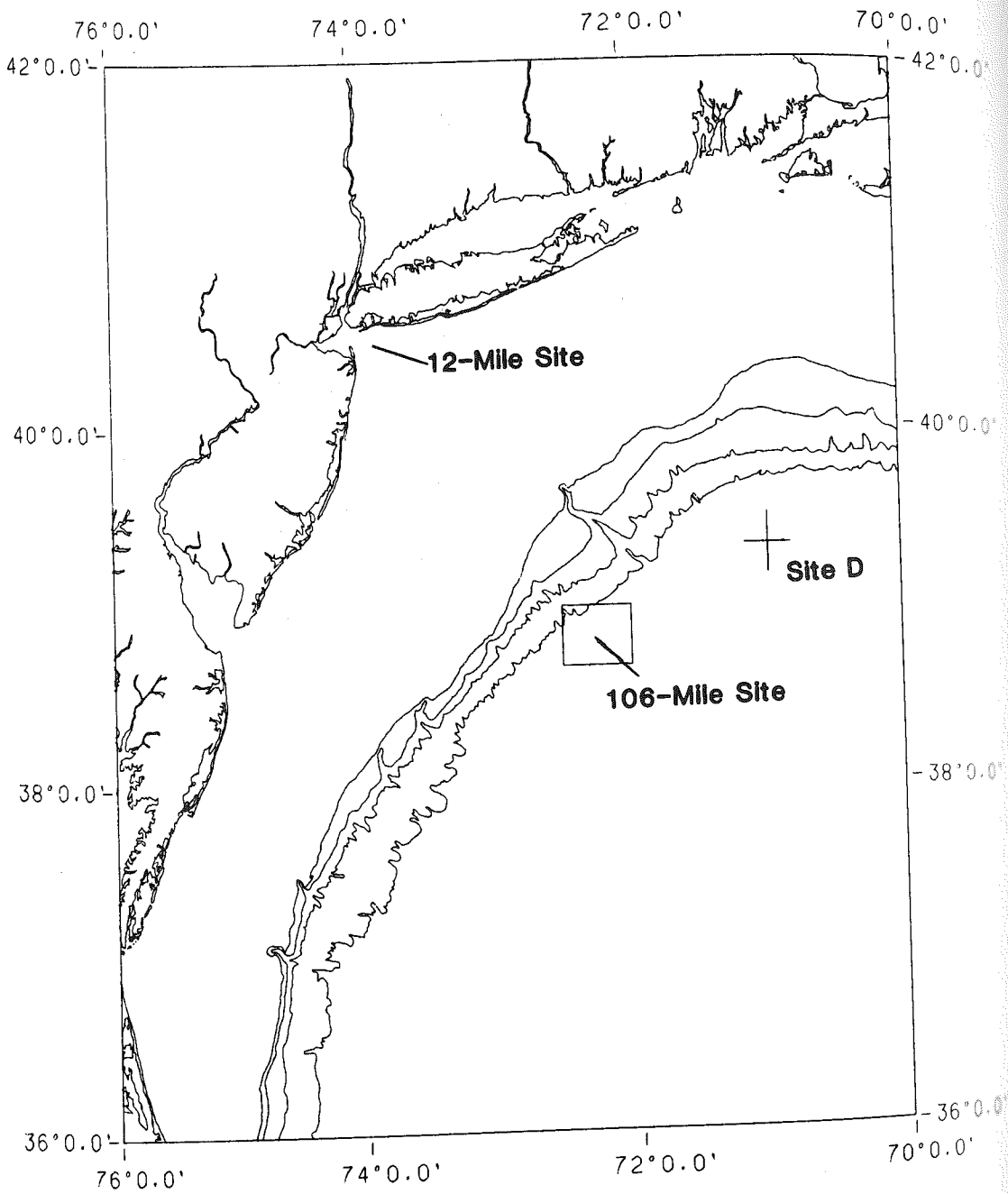

Fig. A-1. Location of the 106-Mile Site and Site D off the northeast coast of the United States.

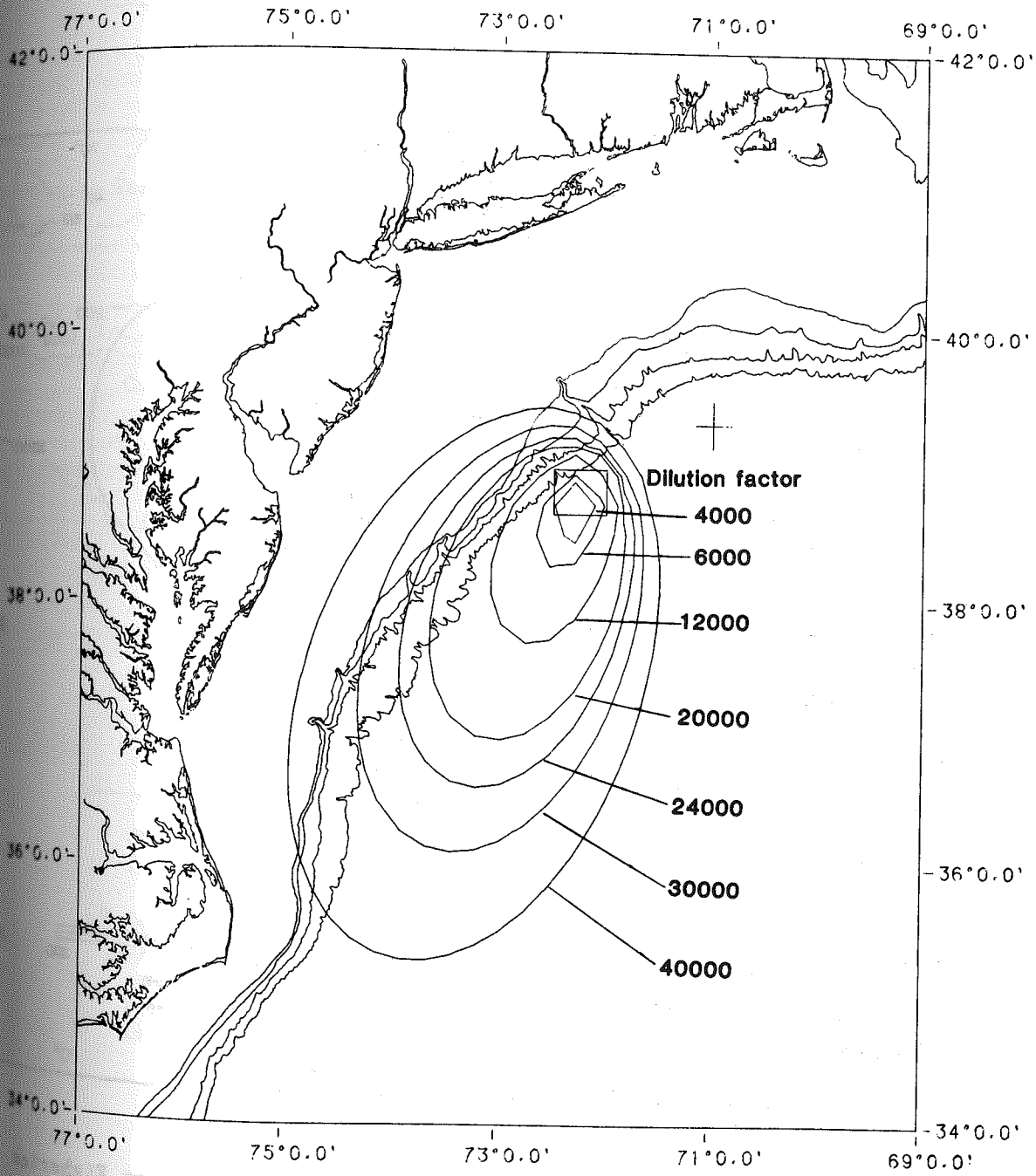

Fig. A-2. Time-averaged waste dilutions relative to the initial dilution for 100 days of daily disposal at the 106-Mile Site.

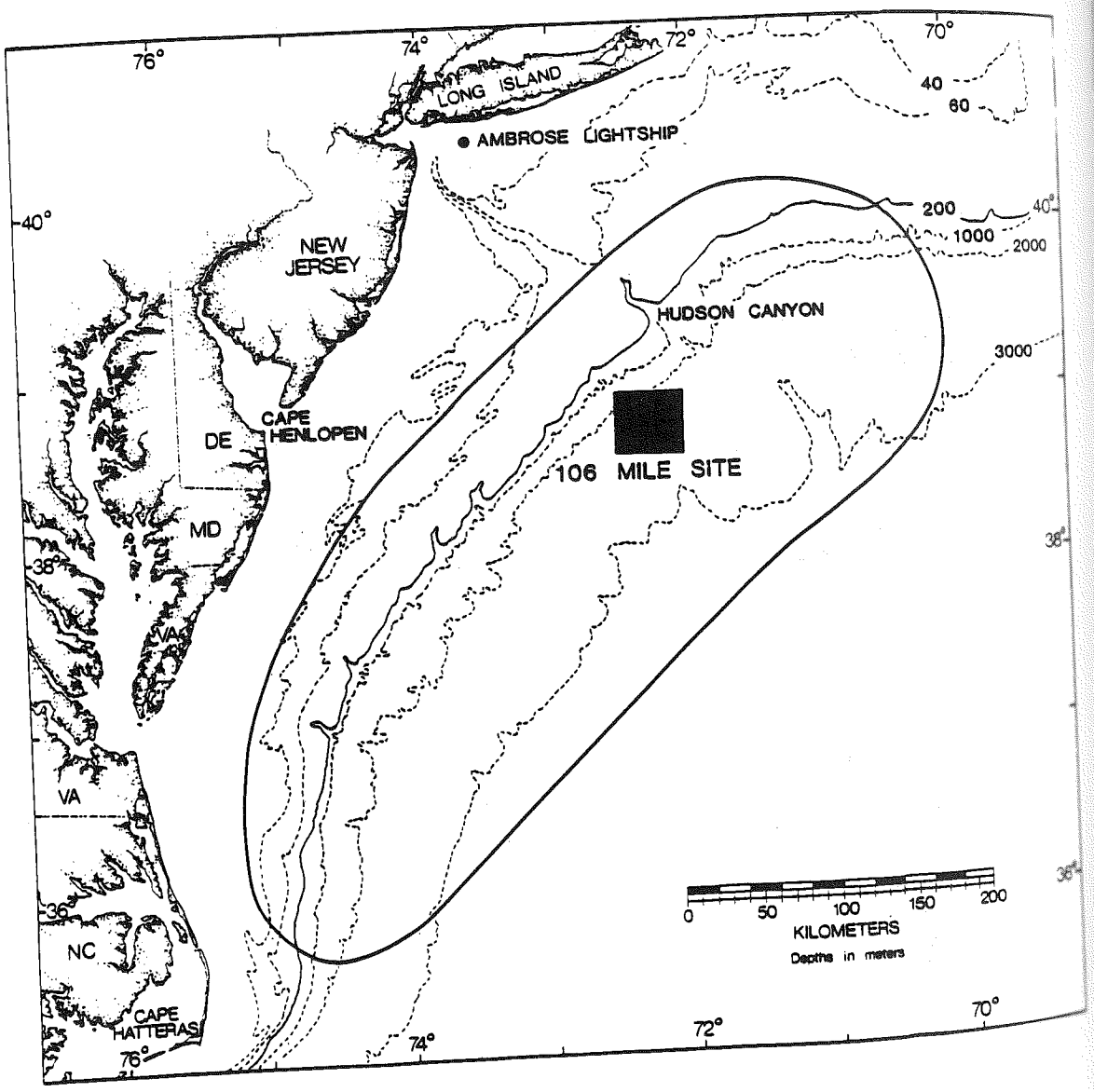

Fig. A-3. The 106-Mile Site and the National Marine Fisheries Service potential area of influence.

Table A-1. Velocity characteristics used for the calculation of of the potential area of influence.

		Observed Values[a]	Values Used For Calculation[b]
Mean vector (cm/sec)	$\begin{bmatrix} \text{east} \\ \text{north} \end{bmatrix}$	$\begin{bmatrix} -12.34 \\ 1.12 \end{bmatrix}$	$\begin{bmatrix} -12.34 \\ 1.12 \end{bmatrix}$
Variance-covariance matrix ((cm/sec)^2)	$\begin{bmatrix} E & E\text{-}N \\ E\text{-}N & N \end{bmatrix}$	$\begin{bmatrix} 249.73 & -46.94 \\ -46.94 & 257.34 \end{bmatrix}$	$\begin{bmatrix} 89.90 & -16.90 \\ -16.90 & 92.64 \end{bmatrix}$
Coefficient of variation	$\begin{bmatrix} \text{east} \\ \text{north} \end{bmatrix}$	$\begin{bmatrix} 1.28 \\ 14.32 \end{bmatrix}$	$\begin{bmatrix} .768 \\ 8.592 \end{bmatrix}$
Skewness[c]	$\begin{bmatrix} \text{east} \\ \text{north} \end{bmatrix}$	$\begin{bmatrix} -.210 \\ .122 \end{bmatrix}$	$\begin{bmatrix} -- \\ -- \end{bmatrix}$
Kurtosis[c]	$\begin{bmatrix} \text{east} \\ \text{north} \end{bmatrix}$	$\begin{bmatrix} 2.591 \\ 3.170 \end{bmatrix}$	$\begin{bmatrix} -- \\ -- \end{bmatrix}$

[a] Observed values at Site D (39 9.7' N, 69 57.1' W) at 54 m for 12/12/71 to 3/5/72 (Tarbell and Whitlatch 1977).

[b] Same mean as that observed, coefficient of variation reduced by 40 percent.

[c] For a normal distribution, skewness is 0.0 and kurotsis is 3.0.

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