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Pelagic Distributions of Marine Birds Off the Northeastern United States

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INTRODUCTION

Seabirds are highly mobile marine animals that must compete with other predators for available food. Seabirds return to land to breed, but they spend at sea the nonbreeding season that amounts to 50 to 90 percent of their lives (Fisher and Lockley 1954; Ainley 1980). Their distribution at sea presumably reflects the availability of preferred types of prey and in turn, the oceanographic structure and processes that govern production and availability (Murphy 1936; Brown 1980a). This is not to say that seabirds are specialists to certain prey species. Instead they are probably attracted to a variety of food items provided these are abundant enough to make foraging efficient.

The continental shelf of the western North Atlantic off the northeastern United States is one of the better studied regions of any shelf ecosystem (Walsh 1981), yet little is known about seabird distributions in this area. The available published reports on pelagic distributions of seabirds concern shelf waters off the coasts of Maryland (Rowlett 1973; 1980) and North Carolina (Lee and Booth 1979; Lee and Rowlett 1979), seaward of the continental shelf (Baker 1947; Brown 1977), and farther north off eastern Canada (Wynne-Edwards 1935; Rankin and Duffey 1948); Brown et al. 1975). Other reports include reviews of literature and unpublished sightings which provide generalized maps of species distributions (Palmer 1962; Murphy 1967; Butcher et al. 1968).

Millions of people live along the coast from North Carolina to Maine and as a result, the adjacent continental shelf is under increasing pressure from economic development (waste disposal, shipping, oil and gas extraction) including commercial fishing. Any or all of these activities may alter marine food webs, including seabird populations. Adequate baseline data on seabirds are needed in order to evaluate the significance of changes in seabird abundance that might be associated with any of these activities.

This report summarizes 26 consecutive months of seabird observation data collected by the Manomet Bird Observatory (MBO) and provides a baseline of understanding of the pelagic distributions and abundances of seabirds in shelf waters off the northeastern United States. I have also attempted to describe the structure of the marine bird community and discuss the trophic biology of the birds in relation to their physical and biological oceanographic environment. My findings will contribute to a characterization of the seabird community so that future research may progress accordingly and environmental changes can be identified and evaluated in context of the birds.

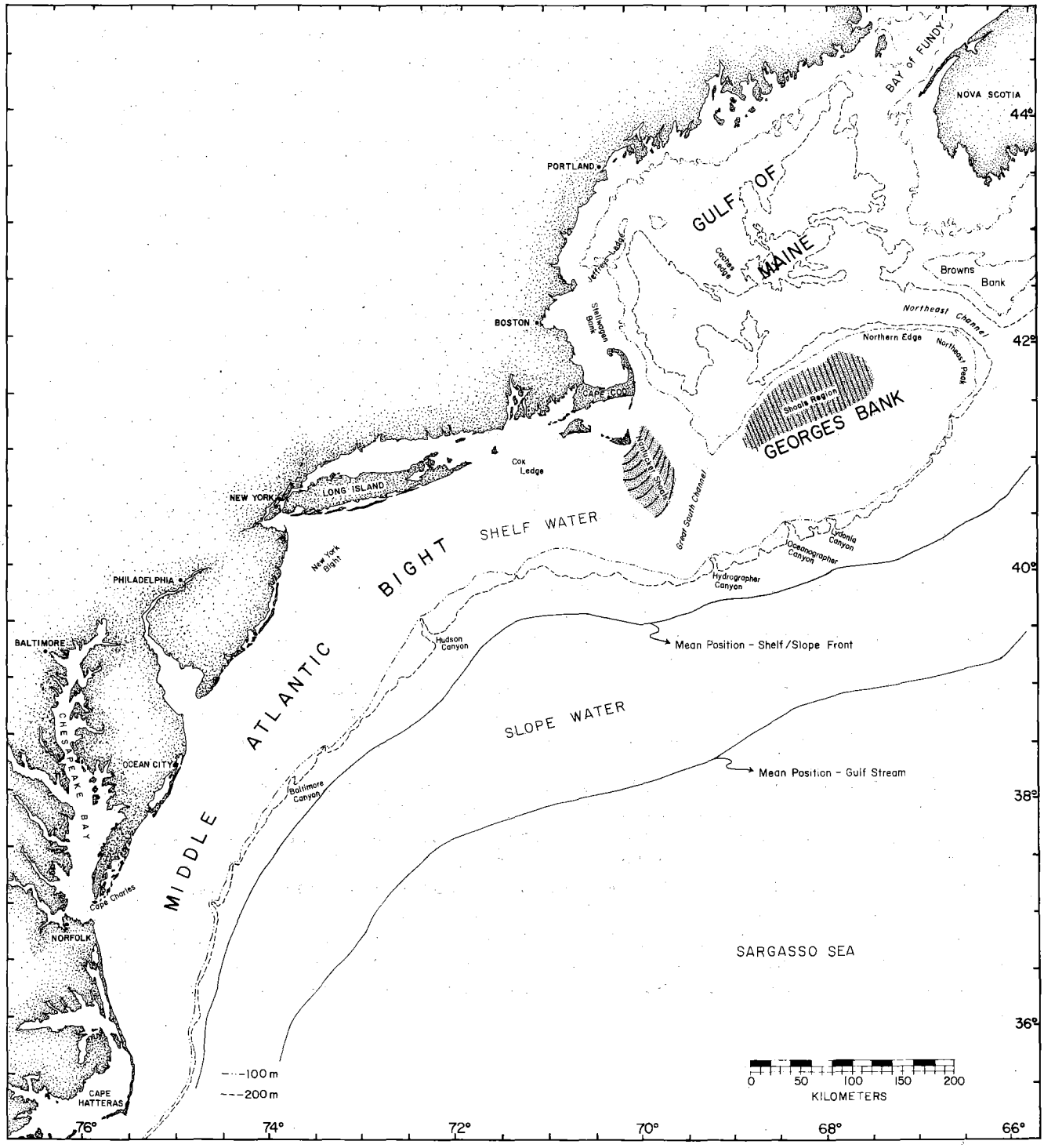

Fig. 1. Bathymetry and principal features of the continental shelf and slope off the northeastern United States.

OCEANOGRAPHIC BACKGROUND

The bathymetry of the continental shelf and slope off the northeastern United States is illustrated in Figure 1. The Gulf of Maine lies in the northeast. It is bounded on the northwest by the coast of northern New England, on the northeast by the Bay of Fundy and coast of Nova Scotia, and on the south and east by the offshore banks, Georges and Browns. The Gulf is characterized by its deep basins that are interrupted by ridges and swells. Georges Bank is separated on the east from Browns Bank by the deep Northeast Channel (230m) and on the west from the Middle Atlantic Bight by the shallow Great South Channel (65m).

The broad Middle Atlantic Bight extends from Nantucket Shoals on the east and narrows to Cape Hatteras to the south. The floor of the Bight is the gently sloping continental shelf which steepens sharply at the shelf-break, at about 200m depth, to form the continental slope. The outer edge of the shelf north of Hatteras is cut by numerous submarine canyons.

The shelf-break also approximately marks the hydrographic boundary, or front, which separates relatively fresh 'shelf' water from the more saline 'slope' water offshore (Bumpus 1973; Wright 1976). Salinity is the best criterion to distinguish shelf water ($32\text{-}34^{o}/oo$) from slope ($>35^{o}/oo$), because temperature is not a reliable index throughout the year in surface water (Wright and Parker 1976). The surface position of the front is +20km ($\pm$30km) seaward of the shelf break between Cape Charles and the Great South Channel; this increases to about +80km ($\pm$65km) near the Northeast Channel (Halliwell and Mooers 1979). The boundary is a complicated three-dimensional feature that changes shape and position constantly under the effects of atmospheric and oceanographic forces including warm-core rings from the Gulf Stream which can entrain quantities of shelf water into slope water (Wright 1976). These rings represent parcels of Gulf Stream water (Figure 1) and are surrounded by pieces of the strong front that separates slope water from the Gulf Stream.

Seasonally, the hydrographic conditions of shelf water in this area can best be explained by mixing regimes (cf. Walsh et al. 1978). During winter months (December to February), vertical mixing caused by storms results in a water column which is homogeneous to depths of 50-60m throughout the continental shelf (Figure 2). Surface temperatures are lowest at this time. Spring months (March to May) mark the onset of stratification (horizontal changes in temperature with depth) and the peak in primary production (organic carbon produced from photosynthesis). Annual carbon production for shelf waters from Cape Hatteras to Nova Scotia ranges from 405 to 726g $C/m^2/yr$, which indicates that these shelf waters are among the most productive in the world (O'Reilly et al. 1981). During summer months (June to August) waters are well-stratified and surface temperatures are greatest (Figure 2). Tidal currents over the shallow parts of Georges Bank and Nantucket Shoals cause vigorous mixing of the water column and generally prevent the development of any thermocline, even during mid-summer. The beginning of a breakdown of the thermocline, hence well-stratified conditions, is usually noted in September.

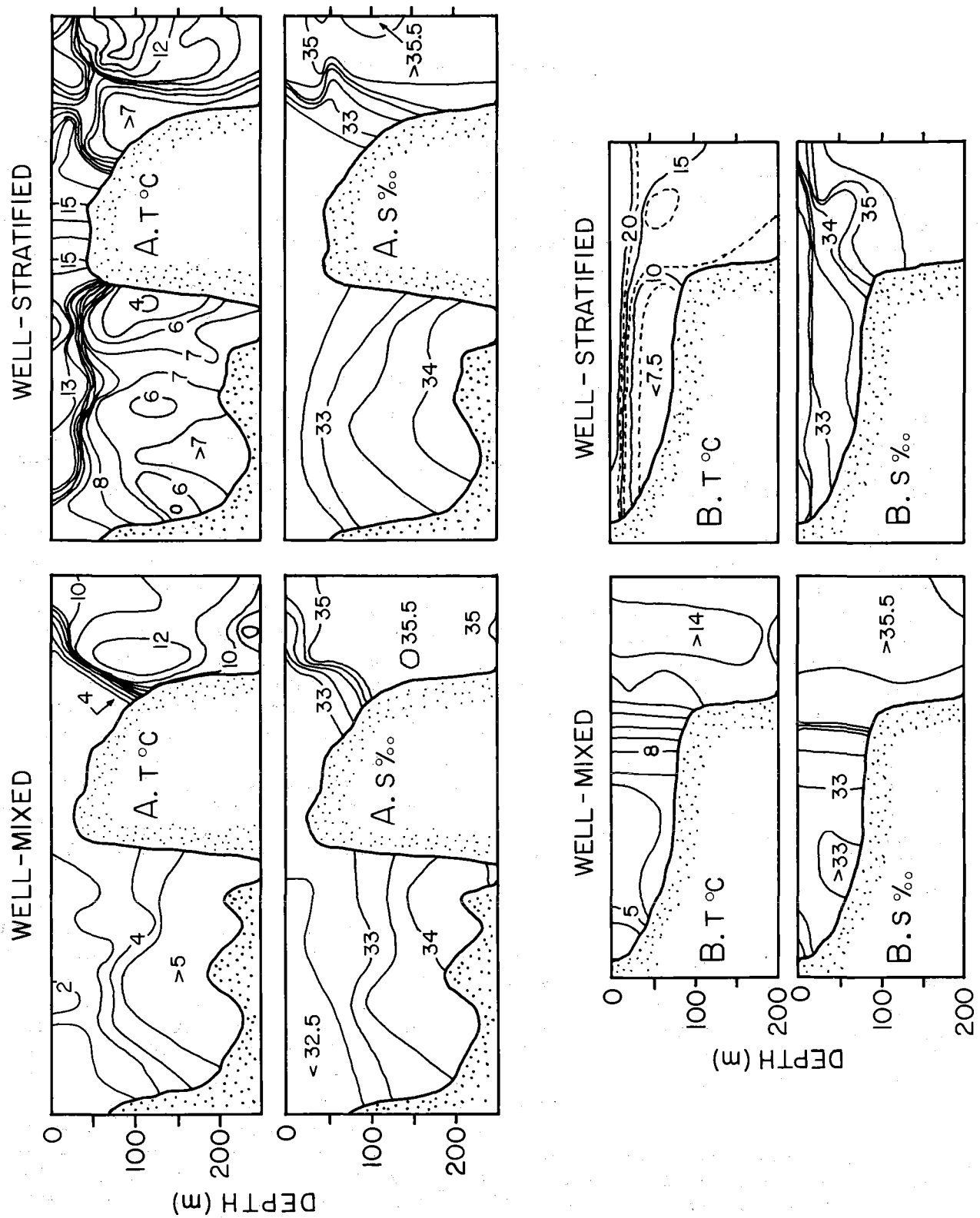

Fig. 2. Typical temperature (T) and salinity (S) sections across the continental shelf for well-mixed (winter) and well-stratified (summer) regimes. A. After Colton et al. (1968), section E across Georges Bank, March (left) and September (right) 1966. B. After Ketchum and Corwin (1964), section south of Montauk Point, February (left) and July (right) 1957.

In a broad sense, fauna in these shelf waters depend on the adjacent waters of the western North Atlantic and can be divided into zoogeographic provinces. Such zonation helps to describe the way in which the ocean changes physically at those places where it changes faunally (Backus et al. 1977). Brown et al. (1975) divided eastern Canadian waters into 4 zones: high arctic, low arctic, boreal and cool subtropical; and they related bird distributions to these areas. In a similar fashion, Backus et al. (1977) identified zoogeographic regions and provinces in the Atlantic Ocean using distributions of mesopelagic mid-water and oceanic fishes. Within the area from Cape Hatteras to Nova Scotia, the boreal zone extends south to include waters of Georges Bank and the Gulf of Maine; the northern limit of the subtropical zone occurs in shelf waters of the Middle Atlantic Bight and adjacent slope water.

Table 1. Seasonal effort (no. of 10-min. transects) and area sampled (km^2) by subarea, January 1978 to February 1980.

Season	Subarea			
	Gulf of Maine	Georges Bank	S. New England	Mid-Atlantic
Spring (Mar-May)				
No. transects	225	488	451	213
Area sampled (km^2)	197	459	430	203
Summer (Jun-Aug)				
No. transects	404	576	648	307
Area sampled (km^2)	380	536	611	288
Fall (Sep-Nov)				
No. transects	330	889	541	136
Area samples (km^2)	310	801	482	126
Winter (Dec-Feb)				
No. transects	383	410	279	28
Area sampled (km^2)	344	363	273	27

METHODS

Bird observations were recorded throughout the year in shelf waters off the northeastern United States. Data were collected on board ships taking part in oceanographic monitoring and assessment surveys made by the National Oceanic and Atmospheric Administration, the National Marine Fisheries Service (NOAA/NMFS), foreign research vessels, and from U. S. Coast Guard (USCG) ships on offshore law enforcement patrols. Observers were aboard these vessels under an agreement that they were "not to interfere with general operations." Therefore, the data were collected opportunistically from a variety of ships, and observers did not determine or influence cruise tracks.

Estimates of seabird density (birds/km^2) were derived from a strip transect procedure (Powers 1982). Observations were recorded in 10-min periods when the vessel proceeded on a steady course at a constant speed. Ship speeds ranged from 4 to 12 knots (7 to 22 km/h) among counting periods. Therefore, time duration was constant among transects, but area sampled varied according to ship speed.

The observer counted all birds on one side of the ship out to 300 m and forward of mid-ship to the projected end of the transect. The width of the strip sampled was determined with a hand-held, fixed-interval rangefinder (Heinemann 1981). A ship-following bird that passed through the strip for the first time (a subjective judgement) was counted, but that bird in all transects thereafter was considered a recount. Recounts were tallied separately and were not included in the density estimates. This strip-census method does not eliminate the problem of ship attraction (which varies according to cruise objective) or chronic ship-following (which varies by bird species), but it does minimize its inflationary effect on density estimates (Powers 1982). Differences in the abilities of observers to count birds is a principal, but unavoidable, source of variability in any estimates of bird density at sea (Powers 1982).

Estimates of seabird density were calculated by dividing bird counts from the sampling strip by the area sampled for each transect. Area sampled (A) per transect was calculated from Eq. (1).

$$A = \frac{\text{speed(nm/hr)}}{60 \text{ min/hr}} \times 10 \text{ min} \times \frac{1852 \text{ m}}{1 \text{ nm}} \times 300 \text{ m} \frac{1 \text{ km}^2}{1 \times 10^6 \text{m}^2} \qquad \text{Eq. (1)}$$

A total of 61 cruises was made from January 1978 through February 1980, during which 6308 transects were recorded and 5830 km^2 were sampled in shelf waters from 35^o to 44^o N latitude. Observations were divided into four seasons: spring (March - May), summer (June - August), fall (September - November), and winter (December - February). Distribution plots of survey effort (number of 10-min transects per 10′ x 10′ blocks of latitude and longitude) for each season are presented in Fig. 3 - 6. Survey coverage in winter was not as complete as the other seasons, particularly off the mid-Atlantic states (Fig. 6 and Table 1). Only monthly plots of intervals of mean densities (i.e., 0, $> 0 \leq 3$, > 3 and ≤ 10, etc.) by 10′-square 'blocks' of latitude and longitude sampled were available for analysis. Thus the

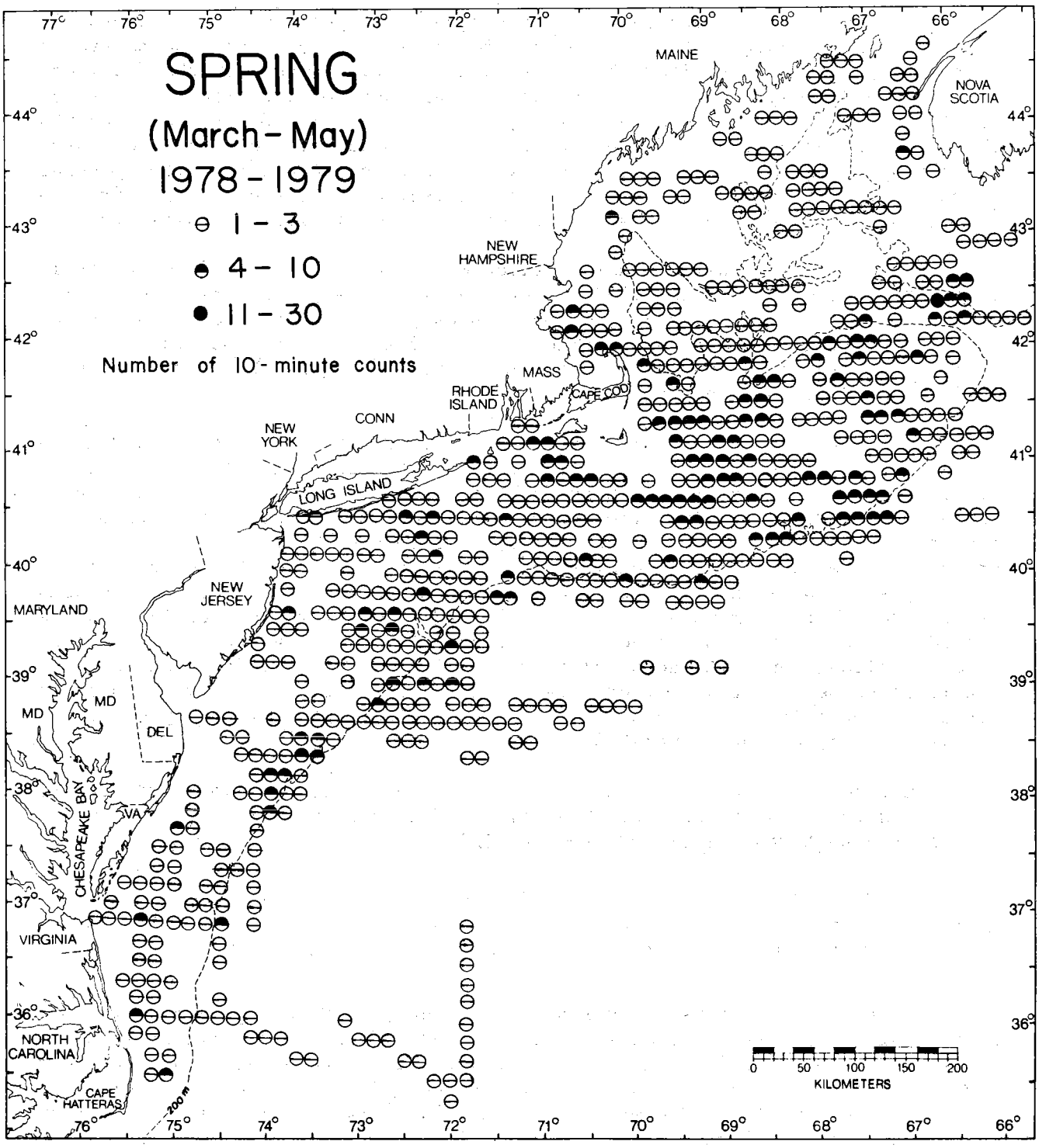

Fig. 3. Distribution of sampling effort (no. of 10-min. transects) per 10′ x 10′ square blocks of latitude and longitude in spring (March - May).

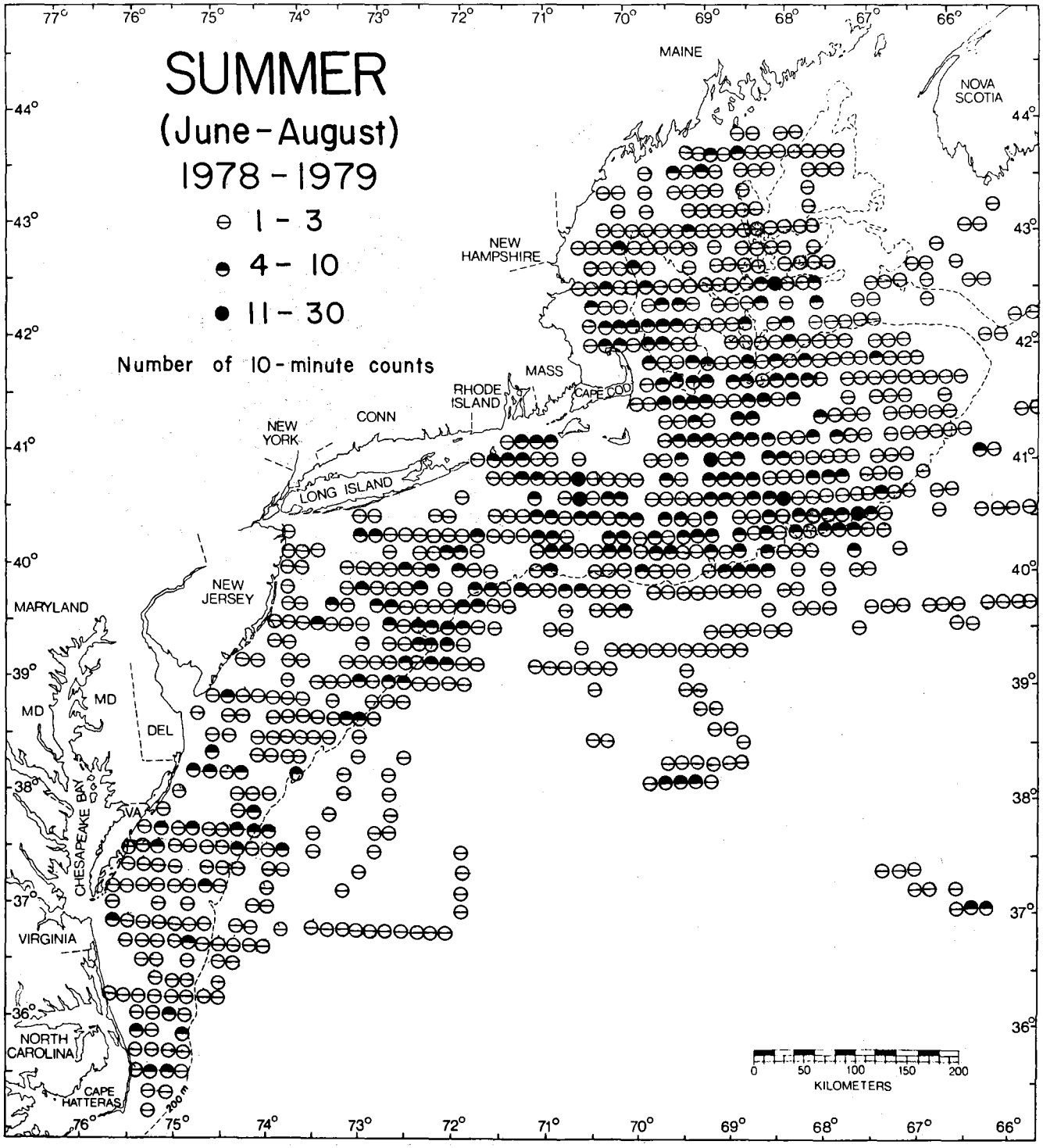

Fig. 4. Distribution of sampling effort (no. of 10-min. transects) per 10′ x 10′ square blocks of latitude and longitude in summer (June - August).

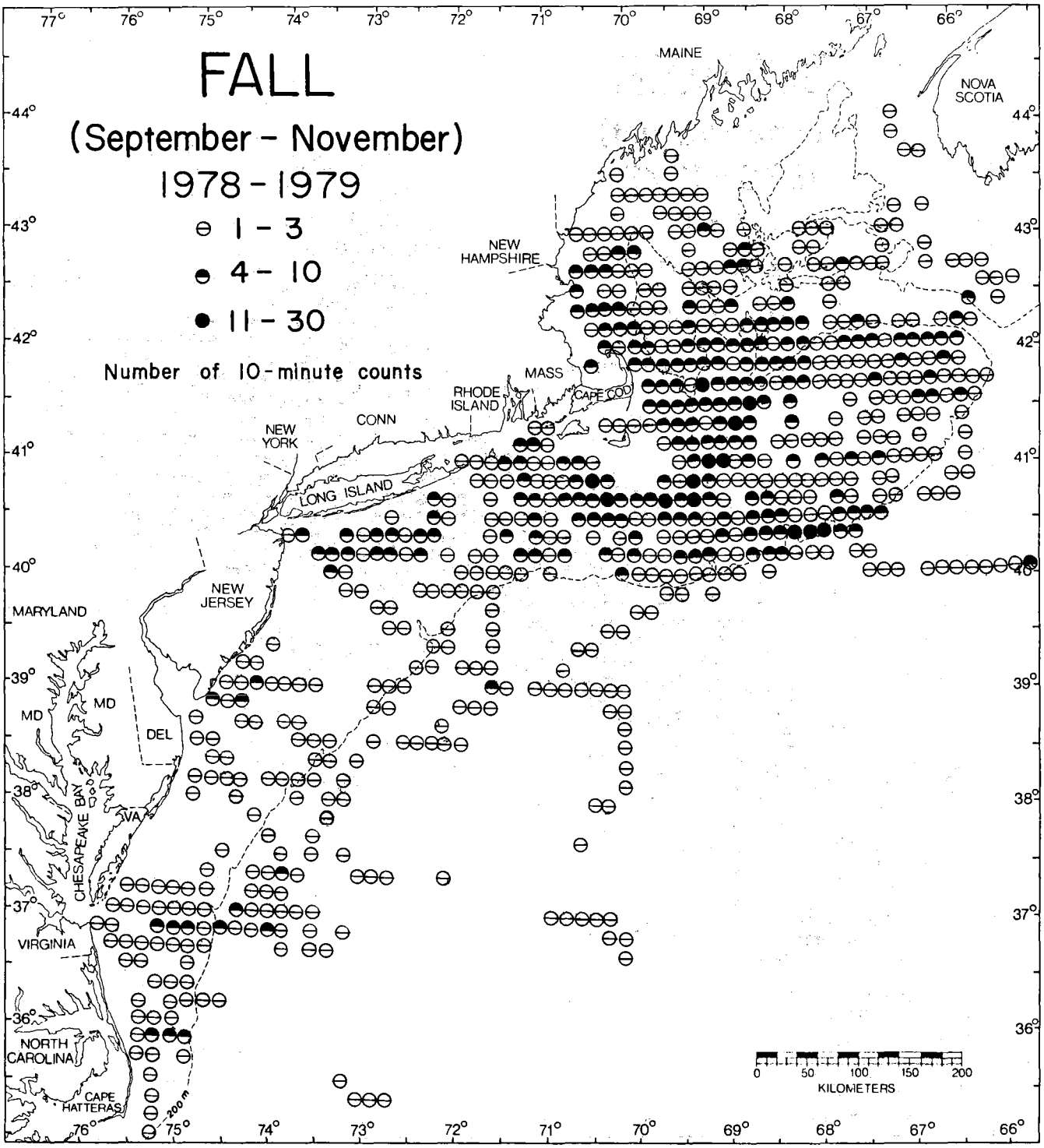

Fig. 5. Distribution of sampling effort (no. of 10-min. transects) per 10′ x 10′ square blocks of latitude and longitude in fall (September - November).

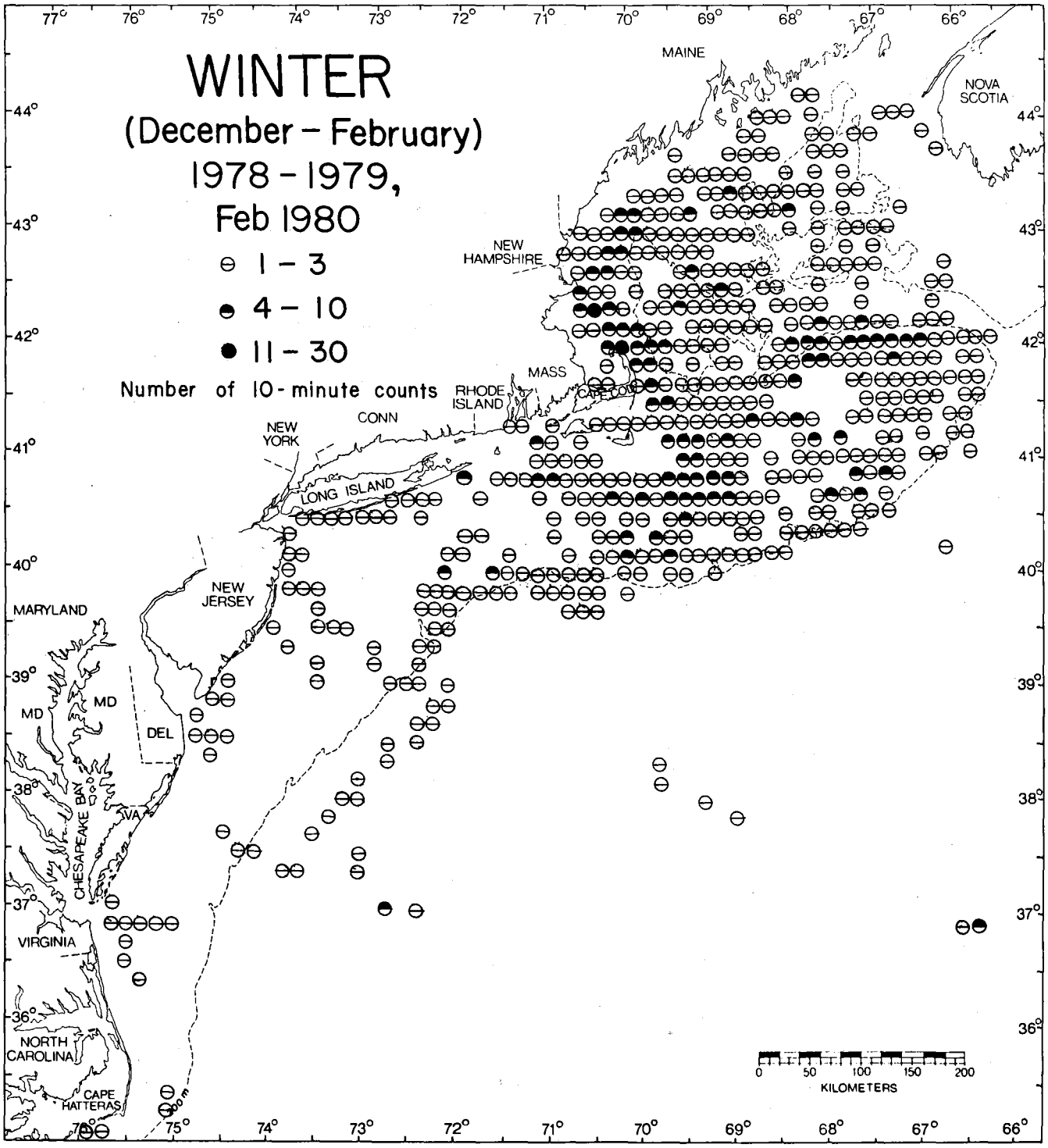

Fig. 6. Distribution of sampling effort (no. of 10-min. transects) per 10′ x 10′ square blocks of latitude and longitude in winter (December - February).

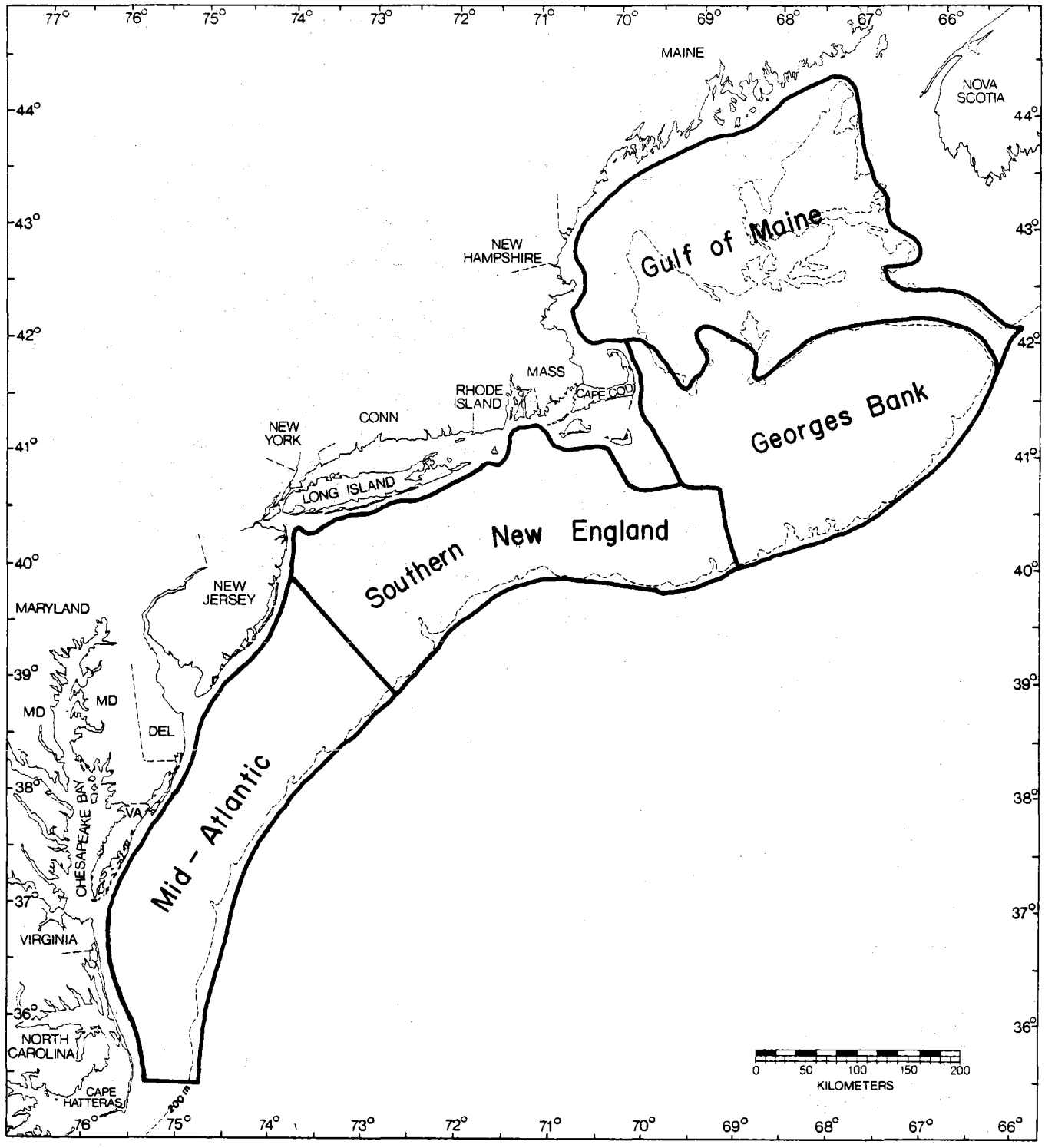

Fig. 7. Outline of subareas used in quantitative analyses.

seasonal distribution maps do not necessarily represent average densities for a given season. Instead, they are plots of the largest density interval given from those months in which that block was sampled. These maps are useful in depicting relative distribution and abundance both within and among species, but it should be noted that confidence in the density interval plotted increases with sample size.

The study area was divided into four subareas: Gulf of Maine, Georges Bank, southern New England, and mid-Atlantic (Fig. 7). These subareas were adapted from NMFS assessment surveys of zooplankton and groundfish stocks on the northeast continental shelf (Grosslein et. al 1980; Sherman 1981). A seasonal breakdown of area sampled by subarea is given in Table 1. Mean densities with standard deviations for each species were calculated by season and subarea. These are listed by subareas in Appendices 1 - 4. Population estimates with 95 percent confidence intervals were derived for the entire study area (Appendix 5). These estimates were based on 61,370 km^2 of surface area on the Gulf of Maine, 52,479 km^2 on Georges Bank, 52,009 km^2 on the southern New England shelf and 43,534 km^2 on the mid-Atlantic shelf. No densities or population estimates were calculated for slope waters beyond the shelf-break, because too few samples were available.

In the analysis of community structure, two bird communities, Gulf of Maine/Georges Bank and Middle Atlantic Bight (S. New England and mid-Atlantic subareas) were examined for seasonal abundance, biomass and diversity . In order to make comparisons more meaningful, a random sample of 100 transects was selected from each region and season. Although the area sampled per transect may have varied from 0.55 to 11.12 km^2, most transects were conducted at 10 kt (0.93 km^2) and for the purposes of this section I assumed there was no difference in area sampled between transects. The number of individuals per species recorded in each region and season is given in Appendices 6 and 7. Density and biomass estimates were compiled by family group for easier interpretation in the results. Species diversity was measured with the Shannon-Weaver index $H'(H' = \sum p_i \log p_i)$, where p_i is the fraction of individuals comprised by the ith species in the sample (Shannon and Weaver 1949; Margalef 1958), and the evenness index $J'(J' = H'/\log s)$, where s is the number of species in the sample (Pielou 1966). Unidentified bird categories (e.g. unidentified auk, unidentified large gull) were numerically apportioned to identified species in that category and season. Therefore, species richness was always conservatively estimated and heterogeneity was assigned in accordance with observed species abundance.

RESULTS

A. Species Accounts

The following section has (1) accounts of species or species group and (2) maps of distribution and abundance by season and (3) histograms of monthly densities both by subareas and for the entire shelf (cumulative) off the northeastern United States. Each account has the following information: (1) brief summary of breeding distribution, (2) principal trophic levels the species use, (3) known pelagic range in western North Atlantic, (4) discussion of monthly and seasonal changes in distribution and abundance within shelf waters off the northeastern United States, and (5) an estimate of the size of the population in the study area. The terms used to describe bird trophic levels and food categories were the same used by Ainley and Sanger (1979). Secondary carnivores feed on zooplankton and ichthyoplankton; secondary carnivores feed on fish and cephalopods; tertiary carnivores feed on other birds; and scavengers feed on carrion, offal and detritus.

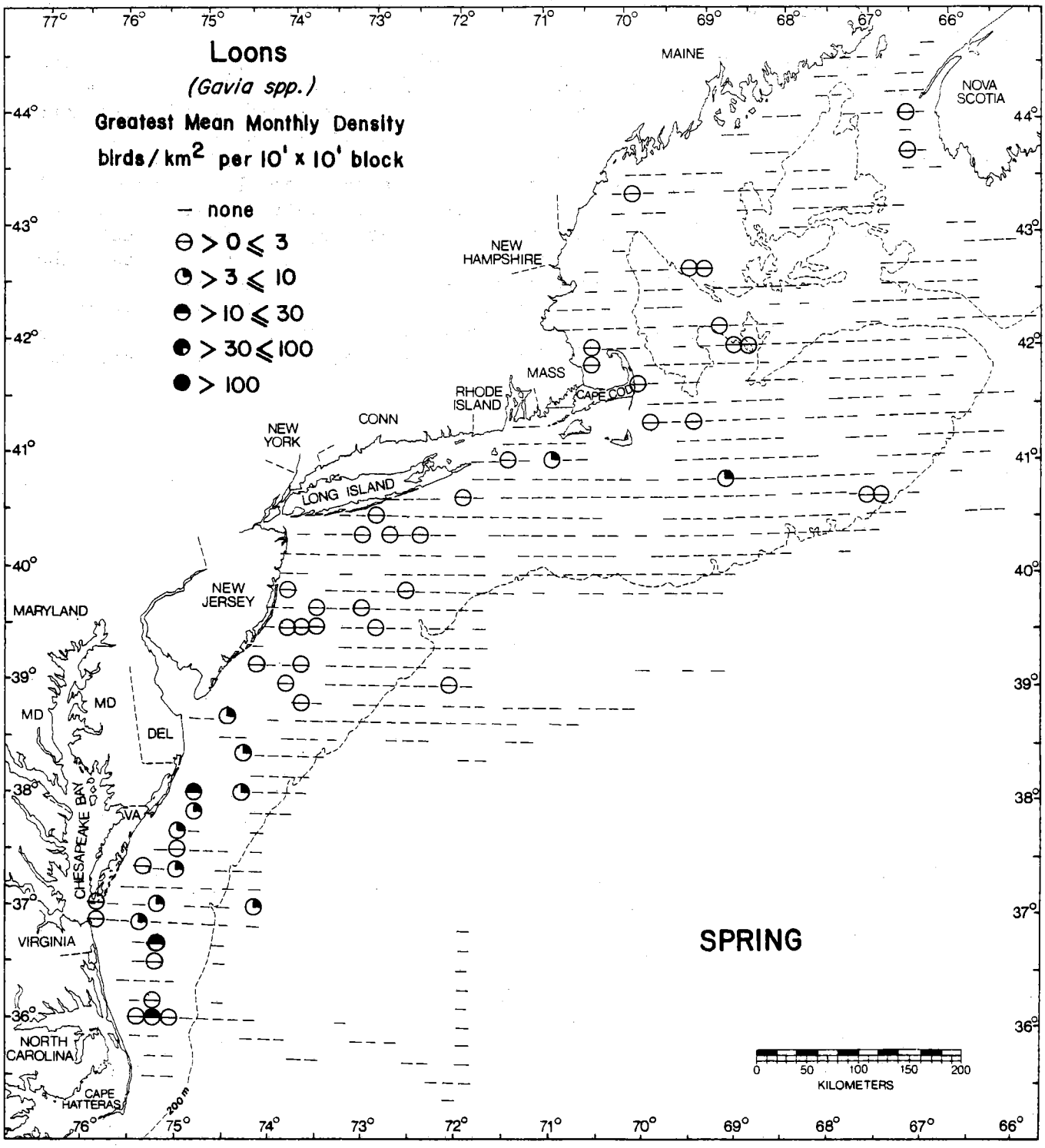

Fig. 8. Relative distribution and abundance of loons (Gavia spp.) in spring.

COMMON LOON (Gavia immer)

RED-THROATED LOON (Gavia stellata)

Common Loons breed throughout boreal and low and high arctic life zones of North America (Palmer 1962; Godfrey 1966). In eastern North America Red-throated Loons breed principally from Labrador and the northern coast of the Gulf of St. Lawrence west to Hudson Bay and north to Greenland and the Canadian arctic (Palmer 1962; Todd 1963; Godfrey 1966).

Loons are pursuit-divers, which feed as tertiary carnivores mostly on fishes, and to a lesser extent as secondary carnivores, on crustaceans, molluscs and aquatic insects (Palmer 1962).

In eastern North America Common Loons winter in nearshore waters from Atlantic Canada south to the Gulf of Mexico (Palmer 1962). Winter distribution of Red-throated Loons overlaps that of the Commons, but their range is slightly more restricted, Nova Scotia to western Florida (Palmer 1962).

Loons were recorded frequently offshore during spring and fall migration (Fig. 8-9). Several late fall migrants were noted in December and were plotted among those individuals that were apparently overwintering in coastal areas (Fig. 10). The vast majority of sightings were identified as Common Loon in both spring and fall. Although relatively few Red-throated Loons were identified, some evidently crossed the western Gulf of Maine in spring and fall. The offshore movements of Common Loons in fall across Georges Bank and the Gulf of Maine may originate from breeding grounds on Nova Scotia and Newfoundland (Powers and Cherry 1983).

No population estimate of loons was calculated.

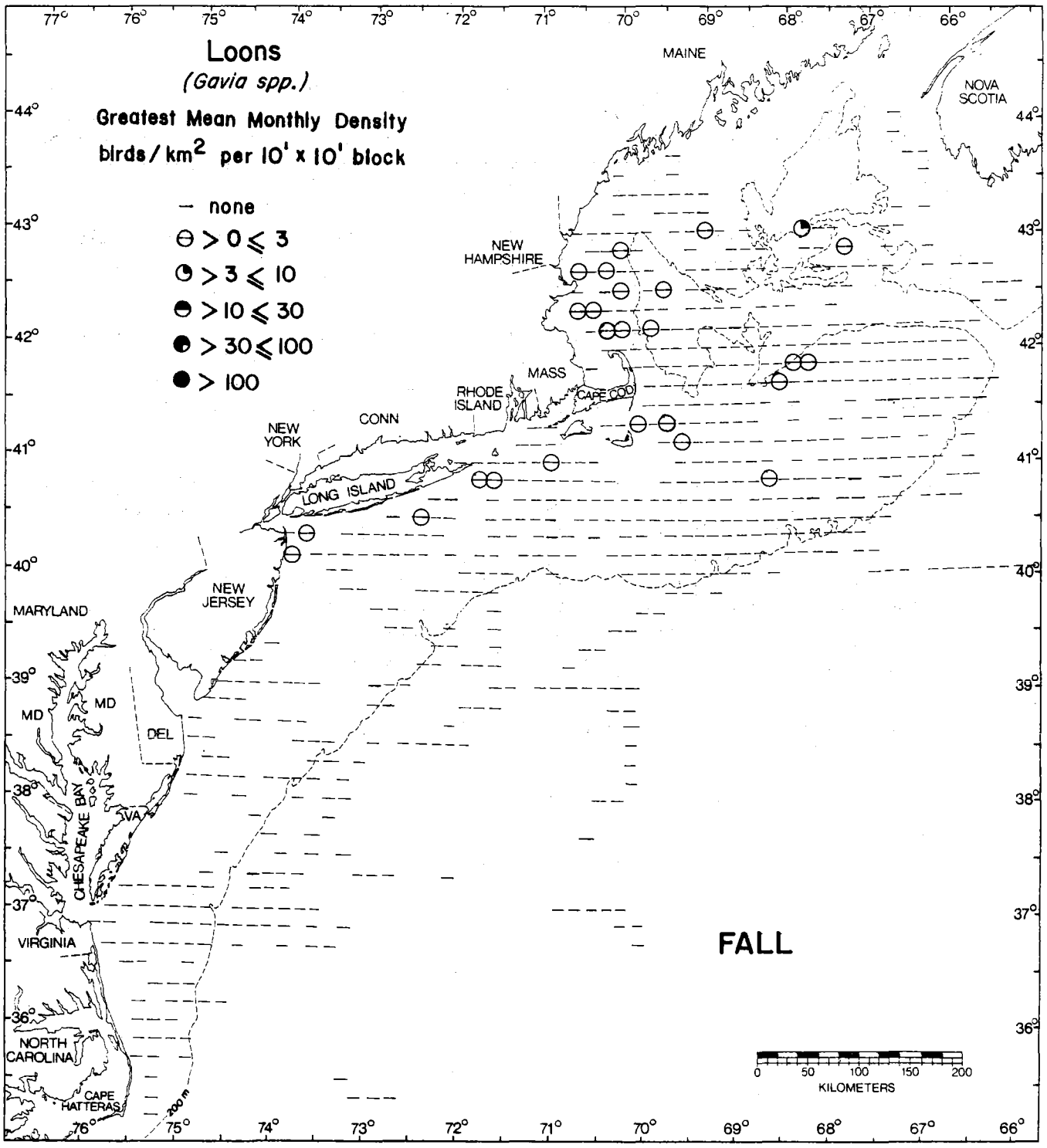

Fig. 9. Relative distribution and abundance of loons (Gavia spp.) in fall.

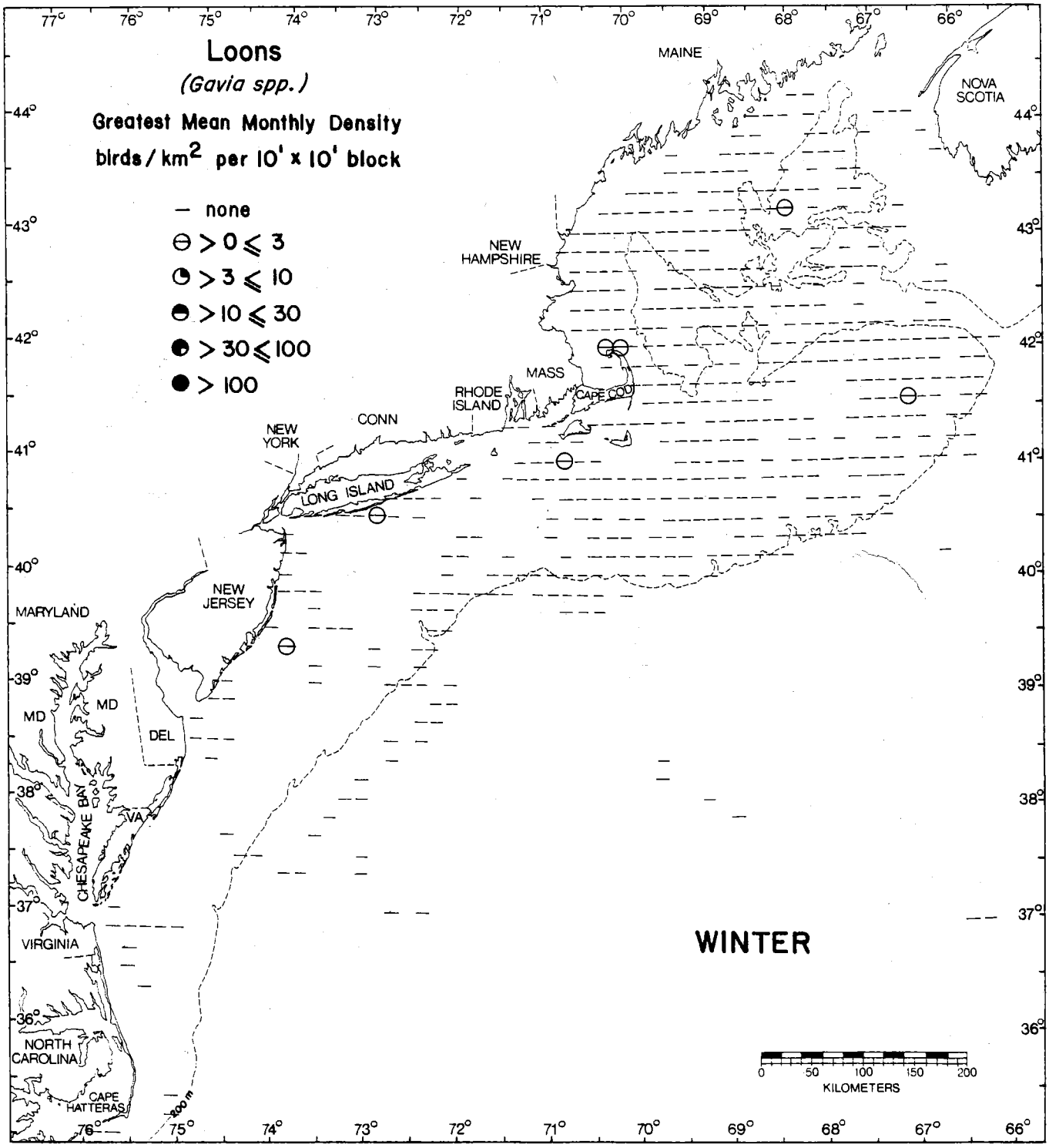

Fig. 10. Relative distribution and abundance of loons (Gavia spp.) in winter.

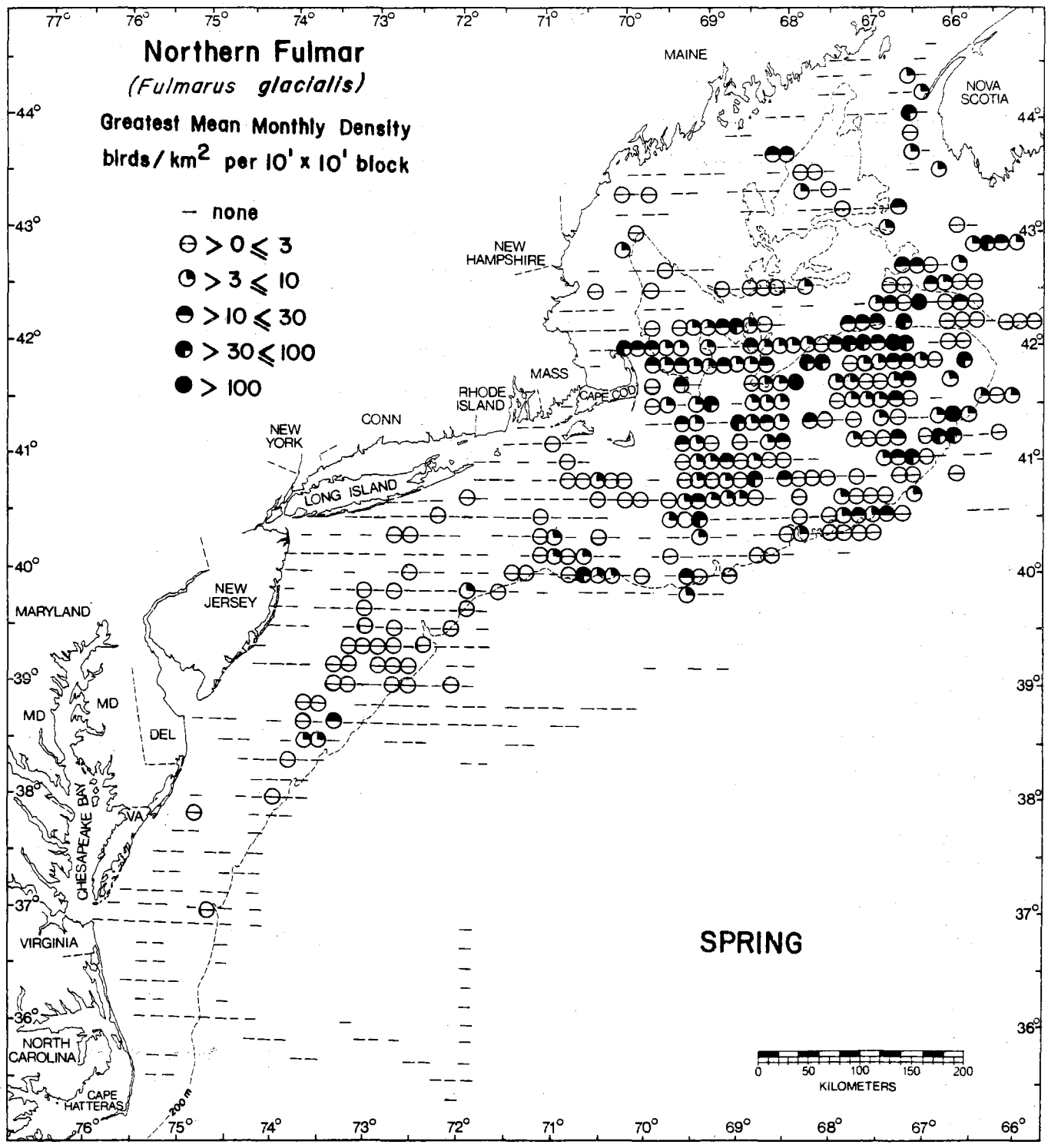

Fig. 11. Relative distribution and abundance of Northern Fulmars (Fulmarus glacialis) in spring.

NORTHERN FULMAR (Fulmarus glacialis)

Northern Fulmars breed abundantly in arctic areas of North America (Palmer 1962; Brown et al. 1975). Its spread in breeding range in the eastern North Atlantic (Fisher 1952, 1966) has recently extended west to southwest Greenland (Salomonsen 1979), Newfoundland (Nettleship and Montgomerie 1974) and Labrador (D. N. Nettleship, personal communication). Banding recoveries suggest that fulmars 'wintering' off the coast of eastern Canada are from British and W. Greenland colonies (Salomonsen 1965; Brown 1970).

Fulmars feed at the surface as secondary and tertiary carnivores and as scavengers (Fisher 1952; Palmer 1962; Ainley and Sanger 1979; Hunt et al. 1981). They are "opportunists" that consume a variety of zooplankton, fish and squid, as well as offal from fishing vessels.

Highest densities were found on Georges Bank and the Gulf of Maine (Fig. 11-14). Flocks of several thousand fulmars were noted each winter in these subareas, often associated with fishing vessels. In the S. New England and mid-Atlantic subareas numbers of fulmars seen were usually < 1 bird/km^2 (Fig. 15).

Fulmars were present off the New England coast throughout the year (Fig. 15) except for August. After a mid-summer withdrawal toward the north, they increase steadily in the Gulf of Maine and Georges Bank subareas from September until February. Although the increase was not as marked, fulmar density also appeared to increase during fall and to peak in February in the S. New England subarea. Shifts in distribution were apparent in March when fulmars in the Gulf of Maine began to return to the Scotian shelf, while others may have moved onto northern Georges Bank (Fig. 15). Densities on Georges Bank remained constant or increased slightly from February through April (Fig. 15), but by May it was apparent that there had been a sharp decrease in abundance throughout the shelf. In July only a few stragglers were found on the Gulf of Maine and Georges Bank.

A high percentage of light-phase (Fisher 1952, Type LL and L) as contrasted with dark-phase (Fisher 1952, Type DD and D) fulmars were found in this study, which is in agreement with findings by Brown et al. (1975) in the western North Atlantic and by Fisher (1952) in the western and eastern North Atlantic. More than 95 percent of fulmars off the northeastern United States during any season were light phase, and the vast majority were Fisher's LL form, which has a white head, neck, and underparts.

Approximately 1.0 million fulmars were present in shelf waters off the New England coast during winter when peak abundance was reached (Appendix 5). However, this estimate was most likely inflated because of biases in the data collection. For instance, the large, clumped concentrations found in the Gulf of Maine and Georges Bank in winter disproportionately skewed mean densities upwards. Another problem in my sampling is that fulmars circle and follow vessels in areas of commercial fishing (Hunt et al. 1978). Attraction to fishing vessels, which are common on Georges Bank and the Gulf of Maine, may have inflated density estimates, because birds may have been attracted to

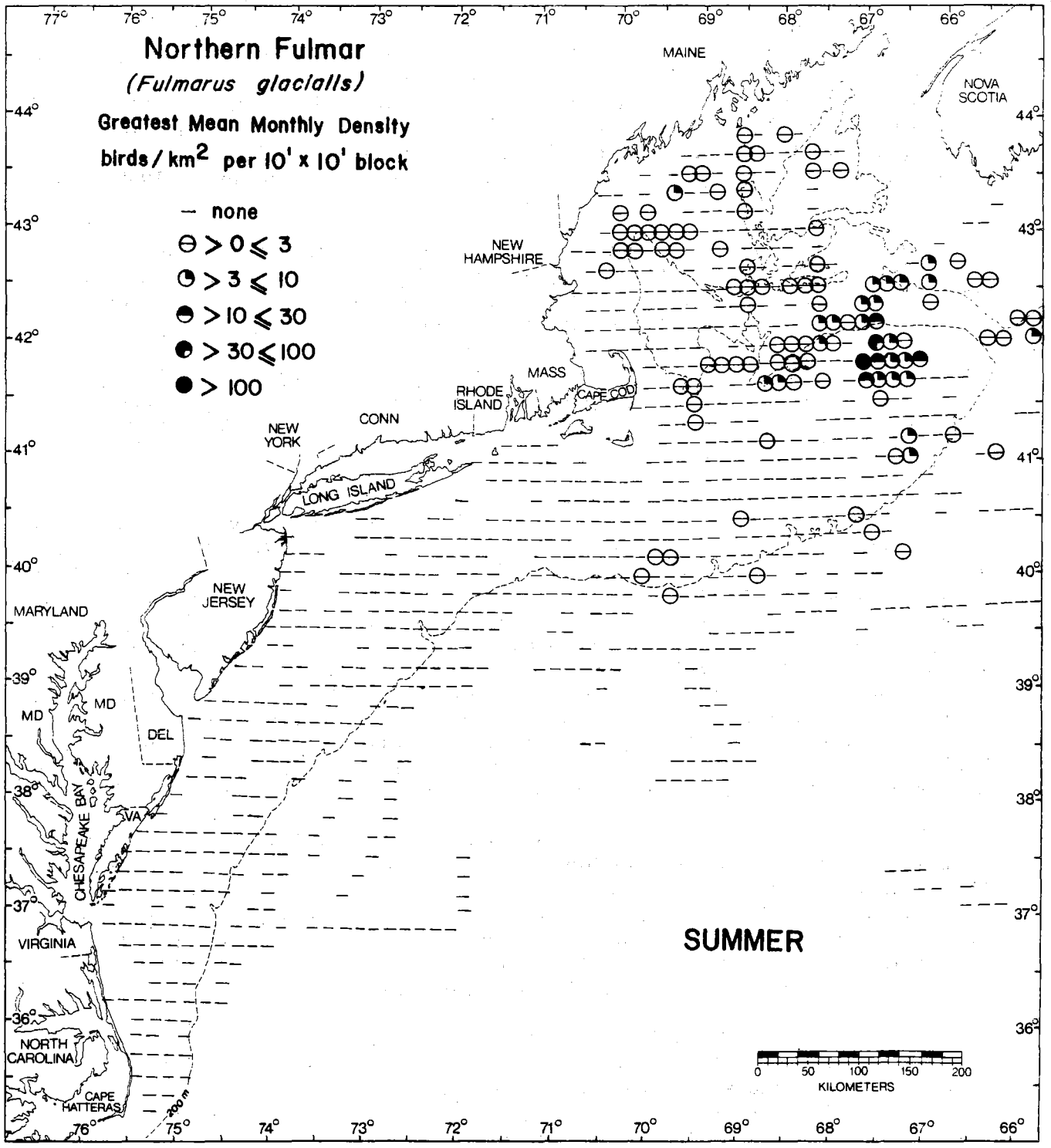

Fig. 12. Relative distribution and abundance of Northern Fulmars (Fulmarus glacialis) in summer.

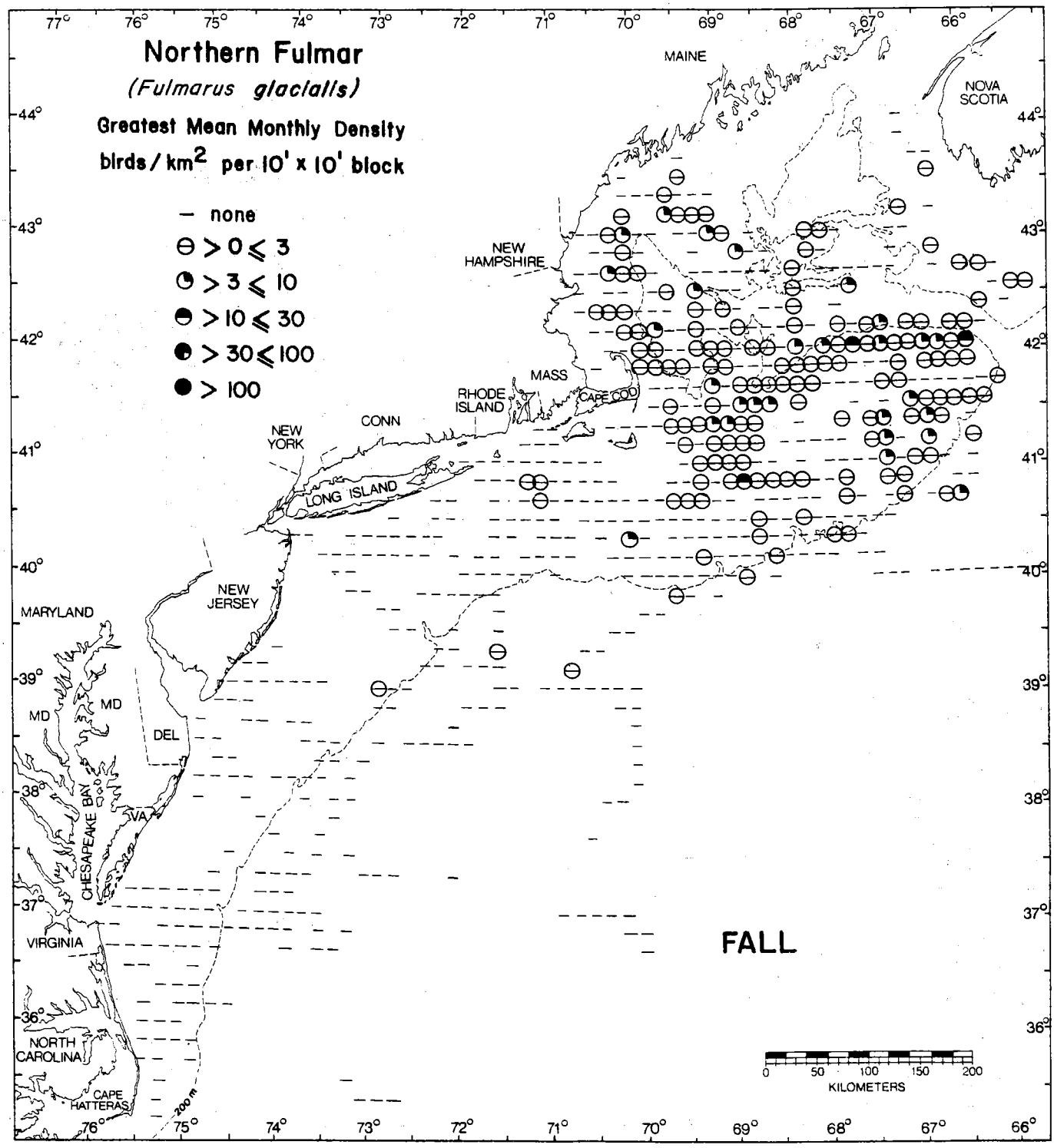

Fig. 13. Relative distribution and abundance of Northern Fulmars (Fulmarus glacialis) in fall.

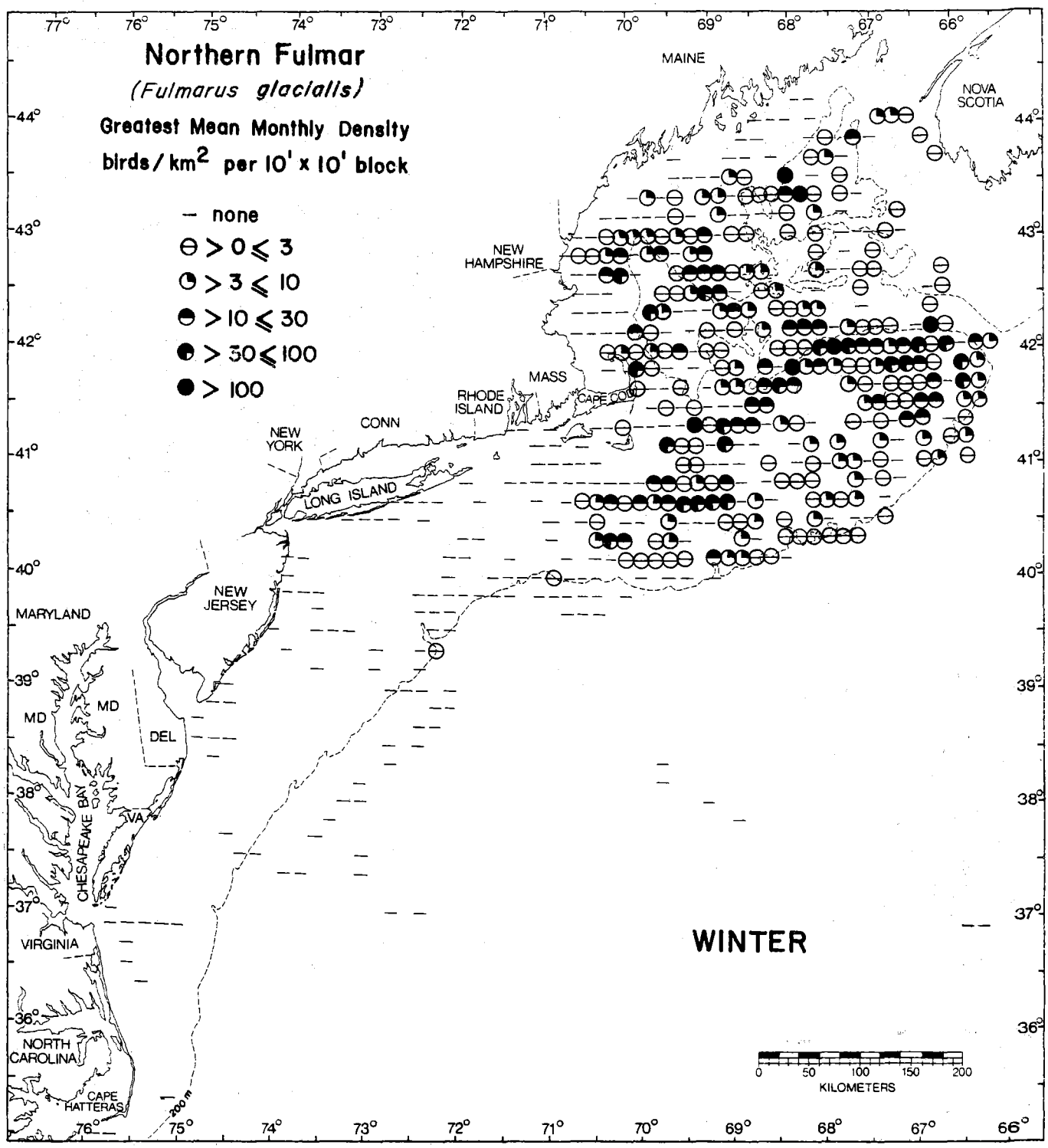

Fig. 14. Relative distribution and abundance of Northern Fulmars (Fulmarus glacialis) in winter.

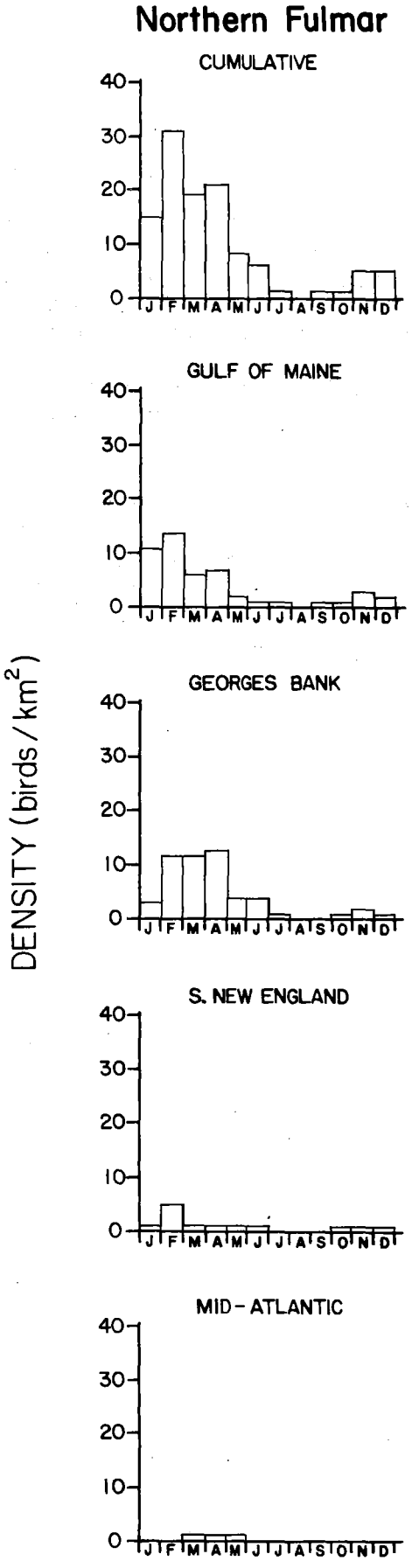

Fig. 15. Histogram of mean monthly densities of Northern Fulmars (Fulmarus glacialis) by subarea and the entire study area (cumulative).

vessels used in this study, and the Coast Guard patrols often spent most of their time in areas being fished.

The range expansion of fulmars into boreal waters off the eastern North Atlantic was discussed in detail by Fisher (1952) and restated by Salomonsen (1965). Salomonsen's theory was that fulmar distribution in the North Atlantic was better explained by a recent exploitation of available "natural" prey in low arctic and boreal waters, rather than an increased dependence on offal from a growing fishing industry, as Fisher contended. Brown (1970) supported Salomonsen's hypothesis arguing that fulmars were present on the fishing banks in the low arctic waters off eastern Newfoundland, but not on those in the boreal waters east of Nova Scotia. However, Brown's observations were all north and east of Nova Scotia, which is north of my study area. It is apparent from my data that fulmars are present in substantial numbers in boreal waters of the western North Atlantic. This increase may not be that recent, since Forbush (1925) noted fulmars as "plentiful" on Georges Bank and casually south to New Jersey in winter.

CORY'S SHEARWATER (Calonectris diomedea)

Cory's Shearwaters breed on islands in the eastern North Atlantic (Selvagems, Canaries, Madeira, Azores, and Cape Verde) and throughout the Mediterranean (Cramp et al. 1977). Although specimens of the Mediterranean race C. d. diomedea have been collected off eastern North America (Murphy 1922; Forsythe 1980), the eastern Atlantic race C. d. borealis dominates the population visiting the study area (K. D. Powers, unpubl. data).

Cory's Shearwaters feed at or near the surface (Bauer and Glutz 1966; Brown et al. 1978) as secondary and tertiary carnivores on fish, fish spawn, cephalopods, and crustaceans (Cramp et al. 1977). The eastern Atlantic race C. d. borealis also scavenges offal from fishing vessels (Cramp et al. 1977), although I have not observed this attraction in the western North Atlantic.

Cory's Shearwaters were found in greatest densities on the S. New England shelf from the Great South Channel west to Cox Ledge (Fig. 16-17). Overall mean densities never exceeded 5 birds/km^2 in any subarea or season (Fig. 18). The largest local concentrations recorded rarely exceeded 30-100 birds/km^2. Flocks actively feeding on small fish (in some instances, sauries Scomberesox saurus), which were driven to the surface by larger predatory fish, possibly bluefish (Pomatomus sp.), were noted in the Great South Channel area in July and August. From September to October, Baird (1887) noted "thousands" of Cory's Shearwaters feeding on young sea herring (Clupea harengus) driven to the surface by predatory mackerel (Scomber scomber) and bluefish off the island of Martha's Vineyard, Massachusetts.

Early arrivals were noted in late May. Peak abundance was reached in July, after which the population apparently remained static until October (Fig. 18). During mid-summer, Cory's Shearwaters were common on shelf waters from western Georges Bank south to Cape Hatteras (Fig. 16) and in slope water (cf. Brown 1977). This species did not usually penetrate into the colder waters of the Gulf of Maine. However, in 1979 there was a late-summer and early-fall shift of Cory's Shearwaters to nearshore waters east of Cape Cod and north to Jeffreys Ledge (Fig. 17 and 18). In this year, they were also seen as far north as east Cape Breton, Nova Scotia (R. G. B. Brown, personal communication). There was no immediate explanation for this anomaly. Generally, Cory's Shearwaters left the study area by mid-October, except for a few stragglers which sometimes remained through November.

Approximately 161,000 Cory's Shearwaters were present in the shelf waters off the northeastern United States during summer and fall (Appendix 5). No estimates are available for the world breeding population of C. d. borealis. Yet, since this species breeds from May to October in the eastern North Atlantic (Cramp et al. 1977), this estimate represents an unknown fraction of the nonbreeding population because the adults are at breeding colonies during this period.

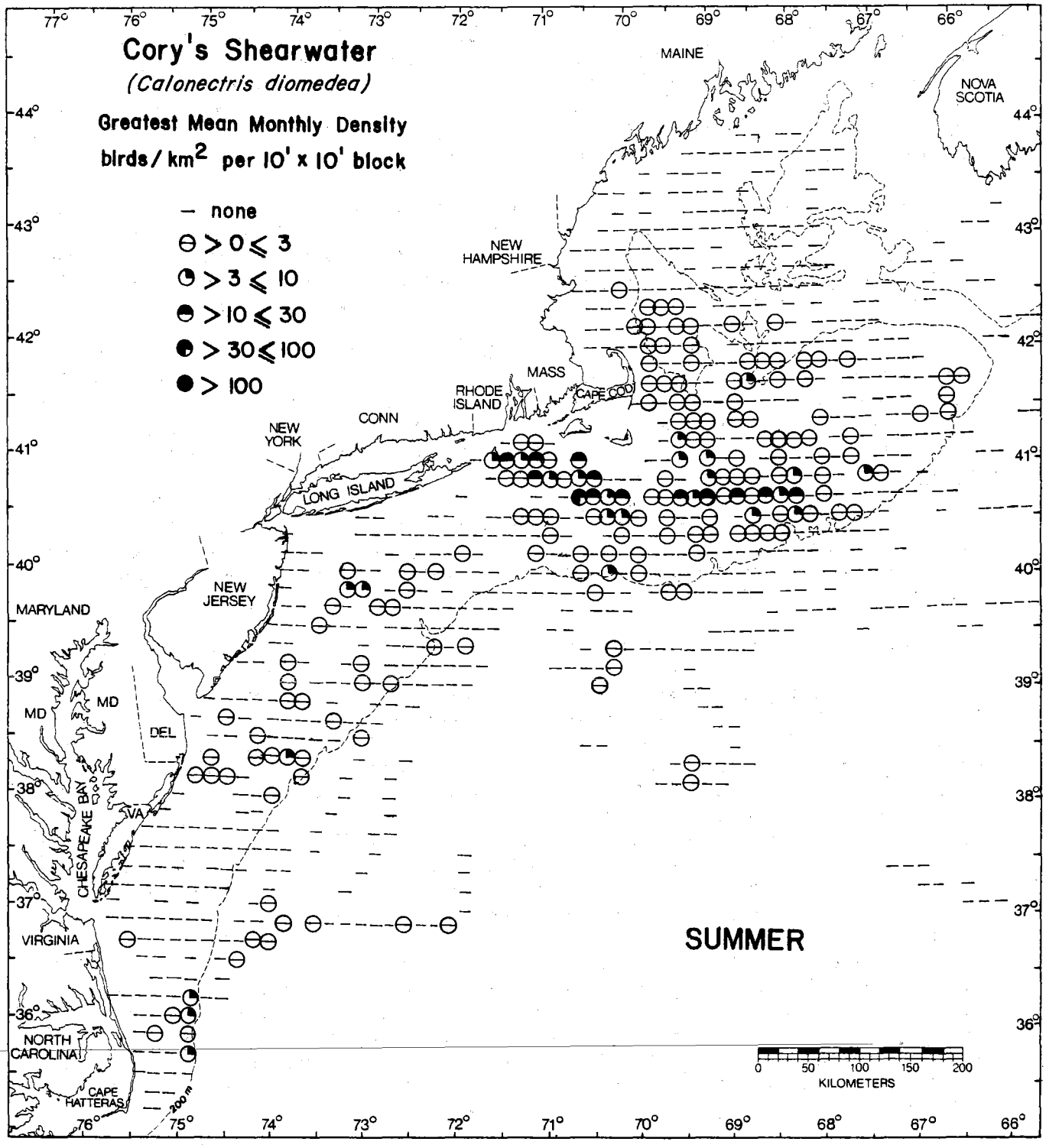

Fig. 16. Relative distribution and abundance of Cory's Shearwaters (Calonectris diomedea) in summer.

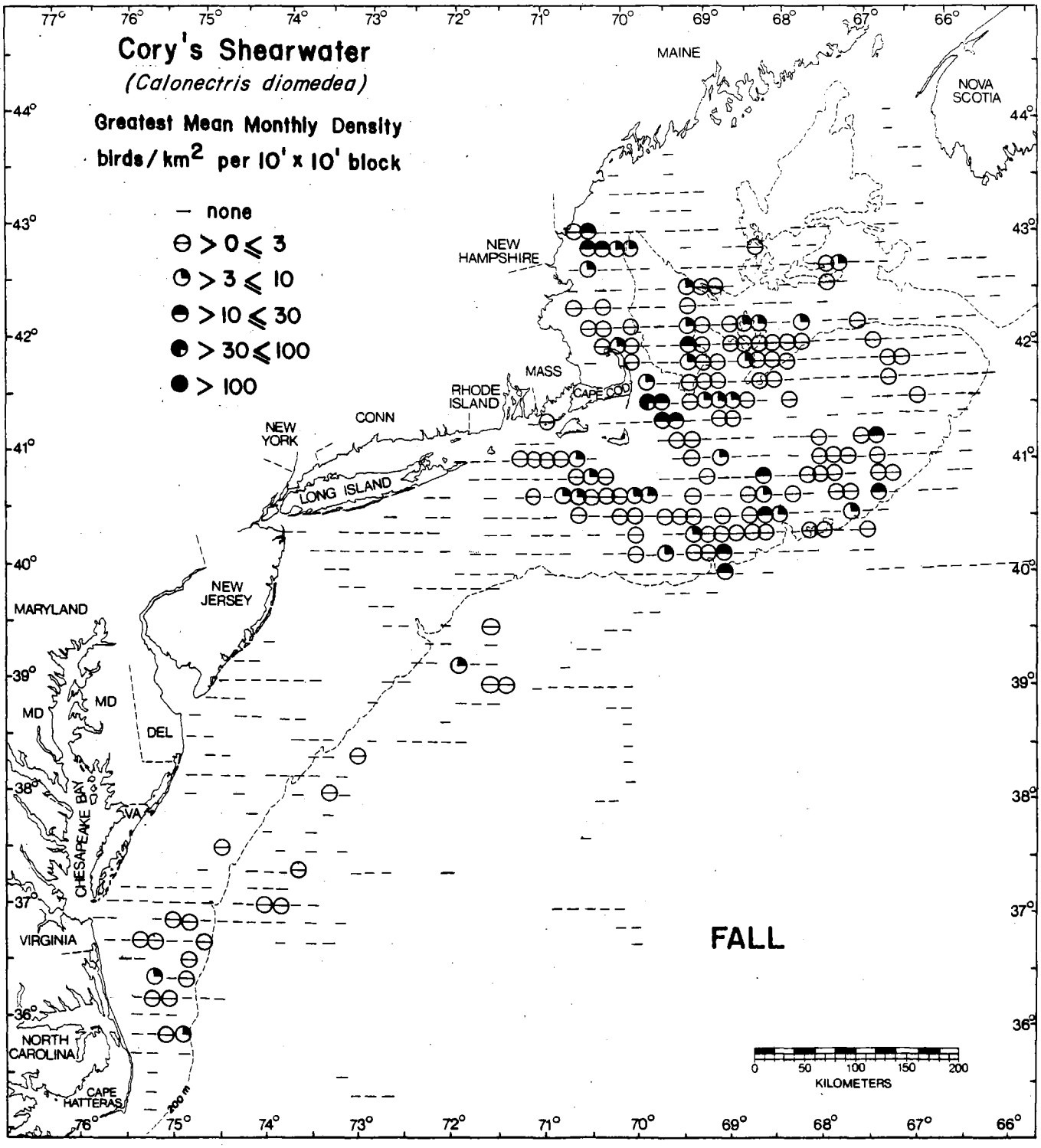

Fig. 17. Relative distribution and abundance of Cory's Shearwaters (Calonectris diomedea) in fall.

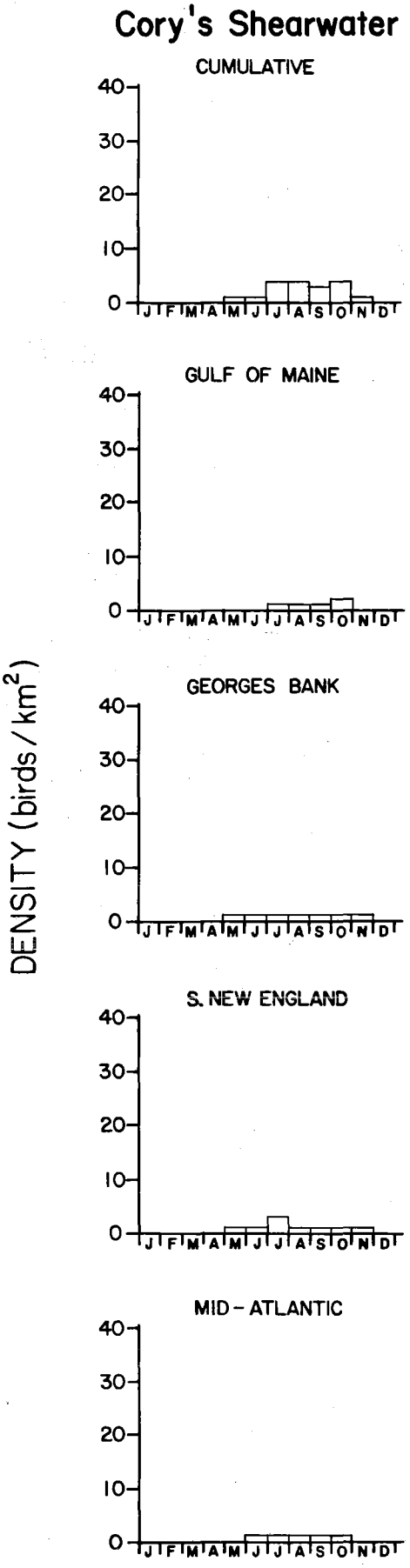

Fig. 18. Histogram of mean monthly densities of Cory's Shearwaters (Calonectris diomedea) by subarea and the entire study area (cumulative).

GREATER SHEARWATER (Puffinus gravis)

Greater Shearwaters breed on the Tristan da Cunha island group in the South Atlantic (Rowan 1952; Elliott 1970) and on the Falkland Islands (Woods 1970).

Greater Shearwaters feed as tertiary carnivores on fish and cephalopods, as secondary carnivores on crustaceans, and as scavengers on offal from fishing vessels (Collins 1884; Bent 1922; Rees 1961; Brown et al. 1981).

During summer months (May to August) most Greater Shearwaters are in the North Atlantic (Cramp et al. 1977) with the majority in boreal and low arctic waters on the western side (Wynne-Edwards 1935; Voous and Wattel 1963; Streseman and Streseman 1970; Brown et al. 1975; Brown 1977). Although Greater Shearwaters were recorded almost throughout the year, greatest densities were found on Georges Bank in summer and fall and on the Gulf of Maine in fall (Fig. 19-22). Flocks of hundreds to more than 10,000 birds were observed in these areas, often in association with fishing activity. Except for local areas, such as Cox Ledge south of Narragansett Bay and along the shelf-break when squid fleets were active, Greater Shearwater density rarely exceeded 5 birds/km^2 south and west of Cape Cod.

The temporal distribution of Greater Shearwaters was bimodal (Fig. 23). Birds typically began to arrive on Georges Bank in the last week of May and en masse in June. Densities on Georges Bank reached 25 birds/km^2 in June and July, but by August no subarea contained more than 5 birds/km^2. The emigration in late summer may have resulted from two causes: (1) adults returning to the South Atlantic to breed or (2) subadults and juveniles moving into the Bay of Fundy (cf. Brown et al. 1975, Fig. 6) to capitalize on daytime euphausiid swarms (Brown et al. 1979). In early October, density increased in the eastern Gulf of Maine and on Browns Bank. By late October, Greater Shearwaters were again abundant in the southern Gulf of Maine, Georges Bank, and eastern S. New England subareas. The majority of the population was gone by mid-November although a few flocks of up to 100 birds were noted in early December. Some individuals overwintered in the North Atlantic (Appendix 8) (cf. Brown 1977).

The world breeding population of Greater Shearwaters is estimated to be at least five million (Rowan 1952; Elliot 1957; Elliot 1970). I estimated that approximately 1.3 million Greater Shearwaters were present in shelf waters off the New England coast during summer and ca. 1.5 million during fall (Appendix 5). Powers and Van Os (1979) noted one sighting ca. 200,000 on Georges Bank on 11 November 1977. This abundance in fall off the New England coast indicates that a substantial number of Greater Shearwaters are in the western North Atlantic, at the time when breeding is underway in the southern hemisphere (Rowan 1952). This estimate of 1.5 million birds thus reflects the minimum size of the nonbreeding population.

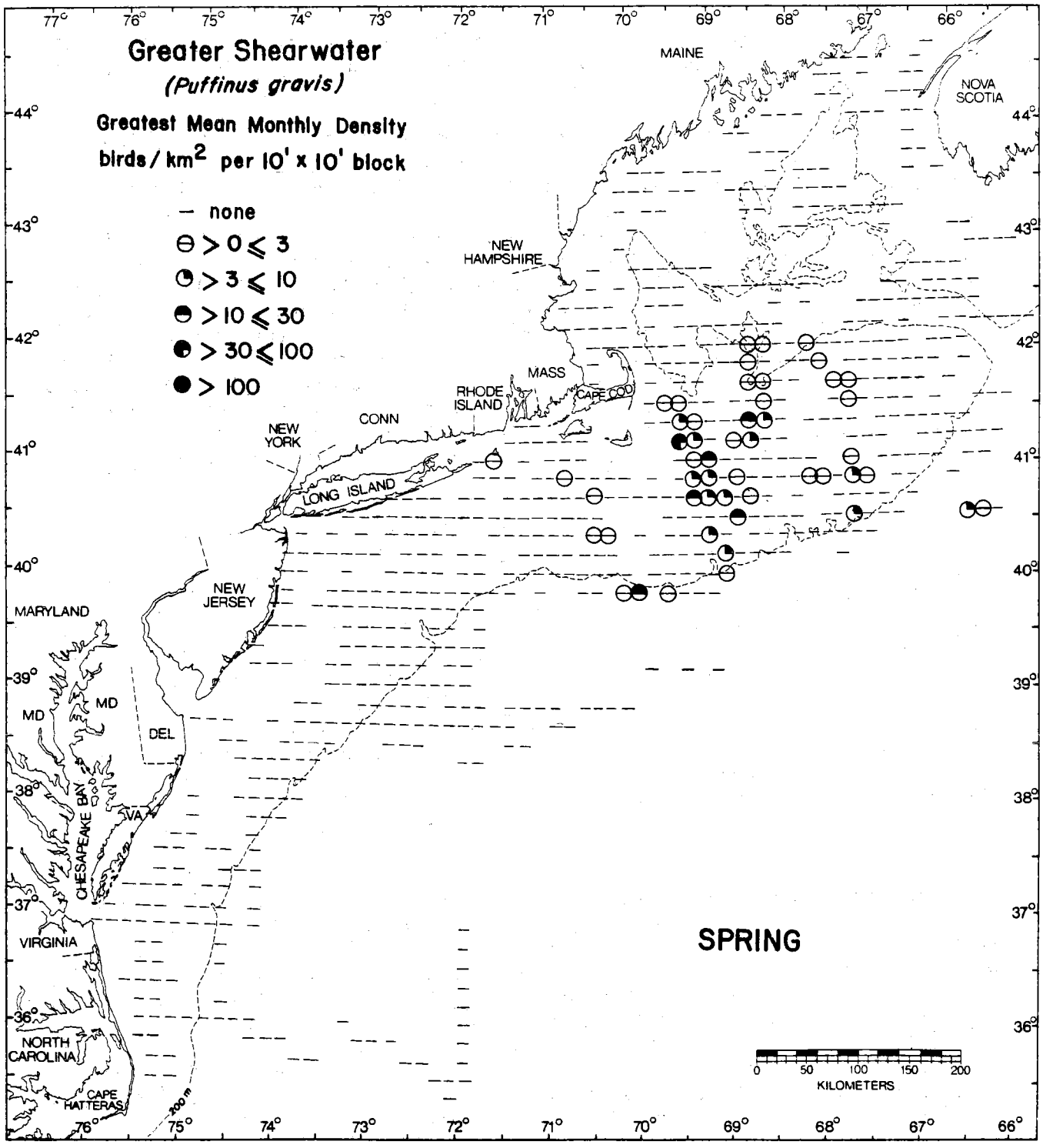

Fig. 19. Relative distribution and abundance of Greater Shearwaters (Puffinus gravis) in spring.

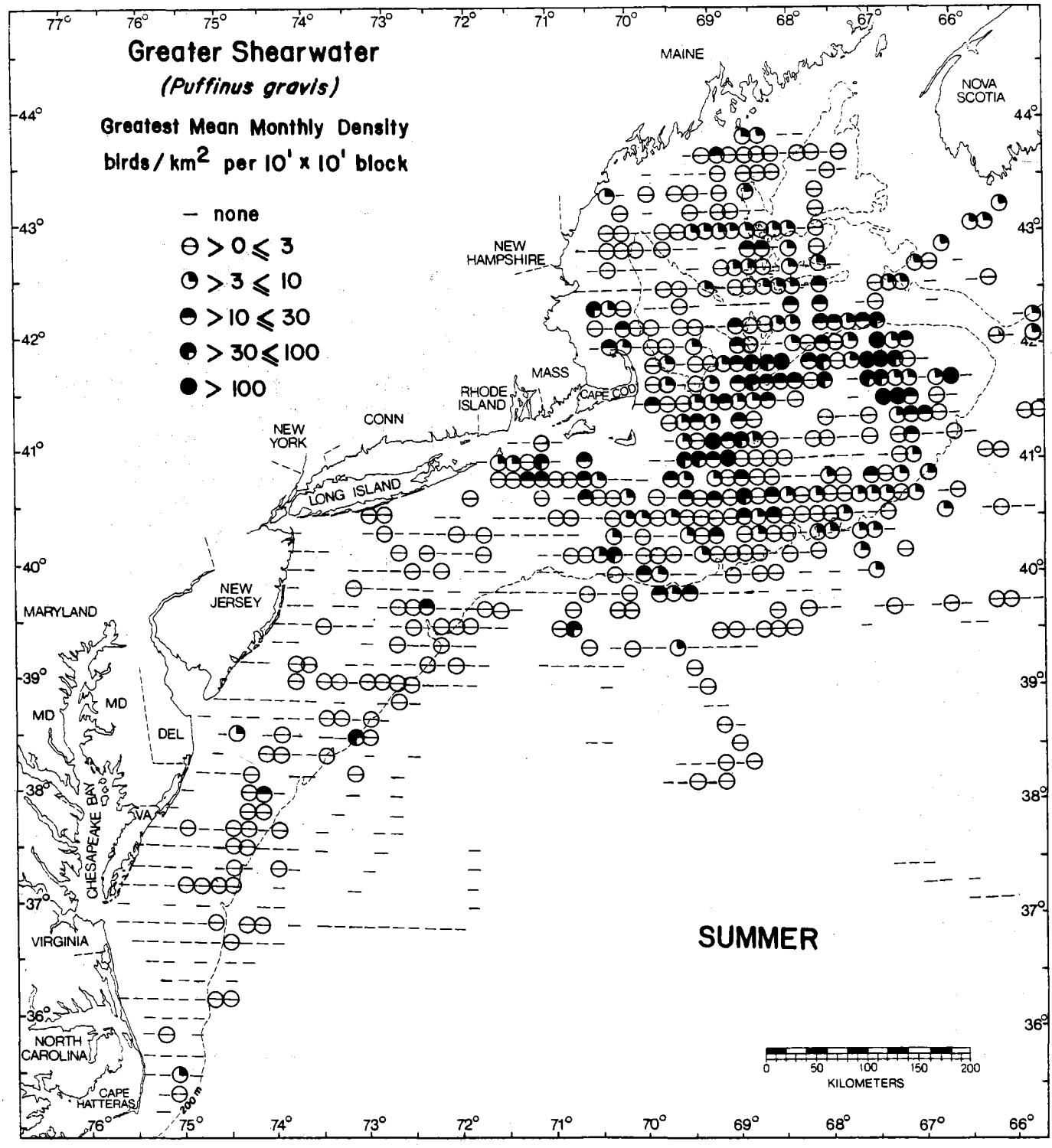

Fig. 20. Relative distribution and abundance of Greater Shearwaters (Puffinus gravis) in summer.

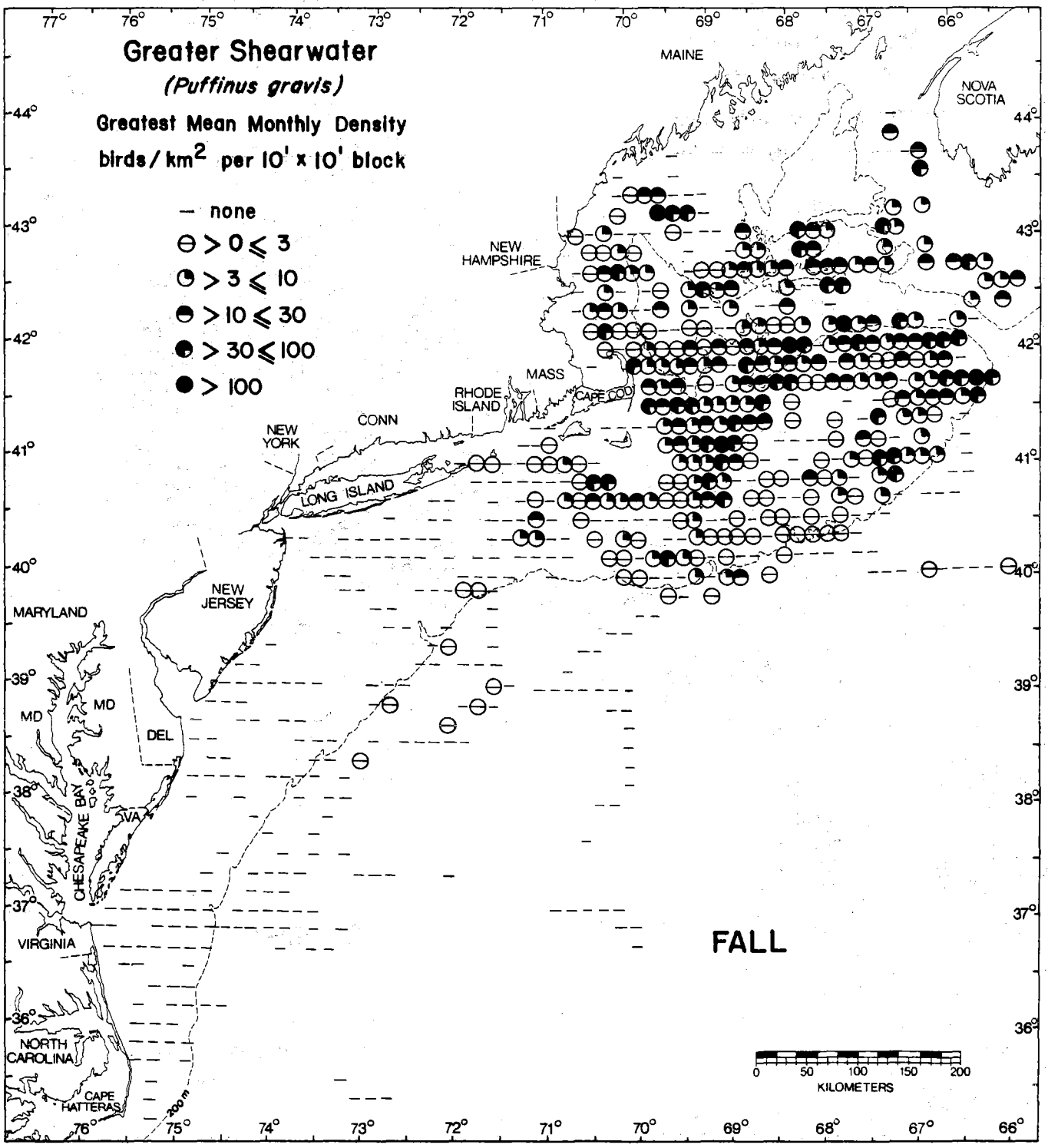

Fig. 21. Relative distribution and abundance of Greater Shearwaters (Puffinus gravis) in fall.

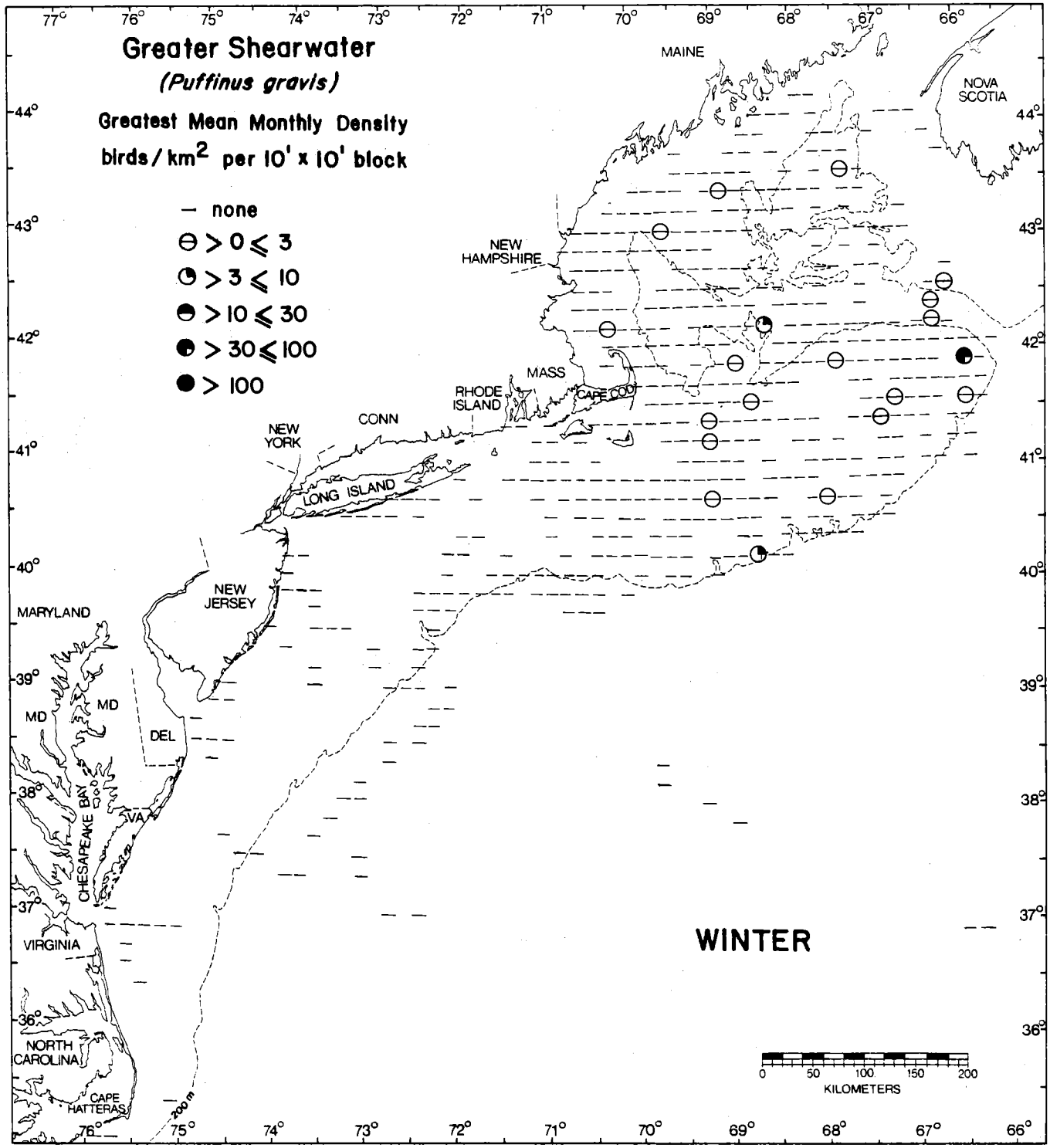

Fig. 22. Relative distribution and abundance of Greater Shearwaters (Puffinus gravis) in winter.

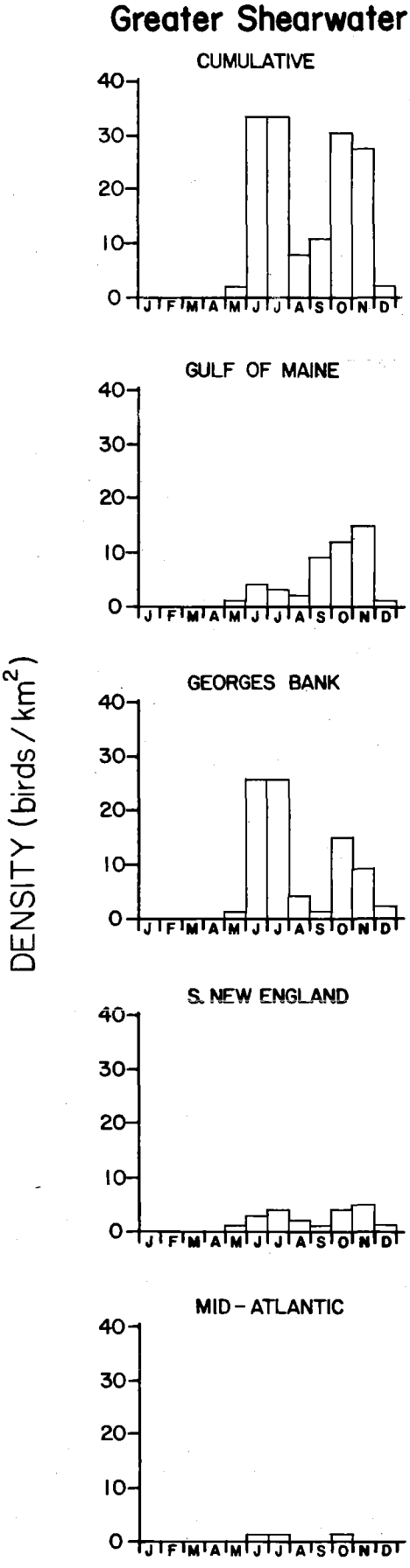

Fig. 23. Histogram of mean monthly densities of Greater Shearwaters (Puffinus gravis) by subarea and the entire study area (cumulative).

SOOTY SHEARWATER (Puffinus griseus)

Sooty Shearwaters breed in the Falklands and islands off southern South America, New Zealand, and southeast Australia (Watson 1975).

They feed at or near the surface as secondary and tertiary carnivores on fish, cephalopods, and crustaceans (Palmer 1962; Wiens and Scott 1975; Ainley and Sanger 1979; Brown et al. 1981). Although Sooty Shearwaters are sometimes observed among fishing vessels, their co-occurrence may be related to distributions of preferred "natural" prey there (Wahl and Heinemann 1979).

In the Atlantic, Sooty Shearwaters migrate across the equator to 'winter' (April to October) in boreal and low arctic waters of the North Atlantic, where they move in a clockwise-manner with the prevailing winds (Phillips 1963). Greatest densities in the study area were found on Georges Bank (Fig. 24-26). Concentrations of several hundred to a few thousand were noted on the northern parts of Georges Bank from the Great South Channel east to the Northeast Peak, and on Cox Ledge in the S. New England subarea. These concentrations were sometimes associated with fishing activity. Mean densities in the Gulf of Maine and the mid-Atlantic subareas never exceeded 1 bird/km^2.

The temporal distribution of Sooty Shearwaters was unimodal (Fig. 27). Birds began to arrive in late April, abundance peaked in June, and the majority of the population was out of the study area by mid-July. However, individual birds were regular but uncommon in the Great South Channel until December. A record in February suggests that some birds may overwinter in the North Atlantic (Appendix 8) (cf. Brown 1977).

Approximately 235,000 Sooty Shearwaters were present off the New England coast in early summer (June), when the peak in density was reached (Appendix 5). Estimates of the size of the world population have not been made, although it is probably in the millions. Since most of the world population winters in the North Pacific, it may be that only birds breeding in the Falklands migrate into the North Atlantic.

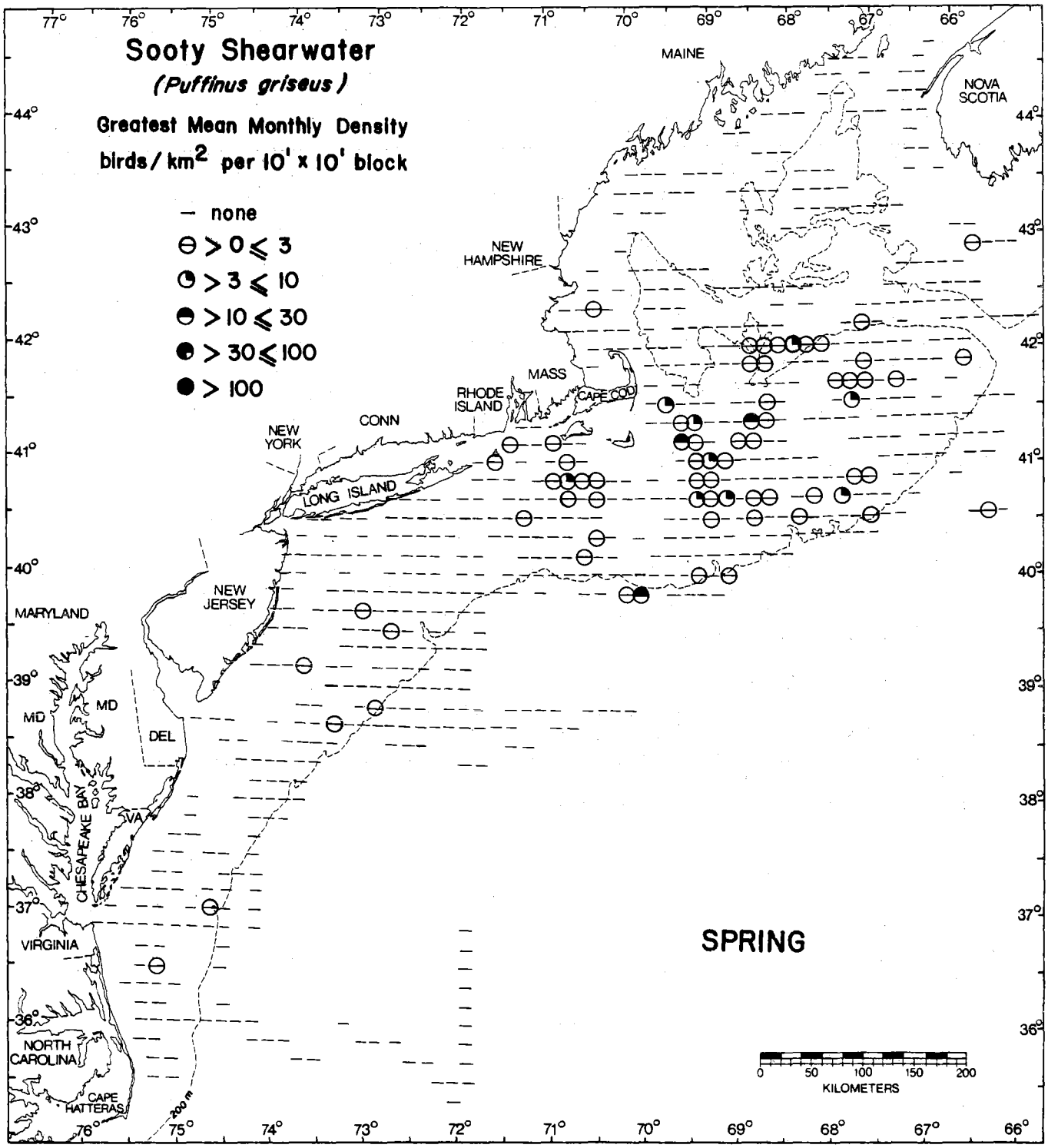

Fig. 24. Relative distribution and abundance of Sooty Shearwaters (Puffinus griseus) in spring.

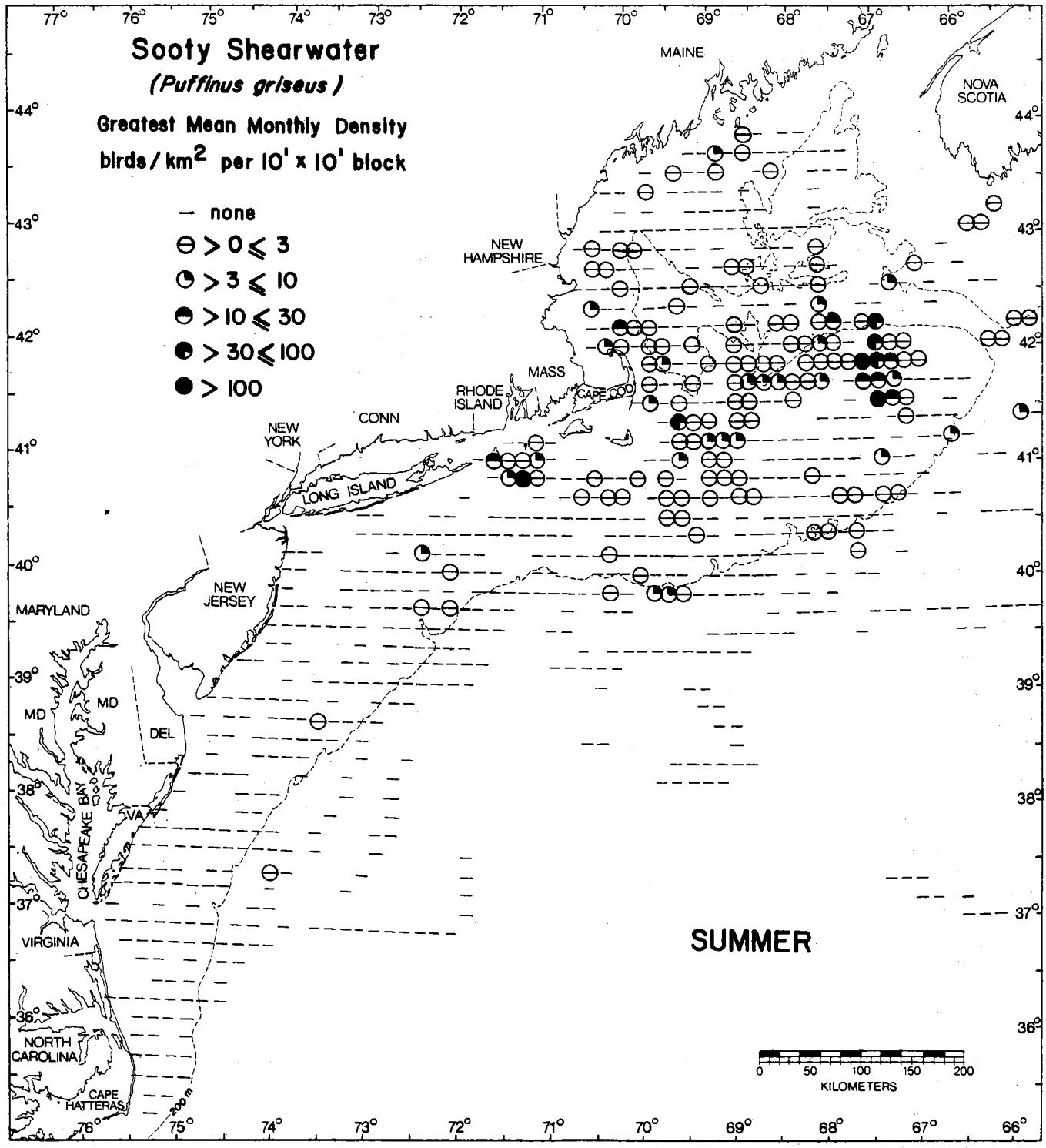

Fig. 25. Relative distribution and abundance of Sooty Shearwaters (Puffinus griseus) in summer.

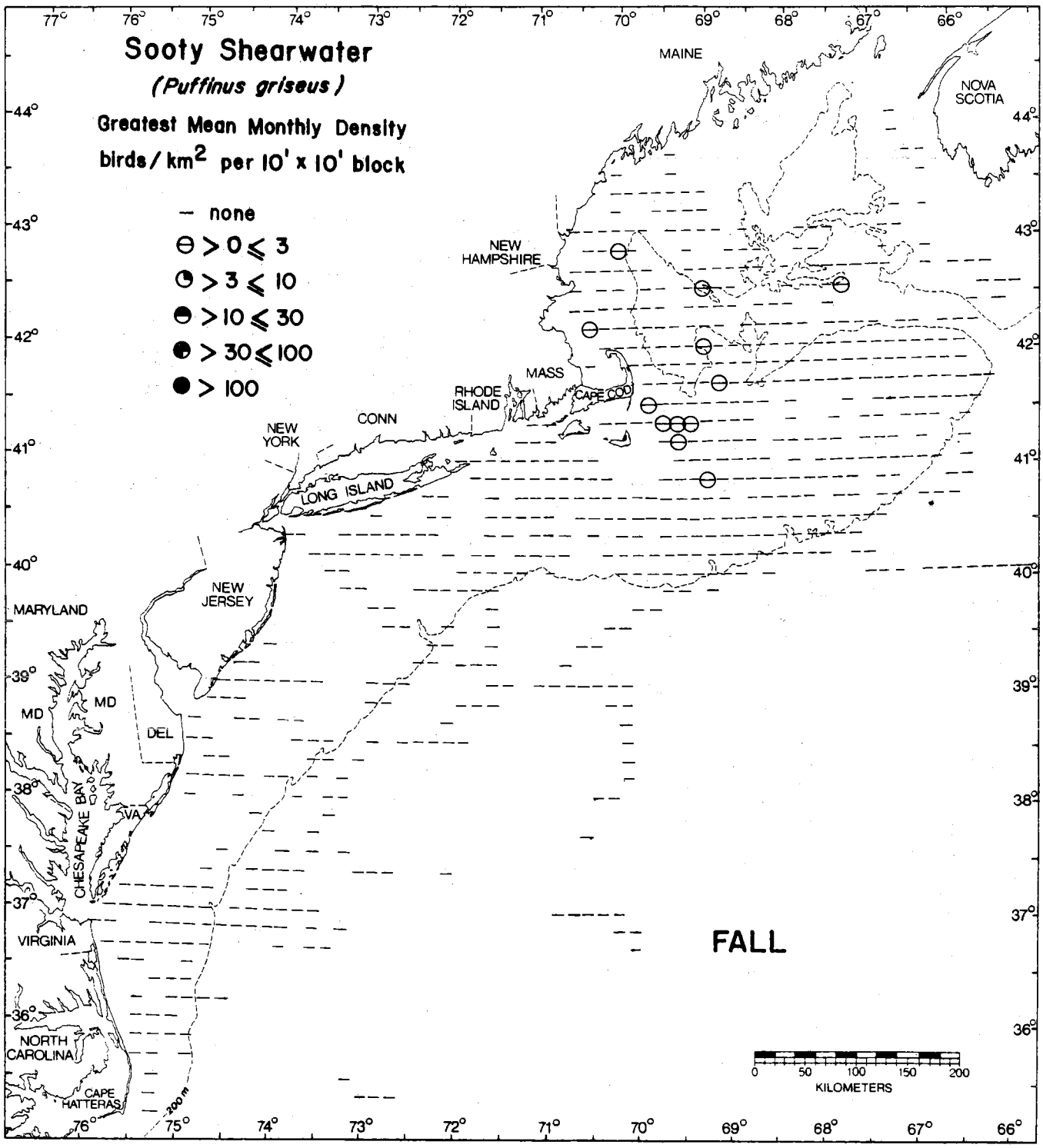

Fig. 26. Relative distribution and abundance of Sooty Shearwaters (Puffinus griseus) in fall.

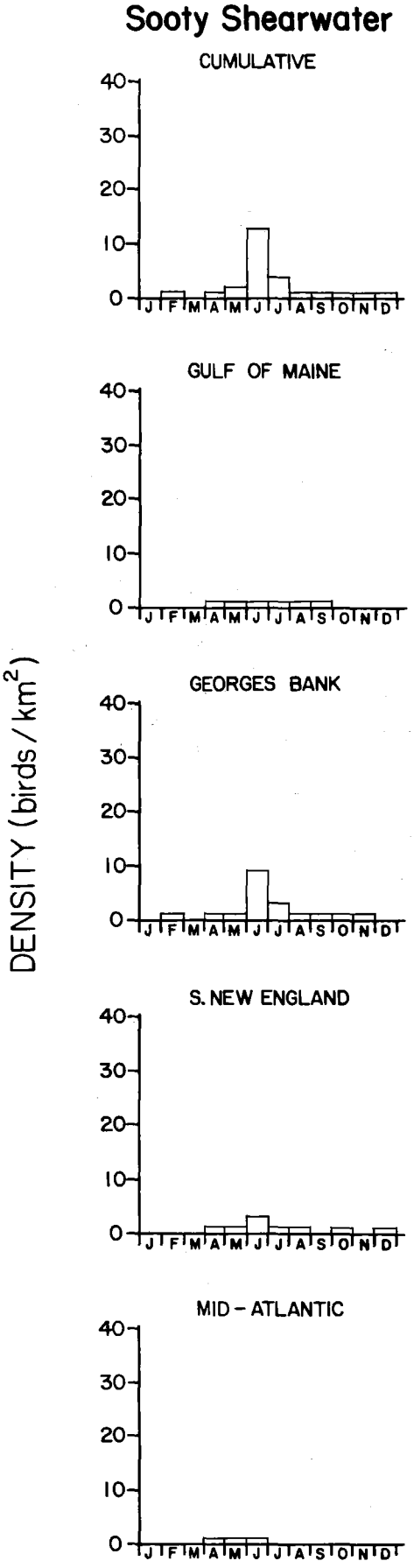

Fig. 27. Histogram of mean monthly densities of Sooty Shearwaters (Puffinus griseus) by subarea and the entire study area (cumulative).

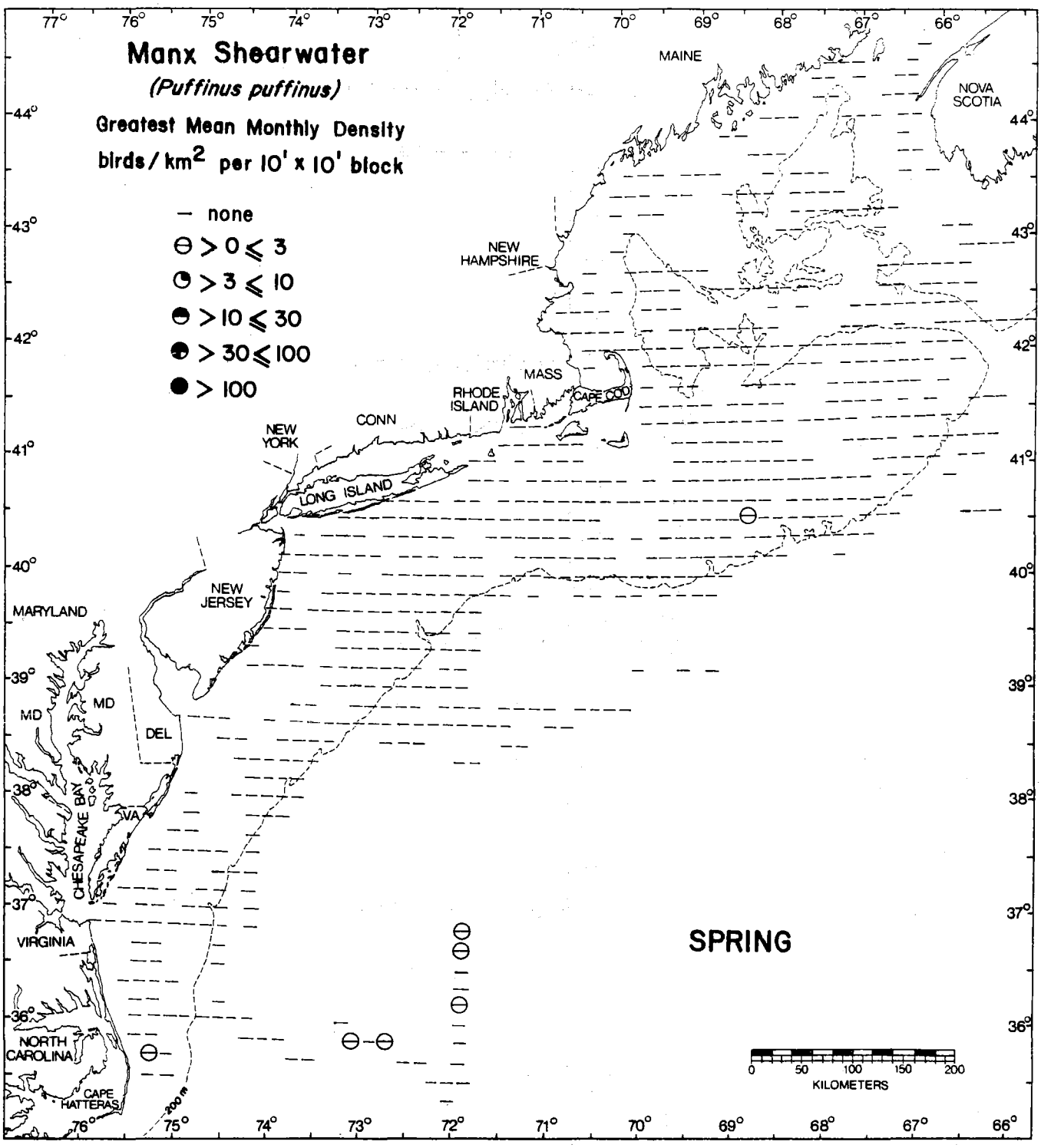

Fig. 28. Relative distribution and abundance of Manx Shearwaters (Puffinus puffinus) in spring.

MANX SHEARWATER (Puffinus puffinus)

The center of the Manx Shearwater breeding range in the Atlantic is in the east, Iceland to the Mediterranean and Black seas (Cramp et al. 1977). The species formerly bred on Bermuda (Palmer 1962). Recently, Manx Shearwater has been found breeding in Newfoundland (Lien and Grimmer 1978) and Massachusetts (Bierregaard et al. 1975). It is the eastern North Atlantic race P. p. puffinus that appears to be expanding its range in the western North Atlantic (cf. Snyder 1958).

Manx Shearwaters are secondary and tertiary carnivores, which feed on small fish, cephalopods, and crustaceans (Cramp et al. 1977). Bent (1922) noted that they also scavenge on offal.

They were uncommon in shelf waters from April to November, but were present in slope water in March (Fig. 28-30). Densities never exceeded 1 bird/km^2 in any subarea (Fig. 31). Sightings in spring were primarily limited to slope waters adjacent the mid-Atlantic shelf (cf. Post 1967). During summer and early fall, sightings of Manx Shearwaters were regular in shoal waters of Georges Bank west to Cox Ledge, and north to Stellwagen Bank. I question many of the Manx Shearwater identifications of this study made seaward of the shelf-break during summer (Fig. 29). This species can be confused with Audubon Shearwater (P. lherminieri), and the latter species is far more common in North Atlantic slope water (Post 1967; Brown 1977). Approximately 5,000 Manx Shearwaters were in shelf waters off the New England coast during summer and 2,000 during fall (Appendix 5).

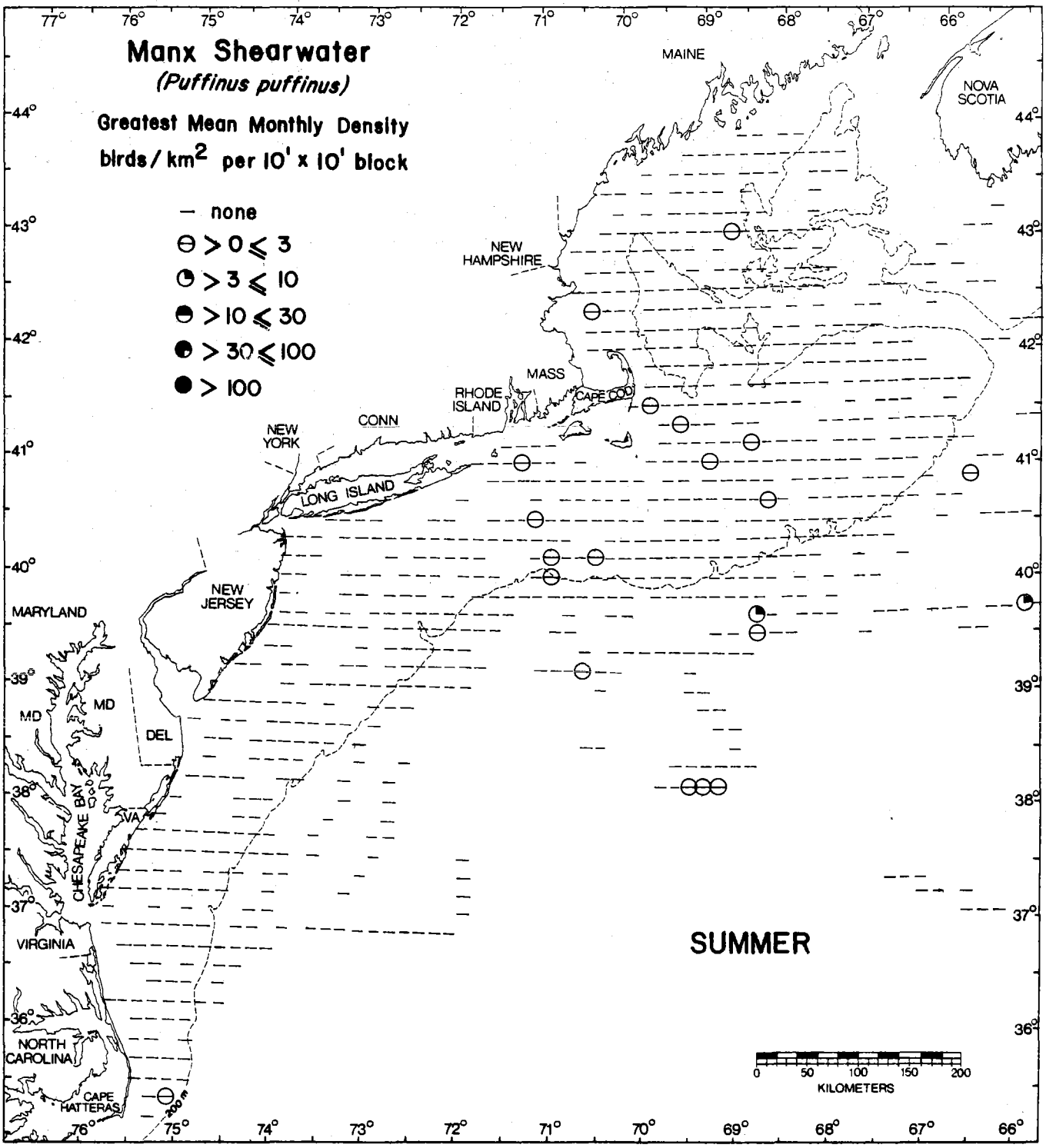

Fig. 29. Relative distribution and abundance of Manx Shearwaters (Puffinus puffinus) in summer.

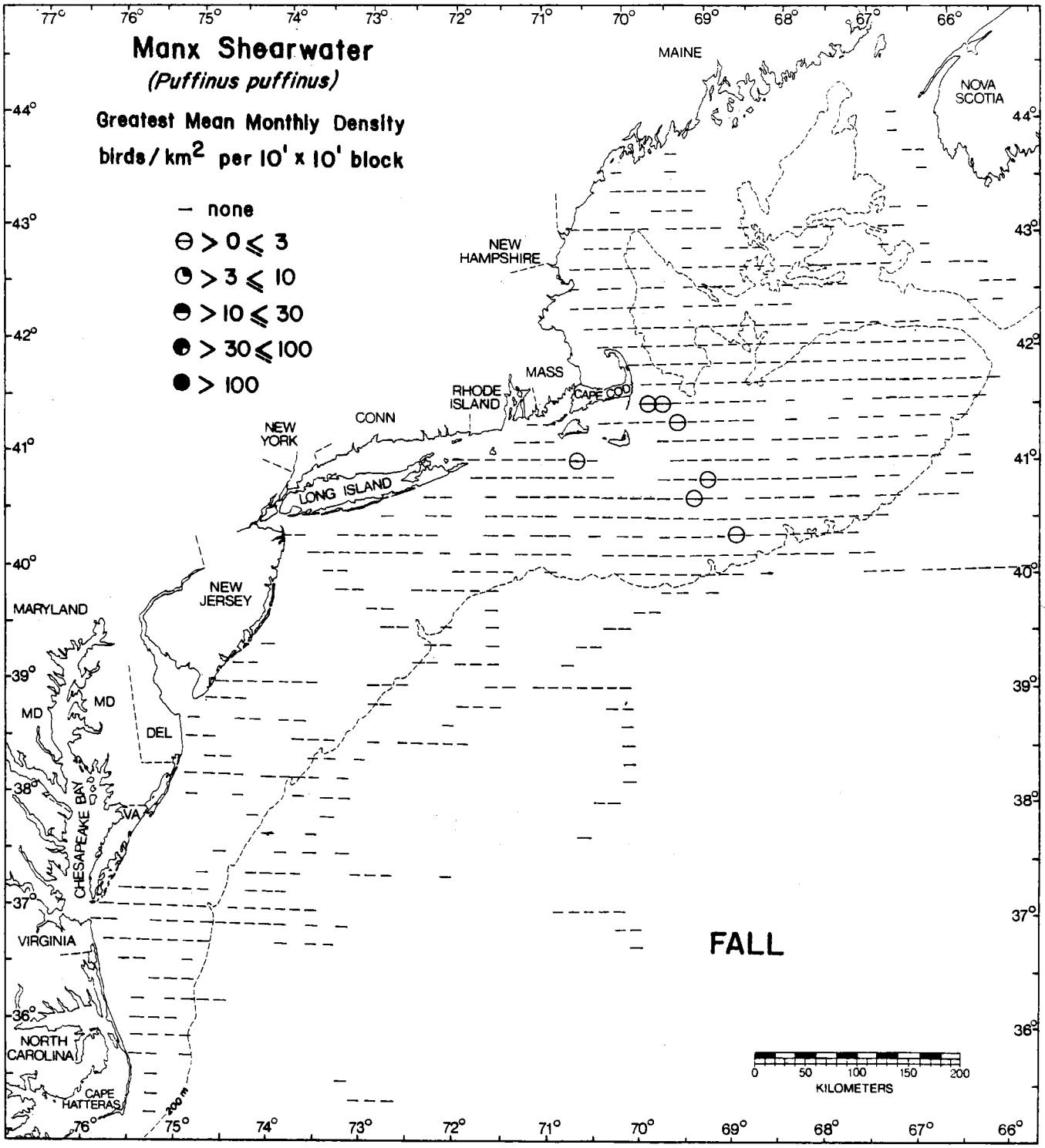

Fig. 30. Relative distribution and abundance of Manx Shearwaters (Puffinus puffinus) in fall.

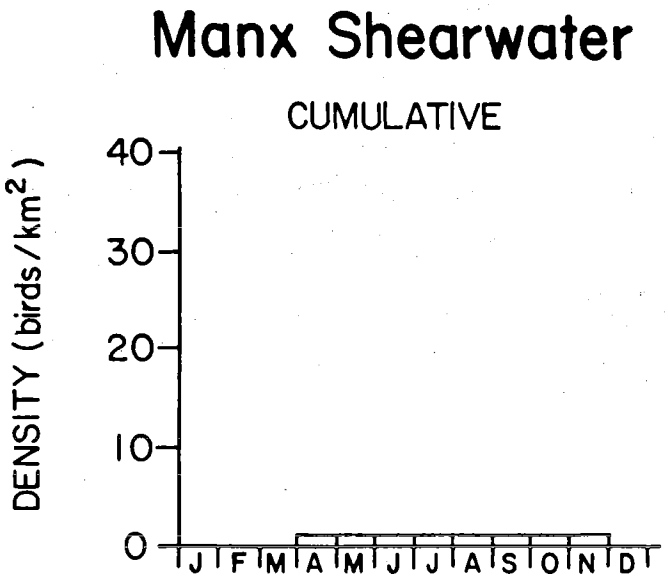

Fig. 31. Histogram of mean monthly densities of Manx Shearwaters (Puffinus puffinus) for the entire study area (cumulative).

AUDUBON'S SHEARWATER (Puffinus lherminieri)

Audubon's Shearwaters breed on islands in the Caribbean, the Bahamas, and elsewhere in the tropics. A Bermuda population is almost extinct (Palmer 1962). Only the nominate race P. l. lherminieri is known in the western North Atlantic (Palmer 1962).

Audubon's Shearwaters are tertiary carnivores, which feed on small fish and cephalopods (Palmer 1962).

They were uncommon in shelf waters of the Georges Bank, S. New England, and mid-Atlantic subareas from August to October (Fig. 32-34), and were present in slope water from early June to November. Their occurrence in shelf water appeared to correlate with summer intrusions of slope water onto the shelf south of Cape Cod (cf. Gordon 1955). However, they were most common in slope water during summer and fall (cf. Brown 1977), when several flocks exceeding 100 birds were noted there in July and September. The population of Audubon's Shearwaters was estimated at approximately 2,000 birds on the shelf in summer (Appendix 5).

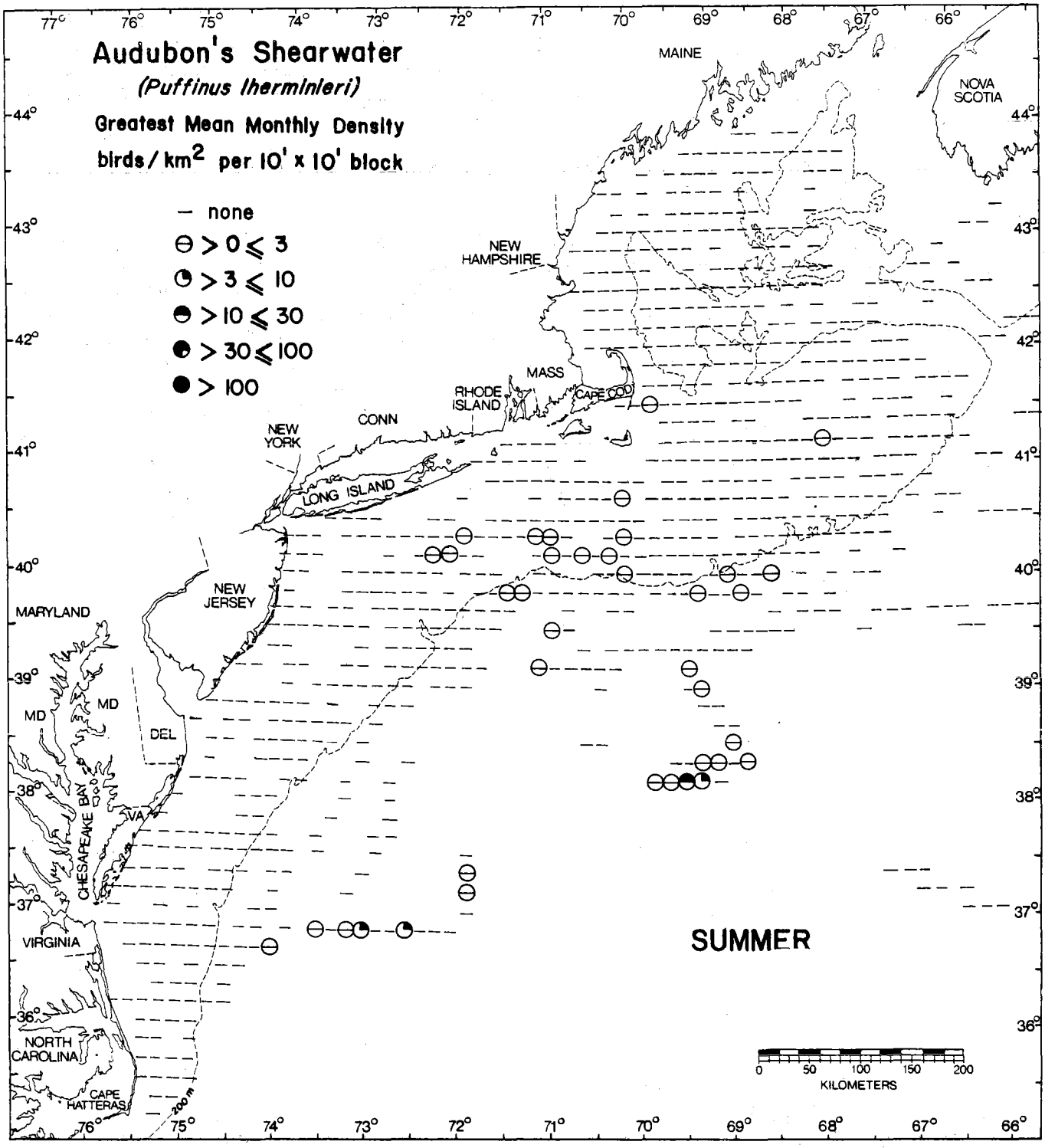

Fig. 32. Relative distribution and abundance of Audubon's Shearwaters (Puffinus lherminieri) in summer.

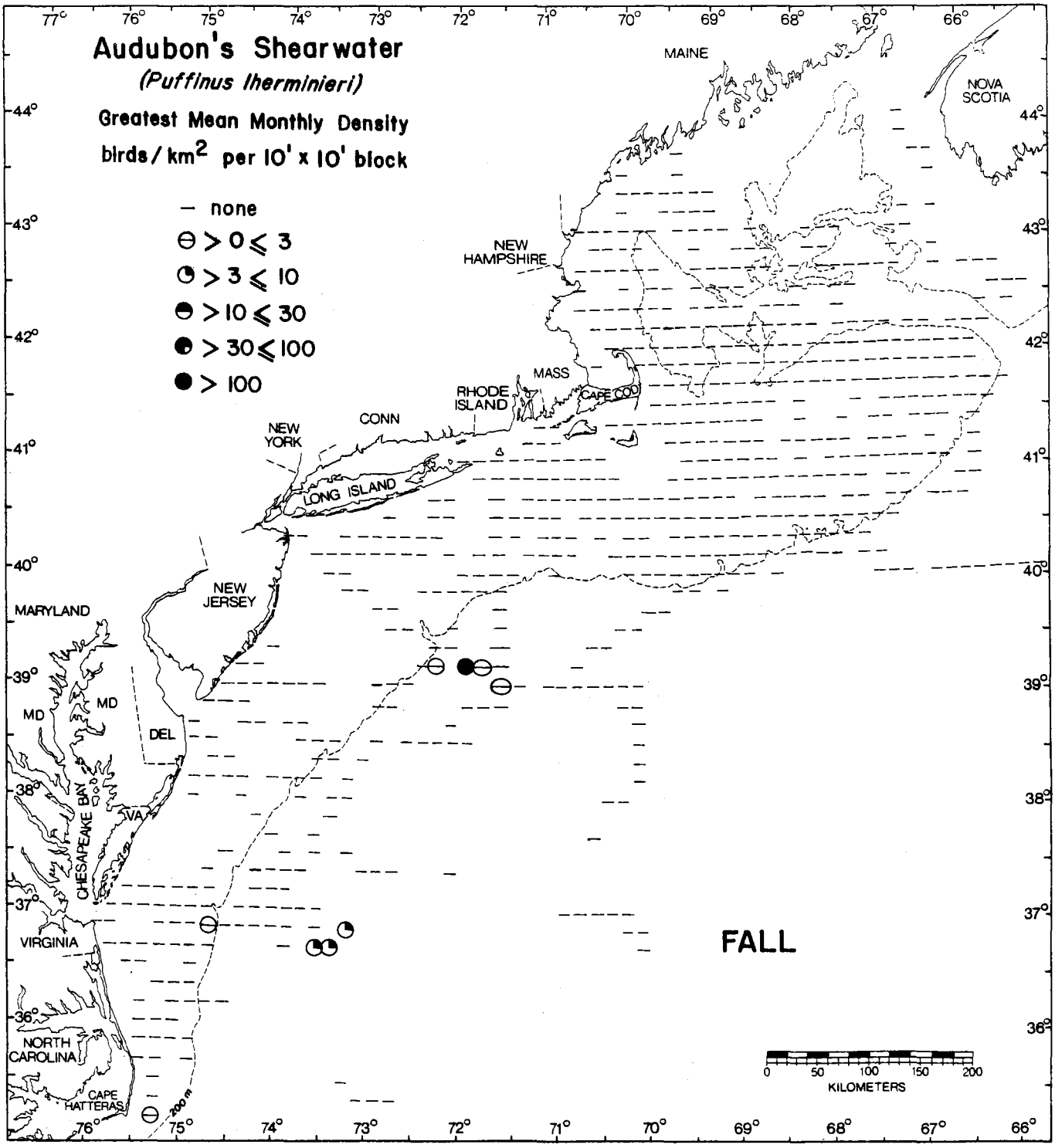

Fig. 33. Relative distribution and abundance of Audubon's Shearwaters (Puffinus lherminieri) in fall.

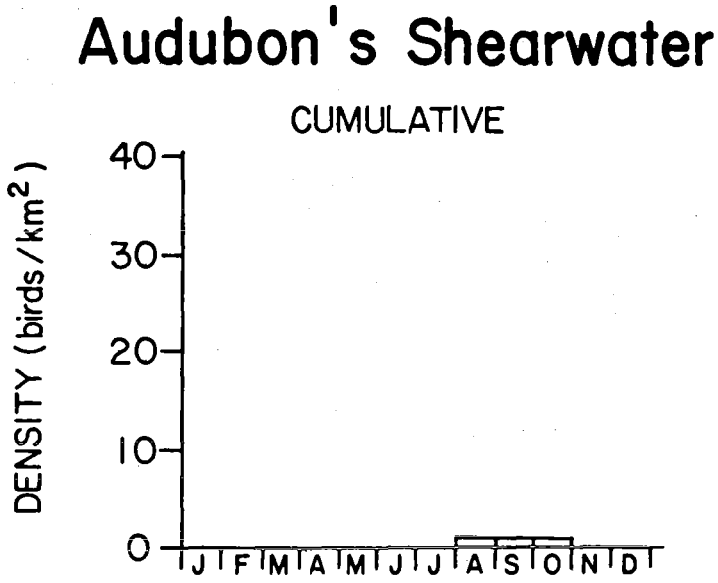

Fig. 34. Histogram of mean monthly densities of Audubon's Shearwaters (Puffinus lherminieri) for the entir study area (cumulative).

BLACK-CAPPED PETREL (Pterodroma hasitata)

In the Atlantic, Black-capped Petrels breed around summits of inland mountains on Guadeloupe, Dominica (Palmer 1962), and Hispaniola (Wingate 1964). A small colony of the closely allied Bermuda Petrel (P. cahow) breeds on Bermuda (Murphy and Mowbray 1951).

Little is known of the pelagic range of the Black-capped Petrel but it is believed to include much of the western North Atlantic south of 40°N latitude (Palmer 1962; Murphy 1967). Numerous sight records off the coast of North Carolina (Lee and Booth 1979; Lee and Rowlett 1979) and scattered sightings from the Sargasso Sea (Wetmore 1927; Morzer Bruyns 1967; Brown 1977) indicate that the northern limit of the pelagic range of capped petrels is farther south of 40°N. In this study, Black-capped Petrels were rare north of 35°N (Appendix 8) except for a cruise in August-September 1979 (Appendix 9). Their distribution in that cruise often correlated with the location of the Gulf Stream.

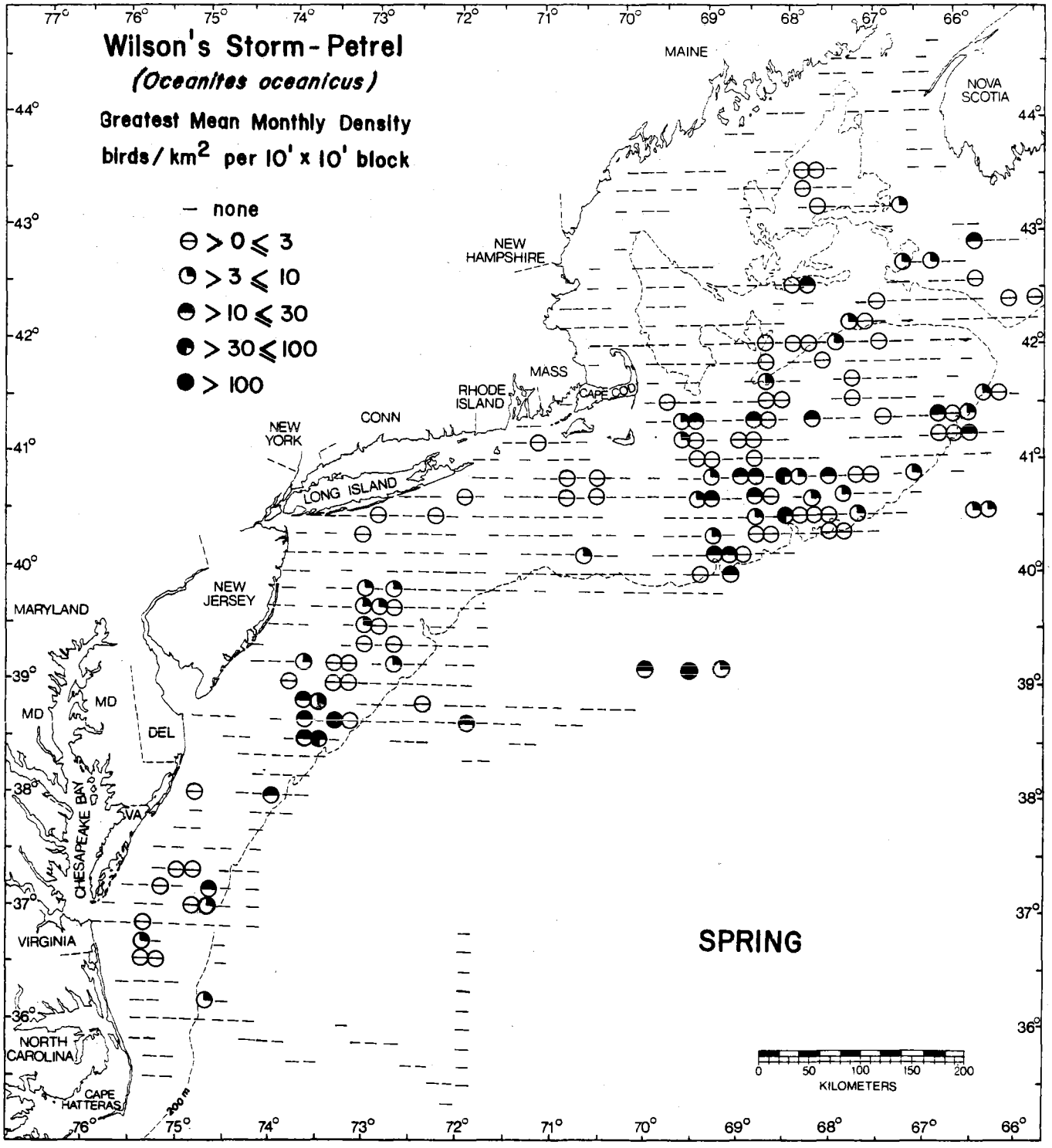

Fig. 35. Relative distribution and abundance of Wilson's Storm-Petrels (Oceanites oceanicus) in spring.

WILSON'S STORM-PETREL (Oceanites oceanicus)

Wilson's Storm-Petrels breed on Tierra del Fuego and the Falklands in South America, on the continent and peninsula of Antarctica and adjacent offshore islands (Palmer 1962; Watson 1975). They are present at antarctic and subantarctic colonies from November to mid-April, and during this period their pelagic distribution is mainly south of 50°S (Cramp et al. 1977).

Wilson's Storm-Petrels feed chiefly at the surface as secondary carnivores on zooplankton, euphausiids (Roberts 1940) and amphipods (Falla 1937), and to a lesser extent as tertiary carnivores on small fish and cephalopods (Witherby et al. 1940; Watson 1966). They are also scavengers on offal from whaling stations in the Antarctic (Murphy 1936) and from fishing vessels in the North Atlantic (Bent 1922).

In the Atlantic, northward migration (post-breeding) is mainly up the west side beginning in late April (Roberts 1940) and most cross the equator by mid-June (Cramp et al. 1977). In spring, Wilson's Storm-Petrels were most abundant along the shelf-break from Chesapeake Bay to the Northeast Channel with greatest densities in the mid-Atlantic subarea (Fig. 35). By late May to early June, large flocks of one to several thousand were common in the Gulf of Maine (Fig. 36). During summer, greatest densities were consistently found in the western Gulf of Maine south to the Great South Channel and east along the Northern Edge of Georges Bank. Redfield (1941) noted that the timing of Wilson's Storm-Petrel occurrence in the Gulf of Maine correlated with a seasonal peak in abundance of zooplankton. Flocks of several hundred to sometimes a few thousand were also found during summer at Cox Ledge to the west of Nantucket Shoals. Their distribution in fall was patchy and limited to the edges of Georges Bank and along the shelf-break (Fig. 37).

Wilson's Storm-Petrels first arrived in April (Fig. 38). In May, density abruptly increased from 1 to 19 birds/km^2 in the mid-Atlantic subarea. By June, the summer population peaked with over 30 birds/km^2 in the Gulf of Maine; however, the cumulative mean density (22 to 37 birds/km^2) indicated a fairly stable population from May through August for the entire study area (Fig. 38). In September, densities declined to less than 1 bird/km^2 for any subarea (Fig. 38). Late stragglers were noted along the shelf-break into mid-November.

Approximately 1.5 million Wilson's Storm-Petrels were present in shelf waters off the northeastern United States during summer (Appendix 5). Thus Wilson's Storm-Petrel was the most numerous bird in these waters during any single season. This corroborates accounts by Roberts (1940), Brown et al. (1975), Brown (1977), and Cramp et al. (1977) which indicated that the waters off New England are the most important wintering area for the Wilson's Storm-Petrel population that migrates into the North Atlantic.

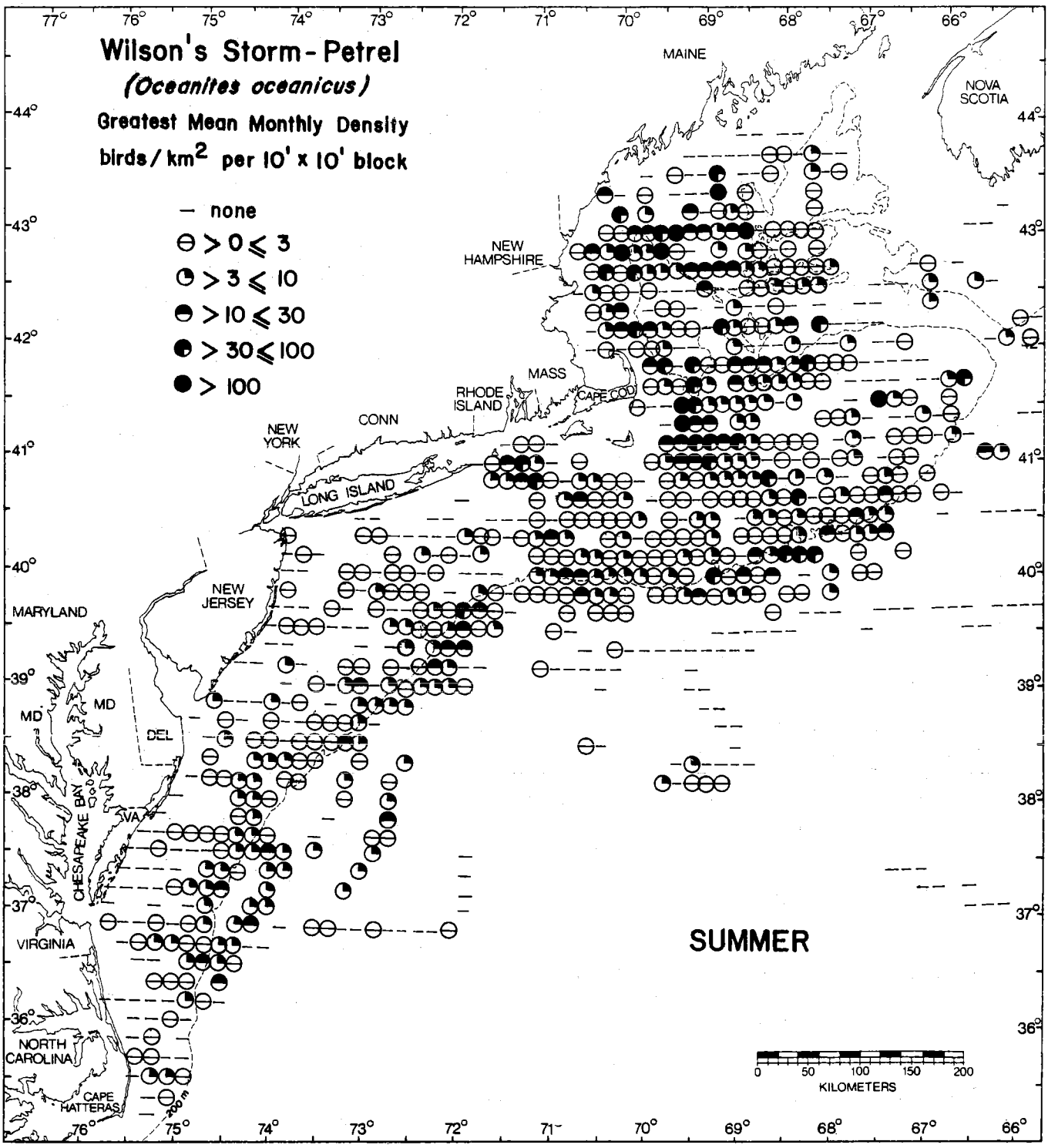

Fig. 36. Relative distribution and abundance of Wilson's Storm-Petrels (Oceanites oceanicus) in summer.

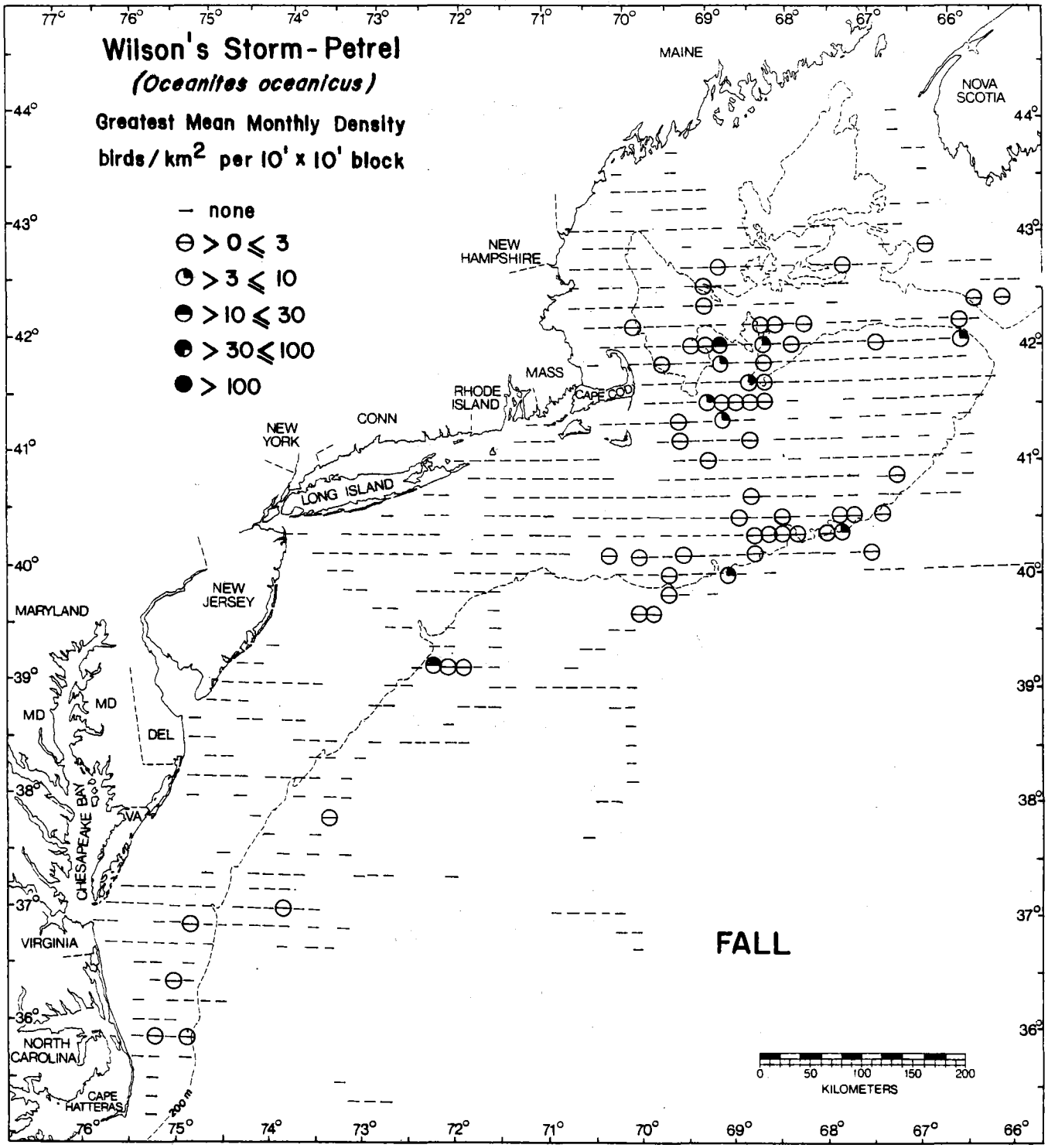

Fig. 37. Relative distribution and abundance of Wilson's Storm-Petrels (Oceanites oceanicus) in fall.

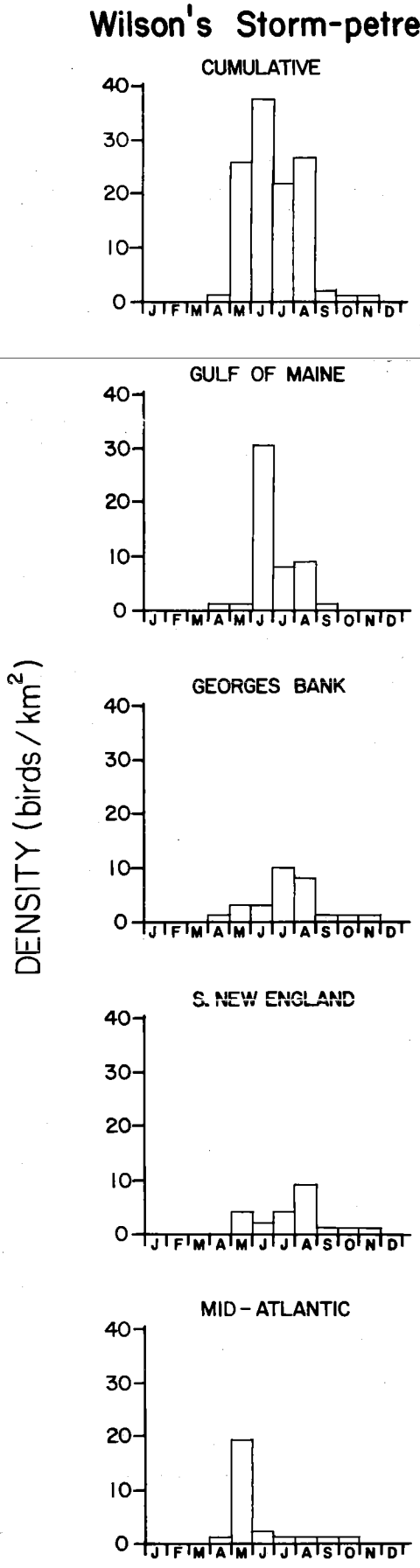

Fig. 38. Histogram of mean monthly densities of Wilson's Storm-Petrels (Oceanites oceanicus) by subarea and the entire study area (cumulative).

LEACH'S STORM-PETREL (Oceanodroma leucorhoa)

The center of the breeding range of Leach's Storm-Petrels in the western North Atlantic is in eastern Newfoundland, although colonies exist from Cape Cod (Penikese I.) to southern Labrador (Drury 1973-74, Godfrey 1966).

They feed at the surface as secondary and tertiary carnivores chiefly on planktonic crustaceans, molluscs and small fish (Cramp et al. 1977). Fish, notably myctophids, followed by a euphausiid (Meganyctiphanes norvegica) and amphipod (Hyperia galba) were the most important food items of Leach's Storm-Petrels breeding in Nova Scotia and Newfoundland (Linton 1978). Their prey preferences suggest that these birds feed extensively at night (Wynne-Edwards 1935; Linton 1978).

Spring arrivals were noted from late April to early May (Fig. 38-39). The species was most common during summer on the southern Scotian shelf and on slope water seaward of the shelf-break from 65° to 72° W (Fig. 41). Brown (1977) found Leach's Storm-Petrels most abundant in colder boreal waters adjacent to the center of its breeding range, eastern Newfoundland and Nova Scotia. However, both he and Butcher et al. (1968) also noted their presence in the warmer slope water beyond the shelf-break; but, this species can be confused with Wilson's Storm-Petrel. Fall movements were not clear but late migrants were recorded into November (Fig. 40 and 42). The peak of the fall passage probably occurs in late August (Lincoln 1934; Palmer 1962).

The population of Leach's Storm-Petrels in shelf waters off the New England coast was estimated at approximately 22,000 during summer (Appendix 5).

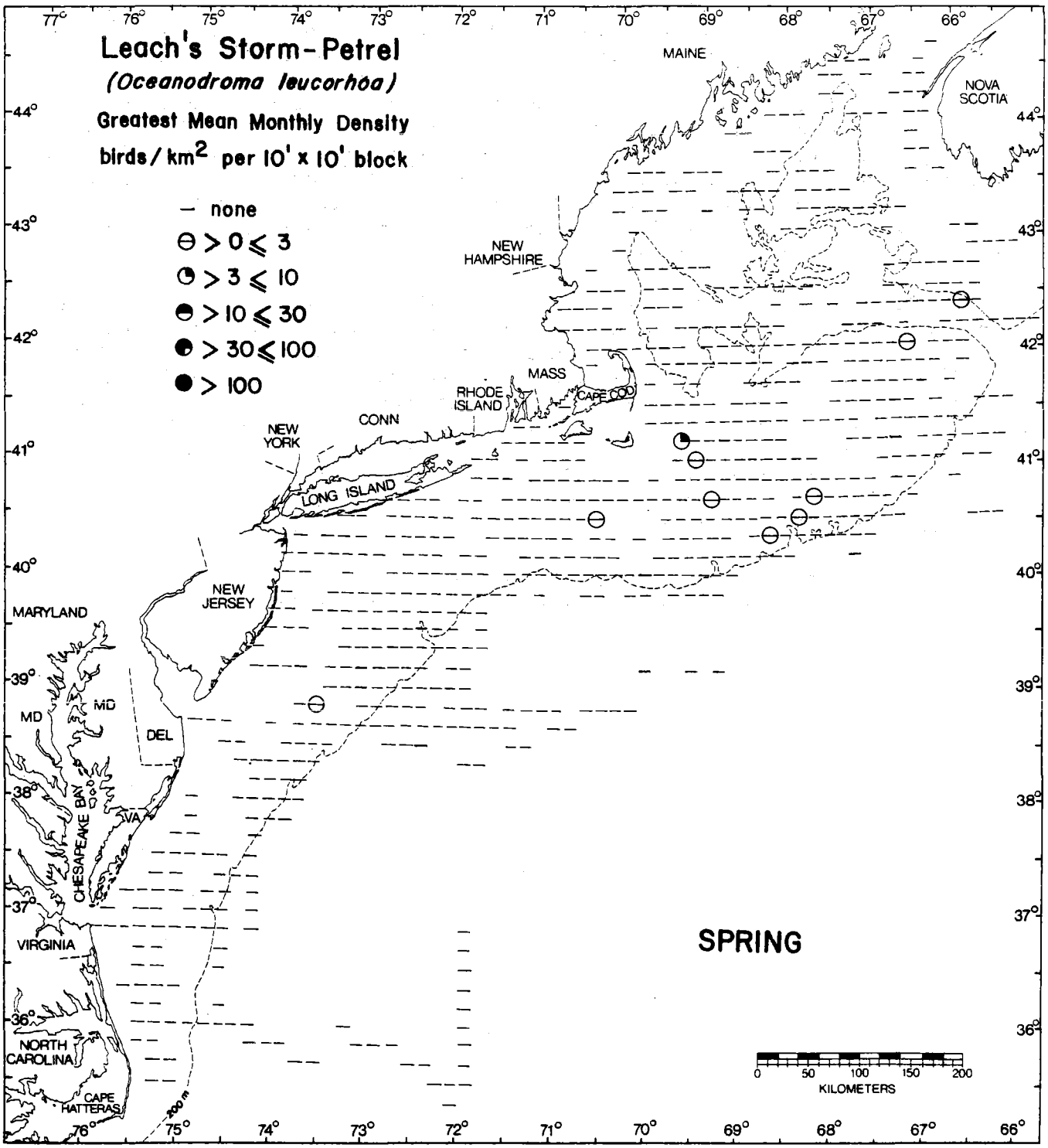

Fig. 39. Relative distribution and abundance of Leach's Storm-Petrels (Oceanodroma leucorhoa) in spring.

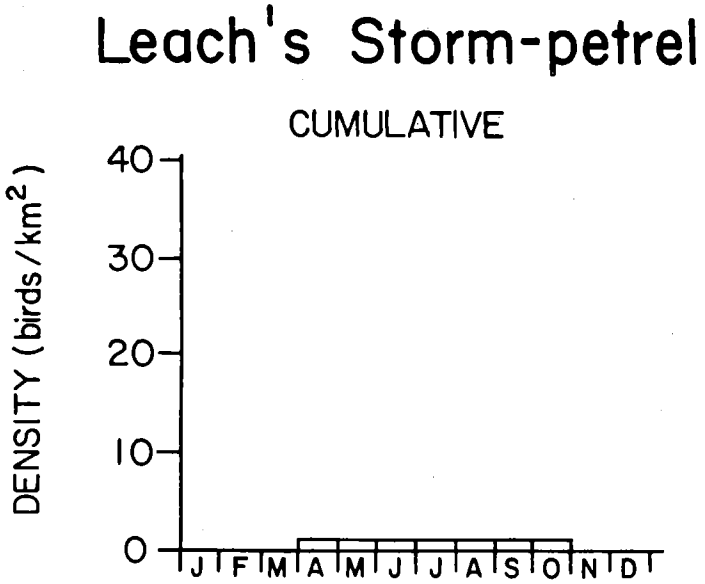

Fig. 40. Histogram of mean monthly densities of Leach's Storm-Petrels (Oceanodroma leucorhoa) for the entire study area (cumulative).

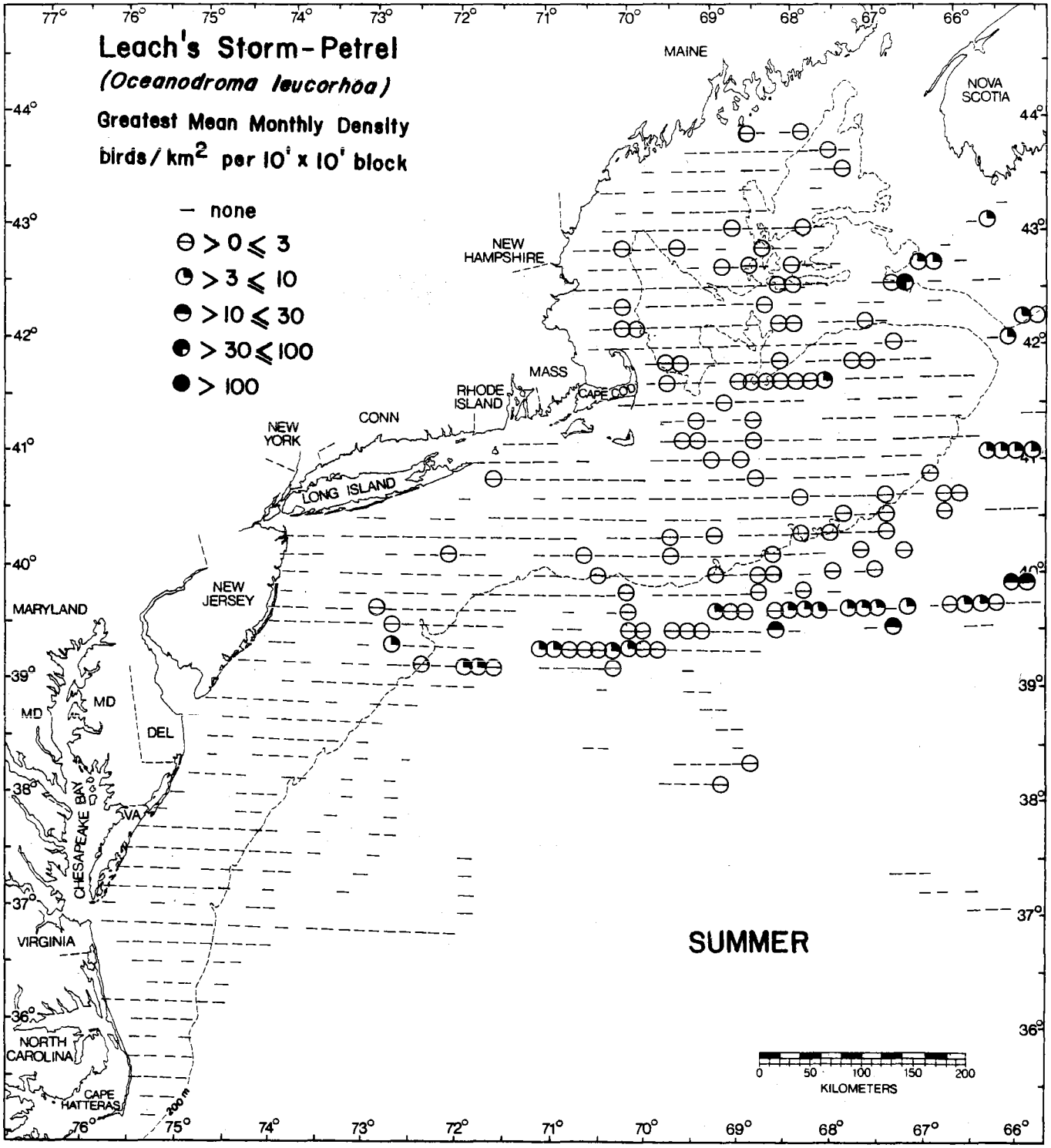

Fig. 41. Relative distribution and abundance of Leach's Storm-Petrels (Oceanodroma leucorhoa) in summer.

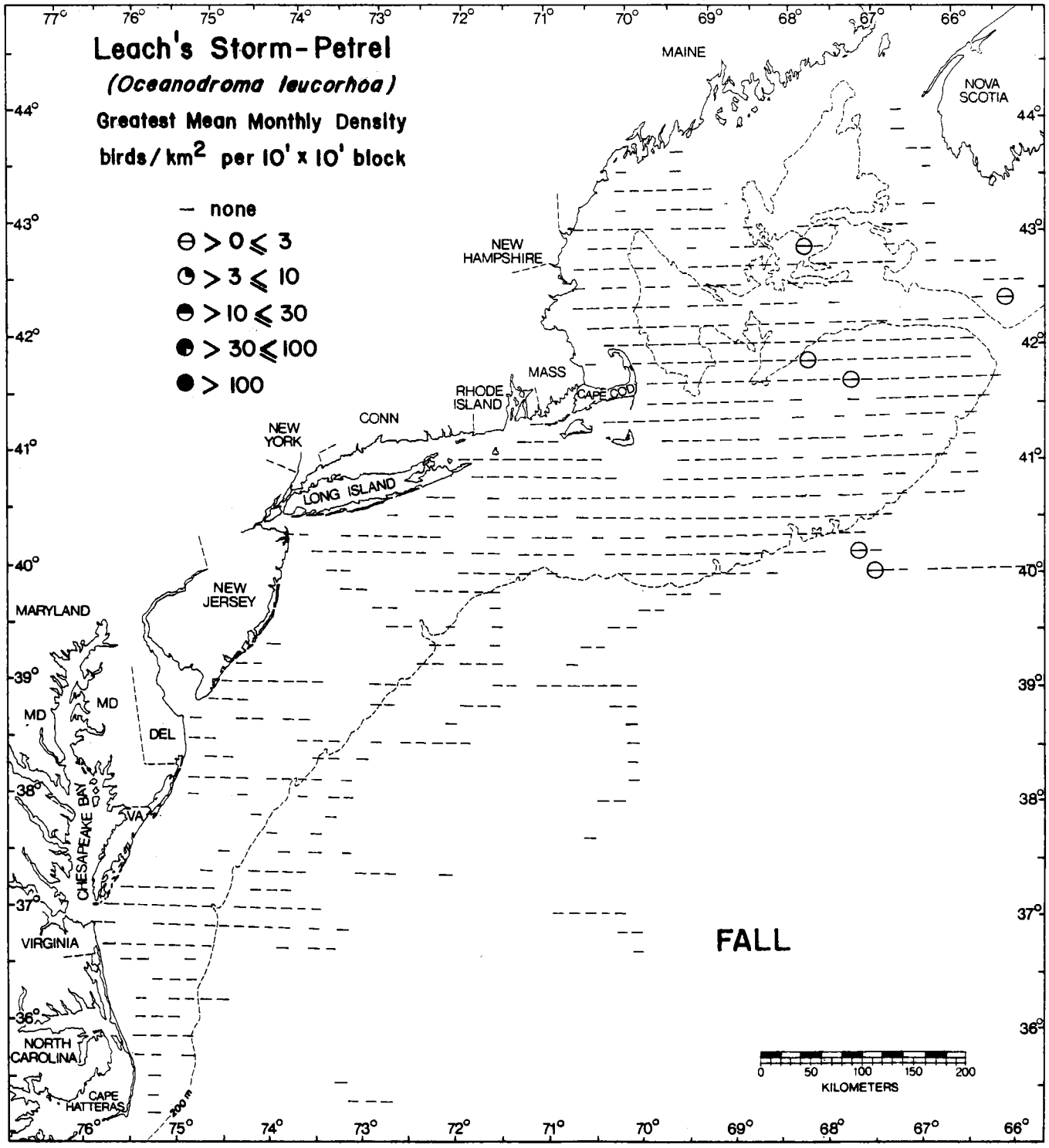

Fig. 42. Relative distribution and abundance of Leach's Storm-Petrels (Oceanodroma leucorhoa) in fall.

WHITE-FACED STORM-PETREL (Pelagodroma marina)

White-faced Storm-Petrels breed in the Selvagems, Cape Verde Islands, and Tristan group (Watson 1966; Cramp et al. 1977).

Sight records scattered far to the west and north of known colonies, mostly from August to October, suggest post-breeding dispersal extends into the central and western North Atlantic (Brown 1977; Cramp et al. 1977). Two sightings recorded in this study support that hypothesis. One bird was seen 250 km SE of Ocean City, Maryland on 30 August 1979, and another was seen 160 km E of Atlantic City, New Jersey on 19 September 1979 (Appendix 8).

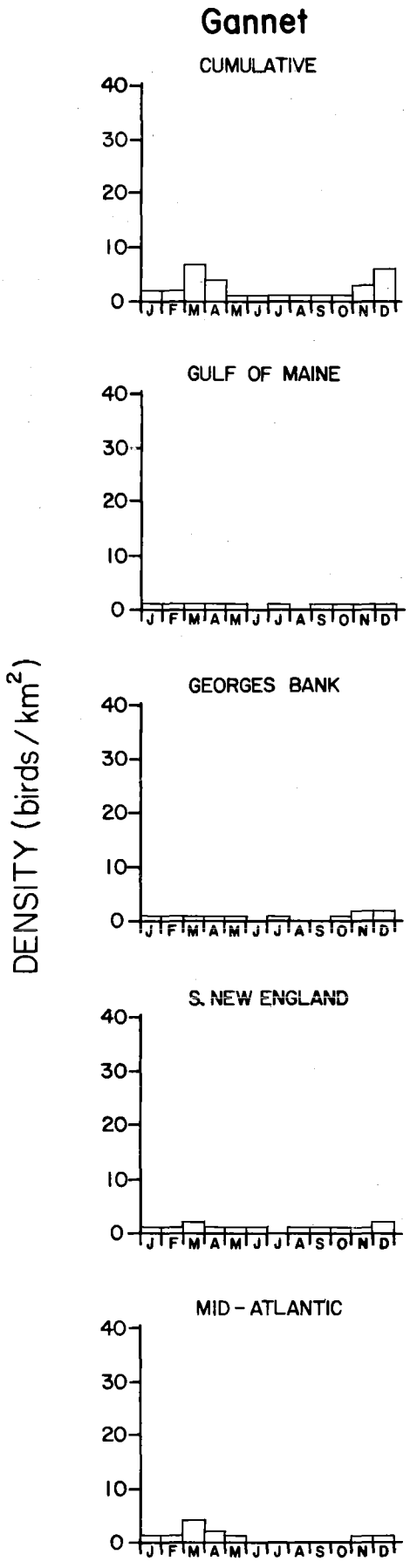

Fig. 43. Histogram of mean monthly densities of Northern Gannets (Sula bassanus) by subarea and the entire study area (cumulative).

NORTHERN GANNET (Sula bassana)

The North American population of gannets breed only off eastern Newfoundland and in the Gulf of St. Lawrence (Brown et al. 1975). It also formerly bred at two sites in the Bay of Fundy until ca. 1880 when these colonies were exterminated by man (Bent 1922).

Gannets feed as tertiary carnivores mainly on schooling fish (Palmer 1962) and to a much lesser extent on squids (Palmer 1962; K. D. Powers, unpubl. data). Gannets scavenge offal from fishing vessels (Palmer 1962), but they will also take fish from fishing-nets near the surface (Cramp et al. 1977).

During summer gannets frequent boreal and southern low-arctic waters adjacent to breeding colonies off eastern Canada (Brown et al. 1975). During winter they are visitors to cool subtropical waters off eastern United States and warm tropical waters of the Gulf of Mexico and Caribbean Sea (Palmer 1962; Butcher et al. 1968).

During spring, migration began by late March and peaked in mid-April (Fig. 43-44). The adult movement northwards across Georges Bank occurred before any noticeable increase in immatures. By May the vast majority of gannets off the New England coast were immatures. Some immatures remained in the Gulf of Maine and Bay of Fundy throughout the summer (Fig. 45).

In late October, gannets began to pass south of Nova Scotia and cross the Gulf of Maine to the New England coast from approximately Jeffreys Ledge off New Hampshire south to Nantucket Island (Fig. 46). In November, several flocks of thousands were found from Stellwagen Bank and around Cape Cod to the Great South Channel. By December, gannets were abundant in the mid-Atlantic subarea (Fig. 43 and 47). Mostly adults remained north of Cape Hatteras throughout the winter. Rowlett (1980) indicated that 75 to 85 percent of gannets in the northern Chesapeake Bight (Ocean City, MD east to Baltimore Canyon) from December to March were adults. The immatures apparently continued south since they are the dominant age cohort in the Gulf of Mexico (Lowrey and Newman 1954). During winter, gannets often aggregated around trawlers fishing along the shelf-break between Hudson and Hydrographer canyons.

Approximately 168,000 gannets were estimated in shelf waters off the northeastern United States during winter, and 186,000 in spring (Appendix 5). Nettleship (1976) estimated the breeding population of gannets in North America at c. 65,000 (32,731 pair), an estimate which does not account for subadults and juveniles. Although my population estimate should be indicative of the entire North American population, because virtually all gannets emigrate from Canadian waters by winter, it appears to be 30-40 percent too high. Given Nelson's (1978) breeding success and survivorship data for the Bass Rock colony, one may expect approximately 45 percent of a given breeding population of gannets to be nonbreeders (less than 5 years old). Thus, Nettleship's estimate for the size of the North American breeding population of gannets indicates that the total population should be in the order of 120,000 to 125,000 birds, not 168,000 to 186,000. An immigration of European gannets might explain this discrepancy, but there is no evidence to support such a theory.

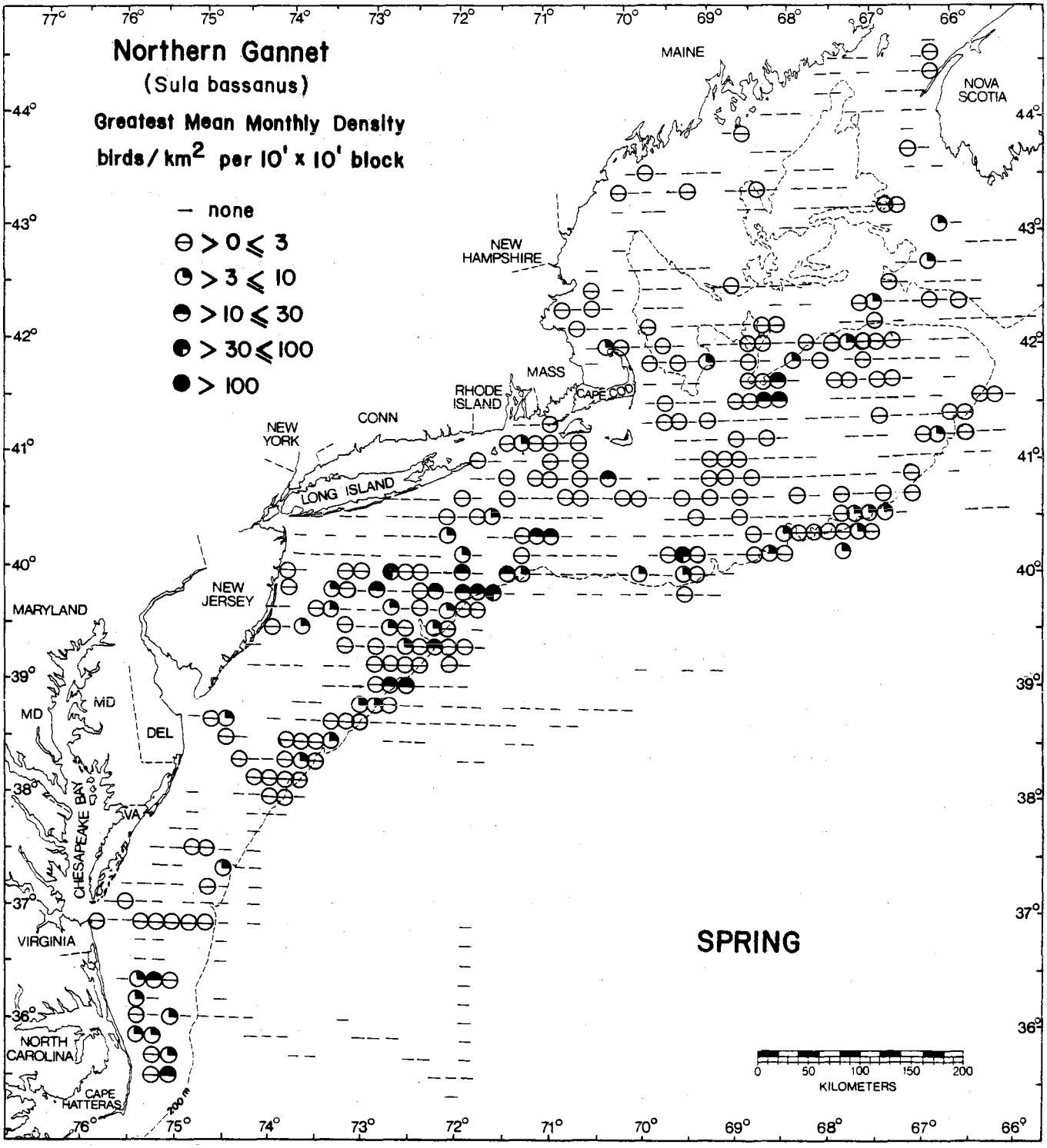

Fig. 44. Relative distribution and abundance of Northern Gannets (Sula bassanus) in spring.

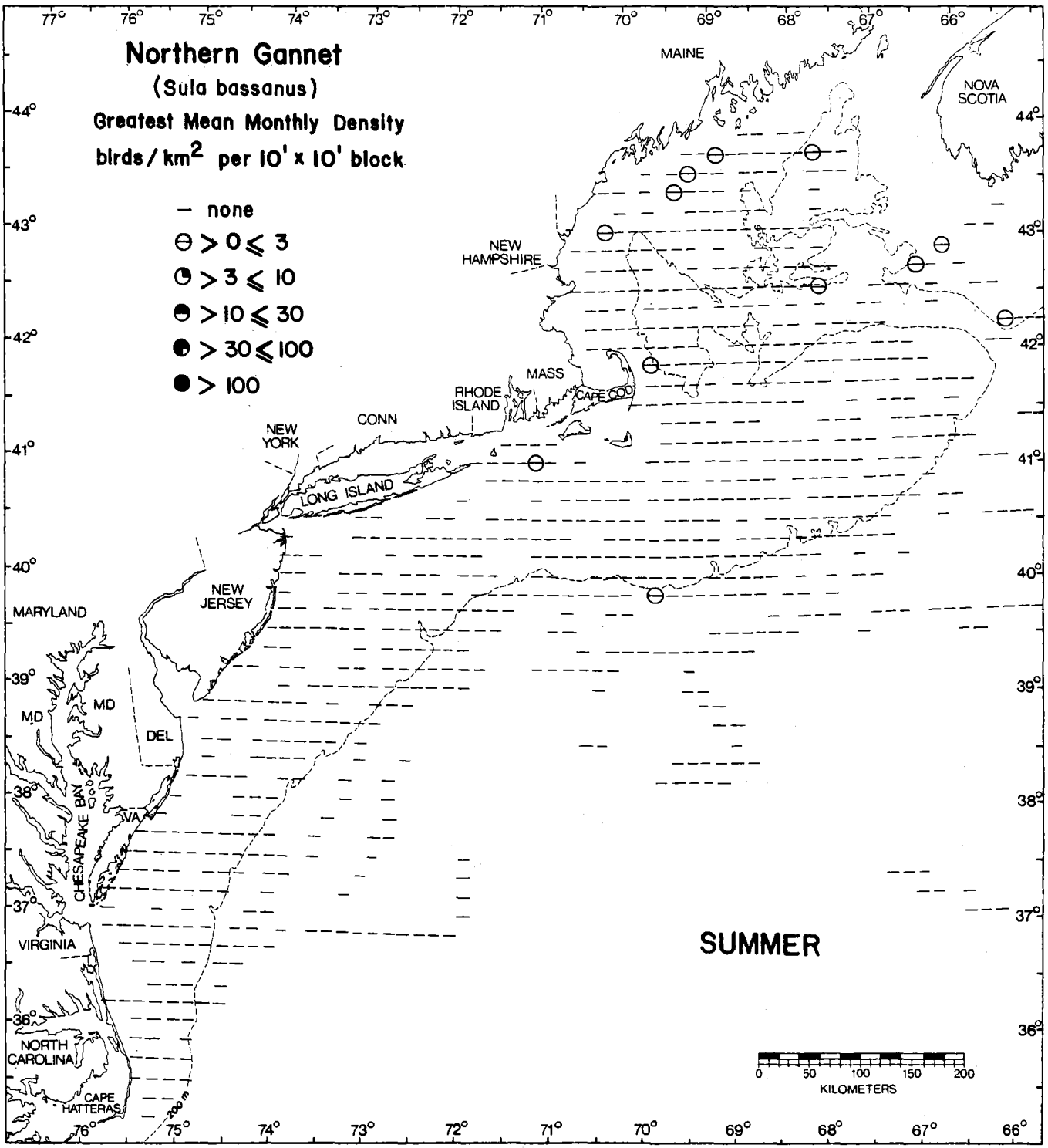

Fig. 45. Relative distribution and abundance of Northern Gannets (Sula bassanus) in summer.

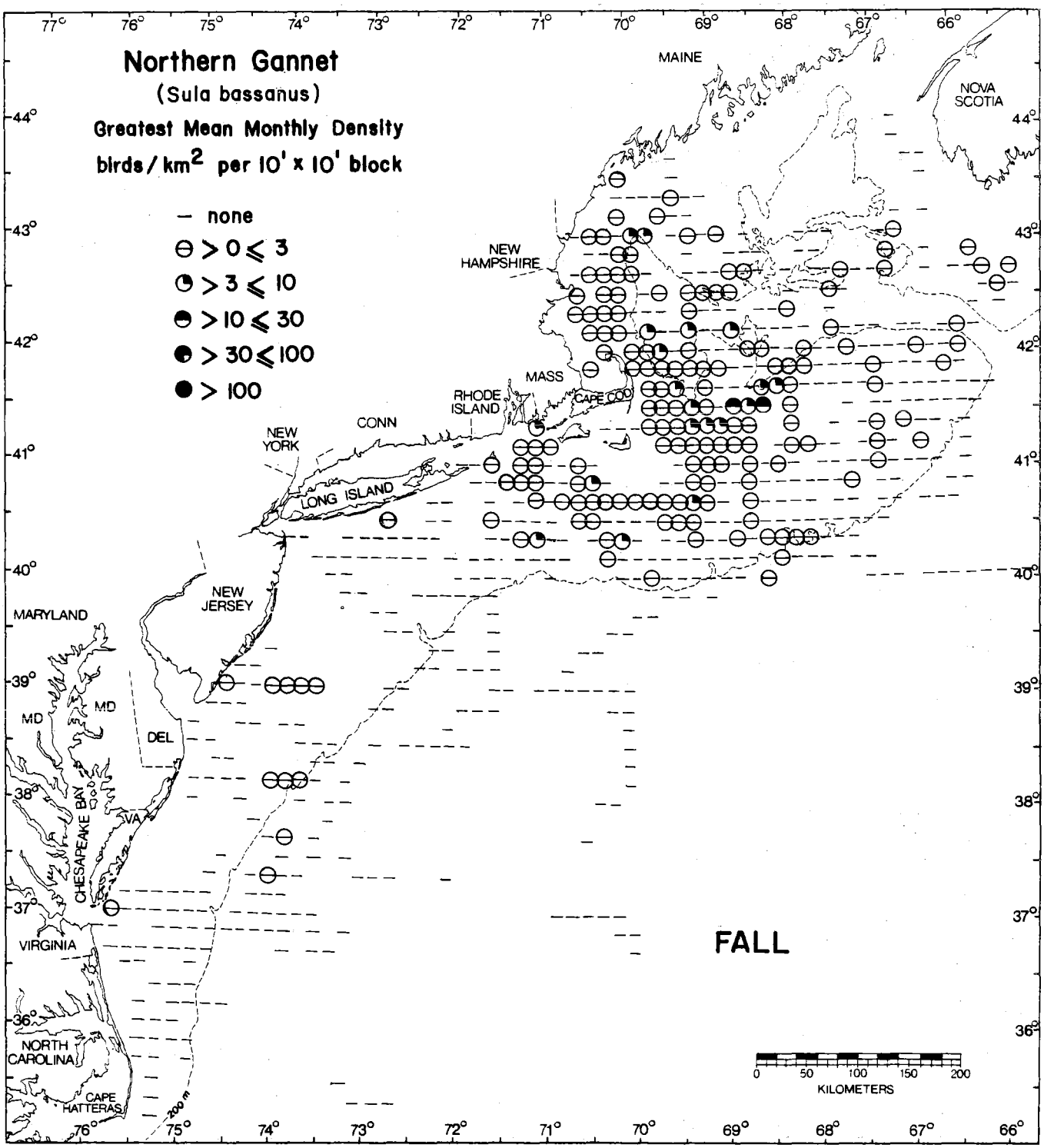

Fig. 46. Relative distribution and abundance of Northern Gannets (Sula bassanus) in fall.

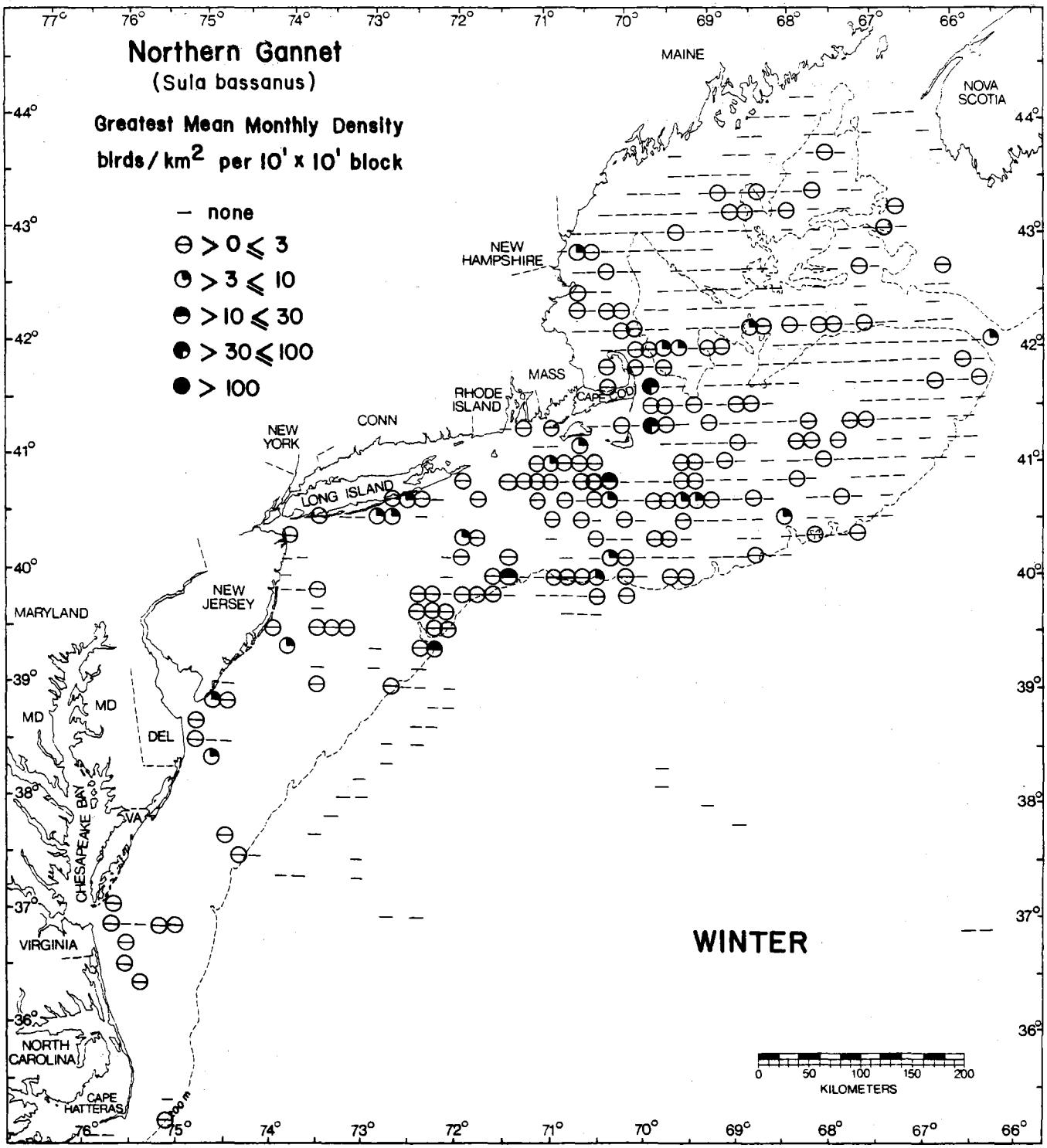

Fig. 47. Relative distribution and abundance of Northern Gannets (Sula bassanus) in winter.

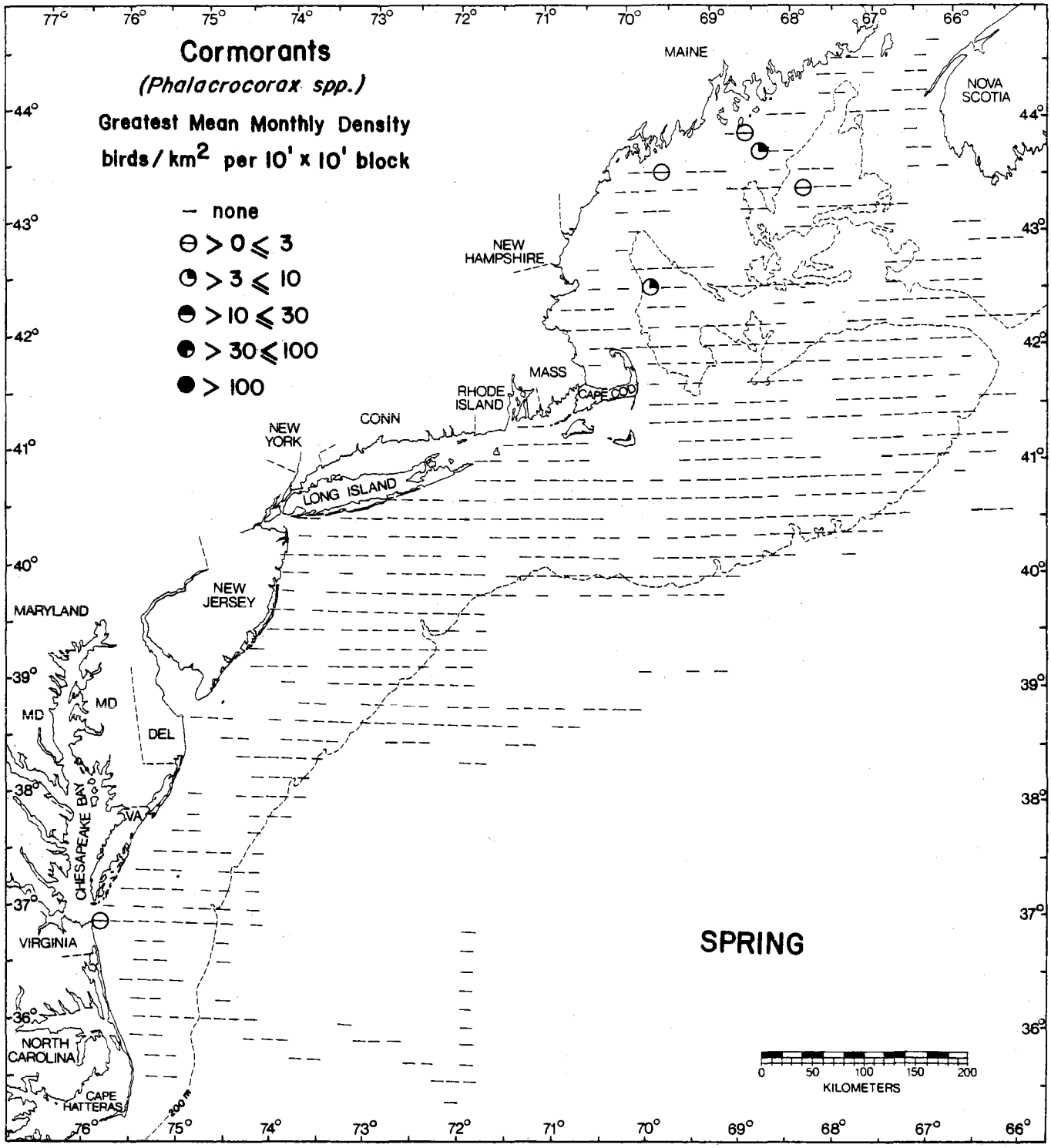

Fig. 48. Relative distribution and abundance of cormorants (Phalacrocorax spp.) in spring.

GREAT CORMORANT (Phalacrocorax carbo)

DOUBLE-CRESTED CORMORANT (Phalacrocorax auritus)

In North America, Great Cormorants breed in Newfoundland, Nova Scotia and along the shores of the Gulf of St. Lawrence (Brown et al. 1975). A disjunct population breeds in west Greenland (Salomonsen 1950). Double-crested Cormorants breed in many areas of eastern North America from the Canadian Maritimes (Brown et al. 1975) south to Cuba (Drury 1973-74; Erwin and Korshgen 1979; Portnoy et al. 1981).

Cormorants are strictly coastal inhabitants that do not use pelagic habitats. Spring and fall migratory movements were noted in the western Gulf of Maine and in nearshore waters from the Cape Cod islands west to New Jersey (Fig. 48-49). Species identification of cormorants at-sea was difficult, but Double-crested was the only species identified south of Cape Cod.

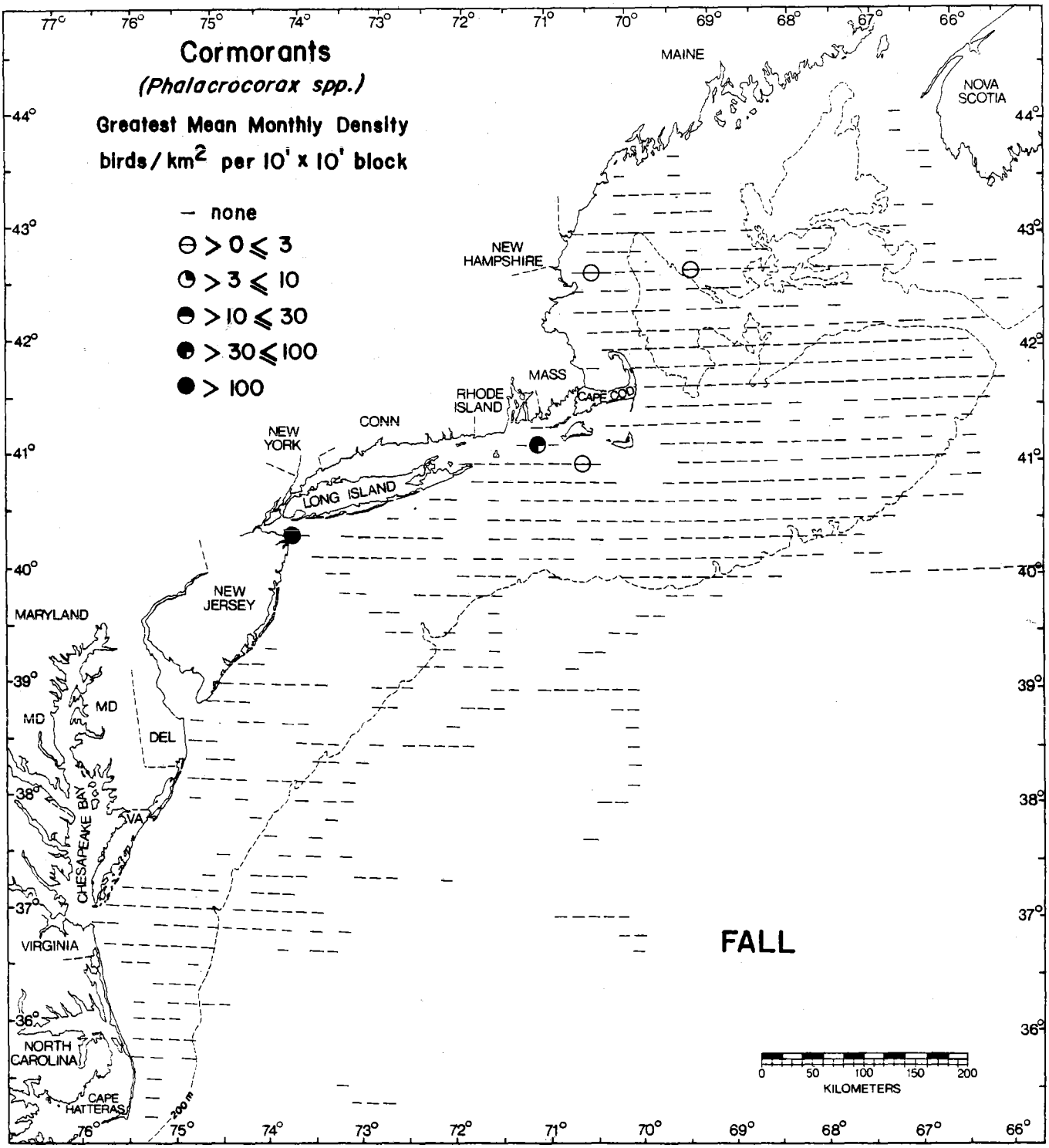

Fig. 49. Relative distribution and abundance of cormorants (Phalacrocorax spp.) in fall.

RED PHALAROPE (Phalaropus fulicaria)

RED-NECKED PHALAROPE (Phalaropus lobatus)

Red and Red-necked phalaropes breed in the North American arctic and have circumpolar distributions (Brown et al. 1975). In eastern North America, Red Phalaropes breed south only to ca. 69°N in west Greenland and ca. 60°N in Canada (Godfrey 1966; Salomonsen 1950). Red-necked Phalaropes breed in the low arctic from about 54° to 65°N in Canada, north to about 71°N in west Greenland (Brown et al. 1975).

Phalaropes feed at the surface as secondary carnivores on planktonic crustaceans, and fish and squid eggs and larvae (Ainley and Sanger 1979). They often feed at convergent fronts, areas of local turbulence and similar areas where zooplankton is concentrated at the surface (Brown 1980a).

Phalaropes were most common during spring (April to June) and fall (August to October), although they were found off the northeastern United States in almost every month of the year (Fig. 50-51). During spring, Red Phalaropes were most abundant in the mid-Atlantic subarea in late April and on Georges Bank by mid-May (Fig. 52). Griscom (1939) noted early arrivals off Massachusetts from 2 to 12 April. In my observations, the northward movement of phalaropes was mostly confined to the outer edge of the shelf (60-200 m), where hydrographic features at the shelf-break may lead to increased concentrations of zooplankton. No significant passage was noted in the Gulf of Maine. This pattern agrees with the distribution maps by Brown et al. (1975) and implies that most Red Phalaropes passed east of Nova Scotia. Spring records from Sable Island, Nova Scotia suggest that they continue to follow the shelf-break on their way north (Orr et al. 1982). The peak passage of Red Phalaropes off the Labador coast was during the first two weeks of June (Orr et al. 1982). Spring densities of Red Phalaropes off the northeastern United States were often spectacular and flocks of hundreds to thousands were locally common (cf. Lamb 1964).

Spring migration of Red-necked Phalaropes coincided with movements of Reds, except that fewer numbers were recorded and part of the Red-necked population continued up the New England coast into the western Gulf of Maine (Fig. 52). Cumulative densities of Red-necked Phalaropes did not exceed 1 bird/km^2 and only several flocks of more than 100 birds were noted. Additional important sightings of Red-necked Phalaropes include about 1000 birds at 40°18'N, 70°38'W, 130 km S of Woods Hole, Massachusetts on 1 May 1976, and about 1000 birds off Plymouth, Massachusetts in Cape Cod Bay on 11 May 1977 following a northeasterly gale. The largest flock of Red-necked Phalaropes seen by Rowlett (1980) was 900 on 9 May 1976, at 38°15'N, 74°01'W, 94 km E of Ocean City, Maryland. Griscom (1939) noted that the main flight of Red-necked Phalaropes off Massachusetts occurred from 15 to 25 May.

The fall migration of Red Phalaropes out of the arctic is rapid and peak flights occur off southeast Baffin Island and at the shelf-break off northeast Labrador during the last week of July and first two weeks of August (Orr et al. 1982). Orr et al. (1982) found no evidence that Red-necked Phalaropes migrate offshore, which suggests that this species travels overland from Baffin Island to the Gulf of Maine. The fall migration of

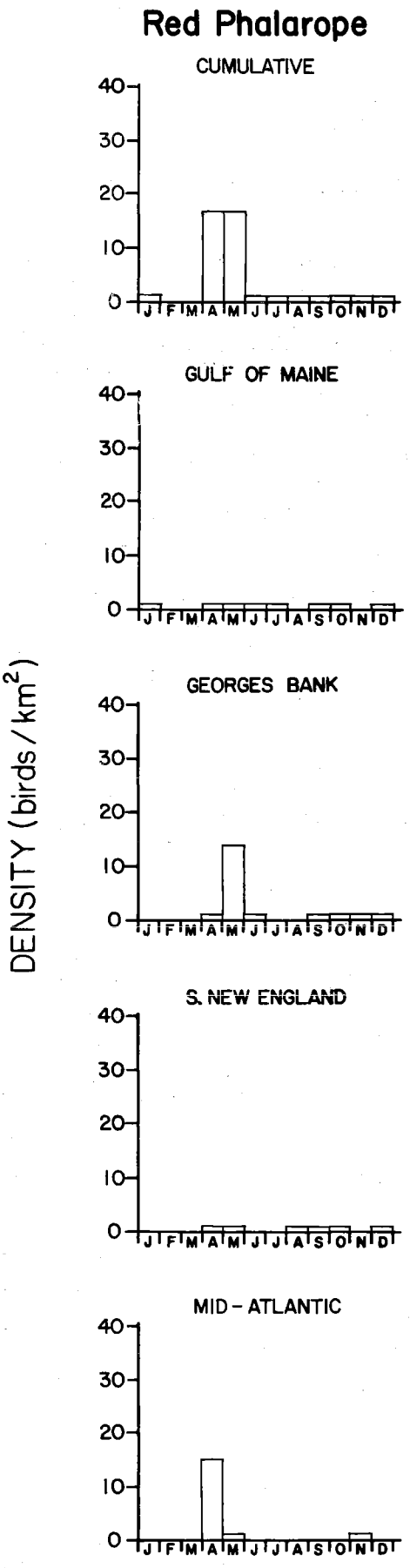

Fig. 50. Histogram of mean monthly densities of Red Phalaropes (Phalaropus fulicaria) by subarea and the entire study area (cumulative).

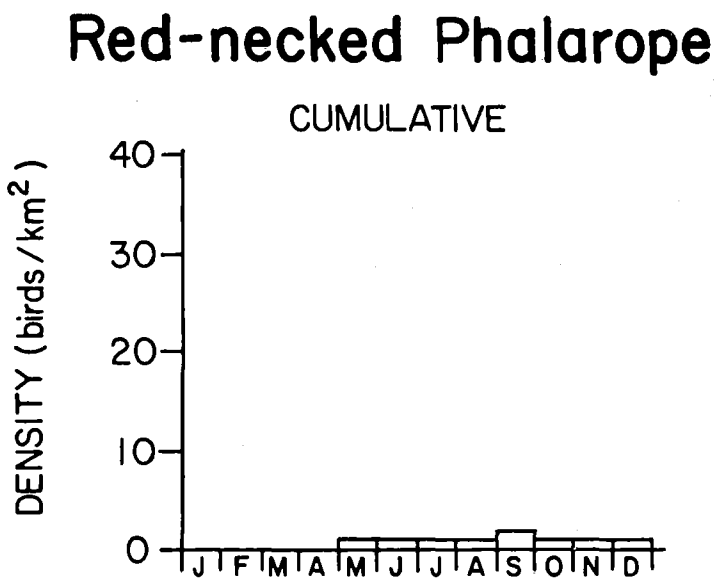

Fig. 51. Histogram of mean monthly densities of Red-necked Phalaropes (Phalaropus lobatus) for the entire study area (cumulative).

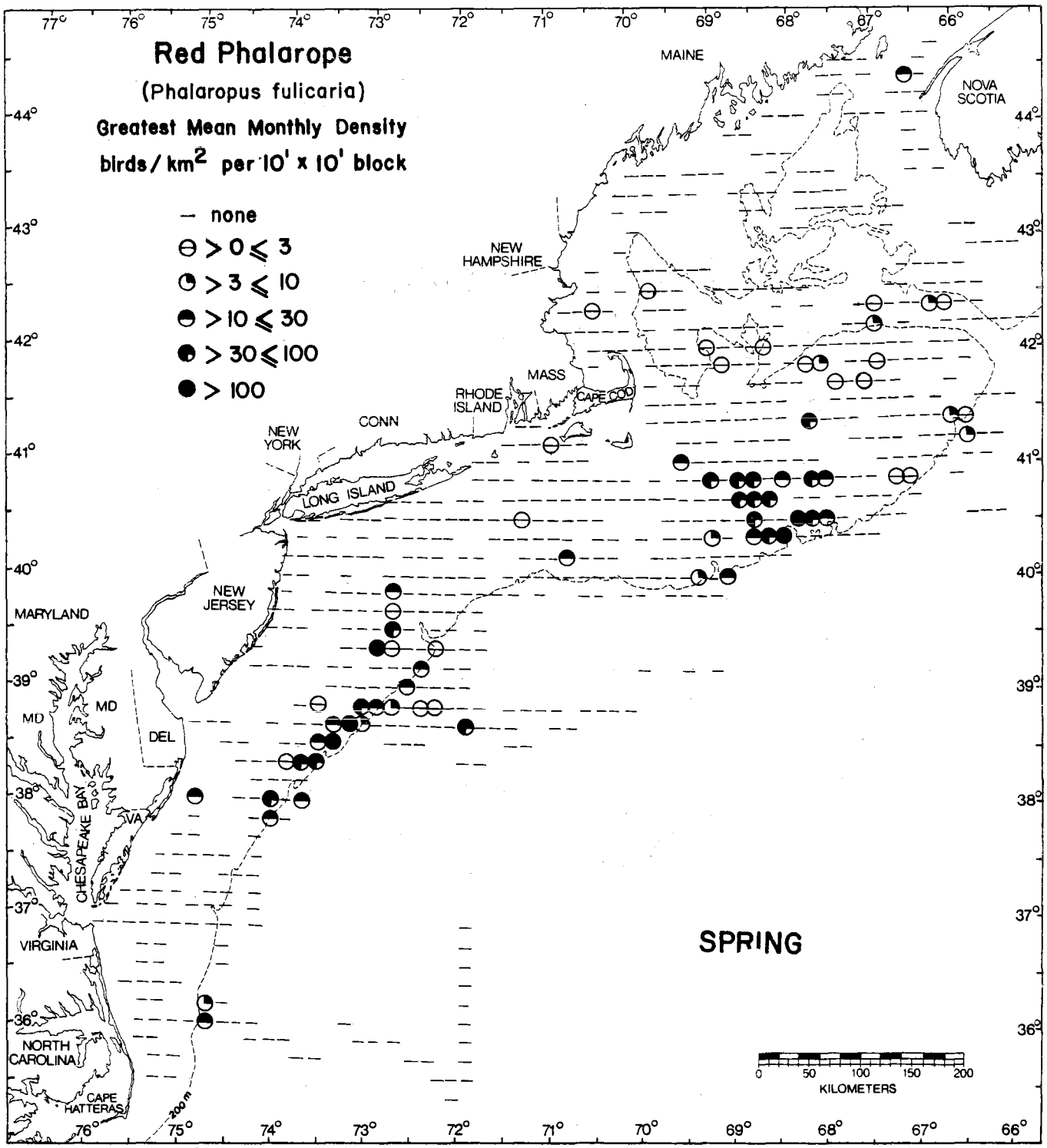

Fig. 52. Relative distribution and abundance of Red Phalaropes (Phalaropus fulicaria) in spring.

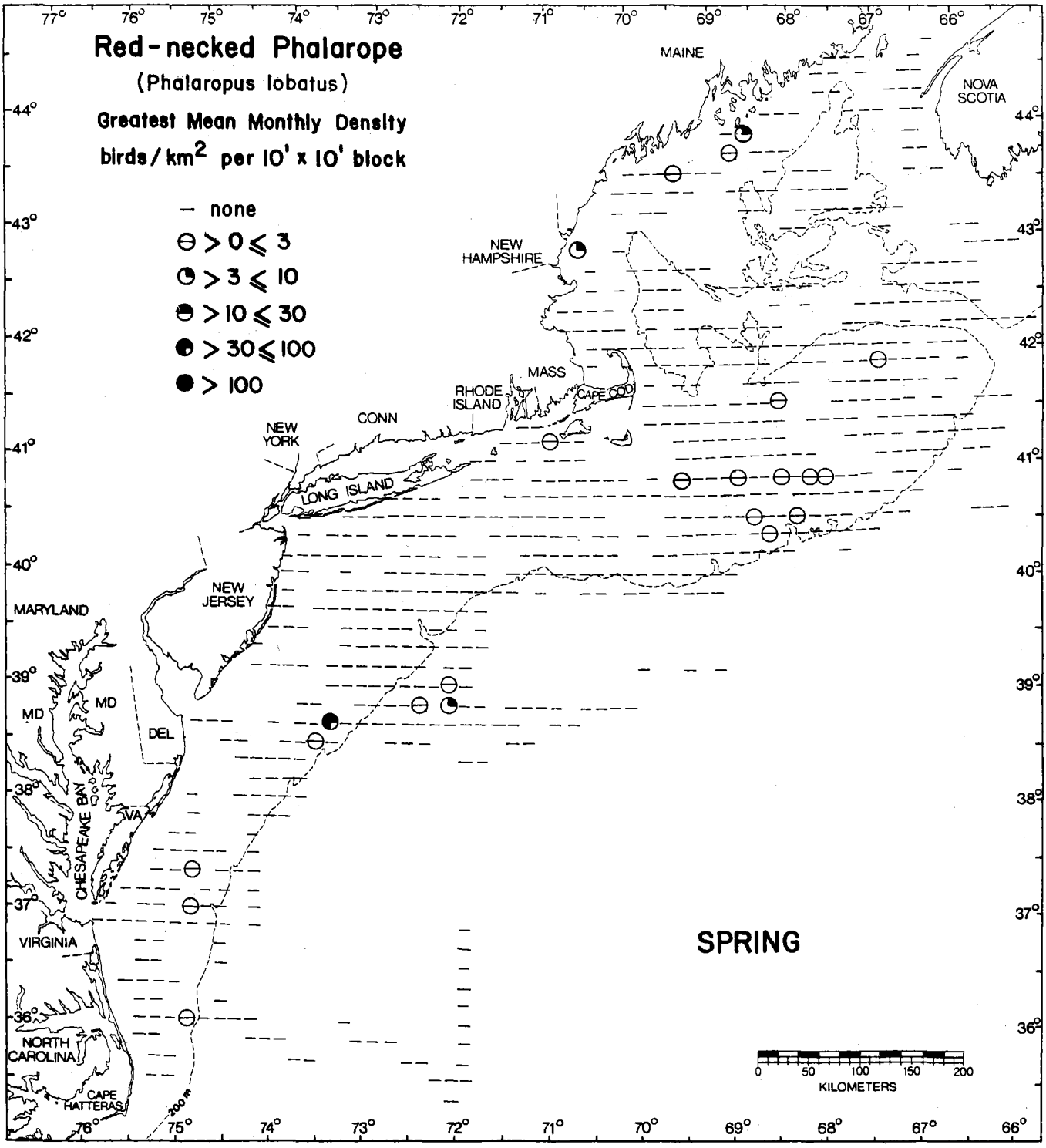

Fig. 53. Relative distribution and abundance of Red-necked Phalaropes (Phalaropus lobatus) in spring.

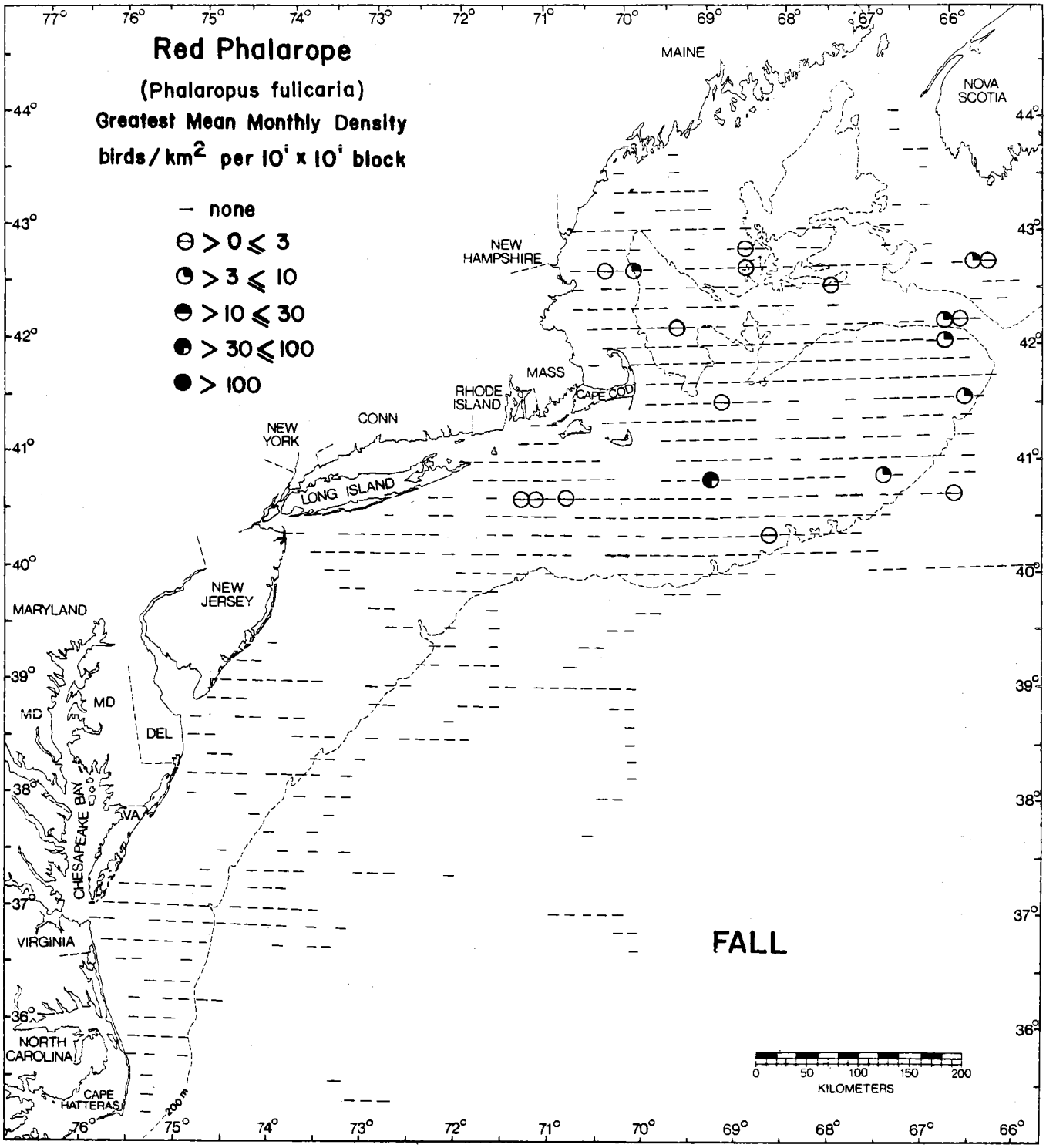

Fig. 54. Relative distribution and abundance of Red Phalaropes (Phalaropus fulicaria) in fall.

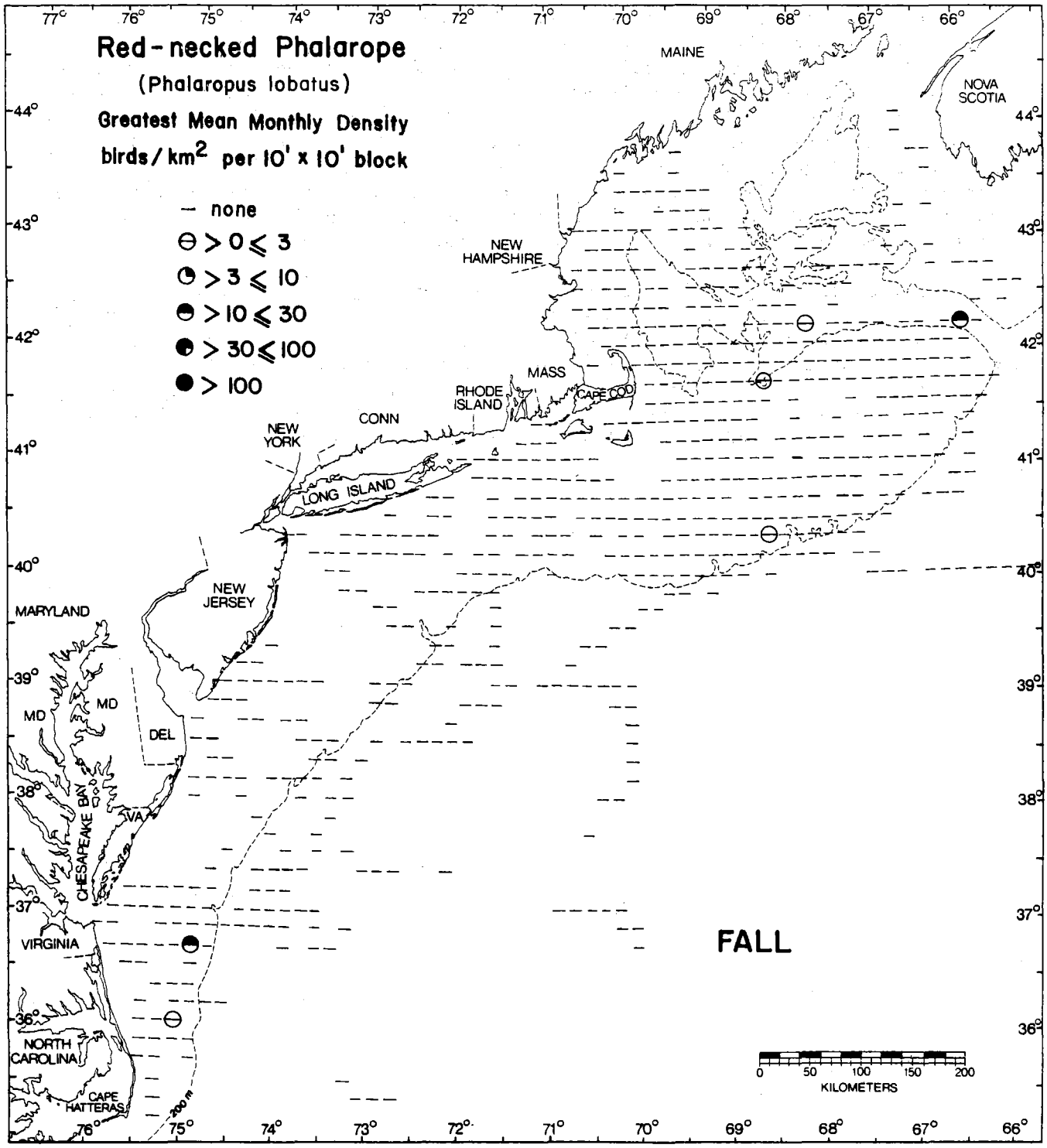

Fig. 55. Relative distribution and abundance of Red-necked Phalaropes (Phalaropus lobatus) in fall.

phalaropes off the northeastern United States occurred primarily from mid-August to late September (Fig. 54-55); however, stragglers of both species were noted into December (Fig. 50-51). Griscom (1939) indicated that the peak flights of Red-necked off Massachusetts in autumn are from late August to mid-September, and by inference late September through October for Reds. In this study no substantial densities of either species were recorded during this time (cf. Griscom 1939). Paxton et al. (1976) reported a summary of seabird observations made at Hudson Canyon during fall 1975. Their compilation indicated a peak of Red-necked Phalaropes (11 to 57 birds per day) from 30 August to 9 September, and of Red Phalaropes (12 to 887 birds per day) from 2 to 19 November. Some Red Phalaropes apparently overwinter on the shelf from Chesapeake Bay south to the Carolinas (Lee and Booth 1979; Rowlett 1980; Powers, unpubl. data) and Florida (Weston 1953).

During spring approximately 620,000 Red and 16,000 Red-necked phalaropes passed off the coast of northeastern United States (Appendix 5). Another 181,000, which were unidentified, were probably Red Phalaropes. The high proportion of unidentified phalaropes at this time was because the majority of Red Phalaropes observed in April were still in basic (non-breeding) plumage. In fall, approximately 28,000 Red and 26,000 Red-necked phalaropes were estimated with only ca. 2,000 unidentified (Appendix 5).

POMARINE JAEGER (Stercorarius pomarinus)

PARASITIC JAEGER (Stercorarius parasiticus)

LONG-TAILED JAEGER (Stercorarius longicaudus)

Pomarine and Parasitic jaegers are birds of the high and low arctic zones in North America (Brown et al. 1975). Both species breed between ca. 75° and 60°N in Canada (Godfrey 1966). The Pomarine breeds between ca. 73° and 65°N and the Parasitic to ca. 60°N in west Greenland (Salomonsen 1950). The Long-tailed Jaeger breeds in the high arctic, north of ca. 60°N in Canada (Godfrey 1966) and of ca. 75°N in west Greenland (Salomonsen 1950).

Jaegers feed by seizing prey at the surface or by pirating other birds (e.g. gulls, terns). They are secondary and tertiary carnivores that feed on crustaceans, fish and cephalopods, and are scavengers of offal (Ainley and Sanger 1979).

Pomarine Jaeger was the most frequently observed jaeger off the coast of the northeastern United States during spring and fall (Fig. 56-59). Especially from late April through May, adult Pomarines were most common (Fig. 57). Subadults were recorded occasionally east and northeast of Long Island during summer (Fig. 58). In late August sighting frequency increased and by October, Pomarines were common but not abundant on Georges Bank and the Gulf of Maine (Fig. 56 and 59). Their movements south reached the mid-Atlantic subarea by late October. Stragglers were noted into December on Georges Bank. The majority of Pomarine Jaegers identified to age during fall were subadults and juveniles.

Parasitic Jaegers were present but uncommon in both spring (May and June) and fall (September and October) (Fig. 60-61). Sightings of jaegers from the New England coast are usually this species, although pelagic movements throughout the North Atlantic are known (Wynne-Edwards 1935).

Long-tailed Jaegers were rare with only a few sightings recorded (Appendix 8).

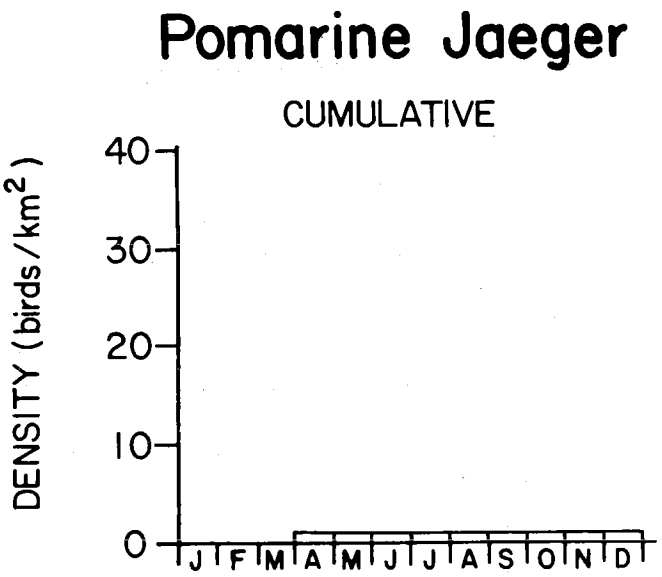

Fig. 56. Histogram of mean monthly densities of Pomarine Jaegers (Stercorarius pomarinus) for the entire study area (cumulative).

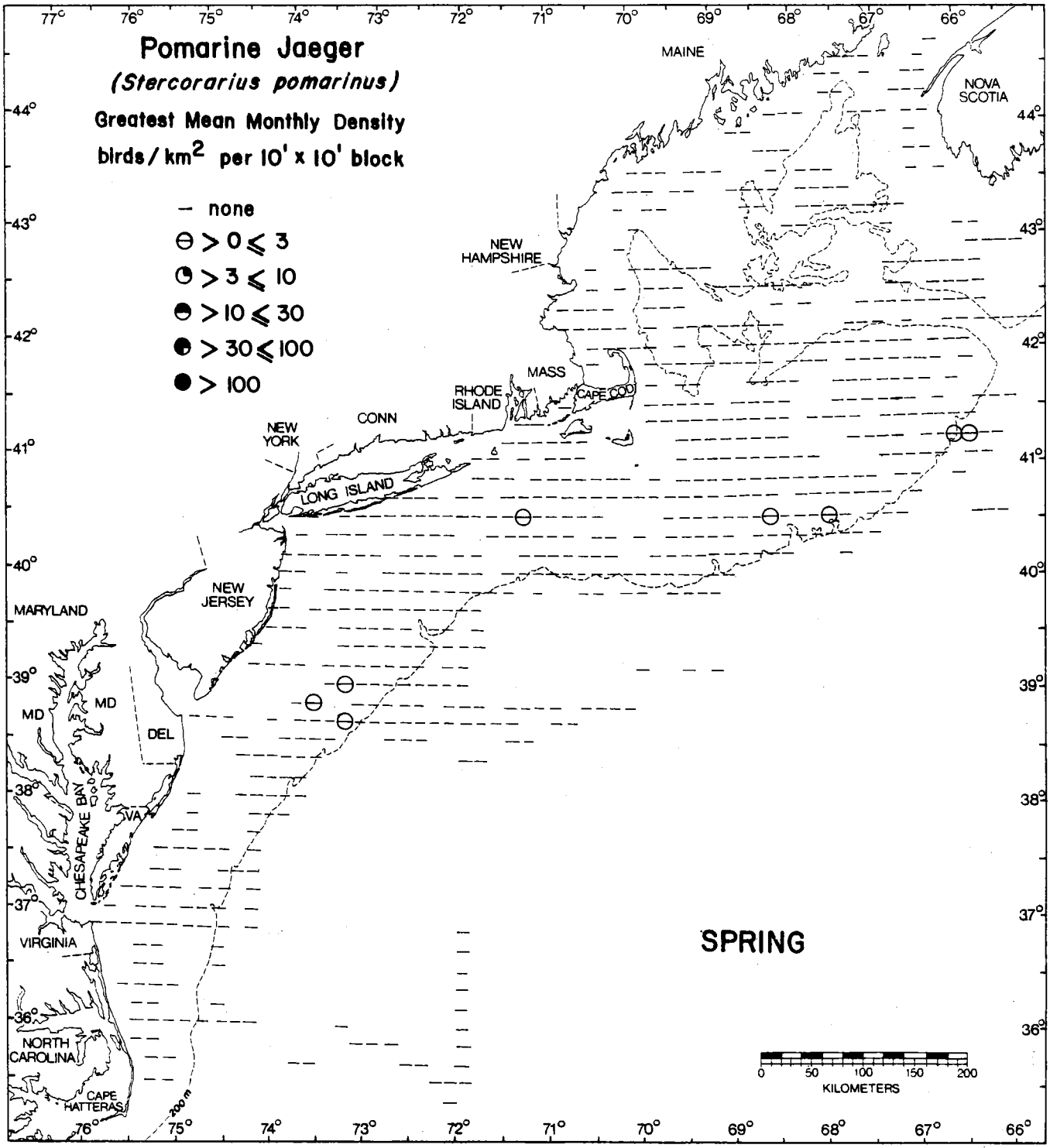

Fig. 57. Relative distribution and abundance of Pomarine Jaegers (Stercorarius pomarinus) in spring.

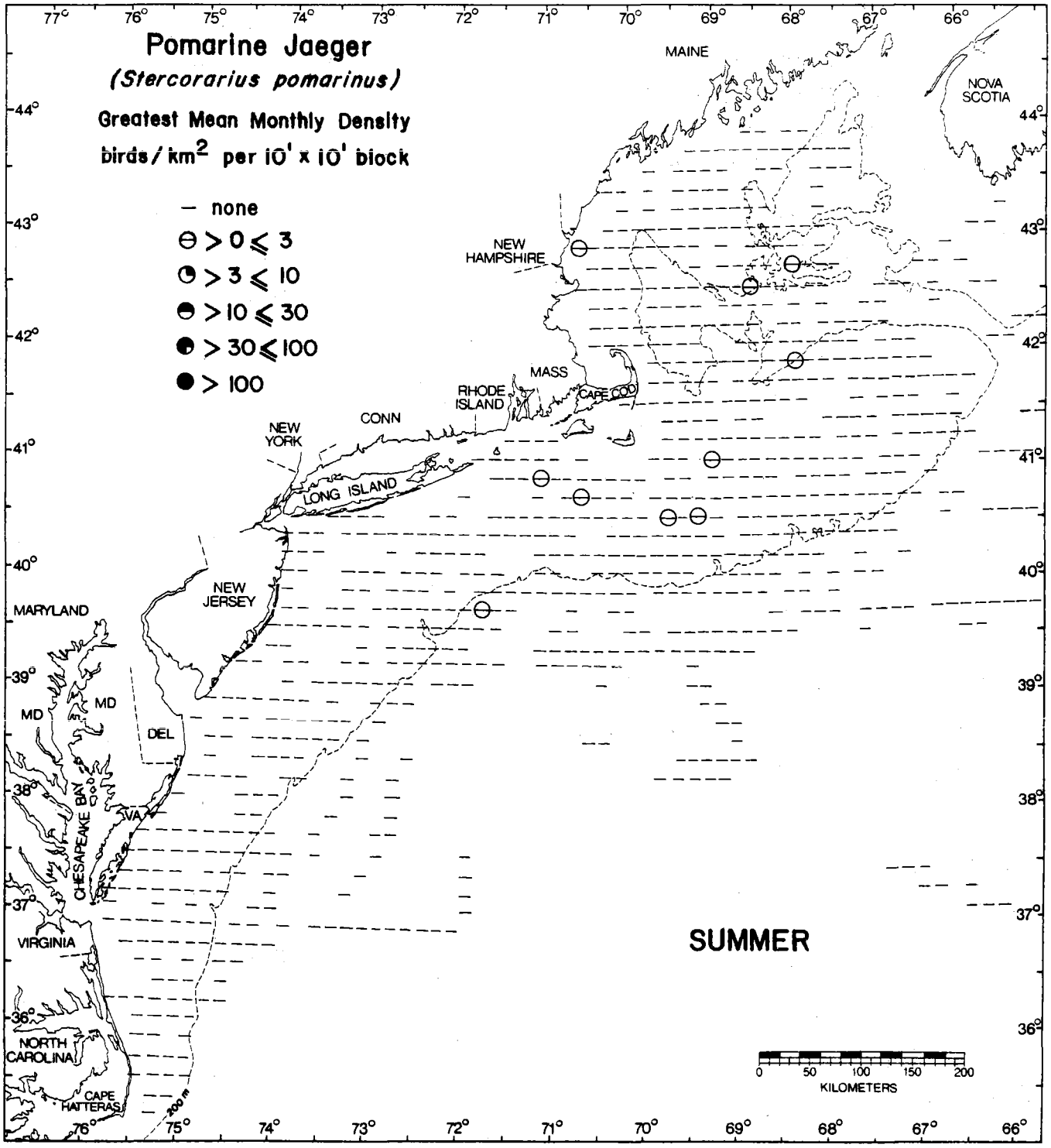

Fig. 58. Relative distribution and abundance of Pomarine Jaegers (Stercorarius pomarinus) in summer.

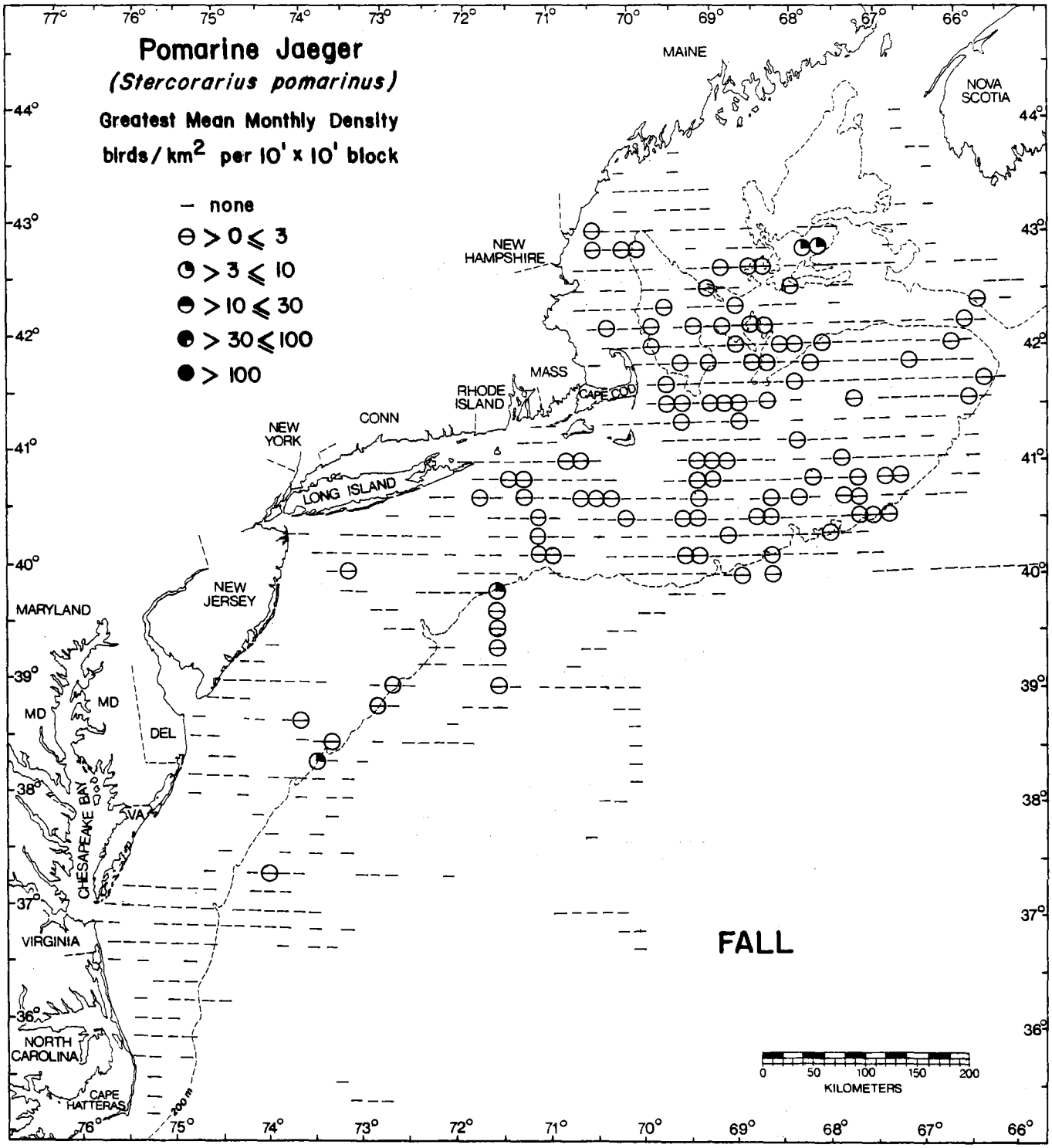

Fig. 59. Relative distribution and abundance of Pomarine Jaegers (Stercorarius pomarinus) in fall.

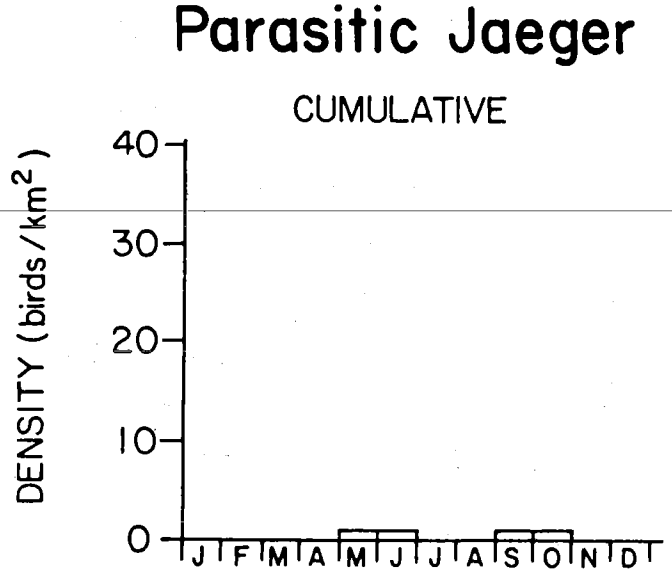

Fig. 60. Histogram of mean monthly densities of Parasitic Jaegers (Stercorarius parasiticus) for the entire study area (cumulative).

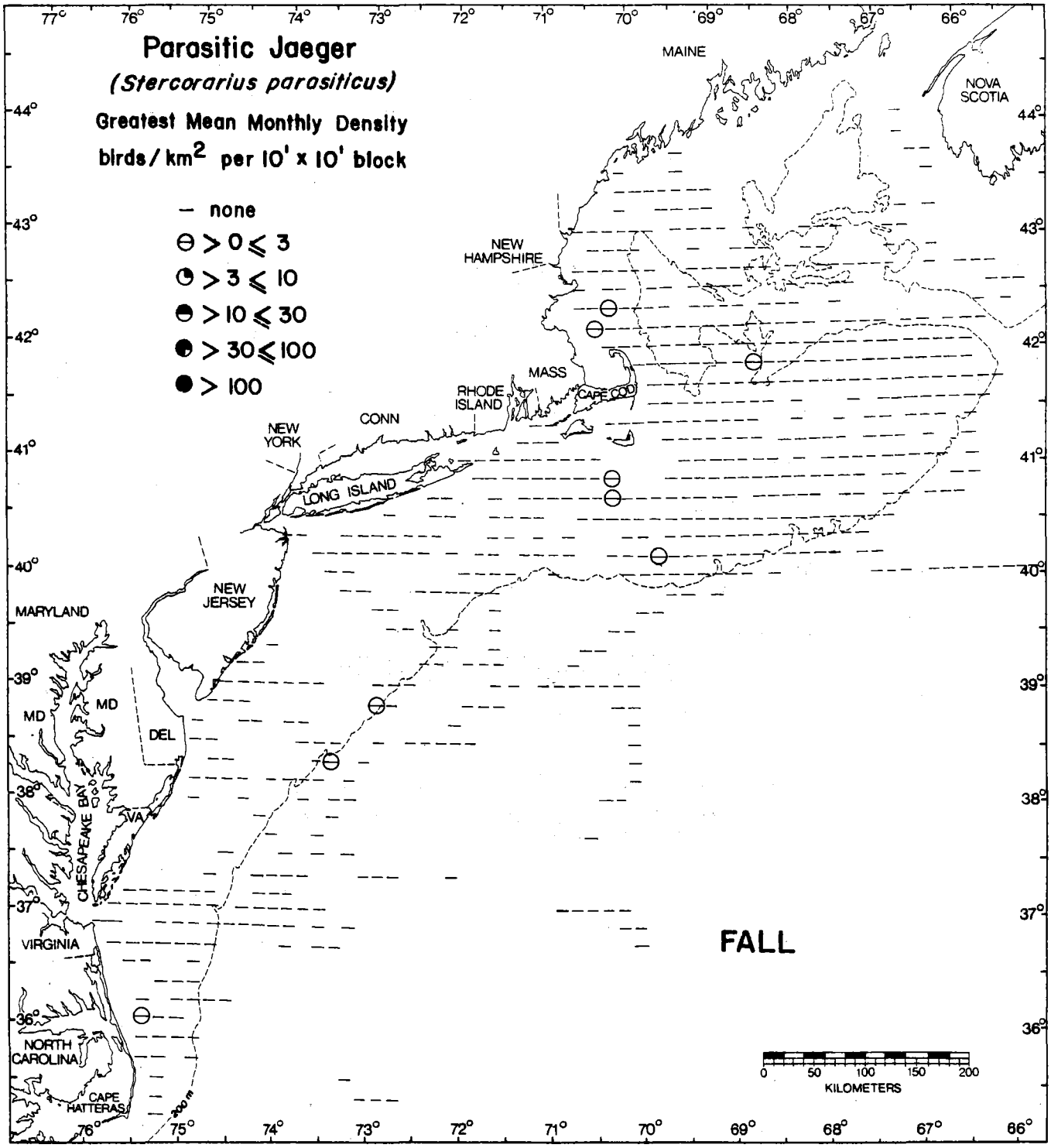

Fig. 61. Relative distribution and abundance of Parasitic Jaegers (Stercorarius parasiticus) in fall.

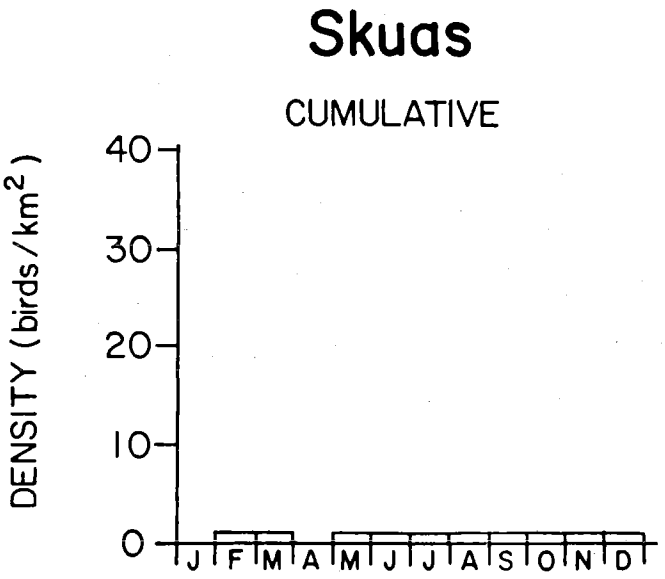

Fig. 62. Histogram of mean monthly densities of skuas (Catharacta spp.) for the entire study area (cumulative).

GREAT SKUA (Catharacta skua skua)

SOUTH POLAR SKUA (Catharacta maccormickii)

In the northern hemisphere, Great Skuas breed at the northern edge of the boreal zone in Scotland, Faeroe and Iceland (Fisher and Lockley 1954; Brown et al. 1975). South Polar Skuas breed in the Southern Hemisphere on the South Shetland Islands and on the Antarctic Peninsula, continent and adjacent islands (Watson 1975).

Great and South Polar skuas feed as secondary, tertiary and upper-level carnivores on crustaceans, fish, terrestrial mammals, eggs and birds, and as scavengers on offal and carrion (Watson 1975; Furness 1979).

Brown et al. (1975) found skuas off eastern Canada throughout the year. Finch et al. (1978) recorded skuas uncommonly from late June to early October along the ferry route from Bar Harbor, Maine to Yarmouth, Nova Scotia in the northern Gulf of Maine. Rowlett (1980) considered skuas rare but regular winter and spring (December to early May) visitants to the northern Chesapeake Bight off the mid-Atlantic states.

In this study, skuas were uncommonly reported at almost any time of the year off the northeastern United States (Fig. 62-66); however, two species are known to occur here and it was often difficult to identify a sighting to species positively. Banding recoveries indicate that many, perhaps most, Great Skuas in the western North Atlantic are 2nd-year subadults from colonies in the eastern North Atlantic (e.g. Thomson 1966; Furness 1978). Furness (1978) noted that the bulk of recoveries of Great Skuas up to 1 year 7 months are from November to February and are south of 50°N on both sides of the Atlantic. More recently, a second-year male Great Skua banded in the Shetlands was collected on 13 July 1978 at 41°09'N, 67°10'W (U. S. Nat'l. Mus. #57076). Garrison (1940) and Hill (1965) reported specimens of Great Skuas taken off the New England coast between July and September, but these ought to be re-examined in light of more recent evidence that two species occur off the northeastern United States.

Sighting and specimen evidence suggest that there is a small-scale movement of South Polar Skuas into the western North Atlantic (Salomonsen 1976; Veit 1977; Lee and Rowlett 1979; Rowlett 1980). In addition to these references, a South Polar Skua was collected on Georges Bank at 40°03'N, 69°10'W on 25 May 1981 (U. S. Nat'l. Mus. #582499). Sightings from this study indicate that South Polar Skuas were present off the northeastern United States from May to October, but Salomonsen's (1976) west Greenland specimen demonstrates that their movements extend much farther north.

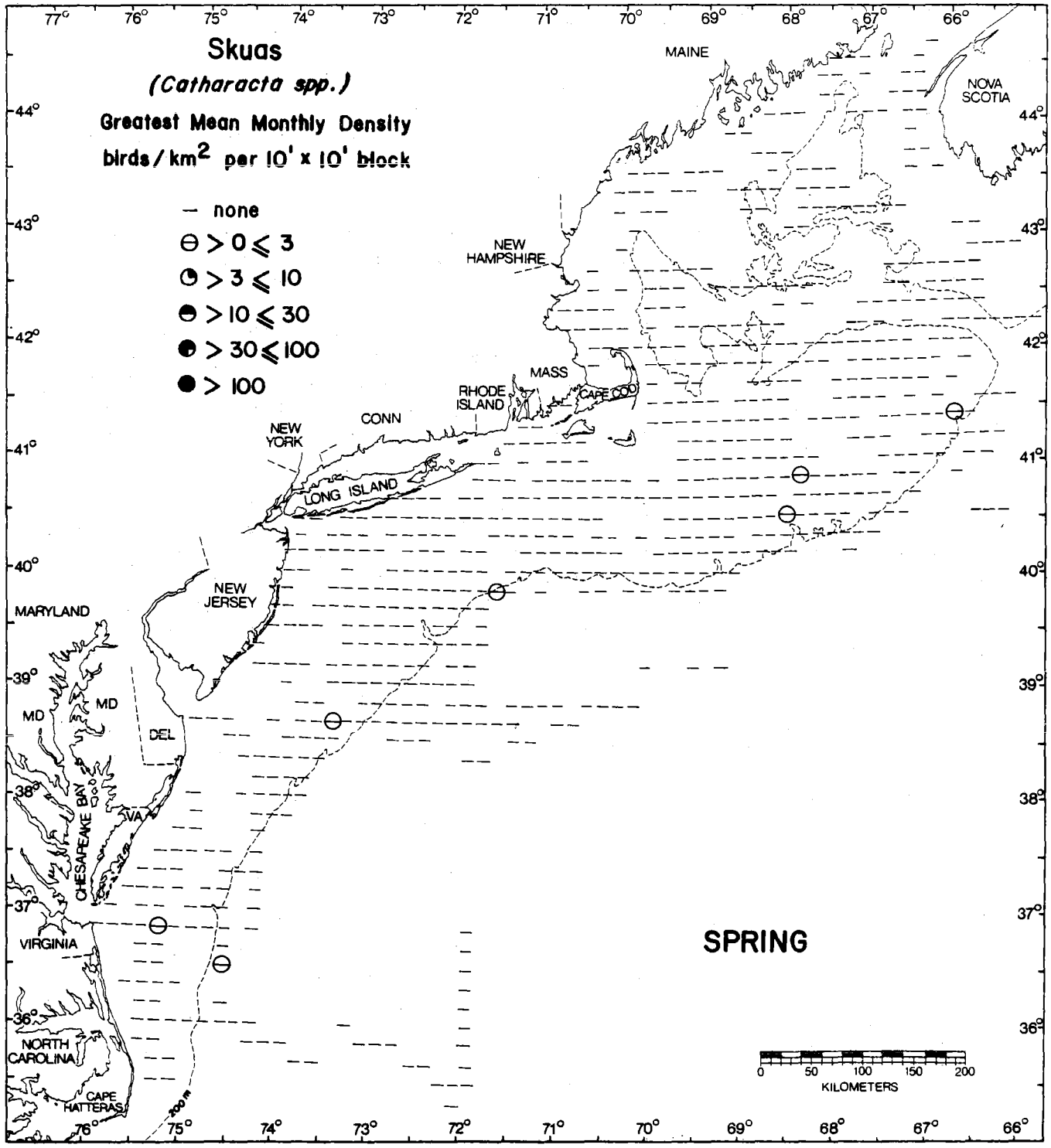

Fig. 63. Relative distribution and abundance of skuas (Catharacta spp.) in spring.

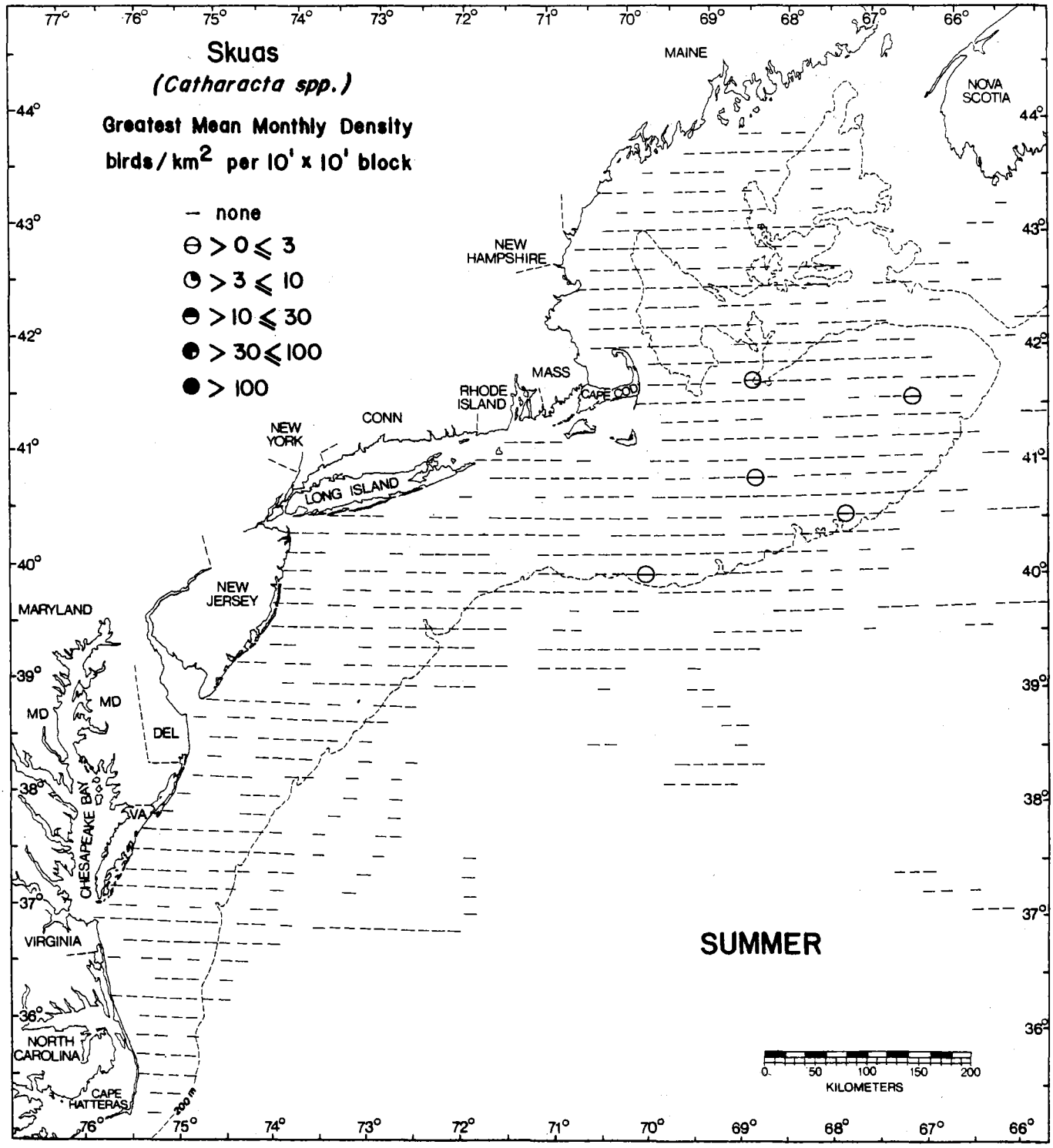

Fig. 64. Relative distribution and abundance of skuas (Catharacta spp.) in summer.

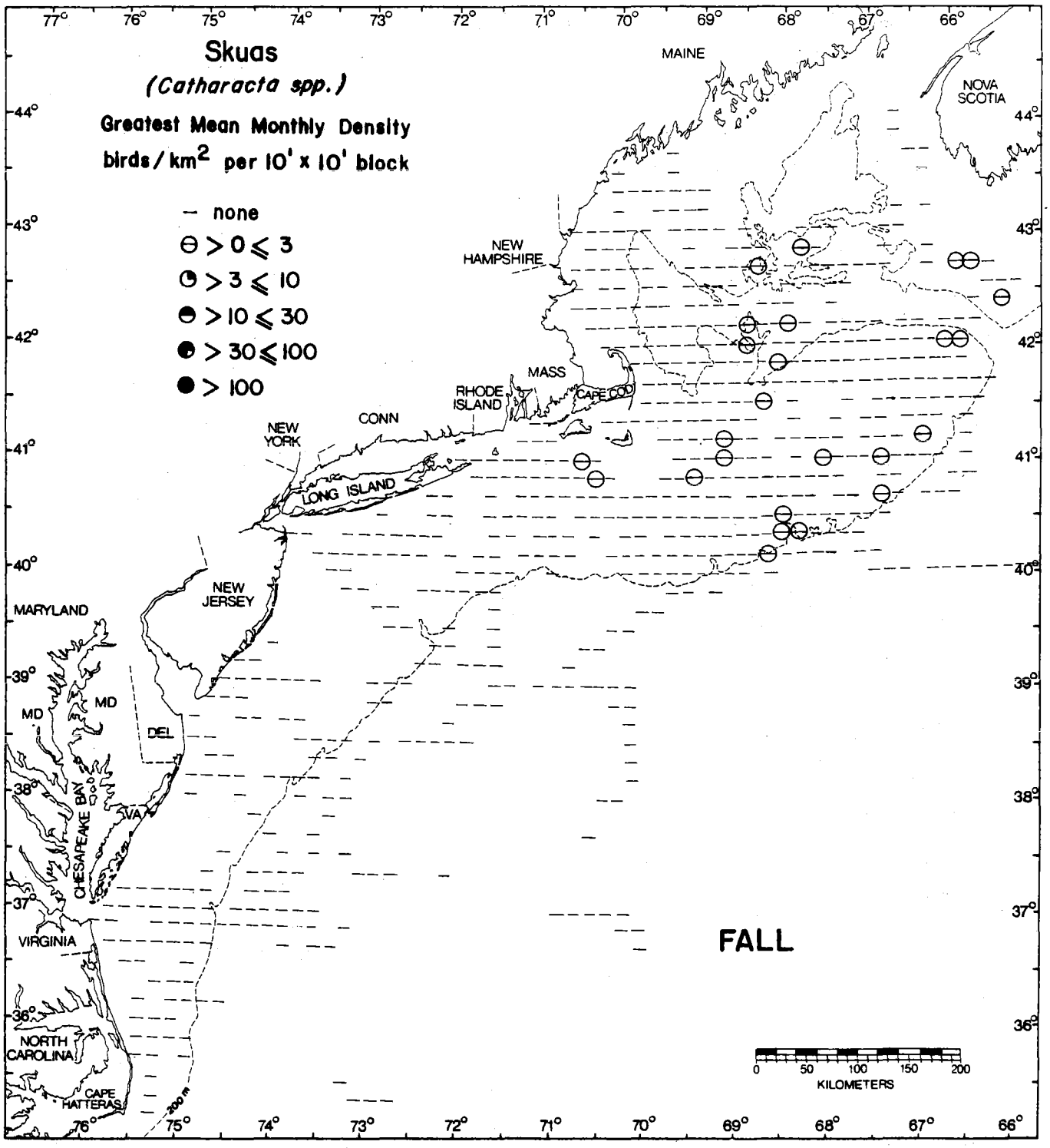

Fig. 65. Relative distribution and abundance of skuas (Catharacta spp.) in fall.

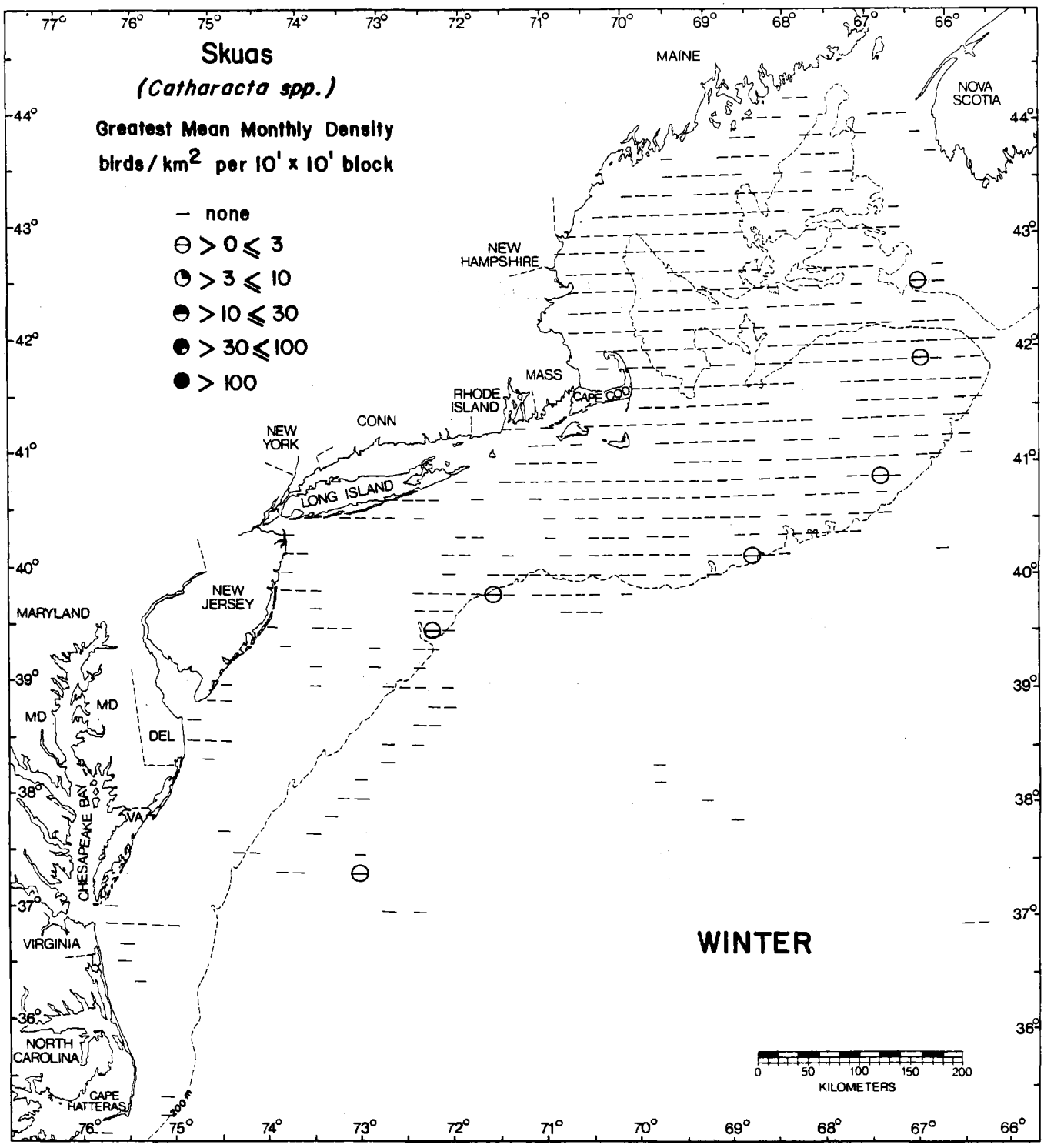

Fig. 66. Relative distribution and abundance of skuas (Catharacta spp.) in winter.

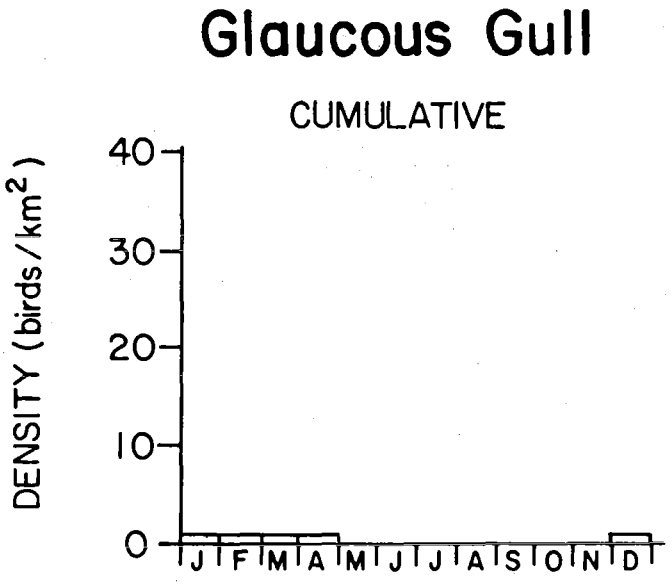

Fig. 67. Histogram of mean monthly densities of Glaucous Gulls (Larus hyperboreus) for the entire study area (cumulative).

GLAUCOUS GULL (Larus hyperboreus)

ICELAND GULL (Larus glaucoides glaucoides)

KUMLIEN'S GULL (Larus glaucoides kumlieni)

In eastern North America, Glaucous Gulls breed through most of the high arctic, and their breeding range extends south to 55°N on the Labrador coast (Brown et al. 1975). Iceland Gulls breed in boreal and low arctic zones in west Greenland and Kumlien's in southeast Baffin Island (Brown et al. 1975).

Glaucous and Iceland gulls feed as secondary, tertiary and upper level carnivores on macrozooplankton, fish, and the eggs and young of other seabirds, as well as scavengers of carrion and offal (Bent 1921; Ainley and Sanger 1979).

Glaucous and Iceland gulls were recorded from late November through April (Fig. 67-71). Adult-plumaged birds of the latter species were identified as the Kumlien's subspecies, L. g. kumlieni, in all but one instance. The southward movement of these species from their breeding grounds probably starts in October, and they reach Newfoundland and Nova Scotian waters by November (Brown et al. 1975). Both species were often found in areas of fishing activity where Great Black-backed and Herring gulls were abundant.

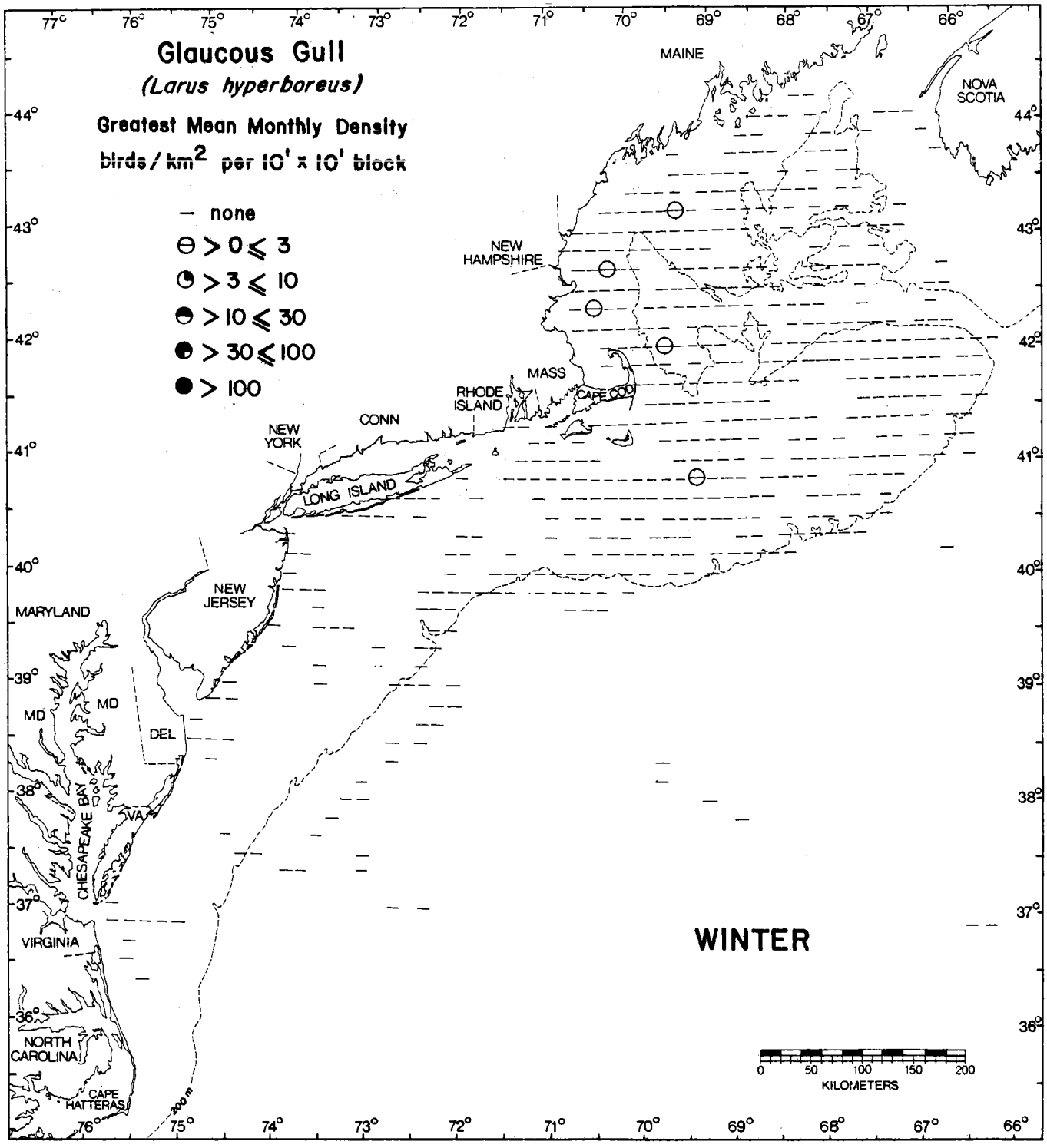

Fig. 68. Relative distribution and abundance of Glaucous Gulls (Larus hyperboreus) in winter.

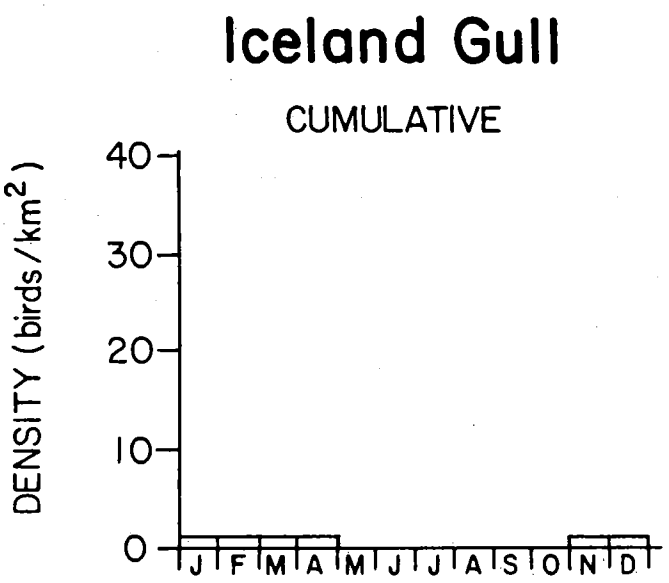

Fig. 69. Histogram of mean monthly densities of Iceland Gulls (Larus glaucoides) for the entire study area (cumulative).

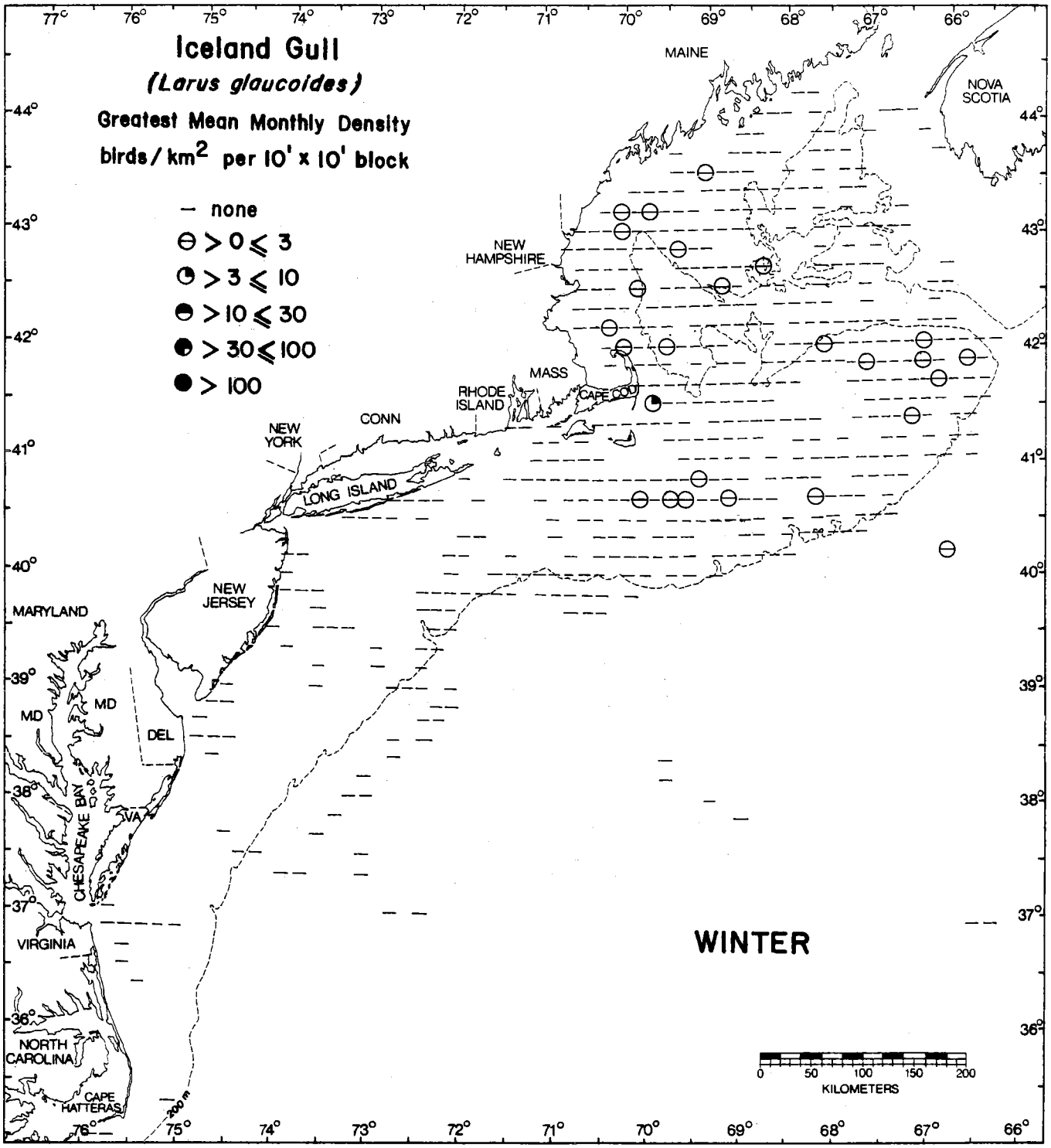

Fig. 70. Relative distribution and abundance of Iceland Gulls (Larus glaucoides) in winter.

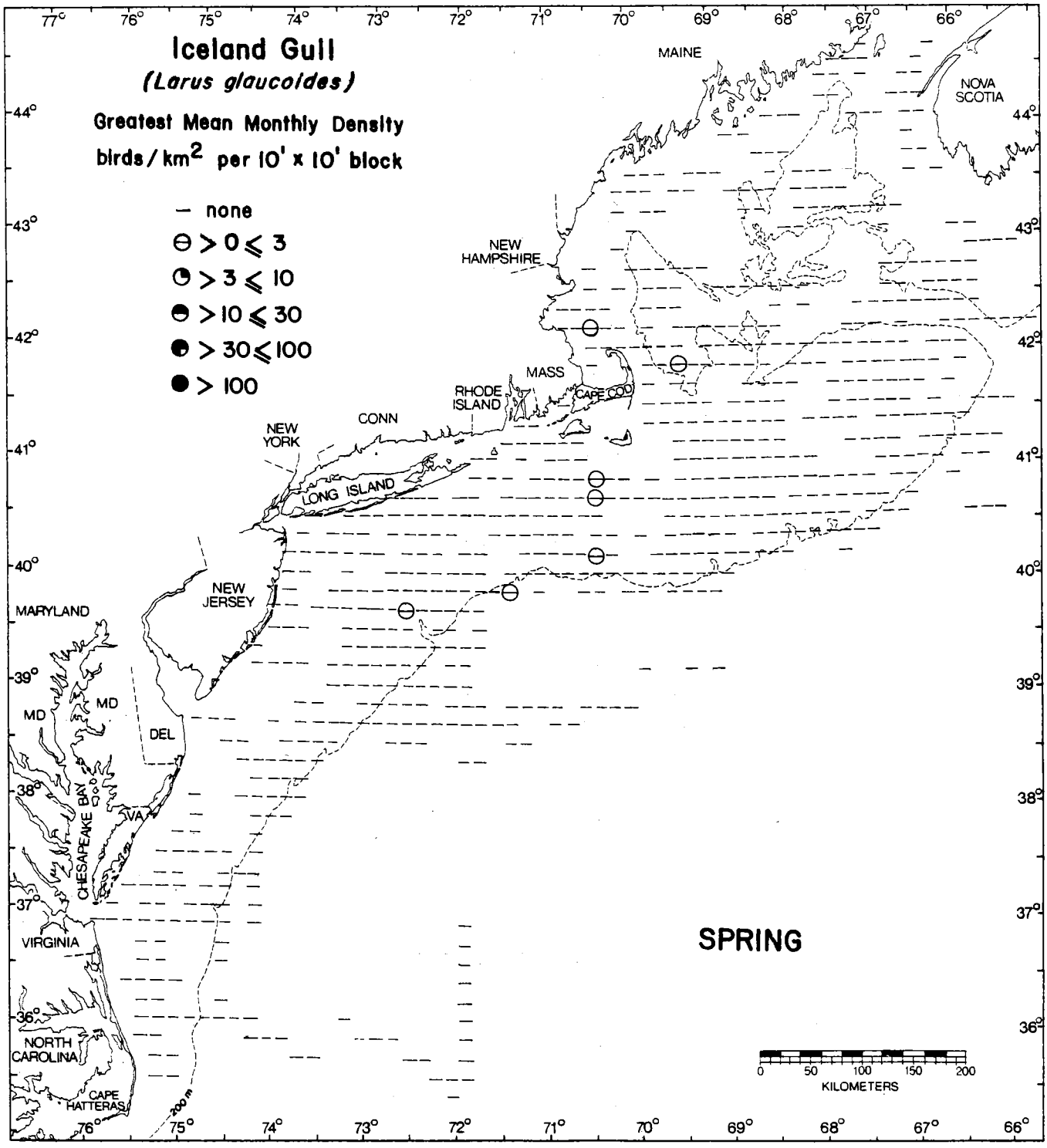

Fig. 71. Relative distribution and abundance of Iceland Gulls (Larus glaucoides) in spring.

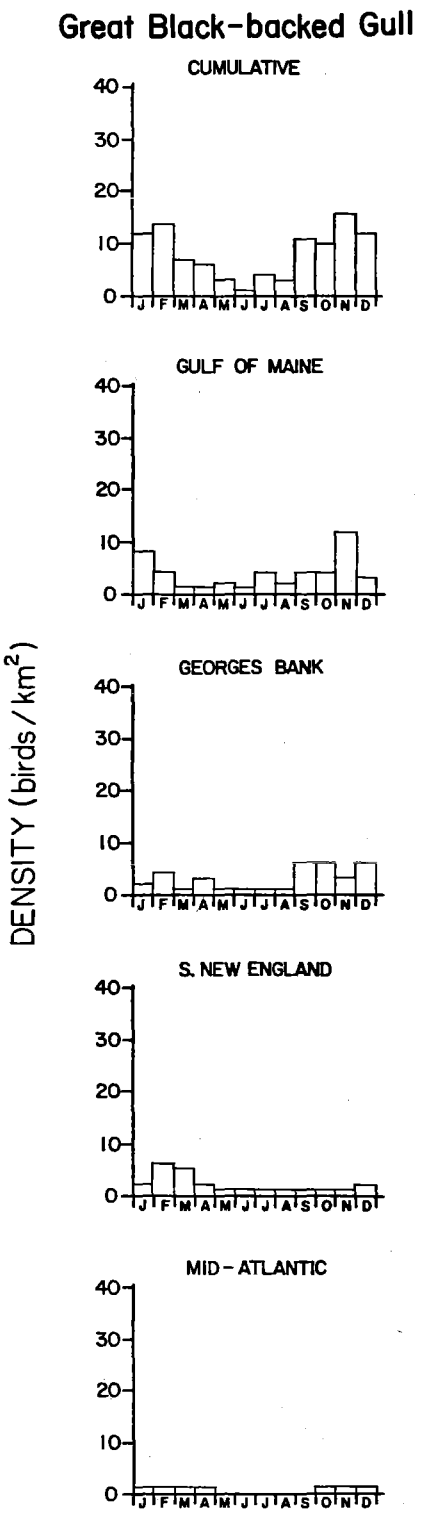

Fig. 72. Histogram of mean monthly densities of Great Black-backed Gulls (Larus marinus) by subarea and the entire study area (cumulative).

GREAT BLACK-BACKED GULL (Larus marinus)

HERRING GULL (Larus argentatus)

Great Black-backed and Herring gulls breed in boreal and arctic areas of eastern Canada and Greenland (Salomonsen 1950; Godfrey 1966). In the eastern United States, the breeding range of Great Black-backed Gulls extends south to Virginia (Drury 1973-74; Erwin 1979) and of Herring Gulls to North Carolina (Portnoy et al. 1981).

Great Black-backed and Herring gulls are omnivorious. They feed as secondary, tertiary, and upper level carnivores on crustaceans, insects, fish, squids, birds and eggs, and as scavengers on offal and carrion (Bent 1921; Ainley and Sanger 1979).

Great Black-backed Gulls were most abundant in the Georges Bank and Gulf of Maine subareas from September to April (Fig. 72-76). Herring Gulls were abundant throughout shelf waters from Cape Hatteras to Nova Scotia from October to April (Fig. 77-81). In summer, the distribution of both species was limited to waters within 150 km of the New England and the Nova Scotian coasts (Fig. 74 and 79).

The pelagic distribution of Great Black-backed and Herring gulls was greatly influenced by fishing activity throughout the year. Greatest densities of either species in all seasons were found among fishing fleets from Jeffreys Ledge south to the Great South Channel and east along northern Georges Bank, and over Cox Ledge. Both species also aggregated around trawlers primarily in winter and spring, when foreign fleets were active along the continental slope from Hudson Canyon east to Lydonia Canyon. Concentrations greater than 10,000 birds were sometimes estimated around these foreign fleets.

Population estimates of both species were undoubtedly biased because of their propensity to follow ships and to aggregate around fishing vessels (cf. Powers 1982). Population estimates for Great Black-backed Gulls in the entire study area were highest in fall and winter (ca. 711,000 - 736,000) and lowest in summer (ca. 160,000) (Appendix 5). Estimates for Herring Gulls were greatest in fall (ca. 1,000,000) and also least in summer (ca. 118,000) (Appendix 5). The summer estimates for both species probably reflect numbers of nonbreeders. Estimates for Herring Gulls at sea in winter and spring (ca. 738,000 - 795,000) indicated little change in abundance between these seasons (Appendix 5).

The New England Herring Gull population increased exponentially from 11,000 breeding pairs in 1901 to 89,500 breeding pairs in 1972 (Drury 1973-74). Kadlec and Drury (1968) estimated that between 286,000 and 450,000 Herring Gulls winter along the coast from Maine to Virginia; a figure which also reflects an immigration of gulls from the Canadian Maritimes. Gross (1940) showed that many Herring Gulls from the Bay of Fundy move south to coastal areas from New England to Cape Hatteras during fall, and that there is an influx of birds to the Fundy area from points north during winter. Growth in the New England Great Black-backed population paralleled that of Herring Gulls. The population increased from 30 breeding pair in 1930 to

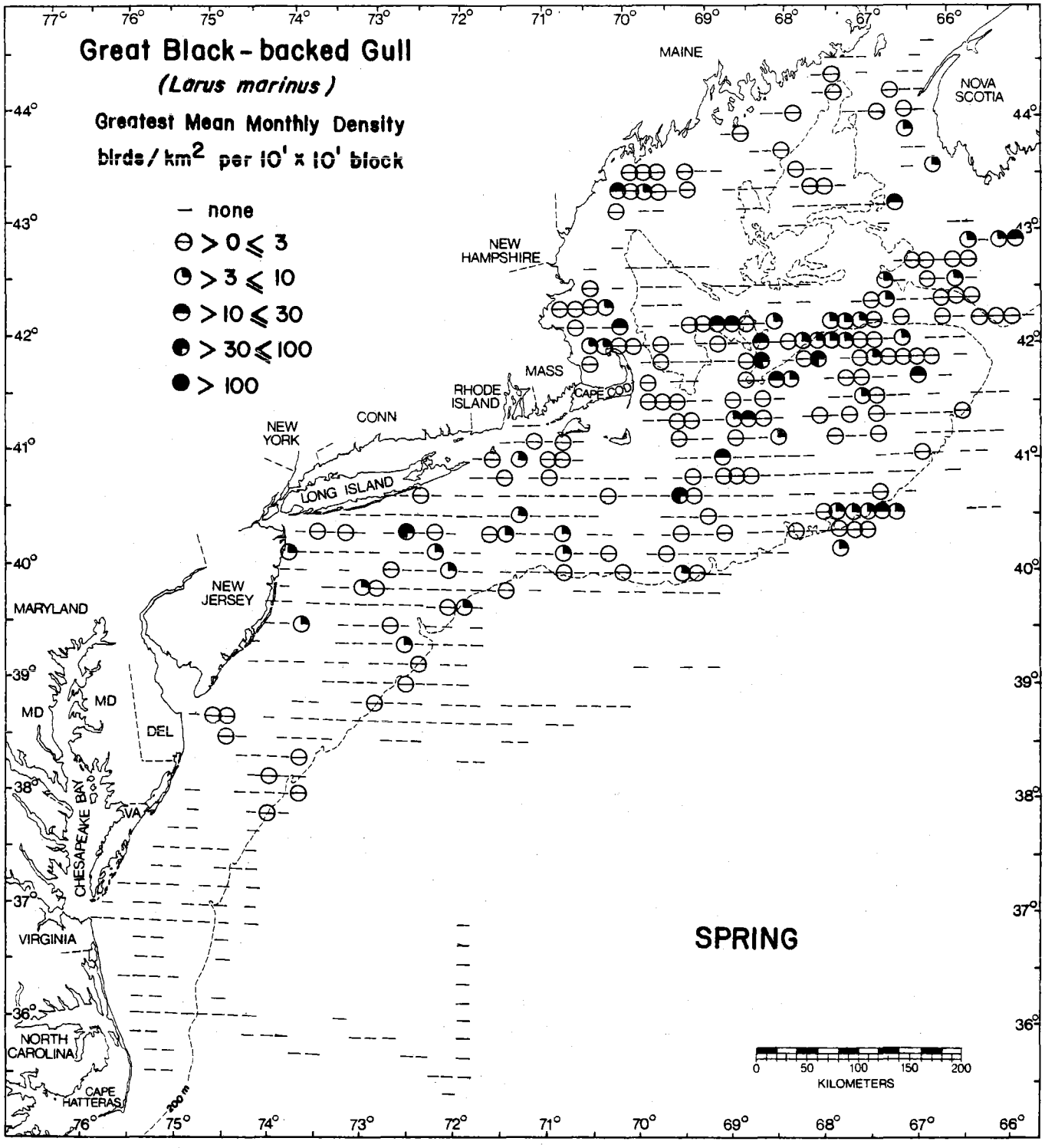

Fig. 73. Relative distribution and abundance of Great Black-backed Gulls (Larus marinus) in spring.

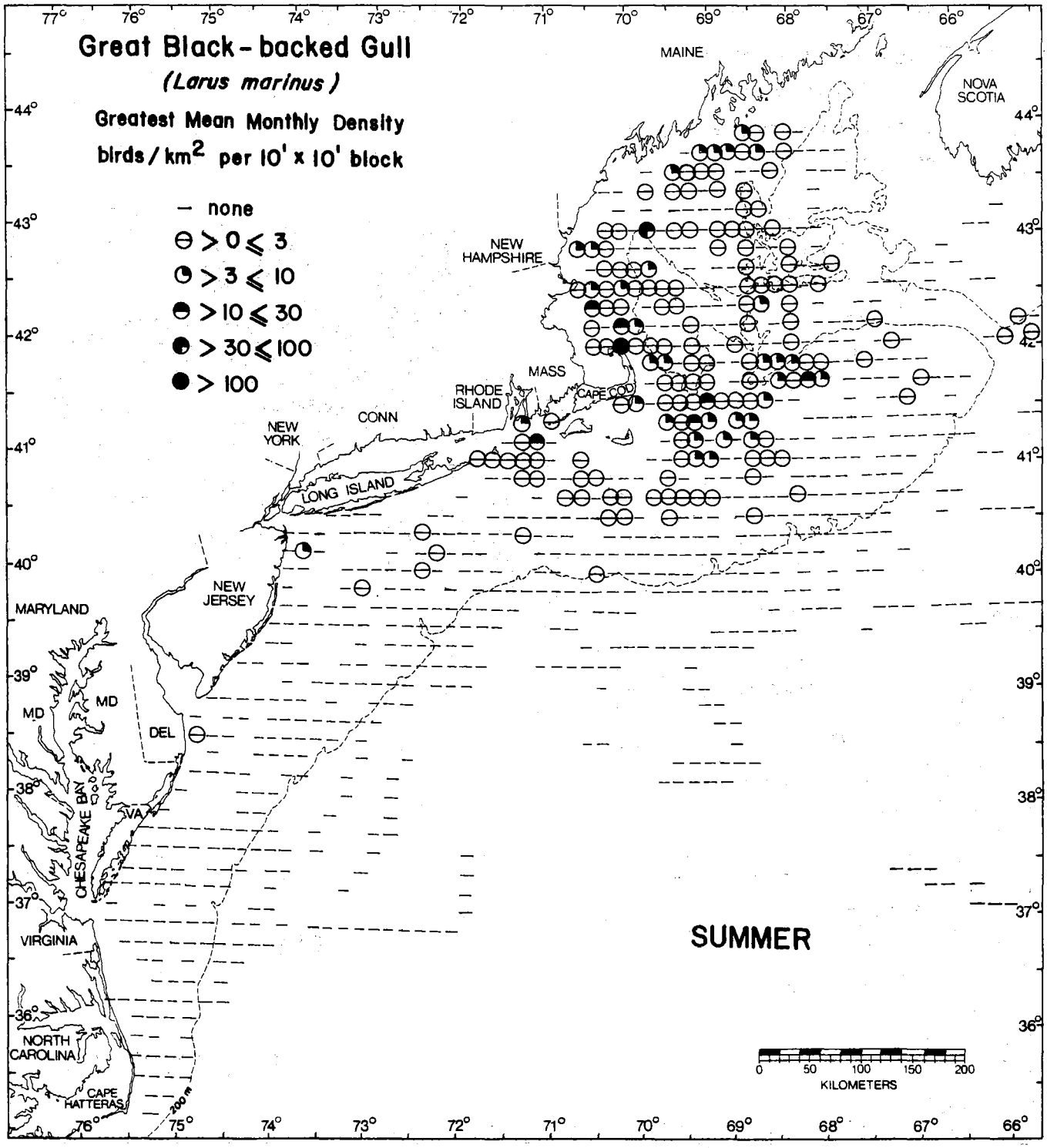

Fig. 74. Relative distribution and abundance of Great Black-backed Gulls (Larus marinus) in summer.

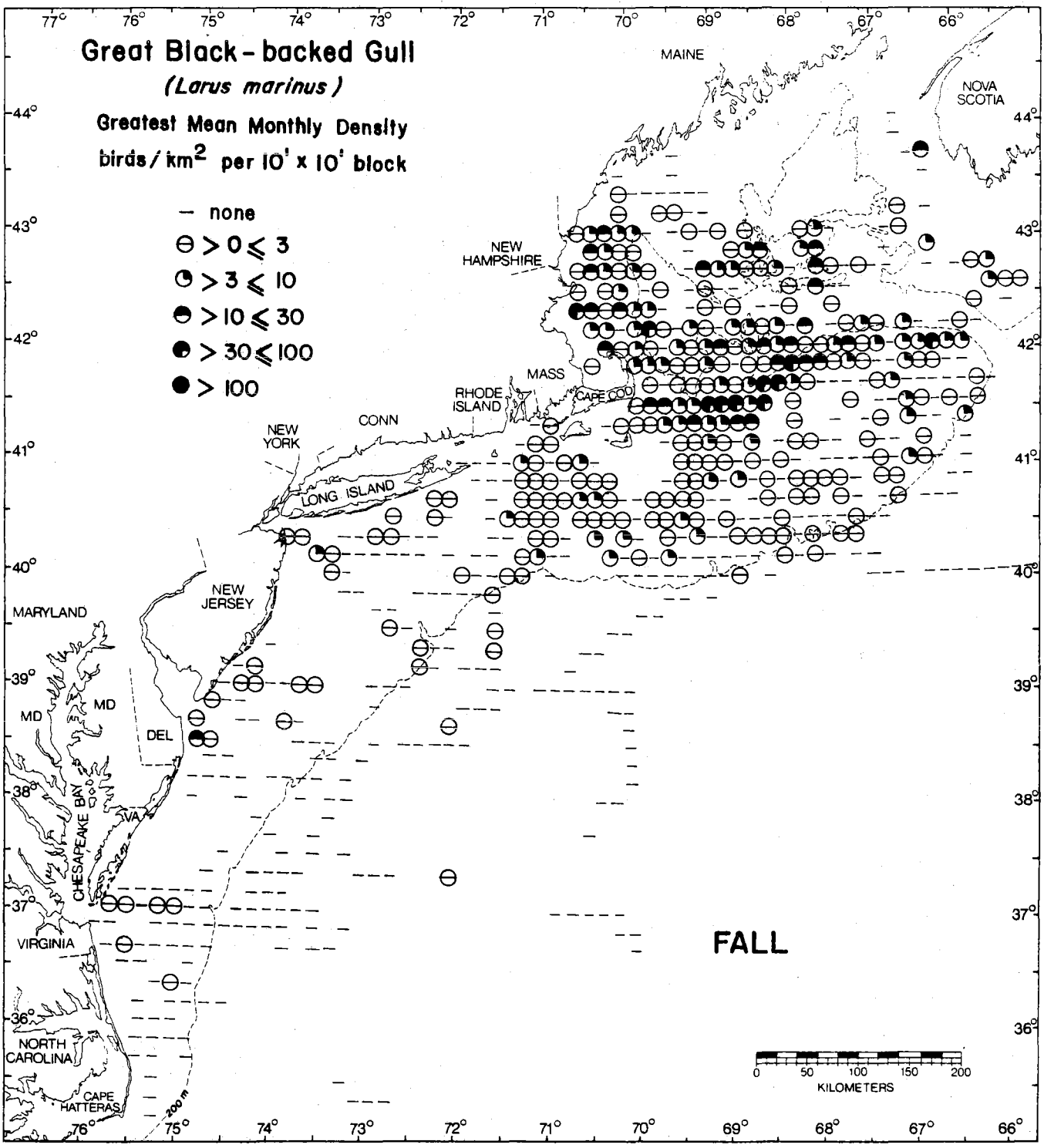

Fig. 75. Relative distribution and abundance of Great Black-backed Gulls (Larus marinus) in fall.

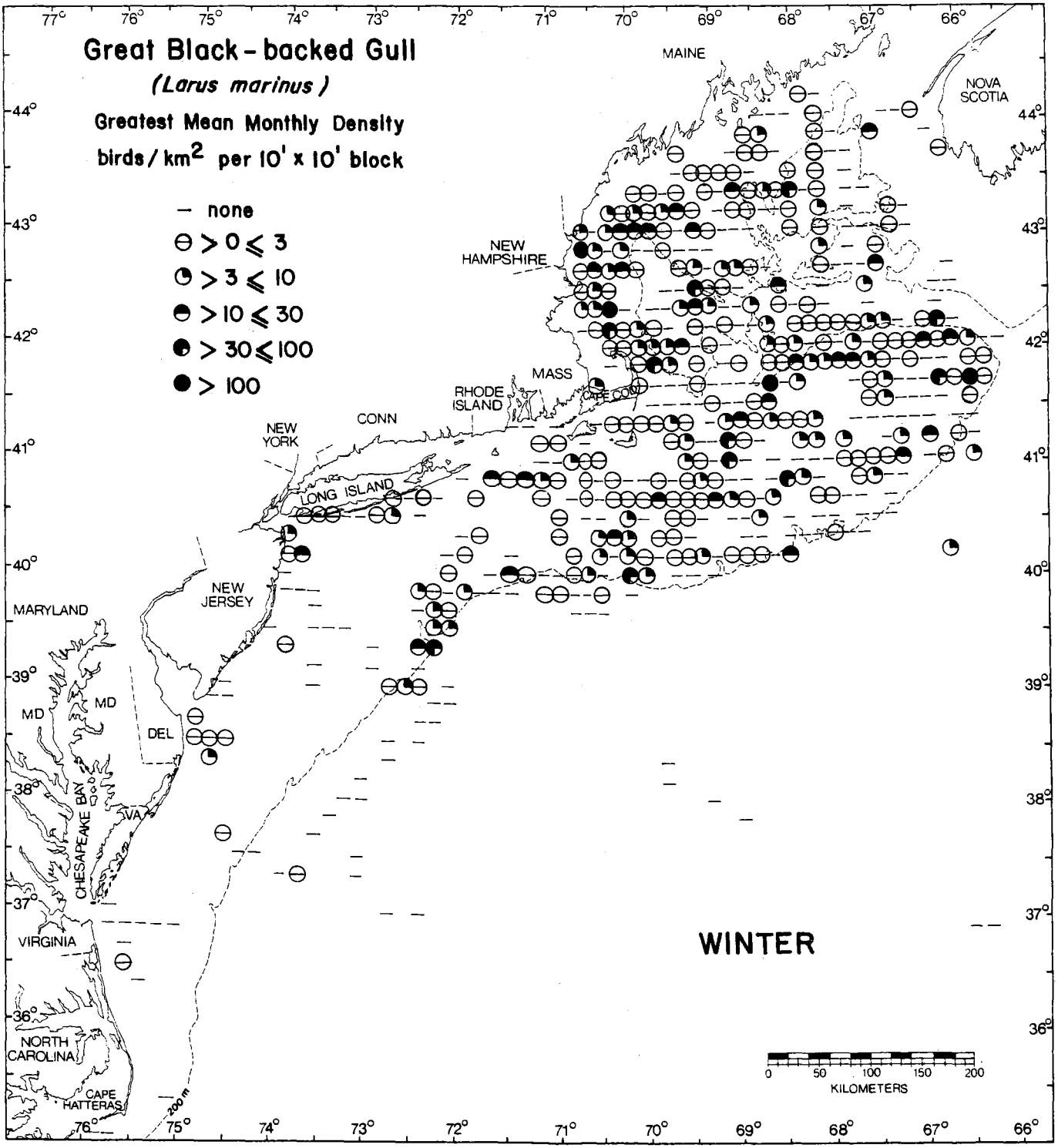

Fig. 76. Relative distribution and abundance of Great Black-backed Gulls (Larus marinus) in winter.

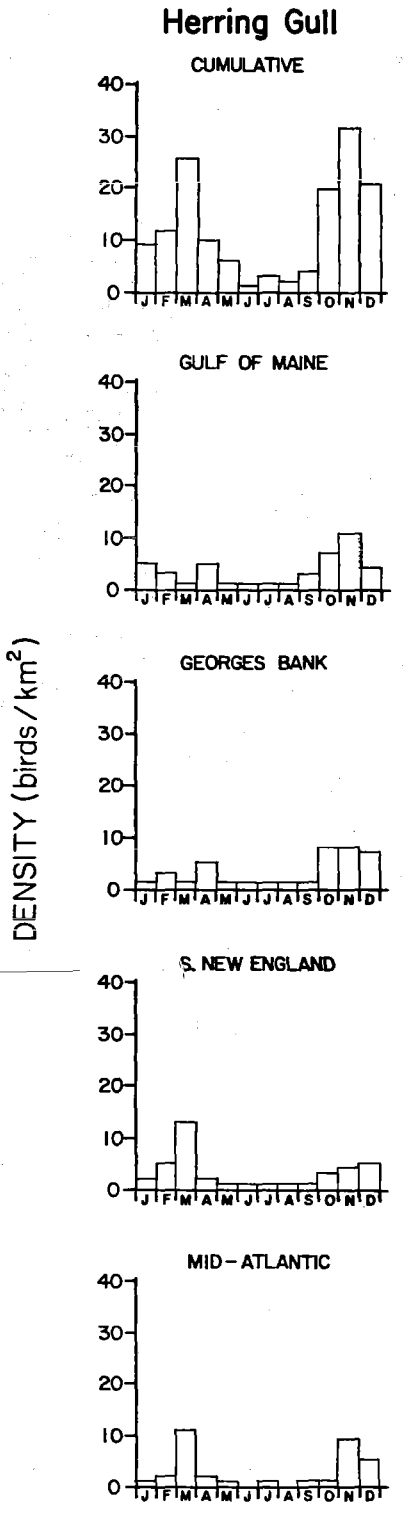

Fig. 77. Histogram of mean monthly densities of Herring Gulls (Larus argentatus) by subarea and the entire study area (cumulative).

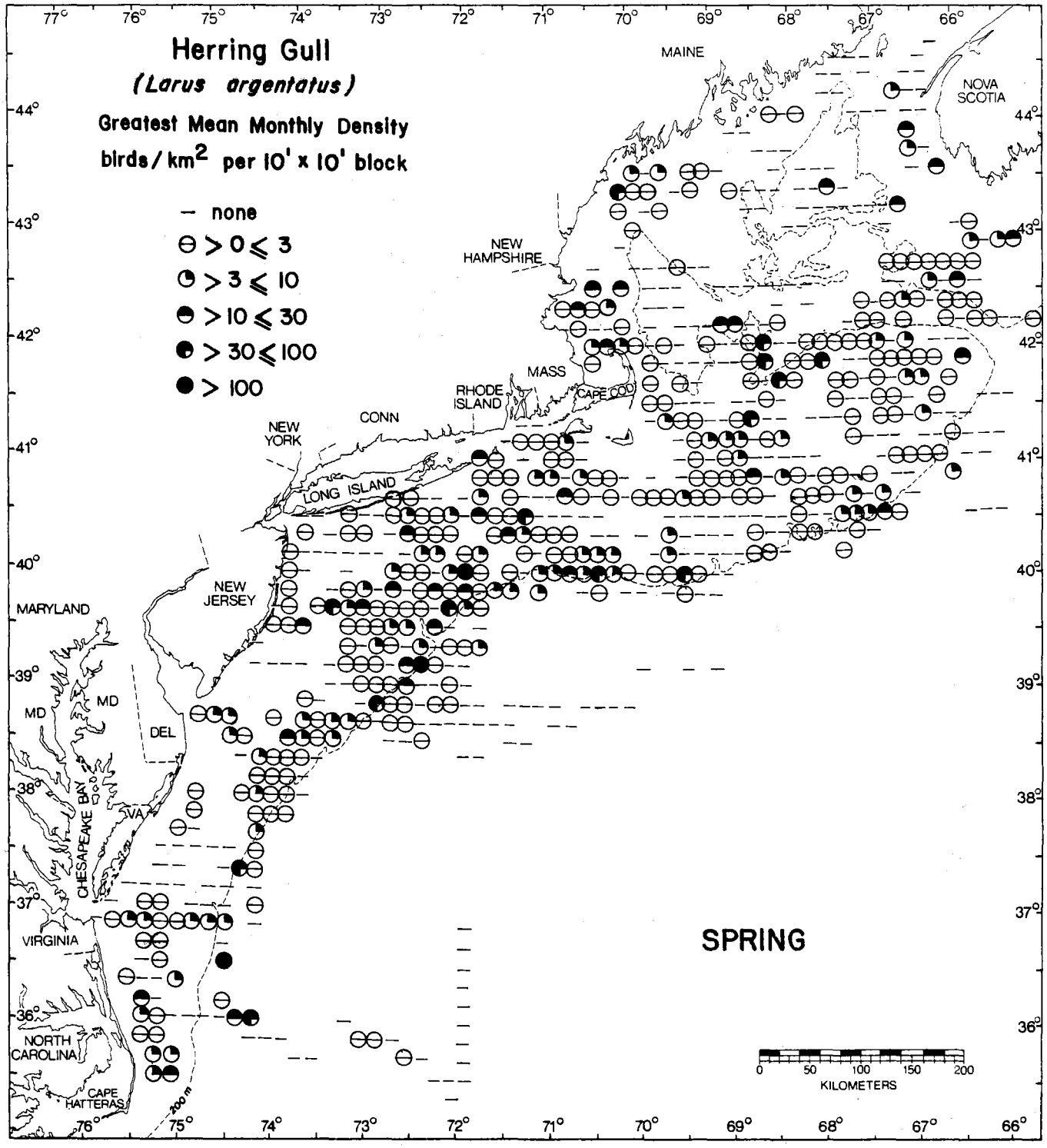

Fig. 78. Relative distribution and abundance of Herring Gulls (Larus argentatus) in spring.

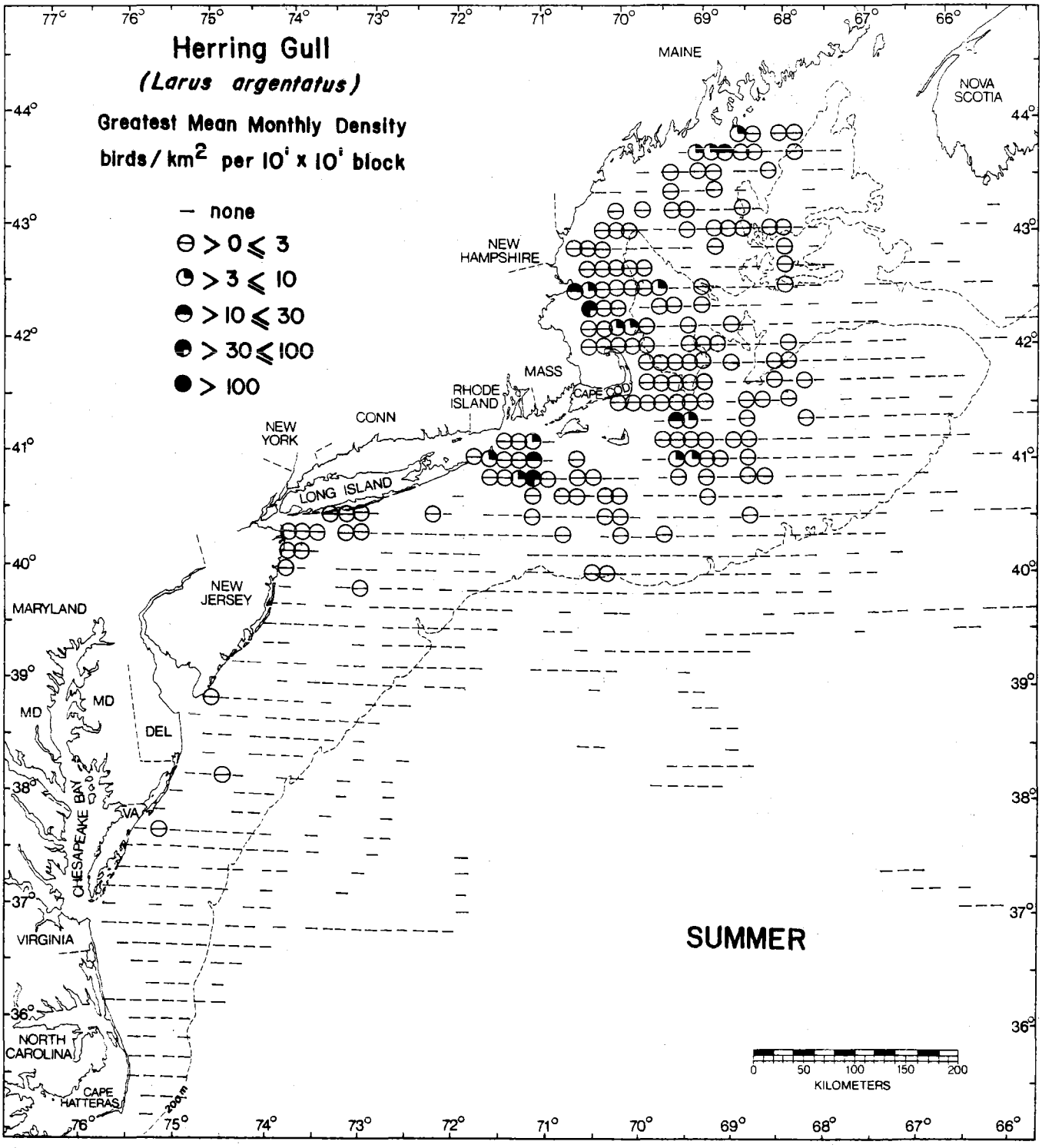

Fig. 79. Relative distribution and abundance of Herring Gulls (Larus argentatus) in summer.

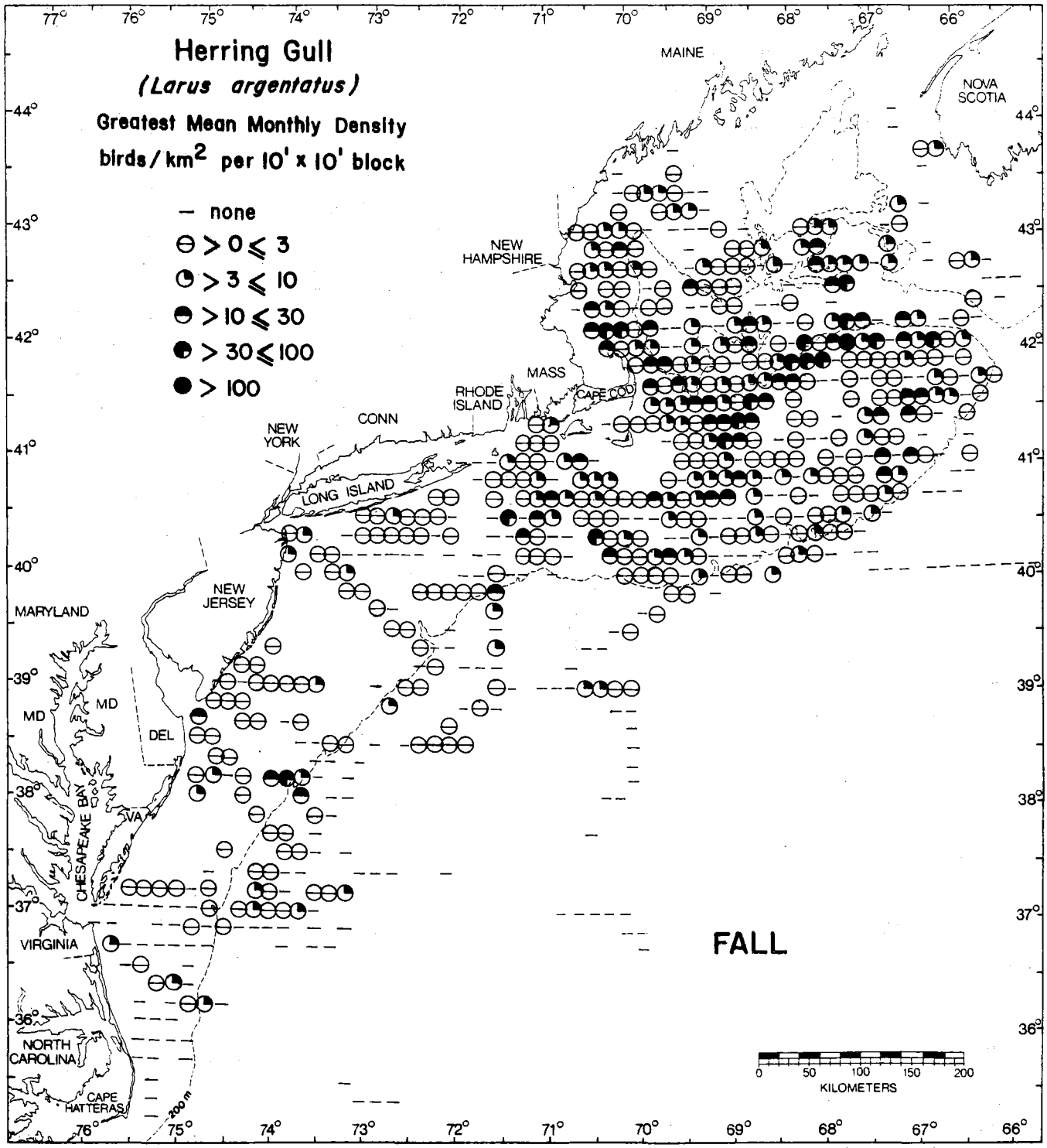

Fig. 80. Relative distribution and abundance of Herring Gulls (Larus argentatus) in fall.

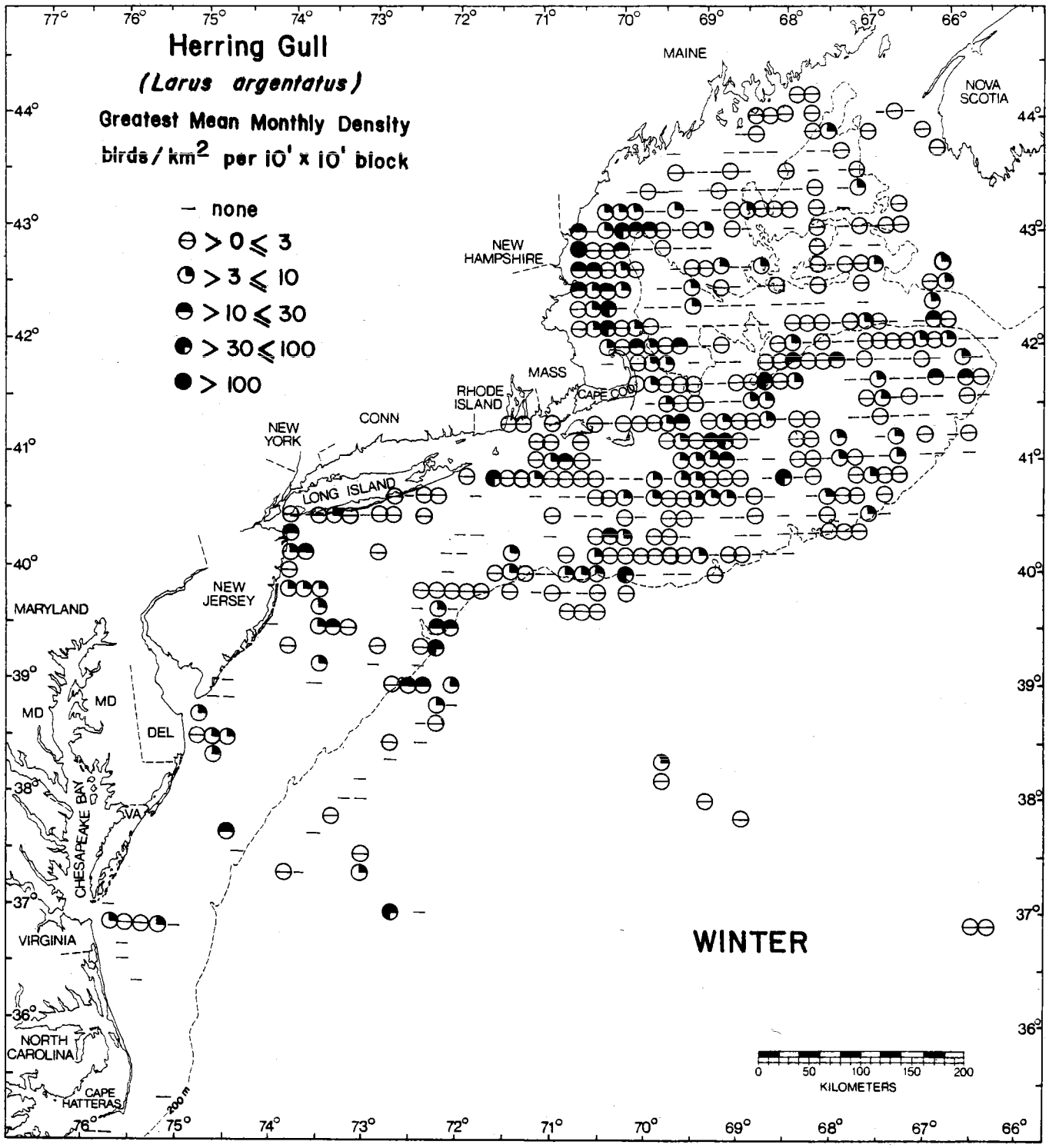

Fig. 81. Relative distribution and abundance of Herring Gulls (Larus argentatus) in winter.

12,400 in 1972 (Drury 1973-74). Based on Drury's figures, my estimates seem too large to be accounted for by immigrants from Canada. In addition, my ratios of Herring to Great Black-backed abundance are never more than 2:1 against 7:1 to be expected from Drury's (1973-74) breeding abundance data. Thus, I note that there are serious problems with measuring the abundance of either large gull at sea, primarily because of their attraction to vessels (Powers 1982), and I have little confidence in the accuracy of these estimates. However, the reader should bear in mind that both species are among the most abundant off the northeastern United States from fall through spring.

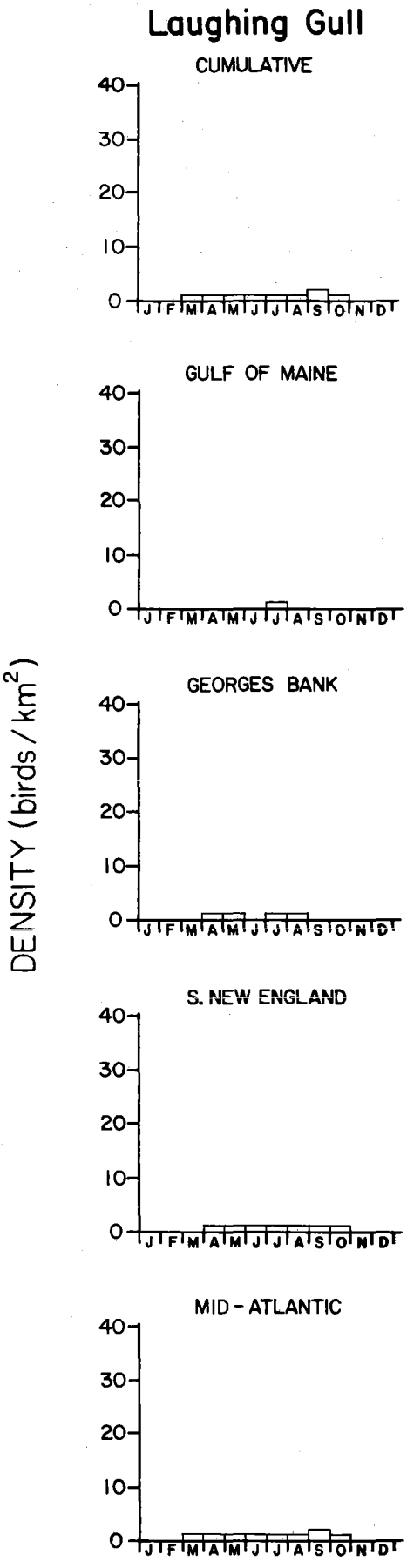

Fig. 82. Histogram of mean monthly densities of Laughing Gulls (Larus atricilla) by subarea and the entire study area (cumulative).

LAUGHING GULL (Larus atricilla)

In eastern North America, Laughing Gulls breed from Texas to southern Nova Scotia (Bent 1921; Godfrey 1966; Drury 1973-74; Erwin 1979; Portnoy et al. 1981).

Laughing Gulls are tertiary and upper level carnivores that feed on small fish in surface waters, take tern eggs on land, and scavenge on offal from fishing vessels (Bent 1921).

They are primarily a coastal inhabitant of subtropical areas from New Jersey south to the Gulf of Mexico. From March to October they were common in the mid-Atlantic subarea within 50 km of their breeding colonies (Fig. 82-85). In spring (April and May) they were rare on Georges Bank and the Gulf of Maine, but in fall (September to October) juveniles were uncommon in coastal waters around the periphery of Cape Cod. In September, an offshore dispersal of adults and immatures was noted from New Jersey south.

The population of Laughing Gulls was estimated at approximately 7,000 to 8,000 in spring and summer, and 40,000 in fall (Appendix 5).

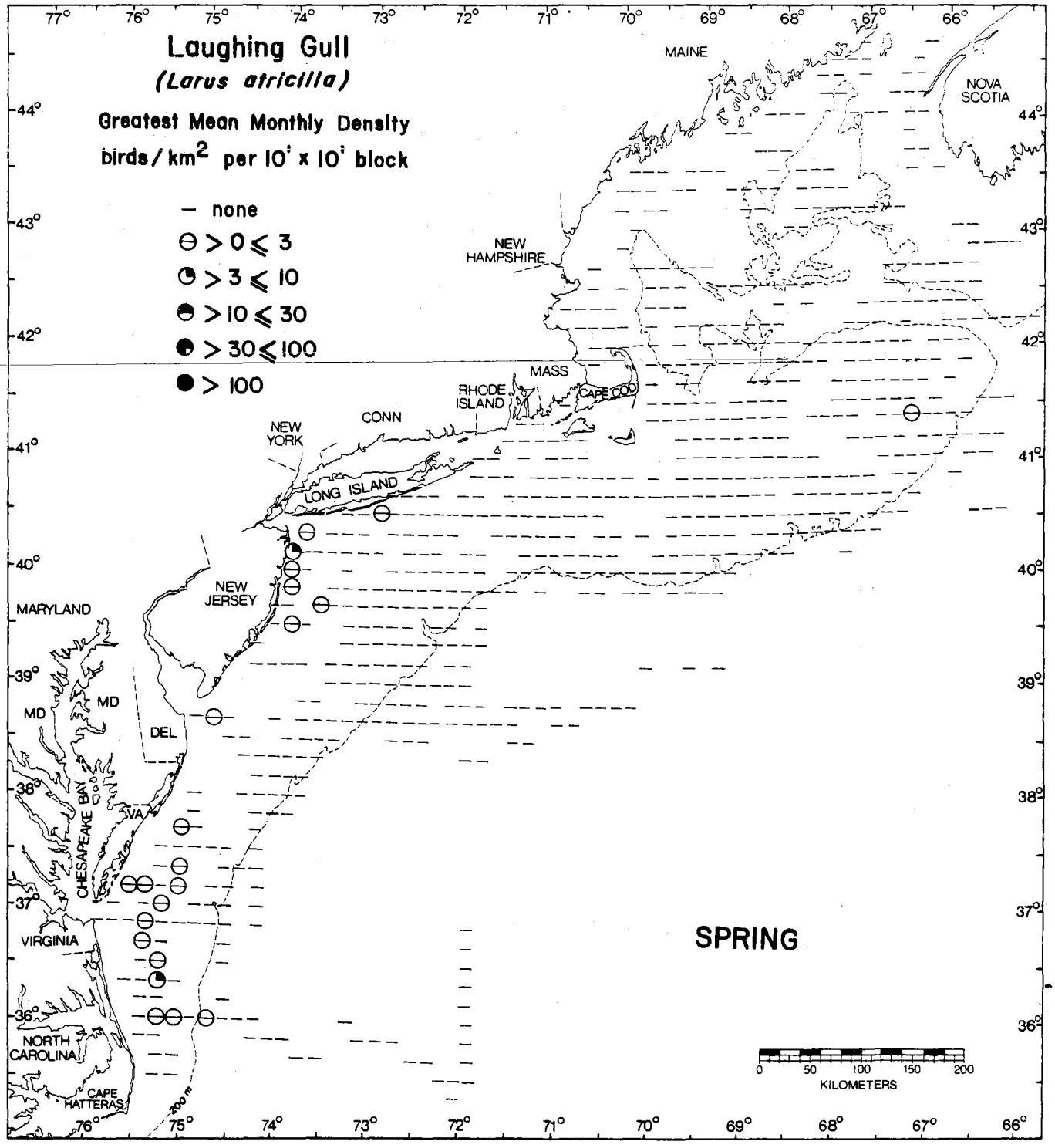

Fig. 83. Relative distribution and abundance of Laughing Gulls (Larus atricilla) in spring.

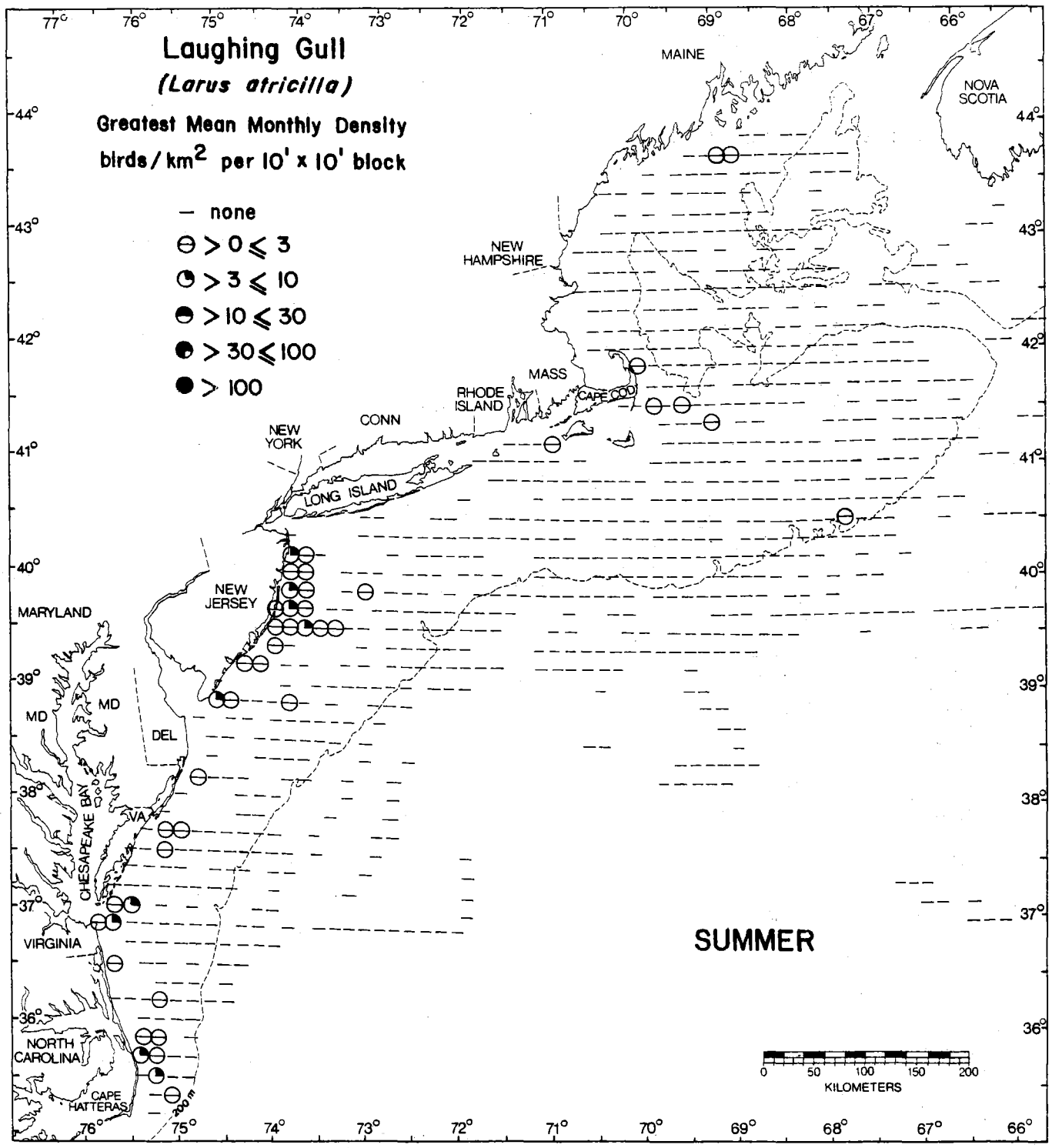

Fig. 84. Relative distribution and abundance of Laughing Gulls (Larus atricilla) in summer.

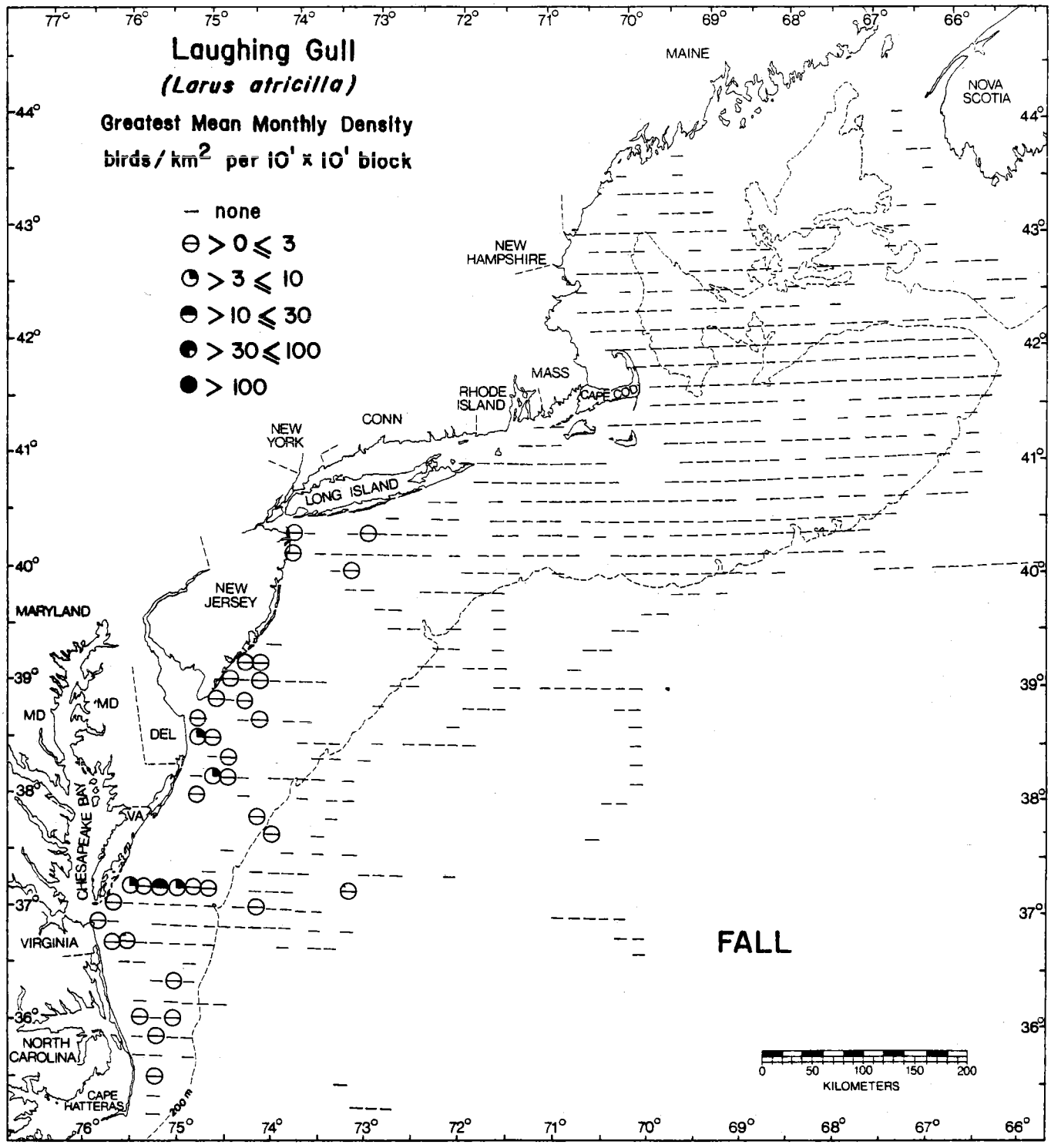

Fig. 85. Relative distribution and abundance of Laughing Gulls (Larus atricilla) in fall.

RING-BILLED GULL (Larus delawarensis)

BONAPARTE'S GULL (Larus philadelphia)

SABINE'S GULL (Xema sabini)

Ring-billed Gulls breed around the periphery of the Gulf of St. Lawrence, south to New York, and west across much of central North America (Bent 1921; Godfrey 1966; Brown et al. 1975). The population in Newfoundland has recently increased (Brown et al. 1975). Bonaparte's Gulls breed in inland waters in the boreal forest zones of western Canada (Godfrey 1966; Brown et al. 1975). In eastern North America, Sabine's Gulls breed in scattered parts of northwest Greenland and in the Canadian arctic (Blomquist and Elander 1981).

The occurrence of these species in offshore waters is limited to migratory periods. Rowlett (1980) found Ring-billed Gulls uncommon in the Chesapeake Bight during fall, and Bonaparte's Gulls common during spring and fall within 20 km of the coast. In this study, Ring-billed Gulls were uncommon during fall migration (Fig. 86-87), and by winter their occurrence was limited to coastal waters.

Bonaparte's Gulls occurred entirely in coastal waters. Braune and Gaskin (1982) estimated 5,000 to 10,000 Bonaparte's Gulls in the inshore passages on the Maine/New Brunswick border during August, and between 2,000 and 5,000 birds from September through November. In winter, I found them uncommon nearshore and in spring they were locally abundant within 50 km of Cape Hatteras (Fig. 88-90). Lee and Booth (1979) noted thousands of Bonaparte's Gulls in Oregon Inlet, North Carolina during mid-winter.

Sabine's Gulls were rarely recorded and only during fall (Appendix 8). Lambert (1973) suggested that most Sabine's Gulls migrate directly from the Canadian arctic to Europe, although he believed a few migrate south in fall via James Bay and the Great Lakes to the Gulf of Maine. Observations from this study and those compiled by Mason (1951) may be part of the latter migration route.

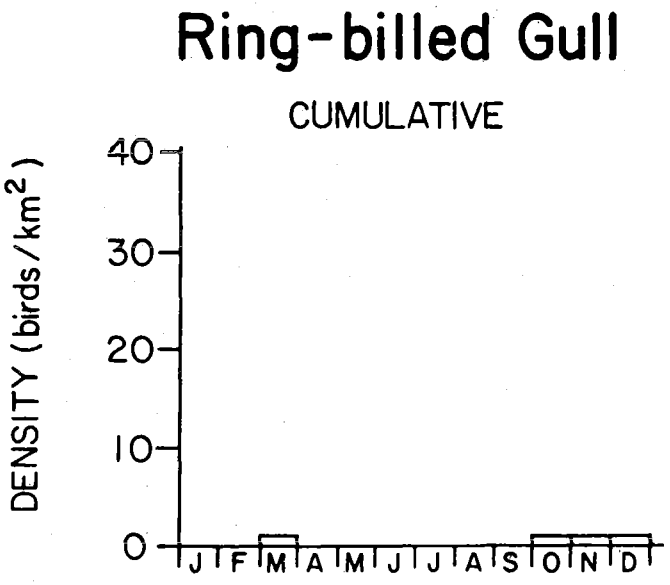

Fig. 86. Histogram of mean monthly densities of Ring-billed Gulls (Larus delawarensis) for the entire study area (cumulative).

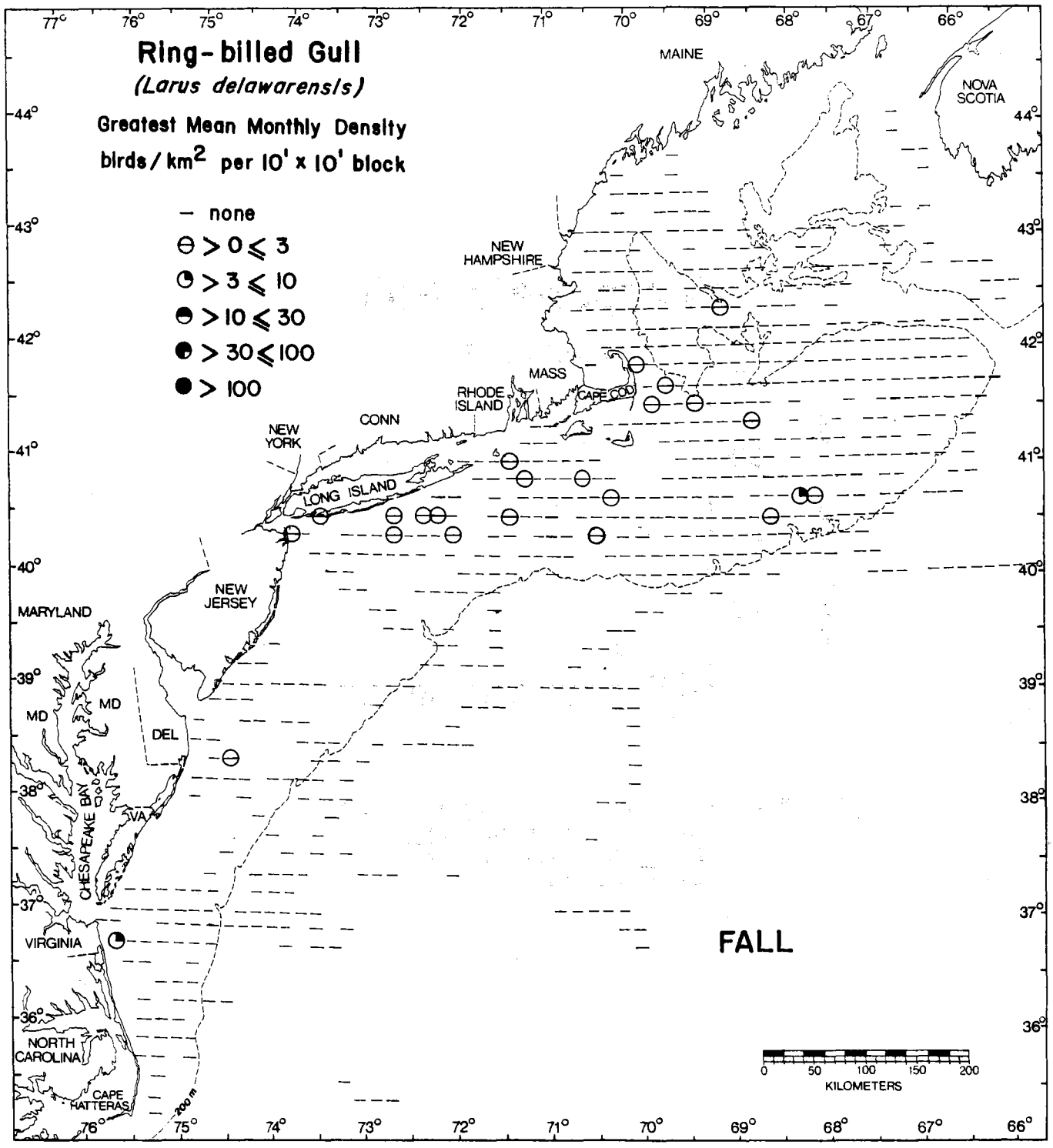

Fig. 87. Relative distribution and abundance of Ring-billed Gulls (Larus delawarensis) in fall.

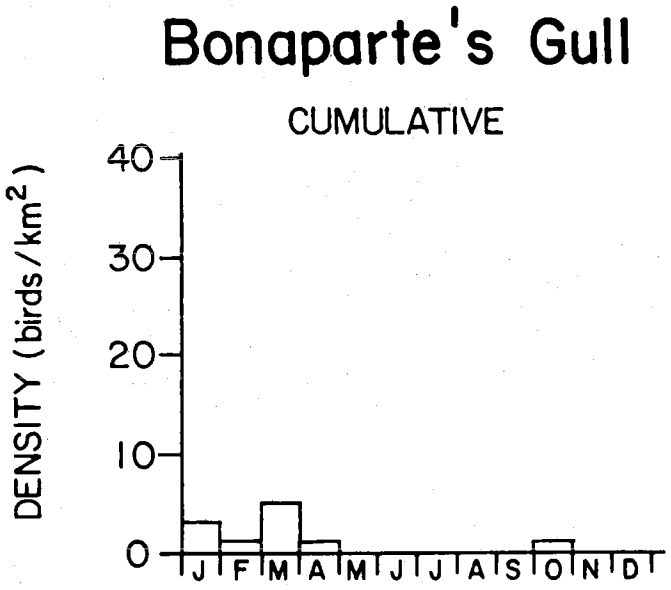

Fig. 88. Histogram of mean monthly densities of Bonaparte's Gulls (Larus philadelphia) for the entire study area (cumulative).

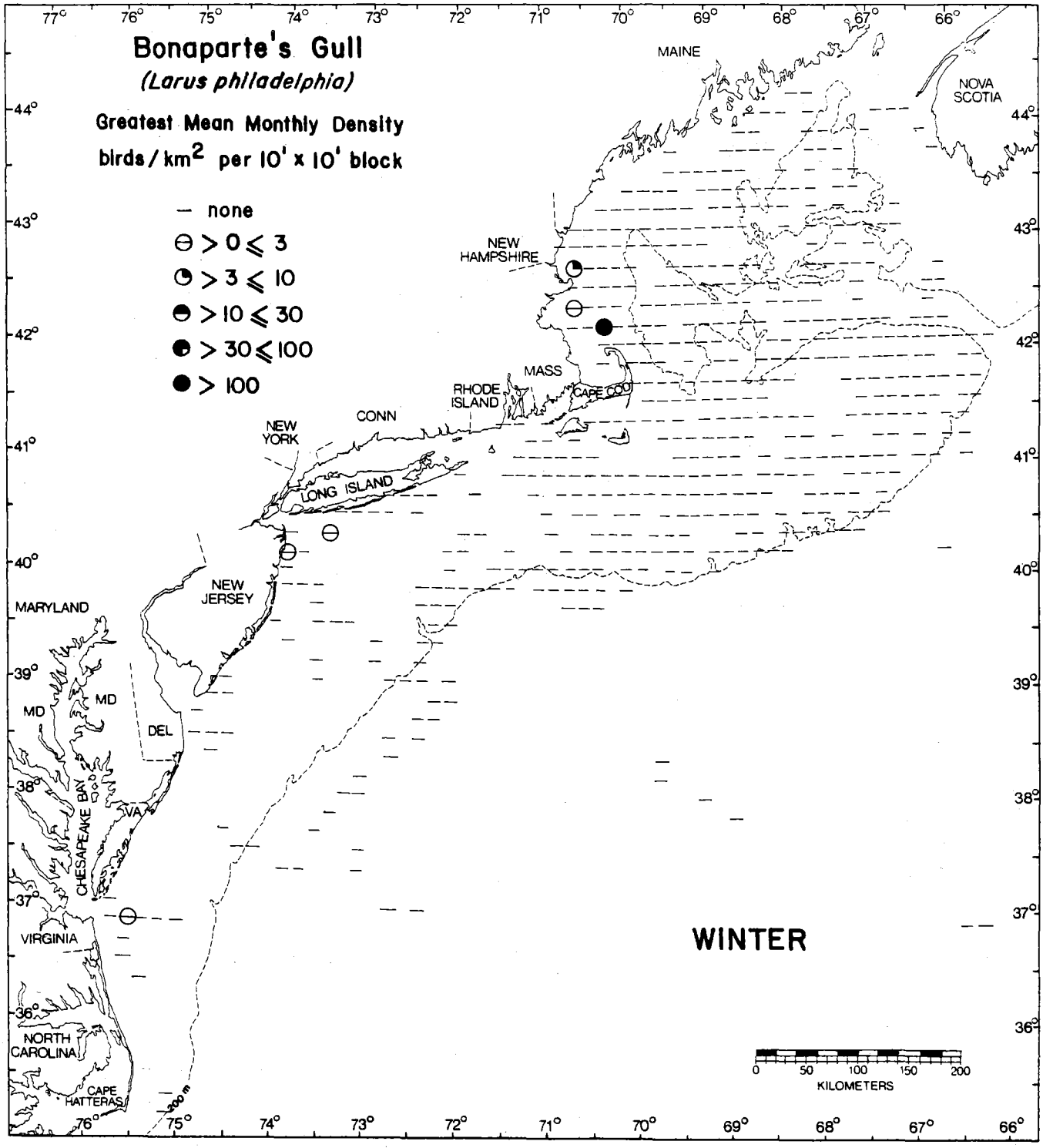

Fig. 89. Relative distribution and abundance of Bonaparte's Gulls (Larus philadelphia) in winter.

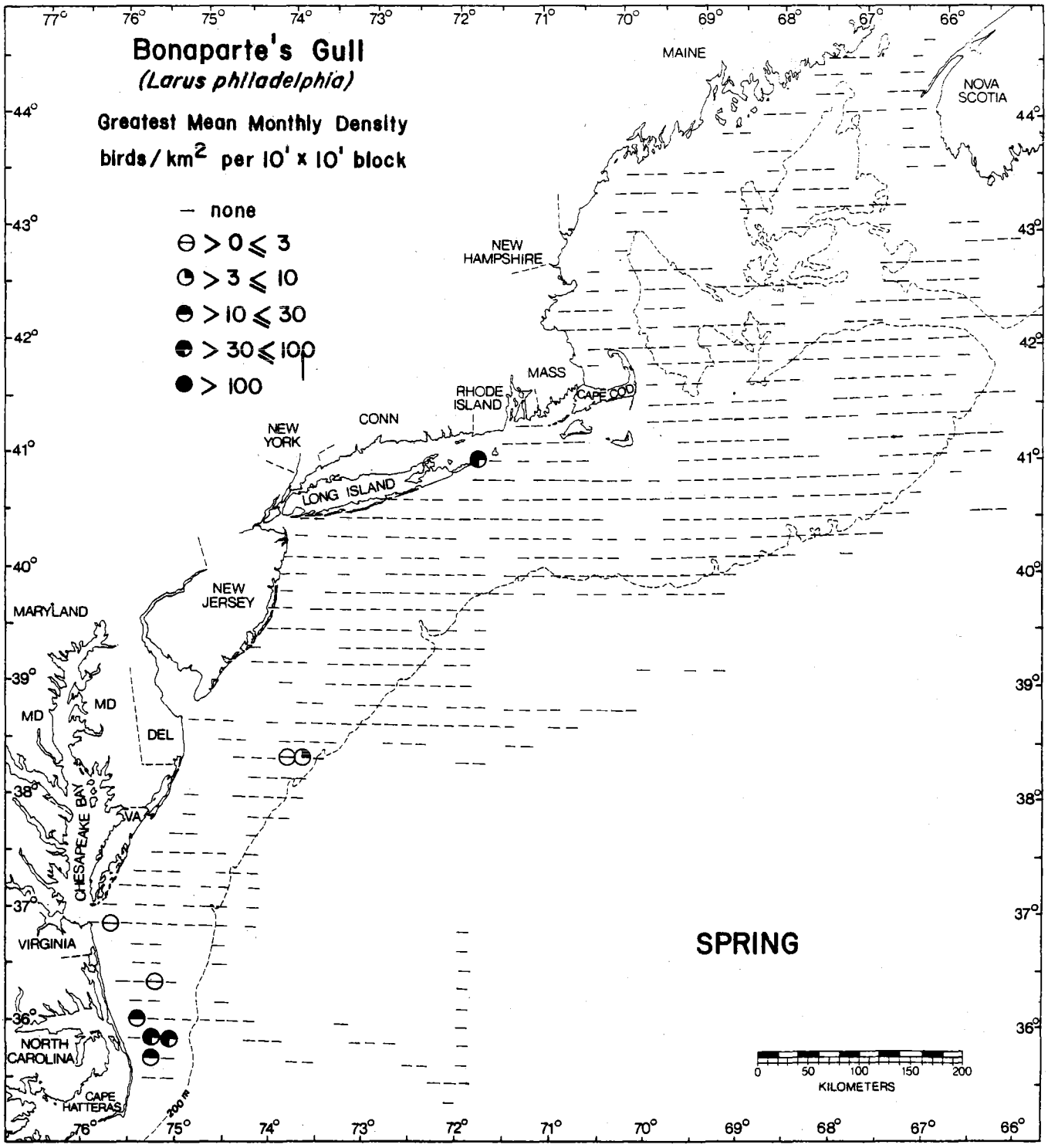

Fig. 90. Relative distribution and abundance of Bonaparte's Gulls (Larus philadelphia) in spring.

BLACK-LEGGED KITTIWAKE (Rissa tridactyla)

In eastern North America, kittiwakes breed on both high and low arctic sides of Baffin Bay and on the low arctic coasts of Newfoundland and the northern Gulf of St. Lawrence and in northern Nova Scotia (Brown et al. 1975).

Kittiwakes feed in near surface waters as secondary and tertiary carnivores on crustaceans, fish and squid (Ainley and Sanger 1979). They also feed as scavengers on offal from fishing vessels (Ainley and Sanger 1979; Wahl and Heineman 1979).

The pelagic distribution of kittiwakes in the western North Atlantic is widespread from high arctic waters off west Greenland south to cool subtropical waters north of the Gulf Stream (Rankin and Duffey 1948; Butcher et al. 1968; Brown et al. 1975). Off the northeastern United States greatest densities were found in the Gulf of Maine and Georges Bank subareas (Fig. 91-94). Within these areas during winter months flocks of several thousand were sometimes recorded, often near fishing fleets on Jeffreys Ledge and Stellwagen Bank in the Gulf of Maine, and over north and east parts of Georges Bank (cf. Snyder 1954; Powers and Rumage 1978). In spite of their co-occurrence with fishing vessels in these areas, kittiwakes were not attracted in large numbers to foreign fleets fishing along the edge of the shelf from southern Georges Bank west to Hudson Canyon.

Early fall migrants recorded in late August were immatures. In late October to early November, both adults and immatures became more common. Peak densities of 15-25 birds/km^2 occurred from December to March in the Georges Bank and Gulf of Maine subareas, and dropped to < 1 bird/km^2 in April. Age composition in winter months was dominated by adults (> 90%) in the Georges Bank and Gulf of Maine subareas, but immatures were probably as abundant as adults in the more southerly subareas (cf. Rowlett 1980). Summer stragglers, usually immatures, were found around Cape Cod as late as June.

Approximately 1.0 million kittiwakes were present on shelf waters in winter off the northeastern United States with over 90 percent occurring north and east of Cape Cod (Appendix 5). The breeding population of kittiwakes in eastern North America has been estimated at ca. 456,000 (200,000 in Atlantic Canada, 222,000 in the eastern Canadian arctic, and 34,000 in west Greenland) (Brown et al. 1975). Kittiwakes banded on the Murmansk coast of Russia have been recovered in Newfoundland (Tuck 1971), which suggests they may also winter off the New England coast as well. As was already noted for other ship-attracted species (fulmars, gannets, Great Black-backed and Herring gulls), this population estimate seems rather high. If half of the eastern North American population were non-breeding immatures, then my estimate would account for the entire population during winter when kittiwakes are equally abundant further north off Canada (Brown et al. 1975).

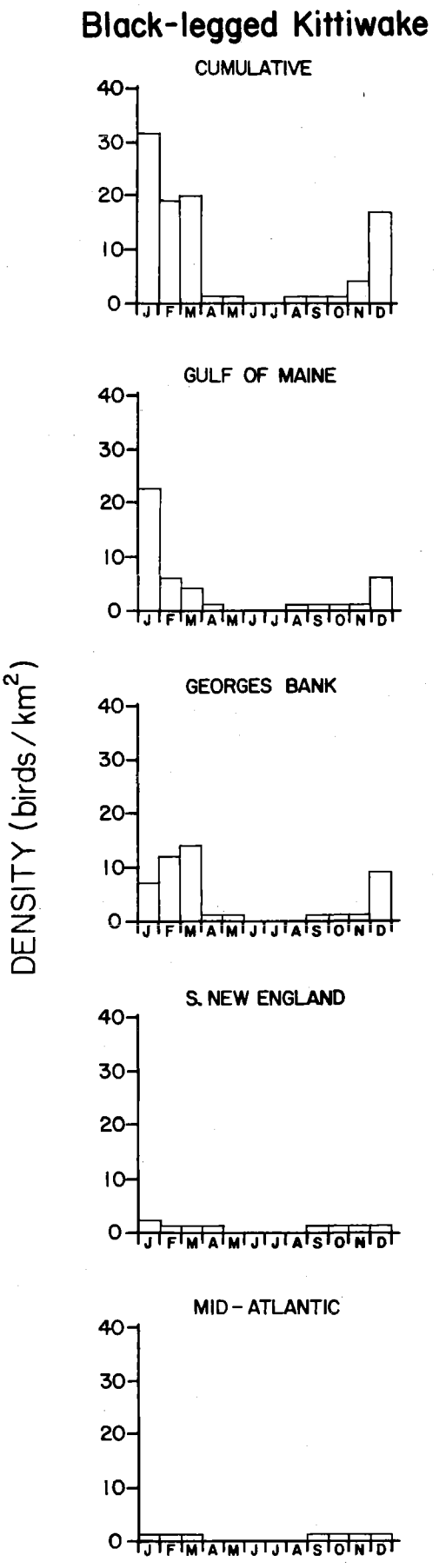

Fig. 91. Histogram of mean monthly densities of Black-legged Kittiwakes (Rissa tridactyla) by subarea and the entire study area (cumulative).

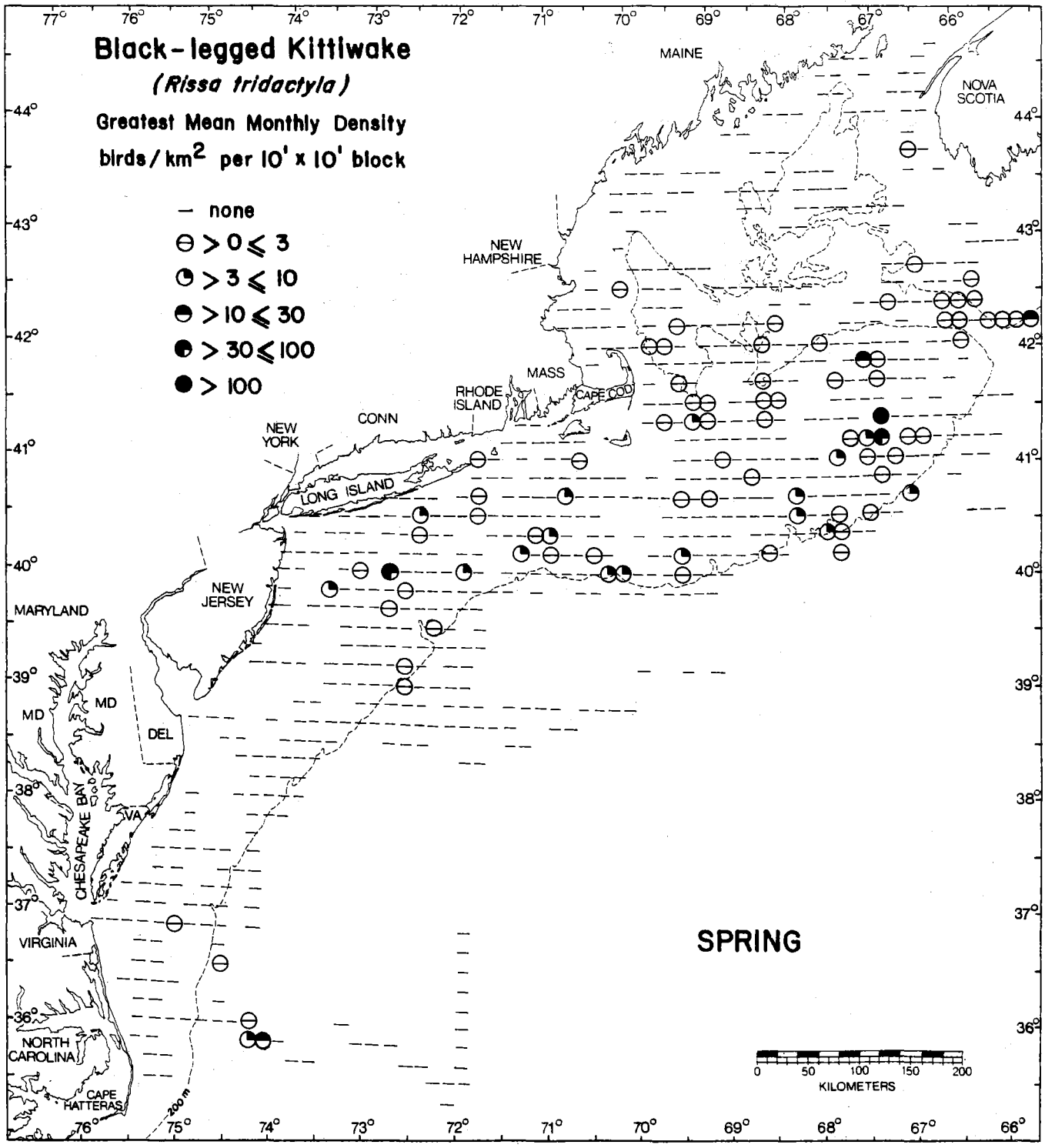

Fig. 92. Relative distribution and abundance of Black-legged Kittiwakes (Rissa tridactyla) in spring.

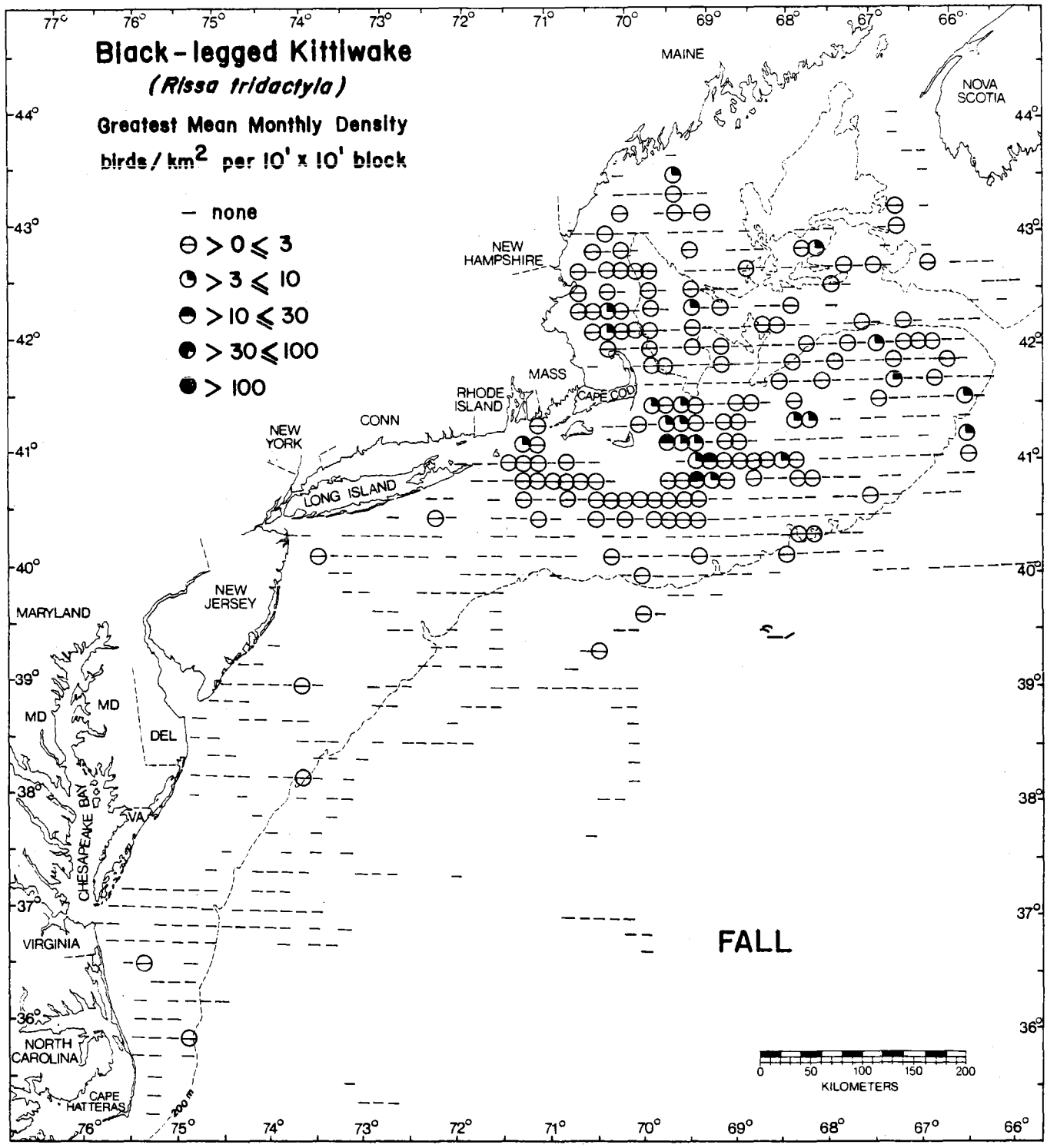

Fig. 93. Relative distribution and abundance of Black-legged Kittiwakes (Rissa tridactyla) in fall.

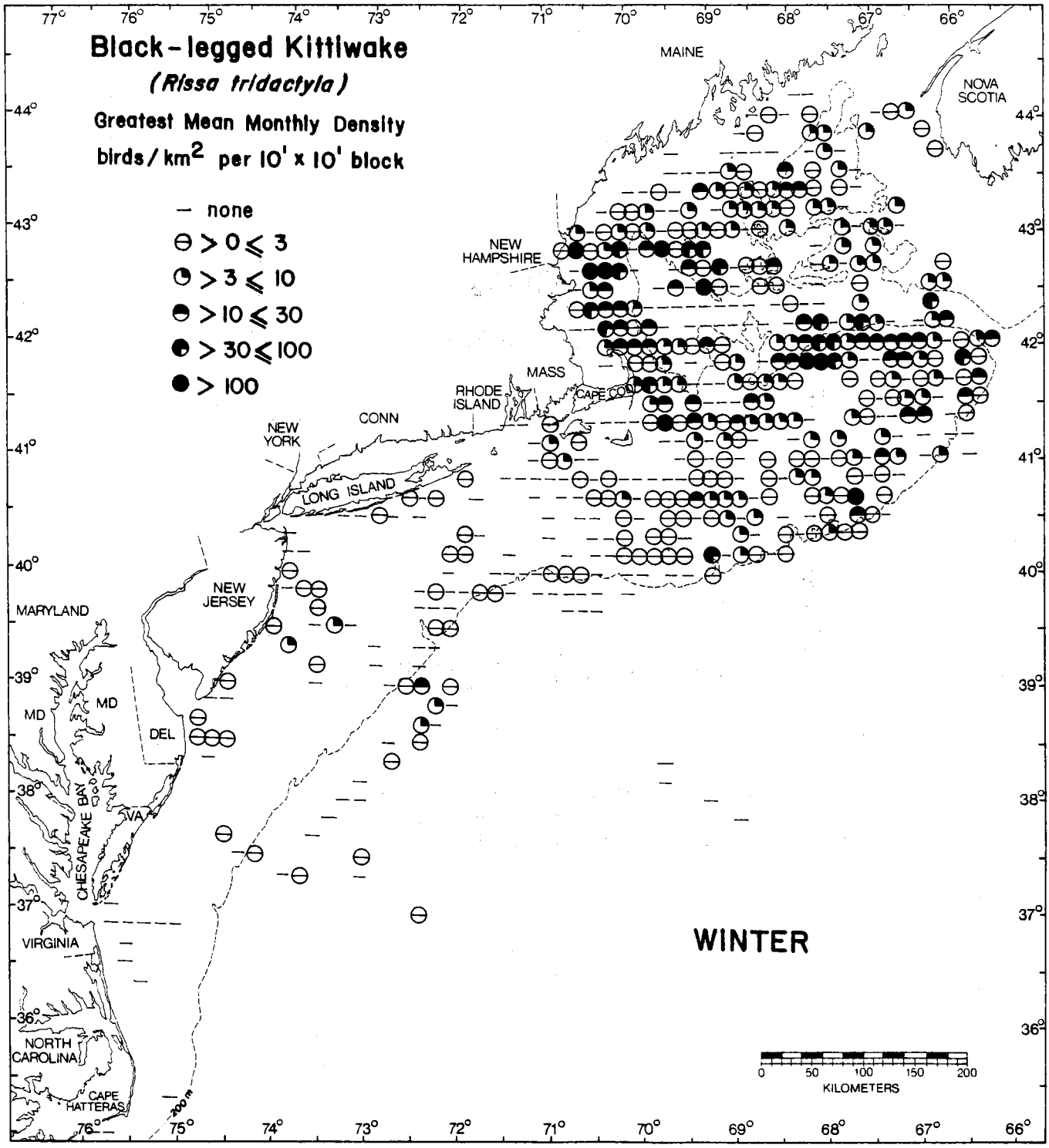

Fig. 94. Relative distribution and abundance of Black-legged Kittiwakes (Rissa tridactyla) in winter.

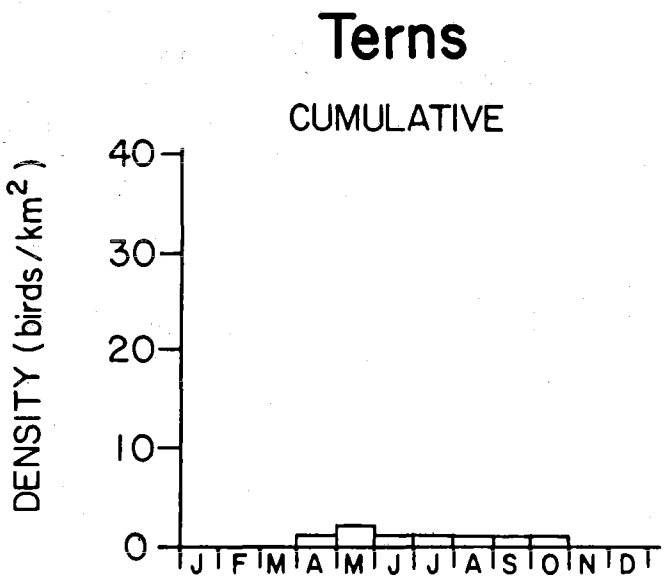

Fig. 95. Histogram of mean monthly densities of terns (Sterna spp.) for the entire study area (cumulative).

COMMON TERN (Sterna hirundo)

ARCTIC TERN (Sterna paradisaea)

ROSEATE TERN (Sterna dougallii)

LEAST TERN (Sterna albifrons)

Within the study area Common Terns breed along the Atlantic coast from northern Nova Scotia south to Cape Hatteras. Arctic Terns breed in low and high arctic areas of eastern Canada and south to Massachusetts. Roseate Terns breed along the Atlantic coast from Nova Scotia locally to Virginia, and Least Terns from Maine to the Florida Keys and along the Gulf coast to Texas. Breeding distributions were taken from Bent (1921), Godfrey (1966), Drury (1973-74), Nisbet (1973), and Brown et al. (1975).

Common and Arctic terns were difficult to separate at sea, therefore their distributions were mapped collectively (Fig. 95-98). Definite Arctic Tern sightings were limited to April and May. The vast majority, if not all of summer and fall sightings were Commons, particularly south of Cape Cod. There was evidence of a build-up of Common Tern numbers before fall migration just north and east of Cape Cod in September and October (Fig. 97).

A few sightings of Roseate Terns and Least Terns were recorded (Appendix 8).

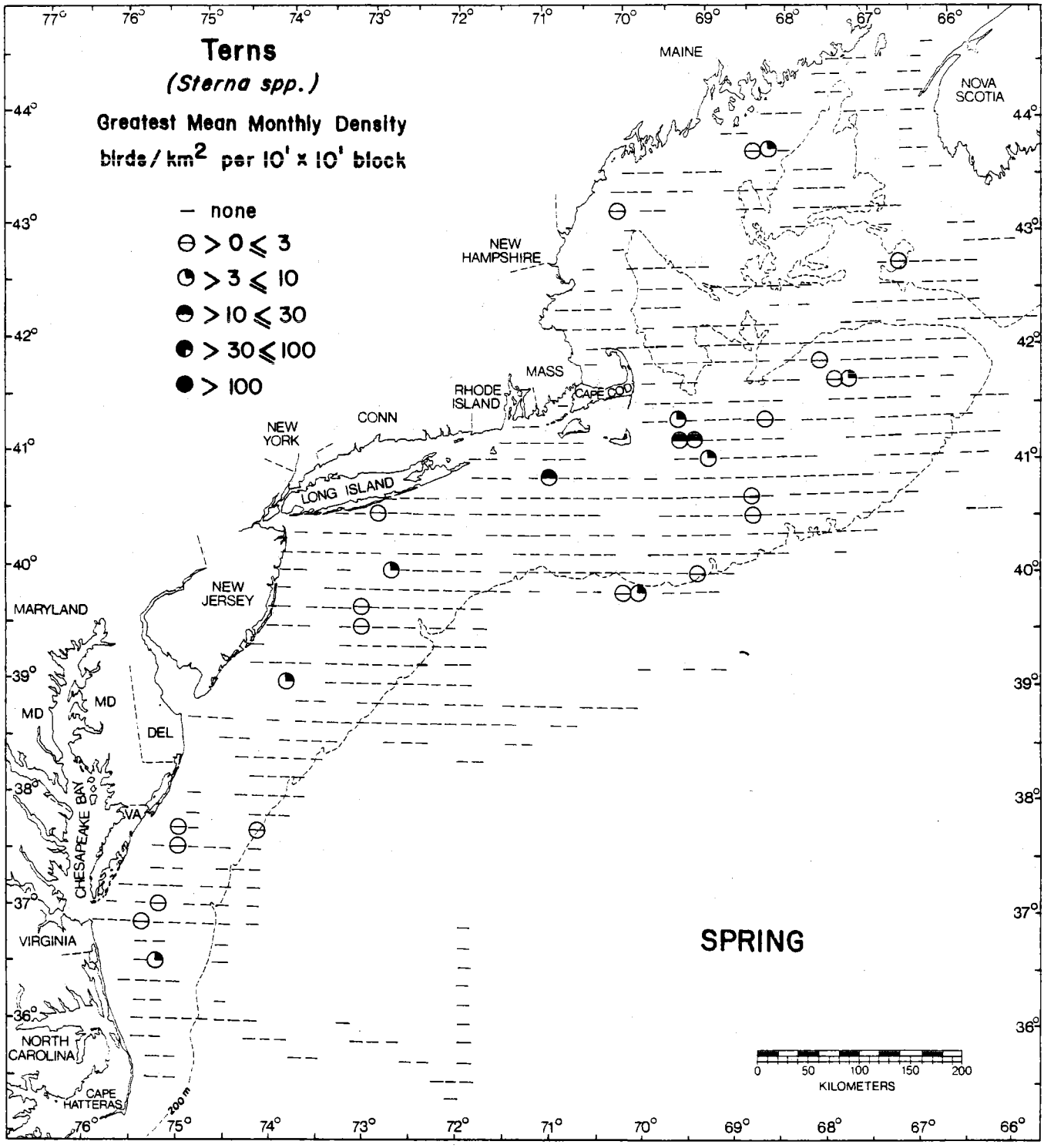

Fig. 96. Relative distribution and abundance of terns (Sterna spp.) in spring.

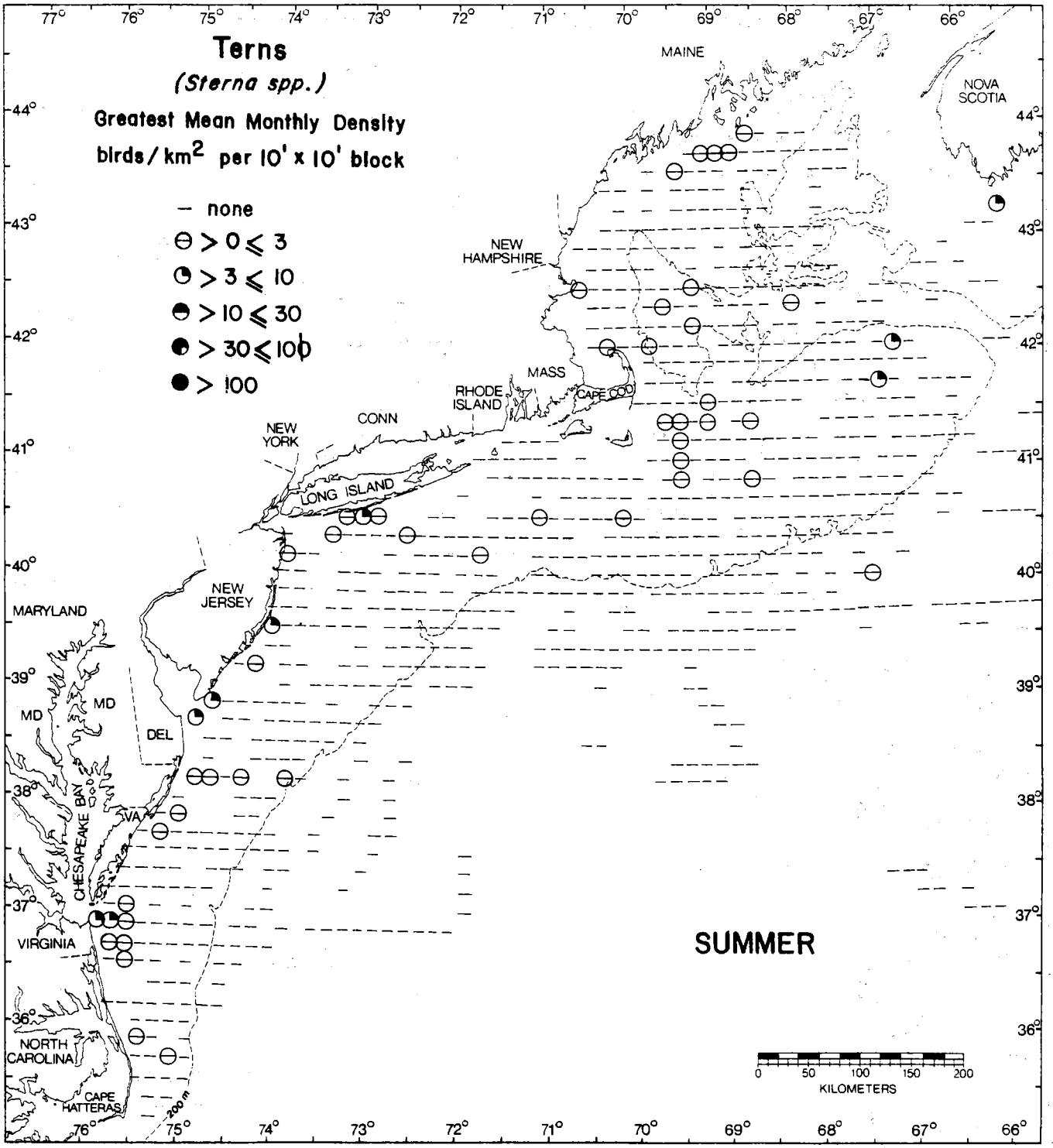

Fig. 97. Relative distribution and abundance of terns (Sterna spp.) in summer.

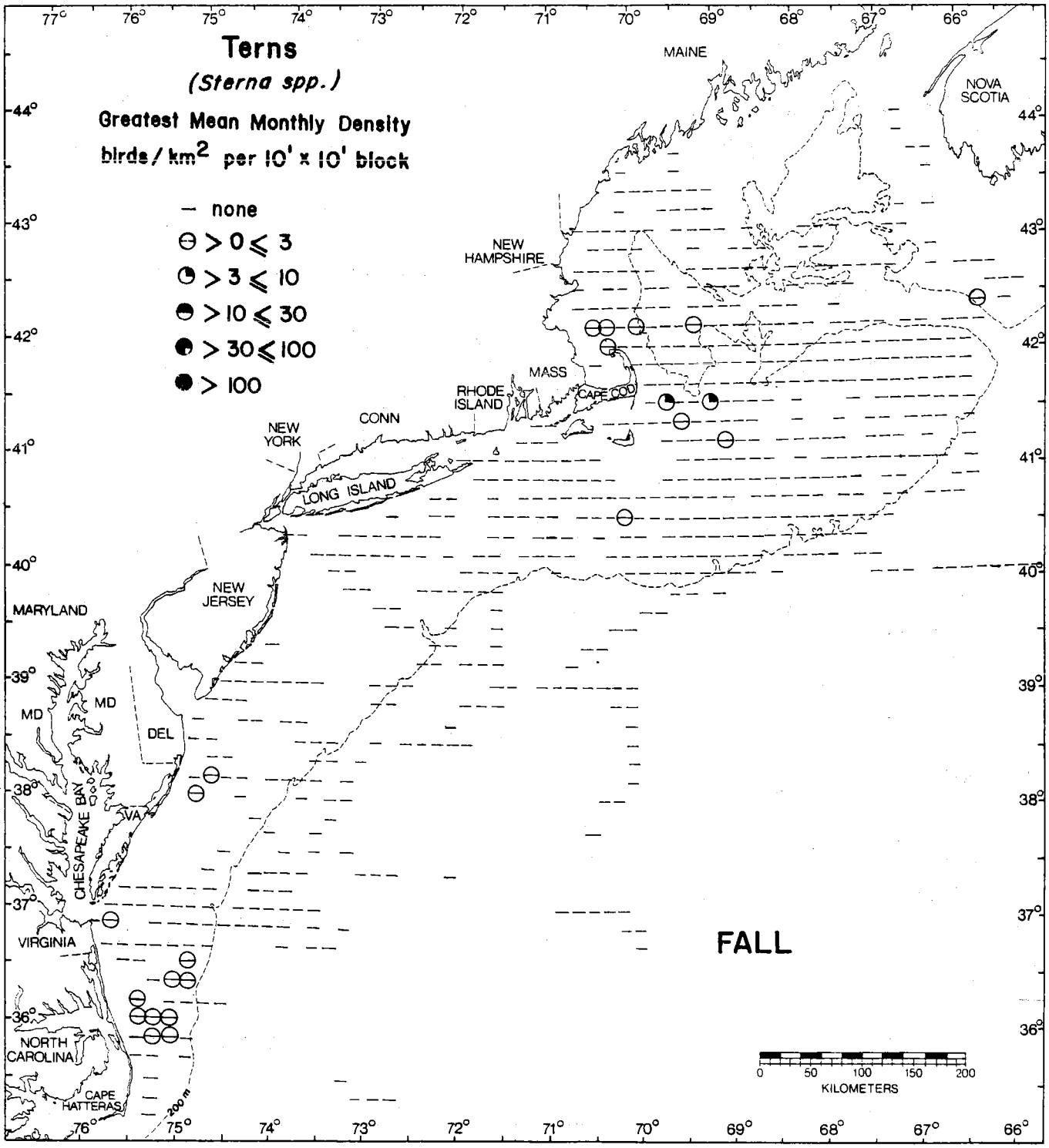

Fig. 98. Relative distribution and abundance of terns (Sterna spp.) in fall.

ROYAL TERN (Sterna maxima)

SANDWICH TERN (Sterna sandvicensis)

BRIDLED TERN (Sterna anaethetus)

Royal and Sandwich terns breed along Atlantic and Gulf coasts in southeastern United States from Virginia to Texas (Bent 1921). In the Atlantic, the Bridled Tern breeds in the Bahamas, West Indies to Venezuela, and westward throughout the Caribbean Sea to Belize (Bent 1921).

Royal Terns were uncommon in coastal waters of the mid-Atlantic subarea south of Chesapeake Bay in summer and fall (Fig. 99-101). Sightings of Sandwich Terns were limited to nearshore waters around Cape Hatteras during summer and early fall months (Appendix 8). Bridled Terns were found in slope water north of 35°N in late August and early September 1979 (Appendix 9), which corresponded with the close of their breeding season (Bent 1921).

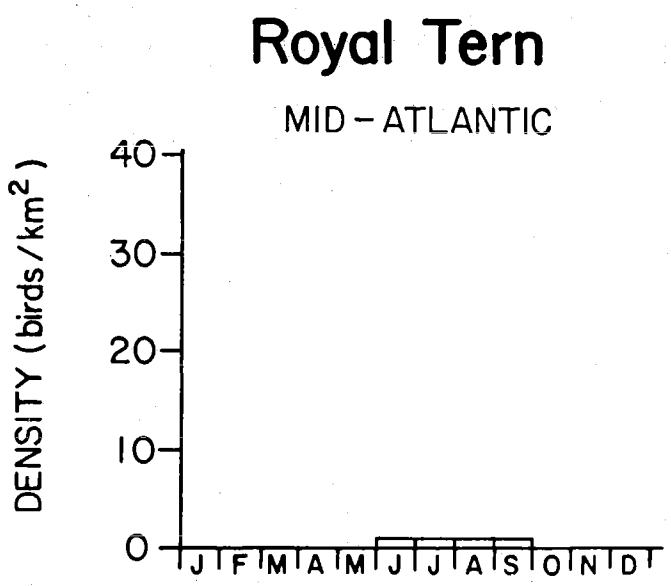

Fig. 99. Histogram of mean monthly densities of Royal Terns (Sterna maxima) for the mid-Atlantic subarea.

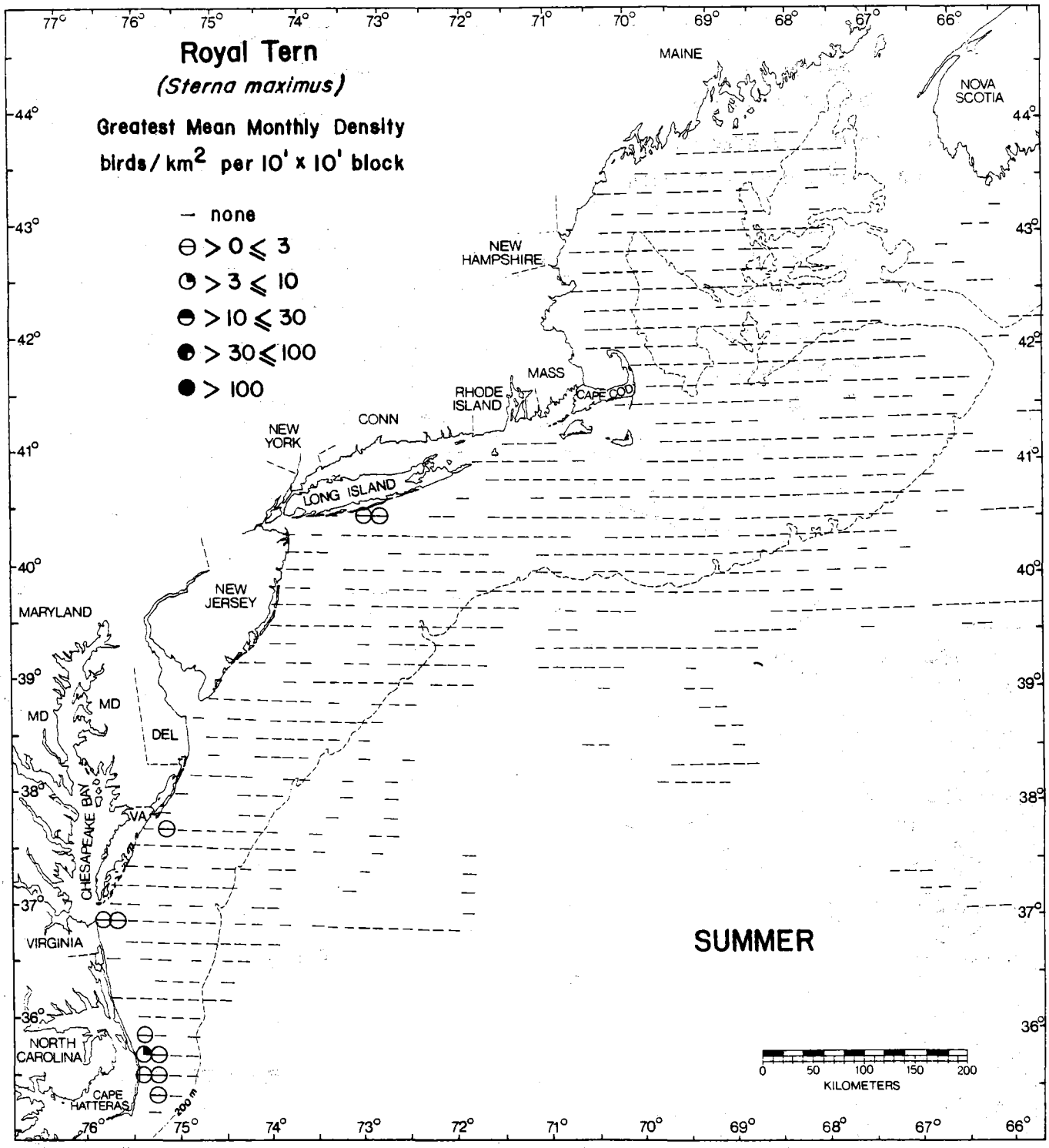

Fig. 100. Relative distribution and abundance of Royal Terns (Sterna maxima) in summer.

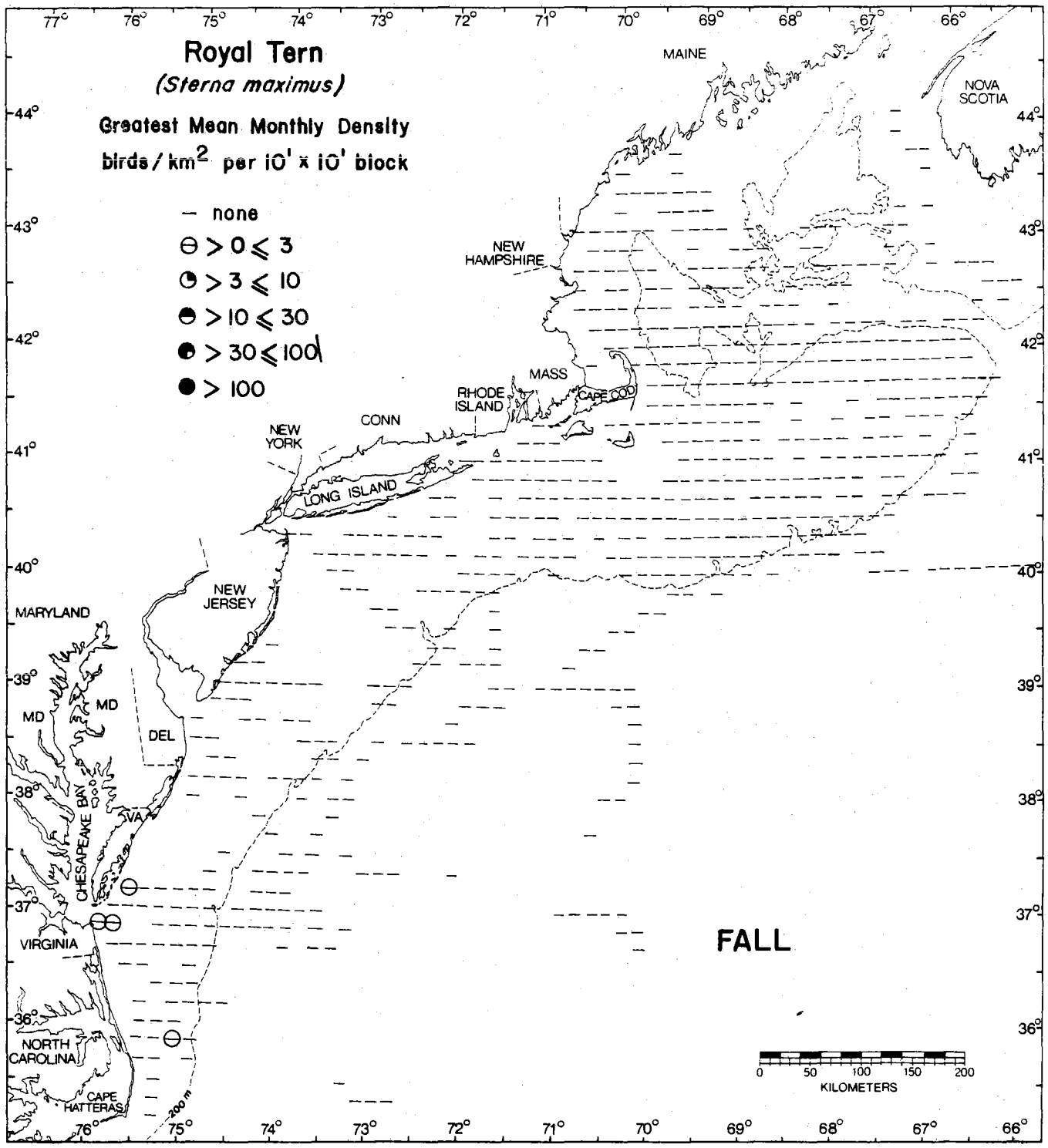

Fig. 101. Relative distribution and abundance of Royal Terns (Sterna maxima) in fall.

RAZORBILL (Alca torda)

In eastern North America, Razorbills breed throughout Atlantic Canada and up the low arctic coast of west Greenland (Brown et al. 1975). They are most common in Atlantic Canada between 54° and 58°N (Brown et al. 1975), although they breed as far south as Matinicus Rock, Maine (Drury 1973-74).

Razorbills are pursuit-divers which feed as secondary and tertiary carnivores on crustaceans and fishes (Madsen 1957; Tuck 1961; Harris 1970).

Brown et al. (1975) plotted sightings of Razorbills at sea in waters off Atlantic Canada during summer months. McKittrick (1929) noted ca. 3000 Razorbills on the southern end of the Grand Bank, but he may have mistaken these flocks for murres. Razorbills were the second most frequent alcid found dead on the beaches of Nantucket Island, Massachusetts after the ARGO MERCHANT oil spill (Powers and Rumage 1978). At the southern limits of their pelagic range, Razorbills were uncommon from December to March in the northern Chesapeake Bight (Rowlett 1980) and rare in coastal areas of the southeastern United States as far south as Florida (Patterson and Menk 1977).

Off the northeastern United States, Razorbills were present from late November to May (Fig. 102). During winter, they were most common in shoal areas around Cape Cod, south of the islands of Nantucket and Martha's Vineyard, and east along northern Georges Bank (Fig. 103). Although poor sampling effort on the mid-Atlantic shelf at this time prevented any quantitative comparison between subareas, Georges Bank and Nantucket Shoals appeared to be the southern limits of any significant numbers of Razorbills. Their distribution was more widespread in spring (Fig. 104) and generally included sightings of individuals rather than flocks. The occurrence of Razorbills during spring in the S. New England subarea and on the southern parts of the shelf probably indicated a northward movement from more southerly shelf waters.

Approximately 26,000 Razorbills were estimated in winter. Another 16,000 unidentified large auks, which included Razorbills, were also estimated at this time (Appendix 5). Observations from this study, as well as a comparison of ratios of alcid mortality from oil spills in the western North Atlantic (Brown, in press), suggest that a large fraction of the North American Razorbill population, not including the Greenland breeders, spend the winter south of Nova Scotia. Using data from Brown et al. (1975), there are approximately 38,000 Razorbills breeding in Atlantic Canada and northeast Maine. Using breeding and survivorship data from Lloyd and Perrins (1977), one may expect breeders (birds more than 5 years old) to constitute about 60 percent of a Razorbill population. Thus, the total population of Razorbills in Atlantic Canada may be in the order 60,000 to 65,000, and my estimate for shelf waters off the New England coast accounts for only about 40 to 45 percent of that.

This result offers several possible explanations. (1) There may be substantial numbers of Razorbills wintering elsewhere, such as, the Bay of Fundy (R. G. B. Brown, personal communication) or the southern Grand Banks (McKittrick 1929). The latter case seems unlikely since Brown et al. (1975) found no evidence of any numbers of Razorbills on the Grand Banks. (2) The

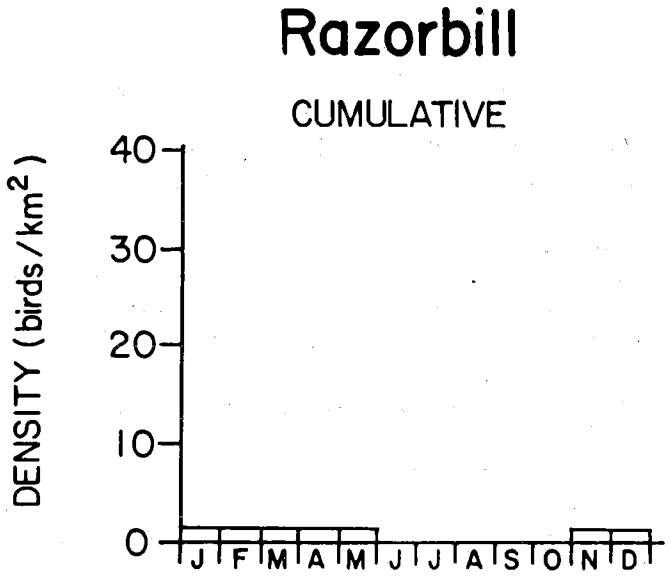

Fig. 102. Histogram of mean monthly densities of Razorbills (Alca torda) for the entire study area (cumulative).

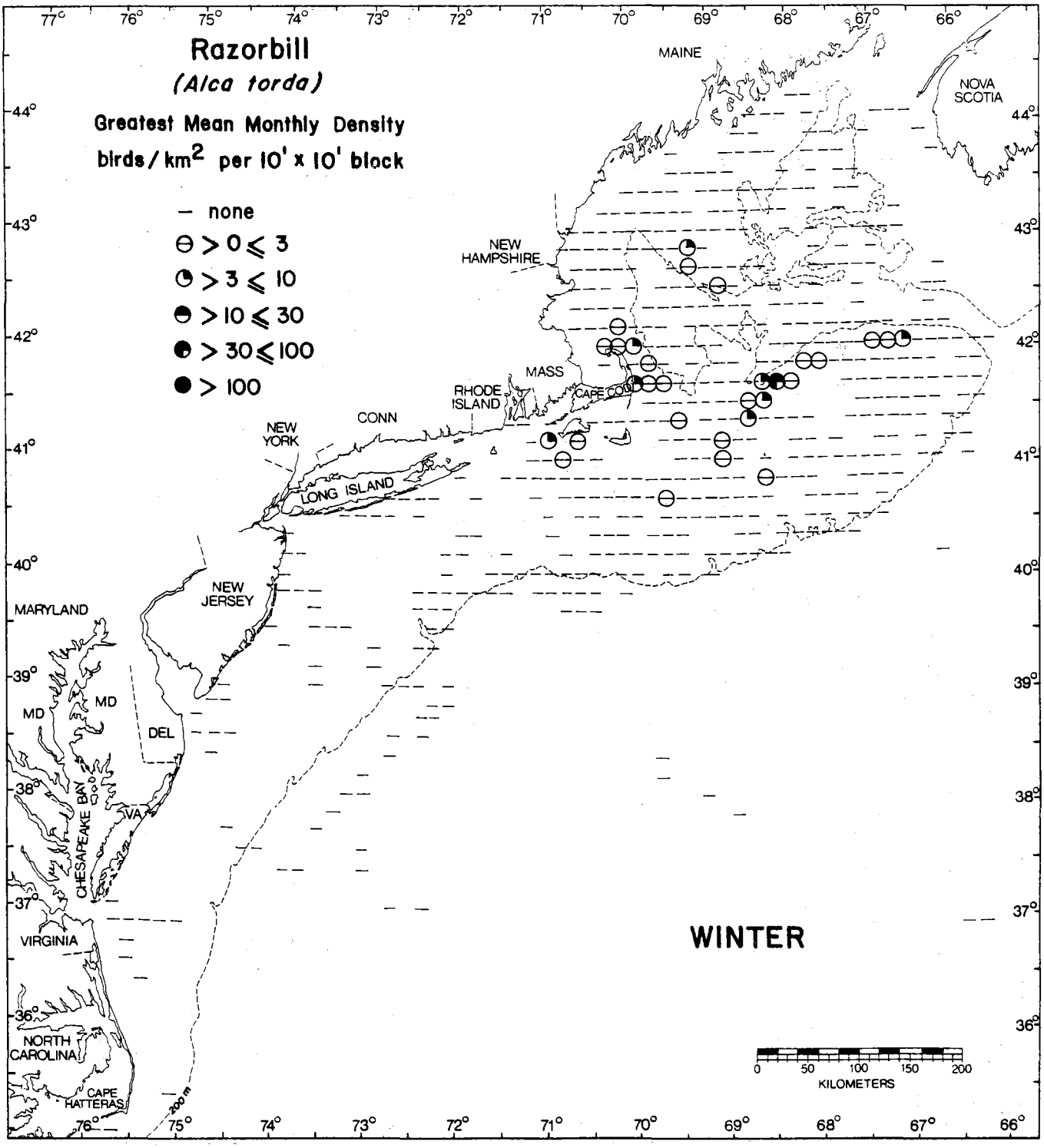

Fig. 103. Relative distribution and abundance of Razorbills (Alca torda) in winter.

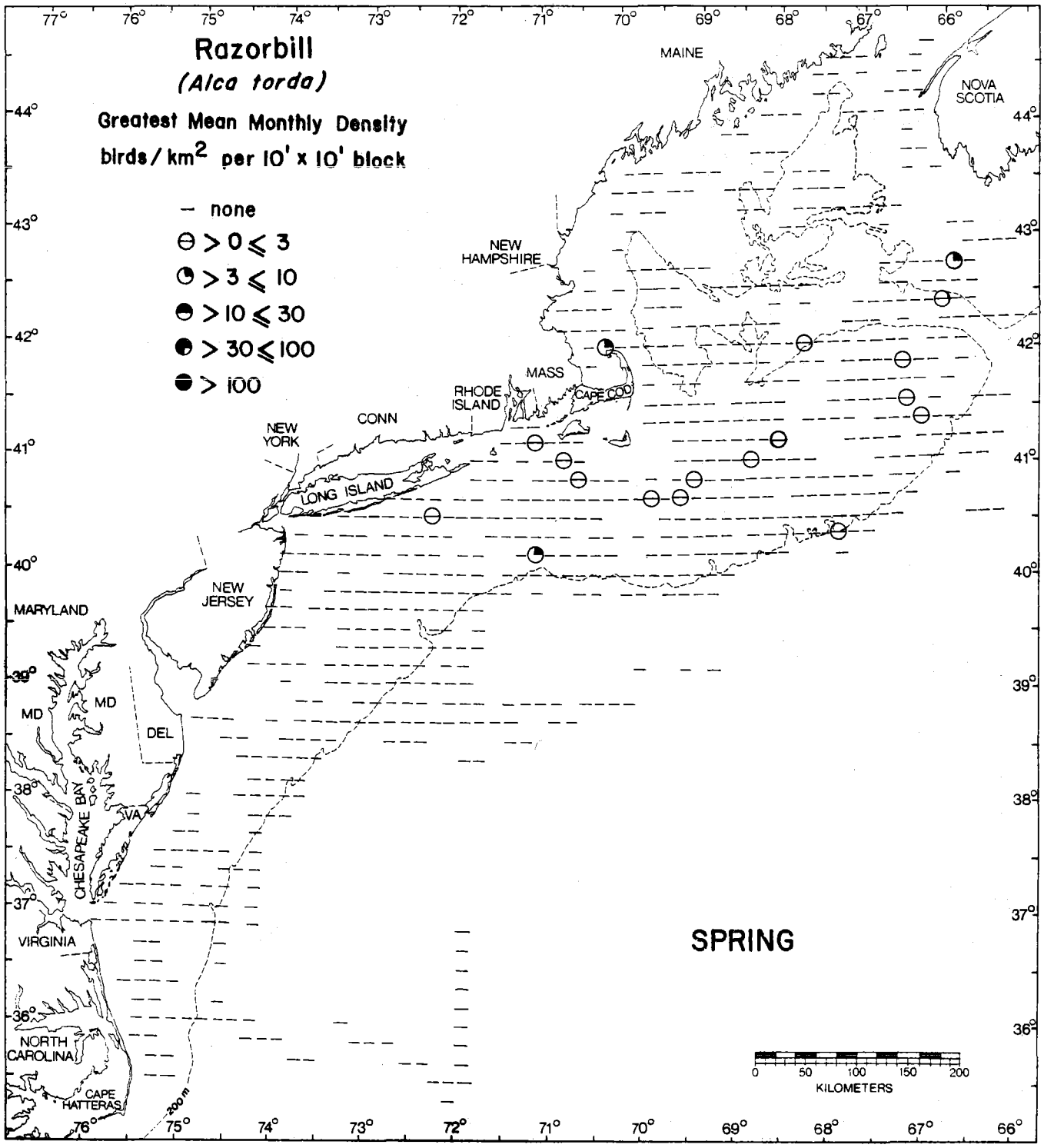

Fig. 104. Relative distribution and abundance of Razorbills (Alca torda) in spring.

census technique used in this study may have resulted in an underestimation of Razorbills, which are hard to see and to identify at sea. (3) The first two possibilities combined.

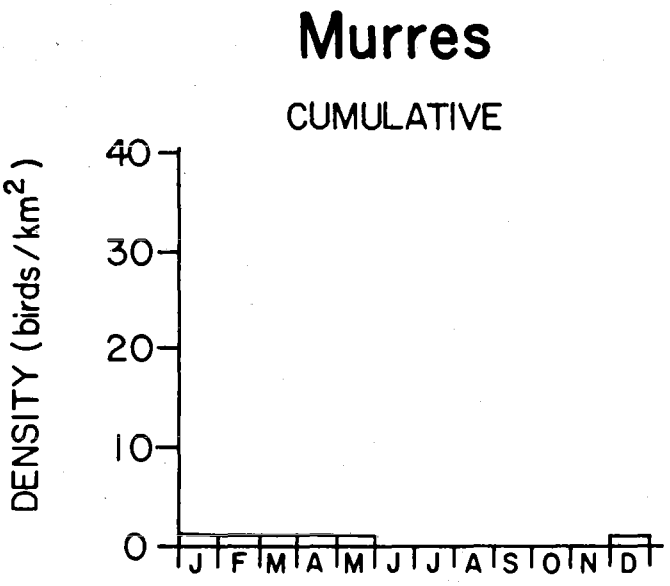

Fig. 105. Histogram of mean monthly densities of murres (Uria spp.) for the entire study area (cumulative).

COMMON MURRE (Uria aalge)

THICK-BILLED MURRE (Uria lomvia)

In eastern North America, Common Murres breed in boreal and low arctic zones of Atlantic Canada from the Gulf of St. Lawrence north to Labrador (Tuck 1961) and at one site in west Greenland (Salomonsen 1967). The center of breeding distribution is in eastern Newfoundland (Brown et al. 1975). Small numbers of Thick-billed Murres also breed in Atlantic Canada, but the species is primarily high arctic with the largest colonies north of 60°N in the eastern Canadian arctic and north of ca. 70°N in west Greenland (Brown et al. 1975).

Murres are pursuit-divers, which feed as secondary and tertiary carnivores on crustaceans, fishes and cephalopods (Tuck 1961; Harris 1970; Ainley and Sanger 1979). Crustaceans may be important to adults only in summer months (Tuck 1961).

Differences in the pelagic distributions of these two species in the western North Atlantic are not clear because the species cannot be separated easily in the field. Common Murres may be the more prevalent species in winter off the Scotian shelf (Johnson 1940; Brown in press). The majority of Thick-billed Murres winter off eastern Newfoundland and west Greenland (Salomonsen 1972; Brown et al. 1975). Both species were killed in the ARGO MERCHANT oil spill southeast of Cape Cod (Powers and Rumage 1978), although Common Murres were found in greater abundance. The southern limits in the pelagic range of murres are off the southeastern United States: Common Murres to Maryland (Rowlett 1980) and Thick-billed Murres to Florida (Landridge 1977).

Murres were uncommon from December to May and were never found in any local abundance (Fig. 105). During winter, sightings were widespread across the shelf from Long Island east and north to the southern Gulf of Maine (Fig. 106). Northeasterly gales blew them into nearshore waters off Cape Cod in January and February. In March, murres were most common on northeast Georges Bank and in the Northeast Channel (Fig. 107). These birds were probably in residence there throughout the winter, rather than representing an accumulation of spring migrants from waters further west and southwest.

The murre populations were collectively estimated at 5,000 in winter and 17,000 in spring, but these numbers are misleading since another 16,000 and 12,000 unidentified large auks, which included murres, were also estimated in winter and spring, respectively (Appendix 5). If the ratio of Common to Thick-billed murres oiled in the ARGO MERCHANT spill (Powers and Rumage 1978) is indicative of their abundance off the New England coast relative to each other, then Common Murres are 5 times more abundant than Thick-billed. Using colony data given in Brown et al. (1975), there are approximately 1.3 million Common Murres breeding in eastern North America. My estimate indicates that the population wintering off the northeastern United States is only a small fraction of their total population in the western North Atlantic.

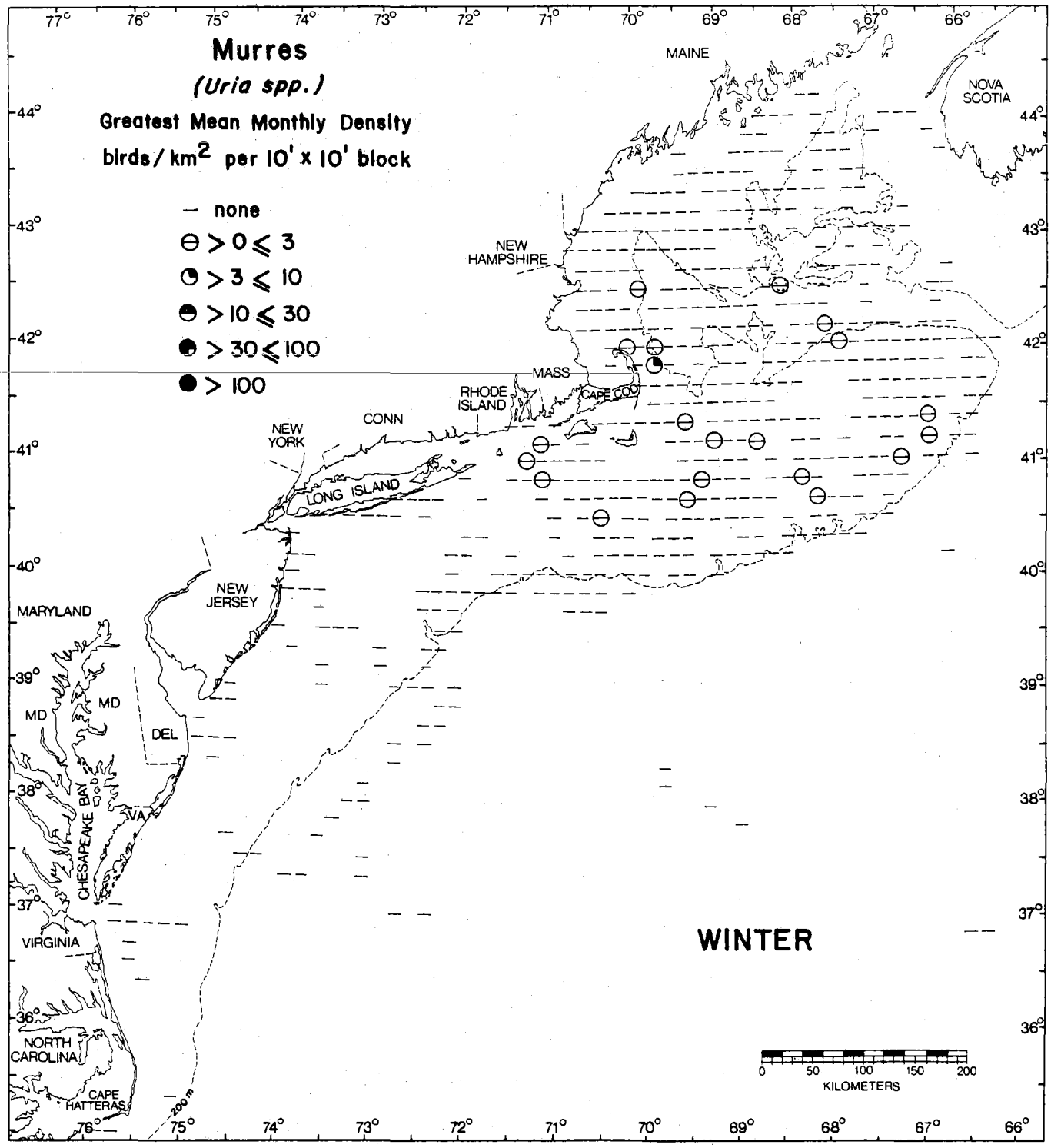

Fig. 106. Relative distribution and abundance of murres (Uria spp.) in winter.

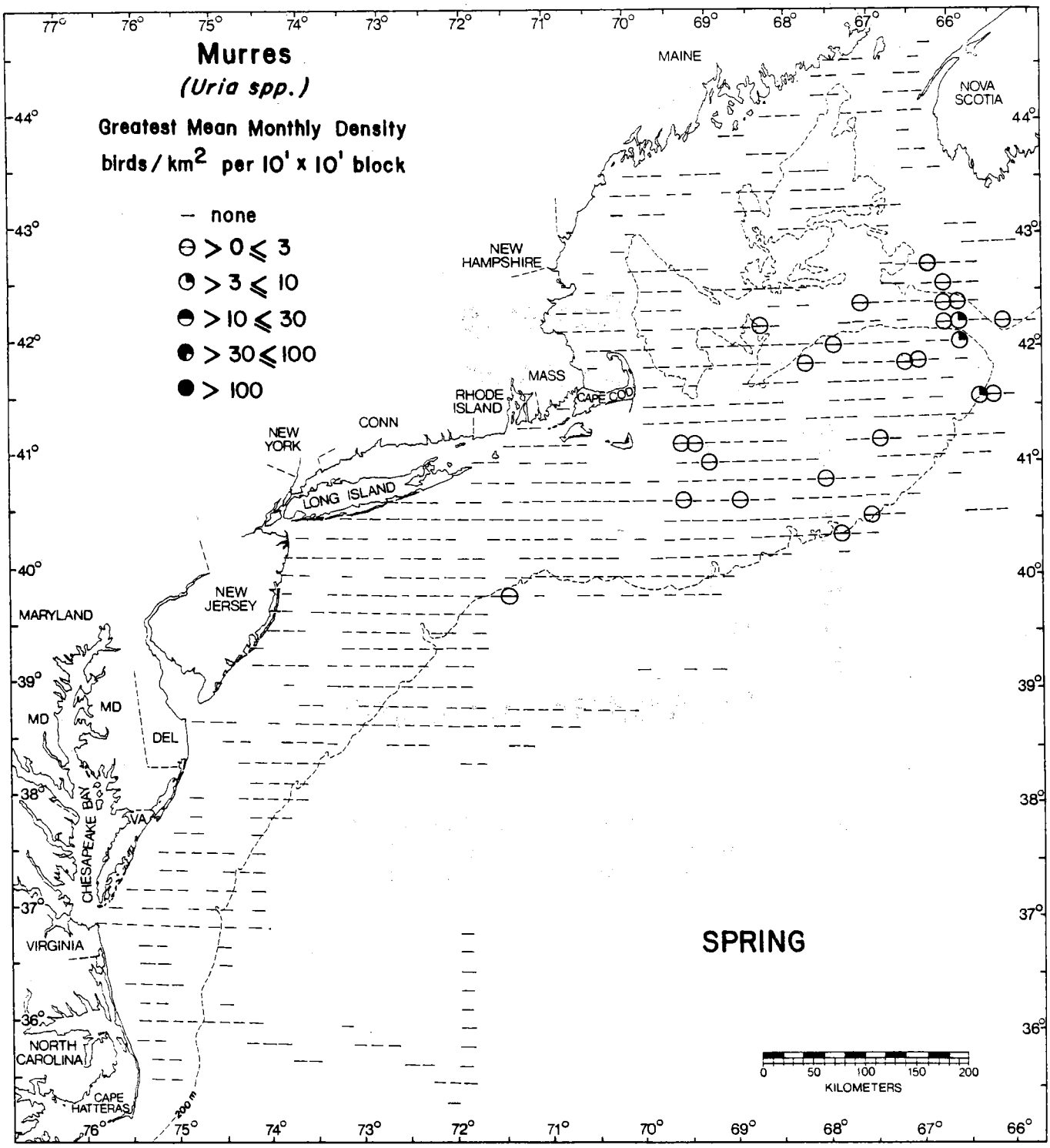

Fig. 107. Relative distribution and abundance of murres (Uria spp.) in spring.

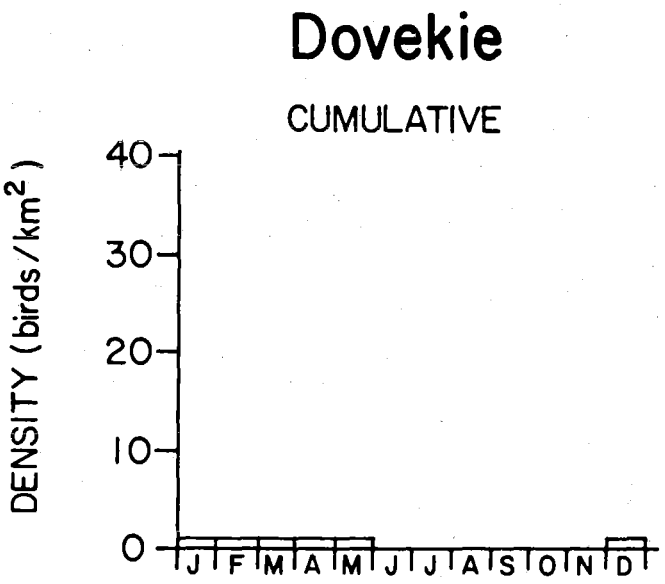

Fig. 108. Histogram of mean monthly densities of Dovekies (Alle alle) for the entire study area (cumulative).

DOVEKIE (Alle alle)

Dovekies breed in the high arctic which in eastern North America includes only west Greenland (Brown et al. 1975). In that area, the bulk of the population, of the order of 30 million birds, breeds north of about 76°N (Salomonsen 1950).

Dovekies feed as secondary carnivores principally on crustaceans, but probably take other locally abundant zooplankton (Bent 1919; Norderhaug 1970; Bruemmer 1972; Evans 1981).

Dovekies from the Greenland colonies winter in low arctic and boreal waters of the northwest Atlantic where they are locally common as far south as the Scotian shelf (Brown et al. 1975). Forbush (1925) considered Dovekies as irregular but sometimes abundant winter visitors to Massachusetts. Powers and Rumage (1978) found flocks of as many as 50 birds on northern Georges Bank in January. The southern range limit of Dovekies in the North Atlantic is complicated by 'wrecks' (Fisher and Lockley 1954). Their occurrence south of New England also appears to be storm-related, as winds may push "thousands" to the coasts of mid-Atlantic states (Stewart and Robbins 1953) or as far south as southern Florida (Sprunt 1938).

In this study Dovekies were recorded from December to May (Fig. 108). They were most frequently seen on the north and east parts of Georges Bank in winter months (Fig. 109) and small flocks were still evident along the eastern edge of the Bank in late March (Fig. 110). Preferred prey may be abundant on the north and east edges of the Bank because of enhanced vertical mixing (Cohen et al. 1981) or surface intrusions of Scotian shelf water across the Northeast Channel (EG & G 1978). Brown (1980b) found Dovekies concentrated on the west slope of the Grand Bank of Newfoundland, where water masses influenced by the Gulf Stream impinge upon the western edge of the shelf.

The Dovekie population, which was primarily limited to Georges Bank, was estimated at 19,000-20,000 in winter and spring (Appendix 5). Freuchen and Salomonsen (1958) speculated that the Thule area Dovekie population in Greenland, the center of its breeding range, is of the order of 30 million birds. Salomonsen (1967) believed that most of that population winters off southeastern Canada. My low estimate indicates that the Georges Bank area is on the southern fringe of its wintering distribution.

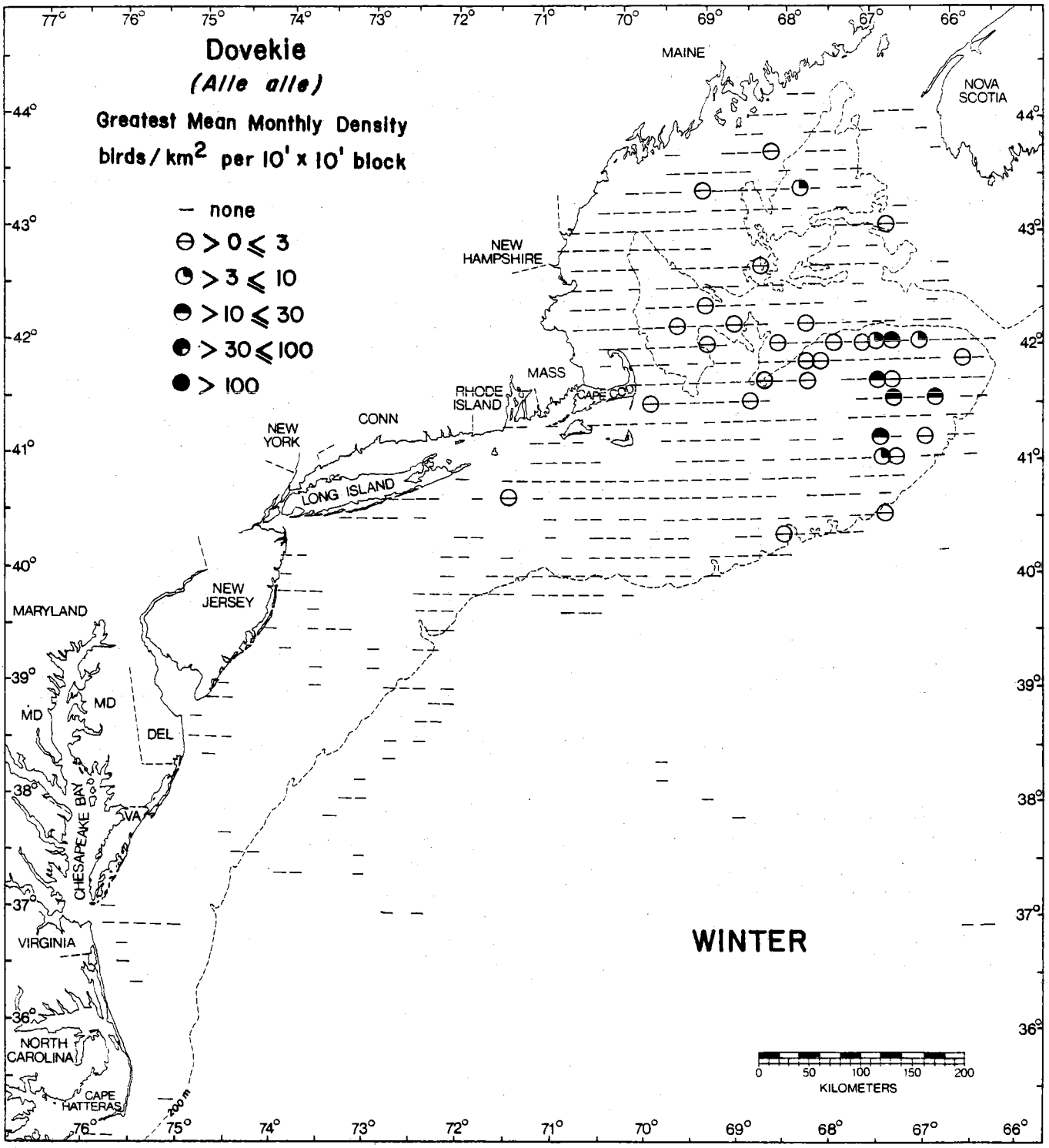

Fig. 109. Relative distribution and abundance of Dovekies (Alle alle) in winter.

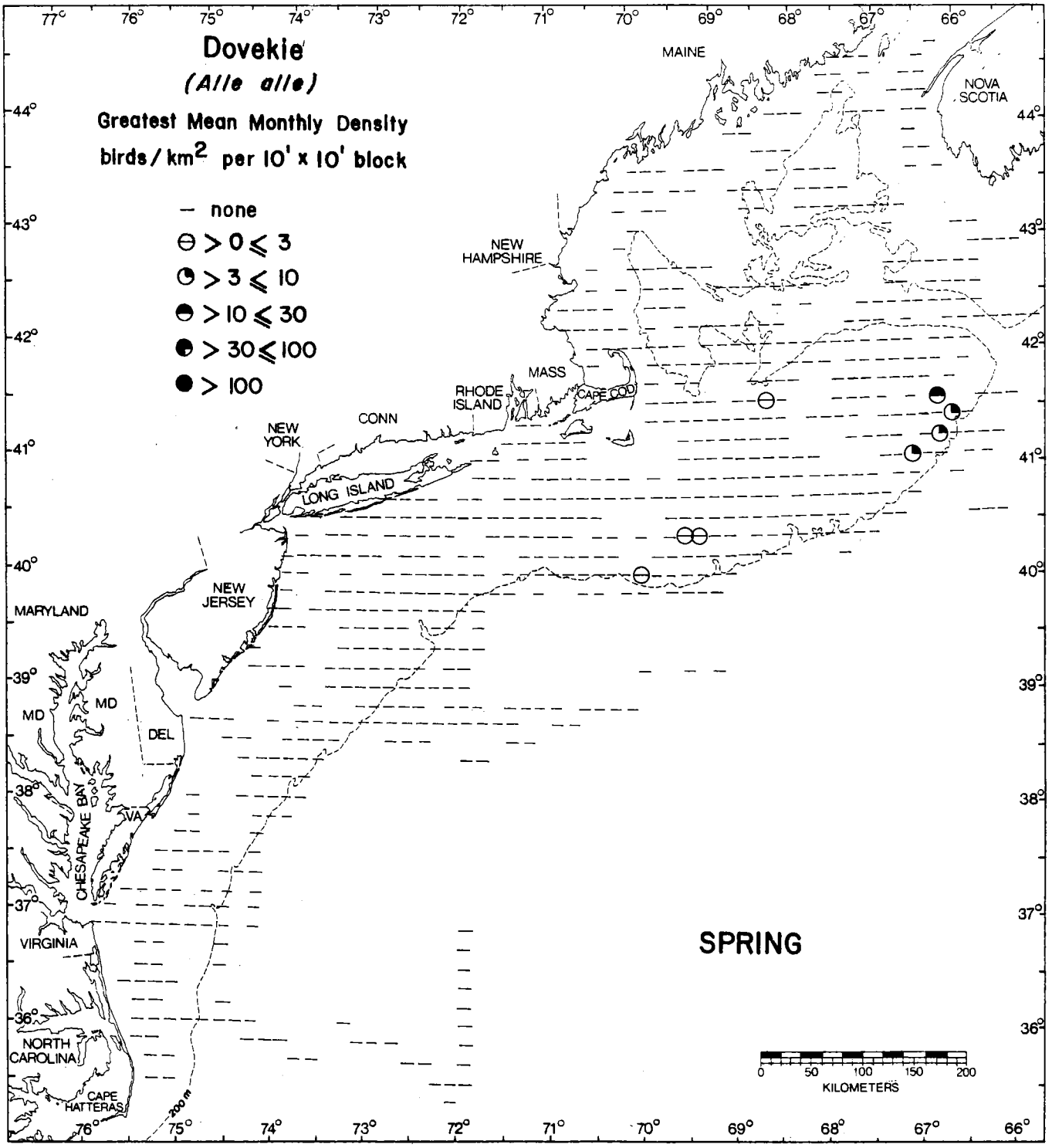

Fig. 110. Relative distribution and abundance of Dovekies (Alle alle) in spring.

BLACK GUILLEMOT (Cepphus grylle)

Black Guillemots breed throughout coastal eastern North America (Godfrey 1966; Salomonsen 1950; Brown et al. 1975) south to Maine (Drury 1973-74).

Guillemots are pursuit-divers, which feed as secondary and tertiary carnivores on benthic crustaceans and molluscs, and fishes (Bent 1919; Ainley and Sanger 1979).

Guillemots are strictly coastal inhabitants and are seldom seen at any great distance from land (Brown et al. 1975). The few sightings recorded in this study are listed in Appendix 8.

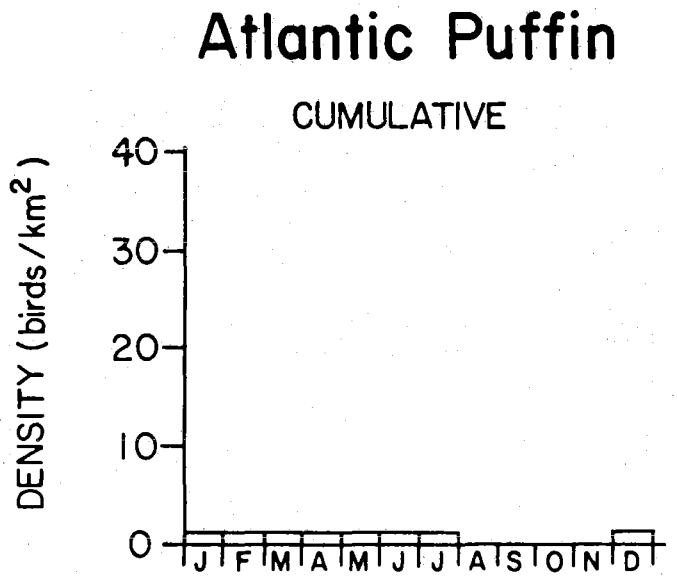

Fig. 111. Histogram of mean monthly densities of Atlantic Puffins (Fratercula arctica) for the entire study area (cumulative).

ATLANTIC PUFFIN (Fratercula arctica)

In North America, Atlantic Puffins breed from Maine (Matinicus Rock) north to west Greenland (Drury 1973-74; Brown et al. 1975). Birds breeding in northwest Greenland are a high-arctic subspecies F. a. naumanni (Salomonsen 1950). The center of the low-arctic and boreal race F. a. arctica in North America is in Atlantic Canada, eastern Newfoundland and southeast Labrador (Brown et al. 1975).

Puffins are pursuit-divers, which feed as tertiary carnivores on fish almost exclusively (Bent 1919; Corkhill 1973; Harris 1970; Nettleship 1972). Important prey include species of the genera Ammodytes, Clupea, Gadus, and Mallotus.

Puffins winter from Canadian waters (Brown et al. 1975) south regularly to waters off Massachusetts (Forbush 1925) and are probably uncommon in late winter in the Middle Atlantic Bight (Rowlett 1980). The most southern record may be a sighting by Audubon at the mouth of the Savannah River (Bent 1919).

Puffins were recorded in this study from December to early June (Fig. 111), but primarily on Georges Bank in winter and spring (Fig. 112-113). A "loose" flock of 30 birds was recorded on 23 March 1979 on the southern edge of the Bank between Oceanographer and Lydonia canyons. Three sightings in July were made in the Gulf of Maine near Matinicus Rock (Appendix 8).

Approximately 4,000 to 5,000 puffins were estimated on the shelf off the New England coast during winter and spring (Appendix 5). Using colony data from Brown et al. (1975), there are approximately 600,000 puffins breeding from Atlantic Canada south to northeast Maine. My estimate accounts for only a small fraction of the possible total puffin population in eastern North America. In general, it is not clear where most of the North American puffin population spends the winter. Their distribution is further complicated by the fact that many of the Icelandic and northern European puffins migrate west to the waters off eastern North America as well (Tuck 1971).

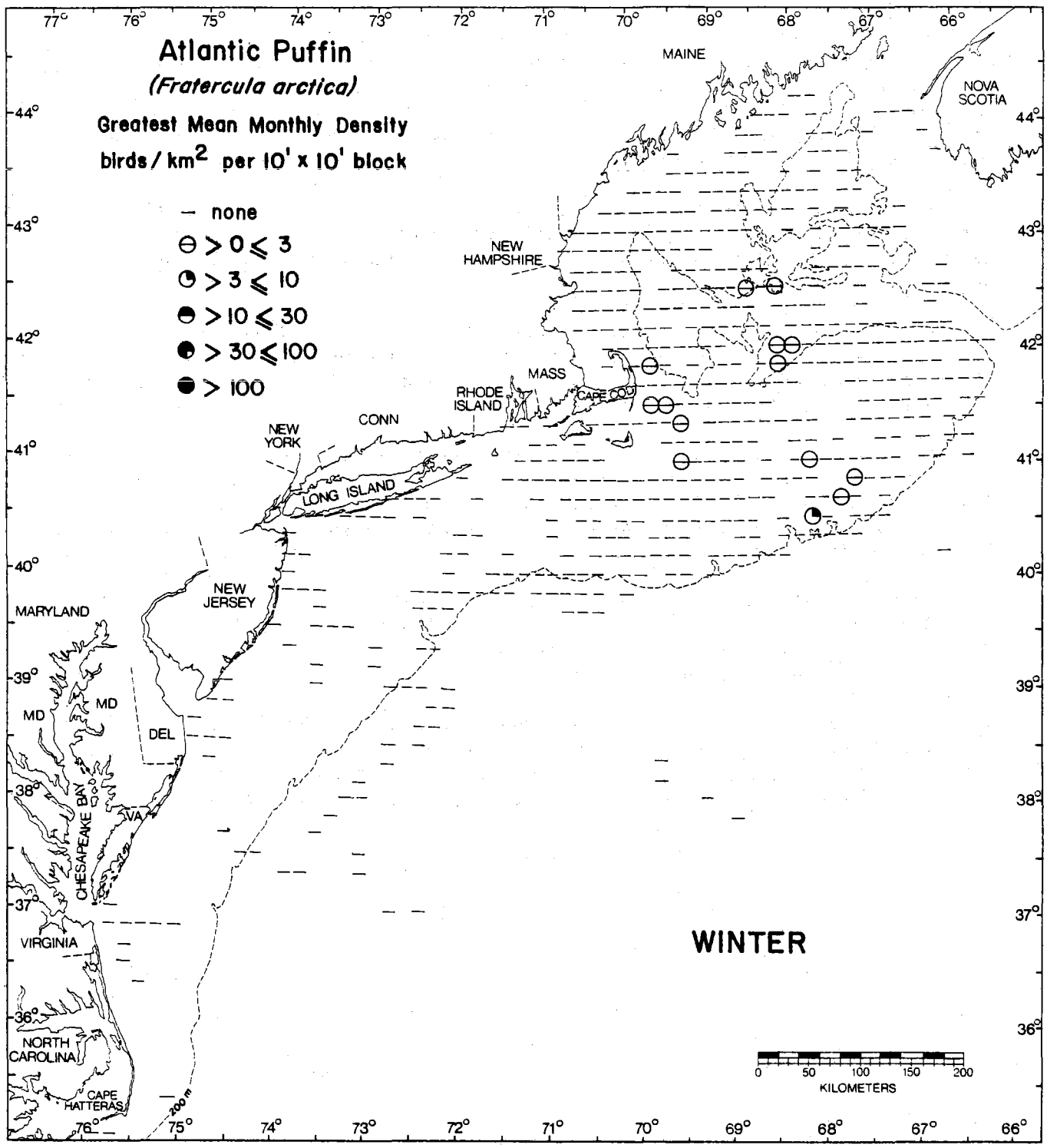

Fig. 112. Relative distribution and abundance of Atlantic Puffins (Fratercula arctica) in winter.

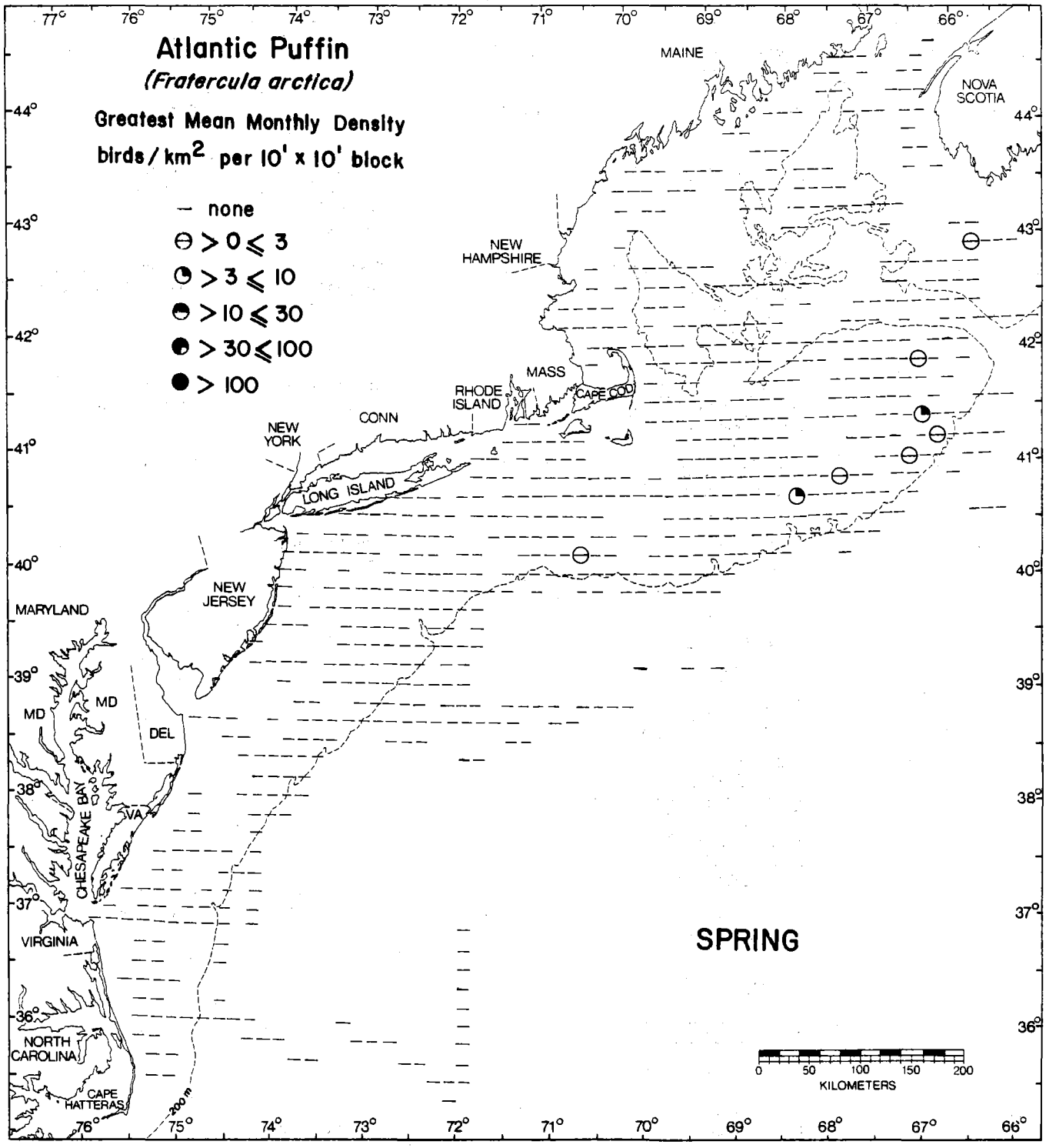

Fig. 113. Relative distribution and abundance of Atlantic Puffins (Fratercula arctica) in spring.

Table 2. Simplified ecological classification of seabirds in shelf waters off the northeastern United States.

Group	Species	Weight(g)	Major Food	Feeding Method
Loons	*Gavia immer* *G. stellata*	1100-3500	Fish	Pursuit diving
Albatross	*Diomedea* sp.	c. 3500	Fish, cephalopods	Surface seizing
Fulmar	*Fulmarus glacialis*	800	Fish, crustaceans, cephalopods, offal	Surface seizing, scavenging
Shearwaters	*Calonectris diomedea* *Puffinus gravis* *P. griseus* *P. puffinus* *P. lherminieri*	175-900	Fish, cephalopods, crustaceans	Surface seizing, pursuit plunging
Storm-Petrels	*Oceanites oceanicus* *Oceanodroma leucorhoa* *Pelagroma marina*	35-45	Crustaceans, fish, cephalopods	Pattering, surface seizing
Gannet/Cormorant	*Sula bassanus* *Phalacrocorax carbo* *P. auritus*	2500-3000	Fish	Plunging
Phalaropes	*Phalaropus fulicaria* *P. lobatus*	35-55	Crustaceans, fish eggs, fish larvae	Surface seizing
Gulls/Jaegers/Skuas	*Larus hyperboreus* *L. glaucoides* *L. marinus* *L. argentatus* *L. delawarensis* *L. atricilla* *L. philadelphia* *Rissa tridactyla* *Xema sabini* *Stercorarius pomarinus* *S. parasiticus* *S. longicaudus* *Catharacta skua* *C. maccormickii*	275-1700	Fish, cephalopods, offal	Dipping, surface seizing, scavenging, piracy
Terns	*Sterna hirundo* *S. paradisaea* *S. dougalii* *S. albrifrons* *S. maxima* *S. sandivicensis* *S. anaethetus* *S. fuscata* *Chlidonias niger*	100-450	Small fish	Plunging
Alcids	*Alca torda* *Uria aalge* *U. lomvia* *Alle alle* *Cepphus grylle* *Fratercula arctica*	100-975	Fish, crustaceans[1]	Pursuit-diving

[1]Crustaceans important to *Alle alle*.

B. Community Structure

In order to characterize the seabird populations in shelf waters off the northeastern United States, one should consider the structure of the bird community as well as the spatial and temporal accounts of each species. The following analysis compares the seabird communities between two regions of the study area: Gulf of Maine/Georges Bank and the Middle Atlantic Bight (S. New England and mid-Atlantic subareas). I selected these two regions because regardless of season the Georges Bank/Gulf of Maine subareas appeared to support a larger abundance and biomass of seabirds than the two subareas in the Middle Atlantic Bight. The following comparison of bird communities was examined with consideration of the physical and biological background of each region.

Seasonal Abundance

A simplified ecological classification of the seabirds in shelf waters off the northeastern United States is given in Table 2. Species that were recorded in this study are listed. They were grouped by family and feeding method according to Ashmole (1971). A total of 46 seabird species was recorded (Table 2). Ten species were numerically dominant: Northern Fulmar, Cory's Shearwater, Greater Shearwater, Sooty Shearwater, Wilson's Storm-Petrel, Northern Gannet, Red Phalarope, Great Black-backed Gull, Herring Gull and Black-legged Kittiwake. On a seasonal basis, these 10 species represented more than 97 percent of the total density of seabirds on the shelf from Cape Hatteras to Nova Scotia.

The Gulf of Maine/Georges Bank region (GM/GB) supported higher densities of birds than the Middle Atlantic Bight region (MAB) throughout the year, although species composition within each family group and seasonal trends in abundance within each region were similar. Total density on GM/GB ranged from 13.57 birds/km^2 during spring to 28.70 birds/km^2 during summer, and on MAB from 6.69 birds/km^2 during summer to 13.04 birds/km^2 during spring (Table 3).

During spring, fulmars, gannets, phalaropes and large gulls (Great Black-backed and Herring gulls) were dominant in abundance (Table 3). Dominance was defined as any species group which contributed at least 10 percent of the total seasonal density to either region. Fulmars accounted for nearly half (48%) of the birds in GM/GB with the majority of the population on the northern and eastern part of Georges Bank. Fulmars made up only 8 percent of the birds in MAB. Gannets and phalaropes were more abundant in MAB but, since these populations were migrating to breeding colonies further north, they also crossed GM/GB by early June. The phalarope movement was concentrated on the outer shelf (60-200m) of the Middle Atlantic Bight in April and on Georges Bank in May (Fig. 52). The two large gulls were the most abundant members of the gull/jaeger/skua group, which made up 38 to 45 percent of total density in GM/GB and MAB, respectively. Immature and subadult Great Black-backed and Herring gulls were far more common than adults at this time. Both species were restricted to fishing areas throughout the shelf, although most Great Black-backed Gulls were north and east of Hudson Canyon (Fig. 73).

Table 3. Seasonal estimates of seabird density (birds/km^2) by family groups in shelf waters off the northeastern United States. The Gulf of Maine and Georges Bank is GM/GB and the Middle Atlantic Bight is MAB. Densities are based on equal samples (Appendices 6 and 7).

Family Groups	Spring		Summer		Fall		Winter	
	GM/GB	MAB	GM/GB	MAB	GM/GB	MAB	GM/GB	MAB
Loons		0.09			0.08	0.04	0.05	0.03
Fulmars	6.46	1.02	1.52		0.80		3.76	0.92
Shearwaters	0.64	0.19	15.26	3.03	10.21	2.12		
Storm-Petrels	0.24	0.92	10.25	2.88	0.07	0.12		
Gannet	0.26	1.53	0.02	0.01	0.86	0.53	0.26	1.47
Phalaropes	0.36	2.90	0.19	0.08	0.04	0.03	0.05	
Gulls/Jaegers/Skuas	5.25	5.93	1.42	0.64	15.45	4.72	12.90	6.09
Terns	0.10	0.09	0.03	0.05	0.33	0.13		
Alcids	0.26	0.37	0.01			0.01	0.67	0.19
Total Birds	13.57	13.04	28.70	6.69	27.84	7.70	17.69	8.70

Surface-feeding birds were important in both regions during spring: fulmars and phalaropes on Georges Bank, and storm-petrels and phalaropes on the Middle Atlantic Bight. Spring "blooms" of phytoplankton and subsequent growth in zooplankton stocks are the most relevant oceanographic conditions throughout the shelf at this time. This was also the season when total densities were most similar between regions, 13.57 birds/km^2 in GM/GB and 13.04 birds/km^2 in MAB (Table 3).

During summer, shearwaters and storm-petrels were dominant when their combined abundance made up 80 to 90 percent of the birds in both regions (Table 3). Cory's Shearwaters were most abundant from Cox Ledge east to the Great South Channel in July and August (Fig. 16). Densities of Greater and Sooty shearwaters were greatest from the Great South Channel east across the northern and eastern parts of Georges Bank in June and July (Fig. 20 and 25). Wilson's Storm-Petrels were prevalent on the outer-shelf of the Middle Atlantic Bight and southern edge of Georges Bank, but the vast majority had moved into southern and western parts of the Gulf of Maine by June and remained there until the end of August (Fig. 36).

Although species composition was similar between GM/GB and MAB during summer, total density indicated a marked difference between the regions, 28.70 birds/km^2 and 6.69 birds/km^2, respectively (Table 3). Much of the difference is due to the higher abundance of shearwaters on northern Georges Bank and storm-petrels on the southwestern margin of the Gulf of Maine. One explanation for this may involve food availability. Shearwaters and storm-petrels feed at or within 5m of the surface on fish, squid and crustaceans. The tidally well-mixed waters from Nantucket Shoals across northern Georges Bank maintain high rates of primary productivity in near surface waters during summer (Flagg et al. 1982); whereas, the surface layer of the well-stratified waters in the Middle Atlantic Bight becomes nutrient-depleted and chlorophyll maxima are found 30-40m deep near the thermocline (Walsh et al. 1978). A continuous abundance of phytoplankton near the surface would maintain a pelagic food-web beneficial to surface-feeding birds.

During fall, shearwaters and large gulls were dominant when together they comprised about 90 percent of the birds in both regions (Table 3). Cory's Shearwaters remained abundant in the Great South Channel area into October (Fig. 17). After a sharp decline in abundance in August, Greater Shearwaters again became abundant on the southern Gulf of Maine and on northern Georges Bank from October through November (Fig. 21). A massive dispersal of Great Black-backed and Herring gulls from coastal breeding colonies to offshore fishing areas occurred during September and October (Fig 75 and 80). It was also during fall that gannets were migrating south from eastern Canada; in November they were locally abundant from Jeffreys Ledge south to the Great South Channel (Fig. 46). Further south, an offshore dispersal of Laughing Gulls occurred in October from New Jersey south to Cape Hatteras (Fig. 85).

During the fall, the contrast in total density between the GM/GB and MAB regions was similar to that of summer. GM/GB continued to support large numbers of birds, 27.84 birds/km^2, while MAB held relatively few, 7.70 birds/km^2. GM/GB held nearly five times as many shearwaters and four times as many gulls than MAB (Table 3). Photoperiod and rates of primary

Table 4. Seasonal estimates of seabird biomass (kg/km^2) in shelf waters off the northeastern United States. The Gulf of Maine and Georges Bank is GM/GB and the Middle Atlantic Bight is MAB. Biomass is based on equal sample sizes (Appendices 6 and 7).

Family Groups	Spring		Summer		Fall		Winter	
	GM/GB	MAB	GM/GB	MAB	GM/GB	MAB	GM/GB	MAB
Loons		0.24			0.30	0.15	0.06	0.11
Fulmar	5.17	0.82	1.22		0.65		3.01	0.74
Shearwaters	0.54	0.17	13.02	2.60	8.74	1.83		
Storm-Petrels	0.02	0.03	0.37	0.11	0.01	0.01		
Gannet	0.81	4.61	0.06	0.03	2.58	1.61	0.81	4.42
Phalaropes	0.03	0.17	0.03	0.01	0.02	0.02	0.01	
Gulls/Jaegers/Skuas	7.42	6.73	1.47	0.35	21.20	5.26	11.92	7.18
Terns	0.02	0.03	0.01	0.04	0.03	0.04		
Alcids	0.16	0.29	0.01			0.01	0.17	0.14
Total Birds	14.17	13.09	16.19	3.14	33.53	8.93	15.98	12.59

production decreased during fall as there was a transition from well-stratified to well-mixed hydrographic conditions.

During winter, fulmars, gannets, large gulls and kittiwakes were dominant (Table 3). Fulmars and kittiwakes were most abundant in GM/GB throughout winter months (Fig. 14 and 94) and were sometimes concentrated in fishing areas. Although effort was poor in MAB during winter, gannets appeared to be locally abundant in the Middle Atlantic Bight, either nearshore along the coast south of Chesapeake Bay or offshore with fishing fleets at the edge of the shelf from Hudson Canyon to the south (cf. Fig. 44 and 47). Great Black-backed and Herring gulls were abundant throughout shelf waters (Fig. 76 and 81) and were usually concentrated in fishing areas. Although alcids were not numerically dominant, they were most abundant during winter, particularly on Georges Bank and nearshore around Cape Cod (Fig. 103, 106, 109 and 112).

There was still a two-fold difference in bird abundance between the regions during winter, 17.69 birds/km^2 on GM/GB and 8.70 birds/km^2 on MAB. Although gannets were most abundant in MAB, the much larger standing stocks of fulmars and gulls were two and three times greater on GM/GB than on MAB (Table 3). A well-mixed water column was prevalent throughout shelf waters during winter when there was little contrast in hydrographic conditions between the two regions.

Biomass

Eight seabird species were dominant in biomass (kg/km^2): Northern Fulmar, Cory's Shearwater, Greater Shearwater, Sooty Shearwater, Northern Gannet, Great Black-backed Gull, Herring Gull and Black-legged Kittiwake. Although Wilson's Storm-Petrels and Red Phalaropes were numerically dominant, they were not important contributors to biomass because they are so small.

As might be expected from the density analysis, the GM/GB region supported a greater biomass of birds than the MAB region throughout the year. Biomass estimates on GM/GB ranged from 14.17 kg/km^2 during spring to 33.53 kg/km^2 during fall, and on MAB from 3.14 kg/km^2 during summer to 13.09 kg/km^2 during spring (Table 4).

During spring, fulmars accounted for 36 percent of total biomass in GM/GB but only 6 percent on MAB. Conversely, gannets made up only 6 percent of the biomass on GM/GB and 35 percent on MAB. Great Black-backed and Herring gulls accounted for nearly half of the total biomass in both regions. Both regions supported similar rates of biomass at this time (Table 4).

During summer, shearwaters accounted for more than 80 percent and gulls for about 10 percent of the total biomass in both regions. Four times as much shearwater biomass was found on GM/GB. Great Black-backed and Herring gulls dominated coastally around Cape Cod and on Stellwagen Bank in the GM/GB region, and Herring and Laughing gulls in MAB. There was a marked difference in biomass between regions during summer, 16.19 kg/km^2 on GM/GB and 3.14 kg/km^2 on MAB.

Table 5. Seasonal diversity measures for the seabird community in shelf waters off the northeastern United States.

Diversity Measurement	Spring	Summer	Fall	Winter
Gulf of Maine/Georges Bank				
Species richness (no. of species)	20	18	19	13
Total number individuals	1269	2641	2595	1650
Shannon-Weaver Index (H')	1.62	1.55	1.58	1.61
Evenness (J')	0.54	0.54	0.54	0.63
Middle Atlantic Bight				
Species richness (no. of species)	22	15	20	12
Total number individuals	1222	627	722	814
Shannon-Weaver Index (H')	2.18	1.53	1.87	1.64
Evenness (J')	0.71	0.56	0.62	0.66

During fall, shearwater biomass dropped from a summer peak to 20 to 26 percent of the total biomass between regions. Gannets made up 7 to 18 percent and gulls from 59 to 63 percent of total biomass. There was still a marked contrast in biomass between regions during fall, as the GM/GB region reached its seasonal peak of 33.53 kg/km^2 (Table 4). The offshore dispersal of Great Black-backed and Herring gulls accounted for most of the increase.

During winter, fulmars made up 19 percent of the total biomass on GM/GB and 6 percent on MAB. Thirty-five percent of the total biomass on MAB was gannets, but only 5 percent on GM/GB. The large gulls were still dominant in both regions, but kittiwakes shared dominance on the GM/GB region.

Species Diversity

Diversity of an ecological community is usually defined by two components: species richness and species evenness. Species richness is simply the number of different species present in a population, while species evenness is the proportional distribution of individuals between those species. The relations between abundance and the number of species possessing that abundance are of fundamental interest in the study of any ecological community. The intent of this section is to compare the diversity in the seabird community found on Gulf of Maine and Georges Bank with that on the Middle Atlantic Bight to determine if differences exist in their structure.

Species richness varied on GM/GB from 13 species during winter to 20 species during spring, and on MAB from 12 species during winter to 22 species during spring (Table 5). In both regions species richness was highest during spring and fall, which are periods of bird migration. During these seasons, the passage of migrants combined with vanguards and stragglers from the transition of summer and winter bird communities may explain the seasonal peaks in species richness. However, these peaks had little or no effect on diversity and evenness. Diversity only ranged on GM/GB from 1.55 to 1.62 and evenness from 0.54 to 0.63 (Table 5). There was a slight bimodal trend in seasonal diversity values on MAB, but not in evenness. Values computed for both indices are quite low when compared to similar calculations for terrestrial communities of breeding birds (James and Rathburn 1981).

These two seabird communties do not appear to be species-poor, but the low measurements of diversity and evenness suggest that they have high dominance patterns. The previous sections on abundance and biomass corroborate such a conclusion in that only two or three species were dominant in density or biomass in any given season or region. In light of James and Rathburn's argument about the limitations of H' and J', I developed seasonal curves of relative abundance and biomass for each region (Fig. 114 and 115). The high relative abundance and biomass of the first-ranked species in each case strongly suggest high dominance patterns in these communities, as the steepness of the curves indicate low evenness. In every case, except maybe winter, the curves were not truncated from limited sample sizes. Thus, one may infer that increased sampling would only add to species richness and possibly increase a diversity calculation, but it would not alter the more important point that these communities are seasonally dominated by only a few species.

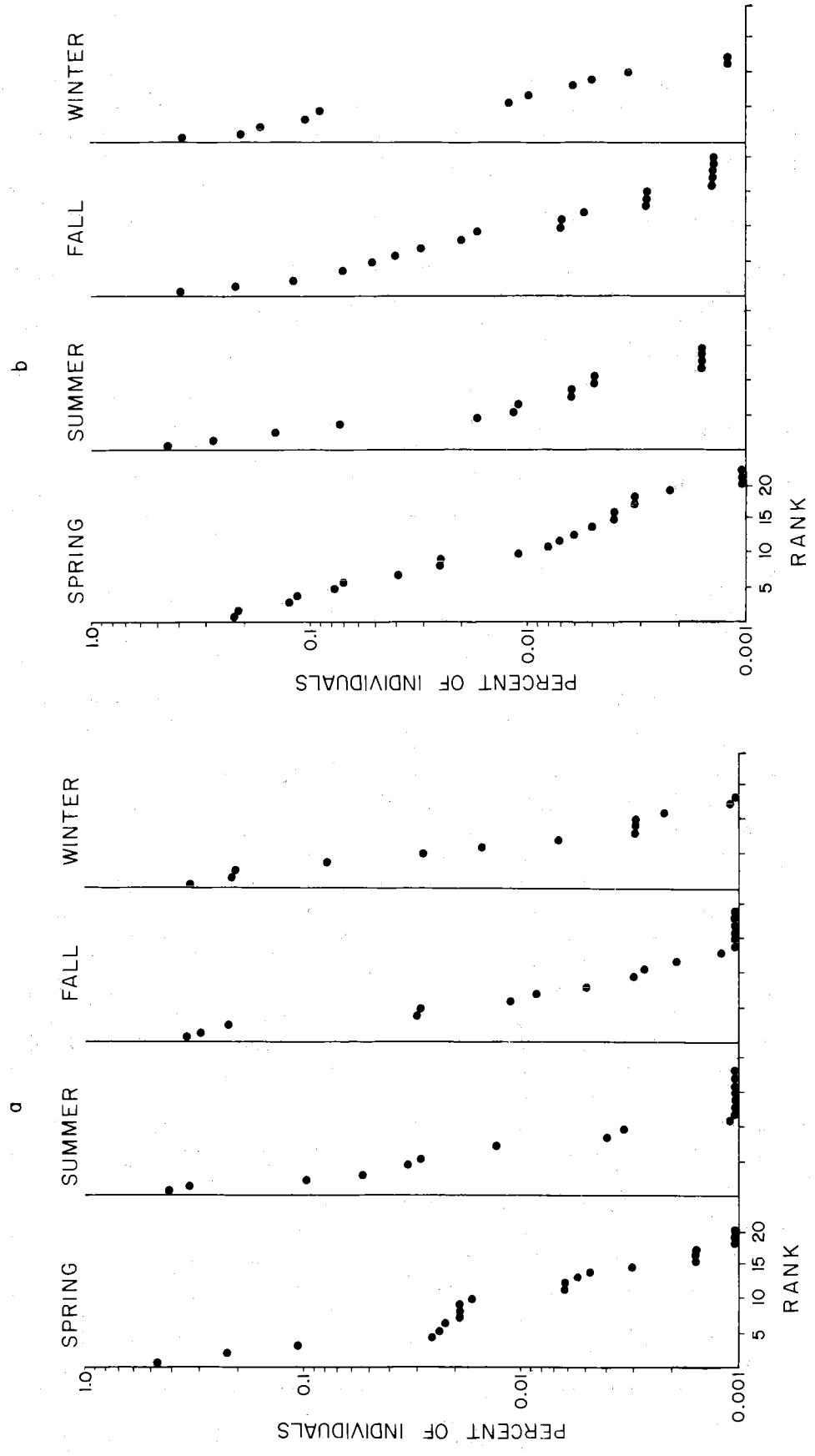

Fig. 114. Seasonal curves of relative abundance for which the ordinate is the percentage of the total individuals (Appendices 6 and 7) on a logarithmic scale and the abcissa is the rank from the most common to the least common species. Curves for the Gulf of Maine/Georges Bank region are given in (a) and for the Middle Atlantic Bight in (b).

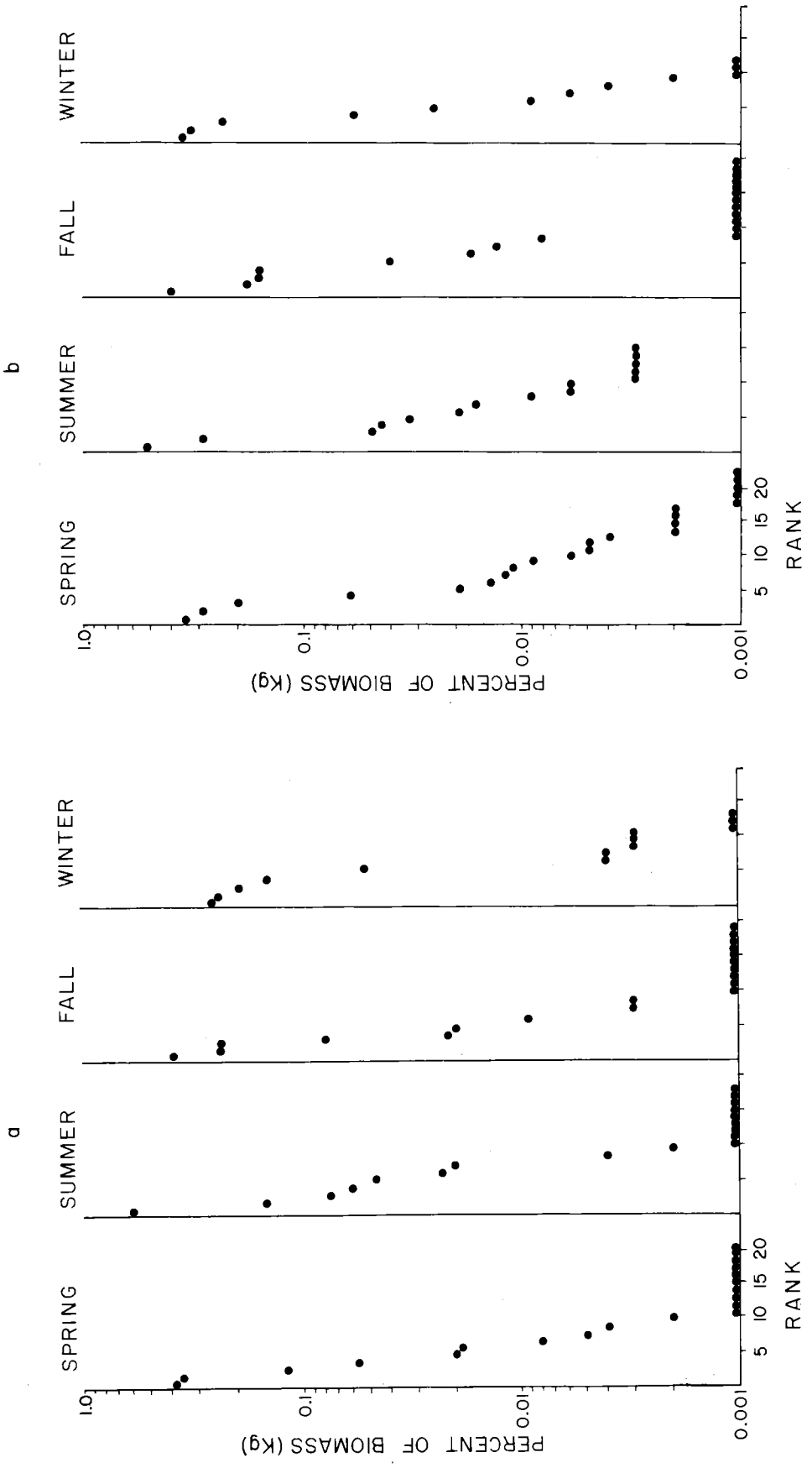

Fig. 115. Seasonal curves of biomass for which the ordinate is the percentage of the total biomass plotted on a logarithmic scale and the abcissa is the rank from the most abundant to the least abundant species. Curves for the Gulf of Maine/Georges Bank region are given in (a) and for the Middle Atlantic Bight in (b).

DISCUSSION

There are no previous ornithological studies of a broad-based and quantitative nature in shelf waters off the northeastern United States to compare with the results of this study. The findings presented here provide information on an additional component of an oceanographically well-studied area. The data will be useful in examining the effects of proposed offshore extractions of oil and gas, and in developing mathematical models for multi-species fisheries management.

The available literature on the distribution of marine birds in the western North Atlantic was examined and compared with this study. My findings are in general agreement with that of previous authors; however, two important points should be made. First, the present high abundance of fulmars on Georges Bank and the Gulf of Maine during winter and spring months was not expected from the accounts of Palmer (1962) and Brown et al. (1975). I suspect that this discrepancy was due to a previous lack of sampling in this area, not to a dramatic increase in the fulmar population south of the Grand Banks in the past two decades. Rees (1965) suggested that the Nova Scotian and New England fishing banks were the southwestward normal limits of fulmar distribution in the North Atlantic.

Second, I found a bimodal peak (June to July and October to November) in Greater Shearwater abundance on Georges Bank and the Gulf of Maine. Wynne-Edwards (1935) and Voous and Wattel (1963) suggested that the majority of Greater Shearwaters returned south from northern latitudes close to the European coast, although they recognized a population which migrated in November over the Grand Banks and Scotian shelf off the North American coast. My observations support findings by Rankin and Duffey (1948) and Brown et al. (1975), in that a major movement of Greater Shearwaters occurs during fall in the western North Atlantic. Georges Bank may be a mid-latitude staging area before the southward migration for a population, which presumably consists of nonbreeding juvenile and subadult birds.

The densities calculated in this study, as well as those from other pelagic studies, should be interpreted with caution. These densities are best construed as relative assessments of variation in abundance within a given species. They may not be so comparable between species. Densities for those species, which spend most of their time in flight (e.g. fulmars, shearwaters, storm-petrels), may be inflated because the counts of individual birds were cumulative during the 10-min observation periods; yet, they were treated as instantaneous estimates of abundance for each 10-min count. Conversely, birds which spend most of their time sitting on the surface (e.g. Razorbills, murres, Dovekies), may be underestimated because they are not easily observed out to 300m and even a light sea would impair an observer's ability to find them.

There are several other important inherent biases in the methods to consider. First, many observers were used in this study. Powers (1982) found considerable variability between the ability of observers to estimate bird numbers at sea, particularly in areas of high density. Second, the attraction of the birds, themselves, to the observer's vessel could not be controlled. Some of the ships used in this study were fishing, which likely

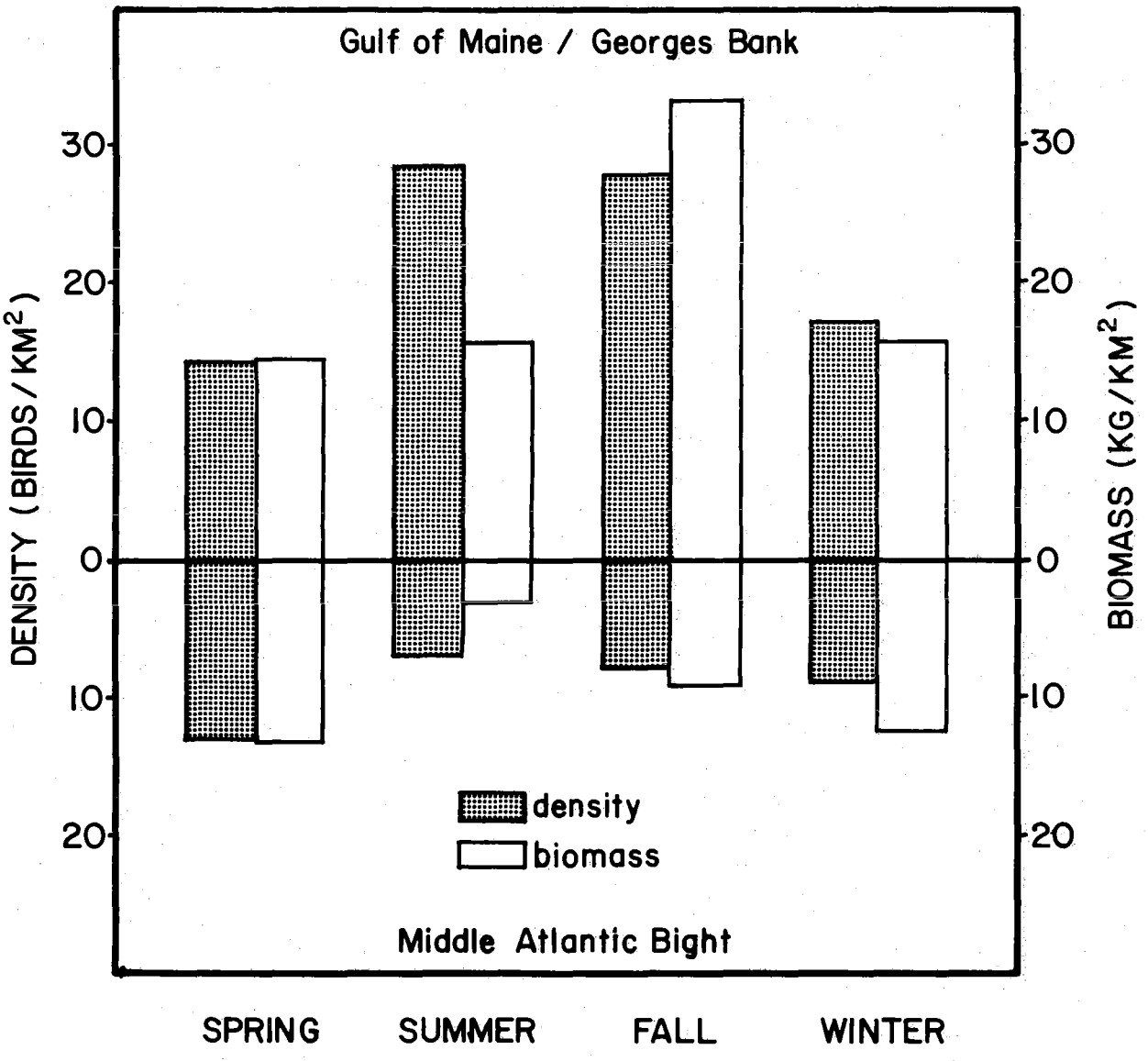

Fig. 116. A comparison of seasonal changes in seabird density (birds/km^2) and biomass (kg/km^2) between the shelf regions of the Gulf of Maine/Georges Bank and the Middle Atlantic Bight.

influenced the local abundance of species such as: fulmars, Greater Shearwaters, gannets, kittiwakes and large gulls. Third, population estimates were based on three-month seasons for four separate subareas using two years of data. The same concentrations of species, which were migrating rapidly through parts or all of the study area (e.g. loons, gannets, phalaropes), may have been observed in different but adjacent subareas and seasons. Recounting these concentrations would exaggerate the overall estimate of abundance for the entire study area. For example, densities of gannets estimated from flocks at the Great South Channel (Georges Bank subarea) in December and recounted at Hudson Canyon (S. New England subarea) in February, would inflate a population estimate for the winter season (December to February) when all subareas were combined. It may be more reasonable in future studies to develop population estimates from single cruises or series of cruises, which have non-overlapping coverage of the study area in a relatively brief time-frame (i.e. 1 to 2 months).

The structure of seabird communities off the northeastern United States reflects a high dominance pattern (low evenness) throughout shelf waters and relatively few species are important to density and biomass during each season. In comparison, communities of terrestrial birds with low diversity and evenness are usually found where habitats are in a climax condition and lack differences in available subhabitats (e.g., stands of wax myrtle or birch-poplar, and arctic tundra) (James and Rathburn 1981), which may be the case in the pelagic environments. Niche partitioning by seabirds in pelagic habitats may have evolved through a differentiation of feeding methods and sizes of prey selected (Ashmole 1971; Ainley 1977). Thus, the seabird communities on the Gulf of Maine/Georges Bank and on the Middle Atlantic Bight regions, which are generally dominated by both surface and subsurface feeders (e.g. fulmars, shearwaters, storm-petrels, gannets and gulls), suggest that the types of prey preferred by the birds are found in both regions.

The greatest and most important difference in the community structure between the shelf regions off the northeastern United States is that the Gulf of Maine/Georges Bank area supports a greater abundance and biomass of seabirds than the Middle Atlantic Bight throughout the year (Fig. 116). Both regions are most similar during winter and spring when waters overlying the entire shelf are well-mixed by gales and cold air temperatures. A uniformity in hydrographic conditions throughout the shelf at this time reflects little differentiation in available niches to be occupied by predatory seabirds. During summer and fall, when there is a three and four-fold difference in density and biomass between regions (Fig. 116), there is a corresponding difference in hydrographic conditions. Waters in the Middle Atlantic Bight are well-stratified due to increased solar insolation and less frequent wind events; whereas, tidal currents over the shallow shoals of Georges Bank maintain vertical mixing and only a weak thermocline may develop (Bumpus 1976).

The hydrographic structure of shelf waters off the northeastern United States is important to the development of marine food-webs. Well-developed pelagic food-webs, which are important to near-surface feeding seabirds, have been demonstrated for several outer-shelf regions (Joiris 1978; Iverson et al. 1979; Schneider and Hunt 1982). The proposed mechanisms for energy transfer are the capture of the spring phytoplankton by large copepods that

rise from deep water during spring in the Bering Sea (Iverson et al.) and differential microbial activity during summer in the North Sea (Joiris). During spring (April and May) in the New York Bight the subsurface chlorophyll maxima are found at about the 45m-isobath and just seaward of the shelf-break (ca. the 200-m isobath), when wind events favor upwelling conditions (Walsh et al. 1978). The peak in zooplankton biomass for this shelf area occurs offshore in waters deeper than 50m during or shortly after the spring phytoplankton bloom (Judkins et al. 1980). As hydrographic stratification increases and the frequency of storms diminishes during summer in the New York Bight, the area of high chlorophyll moves onshore (Walsh et al. 1978) with a corresponding inshore (waters < 50m deep) zooplankton maximum in July (Judkins et al. 1980).

The passage of zooplankton-feeding phalaropes and storm-petrels along the outer shelf of the Middle Atlantic Bight during April and May, which correlates with the offshore peak in zooplankton biomass, suggests a well-developed pelagic food-web at this time. Walsh et al. (1978) suggested that during the summer stratified regime the offshore phytoplankton are too large for copepods to eat. They also indicated that this may represent the end of this herbivorous food chain suggesting a direct transfer of energy to benthic herbivores. Such a break in pelagic linkage would limit food availability to near-surface feeding seabirds and explain the season minimum in seabird density and biomass for the Middle Atlantic Bight.

The greater topographic complexity of Georges Bank and its tidal mixing over shallow depths may provide opportunities for continuous nutrient replenishment from the deeper surrounding waters and maintain high rates of productivity throughout summer months (Cohen et al. 1981). Chlorophyll maxima on Georges Bank occur during April and May, but high concentrations are found on the surface at the edge of fronts during summer months as well (Walsh 1981; Yentsch and Garfield 1981). Flagg et al. (1982) found productivity highest during summer in well-mixed waters from the northern Great South Channel east across the northern flank of Georges Bank, relative to areas north and south of the well-mixed zone. The high phytoplankton biomass and primary production on the north flank of Georges Bank observed during summer are probably a function of upwelling under a jet-flow along the northern edge of the Bank (Flagg et al. 1982). Hopkins and Garfield (1981) indicated that the jet-flow tends to entrain nutrient-rich water from deep in the Gulf of Maine and causes it to discharge near the surface on Georges Bank. Peaks in zooplankton abundance on the southern Gulf of Maine and on Georges Bank in May and June (Redfield 1941) and again on Georges Bank in August (Sherman and Jones 1980) suggest that a herbivorous food chain is maintained throughout summer months in this area. Such oceanographic conditions prevent any breaks in pelagic linkage as found in the Middle Atlantic Bight during the period of the stratified regime. Thus, the high densities and biomass of surface and subsurface feeding seabirds observed in the Georges Bank area during summer and fall (Fig. 116) could be supported by an increase in food availability from enhanced levels of primary production.

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LITERATURE CITED

Ainley, D. G. 1977. Feeding methods in seabirds: a comparison of polar and tropical nesting communities in the eastern Pacific Ocean. pp. 669-685 in Adaptations within Antarctic Ecosystems. Gulf Publishing Co., Book Division, Houston, Texas.

Ainley, D. G. 1980. Birds as marine organisms: a review. CalCOFI Rept. 21:48-52.

Ainley, D. G., and G. A. Sanger. 1979. Trophic relations of seabirds in the northeastern Pacific Ocean and Bering Sea. pp. 95-122 in (J. C. Bartonek and D. N. Nettleship, eds.) Conservation of Marine Birds of Northern North America. U. S. Fish and Wildl. Serv., Wildl. Res. Rept. 11, Washington, D. C.

Ashmole, N. P. 1971. Seabird ecology and the marine environment. pp. 223-286 in (D. S. Farner and J. R. King, eds.) Avian Biology. Vol. 1, Academic Press, New York.

Backus, R. H., J. E. Craddock, R. L. Haedrich, and B. H. Robison. 1977. Atlantic mesopelagic zoogeography. pp. 266-288 in (R. H. Gibbs, Jr., ed.) Fishes of the Western North Atlantic. Allen Press, Inc., Lawrence, Kansas.

Baird, S. F. 1887. Occurrence of Cory's Shearwater (Puffinus borealis) and several species of jaegers in large numbers in the vicinity of Gayhead, Mass., during the autumn of 1886. Auk 4:71-72.

Baker, R. H. 1947. Observations on the birds of the North Atlantic. Auk 64:245-259.

Bent, A. C. 1919. Life histories of North American diving birds. U. S. Nat'l. Mus. Bull. 107:1-245.

Bent, A. C. 1921. Life histories of North American gulls and terns. U. S. Nat'l. Mus. Bull. 113:1:345.

Bent, A. C. 1922. Life histories of North American petrels and pelicans and their allies. U. S. Nat'l. Mus. Bull. 121:1-343.

Bierregaard, R. O., Jr., A. B. David, II, T. D. Baird, and R. E. Woodruff. 1975. First northwestern Atlantic breeding record of the Manx Shearwater. Auk 92:145.

Blomquist, S., and M. Elander. 1981. Sabine's Gull (Xema sabini), Ross' Gull (Rhodostethia rosea), and Ivory Gull (Pagophila eburnea) in the Arctic: Gulls in the Arctic -- a review. Arctic 34:122-131.

Braune, B. M., and D. E. Gaskin. 1982. Feeding ecology of nonbreeding populations of Larids off Deer Island, New Brunswick. Auk 99:67-76.

Brown, R. G. B. 1970. Fulmar distribution: a Canadian perspective. Ibis 112:44-51.

Brown, R. G. B. 1977. Atlas of eastern Canadian seabirds. Supplement I (Bermuda-Halifax transects). Can. Wildl. Serv., Minister of Supply and Services, Canada.

Brown, R. G. B. 1980a. Seabirds as marine animals. pp. 1-39 in (J. Burger, H. E. Winn, and B. L. Olla, eds.) Behavior of Marine Animals. Vol. 4, Birds. Plenum Publ. Co., New York.

Brown, R. G. B. 1980b. The pelagic ecology of seabirds. pp. 15-21 in Trans. of the Linnaean Society of New York, Vol. IX.

Brown, R. G. B. in press. The Atlantic alcidae at sea. in (D. N. Nettleship and T. R. Birkhead, eds.) The Atlantic Alcidae. Academic Press, London.

Brown, R. G. B., S. P. Barker, and D. E. Gaskin. 1979. Daytime swarming by Meganyctiphanes norvegica (M. Sars) (Crustacea, Euphausiacea) off Brier Island, Bay of Fundy. Can. J. Zool. 57:2285-2291.

Brown, R. G. B., S. P. Barker, D. E. Gaskin, and M. R. Sandeman. 1981. The foods of Great and Sooty Shearwaters Puffinus gravis and P. griseus in eastern Canadian waters. Ibis 123:19-30.

Brown, R. G. B., D. N. Nettleship, P. Germain, C. E. Tull, and T. Davis. 1975. Atlas of eastern Canadian seabirds. Can. Wildl. Serv., Ottawa.

Bruemmer, F. 1972. Dovekies. Beaver 303:40-47.

Bumpus, D. F. 1973. A description of the circulation on the continental shelf of the east coast of the United States. Progr. in Oceanogr. 6:111-156.

Bumpus, D. F. 1976. Review of the physical oceanography of Georges Bank. International Comm. for Northwest Atlantic Fish. Bull. 12:119-134.

Butcher, W. S., R. P. Anthony, and J. B. Butcher. 1968. Distribution charts of oceanic birds in the North Atlantic. Woods Hole Oceanogr. Inst. Tech. Rept. No. 68-69.

Cohen, E., W. R. Wright, and R. J. Schlitz. 1981. Primary productivity on Georges Bank with an explanation of why it is so high. p. 50 in The Third Informal Workshop on the Oceanography of the Gulf of Maine and Adjacent Seas. Univ. New Hampshire, Durham, N. H., abstract.

Collins, J. W. 1884. Notes on the habits and methods of capture of various species of sea birds that occur on the fishing banks off the eastern coast of North America, and which are used for catching codfish by New England fishermen. Pp. 311-335 in Rept. U. S. Fish. Comm., 1882.

Colton, J. B., Jr., R. R. Marak, S. E. Nickerson, and R. R. Stoddard. 1968. Physical, chemical, and biological observations on the continental shelf, Nova Scotia to Long Island, 1964-1966. U. S. Fish and Wildl. Serv. Data Rept. 23, 190 pp.

Corkhill, P. 1973. Food and feeding ecology of puffins. Bird Study 20:207-220.

Cramp, S. (chief ed.). 1977. Handbook of the birds of Europe, the Middle East and North Africa. Vol. 1, Ostrich-Ducks. Oxford Univ. Press, Oxford.

Drury, W. H. 1973-74. Population changes in New England seabirds. Bird-Banding 44:267-313, 45:1-15.

E.G. and G. 1978. Data report, support hydrography cruise. February 1978. Append. C of Seventh Quarterly Progr. Rept. submitted to Bureau Land Mgmt., Washington D. C. (BLM Contract AA550-CT6-50).

Elliott, C. C. H. 1970. Ecological considerations and the possible significance of weight variations in the chicks of the Greater Shearwater on Gough Island. Ostrich Suppl. 8:365-396.

Elliott, H. R. I. 1957. A contribution to the ornithology of the Tristan da Cuhna group. Ibis 99:545-586.

Erwin, R. M. 1979. Coastal waterbird colonies: Cape Elizabeth, Maine to Virginia. U. S. Fish and Wildl. Serv., Biol. Serv. Progr., FWS/OBS-79/10.

Erwin, R. M., and C. E. Korschgen. 1979. Coastal waterbird colonies: Maine to Virginia, 1977. U. S. Fish and Wildl. Serv., Biol. Serv. Progr., FWS/OBS-79/08.

Evans, P. G. H. 1981. Ecology and behaviour of the Little Auk Alle alle in west Greenland. Ibis 123:1-18.

Falla, R. A. 1937. Birds. Brit. Austr. N. Z. Antarctic Research Exped. 1929-1921 Reports, Series B, 2:1-304.

Finch, D. W., W. C. Russell, and E. V. Thompson. 1978. Pelagic birds in the Gulf of Maine. Amer. Birds 32:140-145, 281-294.

Fisher, J. 1952. The Fulmar. Collins, St. James Place, London.

Fisher, J. 1966. The fulmar population of Britain and Ireland, 1959. Bird Study 13:5-76.

Fisher, J., and R. M. Lockley. 1954. Sea-birds. Collins, London.

Flagg, C., B. Magnell, D. Frye, J. Cura, S. McDowell, and R. Scarlet. 1982. Interpretations of the physical oceanography of Georges Bank. Vol. I of Final Rept. to U. S. Bur. of Land Manage. by E G & G, Waltham, Mass., E G & G Rept. no. 82-B4569.

Forbush, E. H. 1925. Birds of Massachusetts and other New England states. Commonwealth of Mass., Dept. of Agric., Boston, Mass.

Forsythe, D. M. 1980. Cory's Shearwater off the South Carolina coast. Wilson Bull. 92:265-266.

Freuchen, P., and F. Salomonsen. 1958. The arctic year. G. P. Putnam's Sons, New York.

Furness, R. W. 1979. Foods of Great Skuas Catharacta skua at North Atlantic breeding localities. Ibis 121:86-92.

Garrison, D. L. 1940. Northern skua in Massachusetts. Auk 57:567-568.

Godfrey, W. E. 1966. The birds of Canada. Nat'l. Mus. Can. Bull. 203:1-428.

Gordon, M. S. 1955. Summer ecology of oceanic birds off southern New England. Auk 72:138-147.

Griscom, L. 1939. Migrations of the red phalarope off Massachusetts. Auk 56:185.

Gross, A. O. 1940. The migration of Kent Island Herring Gulls. Bird-Banding 11:129-155.

Grosslein, M. D., R. W. Langton, and M. P. Sissenwine. 1980. Recent fluctuations in pelagic fish stocks of the northwest Atlantic, Georges Bank region, in relation to species interactions. Rapp. P.-v. Reun. Cons. int. Explor. Mer. 177:374-404.

Halliwell, G. R., Jr., and C. N. K. Mooers. 1979. The space-time structure and variability of the shelf water-slope water and Gulf Stream surface temperature fronts and associated warm-core eddies. J. Geophys. Res. 84:7707-7725.

Harris, M. P. 1970. Differences in the diet of the British auks. Ibis 112:540-541.

Heinemann, D. A rangefinder for pelagic bird censusing. J. Wildl. Manage. 45:489-493.

Hill, N. P. 1965. The birds of Cape Cod, Massachusetts. Wm. Morrow and Co., New York, New York.

Hopkins, T. S., and N. Garfield III. 1981. Physical origins of Georges Bank water. J. Mar. Res. 39:465-500.

Hunt, G. L., Jr., B. Mayer, W. Rodstrom, and R. Squibb. 1978. Reproductive ecology, foods and foraging areas of seabirds nesting on the Pribilof Islands. pp. 570-775 in Vol. 1 of Envir. Assess. of the Alaskan Continental Shelf. Annual Repts. of Principal Invest. NOAA/OCSEAP, Boulder, Colo.

Hunt, G. L., Jr., G. A. Sanger, and B. Burgeson. 1981. Trophic relations of seabirds on the eastern Bering Sea. pp. 629-647 in (D. W. Hood, ed.) The Bering Sea Shelf. Inst. of Marine Sci., U. Alaska, Fairbanks, Alaska.

Iverson, R. L., L. K. Coachman, R. T. Cooney, T. S. English, J. J. Goering, G. L. Hunt, Jr., M. C. Macauley, C. P. McRoy, W. S. Reeburg, and T. E. Whitledge. 1979. Ecological significance of fronts in the southeastern Bering Sea. pp. 437-466 in (R. J. Livingston, ed.) Ecological Processes in Coastal and Marine Systems. Plenum Publ. Corp., New York.

James, F. C., and S. Rathburn. 1981. Rarefaction, relative abundance, and diversity of avian communities. Auk 98:785-800.

Johnson, R. A. 1940. Present range, migration and abundance of the Atlantic murre in North America. Bird-Banding 11:1-17.

Joiris, C. 1978. Seabirds recorded in the northern North Sea in July: the ecological implications of their distribution. Le Gerfaut 68:419-440.

Judkins, D. C., C. D. Wirick, and W. E. Esias. 1980. Composition, abundance, and distribution of zooplankton in the New York bight, September 1974-September 1975. Fish. Bull. 77:669-683.

Kadlec, J. A., and W. H. Drury. 1968. Structure of the New England herring gull population. Ecology 49:644-676.

Ketchum, B. H., and N. Corwin. 1964. The persistence of "winter" water on the continental shelf south of Long Island, N. Y. Limnol. Oceanogr. 9:467-475.

Lamb, K. D. A. 1964. Seabirds at the confluence of the Gulf Stream and Labrador Current east of New York. Sea Swallow 16:65.

Langridge, H. P. 1977. First sighting of a Thick-billed Murre for Florida. Fla. Field Nat. 5:19.

Lee, D. S., and J. Booth, Jr. 1979. Seasonal distribution of offshore and pelagic birds in North Carolina waters. Am. Birds 33:715-721.

Lee, D. S. and R. A. Rowlett. 1979. Additions to the seabird fauna of North Carolina. Chat 43:1-9.

Lien, J., and L. Grimmer. 1978. Manx Shearwater breeding in Newfoundland. Osprey 9:50-54.

Lincoln, F. C. 1934. An influx of Leach's petrels. Auk 51:74-75.

Linton, A. 1978. The food and feeding habits of Leach's Storm-petrel (Oceanodroma leucorhoa) at Pearl Island, Nova Scotia and Middle Lawn Island, Newfoundland. Unpubl. M. Sci. thesis, Dalhousie Univ., Halifax, Nova Scotia.

Lloyd, C. S., and C. M. Perrins. 1977. Survival and age at first breeding in the Razorbill (Alca torda). Bird-Banding 48:239-252.

Lowery, G. H., Jr., and R. J. Newman. 1954. The birds of the Gulf of Mexico. Fishery Bull. U. S. Fish and Wildl. Serv. 89, 55:519-540.

Madsen, F. J. 1957. On the food habits of some fish-eating birds in Denmark. Dan. Rev. Game Biol. 3:19-83.

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

Mason, C. R. 1951. Records of Sabine's Gull, Xema sabini, in Massachusetts. Auk 68:236.

McKittrick, T., Jr. 1929. Auk flights at sea. Auk 46:529-532.

Morzer Bruyns, W. F. J. 1967. Black-capped Petrels (Pterodroma hasitata) in the Atlantic Ocean. Ardea 55:270.

Murphy, R. C. 1922. Notes on tubinares, including records which affect the A.O.U. checklist. Auk 39:58-65.

Murphy, R. C. 1936. The oceanic birds of South America. Amer. Mus. Nat. Hist., New York.

Murphy, R. C. 1967. Distribution of North Atlantic pelagic birds, Folio 14. in (W. Webster, ed.) Serial Atlas of the Marine Environment, Amer. Geogr. Soc., New York.

Murphy, R. C., and L. S. Mowbray. 1951. New light on the cahow, Pterodroma cahow. Auk 68:266-280.

Nelson, J. B. 1978. The Gannet. Buteo Books, Vermillion, S. D.

Nettleship, D. N. 1972. Breeding success of the Common Puffin (Fratercula arctica L.) on different habitats at Great Island, Newfoundland. Ecol. Monogr. 42:239-268.

Nettleship, D. N. 1976. Gannets in North America: present numbers and recent population changes. Wilson Bull. 88:300-313.

Nettleship, D. N., and R. D. Montgomerie. 1974. The Northern Fulmar, Fulmarus glacialis, breeding in Newfoundland. Am. Birds 28:16.

Nisbet, I.C.T. 1973. Terns in Massachusetts: present numbers and historical changes. Bird-Banding 44:27-55.

Norderhaug, M. 1970. The role of the Little Auk Plautus alle (L.) in arctic ecosystems. pp. 558-560 in (M. W. Holdgate, ed.) Antarctic ecology, Vol. 1. Academic Press, London.

O'Reilly, J. E., C. A. Evans, and D. A. Busch. 1981. Distribution of phytoplankton biomass (chlorophyll a) and primary productivity in shelf water between Cape Hatteras and Nova Scotia. pp. 66-67 in Third Informal Workshop on the Oceanography of the Gulf of Maine and Adjacent Seas. Univ. New Hampshire, Durham, N. H., abstract.

Orr, C. D., R. M. P. Ward, N. A. Williams, and R. G. B. Brown. 1982. Migration patterns of Red and Northern Phalaropes in southwest Davis Strait and in the northern Labrador Sea. Wilson Bull. 94:303-312.

Palmer, R. S. (ed.). 1962. Handbook of North American Birds. Vol. 1. Yale Univ. Press, New Haven, Conn.

Patterson, J. R., and Menk, G. E. 1977. A Razorbill at St. George Island, Florida. Fla. Field Nat. 5:18-19.

Paxton, R. O., P. A. Buckley and D. A. Cutler. 1976. Hudson-Delaware Region. Am. Birds 30:39-46.

Phillips, J. H. 1963. The pelagic distribution of the Sooty Shearwater, Procellaria grisea. Ibis 105:340-353.

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

Portnoy, J. W., R. W. Erwin, and T. W. Custer. 1981. Atlas of gull and tern colonies: North Carolina to Key West, Florida (including pelicans, cormorants, and skimmers). U. S. Fish and Wildl. Serv., Office of Biol. Serv., Washington, D. C. FWS/OBS-80/05.

Post, P. W. 1967. Manx, Audubon's, and Little Shearwaters in the northwestern North Atlantic. Bird-Banding 38:278-305.

Powers, K. D. 1982. A comparison of two methods of counting birds at sea. J. Field Ornith. 53:209-222.

Powers, K. D., and J. Cherry. 1983. Loon migrations off the coast of the northeastern United States. Wilson Bull. 95:125-132.

Powers, K. D., and W. T. Rumage. 1978. Effect of the ARGO MERCHANT oil spill on bird populations off the New England coast, 15 Dec 1976 - Jan 1977. pp. 142-148 in In the Wake of the ARGO MERCHANT, symp. at Center for Ocean Mgmt. Studies, U. Rhode Island, Narragansett.

Powers, K. D., and J. A. Van Os. 1979. A concentration of Greater Shearwaters in the western North Atlantic. Am. Birds 33:253.

Rankin, M. N., and E. A. G. Duffey. 1948. A study of the bird life of the North Atlantic. Brit. Birds 41. (suppl.):1-42.

Redfield, A. C. 1941. The effect of the circulation of the water on the distribution of the calanoid community in the Gulf of Maine. Biol. Bull. 80:86-110.

Rees, E. I. S. 1961. Notes on the food of the Greater Shearwater. Sea Swallow 14:54-55.

Rees, E. I. S. 1965. The fulmar in the western North Atlantic. Ibis 107:428-429.

Roberts, B. B. 1940. The life cycle of Wilson's Petrel Oceanites oceanicus (Kuhl). Brit. Graham Land Exped. 1934-1937, Sci. Rept. 1:141-194.

Rowan, M. K. 1952. The Greater Shearwater Puffinus gravis at its breeding grounds. Ibis 94:97-121.

Rowlett, R. A. 1973. Sea birds wintering off Maryland shores, 1972-73. Maryland Birdlife 29:88-102.

Rowlett, R. A. 1980. Observations of marine birds and mammals in the northern Chesapeake Bight. U. S. Fish and Wildl. Serv., Biol. Serv. Progr. FWS/OBS-80/04.

Salomonsen, F. 1950. Gronlands Fugle. Ejnar Munksgaard, Copenhagen.

Salomonsen, F. 1965. The geographical variation of the fulmar and the zones of marine environment in the North Atlantic. Auk 82:327-355.

Salomonsen, F. 1967. Fuglene pa Gronland. Rhodos, Copenhagen. 340 pp.

Salomonsen, F. 1972. Zoogeographical and ecological problems in Arctic birds. Proc. XVth Intern. Ornithol. Congr.:25-77.

Salomonsen, F. 1976. The South Polar Skua (Stercorarius maccormicki) in Greenland. Dan. Ornithol. Foren. Tidsskr. 70:81-89.

Salomonsen, F. 1979. Ornithological and ecological studies in S. W. Greenland ($59^{o}46'$N-$62^{o}27'$N lat.). Meddel. om Gronland 204:1-214.

Schneider, D., and G. L. Hunt. 1982. Carbon flux to seabirds in waters with different mixing regimes in the southeastern Bering Sea. Mar. Biology 67:337-344.

Shannon, C. E., and W. Weaver. 1949. The mathematical theory of communication. Univ. of Ill. Press, Urbana, Ill.

Sherman, K. 1981. Zooplankton of Georges Bank and adjacent waters in relation to fisheries ecosystem studies. pp. 40-43 in Third Informal Workshop on the Oceanography of the Gulf of Maine and adjacent seas. Univ. New Hampshire, Durham, N. H.

Sherman, K., and C. Jones. 1980. The zooplankton component of a northwest Atlantic ecosystem. ICES CM 1980/L:67, 32 p., mimeo.

Sprunt, A., Jr., 1938. The southern Dovekie flight of 1936. Auk 55:85-88.

Stresemann, E., and V. Stresemann. 1970. Uber Mauser und Zug von Puffinus gravis. J. Ornithol. 111:378-393.

Stewart, R. E., and C. S. Robbins. 1958. Birds of Maryland and the District of Columbia. N. America Fauna No. 62, U. S. Gov't. Printing Office, Washington, D. C.

Snyder, D. E. 1954. A great flight of kittiwakes (Rissa tridactyla). Auk 71:463-464.

Snyder, D. E. 1958. Recent occurrences of the Manx Shearwater in Massachusetts. Auk 75:213-214.

Thomson, A. L. 1966. An analysis of recoveries of Great Skuas ringed in Shetland. Brit. Birds 59:1-15.

Todd, W. E. C. 1963. Birds of the Labrador penninsula and adjacent areas. Univ. Toronto Press, Toronto, Ont.

Tuck, L. M. 1961. The murres. Can. Wildl. Serv., Ottawa.

Tuck, L. M. 1971. The occurrence of Greenland and European birds in Newfoundland. Bird-Banding 42:184-209.

Veit, R. R. 1978. Some observations of South Polar Skuas (Catharacta maccormicki) on Georges Bank. Am. Birds 32:300-302.

Voous, K. H., and J. Wattel. 1963. Distribution and migration of the Greater Shearwater. Ardea 51:143-157.

Wahl, T. R., and D. Heinemann. 1979. Seabirds and fishing vessels: co-occurrence and attraction. Condor 81:390-396.

Walsh, J. J. 1981. Shelf-sea ecosystems. Pp. 159-196 in (A. R. Longhurst, ed.) Analysis of Marine Ecosystems. Academic Press, New York.

Walsh, J. J., T. E. Whitledge, F. W. Barvenik, C. D. Wirick, S. O. Howe, W. E. Esaias, and J. T. Scott. 1978. Wind events and food chain dynamics within the New York Bight. Limnol. Oceanogr. 23:659-683.

Watson, G. E. 1966. Seabirds of the tropical Atlantic Ocean. Smithsonian Identification Manual. Smithsonian Press. Washington, D. C.

Watson, G. E. 1975. Birds of the Antarctic and sub-Antarctic. Amer. Geophys. Union, Washington, D. C.

Weston, F. M. 1953. Red Phalarope (Phalaropus fulicarius) wintering near Pensacola, Florida. Auk 70:491-492.

Wetmore, A. 1927. The birds of Porto Rico and the Virgin Islands. Colymbiformes to Columbiformes. Pt. 3, pp. 248-406 in Scientific survey of Porto Rico and the Virgin Islands of the New York Acad. Sci., vol. 9.

Wiens, J. A., and J. M. Scott. 1975. Model estimation of energy flow in Oregon coastal seabirds populations. Condor 77:439-452.

Wingate, D. B. 1964. Discovery of breeding Black-capped Petrels on Hispaniola. Auk 81:147-159.

Witherby, H. F., F. C. R. Jourdain, N. F. Ticehurst, and B. W. Tucker. 1940. The handbook of British birds. Vol. IV, Cormorants to Crane. H. F. and G. Witherby Ltd., London.

Woods, R. R. 1970. Greater Shearwater Puffinus gravis breeding in the Falkland Islands. Ibis 112:259-260.

Wright, W. R. 1976. The limits of shelf water south of Cape Cod, 1941 to 1972. J. Mar. Res. 34:1-14.

Wright, W. R., and C. E. Parker. 1976. A volumetric temperature/salinity census for the Middle Atlantic Bight. Limnol. Oceanogr. 21:563-571.

Wynne-Edwards, V. C. 1935. On the habits and distribution of birds on the North Atlantic. Proc. Boston Soc. Natur. Hist. 40:233-346.

Yentsch, C. S., and N. Garfield. 1981. Principal areas of vertical mixing in the waters of the Gulf of Maine, with reference to the total productivity of the area. Pp. 59 in Third Informal Workshop on the Oceanography of the Gulf of Maine and adjacent seas. Univ. of New Hampshire, Durham, N. H.

Appendix 1. Seasonal mean densities of seabirds (birds/km^2) with standard deviations in the Gulf of Maine subarea from January 1978 through February 1980. Sample sizes are given in Table 1.

Species	Spring	Summer	Fall	Winter
Common Loon	0.02(±0.08)		0.05(±0.18)	0.01(±0.03)
Red-throated Loon			0.01(±0.02)	0.01(±0.03)
Northern Fulmar	4.46(±4.91)	0.37(±0.42)	0.84(±1.48)	8.73(±21.18)
Cory's Shearwater		0.07(±0.14)	1.42(±1.89)	
Greater Shearwater	0.02(±0.10)	2.88(±4.03)	11.47(±10.55)	0.01(±0.04)
Sooty Shearwater	0.08(±0.18)	0.41(±0.61)	0.01(±0.05)	
Manx Shearwater		0.01(±0.05)		
Leach's Storm-Petrel	0.01(±0.09)	0.25(±1.05)		
Wilson's Storm-Petrel	0.16(±0.85)	12.03(±23.43)	0.09(±0.15)	
Northern Gannet	0.19(±0.21)	0.01(±0.05)	0.54(±0.44)	0.34(±0.33)
Unid. cormorant	0.09(±0.38)		0.02(±0.07)	
Red Phalarope	0.10(±0.18)	0.05(±0.26)	0.02(±0.09)	0.01(±0.02)
Red-necked Phalarope		0.08(±0.40)	0.12(±0.65)	0.06(±0.40)
Unid. phalarope	0.01(±0.01)	0.03(±0.29)	0.01(±0.04)	0.10(±0.46)
Pomarine Jaeger		0.01(±0.04)	0.14(±0.24)	
Parasitic Jaeger			0.01(±0.03)	
Unid. jaeger		0.01(±0.01)	0.02(±0.07)	
Unid. skua			0.01(±0.07)	
Glaucous Gull	0.01(±0.05)			0.01(±0.04)
Iceland Gull	0.01(±0.02)			0.03(±0.08)
Great Black-backed Gull	1.36(±1.88)	2.61(±7.22)	6.60(±7.91)	4.40(±4.37)
Herring Gull	1.83(±2.24)	1.12(±1.33)	6.91(±6.31)	3.83(±2.87)
Unid. large gull	2.09(±5.53)	0.01(±0.01)	0.17(±0.57)	1.18(±4.22)
Ring-billed Gull			0.01(±0.05)	

Appendix 1 (continued).

Species	Spring	Summer	Fall	Winter
Laughing Gull		0.01(±0.04)		
Bonaparte's Gull				0.71(±2.81)
Black-legged Kittiwake	1.75(±0.51)	0.01(±0.04)	0.50(±0.49)	9.31(±6.11)
Unid. tern	0.01(±0.28)	0.09(±0.28)	0.09(±0.43)	
Least Tern		0.01(±0.01)		
Razorbill	0.02(±0.04)		0.01(±0.02)	0.05(±0.10)
Unid. murre	0.19(±0.60)			0.01(±0.04)
Unid. large alcid	0.09(±0.22)			0.08(±0.31)
Dovekie	0.19(±0.66)			0.05(±0.11)
Black Guillemot				0.01(±0.01)
Atlantic Puffin		0.01(±0.04)		0.02(±0.07)

Appendix 2. Seasonal mean densities of seabirds (birds/km^2) with standard deviations in the Georges Bank subarea from January 1978 through February 1980. Sample sizes are given in Table 1.

Species	Spring	Summer	Fall	Winter
Common Loon	0.02(±0.07)		0.01(±0.03)	0.01(±0.01)
Northern Fulmar	9.81(±6.89)	0.96(±1.91)	0.84(±0.81)	7.39(±8.03)
Cory's Shearwater	0.01(±0.01)	0.76(±0.68)	0.69(±1.37)	
Greater Shearwater	0.47(±1.14)	17.85(±41.73)	10.30(+11.75)	0.50(±1.62)
Sooty Shearwater	0.26(±0.42)	3.36(±8.66)	0.03(±0.12)	0.01(±0.01)
Manx Shearwater	0.01(±0.04)	0.06(±0.38)	0.03(±0.11)	
Audubon's Shearwater		0.01(±0.02)		
Leach's Storm-Petrel	0.02(±0.06)	0.10(±0.11)	0.01(±0.02)	
Wilson's Storm-Petrel	0.98(±1.54)	7.50(±4.94)	0.32(±0.94)	
Northern Gannet	0.80(±1.26)	0.01(±0.01)	0.52(±0.40)	0.63(±1.26)
Unid. cormorant			0.04(±0.32)	
Red Phalarope	4.79(±9.18)	0.01(±0.02)	0.03(±0.08)	0.01(±0.01)
Red-necked Phalarope	0.30(±0.10)		0.01(±0.01)	
Unid. phalarope	0.01(±0.04)		0.01(±0.08)	
Pomarine Jaeger	0.01 (±0.03)	0.01(±0.02)	0.08(±0.14)	0.01(±0.03)
Parasitic Jaeger	0.01(±0.02)	0.01(±0.01)	0.01(±0.01)	
Unid. jaeger		0.01(±0.01)	0.03(±0.07)	0.01(±0.01)
Unid. skua	0.01(±0.05)	0.01(±0.02)	0.02(±0.05)	0.01(±0.02)
Glaucous Gull	0.01(±0.01)			
Iceland Gull	0.01(±0.02)		0.01(±0.04)	0.04(±0.09)
Great Black-backed Gull	2.05(±1.96)	0.53(±0.68)	4.87(±7.53)	4.51(±4.83)
Herring Gull	3.02(±3.78)	0.32(±0.31)	6.29(±7.23)	3.58(±3.42)
Unid. large gull	0.13(±0.67)	0.07(±0.42)	1.46(±6.82)	0.09(±0.68)
Ring-billed Gull			0.05(±0.23)	

Appendix 2 (continued).

Species	Spring	Summer	Fall	Winter
Laughing Gull	0.01(±0.02)	0.01(±0.02)		
Bonaparte's Gull			0.01(±0.01)	
Black-legged Kittiwake	2.01(±8.20)		0.43(±0.70)	9.99(±17.87)
Unid. tern	0.27(±0.83)	0.05(±0.13)	0.06(±0.30)	
Razorbill	0.05(±0.16)			0.28(±0.72)
Unid. murre	0.09(±0.25)			0.05(±0.10)
Unid. large alcid	0.07(±0.26)			0.13(±0.43)
Dovekie	0.13(±0.23)			0.30(±0.79)
Atlantic Puffin	0.09(±0.22)	0.01(±0.01)		0.05(±0.16)

Appendix 3. Seasonal mean densities of seabirds (birds/km^2) with standard deviations in the Southern New England subarea from January 1978 through February 1980. Sample sizes are given in Table 1.

Species	Spring	Summer	Fall	Winter
Common Loon	0.06(±0.13)		0.02(±0.10)	0.02(±0.07)
Red-throated Loon	0.02(±0.05)		0.01(±0.03)	
Unid. albatross		0.01(±0.01)		
Northern Fulmar	0.91(±1.06)	0.01(±0.61)	0.07(±0.15)	2.81(±3.99)
Cory's Shearwater	0.01(±0.03)	2.00(±3.40)	0.44(±0.53)	
Greater Shearwater	0.24(±0.53)	2.81(±3.42)	4.09(±8.46)	0.01(±0.26)
Sooty Shearwater	0.13(±0.15)	0.63(±2.99)	0.01(±0.01)	0.01(±0.02)
Manx Shearwater		0.01(±0.03)	0.01(±0.03)	
Audubon's Shearwater		0.05(±0.12)	0.01(±0.01)	
Leach's Storm-Petrel	0.01(±0.02)	0.03(±0.06)		
Wilson's Storm-Petrel	1.05(±3.23)	5.71(±14.06)	0.02(±0.15)	
White-faced Storm-Petrel			0.01(±0.01)	
Northern Gannet	1.18(±2.27)	0.01(±0.01)	0.33(±0.91)	1.60(±0.93)
Red Phalarope	0.92(±1.67)	0.04(±0.16)	0.48(±1.55)	
Red-necked Phalarope		0.01(±0.01)		
Unid. phalarope	0.07(±0.14)	0.02(±0.15)	0.01(±0.01)	
Pomarine Jaeger		0.02(±0.03)	0.12(±0.29)	0.01(±0.03)
Parasitic Jaeger			0.01(±0.03)	
Unid. jaeger	0.01(±0.01)	0.01(±0.01)	0.02(±0.04)	0.01(+0.01)
Unid. skua	0.01(±0.01)	0.01(±0.01)	0.01(±0.03)	0.01(±0.01)
Glaucous Gull	0.01(±0.03)			0.01(±0.02)
Iceland Gull	0.02(±0.06)		0.01(±0.01)	0.01(±0.04)
Great Black-backed Gull	2.57(±5.50)	0.17(±0.18)	0.88(±1.05)	3.91(±3.13)
Herring Gull	5.75(±13.83)	0.62(±2.02)	3.17(±4.05)	4.46(±3.02)

Appendix 3 (continued).

Species	Spring	Summer	Fall	Winter
Unid. large gull	0.52(±1.91)	0.01(±0.01)	0.13(±0.43)	0.33(±0.49)
Ring-billed Gull	0.01(±0.01)		0.05(±0.18)	0.01(±0.01)
Laughing Gull	0.01(±0.02)	0.03(±0.09)	0.01(±0.04)	
Black-legged Kittiwake	0.32(±0.76)		0.50(±0.57)	1.11(±0.83)
Unid. tern	0.19(±0.34)	0.02(±0.07)	0.01(±0.01)	
Razorbill	0.05(±0.19)			0.16(±0.29)
Unid. murre	0.01(±0.01)			0.04(±0.09)
Unid. large alcid	0.05(±0.19)		0.01(±0.03)	0.07(±0.16)
Dovekie	0.01(±0.03)			0.01(±0.07)
Atlantic Puffin	0.01(±0.01)	0.01(±0.01)		

Appendix 4. Seasonal mean densities of seabirds (birds/km^2) with standard deviations in the Mid-Atlantic subarea from January 1978 through February 1980. Sample sizes are given in Table 1.

Species	Spring	Summer	Fall	Winter
Common Loon	0.77(±1.11)		0.01(±0.05)	0.04(±0.20)
Northern Fulmar	0.50(±0.66)			
Cory's Shearwater		0.30(±0.25)	0.34(±0.53)	
Greater Shearwater		0.65(±0.99)	0.01(±0.02)	
Sooty Shearwater	0.04(±0.05)	0.01(±0.02)		
Manx Shearwater	0.01(±0.03)	0.01(±0.02)		
Audubon's Shearwater			0.01(±0.01)	
Leach's Storm-Petrel	0.03(±0.03)			
Wilson's Storm-Petrel	6.05(±16.92)	1.64(±1.14)	0.10(±0.24)	
Northern Gannet	1.57(±1.51)		0.21(±0.35)	0.70(±0.50)
Red Phalarope	7.21(±15.36)			
Red-necked Phalarope	0.34(±2.07)	0.02(±0.06)	0.43(±2.25)	
Unid. phalarope	4.05(±9.09)		0.02(±0.11)	
Pomarine Jaeger	0.02(±0.06)		0.07(±0.10)	
Parasitic Jaeger	0.01(±0.04)		0.03(±0.09)	
Long-tailed Jaeger			0.01(±0.01)	
Unid. jaeger	0.01(±0.03)	0.01(±0.02)	0.01(±0.01)	
Unid. skua	0.02(±0.04)			
Great Black-backed Gull			0.12(±0.17)	0.60(±0.98)
Herring Gull	3.84(±3.66)	0.01(±0.04)	2.83(±2.32)	3.12(±2.71)
Unid. large gull	0.23(±0.59)			
Ring-billed Gull	0.18(±0.55)		0.03(±0.46)	
Laughing Gull	0.18(±0.32)	0.11(±0.20)	0.90(±1.98)	
Bonaparte's Gull	1.19(±3.20)			0.01(±0.13)

Appendix 4 (continued).

Species	Spring	Summer	Fall	Winter
Black-legged Kittiwake	0.04(±0.05)		0.05(±0.06)	0.77(±0.69)
Unid. tern	0.14(±0.47)	0.06(±0.13)	0.20(±0.39)	
Royal Tern		0.03(±0.07)	0.02(±0.09)	
Bridled Tern		0.01(±0.02)	0.11(±0.10)	
Sandwich Tern			0.09(±0.47)	
Sooty Tern		0.01(±0.01)		
Black Tern		0.01(±0.01)	0.10(±0.12)	

Appendix 5. Population estimates of most abundant bird species and species groups by season in shelf waters off the northeastern United States from 35°N to 44°N latitude. Estimates are given in thousands with 95 percent confidence intervals.

Species	Spring	Summer	Fall	Winter
Northern Fulmar	858(±81)	74(±10)	99(±13)	1070(±195)
Cory's Shearwater	<1	161(±19)	161(±24)	
Greater Shearwater	39(±10)	1288(±213)	1458(±148)	28(±9)
Sooty Shearwater	27(±4)	235(±51)	3(±1)	<1
Manx Shearwater	<1	5(±2)	2(±1)	
Audubon's Shearwater		2(±1)	<1	
Leach's Storm-Petrel	3(±1)	22(±7)	<1	
Wilson's Storm-Petrel	380(±128)	1500(±222)	28(±7)	
Northern Gannet	183(±27)	1(±1)	87(±11)	168(±23)
Red Phalarope	619(±142)	6(±2)	28(±7)	<1
Red-necked Phalarope	16(±13)	6(±3)	26(±21)	<1
Unidentified phalarope	181(±54)	3(±1)	2(±1)	<1
Great Black-backed Gull	325(±51)	197(±47)	711(±84)	736(±87)
Herring Gull	738(±123)	119(±18)	1043(±101)	795(±99)
Unidentified large gull[1]	172(±60)	4(±2)	94(±29)	95(±32)
Laughing Gull	8(±2)	7(±2)	40(±15)	
Black-legged Kittiwake	231(±83)	1(±1)	82(±9)	1187(±145)
Razorbill	6(±2)		<1	26(±6)
Murres[2]	17(±6)			5(±1)
Unidentified large auk[3]	12(±4)		<1	16(±5)
Dovekie	19(±6)			20(±5)
Atlantic Puffin	5(±1)	<1		4(±1)

[1]Great Black-backed or Herring gull
[2]Common or Thick-billed murre
[3]Razorbill or murre

Appendix 6. Number of individuals per species and season recorded from 100 transects randomly selected each season from the Gulf of Maine and Georges Bank subareas, January 1978 to February 1980. Total area sampled per season was assumed to be $93km^2$.

Species	Spring	Summer	Fall	Winter
Common Loon			8	
Red-throated Loon				5
Northern Fulmar	601	142	75	350
Cory's Shearwater		79	76	
Greater Shearwater	29	1078	872	
Sooty Shearwater	31	263	1	
Manx Shearwater		1	1	
Audubon's Shearwater			1	
Leach's Storm-Petrel	1	86		
Wilson's Storm-Petrel	22	868	7	
Northern Gannet	25	2	80	25
Red Phalarope	33	10	3	5
Red-necked Phalarope	1	9	1	
Pomarine Jaeger		1	14	1
Parasitic Jaeger			1	
Unid. skua		1	2	
Glaucous Gull	2			
Iceland Gull	2			4
Great Black-backed Gull	323	59	761	293
Herring Gull	138	34	634	364
Ring-billed Gull			5	
Laughing Gull		2		

Appendix 6 (continued).

Species	Spring	Summer	Fall	Winter
Black-legged Kittiwake	25	2	22	539
Common Tern	6	3	31	
Arctic Tern	4			
Razorbill	8			5
Common Murre	1			2
Thick-billed Murre	7			
Dovekie	8			46
Atlantic Puffin	2	1		11

Appendix 7. Number of individuals per species and season recorded from 100 transects randomly selected each season from the Southern New England and mid-Atlantic subareas, January 1978 to February 1980. Total area sampled per season was assumed to be 93km^2.

Species	Spring	Summer	Fall	Winter
Common Loon	5		4	3
Red-throated Loon	4			
Northern Fulmar	95			86
Cory's Shearwater	1	92	37	
Greater Shearwater	8	178	160	
Sooty Shearwater	10	7		
Manx Shearwater		3	1	
Audubon's Shearwater		4		
Leach's Storm-Petrel		1		
Wilson's Storm-Petrel	86	267	12	
Northern Gannet	143	1	50	137
Red Phalarope	265		1	
Red-necked Phalarope	6	8	2	
Pomarine Jaeger		1	15	
Parasitic Jaeger	1		2	
Glaucous Gull				1
Iceland Gull			1	1
Great Black-backed Gull	154	3	86	169
Herring Gull	299	11	286	316
Ring-billed Gull	13			
Laughing Gull	9	46	22	
Bonaparte's Gull	48			8
Black-legged Kittiwake	31		29	74

Appendix 7 (continued).

Species	Spring	Summer	Fall	Winter
Common Tern	4	1	5	
Royal Tern	5	4	1	
Sandwich Tern			5	
Black Tern			2	
Razorbill	31			10
Common Murre	3			5
Dovekie				4
Atlantic Puffin	1		1	

Appendix 8. List of noteworthy bird sightings which are not included in the species distribution maps.

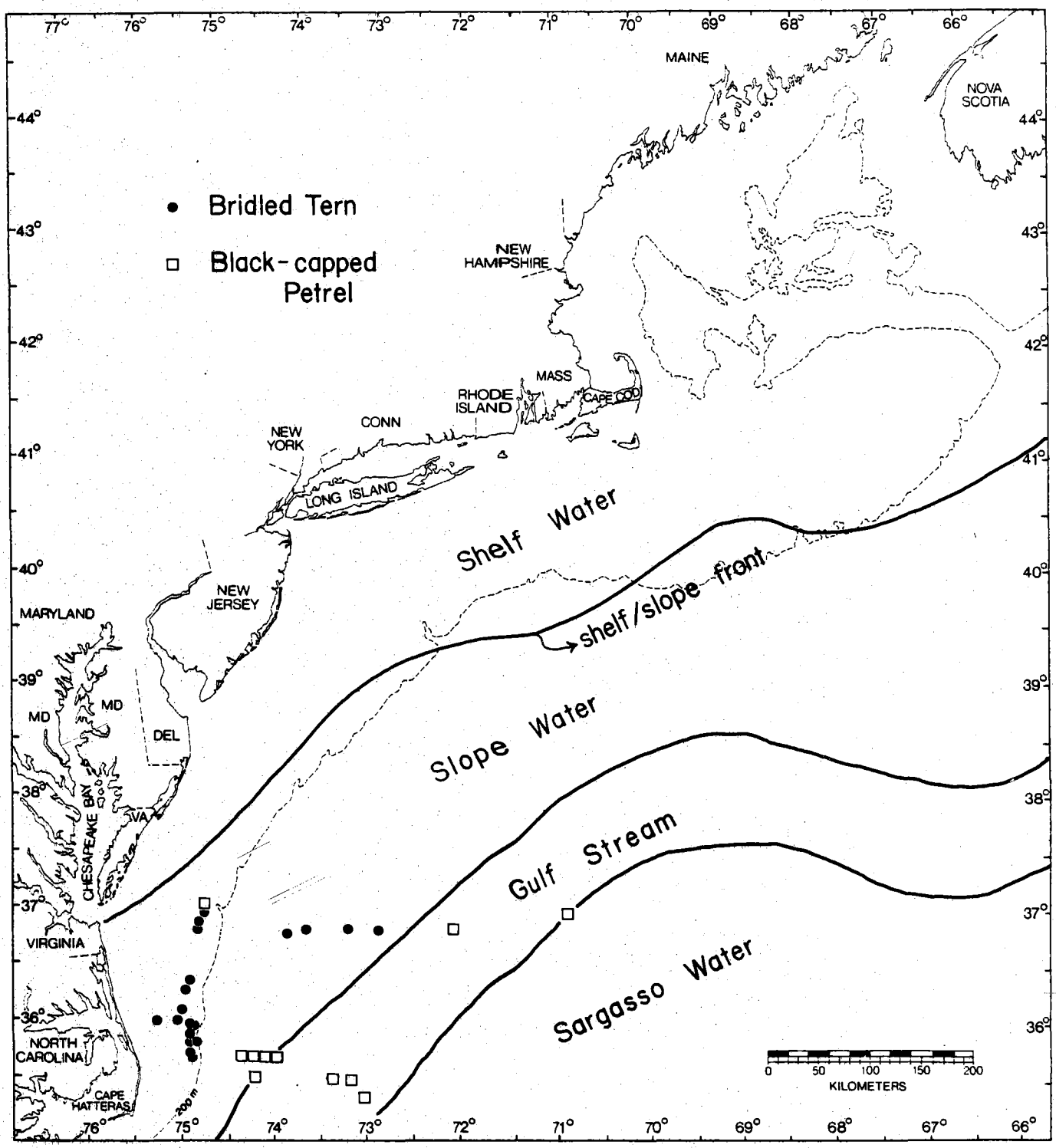
Common Loon		*Gavia immer*
19 Jul 1979	40°27′N, 69°05′W	1
Yellow-nosed Albatross		*Diomedea chlororhynchos*
14 Jun 1976	41°39′N, 68°19′W	1
Unidentified albatross		*Diomedea* sp.
13 Jul 1978	42°24′N, 68°22′W	1
7 Jul 1979	41°09′N, 71°22′W	1
Northern Fulmar		*Fulmarus glacialis*
9 Feb 1980	32°19′N, 79°17′W	1
Black-capped Petrel		*Pterodroma hasitata*
30 Apr 1976	37°39′N, 68°54′W	1
17 May 1976	34°58′N, 67°55′W	1
Cory's Shearwater		*Calonectris diomedea*
19 Apr 1979	40°41′N, 71°22′W	1
Greater Shearwater		*Puffinus gravis*
4 Mar 1976	41°26′N, 68°30′W	1
2 Feb 1977	41°09′N, 69°05′W	1
Sooty Shearwater		*Puffinus griseus*
27 Jan 1977	41°38′N, 69°02′W	1
2 Feb 1978	39°54′N, 71°32′W	1
11 Dec 1978	41°43′N, 68°06′W	1
27 Feb 1979	41°28′N, 68°44′W	1
2 Mar 1979	37°00′N, 74°38′W	1
7 Mar 1979	40°06′N, 72°49′W	1
Leach's Storm-Petrel		*Oceanodroma leucorhoa*
26 Jun 1978	37°40′N, 74°02′W	1
White-faced Storm-Petrel		*Pelagodroma marina*
30 Aug 1979	37°27′N, 71°55′W	1
19 Sep 1979	39°18′N, 72°16′W	1

White-tailed Tropicbird		Phaethon lepturus
5 Sep 1979	36°39'N, 70°00'W	1
Red-necked Phalarope		**Phalaropus lobatus**
8 Mar 1979	36°31'N, 71°53'W	1
Red Phalarope		**Phalaropus fulicaria**
15 Jan 1978	42°14'N, 70°01'W	1
5 Feb 1978	42°22'N, 68°49'W	1
Long-tailed Jaeger		**Stercorarius longicaudus**
16 May 1976	36°31'N, 68°16'W	1
7 Jun 1978	40°49'N, 67°03'W	1
2 Sep 1979	35°50'N, 74°55'W	1
5 Sep 1979	36°58'N, 70°14'W	1
Lesser Black-backed Gull		**Larus fuscus graellsii**
7 Mar 1979	39°50'N, 73°25'W	1
7 Mar 1979	37°32'N, 74°50'W	1
23 Nov 1979	36°56'N, 76°11'W	1
Laughing Gull		**Larus atricilla**
7 Apr 1976	42°05'N, 68°15'W	1
Little Gull		**Larus minutus**
23 May 1978	40°40'N, 71°12'W	1
3 Dec 1979	41°51'N, 70°25'W	1
Sabine's Gull		**Xema sabini**
3 Nov 1976	42°38'N, 70°04'W	1
25 Aug 1979	31°40'N, 80°10'W	1
Black Tern		**Chlidonias niger**
29 Aug 1979	35°52'N, 74°55'W	1
29 Aug 1979	36°01'N, 74°56'W	4
2 Sep 1979	35°56'N, 75°17'W	1
2 Sep 1979	36°02'N, 75°19'W	4
4 Sep 1979	36°59'N, 75°51'W	1
7 Sep 1979	36°05'N, 75°03'W	6
7 Sep 1979	36°21'N, 75°00'W	3

Roseate Tern		Sterna dougallii
16 Sep 1979	42°51′N, 68°34′W	2
Bridled Tern		**Sterna anaethetus**
25 Jan 1979	36°46′N, 71°32′W	1
Sooty Tern		**Sterna fuscata**
1 Jun 1977	40°31′N, 68°38′W	1
5 Sep 1979	37°04′N, 70°57′W	1
6 Sep 1979	35°36′N, 73°24′W	1
7 Sep 1979	41°15′N, 68°57′W	1
11 Sep 1979	36°49′N, 73°58′W	5
11 Sep 1979	36°42′N, 73°30′W	102
Least Tern		**Sterna albifrons**
20 Aug 1979	41°57′N, 69°49′W	1
21 Aug 1979	41°57′N, 69°10′W	1
26 Aug 1979	40°35′N, 67°15′W	1
3 Sep 1979	40°16′N, 69°24′W	1
15 Sep 1979	41°32′N, 69°00′W	3
Sandwich Tern		**Sterna sandvicensis**
24 Jun 1978	35°44′N, 75°24′W	2
24 Jun 1978	35°50′N, 75°29′W	1
24 Jun 1978	35°56′N, 75°23′W	1
23 Aug 1979	36°55′N, 75°54′W	1
2 Sep 1979	35°56′N, 75°17′W	5
Brown Noddy		**Anous stolidus**
9 Sep 1979	34°47′N, 75°48′W	1
Razorbill		**Alca torda**
15 Nov 1976	42°28′N, 65°20′W	1
Thick-billed Murre		**Uria lomvia**
10 Jun 1976	42°03′N, 67°04′W	1
Dovekie		**Alle alle**
17 Nov 1976	44°08′N, 67°42′W	1

Black Guillemot		Cepphus grylle
28 Jan 1977	40°40′N, 69°30′W	2
6 Feb 1978	42°00′N, 70°00′W	3
21 Feb 1980	43°44′N, 69°22′W	1
Atlantic Puffin		**Fratercula arctica**
14 Jul 1978	43°43′N, 68°51′W	1
21 Jul 1979	43°44′N, 68°53′W	1
22 Jul 1979	43°55′N, 67°30′W	1

Appendix 9. Distribution of sightings of Black-capped Petrels (Pterodroma hasitata) and Bridled Terns (Sterna anaethetus) in relation to major surface hydrographic features off Cape Hatteras, North Carolina in early September 1979.



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