MANOMET BIRD OBSERVATORY

MANOMET, MASSACHUSETTS 02345

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Master

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**DISTRIBUTION OF MARINE BIRDS
ON THE MID- AND NORTH-ATLANTIC
U.S. OUTER CONTINENTAL SHELF**

**Technical Progress Report
Summary of Activities from: January 1978 - July 1980**

**K.D. Powers, G.L. Pittman, and S.J. Fitch
Manomet Bird Observatory
Manomet, MA 02345**

September 1980

Prepared for

**U.S. Department of Energy
Office of Health & Environmental Research
Ecological Research Division
Marine Research Division
Washington, D.C. 20545**

DOE Contract Number DE-AC02-78EV04706.A002

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

	<u>PAGE</u>
TITLE PAGE	1
TABLE OF CONTENTS	11
LIST OF TABLES	iii
LIST OF FIGURES	v
LIST OF APPENDICES	viii
ABSTRACT	1
INTRODUCTION	2
METHODS	4
1. Census Method	4
2. Bird Abundance	7
a. Stratification	
b. Indices of Species Structure in the Bird Community	
3. Comparison of Two Census Methods	14
4. Feeding Habits	16
RESULTS AND DISCUSSION	18
1. Sampling Effort	18
a. Ships-of-opportunity and Utilization of Volunteers	
b. Quantitative Analysis by Region	
2. Comparison of Two Census Methods	25
a. Paired Observations	
b. Bias from Fishing Activity	
c. Correlation and Linear Regression	
3. Species Accounts	40
4. Factors Influencing Distribution	95
a. Physical Oceanographic Features	
b. Fishing Activities	
5. Seabird Community Structure	110
a. Ecological Dominance	
b. Species Diversity	
6. Feeding Ecology	125
7. Oil-Bird Interactions	137
DATA MANAGEMENT	146
SUMMARY	148
ACKNOWLEDGEMENTS	151
LITERATURE CITED	153
APPENDIX	162

LIST OF TABLES		PAGE
Table 1.	Total area (km ²) of regions and subregions used in community structure analyses.	12
Table 2.	List of the number of cruises utilized in sampling effort from 1978-1980 by cooperating agencies.	20
Table 3.	A comparison of the number of cruises and man-days at sea made by MBO/DOE staff and volunteer observers from January 1978 to April 1980.	21
Table 4.	Seasonal sampling effort (km ² surveyed) by region and subregion, January 1978 to July 1979.	23
Table 5.	Species comparison of differences between observer estimates of bird density (birds/km ²) and abundance (birds/10 minutes) from paired observations made at sea, 15-30 August 1979 on USSR RV ALIOT and 13-21 November 1979 on PRP RV WIECZNO.	26
Table 6.	The overall mean percent of relative abundance (birds seen per 10 minutes) estimates composed of recounts for each species and the frequency of cruises in which the recount percent for each cruise was above or below the overall mean for each species examined.	31
Table 7.	The overall mean density (birds/km ²) estimates for each species and the frequency of cruises in which the mean density per cruise was above or below the overall mean for each species examined.	33
Table 8.	Results from linear regression analyses to predict abundance estimates (birds/10 minutes) from density (birds/ km ²) values for bird species by cruise.	36
Table 9.	List of species according to distribution and abundance categories for shelf and shelf-break waters in the northeastern U.S. from 36°N to 44°N latitude.	43
Table 10.	Total standing stock by season and region in 1000's of individuals.	112
Table 11.	Total biomass by season and region in metric tons.	114
Table 12.	Weights and their source used for each bird species in biomass calculations.	115
Table 13.	A seasonal and regional summary of diversity measures calculated in the community structure analyses.	119

	<u>PAGE</u>
Table 14. Stomach contents analysis of 3 Northern Fulmars collected on Georges Bank.	126
Table 15. Stomach contents analysis of 36 Cory's Shearwaters collected on Georges Bank and adjacent waters.	127
Table 16. Stomach contents analysis of 44 Greater Shearwaters collected on Georges Bank and adjacent waters.	128
Table 17. Stomach contents analysis of 7 Sooty Shearwaters collected on Georges Bank and adjacent waters.	129
Table 18. Stomach contents analysis of 18 Wilson's Storm-Petrels collected on Georges Bank and adjacent waters.	130
Table 19. Stomach contents analysis of 3 Pomarine Jaegers collected on Georges Bank and adjacent waters.	131
Table 20. Stomach contents analysis of a skua collected on Georges Bank.	131
Table 21. Stomach contents analysis of 18 Great Black-backed Gulls collected on Georges Bank and adjacent waters.	132
Table 22. Stomach contents analysis of 4 Herring Gulls collected on Georges Bank and adjacent waters.	133
Table 23. Stomach contents analysis of 10 Black-legged Kittiwakes collected on Georges Bank.	134
Table 24. Average oiled bird index (no. oiled birds seen per 10 minutes) by month and species, February 1976 to December 1979.	139

LIST OF FIGURES		<u>PAGE</u>
Figure 1.	Map of study area from Cape Hatteras to the Bay of Fundy, indicating important water masses, geophysical features, and final OCS lease sale areas.	3
Figure 2.	Illustration of bird counting categories for shipboard observations.	6
Figure 3.	Illustration of National Marine Fisheries Service groundfish survey strata (Grosslein et al. 1978).	9
Figure 4.	Outline of general regions used in quantitative analyses of bird distribution within the study area.	10
Figure 5.	Example of a Type I regression model (flying birds).	37
Figure 6.	Example of a Type II regression model (sitting birds).	39
Figure 7.	Spatial and temporal distribution of Northern Fulmar.	47
Figure 8.	Spatial and temporal distribution of Cory's Shearwater.	49
Figure 9.	Spatial and temporal distribution of Greater Shearwater.	51
Figure 10.	Spatial and temporal distribution of Sooty Shearwater.	53
Figure 11.	Spatial and temporal distribution of Wilson's Storm-Petrel.	55
Figure 12.	Spatial and temporal distribution of Gannet.	57
Figure 13.	Spatial and temporal distribution of Red Phalarope.	59
Figure 14.	Spatial and temporal distribution of Great Black-backed Gull.	61
Figure 15.	Spatial and temporal distribution of Herring Gull.	63
Figure 16.	Spatial and temporal distribution of Black-legged Kittiwake.	65
Figure 17.	Spatial and temporal distribution of Manx Shearwater.	69
Figure 18.	Spatial and temporal distribution of Audubon's Shearwater.	71
Figure 19.	Spatial and temporal distribution of Leach's Storm-Petrel.	73

Figure 20.	Spatial and temporal distribution of Northern Phalarope.	76
Figure 21.	Spatial and temporal distribution of Pomarine Jaeger.	78
Figure 22.	Spatial and temporal distribution of skuas.	80
Figure 23.	Spatial and temporal distribution of Iceland Gull.	82
Figure 24.	Spatial and temporal distribution of Laughing Gull.	84
Figure 25.	Spatial and temporal distribution of Common/Arctic Terns.	86
Figure 26.	Spatial and temporal distribution of Razorbill.	88
Figure 27.	Spatial and temporal distribution of murres.	90
Figure 28.	Spatial and temporal distribution of Dovekie.	92
Figure 29.	Spatial and temporal distribution of Puffin.	94
Figure 30.	Distribution of Red Phalarope in mid- and north-Atlantic U.S. continental shelf waters, April 1978-79.	97
Figure 31.	Distribution of Red Phalarope in mid- and north-Atlantic U.S. continental shelf waters, May 1978-79.	98
Figure 32.	Ocean frontal analysis from satellite imagery of sargasso, slope, and shelf water regimes off northeastern U.S., 22-28 April 1979.	99
Figure 33.	Ocean frontal analysis from satellite imagery of sargasso, slope, and shelf water regimes off northeastern U.S., 13-19 May 1979.	100
Figure 34.	Distribution of copepod volumes (copepods $\times$ ml ⁻¹) per neuston sample from USSR RV ARGUS, 29 April - 5 May 1978.	101
Figure 35.	Vertical section through Georges Bank at c. 68°00'W longitude showing distribution of Wilson's Storm-Petrel density (birds/km ²) and surface water temperatures (°C) in August 1978.	103
Figure 36.	Vertical section through Georges Bank at c. 69°00'W showing distribution of water temperature (°C) and Wilson's Storm-Petrel density (birds/km ²) in August 1979.	105
Figure 37.	Seasonal groupings of Exp(H') values.	120
Figure 38.	Seasonal groupings of 1/ λ values.	121
Figure 39.	Seasonal groupings of n values.	123

- Figure 40. Percent composition of fish, cephalopods, and crustaceans in the diets of six marine bird species. 135
- Figure 41. Cumulative monthly oiled bird index for pelagic distributions of marine birds on Georges Bank and adjacent waters, 1976-1979. 142
- Figure 42. Monthly oiled bird index for pelagic distributions of marine birds on Georges Bank and adjacent waters, 1976-1979. 143

LIST OF APPENDICES

	<u>PAGE</u>
Appendix 1. Diversity index formulations.	162
Appendix 2. List of selected rare bird sighting records from Cape Hatteras (c. 35°N) north to Bay of Fundy (c. 44°N) and from the coast east to 65°W longitude from January 1978 to April 1980.	163

ABSTRACT

The species composition, distribution and abundance of marine birds on continental shelf waters from Cape Hatteras to the Bay of Fundy were examined using ships-of-opportunity. Northern Fulmar, Cory's Shearwater, Greater Shearwater, Sooty Shearwater, Wilson's Storm-Petrel, Gannet, Red Phalarope, Great Black-backed Gull, Herring Gull, and Black-legged Kittiwake were the most abundant and common species. These species were ecologically dominant within the bird community in numbers and biomass. Georges Bank and Gulf of Maine regions generally had greatest estimates of standing stock and biomass; whereas, in the Middle Atlantic region these estimates were consistently lowest. Species diversity throughout the study area was greatest in spring and least in fall.

Oceanic fronts at the continental shelf break and at Nantucket Shoals influenced the distribution of Wilson's Storm-Petrels and Red Phalaropes. Fishing activities were particularly important to *Larus* gull distribution. Fishes, squids and crustaceans were the most important groups of prey items in diets of nine bird species.

An oiled bird or pollution index was developed. According to the index, frequency of oiled birds was greatest in winter and spring, and gulls made up the majority of species with oiled plumages.

INTRODUCTION

Seabirds spend more than half their lives at sea where space and predation are not significant population regulators. Oil in marine environments has been recognized throughout the literature for its capability of killing birds at sea. Not only are birds a highly visible component of the marine environment, but they are an integral part of marine food chains. Oil and gas exploration in the Middle Atlantic Bight (OCS lease sale no. 40) and on Georges Bank (OCS lease sale no. 42) poses a potential threat to bird populations migrating through or wintering within these waters (Fig. 1).

The scope of the research plan for this contract was a system study designed to investigate the general structure and function of the marine bird community off the northeastern U. S. Goals within the study were: (1) to describe the species composition, distribution and abundance of the marine bird community; (2) to describe seasonal and regional patterns of species dominance; (3) to delineate areas of species and community importance; and (4) to identify physical oceanographic factors, fishing activities, and preferred prey resources that influence pelagic distributions of marine birds.

We have attempted to describe the structure of the marine community and to identify parts of major factors that influence the distribution of birds at sea during migration and/or nonbreeding residence in shelf waters of the western North Atlantic off the northeastern U. S. coast. Our findings will hopefully characterize the bird community in several ways, so that natural and man-caused environmental perturbations can be separated and evaluated in context of the bird resource.

Figure 1. Map of study area from Cape Hatteras to the Bay of Fundy, indicating important water masses, geophysical features, and final OCS lease sale areas.

METHODS

1. Census Method

Bird observations were made by MBO staff and by trained volunteer observers aboard research and offshore law enforcement cruises to mid- and north-Atlantic U. S. outer continental shelf waters from January 1978 to April 1980. The cruise objectives of the research vessels were hydrography, zooplankton/ichthyoplankton, or groundfish trawl surveys. The offshore law enforcement cruises were U. S. Coast Guard patrols. Except for two cruises aboard the USSR RV ALIOT in August 1978 and 1979, observers were aboard these vessels on a "not to interfere with general operations" basis and had no opportunity to determine cruise tracks. No cruises had duplicate cruise tracks, although most observations were made in the same general area.

Data were recorded into three sets: location, environment, and bird data. Location and environment data were collected by the observer from the ship's instruments or transcribed from ship's logs on Coast Guard patrols and from scientific station logs on research vessels. Location data included latitude ($^{\circ}$ N) and longitude ($^{\circ}$ W), date (month-day-year) and time (GMT), ship's course ($^{\circ}$ true north) and speed (kt), time zone, and height of observation deck (m) at the start of each counting period and at the time of a general observation. Environment data included depth (m), surface temperature ($^{\circ}$ C) and salinity (ppt) (when available), barometric pressure (mb) and trend (rising, falling, steady), wind speed (kt) and direction ($^{\circ}$ true north), cloud cover and precipitation, presence or

absence of debris (e.g. fishing vessels, nonfishing vessels, algae mats, offal), and strata (i.e. areas defined by depth and latitude by the NMFS). Bird data included taxon, number sighted by age, color phase, presence or absence of visibly oiled plumage, behavior, and zone in which sighted.

Quantitative bird observations were recorded in 10 minute periods when the vessel proceeded on a constant course and speed. A minimum speed of 4 kts was established, below which no quantitative observations were made. Birds were recorded in one of three categories: two categories were distinct spatial zones; the other was a subjectively based behavioral category (Fig. 2). Using a strip census modification of the line transect sampling procedure (Eberhardt 1978), the observer counted all birds seen forward of mid-ship, and laterally on one side to 300m (Gould et al. 1978). The forward scan was extended to the projected end of the transect (e.g. 3000m at 10 kts). The area censused was termed the "fixed-area zone." A ship-following bird which passes through the fixed-area for the first time is counted in the "fixed-area zone." In all transects thereafter, that bird is considered a "recount" and is tallied separately. Birds observed beyond the transect boundary, but not ship-following the observer's platform, were also counted separately in the "outside fixed-area zone." Although no maximum visibility limits were established for this zone, a minimum visibility of 1 km was required for all transects.

In essence, two census methods were employed simultaneously: a relative density (birds per unit area) and a relative abundance (birds per unit time) estimator. Density (birds/km²) estimates

Figure 2. Illustration of Bird Counting Categories for Shipboard Observations

were derived from the fixed-area zone counts, as described by Gould et al. (1978). Abundance (birds seen per 10 minutes) estimates were derived from a summation of all birds recorded in the fixed-area and outside fixed-area zones and recounts. The abundance estimates are equivalent to those described by Brown et al. (1975).

The density estimator is used for all quantitative bird data in this report, except for the methodology discussion section. Otherwise, the terms "abundance" and "density" are used interchangeably throughout the report to indicate the same measurement (birds/km²).

Noteworthy sightings, made between the 10 minute counting periods or when the ship's speed or visibility (due to fog) was below the requirements of a standard transect, were recorded as general observations. A noteworthy sighting included all marine mammals and turtles, bird species rare to the study area, extra-seasonal or extra-limital sightings of common bird species, and large bird concentrations (usually greater than 100 birds per sighting of any bird species).

2. Bird Abundance

a. Stratification

Indices of population abundance are necessary for a description of the quantitative and qualitative aspects of the structure of the marine bird community in the mid- and north-Atlantic U. S. outer continental shelf. The species and numbers of birds were assessed in terms of time and space. The pelagic distributions of marine birds were heterogeneous, so a stratified sampling scheme was used. Stratification reduces an inflationary

bias in estimates of population size caused by patchy or clustered distributions (Burham et al. 1980).

A stratified sampling scheme developed and used by the National Marine Fisheries Service (NMFS), Northeast Fisheries Center (NEFC) groundfish survey unit in the northeastern U. S. continental shelf (Grosslein et al. 1978), was applied to this study (Fig. 3). Since we had no previous basis upon which to develop a stratification scheme for marine birds, we combined the NMFS strata into regions and subregions to facilitate the data analysis. The NMFS strata are also potentially useful in categorizing distributions of bird populations because they allow direct comparisons of bird densities with other estimates of biomass, i.e. finfishes and squid.

The study area was divided into four general regions which are primarily based on geophysical and oceanographic features. The Gulf of Maine is a deep water basin within the shelf with relatively fresh, cold, low density water. Georges Bank is a submarine bank with steep edges and well-mixed waters intermediate between Gulf of Maine and warm slope regimes (Bumpus 1976). The southern New England and Middle Atlantic regions generally represent the New York and Middle Atlantic Bights. They are marked by a gradual sloping shelf from the coast to the continental slope and water regimes which are more typically subtropical.

In order to minimize inflationary bias in estimating densities over large areas, because of localized bird concentrations; the regions were partitioned into subregions. The delineation

Figure 3. Illustration of National Marine Fisheries Service groundfish survey strata (Grosslein et al. 1978).

Figure 4. Outline of general regions used in quantitative analyses of bird distribution within the study area.

of subregions was based upon similar habitat (i.e. physical and biological oceanography) and fishing activities. These factors may influence the pelagic distribution of birds. The regions and subregions and their derivation from NMFS strata are listed in Table 1 and are illustrated in Figures 3 and 4.

Regional species density values were computed by season (i.e. spring, summer, fall and winter). The seasons correspond to periods of change in species composition and abundance from spring and fall migration and summer and winter residence within the study area. Density values were calculated from total numbers of individuals per species divided by the total area sampled (km^2) for each subregion. Since each subregional species density value represents a single sample estimate, no variances or confidence intervals were considered in this analysis. The intent of these data are not to present absolute estimates of population abundance, but are stated merely to provide a relative ranking of dominance within the bird community. Confidence limits will be examined in future analyses, when software capabilities are apparent (cf. DATA MANAGEMENT).

b. Indices of Species Structure in the Bird Community.

The subregional and regional abundance computations formed a nucleus from which several useful indices of species structure within the bird community were developed. The indices examine ecological dominance and species diversity. Ecological dominance refers to species that control a major portion of community energy flow (Odum 1971). Standing stock (numerical dominance) and biomass (biomass dominance) estimates of common and abundant

Table 1. Total area (km²) of regions and subregions used in community structure analyses.

Regions and Subregions	NMFS Strata #	Total Area (km ²)
GULF OF MAINE - - - - -		61,370
Fishing Banks	26, 27	5,948
Central Gulf	28-30, 36-40	55,422
GEORGES BANK - - - - -		52,479
Northwest Part	23-25	13,634
Northern Edge	21, 22	3,012
Central Part	13, 16, 19, 20	30,969
Shelf-break	14, 15, 17, 18	4,864
SOUTHERN NEW ENGLAND - - - - -		52,009
Near-shelf	1, 5, 9	18,910
Mid-shelf	2, 6, 10	25,224
Shelf-break	3, 4, 7, 8, 11, 12	7,875
MIDDLE ATLANTIC - - - - -		43,534
Near-shelf	61, 65, 69, 73	29,937
Mid-shelf	62, 66, 70, 74	10,616
Shelf-break	63, 64, 67, 68, 71, 72, 75, 76	2,981

species were computed by season and region. Species that control a major portion of community energy flow usually have high abundances and biomass. It is of value to determine normal patterns of species dominance on a seasonal and annual basis to monitor changes in an ecosystem. Changes in normal dominance patterns within an ecosystem because of unusual environmental perturbations may entail a total shift of a community, both qualitatively and quantitatively (Ward 1978).

A pattern of a few common species with large numbers of individuals associated with many rare species with few individuals is characteristic of most community structures. However, the quantitative species abundance relationships can vary widely (Odum 1971). Species diversity indices are useful in monitoring a bird community. Environmental stress will tend to decrease the number of rare species and increase the importance of dominant ones, or cause a total shift in the dominance pattern.

Several species diversity indices were computed for each region and season. The two principal indices are the Shannon-Weaver species diversity index ($\bar{H}$) (Shannon and Weaver 1949) and Simpson's index (λ) (Simpson 1949). Both indices examine heterogeneity; however, the Shannon-Weaver index is most sensitive to changes in the rarest species, while Simpson's index is most sensitive to changes in the importance of the most abundant species (Peet 1974). Other diversity indices included in the analysis are total number of species (n) and an evenness index (E)

(Buzas and Gibson 1969) which were also computed for each region

and season. The formulas used for derivation of all indices are listed in Appendix 1.

Measurements of species diversity require that all individuals be identified to species. Therefore, certain procedures were developed to eliminate unidentified bird categories (e.g. unidentified murre, unidentified large gull) and assign their numbers to respective species which potentially make up those categories and were recorded in that region and season. The numerical proportion of each species verified in an unidentified category was calculated. Based upon these numerical proportions and the total number of birds recorded in a given unidentified category, unidentified birds were apportioned to each identified category in whole birds. No unidentified individuals were assigned to a species unless that species was positively recorded during that season and region. In this way, species richness was always conservatively determined and species heterogeneity was assigned in accordance with observed species abundances.

3. Comparison of Census Techniques.

Methods of counting birds at sea have varied among investigators on a global scale. Two methods have evolved in recent decades. Essentially, these methods provide indices of relative abundance (e.g. number of birds seen per unit of time or distance traveled) and relative density (e.g. number of birds per unit area). In this section we intend to augment existing knowledge on problems of censusing marine birds at sea by comparing these two methods.

Bias due to observer differences, length of counting period, and presence of fishing activity on the survey platform is discussed by counting method. Seven bird species and two species groups which are seasonally abundant to common in the western North Atlantic are examined: Northern Fulmar, Cory's Shearwater, Greater Shearwater, Wilson's Storm-Petrel, Gannet, Red Phalarope, Great Black-backed and Herring Gulls (large gulls), Black-legged Kittiwake, and Razor-bill and murres (large alcids).

Paired density and abundance estimates, using experienced observers, were recorded in two cruises. Differences and variability between observers (in both density and abundance estimates for standard 10 minute counting periods and density estimates with an additional 5 minutes of observation) are examined using a paired t-test.

Density and abundance estimates of each bird species recorded when the survey vessel was fishing (i.e. groundfish trawl surveys) are compared with those estimates from nonfishing survey platforms (i.e. other research cruises and law enforcement patrols) for significant differences using Fisher's exact test (Siegel 1956). Using the percentage of the abundance estimate composed of recounts for each cruise, the number of cruises for each species is grouped by survey platform in which fishing activity is present or absent. The number of cruises are considered in relation to the overall mean recount percentage for that species, which is computed from all cruises. The number of cruises, which are grouped by the presence or absence of fishing activity, are compared in a 2 x 2 contingency table for significant differences.

Mean density estimates are grouped by values from fishing or nonfishing cruises. Similar to the previous recount percentage, mean density values are considered in relation to the overall mean density for that species computed from all cruises. The number of cruises, which are grouped by the presence or absence of fishing activity, are compared in a 2 x 2 contingency table for significant differences.

The association of density and abundance estimates from each counting method for selected bird species and species group are examined using Spearman's coefficient of correlation test (Sokal and Rohlf 1969). A linear regression analysis is performed to analyze the relationship of abundance estimates to density values for fulmars, Greater Shearwaters, Black-legged Kittiwakes, and murre. Slopes of the regression equations are examined in relation to behavioral differences between species which affect the initial detection of individual birds by the observer.

4. Feeding Habits

The feeding habits of 10 marine bird species are examined using stomach contents analysis. Those species included in the analysis are fulmar, Cory's Shearwater, Greater Shearwater, Sooty Shearwater, Wilson's Storm-Petrel, Pomarine Jaeger, skua, Great Black-backed Gull, Herring Gull, and Black-legged Kittiwake. Except for the jaeger and skua, all species are abundant to common in the study area during part of the year.

The majority of bird stomachs were collected from two cruises dedicated to the feeding ecology of marine birds on Georges Bank

and adjacent waters. These cruises were sponsored by the USSR AtlantNIRO Laboratory and NMFS (NEFC) on USSR RV ALIOT in August 1978 and 1979. Other collections were made from ships-of-opportunity which allowed some ship time for an MBO observer to disembark on a launch from the survey vessel. The Peoples Republic of Poland (PRP) and U. S. Coast Guard cooperated in this effort aboard the PRP RV WIECZNO (November 1979) and CGC VIGILANT (April and June 1978). All samples from CGC VIGILANT were collected within areas of intensive foreign fishing activity.

Contents from stomachs collected on RV ALIOT were separated by food items at the AtlantNIRO Laboratory in Kaliningrad, U.S.S.R. The food items were counted, weighed and identified to the most accurate taxonomic level possible. Results from stomach contents collected in August 1979 have not yet been received by MBO and are not included in this report.

Contents of stomachs collected in RV WIECZNO and CGC VIGILANT were sorted and analyzed at MBO. Food items were separated by stomach. The number of similar food items were counted and measured by length (mm), if whole, and displaced volume (ml).

A breakdown of the results from the analysis includes: bird species, frequency of occurrence and volume of prey item and prey item groups (e.g. fish, squid, euphausiids). Empty stomachs are not included in the analysis. Since volumes of prey items were not recorded with the Russian analyzed samples, we assumed that wet weight (g) was equivalent to displaced volume (ml). We feel that this assumption is valid because fleshy food items are saturated with liquid (water and formalin) during the analysis.

RESULTS AND DISCUSSION

1. Sampling Effort

a. Ships-of-opportunity and Utilization of Volunteers

Ships-of-opportunity represented the principal survey platform. Ships-of-opportunity refer to vessels which were expected to be transiting or working the study area and which made available a berth for an MBO observer. During these cruises the observers had little, if any, opportunity to determine cruise tracks. Except for two cruises, all observations were conducted from ships-of-opportunity. In August 1978 and 1979 cruises dedicated to the feeding ecology of marine birds on Georges Bank were made aboard the USSR RV ALIOT. The PI (Powers) was the Chief Scientist and MBO/DOE staff were members of the scientific crew. These cruises were performed at no additional expense to the contract and represented a cooperative research plan among the AtlantNIRO Laboratory in the USSR, NMFS (NEFC), and MBO.

In 1979 we attempted to conduct aerial surveys from available U. S. Coast Guard offshore law enforcement flights to Georges Bank and the Gulf of Maine (from Otis Air Force Base on Cape Cod) on an opportunistic basis. This survey method was used principally to appraise the shipboard results in determining spatial distribution and abundance. Although we found aircraft to be useful in locating large concentrations of marine birds and their association with fishing activity, we abandoned use of the Coast Guard flights. The flights were made at altitudes (150-210m) which usually exceeded maximum limits of detectability

for several bird species (e.g. alcids and storm-petrels). Location, altitude, heading, and air speed data were often not available during the flights, plus we did not usually have an observer available to assign to these flights, when the Coast Guard and weather permitted. A more detailed discussion was provided in the DOE Annual Progress Report, October 1979.

The availability of ships-of-opportunity throughout the year was usually not a problem except for January. Foreign and domestic research cruises sponsored through NOAA/NMFS and off-shore law enforcement patrols by the U. S. Coast Guard were the principal source of platforms used in this study (Table 2).

Foreign countries which sponsored MBO observers included: the Union of Soviet Socialists' Republics (USSR), People's Republic of Poland (PRP), Federal Republic of Germany (FRG), and Canada. We preferred oceanographic research vessels because: (1) their cruise tracks were more predictable and systematic; and (2) they often provided detailed background data on biological and physical oceanographic variables (e.g. vertical temperature profiles from expendable bathythermographs, neuston tows, groundfish trawls). The U. S. Coast Guard patrols often spent a considerable amount of time within limited areas of fishing activity and could not provide detailed oceanographic measurements.

The use of trained volunteers allowed a substantial increase in sampling effort and coverage without additional funds for salaries in the contract. Table 3 indicates a comparison of the number of cruises and man-days at sea made by MBO/DOE

Table 2. List of the number of cruises utilized in sampling effort from 1978 - 1980 by cooperating agencies.

	1978	1979	1980
NOAA/NMFS			
Domestic vessels	10	13	1
Foreign vessels	6	8	4
U.S. Coast Guard	11	12	1
Woods Hole Oceanographic Institution		3	
Other	1	3	

Table 3. A comparison of the number of cruises and man-days at sea made by MBO/DOE staff and volunteer observers from January 1978 to April 1980.

	1978	1979	1980
Total number of cruises	28	39	6
MBO/DOE staff	17	18	3
Volunteers	9	21	3
Total man-days at sea	362	552	80
MBO/DOE staff (3)	252 (70%)	268 (49%)	49 (61%)
Volunteers (8)	110 (30%)	284 (51%)	31 (39%)

staff and by volunteer observers in 1978-1980. Considering the MBO/DOE staff alone, we were able to make 17-18 cruises per year at an average of 260 man-days at sea per year. However, with the use of trained volunteers, we were able to increase the number of man-days at sea by 30-51 percent with similar increases in sampling. Without this volunteer effort seasonal coverage in the Middle Atlantic region would not have been possible in 1979.

b. Quantitative Analysis by Region

From approximately 4,125 transects, 3830.6 km² were sampled in four general geographic regions from Cape Hatteras to the Bay of Fundy during the period from January 1978 to July 1979. A seasonal breakdown of area surveyed (km²) is presented by region and subregion in Table 4. Additional data collected from August 1979 to April 1980 were not keypunched and verified by September 1980. These data include further sampling in summer 1979, and coverage in fall 1979 and winter and spring 1980. Quantitative results during those seasons are not included in this report, but will be analyzed by December 1980.

In 1978 data were collected monthly in the Gulf of Maine, Georges Bank and Southern New England regions. In 1979, monthly coverage included the Middle Atlantic region (Table 4). The unpredictable nature of cruise tracks using ships-of-opportunity, late changes in sailing orders, and unfavorable observing conditions because of poor weather were factors which contributed to an uneven distribution of effort within these regions. To minimize inflationary bias in density estimates, because of

Table 4. Seasonal sampling effort (km² surveyed) by region and subregion, January 1978 to July 1979.

REGION and Subregion	AREA SAMPLED (Km ²)											
	Winter (Dec-Feb)			Spring (Mar-May)			Summer (Jun-Aug)			Fall (Sep-Nov)		
	1978	1979	Total	1978	1979	Total	1978	1979	Total	1978	1979	Total
GULF OF MAINE			214.1			197.2			213.5			117.9
Fishing Banks	30.0	55.1	85.1	20.2	7.1	27.3	54.4	-	54.4	31.1	-	31.1
Central Gulf	47.7	81.3	129.0	122.3	47.6	169.9	143.3	15.8	159.1	86.8	-	86.8
GEORGES BANK			245.5			458.8			372.2			409.3
Northwest Part	49.7	47.0	96.7	61.3	63.2	124.5	119.8	28.1	147.9	147.5	-	147.5
Northern Edge	2.5	15.3	17.8	11.5	19.0	30.5	25.7	0.9	26.6	44.6	-	44.6
Central Part	21.9	97.0	118.9	111.8	145.3	257.1	129.8	42.2	172.0	194.2	-	194.2
Shelf-break	4.9	7.2	12.1	43.3	3.4	46.7	19.2	6.5	25.7	23.0	-	23.0
SOUTHERN NEW ENGLAND.....			165.5			429.9			375.5			134.4
Near-shelf	15.1	33.1	48.2	31.3	131.8	163.1	75.0	47.6	122.6	75.6	-	75.6
Mid-shelf	19.6	52.4	72.0	41.1	159.4	198.5	129.0	63.5	192.5	46.0	-	46.0
Shelf-break	38.0	7.3	45.3	21.6	46.7	68.3	46.8	13.6	60.4	12.8	-	12.8
MIDDLE ATLANTIC			15.9			203.3			262.5			15.1
Near-shelf	0.9	10.1	11.0	4.5	117.7	122.2	91.4	79.1	170.5	2.3	-	2.3
Mid-shelf	1.7	2.3	4.0	0	56.6	56.6	37.4	36.8	74.2	8.8	-	8.8
Shelf-break	0.9	0	0.9	0	24.5	24.5	6.2	11.6	17.8	4.0	-	4.0

clumped or heterogeneous bird distribution patterns and a non-uniform distribution of sampling effort, the general regions were divided into subregions (cf. METHODS Part 2a. Stratification).

Seasonal sampling effort between years was pooled to obtain a more uniform distribution of coverage between regions. The seasons correspond to major changes in bird species composition and abundance. By combining the effort in this manner, we described and compared changes in species dominance patterns (numerical and biomass) within the bird community by region and season. Effort during each month was used to compute monthly density values of each bird species, so that more precise changes in temporal distribution patterns could be discerned. We suspect considerable annual variation in bird distribution and abundance patterns. Further quantitative analysis of the entire MBO data base (1976-1980) and more complete annual sampling among regions and seasons are needed. However, qualitative comments on annual variability within each species are mentioned, when applicable, in the Species Accounts and Distribution sections of this report.

The sampling effort in the Gulf of Maine, Georges Bank, and Southern New England regions was adequate to describe seasonal distribution patterns; but coverage in the Middle Atlantic region, as presented for fall and winter seasons, was poor. Only 31 km² for both seasons were sampled (Table 4). Therefore, the analysis of species dominance and diversity patterns for these seasons in the Middle Atlantic region is limited by a lack of

adequate sampling. The species accounts include more qualitative descriptions and evidence from the literature in discussions of temporal distribution during fall and winter in the Middle Atlantic region.

2. Comparison of Census Techniques

a. Paired Observations

Paired observations provide a meaningful comparison to examine differences in data collection between observers because counts are made under the same field conditions. Results from three sets of paired analyses are listed in Table 5. Data were collected on two oceanographic cruises (zooplankton surveys) to the Georges Bank and Gulf of Maine areas off the New England coast in 1979: RV ALIOT, 15-30 August and RV WIECZNO, 13-21 November. No significant differences were found between density and abundance estimates from experienced observers. Densities estimated with five additional minutes of observation were comparable to estimates from standard 10-minute transects (Table 5). However, considerable variance was noted in estimates of Wilson's Storm-Petrels and Great Black-backed and Herring Gulls.

The greatest mean difference ($\bar{d}$) and variance (s_d^2) between observers were found with Wilson's Storm-Petrels on the RV ALIOT cruise (Table 5). These data compared only density estimates (birds/km²) for 10 and 15 minute counts using two different observers. The relative inconspicuousness of this species and observer differences in ability to estimate numbers of birds contributed to the mean difference in density estimates per

TABLE 5. Species comparison of differences between observer estimates of bird density (birds/km²) and abundance (birds/10 minutes) from paired observations made at sea, 15-30 August 1979 on USSR RV ALIOT and 13-21 November 1979 on PRP RV WIECZNO.

Bird Species	<u>Mean observer difference (D)</u>		<u>Standard deviation (SD)</u>		<u>Maximum estimate</u>	
	Density	Abundance	Density	Abundance	Density	Abundance
Wilson's Storm-Petrel	11.13		74.20		1600	
Large gulls ¹	3.84	9.96	51.29	41.69	893	911
Northern Fulmar	2.54	5.17	17.11	21.33	102	177
Black-legged Kittiwake	1.14	1.68	14.24	9.33	52	118
Greater Shearwater	0.97	0.88	10.56	9.75	69	68
Gannet	0.81	0.59	6.45	6.71	49	50
Greater Shearwater	0.63		5.29		36	
Cory's Shearwater	0.27		3.07		32	

¹Large gulls = Great Black-backed and Herring Gull

transect ($\bar{d} = 11.1$ birds/km²) and large variance ($s_d^2 = 5506$ birds/km²). The observer who recorded observations in 10 minute periods also recorded outside fixed-area zone birds and recounts. The observer who recorded observations in 15 minute periods was only responsible for fixed-area zone birds. The former observer, who maintained observation in three zones, recorded more storm-petrels in the fixed-area zone in 58 percent of the transects. The latter observer, who maintained observation in only one zone, recorded more storm-petrels in 30 percent of the transects.

Although one observer consistently recorded more storm-petrels, the differences in estimates were greatest when densities exceeded 10 birds/km². In two transects where the density estimate by an observer exceeded 100 birds/km², the observer recording observations in 10 minute periods counted 40 and 200 more storm-petrels than that observer recording observations for five additional minutes. Prater (1979) found that the least experienced bird counters had largest underestimates when bird numbers were highest, and that more experience significantly reduced that bias. Although the observer who recorded lower estimates of storm-petrels in higher density areas in this study had considerable experience at sea, he had no training in counting birds.

Ship-following behaviors contributed to the large variance in estimates of density and abundance for large gulls (Great Black-backed and Herring Gulls) in the RV WIECZNO data (Table 5). The mean difference ($\bar{d}$) between observers in counts of

large gulls per transect was 3.8 birds ($s_d^2 = 2601$) with the density estimator and 9.9 birds ($s_d^2 = 1764$) with the abundance estimator (Table 5). Chronic ship-following by large gulls created numerous problems in the observers' attempts to sort initial ship-followers from recounts. Conflicts in observer judgements to include or exclude large gulls from the fixed-area zone count occurred in 36 percent of the transects. Although ship-followers were not always in sight of the survey vessel, confusion arose because they were generally suspected of being in the immediate vicinity of the ship. This judgement problem in separating initial ship-followers from recounts was also noted with Northern Fulmars in three transects.

Dissimilar estimates of bird numbers between observers in high density areas were important factors contributing to large variances in density and abundance estimates of all species sampled in the RV WIECZNO cruise (Table 5). Variability between observers in counting numbers of birds was exemplified in data from one transect, which included a fishing vessel and attendant flock of birds in the fixed-area zone. Although abundance counts by the observers were similar for large gulls (800 and 900), the density counts were different (600 and 900) for the same species. Differences in the counts for both density and abundance estimates of other species recorded in this transect were striking. Fixed-area zone counts for each observer were respectively 15 and 100 for fulmars, 10 and 50 for Greater Shearwaters, 18 and 50 for Gannets, and 5 and 50 for Black-legged

Kittiwakes. Neither observer recorded any of these species in the outside fixed-area zone. Whereas the former observer counted individual birds for most species, the latter observer apparently estimated numbers for all species. The latter observer had considerable experience at sea, but generally where bird densities averaged less than 10 birds/km². This transect was his initial experience with densities greater than 100 birds/km².

Although a standardized rangefinder was used (Heinemann, unpubl. ms.) to determine transect boundaries for the density estimator, conflicts between observers in judgements to include or exclude birds from the fixed-area zone were found. Seven conflicts with flying birds and two disputes with sitting birds were identified in those transects analyzed in Tables 2 and 3. These conflicts indicated that distance judgements are not always straightforward even with a rangefinder and observers experienced with its use. The degree of bias, between observers, introduced by differences in judging distances could not be determined, but we would expect it to increase in proportion to density.

Differences in observer conditions at sea plus size, color, and number of individuals greatly influence the detectability of birds. A standardized rangefinder used to determine the boundaries of the fixed-area zone minimizes these differences in observer conditions. The lack of an effective visibility range within which an observer can confidently detect and identify most individual birds during the counting period introduces a bias in the abundance estimator. Flocks of birds are visible

at greater distances than individuals; and the species composition of distant flocks is a problem.

b. Bias from Fishing Activity

Abundance estimates of several ship-follower species were biased when the survey vessel was fishing. Significantly larger proportions of abundance estimates from fishing vessels consisted of recounts for Northern Fulmars ($P < .01$), Greater Shearwaters ($P < .05$), and Black-legged Kittiwakes ($P < .05$) than similar estimates of those species from vessels not fishing (Table 6). These species were usually found in greatest abundance in fishing areas. Wahl and Heinemann (1979) found a significant degree of co-occurrence in relative abundances of fulmars and kittiwakes with fishing vessels off the coast of Washington, because of their attraction to discards made available by the fishing activity.

The overall mean percent of recounts in abundance estimates of large gulls was two times greater than that of any other species considered (Table 6), but no significant difference between large gull estimates derived from fishing and nonfishing vessels was found. The influence of fishing activities on the pelagic distribution of large gulls was apparent in cruises made in this study. Watson (1978) and Wahl and Heinemann (1979) found that Herring Gulls were attracted to fishing vessels for food. The influence of fishing activity on large gulls was partly responsible for the lack of power in the statistical test used. The outside fixed-area zone count made up an average of 70 percent of the abundance estimate in four nonfishing cruises. These cruises

TABLE 6. The overall mean percent of relative abundance (birds seen per 10 minutes) estimates composed of recounts for each species and the frequency of cruises in which the recount percent for each cruise was above or below the overall mean for each species examined. Probability of significant differences between groups is indicated.

Species	Overall mean percent recounts ($\bar{X}$)	Number of fishing cruises		Number of nonfishing cruises		Probability of significance (P)
		$\geq \bar{X}$	$< \bar{X}$	$\geq \bar{X}$	$< \bar{X}$	
Large gulls ¹	29.21	4	3	3	9	0.15
Northern Fulmar	15.60	5	1	0	9	0.01**
Black-legged Kittiwake	13.00	2	0	0	6	0.04*
Gannet	8.00	3	3	0	3	0.24
Greater Shearwater	7.50	2	0	0	6	0.04*
Wilson's Storm-Petrel	1.80	0	2	4	0	0.07
Cory's Shearwater	1.50	1	1	0	3	0.40
Red Phalarope	0	(n=5)				
Large auks ²	0	(n=7)				

¹Large gulls = Great black-backed and Herring Gull

²Large auks = Razorbill and murres

*Probability is significant ($p < .05$)

**Probability is highly significant ($p < .01$)

were U. S. Coast Guard patrols with objectives of seeking and identifying fishing vessels. High counts of large gulls attending fishing vessels recorded on the Coast Guard patrols greatly reduced the percentage of the abundance estimate usually comprised by recounts.

Gannets were attracted to vessels with fishing activity, but they generally did not linger long enough to be considered recounts in significant proportions. The percentage of recounts in the abundance estimate for Gannets in the presence of fishing activity was higher than that percentage recorded for each cruise in the absence of fishing with one exception. However, the mean percentage of recounts recorded for Gannets when fishing activity was present was usually below the overall mean computed from all cruises (Table 6).

Cory's Shearwaters and Wilson's Storm-Petrels were recorded as ship-followers, but this behavior was not a problem in the abundance estimator. The greatest abundances of these species were not found in association with fishing activities.

Red Phalaropes and large auks were never recorded as ship-followers. The accuracy of abundance estimates of these species was probably more dependent upon observer conditions, fatigue, and ability to estimate flock sizes.

No significant difference between density estimates derived from vessels fishing vs. not fishing was found with any species examined (Table 7). The density estimator reduced bias from recounts by its tendency to exclude them from the fixed-area zone. Although a fishing vessel may attract certain species,

TABLE 7. The overall mean density (birds/km²) estimates for each species and the frequency of cruises in which the mean density per cruise was above or below the overall mean for each species examined. Probability of significant differences between groups is indicated.

Species	Overall mean density ($\bar{X}$)	Number of fishing cruises		Number of nonfishing cruises		Probability of significance (P)
		$> \bar{X}$	$< \bar{X}$	$> \bar{X}$	$< \bar{X}$	
Red Phalarope	46.41	1	1	1	2	0.60
Northern Fulmar	17.26	3	3	1	7	0.16
Black-legged Kittiwake	11.28	1	1	2	4	0.54
Large gulls ¹	9.91	5	2	3	9	0.06
Greater Shearwater	9.69	1	1	2	4	0.54
Wilson's Storm-Petrel	8.20	0	2	3	1	0.20
Cory's Shearwater	5.48	1	1	2	1	0.60
Large auks ²	3.98	0	2	4	1	0.14
Gannet	2.42	1	5	2	1	0.21

¹Large gulls = Great Black-backed and Herring Gull

²Large auks = razorbill and murres

density estimates of these species were apparently not significantly biased by chronic ship-following. However, neither census method could adequately sample the abundance of large gulls because of their propensity to ship-follow in all environmental conditions.

c. Correlation and Linear Regression

The previous discussion dealt with biases inherent within each counting method. In this section we examine qualitative and quantitative relationships between the estimators. A significant numerical relationship was established between abundance and density estimates, so that values recorded from one method could be transformed into estimates comparable with the other method.

Highly significant associations were found between density and abundance estimates of all species and species groups tested, except for large gulls on one cruise. The relative ranking of density and abundance estimates of Northern Fulmars, Greater Shearwaters, Gannets, kittiwakes, large auks, and large gulls indicated that both estimators correlated in high and low density areas.

Correlation coefficients (r_s) for large gulls were the lowest of all species tested in each cruise. The density and abundance estimates of large gulls collected during one cruise on an oceanographic research vessel were not associated ($r_s = 0.26$, $df = 86$). Chronic ship-following of Great Black-backed and Herring Gulls caused differences in the relative ranking of density and abundance estimates by transect in that cruise. Zero density values

of large gulls were recorded in 25 transects, but abundance estimates ranged from 1-165 large gulls per 10 minutes for the same transects. These gulls were invariably ship-following re-counts.

Having established a qualitative association between the counting methods for most species with a nonparametric correlation test, a linear regression analysis was performed to predict abundance estimates from density values. Species data from four cruises were used to develop line equations for fulmars, Greater Shearwaters, kittiwakes, murres, and large auks (Razorbills and murres). Large gulls were not used in this analysis because of the censusing problems discussed earlier.

The total count of each species should be at least twice as great as the fixed-area zone count; certain assumptions predicate this statement.

1. Birds are randomly distributed.
2. All birds within 300m to each side of the vessel are equally detectable by the observer.
3. Birds are stationary or not flying.

Gates (1969), Kovner and Patil (1974), Robinette et al. (1974), Myrberget (1976) discussed these assumptions in line transect methodology.

Results of the linear regression analyses are indicated in Table 8. Two types of regression models appear to emerge when bird movement is considered. Figure 5 is an example of a Type I regression model for birds which are apt to be in flight when initially detected by the observer. Fulmars, shearwaters and

Table 8. Results from linear regression analyses to predict abundance estimates (birds/10 minutes) from density (birds/km²) values for bird species by cruise.

Bird Species	Slope (m)	Correlation Coefficient (r)	Y-intercept (b)	Degrees of freedom (df)
Northern Fulmar	1.50	0.95	1.85	62
Greater Shearwater	1.23	0.55	27.81	154
Greater Shearwater	0.72	0.85	1.84	60
Black-legged Kittiwake	1.73	0.96	-4.82	69
Black-legged Kittiwake	1.56	0.45	1.86	39
Murres ¹	2.54	0.79	-5.67	148
Large auks ²	1.4	0.86	0.87	25

¹Murres = *Uria* spp.

²Large auks = Razorbill (*Alca torda*)

Figure 5. Example of a Type I Regression Model (flying birds)

kittiwakes are examples of Type I birds. Figure 6 is an example of a regression model for birds which are typically detected sitting on the water. Alcids are examples of Type II birds.

Regression lines for Type I birds had slopes which ranged from approximately 1.2 to 1.7. These values were found with fulmars, Greater Shearwaters, kittiwakes and large auks (Table 8). In each case these species were generally detected by the observer when flying. The large auk example was probably atypical. Storm conditions prevalent during that cruise caused the birds to be in flight. Slow ship speeds account for the low slope value ($m = 0.7$) found with Greater Shearwaters in one cruise (Table 8). Although the shearwaters were detected in flight, most of the transects were conducted at minimum ship speeds of 4 - 5 kts. Density values in these transects were greater than abundance values because a smaller area (e.g. 0.37 km² at 4 kts) was sampled in the fixed-area zone. Ship speed was not factored in the total count estimate. Generally, transects were conducted at ship speeds of 9 - 11 kts.

Slopes of regression lines in Type I birds were below the expected value of at least 2.0. That is, at least two individuals in the total count should be recorded for each fixed-area zone bird, if the line transect assumptions were met. The assumption that the sampling objects are stationary was obviously fallacious as the birds were flying. Individual flying birds could be counted on both sides of the vessel. Wiens et al. (1978) considered bird movement the most serious source of error

Figure 6. Example of a Type II Regression Model (sitting birds)

in density estimation of birds at sea using line transect methodology. They attempted to reduce bias from bird movement by measuring radial angles and distances to individual birds at the initial point of observer detection. Gould (in preparation) used a series of periodic "instantaneous" counts within a transect to prevent exaggerated densities. Therefore, a regression line slope below 2.0 is reasonable because of bird movement. A density/abundance relationship between 1.0 and 2.0 may account for birds seen beyond the 300m fixed-area zone boundary.

The regression line for the Type II bird had a slope greater than or equal to 2.0 because bird movement was generally not a problem with this species. Detectability of birds within 300m to either side of the ship was equal, if sun glare and wind were not a problem on any given side of the vessel. Chances of counting the same individual bird on both sides of the ship were small, unless that bird flushed off the water.

An example of a Type II regression line is presented in Figure 6. The figure was based on murre data collected from a cruise in Canadian Atlantic and low arctic waters. Murres were abundant during the cruise and were generally detected while sitting. A slope value greater than 2.0 probably accounts for birds seen beyond the 300m fixed-area zone boundary.

3. Species Accounts (Spatial and Temporal Distribution)

Fifty-six species of coastal and marine birds were recorded in coastal, shelf and oceanic waters from Cape Hatteras (c. 35°N latitude) north to the Bay of Fundy (c. 44°N latitude) and from the

coastline east to 65°W longitude (Fig. 1). Bird species were placed in one of three categories which characterized their status within the area of interest. The categories are based upon the seasonal distribution and abundance of each species in shelf and shelf-break waters.

The status of each species within the described categories was determined from computer-generated plots of distribution and abundance. Average density values for each species were plotted for each 10°N latitude by 10°W longitude block surveyed for each month of the year. Although all species recorded during the study are considered in this report, the data analysis is incomplete in several respects. Computerized monthly distribution plots were available for most species only from January 1978 to July 1979 and no plots of 12 nonabundant or uncommon species were available before this report was submitted (cf. DATA MANAGEMENT). The basis for determination of each category is described below.

(a) Abundant and Common Species. Species in which average density values greater than 10 birds/km² were recorded in at least three blocks of 10°N latitude and 10°W longitude during any month of the year. These species were the dominant members of the avian community.

(b) Nonabundant or Uncommon Species. Species in which density values were recorded in at least three blocks of 10°N latitude and 10°W longitude during any month of the year, but whose values did not meet the minimum requirements of common and abundant species category. These species were seasonally predictable within the study area, but they were present in low numbers.

(c) Rare Species. Species in which at least one sighting was recorded during the study, but density values did not meet minimum requirements of the other categories. The seasonal occurrence of these species within shelf and shelf-break waters of the study area was either accidental or nonpredictable.

A list of species for each distribution and abundance category is presented in Table 9. The species accounts provide a spatial distribution map, temporal distribution bar graph, and discussion of seasonal changes in distribution and areas of concentration for species in abundant and common, and nonabundant or uncommon categories. In order to stress those areas where abundant and common species achieve that status, the distribution maps of those species indicate density values in excess of 10 birds/km² only. Selected rare bird species sightings from January 1978 to April 1980 are listed in Appendix 2.

Table 9. List of species according to distribution and abundance categories for shelf and shelf-break waters in the north-eastern U.S. from 36°N to 44°N latitude.

Abundant and Common Species (10 spp.)

Northern Fulmar	(<i>Fulmarus glacialis</i>)
Cory's Shearwater	(<i>Puffinus diomedea</i>)
Greater Shearwater	(<i>Puffinus gravis</i>)
Sooty Shearwater	(<i>Puffinus griseus</i>)
Wilson's Storm-Petrel	(<i>Oceanites oceanicus</i>)
Gannet	(<i>Morus bassanus</i>)
Red Phalarope	(<i>Phalaropus fulicarius</i>)
Great Black-backed Gull	(<i>Larus marinus</i>)
Herring Gull	(<i>Larus argentatus</i>)
Black-legged Kittiwake	(<i>Rissa tridactyla</i>)

Nonabundant or Uncommon Species (28 spp.)

Common Loon	(<i>Gavia immer</i>)
Red-throated Loon	(<i>Gavia stellata</i>)
Great Cormorant	(<i>Phalacrocorax carbo</i>)
Double-crested Cormorant	(<i>Phalacrocorax auritus</i>)
Black-capped Petrel	(<i>Pterodroma hasitata</i>)
Manx Shearwater	(<i>Puffinus puffinus</i>)
Audubon's Shearwater	(<i>Puffinus lherminieri</i>)
Leach's Storm-Petrel	(<i>Oceanodroma leucorhoa</i>)
Northern Phalarope	(<i>Lobipes lobatus</i>)
Pomarine Jaeger	(<i>Stercorarius pomarinus</i>)
Parasitic Jaeger	(<i>Stercorarius parasiticus</i>)
Great Skua	(<i>Catharacta skua</i>)
South Polar Skua	(<i>Catharacta maccormicki</i>)

Table 9. (continued)

Nonabundant or Uncommon Species (continued)

Glaucous Gull	(<i>Larus hyperboreus</i>)
Iceland Gull	(<i>Larus glaucoides</i>)
Ring-billed Gull	(<i>Larus delawarensis</i>)
Laughing Gull	(<i>Larus atricilla</i>)
Bonaparte's Gull	(<i>Larus philadelphia</i>)
Royal Tern	(<i>Sterna maxima</i>)
Arctic Tern	(<i>Sterna paradisaea</i>)
Common Tern	(<i>Sterna hirundo</i>)
Bridled Tern	(<i>Sterna anaethetus</i>)
Least Tern	(<i>Sterna albifrons</i>)
Razorbill	(<i>Alca torda</i>)
Common Murre	(<i>Uria aalge</i>)
Thick-billed Murre	(<i>Uria lomvia</i>)
Dovekie	(<i>Alle alle</i>)
Common Puffin	(<i>Fratercula arctica</i>)
<u>Rare Species</u> (18 spp.)	
Albatrosses	(<i>Diomedea</i> sp.)
White-faced Storm-Petrel	(<i>Pelagodroma marina</i>)
White-tailed Tropicbird	(<i>Phaethon lepturus</i>)
Common Eider	(<i>Somateria mollissima</i>)
Oldsquaw	(<i>Clangula hyemalis</i>)
Black Scoter	(<i>Melanitta nigra</i>)
White-winged Scoter	(<i>Melanitta deglandi</i>)
Surf Scoter	(<i>Melanitta perspicillata</i>)
Red-breasted Merganser	(<i>Mergus serrator</i>)

Table 9. (continued)

Rare Species (continued)

Long-tailed Jaeger	(<i>Stercorarius longicaudus</i>)
Lesser Black-backed Gull	(<i>Larus fuscus</i>)
Little Gull	(<i>Larus minutus</i>)
Sabine's Gull	(<i>Xema sabini</i>)
Roseate Tern	(<i>Sterna dougallii</i>)
Sooty Tern	(<i>Sterna fuscata</i>)
Sandwich Tern	(<i>Sterna sandvicensis</i>)
Black Tern	(<i>Chlidonias niger</i>)
Black Guillemot	(<i>Cepphus grylle</i>)

Abundant and Common Species

Northern Fulmar

Fulmarus glacialis

Fulmars were present in each month of the year, except August (Fig. 7). Fulmars were found in all regions during winter and early spring when their densities were highest. Greatest densities (> 100 birds/km²) were found in the Georges Bank and Gulf of Maine regions.

Fulmars were often associated with fishing activities but their distribution was also suspected to be influenced by oceanic fronts in the northern and eastern parts of Georges Bank. Fulmar concentrations (1000 birds per sighting) were found on the northeast peak of Georges Bank in mid- and late-winter of 1977, 1979, and 1980.

Figure 7. Spatial and temporal distribution of Northern Fulmar.

Abundant and Common Species

Cory's Shearwater

Puffinus diomedea

Cory's Shearwaters were present from May to November (Fig. 8). The peak of density occurred in July and August. Their distribution was usually local and was generally limited to subtropical waters found in Middle Atlantic and Southern New England regions. Cory's Shearwater generally did not associate with fishing activities.

In summer and fall of 1979 Cory's Shearwaters were commonly observed throughout Georges Bank and well into the Gulf of Maine. We considered this distribution anomalous based upon our previous findings in 1976-1978. Individuals of this species which are recorded in the study are probably prebreeders, since their presence in U. S. shelf waters coincides with the known breeding season in the eastern North Atlantic (Cramp 1977). All specimens of Cory's Shearwaters collected in this study were identified to the subspecies *P. d. borealis*, which breeds in the Azores and Canary Islands (Palmer 1962, Cramp 1977).

Figure 8. Spatial and temporal distribution of Cory's Shearwater.

Abundant and Common Species

Greater Shearwater

Puffinus gravis

Greater Shearwaters arrive en masse into the study area during the last week of May or first week of June. They remain prevalent until December. Greater Shearwaters are most abundant in the Georges Bank, Gulf of Maine and eastern parts of the Southern New England regions during summer and fall (Fig. 9). There appears to be a bimodal peak in their abundance, which occurs in June-July and again in October. During August and September the birds may move into the Bay of Fundy to capitalize on daytime surfacing euphausiid swarms (Brown et al. 1979). The October peak probably constitutes nonbreeding birds which are staging on Georges Bank before their fall migration to the South Atlantic (cf. Powers and Van Os 1979).

Greater Shearwaters often associate with fishing vessels. The presence and timing of large-scale fishing activities (i.e. foreign fleets) on Georges Bank may influence their distribution during summer months within the study area. Greater Shearwaters are attracted to the fishing vessels as an available food resource. If fishing fleets are present on the Bank in late May-early June, they may attract large numbers of Greater Shearwaters which would have only briefly passed through the area.

Figure 9. Spatial and temporal distribution of Greater Shearwater.

Abundant and Common Species

Sooty Shearwater

Puffinus griseus

Sooty Shearwaters were present from April to August (Fig. 10) with an abundance peak in June. Sooty Shearwaters were recorded throughout the study area, but all significant concentrations were found in the Southern New England and Georges Bank regions.

Sooty Shearwaters were recorded in association with fishing activity. Contrary to Greater Shearwaters, there is no evidence to suggest that the presence of fishing fleets in the Georges Bank area during their spring arrival influenced any subsequent summer distribution. Sooty Shearwaters migrate along a clockwise route in the North Atlantic during summer months (Wynne-Edwards 1935).

Figure 10. Spatial and temporal distribution of Sooty Shearwater.

Abundant and Common Species

Wilson's Storm-Petrel

Oceanites oceanicus

Wilson's Storm-Petrels are present in the study area from April to October (Fig. 11). The peak in abundance occurs from May to July. The species was recorded in all regions but greatest concentrations (>100 birds/km²) were usually found in the western Gulf of Maine, Great South Channel, and edge of the continental shelf.

Wilson's Storm-Petrels follow ships, but most large concentrations were not associated with fishing activities. Oceanic fronts created by an upwelling near Nantucket Shoals and by the shelf-water/slope-water boundary at the shelf break appear to be important oceanographic factors influencing the pelagic distribution of Wilson's Storm-Petrels.

Figure 11. Spatial and temporal distribution of Wilson's Storm-Petrel.

Abundant and Common Species

Gannet

Morus bassanus

Gannets were present in each month except August and September (Fig. 12). Gannets are common in each region during spring and fall migration. Adults apparently concentrate in the Middle Atlantic Bight during winter, while most juveniles and subadults migrate further south to the Carolinas, Florida and Gulf of Mexico.

Gannets often associate with fishing vessels. Large concentrations were recorded with foreign fishing activities near Hudson Canyon in winter and early spring of 1979. Poor survey coverage in the Middle Atlantic region during winter probably underestimated the frequency of larger density values (>10 birds/km²) for this region (Fig. 12).

Figure 12. Spatial and temporal distribution of Gannet.

Abundant and Common Species

Red Phalarope

Phalaropus fulicarius

Red Phalaropes are present during spring (April-early June) and fall (September-December) migration periods (Fig. 13). Red Phalaropes were recorded in large densities (>100 birds/km²) during spring in each region, except the Gulf of Maine. Red Phalaropes were never recorded in association with fishing activity. Highest densities were usually recorded at the edge of the continental shelf during spring, where an oceanic front is prevalent at the shelf-water/slope-water boundary (Beardsley and Flagg 1976, Bumpus 1976, Wright 1976).

Fall migration of Red Phalaropes is different from spring, as considerably lower densities were recorded and there was no obvious pattern to the distribution of sightings. Since our survey coverage in the Middle Atlantic Bight during winter months was so poor, we could not comment on the frequent flock sightings of 20-80 Red Phalaropes during December in the northern Chesapeake Bight as reported by Rowlett (1980).

Figure 13. Spatial and temporal distribution of Red Phalarope.

Abundant and Common Species

Great Black-backed Gull

Larus marinus

Great Black-backed Gulls were present in all regions and seasons, except the Middle Atlantic Bight during summer. (Fig. 14). The temporal distribution of Great Black-backs at sea corresponds with their breeding phenology. They were least abundant at sea during the peak of the breeding season (May-August).

Their distribution at sea was predominantly influenced by the location of fishing fleets. Important fishing grounds of domestic and Canadian fleets at either Stellwagen Bank, Cultivator Shoals, or Northeast Peak and of foreign fleets at the edge of the continental shelf and submarine canyon areas, were also areas where the largest sightings of Great Black-backs were recorded.

Figure 14. Spatial and temporal distribution of Great Black-backed Gull.

Abundant and Common Species

Herring Gull

Larus argentatus

Herring Gulls were recorded in each region and season of the year (Fig. 15). Their temporal distribution at sea coincided with their breeding phenology. Lowest densities at sea were recorded during summer (June-September). It is not clear why lowest densities of Herring Gulls occur one month later than those months of minimum densities with Great Black-backed Gulls. However, juvenile and subadult Herring Gulls linger at sea later into summer than Great Black-backs, and juvenile Great Black-backs move out to sea earlier than hatch-year Herring Gulls.

As with Great Black-backed Gulls, the pelagic distribution of Herring Gulls is greatly influenced by the location of fishing vessels. The important domestic and foreign fishing grounds correspond to the areas of greatest Herring Gull density. Herring Gulls apparently breeding at colonies on Nantucket Island and Provincetown commute to feeding areas at the Nantucket Shoals and Stellwagen Bank fishing grounds, respectively, during summer months.

Figure 15. Spatial and temporal distribution of Herring Gull.

Abundant and Common Species

Black-legged Kittiwake

Rissa tridactyla

Black-legged Kittiwakes are present in shelf waters from September to May, but the peak in abundance occurred during winter (December to early March) (Fig. 16). In winter kittiwakes were recorded in each region, but greatest densities were found in the Georges Bank and Gulf of Maine regions.

Kittiwakes were often recorded in association with fishing activity. The greatest densities of kittiwakes were recorded near Jeffreys Ledge, Cultivator Shoals, and Northeast Peak which are important domestic and/or Canadian fishing grounds. However, large concentrations (>1000 birds per sighting) were recorded in January and February on Georges Bank. These sightings were not associated with fishing vessels.

Figure 16. Spatial and temporal distribution of Black-legged Kittiwake.

Nonabundant or Uncommon Species

Common Loon

Gavia immer

Red-throated Loon

Gavia stellata

Spatial distribution maps and temporal bar graphs were not available for these species, so this discussion is preliminary. Loons were present in shelf waters during spring and fall migration. The advent of a northward movement in spring was April and it began in the Middle Atlantic region. By late April and early May spring migration peaked in coastal and nearshore shelf waters off the New England coast. Both species were recorded traveling across the Gulf of Maine and north and west parts of Georges Bank. These birds were presumably migrating to Nova Scotia. The majority of specific loon identifications in shelf waters were Common Loons. Red-throated Loons were principally observed in coastal waters.

Fall migration of loons occurred from mid-October to early December. The distribution pattern of loon sightings was similar to spring. Although flights were noted across the Gulf of Maine, most fall sightings tended to be recorded more in coastal waters than was noted during spring.

Nonabundant or Uncommon Species

Black-capped Petrel

Pterodroma hasitata

A spatial distribution map and temporal distribution bar graph were not available during the development of this report. Black-capped Petrels were present in slope and Gulf Stream waters off Cape Hatteras in the extreme southern part of the Middle Atlantic region during late August and early September 1979. Off North Carolina, Lee and Booth (1979) considered Black-capped Petrels an uncommon offhsore resident and listed sight records from February to November. Rowlett (1980) did not indicate any observations of these gadfly petrels in the northern Chesapeake Bight. The pelagic distribution of Black-capped Petrels may be influenced by a front located at the boundary of Gulf Stream and warm slope waters, or to Gulf Stream water itself; not to any oceanographic feature of the continental shelf. Therefore, the status of this species in the designated study area needs further review.

Nonabundant or Uncommon Species

Manx Shearwater

Puffinus puffinus

Manx Shearwaters were present in the study area from May to October (Fig. 17). Observations recorded in the Sargasso Sea during March 1979 are plotted in Fig. 17, but they were not considered in the temporal distribution bar graph because they occurred in oceanic waters only. Manx Shearwaters were not recorded in the Middle Atlantic Bight. Most sightings were limited to Georges Bank. One significant concentration of at least 50 Manx Shearwaters was noted on central Georges Bank in July 1978. These birds were associated with a mixed flock of several thousand Greater and Sooty Shearwaters.

The reliability of identification of those sightings in slope waters south of Georges Bank during summer months (Fig. 17) is questionable. Brown (1977) did not indicate the presence of Manx Shearwaters in the Sargasso Sea from June to September and Rowlett (1980) considered this species a rare spring and fall transient in the northern Chesapeake Bight.

Figure 17. Spatial and temporal distribution of Manx Shearwater.

Nonabundant or Uncommon Species

Audubon's Shearwater

Puffinus herminieri

Audubon's Shearwaters were present in shelf-break waters of the Middle Atlantic, Southern New England, and Georges Bank regions during late summer and early fall (Fig. 18). This species appears to associate almost exclusively with warm slope and Gulf Stream waters. The inclusion of observations from July to September 1979 would enhance their distribution pattern indicated in Fig. 18. The occurrence of Audubon's Shearwaters on the continental shelf was always marked by an intrusion of slope water. Brown (1977) indicated that oceanic fronts at the shelf-water/slope-water and the slope-water/Gulf Stream boundaries may influence their pelagic distribution in the western North Atlantic.

Figure 18. Spatial and temporal distribution of Audubon's Shearwater.

Nonabundant or Uncommon Species

Leach's Storm-Petrel

Oceanodroma leucorhoa

Leach's Storm-Petrels were present in all regions from May to October. The greatest densities (3-10 birds/km²) were recorded in the western Scotian Shelf (e.g. Browns Bank) and in warm slope waters south of Georges Bank (Fig. 19). Individual Leach's Storm-Petrels were caught on research vessels at night as far south as Virginia (c. 37°N latitude) in July. This species is the only storm-petrel which breeds in the western North Atlantic (Palmer 1962). Linton (1978) found that myctophid fish were the most important prey item at a colony in Nova Scotia and Newfoundland during the breeding season, which suggests that the birds feed in oceanic waters seaward of the edge of the continental shelf.

Nonabundant or Uncommon Species

Northern Phalarope

Lobipes lobatus

The distribution and abundance of Northern Phalaropes in the study area coincided with their spring and fall migration (Fig. 20). The spring movement during April and May had a probable peak during the first two weeks of May. Large densities were not recorded during this study. However, MBO seabird data on Northern Phalaropes from 1976-1977 indicated a sighting of c. 1000 birds at the edge of the shelf-break south of Cape Cod on 1 May 1976 and another sighting of c. 1000 birds was made in Cape Cod Bay from the coast at Plymouth, Massachusetts (c. 42°00'N, 70°45'W) subsequent to passage of a north-east storm. In May of 1977 Northern Phalaropes were frequently recorded (1-5 birds per sighting) in coastal waters of the Gulf of Maine and Bay of Fundy. These data suggest a possible spring migration route west of Nova Scotia. This proposed route is unlike Red Phalaropes, which navigate seaward of Nova Scotia in spring.

The fall migration of Northern Phalaropes occurred in all regions during August and September. Stragglers were noted in October and December. However, we found no evidence of any significant densities moving across the study area in fall which could corroborate the spectacular fall build-up of Northerns in Passamaquoddy Bay during August-September (Brown et al. 1975, Gaskin and Smith 1979). Fall migration of both Red and Northern Phalaropes may be at high altitudes, similar to *Calidris* shorebirds.

Figure 20. Spatial and temporal distribution of Northern Phalarope.

Figure 19. Spatial and temporal distribution of Leach's Storm-Petrel.

Nonabundant or Uncommon Species

Great Cormorant

Phalacrocorax carbo

Double-crested Cormorant

Phalacrocorax auritus

Spatial distribution maps and temporal bar graphs were not available for these species, so this discussion is preliminary. Cormorants were present in coastal and nearshore shelf waters during spring and fall migration. Otherwise, they were coastal inhabitants only. Spring and fall migration principally occurred during April to May, and September to November, respectively. Although both species were identified, the majority of specific sightings were Double-crested Cormorants. Migrating flocks of cormorants were recorded in the western Gulf of Maine south to Cape Cod and in coastal waters along the southern shores of New England and Long Island. Single Double-crested Cormorants were observed in shelf waters of the Middle Atlantic Bight region in spring and fall. Rowlett (1980) made no mention of cormorants in northern Chesapeake Bight.

Nonabundant or Uncommon Species

Pomarine Jaeger

Stercorarius pomarinus

Parasitic Jaeger

Stercorarius parasiticus

A spatial distribution map and temporal bar graph were not available for Parasitic Jaegers. The spatial and temporal distributions of Pomarine Jaegers are indicated in Fig. 21. Pomarine and Parasitic Jaegers were present throughout the study area from April to November. Their summer distribution was limited to Georges Bank and Gulf of Maine regions. More sightings of each species were recorded during fall migration which suggests that their spring migration is further offshore and/or that fall migration mostly consists of immature birds. Pomarine Jaegers were common in shelf waters during fall (Fig. 21), particularly in the vicinity of fishing fleets. Parasitic Jaegers were more frequently observed in coastal and nearshore shelf waters. Parasitic Jaegers did not indicate any attraction to fishing activity.

Figure 21. Spatial and temporal distribution of Pomarine Jaeger.

Nonabundant or Uncommon Species

Great Skua

Catharacta skua

South Polar Skua

Catharacta maccormicki

The distribution and status of each skua species in the study area were unclear. A plot of additional sightings of skuas from July-December 1979 and January-April 1980 is necessary for a more adequate discussion of spatial and temporal skua distribution. Both species were present during part of the year (Fig. 22). Most sightings are believed to be Great Skuas. A specimen of Great Skua was collected on Georges Bank at 41°09'N, 67°10'W on 13 July 1978. The specimen was banded as a chick in the Shetland Islands in July 1977. Positive and probable sightings of South Polar Skuas were recorded from June to October. Sighting and photographic records of South Polar Skuas in the study area were discussed by Veit (1978), Lee and Booth (1979), and Rowlett (1980).

Figure 22. Spatial and temporal distribution of skuas.

Nonabundant or Uncommon Species

Glaucous Gull

Larus hyperboreus

Iceland Gull

Larus glaucoides

A spatial distribution map and temporal distribution bar graph for Glaucous Gulls were not available during preparation of the report. The distribution of Iceland Gulls is indicated in Fig. 23. Glaucous and Iceland Gulls were present throughout the study area from December to March. These species were usually observed in mixed species flocks of *Larus* gulls, and often were chronic ship-followers. All sightings of adult Iceland Gulls were of the subspecies *L. g. kumlieni*.

Figure 23. Spatial and temporal distribution of Iceland Gull.

Nonabundant or Uncommon Species

Ring-billed Gull	<i>Larus delawarensis</i>
Laughing Gull	<i>Larus atricilla</i>
Bonaparte's Gull	<i>Larus philadelphia</i>

Spatial distribution maps and temporal distribution bar graphs for Ring-billed Gull and Bonaparte's Gull were not available during preparation of the report. The distribution of Laughing Gulls is indicated in Fig. 24.

Ring-billed Gulls were recorded in all regions from March to May and October to November. Most sightings in shelf waters were made in the southern part of the Middle Atlantic region from Cape Hatteras to the Delmarva Peninsula (c. 39°N latitude) in March and in October. Ring-billed Gulls were usually recorded in mixed species flocks of *Larus* gulls.

Laughing Gulls were present in the Middle Atlantic region from March to November (Fig. 24). Their occurrence offshore north and east of Long Island was only recorded from June to August. The data indicated an offshore dispersal of Laughing Gulls from the coast of New Jersey and Maryland in October.

Bonaparte's Gulls were sporadically present in nearshore shelf and coastal waters throughout all regions during the year. Largest sightings were noted in coastal waters off Provincetown, Massachusetts in January 1978 (200 birds in one sighting) and Oregon Inlet, North Carolina in March 1979 (range of flock sizes was 225 to 1040 birds from several sightings).

Figure 24. Spatial and temporal distribution of Laughing Gull.

Nonabundant or Uncommon Species

Common Tern	<i>Sterna hirundo</i>
Arctic Tern	<i>Sterna paradisaea</i>
Bridled Tern	<i>Sterna anaethetus</i>
Royal Tern	<i>Sterna maxima</i>

Common and Arctic Terns ("comic" terns) were difficult to separate at sea, so their spatial and temporal distribution was collectively mapped (Fig. 25). Spatial distribution maps and temporal bar graphs were not available for Bridled and Royal Terns during preparation of the report.

"Comic" terns were present from May to October throughout the study area. Positive sight identifications of Arctic Terns were usually made north of 42°N latitude, which corresponded with their known breeding distribution in eastern North America (Brown et al. 1975). Common Terns probably made up most, if not all, "comic" tern sightings in the Middle Atlantic, Southern New England, and Georges Bank regions. The abundance of "comic" terns was bimodal with peaks corresponding to migratory periods: May-June and October.

Bridled Terns were present in shelf, slope, and Gulf Stream waters off Cape Hatteras in the extreme southern part of the Middle Atlantic region during late August and early September 1979. Rowlett (1980) considered Bridled Terns as casual late summer visitors in the northern Chesapeake Bight.

Royal Terns were present in the Middle Atlantic Region from April to September, which coincides with their breeding season. Only one sighting was recorded north of 38°N latitude. The frequency of sightings was greatest off Cape Hatteras during June.

Figure 25. Spatial and temporal distribution of Common/Arctic Terns.

Nonabundant or Uncommon Species

Razorbill

Alca torda

Razorbills were present in the Southern New England, Georges Bank, and Gulf of Maine regions from December to April (Fig. 26). Lee and Booth (1979) and Rowlett (1980) found Razorbills in the Middle Atlantic Bight and offshore the Carolinas, but our survey coverage in the Middle Atlantic Bight during winter was poor. Brown et al. (1975) did not discuss the winter distribution of Razorbills in eastern Canadian waters.

The largest concentrations of Razorbills were found in coastal waters off Provincetown (c. 300 birds) and off Martha's Vinyard Island (c. 200 birds) in December^a 1979. On Nantucket Shoals and Cultivator Shoals densities of 3-30 Razorbills per km² were predictable from January to March. Stranding and offshore distribution data from the ARGO MERCHANT oil spill (Powers and Rummage 1978) indicated the occurrence of Razorbills on these shoals. Sandlance (*Ammodytes*), an important prey item of Razorbills at British breeding colonies (Harris 1970), is also abundant in these shoal areas (Bigelow and Schroeder 1953; NMFS, unpubl. groundfish data 1977-1978).

Figure 26. Spatial and temporal distribution of Razorbill.

Nonabundant or Uncommon Species

Common Murre

Uria aalge

Thick-billed Murre

Uria lomvia

Both murre species were present in the study area during winter and early spring (December-April) (Fig. 27), although they were less abundant than Razorbills. Murres occur in the Middle Atlantic Bight and offshore the Carolinas in winter (Lee and Booth 1979, Rowlett 1980). Our distribution data are incomplete, since survey coverage during winter in the Middle Atlantic region was poor. Murres were found stranded on Nantucket Island during the ARGO MERCHANT oil spill (Powers and Rummage 1978). Murres were most frequently recorded on Browns Bank and the north and east parts of Georges Bank.

Figure 27. Spatial and temporal distribution of murre.

Nonabundant or Uncommon Species

Dovekie

Alle alle

Dovekies were present in the study area during winter and early spring (December-April) (Fig. 28). The occurrence of Dovekies in the Middle Atlantic Bight during winter is regular (Howe et al. 1978, Rowlett 1980), but their abundance in this area is probably influenced by northeast storms (Stewart and Robbins 1958). Dovekies were found in greatest densities (3-10 birds/km²) in the north and east parts of Georges Bank (cf. Powers and Rummage 1978).

Figure 28. Spatial and temporal distribution of Dovekie.

Nonabundant or Uncommon Species

Common Puffin

Fratercula arctica

Common Puffins were present in the study area during winter and early spring (December-April) (Fig. 29). They were least abundant of the five alcid species recorded in offshore waters. Rowlett (1980) considered puffins uncommon in the northern Chesapeake Bight. Lee and Booth (1979) did not indicate their presence off North Carolina. Puffins were most frequently recorded as singles or pairs along the southern flank of Georges Bank in February and March. One noteworthy sighting of 33 puffins in a loose flock was recorded in mid-March 1979 on the Southeast Part of Georges Bank. Powers and Rummage (1978) found puffins only on the Northern Edge of Georges Bank in January 1977. The winter distribution of puffins in the western North Atlantic is poorly understood. However, the counter-clockwise surface circulation pattern in the Gulf of Maine and Georges Bank (Bumpus 1976) suggests that puffins in the study area may originate from colonies along the coast of Maine.

Figure 29. Spatial and temporal distribution of Puffin.

4. Factors Influencing Distribution

Seabirds spend more than half their lives at sea away from breeding sites, where space and "natural" predation are not significant. The distribution and availability of prey are probably the crucial determinants of pelagic distributions of marine birds. Important interspecific competition factors that regulate population levels in marine birds at breeding colonies include space, food, and predation (Wynne-Edwards 1962, Bourne 1963, Rowan 1965, Ashmole and Ashmole 1967, Lack 1967). We have identified several important features that influence and concentrate the distribution of marine birds in the mid- and north-Atlantic U. S. outer continental shelf. For convenience of discussion we categorize and discuss these features in two groups (physical oceanographic features and fishing activities), but recognize fully that these factors are interrelated.

a. Physical Oceanographic Features

Oceanic fronts have been identified in the study area at the edge of the continental shelf (Beardsley and Flagg 1976, Bumpus 1976, Wright 1976), Nantucket Shoals area c. 30 miles southeast of Cape Cod (Limeburner 1979, Limeburner and Beardsley 1979), and northern edge of Georges Bank (EG&G 1979). Fronts are defined as narrow bands of water where density changes abruptly. They are recognizable by sharp differences in temperature and salinity (Cromwell and Reid 1956). Fronts are also regions of convergence and relatively strong vertical motions (Bowman and Esias 1978). Oceanic frontal zones directly and indirectly concentrate zooplankton, squid, and fishes (Grice and Hart 1972, Pingree et al. 1974, Fournier et al. 1977, Fournier 1978). The

importance of oceanic frontal zones to the pelagic distributions of marine birds has been discussed by Murphy (1936), Ashmole and Ashmole (1967), and Gould (1971).

A front at the boundary of cold shelf and warm slope water in the Middle Atlantic and New York Bights and southern flank of Georges Bank may influence the pelagic distribution of Red Phalaropes. Red Phalaropes migrate north and northeast through the study area during April and May. Densities of 100-1000 birds/km² of Red Phalaropes were recorded within the frontal zone at the boundary of shelf and slope waters. Figures 30 and 31 illustrate the distribution of Red Phalaropes in the study area during April and May 1978-1979. Figures 32 and 33 indicate the location of the shelf-water/slope-water front based upon satellite imagery for 22-28 April and 13-19 May 1979 respectively (U. S. Naval Oceanographic Office, Ocean Frontal Analysis charts).

Using the general location of the frontal zone and distribution of a potential prey, copepods (Gaskin and Smith 1979); we have examined the correlation between the shelf-water/slope-water frontal zone and Red Phalarope distribution. Selected neuston (surface plankton) samples collected by the National Marine Fisheries Service (NMFS) MARMAP program aboard the RV ARGUS from 29 April - 5 May 1978 were analyzed at MBO. Results from these samples indicated that greater volumes of copepods were found at the edge of the continental shelf in the New York Bight and southern Georges Bank than on the shelf (Fig. 34). In the New York Bight, Walsh et al. (1978) indicated that off-

Figure 30. Distribution of Red Phalarope in mid- and north-Atlantic U.S. continental shelf waters, April 1978-79.

Figure 31. Distribution of Red Phalarope in mid- and north-Atlantic U.S. continental shelf waters, May 1978-79.

Figure 32. Ocean frontal analysis from satellite imagery of sargasso, slope, and shelf water regimes off northeastern U.S., 22-28 April 1979.

Figure 33. Ocean frontal analysis from satellite imagery of sargasso, slope, and shelf water regimes off northeastern U.S., 13-19 May 1979.

shore copepods (e.g. *Calanus finmarchius*) had a seasonal peak in abundance which closely followed the spring phytoplankton bloom period. Therefore, the timing and distribution of Red Phalaropes in the study area, during spring migration, correlates with the location of a front at the boundary of shelf and slope-waters. Also, this correlates with a seasonal peak in the abundance of a potential prey at that front.

The shelf-water/slope-water front may also affect the pelagic distribution of Wilson's Storm-Petrels. Although only surface temperature data were available during a transect across central and southern Georges Bank aboard the USSR RV ALIOT in August 1978, storm-petrels were found in greatest densities in the vicinity of the front. Figure 35 illustrates a pronounced increase in storm-petrel density at the southern edge of the bank. The change in sea surface temperatures at the edge of the shelf indicates the general location of the shelf-water/slope-water front. Vertical profiles of temperature and salinity would provide more precise data on the location of the front, but such hydrographic data were not available during this cruise. Large flocks of Wilson's Storm-Petrels were frequently found at the edge of the continental shelf during spring and summer months (Fig. 11). We suspect that since preferred prey may be more concentrated at the frontal zone, e.g. euphausiids (Mauchline and Fisher 1969), the location of the front may directly influence the pelagic distribution of Wilson's Storm-Petrels.

A front caused by an upwelling in the vicinity of Nantucket Shoals, c. 30 miles southeast of Cape Cod, has been identified.

Figure 35. Vertical section through Georges Bank at c. 68°00'W longitude showing distribution of Wilson's Storm-Petrel density (birds/km²) and surface water temperatures (°C) in August 1978.

Limeburner (1979) and Limeburner and Beardsley (1979) presented hydrographic data revealing the presence of this frontal zone during summer months. In August 1979 from the USSR RV ALIOT, we conducted a transect through the Nantucket Shoals front to examine correlations between the abundance and availability of surface zooplankton and bird distribution in relation to the front. Figure 36 illustrates the distribution and density of Wilson's Storm-Petrels and vertical distribution of water temperatures in the transect. Greatest densities of storm-petrels were found at the front and to its north. Lowest bird densities were recorded in the deeper stratified waters of the Gulf of Maine and shallow well-mixed areas of central Georges Bank. Neuston data analyzed from six stations in the transect indicated that the largest volume of zooplankton (invertebrates < 2.5 cm) was present at the front. Results of a stomach contents analysis from 13 Wilson's Storm-Petrels collected north of the front in the greatest bird density area were not yet available from the USSR during preparation of this report. Until the stomach contents data are available, we conclude that a possible relationship exists between the location of the Nantucket Shoals front and the pelagic distribution of Wilson's Storm-Petrels during summer months.

Another front created by the intrusion of a relatively cold, fresh, and low-density water mass from the Scotian Shelf across the Northeast Channel and onto the eastern half of Georges Bank may be an annual phenomenon in winter and early spring (EG&G 1979). Fulmars were found in highest densities in this area

Figure 36. Vertical section through Georges Bank at c. 69°00'W showing distribution of water temperature (°C) and Wilson's Storm-Petrel density (birds/km²) in August 1975.

during winter and early spring (Fig. 7). Offal from fishing activity apparently is important to the diet of fulmars in the northeast parts of Georges Bank because they are often seen in association with fishing vessels. However, we observed high densities of fulmars in this area when no fishing vessels were present. Fulmar distribution may be linked to the distribution and movements of cold-water zooplankton species (Brown et al. 1975) and the availability of offal (Fisher 1952, Brown 1970).

b. Fishing Activities

Fishing activity influences the pelagic distribution of several marine bird species (Boswell 1977, Watson 1978, Wahl and Heinemann 1979). The distribution of large sightings (i.e. greater than 100 birds per sighting) and their association with fishing vessels was examined for Northern Fulmars, Greater and Sooty Shearwaters, Gannets, Black-legged Kittiwakes, Wilson's Storm-Petrels, and Great Black-backed and Herring Gulls; using data from February 1976 to July 1979. The distribution of large sightings of these species correlated well with the density maps presented in the species accounts. Therefore, density maps presented in the species accounts will be referenced in the following discussion.

The distribution of *Larus* gulls in the study area appears to be influenced predominantly by offshore fishing fleets from late fall to early spring. Fulmars, Greater and Sooty Shearwaters, Gannets, and Black-legged Kittiwakes indicated a local and seasonal preference to fishing activities. Although Wilson's Storm-Petrels follow ships and were sometimes found in association with

fishing fleets, fishing activity did not appear to be an important determinant of their pelagic distribution. Cory's, Manx, and Audubon's Shearwaters, Leach's Storm-Petrels, phalaropes, and alcids were not recorded in association with fishing activity. However, Cory's Shearwaters were observed to follow ships occasionally.

Fulmar concentrations were found only in the Georges Bank and Gulf of Maine regions. Thirty-eight percent of 94 fulmar sightings of more than 100 birds were associated with fishing activity. Fisher (1952, 1966) stated that the ecology of fulmars in the northeast Atlantic is closely linked to the availability of offal from fishing boats. Brown (1970) presented a Canadian perspective to fulmars at sea and found it more reasonable to explain their pelagic distribution and ecology in oceanographic terms rather than to link it with the fishing industry. Our data support Brown's viewpoint. The majority of our large sightings occurred on the Northern Edge and Northeast Peak of Georges Bank. Fishing activity is sporadically prevalent in these areas during winter and spring months when fulmars are present; but commercial fishing is also a predominate feature in other parts of Georges Bank, as well as the Gulf of Maine and New York Bight during the same seasons, where fulmars are not prevalent (Fig. 7). The intrusion of Scotian Shelf surface waters to the north and east parts of Georges Bank in winter and early spring (EG&C 1979) may influence fulmar distribution. Fulmars have diverse diets which, besides offal, include surface zooplankton and fishes. The intrusion of colder Scotian

Shelf water onto Georges Bank may cause a front, which concentrates more preferred colder-water plankton species.

Approximately 40 percent of Greater Shearwater sightings and 25 percent of the Sooty Shearwater sightings were associated with fishing activities. Both species were primarily found in the Georges Bank and Gulf of Maine regions. The stomach contents data indicate that squid may be an important prey in fishing areas, and that fish and euphausiids are important in non-fishing areas. Barker (1976) and Brown et al. (1979) indicated an importance of euphausiids in the diets of both shearwaters in the Bay of Fundy. Rees (1961) found that *Illex* squid was important to Greater Shearwaters in fishing areas of the Grand Banks off Newfoundland. Large concentrations of Sooty Shearwaters were recorded from late May to early July only; whereas, large concentrations of Greater Shearwaters were recorded from late May to early November. Powers and Van Os (1979) noted a sighting of c. 200,000 Greater Shearwaters on Georges Bank on 11 November 1977.

Gannets were abundant in the Middle Atlantic Bight from December to early April. Gannets were associated with foreign fishing activities at the edge of the continental shelf during these months. The foreign fleets were fishing for squid and hake. We observed Gannets taking these items as they fell out of the trawl nets during the fish landing operations. Although all large concentrations of Gannets recorded at the edge of the continental shelf were associated with fishing activities, six large sightings of Gannets near the coast were made in the absence of fishing

boats. Three coastal sightings of more than 100 Gannets were recorded: within 30 miles of Cape Cod; within 30 miles of Cape Ann (Gloucester, Massachusetts); and within 30 miles of Cape Hatteras. We suspect that the coastal Gannet flocks were feeding on surface schooling fish.

The majority of large kittiwake sightings were recorded north of 41°N latitude on Georges Bank and in the Gulf of Maine. Approximately 36 percent of the large kittiwake sightings were associated with fishing boats. These concentrations occurred in coastal fishing areas of Stellwagen Bank and Jeffreys Ledge and on the offshore fishing grounds of Georges Bank and Gulf of Maine. As with fulmars and shearwaters, we believe that kittiwakes will utilize offal from fishing activities, when it is available; but otherwise depend upon fish and macrozooplankton (e.g. euphausiids). Wahl and Heinemann (1979) found a significant co-occurrence of kittiwakes and fishing vessels off the coast of Washington in the Pacific Ocean.

A total of 91 sightings of more than 100 Wilson's Storm-Petrels were recorded from 1976 through 1979. Only 15 percent of those sightings were associated with fishing vessels. The fishing vessel associated sightings occurred on Georges Bank. Large flocks recorded in the Middle Atlantic Bight during the same time were not associated with any fishing activity. Oceanographic features discussed in the previous section appear to be more influential in determining the pelagic distribution of Wilson's Storm-Petrels.

Large sightings of Great Black-backed and Herring Gulls were associated with fishing vessels in a greater proportion than any other species. Fifty-five percent of 161 large sightings of Great Black-backed Gulls and 44 percent of 189 large sightings of Herring Gulls were associated with fishing activity. The southern limit of all large gull sightings was Hudson Canyon in winter, where foreign fleets were fishing at the edge of the continental shelf. The largest concentrations, i.e. several thousand, of Great Black-backed and Herring Gulls were only recorded in association with fishing fleets.

5. Seabird Community Structure

Continental shelf waters from Cape Hatteras to the Bay of Fundy with all its associated physical, chemical, and biological activity support a rich and dynamic seabird community. The structure of the seabird community varies by season as different species groups utilize its productivity in different ways. The goal of the community structure analysis is to identify and describe the major species components that make up the avian portion of this marine ecosystem.

The Seabird community structure analysis is broken in two parts. The first is an examination of seasonal and regional ecological dominance patterns using indices of numerical dominance (i.e. standing stock estimates) and biomass dominance (i.e. biomass estimates). The second involves comparisons of seasonal and regional species diversity measurements. The analysis is a preliminary examination of the seabird community structure. However, these data are ade-

quate to infer spatial and temporal patterns of community structure and partially explain the species compositions that produced those patterns.

a. Ecological Dominance

Estimates of standing stock or biomass are convenient methods of assessing the ecological dominance that a given bird species exhibits within its biological community (Sanger 1972). Standing stock and biomass estimates are also useful in identifying the capability of geographic and biological areas to hold and maintain a community of birds through time (Jehl 1974).

Standing stock estimates were calculated for 10 bird species which were abundant to common within the study area during some part of the year. These species are listed in Table 9 and their spatial and temporal distributions are discussed in the Species Accounts. These 10 bird species made up the majority (usually >90%) of the total standing stock estimates for any given season or region. Therefore, these species were a useful and manageable group with which to compare regions and seasons.

Standing stock estimates for abundant to common species were summed by season and region (Table 10). Throughout the year Georges Bank consistently held the greatest number of birds. The Gulf of Maine region was a close second in this regard. In comparison, the Southern New England and Middle Atlantic regions had much lower standing stock estimates. Whereas, Georges Bank and Gulf of Maine regions consistently dominated the standing stock estimates throughout the year, the estimates indicated that the Georges Bank region was particularly important in spring

Table 10: Total¹ standing stock by season and region in 1000's of individuals.

Regions	Seasons				Regional Total
	Winter	Spring	Summer	Fall	
Gulf of Maine	1,397	547	1,501	1,723	5,168
Georges Bank	1,451	1,133	2,645	1,467	6,696
S. New England	789	646	460	885	2,780
Middle Atlantic	330	817	112	39	1,298
Seasonal Total	3,967	3,143	4,718	4,114	15,942

¹Totals for the ten most common or abundant species only.

and summer. The Georges Bank region shared this distinction with the Gulf of Maine in fall and winter. Seasonal standing stocks summed for the four regions exhibited a more even distribution of bird abundance. That is, an examination of total bird abundance within the study area, i.e. four general regions combined, is similar from season to season. Particular regions held more birds in different seasons, but the total standing stock of the study area was apparently similar throughout the year.

Standing stock estimates provide a useful index to ecological dominance; but interpretation of these estimates, in terms of importance to the overall community, can be misleading. For example, the daily energy requirements of a thousand Gannets would have a much greater influence on energy flow within the overall community than an equal number of Red Phalaropes. Biomass values provide a more direct interpretation of ecological dominance, since they reflect differences in body size by species. Biomass values better represent the dominance of a species within its community or the contribution of a region to the overall community.

Biomass values for each of the abundant and common bird species were calculated from standing stock estimates. These values were summed by region and season (Table 11). Species specific weights used in the biomass calculations are given in Table 12.

Through the year, regional biomass and standing stock estimates reflect the same dominance patterns. The Georges Bank region held the greatest biomass. The Gulf of Maine and Southern New England regional values were intermediate. The Middle At-

Table 11. Total¹ biomass by season and region in metric tons.

Regions	Seasons				Regional Total
	Winter	Spring	Summer	Fall	
Gulf of Maine	1,167	532	460	1,667	3,827
Georges Bank	1,089	842	2,032	1,568	5,531
S. New England	969	732	327	813	2,841
Middle Atlantic	406	364	39	51	859
Seasonal Total	3,631	2,470	2,858	4,099	13,058

¹Totals for the ten most common to abundant species only.

Table 12. Weights and their source used for each bird species in biomass calculations.

Bird Species	Weight (g)	Sources
Northern Fulmar	800	Cramp (1977), Palmer (1962), Warham (1977)
Cory's Shearwater	900	Cramp (1977), Warham (1977), MBO ¹
Greater Shearwater	850	Cramp (1977), Palmer (1962), MBO
Sooty Shearwater	850	Cramp (1977), Warham (1977), MBO
Wilson's Storm-Petrel	35	Cramp (1977), Palmer (1962), Warham (1977), MBO
Gannet	3000	Cramp (1977), Pennycuick (1969)
Red Phalarope	55	Dement'ev et al. (1969)
Great Black-backed Gull	1600	Dement'ev et al. (1969)
Herring Gull	1150	Belopol'skii (1961), Bianki (1977), Dement'ev et al. (1969), Pennycuick (1969)
Black-legged Kittiwake	400	Belopol'skii (1961), Dement'ev et al. (1969)

¹MBO refers to unpublished data collected during the course of field work for this contract.

lantic region had the lowest biomass values throughout the year. Seasonal biomass totals were relatively even, although fall and winter appeared to maintain a higher level than spring and summer. Depending upon the season, the northern regions either individually dominated, e.g. Georges Bank region in summer, or all regions codominated, e.g. winter. No single season or region consistently maintained biomass dominance.

With respect to the species composition of biomass values, Northern Fulmars, Greater Shearwaters and Great Black-backed and Herring Gulls, either individually or in combination, dominated the biomass on Georges Bank and Gulf of Maine regions throughout the year. Great Black-backed and Herring Gulls were the most important contributors to total biomass in the Southern New England region. To a lesser extent, Greater Shearwaters (in fall) and Gannets (in winter) were also major contributors in Southern New England. Herring Gulls and Gannets constituted the greatest portion of total biomass in the Middle Atlantic region, particularly during winter and spring. It should be noted that the Middle Atlantic region had extremely low biomass values for all species in summer and fall (Table 11).

Fall and winter, which had the largest overall seasonal biomass values, were dominated by Great Black-backed and Herring Gulls. Important contributions were also made by Greater Shearwaters in fall and by fulmars, Gannets, and kittiwakes during winter. Those species that dominated in fall and especially winter made up a large portion of the spring biomass total,

e.g. fulmars, Gannets, Great Black-backed and Herring Gulls. Summer was clearly dominated by Greater Shearwaters in all regions with lesser contributions by Sooty Shearwaters and Great Black-backed Gulls.

Red Phalaropes and Wilson's Storm-Petrels, because of their small individual biomass, never made a significant contribution to the total biomass composition. Conversely, standing stock estimates of these species were sometimes significant. For example, standing stock estimates of Wilson's Storm-Petrels in the Middle Atlantic region during spring and in all regions during summer and Red Phalaropes in the Georges Bank and Middle Atlantic regions during spring were high. Their contribution to biomass dominance was minimal during these same seasons.

b. Species Diversity

Diversity is a structural concept of generally theoretical interest and is related to other community attributes, such as maturity, stability, and productivity (Hill 1973). It is generally considered that diversity has richness and evenness components. Richness basically reflects the number of species and evenness refers to the distribution of abundance among species. Communities with highest species diversity exhibit the greatest species richness and equitability among those species.

In order to measure the dual-concept of diversity several diversity indices were used which combine the richness and evenness components into a single heterogeneity index. The Shannon-Weaver index (H') and Simpson's index (λ) consider the dual-concept of diversity. We used transformations of these indices, i.e.

$\text{Exp}(H')$ and $1/\lambda$, which can be interpreted as measuring the number of equally common species needed to produce the same heterogeneity as observed in the sample (MacArthur 1965, Hurlbert 1971, Hill 1973). Since Simpson's index varies inversely with heterogeneity, the reciprocal value was used to express a positive relationship (Peet 1974). As discussed in the methods, these two indices provide separate measures of diversity with different sensitivities to changes in species community structure. Peet (1974) demonstrated that $\text{Exp}(H')$ is most sensitive to changes in the rarest species, while $1/\lambda$ is most sensitive to changes in the importance of the most abundant species.

The results were compared by region and season. Table 13 indicates a compilation of several measures of diversity: number of species (n), antilogarithm of Shannon-Weaver index [$\text{Exp}(H')$], reciprocal of Simpson's index ($1/\lambda$), evenness index (E), and total number of individuals in the sample (N). Differences in diversity among seasons were generally more pronounced than differences among regions. We also found that $\text{Exp}(H')$ and $1/\lambda$ gave similar indications of species diversity patterns (Fig. 37 and 38).

In the seasonal comparison, spring had the highest diversity because of high average richness and good evenness components. In comparing values of the two diversity indices for spring (Fig. 37 and 38), the Shannon-Weaver index contrasts spring from winter and summer to a greater degree than Simpson's index. Evidently the change in species composition during spring mi-

Table 13. A seasonal and regional summary of diversity measures calculated in the community structure analyses.

Regions	Diversity Measures*	Seasons			
		Winter	Spring	Summer	Fall
Gulf of Maine	n	18	20	15	20
	N	6,029	2,009	6,361	3,246
	Exp(H')	4.81	5.53	3.67	3.19
	1/ λ	4.03	3.68	2.50	2.11
	E	0.27	0.27	0.25	0.16
Georges Bank	n	18	28	18	17
	N	6,790	10,485	18,951	13,659
	Exp(H')	4.53	6.69	3.56	3.56
	1/ λ	3.49	4.57	2.66	2.97
	E	0.25	0.24	0.20	0.21
Southern New England	n	11	26	20	15
	N	2,657	5,628	3,292	2,359
	Exp(H')	4.44	7.03	5.31	3.63
	1/ λ	3.92	4.98	4.30	2.32
	E	0.40	0.27	0.27	0.24
Middle Atlantic	n	5	23	10	5
	N	121	5,024	753	29
	Exp(H')	3.00	5.53	3.13	3.03
	1/ λ	2.30	3.74	2.34	2.45
	E	0.60	0.24	0.31	0.61

*Where n = number of species; N = total number of individuals censused; Exp(H') = antilogarithm of the Shannon-Weaver Index; 1/ λ = reciprocal of Simpson's Index; E = evenness index.

Figure 37. Seasonal groupings of $\text{Exp}(H')$ values

Figure 38. Seasonal grouping of λ values

gration, from additional migrant species (Fig. 39), enhanced $\text{Exp}(H')$. However, the numbers present (among the species) were apparently not sufficient to significantly shift heterogeneity as measured by $1/\lambda$.

Summer, with the exception of the Southern New England region, had relatively low diversity values among regions. Species richness in summer was fairly low and evenness was partially suppressed by the superabundance of Greater Shearwaters. Greater Shearwater abundances had their greatest effect on the Gulf of Maine, Georges Bank, and Southern New England regional calculations.

In contrast to the spring migratory period, fall consistently had the lowest diversity values. Species richness in fall was fair, but evenness among species was poor. Low evenness was particularly evident when richness was greatest, thus counteracting the increased diversity tendency. The fall migration was not as species rich as spring, and the poor evenness was partially a holdover from low evenness during summer. Sampling effort in the fall, except on Georges Bank, was the poorest of any season, which could have contributed to that season's apparently low diversity trend.

The winter season was marked by diversity values generally intermediate between fall and spring. Species richness was relatively high in the northern two regions but fairly low farther south. Although evenness was always high, the lack of consistently very high species richness, such as exhibited by spring,

Figure 39. Seasonal groupings of n values

generally produced diversity values less than those for spring, but not as low as those for fall.

A regional comparison of species diversity indicated that the Middle Atlantic region consistently had low diversity values. Evenness values were generally high, particularly in fall and winter. These high evenness values are partially inherent with low n values like those found in the Middle Atlantic region (Table 13). Generally, low richness had the greatest adverse effect on species diversity (Fig. 37 and 38). Perhaps more sampling effort in winter and fall would have increased the species richness. Spring was somewhat of an exception to this low diversity trend but, as has already been established in the seasonal comparison, it consistently maintained high diversity. The Gulf of Maine, Georges Bank, and Southern New England regions generally had low diversity in summer and fall and relatively high diversity in winter and spring. Thus each region had a mixture of high and low diversity values which prevented any consistent year long pattern among them.

In summary, the bird communities associated with the Gulf of Maine, Georges Bank and Southern New England appear to be similar in their structure and collectively different from the Middle Atlantic region. The three northern regions basically have more species and greater numbers of individuals throughout the year. During winter the Middle Atlantic region lacks five species of alcids and large concentrations of fulmars and kittiwakes, which are found in the three northern regions. Increased

sampling in the Middle Atlantic region could enhance the contribution of the former species to the community's species richness and heterogeneity components. We feel confident that concentrations of the latter species were not present in the Middle Atlantic region during winter. In a similar fashion, the Middle Atlantic region lacked large concentrations of three species of shearwaters in summer and fall, which also were found in the three northern regions. Finally, there was considerable agreement in seasonal patterns of species diversity among regions. Generally, across the study area, spring diversity values were highest and fall and summer values were lowest.

6. Feeding Ecology

Stomachs of 156 specimens of nine marine bird species were examined for prey items. Food items were broken into four major groups: fish (Osteichthyes), squid (Cephalopoda), crustaceans (decapods and euphausiids) and miscellany (all other groups). A breakdown of prey items and groups, for each bird species examined, is listed in Tables 14 - 23. Empty stomachs were found in Northern Fulmar (1), Cory's Shearwater (1), Wilson's Storm-Petrel (2), and Great Black-backed Gull (1). The empty stomachs were excluded from the analyses.

Fish occurred in the stomachs of each bird species analyzed. Fishes made up more than 95 percent of the total volume of prey in fulmars, Cory's Shearwaters, the skua, and Black-legged Kittiwakes (Fig. 40). Saury (*Scomberesox saurus*) and sandlance (*Ammodytes*) were the most important fishes utilized. Cory's Shearwaters were

Table 14. Stomach contents analysis of 3 Northern Fulmars collected on Georges Bank.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			100
Sandlance (<i>Ammodytes</i>)	33	18	
Cephalopoda			
Cephalopod beaks	66	trace	
Miscellany			
Polychaete beaks (<i>Nereidae</i>)	66	trace	

Table 15. Stomach contents analysis of 36 Cory's Shearwaters collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			97
Unid. fish	53	344.7	
Atlantic Saury (<i>Scomberesox saurus</i>)	26	357.4	
Silver Hake (<i>Merluccius bilinearis</i>)	3	18.4	
Unid. fish fry	3	3.6	
Cephalopoda			2
Cephalopod beaks	92	10.3	
Unid. cephalopod parts	3	5.3	
Crustacea			
Unid. crustacean parts	3	0.1	
Miscellaneous			1
Unid. material	6	5.7	
Algae	3	0.2	

Table 16. Stomach contents analysis of 44 Greater Shearwaters collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Cephalopoda			53
Unid. cephalopod parts	48	138	
Squid (<i>Ommastriphidae</i>)	2	5	
Unid. cephalopod beaks	100	18	
Osteichthyes			38
Sandlance (<i>Ammodytes</i>)	7	55	
Unid. fish	14	57	
Crustacea			5
"Shrimps"	7	10	
Unid. crustaceans	9	6	
Miscellaneous			3
Algae	23	2	
Unid. material	18	8	
Unid. gastropod	2	trace	
Isopoda	2	trace	
Unid. insects	2	trace	

Table 17. Stomach contents analysis of 7 Sooty Shearwaters collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Cephalopoda			92
<i>Illex illecebrosus</i>	43	150	
Unid. cephalopods	43	4	
Unid. cephalopod beaks	86	trace	
Osteichthyes			8
Unid. fishes	14	13	
Crustacea			
Unid. decapods	14	trace	

Table 18. Stomach contents analysis of 18 Wilson's Storm-Petrels collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			40
Unid. fish fry	44	0.2	
Unid. fish eye lens	44	trace	
Cephalopoda			
Unid. cephalopod beaks and eyes	33	trace	
Unid. cephalopod parts	5	trace	
Unid. squid larva	5	trace	
Crustacea			60
Euphausiidae	33	0.3	
Unid. crustaceans	5	trace	
Miscellaneous			
Amphipoda	11	trace	
Unid. insects	11	trace	
Unid. material	5	trace	

Table 19. Stomach contents analysis of 3 Pomarine Jaegers collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			98
Unid. fish	67	8.9	
Aves			2
Unid. bird	33	0.2	

Table 20. Stomach contents analysis of a skua collected on Georges Bank.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			98
Unid. fish	100	26.0	
Crustacea			2
Unid. crustacean	100	0.5	

Table 21. Stomach contents analysis of 18 Great Black-backed Gulls collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			23
Unid. fishes and parts	58	16.8	
Insecta			15
Unid. insects	63	10.8	
Aves			38
Unid. birds and parts	16	27.6	
Crustacea			11
"Shrimp"	5	8.0	
Miscellaneous			14
Unid. material	16	4.0	
Algae	16	2.3	
Gastropoda	10	1.9	
Sipunculida	5	2.0	

Table 22. Stomach contents analysis of 4 Herring Gulls collected on Georges Bank and adjacent waters.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			1
Unid. fish	50	0.3	
Insecta			10
Unid. insects	100	2.5	
Cephalopoda			
Unid. cephalopod beak	25	trace	
Miscellaneous			89
Unid. material	75	23.0	

Table 23. Stomach contents analysis of 10 Black-legged Kittiwakes collected on Georges Bank.

Stomach Contents	Percent Occurrence (%)	Displaced Volume (ml)	Percent of Total Volume (%)
Osteichthyes			100
Unid. fish	100	53	
Sandlance (<i>Ammodytes</i>)	10	47

Figure 40. Percent composition of fish, cephalopods, and crustaceans in the diets of six marine bird species.

primarily selecting saury, which were driven to the ocean's surface by predatory fishes (Powers, personal observation). Saury is an epipelagic fish, which is distributed throughout the temperate parts of the Atlantic Ocean (Bigelow and Schroeder 1953 and Parin 1963). In the eastern North Atlantic Cory's Shearwaters follow schools of predatory fishes, e.g. tuna (*Thunnus spp.*) (de Naurois 1969, Zino 1971), which make potential prey available to the birds (Brown et al. 1978).

Sandlance were found in the stomachs of fulmars, Greater Shearwaters and Black-legged Kittiwakes (Tables 14, 16, and 23). Sandlance are found primarily along sandy foreshores and over shoaler parts of the offshore fishing banks within the study area (Bigelow and Schroeder 1953). Sandlance are also a staple food of finback whales (*Physalus borealis*) on Stellwagen Bank (Bigelow and Schroeder 1953, Overholtz and Nicolas 1979). The shearwaters and kittiwakes from our sample were collected from a mixed species feeding flock at the northern entrance to the Great South Channel (c. 41°N, 69°W) in November 1979. Gannets, Herring Gulls, and White-sided Dolphins (*Lagenorhynchus acutus*) were most likely feeding on sandlance at this time. Sandlance are also an important food item of Razorbills, murre, and puffins (Tuck 1961, Harris 1970). Therefore, sandlance provide for a wide variety of marine birds on Georges Bank throughout the year.

Cephalopods (or squids) were an important food item in the diets of Greater and Sooty Shearwaters (Fig. 40). Cory's Shearwaters had only beaks of squid in their stomachs. Both Greater and Sooty Shearwaters were observed feeding on squid (*Illex* or *Loligo*) made avail-

able as offal from fishing trawlers (Powers, personal observation). Rees (1961) noted that Greater Shearwaters feed on *Illex* at the Newfoundland Grand Banks, by capturing free-swimming squid or scavenging them from fishing vessels. We suspect that Greater and Sooty Shearwaters are opportunistic in their feeding habits; and are able to utilize several different prey items, as they become available (Brown et al. 1978).

Crustaceans, mostly euphausiids, were found in the stomachs of Greater Shearwaters, Wilson's Storm-Petrels and Great Black-backed Gulls (Fig. 40), but are probably used by other marine bird species as well. Greater and Sooty Shearwaters feed on euphausiids (*Meganyctiphanes norvegica*) in the Bay of Fundy (Barker 1976, Brown et al. 1979). Euphausiids are an important food item in the diets of Wilson's Storm-Petrels in the southern hemisphere during their breeding season (Roberts 1940). The distribution of *Meganyctiphanes* and areas of daytime surface-swarming in the western North Atlantic (Mauchline and Fisher 1969) correlate closely with the spatial and temporal distribution pattern of Wilson's Storm-Petrels. Both the storm-petrel and euphausiid are present from April to October, and in greatest densities along the edge of the continental slope from Cape Hatteras (c. 35°N) to Georges Bank, and across Georges Bank into the Gulf of Maine (Fig. 11). These data corroborate a similar correlation made by Brown (1977).

7. Oil-Bird Interactions

A principal justification of funding for this contract was primarily based upon the potential impact of offshore petroleum and

gas development to marine bird populations in the Georges Bank area. Therefore, we have provided a simplified oiled bird/pollution index as a baseline statistic. We discuss results of the index with regard to the long-term effects of chronic oil pollution.

Using all MBO seabird data during the period 1976-1979, oiled birds of 14 species were recorded. A monthly oil pollution index was determined for each bird species by dividing the total number of oiled birds by the observation effort, for each respective month. A four-year monthly average of these indices for each species is presented in Table 24.

Oiled birds of two species of tubenoses, Northern Fulmars and Greater Shearwaters, were recorded. Oiled Northern Fulmars were observed in 12 of 47 months from February 1976 to December 1979. Oiled fulmars were regularly noted during the winter and spring (December-May). Oiled Greater Shearwaters were noted in summer and fall (June and October).

Only one sighting of an oiled Gannet was noted in April 1977.

Four species of sea ducks were seen oiled: Common Eider, Red-breasted Merganser, White-winged Scoter, and Oldsquaw. All of these sightings occurred during the winter and spring (December and March). In December 1978, Common Eiders comprised 85% of all oiled birds observed during the month, principally due to a sighting of a flock of 20 oiled eiders.

Three oiled Pomarine Jaegers were seen together in October 1977. No other jaegers or skuas were observed oiled.

Table 24. Average oiled bird index (no. oiled birds seen per 10 minutes) by month and species, February 1976 to December 1979.

Species	Monthly Average (oiled birds/10 minutes)											
	J	F	M	A	M	J	J	A	S	O	N	D
Northern Fulmar	.037	.026	.001	.010	.007					.001		.001
Greater Shearwater						.001				.002		
Gannet				.001								
Common Eider			.001									.028
Red-breasted Merganser			.001									
White-winged Scoter			.003									
Oldsquaw			.003									
Pomarine Jaeger										.003		
Iceland Gull	.005		.001									
Great Black-backed Gull	.317	.205	.005	.011	.007		.001			.001		.002
Herring Gull	.186	.237	.036	.062	.018	.003		.001		.003	.001	.007
Black-legged Kittiwake	.180	.012	.005	.001		.001					.003	.025
Razorbill	.004	.002										
Dovekie	.022											

The majority of oiled birds seen during the four years were in the gull family *Laridae*. Four species of gulls were recorded as oiled: Iceland Gull, Great Black-backed Gull, Herring Gull, and Black-legged Kittiwake. Four oiled Iceland Gulls were noted during two months of the study: January and March of 1977. Oiled Herring Gulls were recorded in 22 out of 47 months, whereas Great Black-backed Gulls and Black-legged Kittiwakes occurred in 14 and 10 months, respectively.

Sightings of oiled gulls were, by far, most numerous during the winter months of January and February. In 1977-1979, combined monthly indices of oiled gulls, alone, contributed more than 92 percent of the total index of oiled birds for those two months. The one exception to this pattern was in February 1979, where gulls represented 71 percent of the total index for that month. Only six oiled gulls were seen during the summer months June-August. These birds, in addition to the one oiled Greater Shearwater seen in June 1977, represent all the oiled birds seen during the four summers (1976-1979).

Oiled birds of two species of alcids, Razorbills and Dovekies were observed in the winter months January and February. All oiled Razorbill sightings occurred in January and February of 1979 and all oiled Dovekie sightings were in January 1977. Of the 12 oiled Dovekies seen, 10 were observed together in a flock. The black and white coloration and sitting posture of alcids often prevent reasonable views of those species. This hampers the reliable detection of the presence of oil on their plumage. Few oiled alcids were observed at sea after the ARGO MERCHANT oil spill, but this family made up

49 percent of the oiled individuals in a beached bird survey subsequent to the oil spill (Powers and Rummage 1978). Loons, which like alcids are diving birds, made up another 19 percent of the beached birds found on Nantucket Island after the ARGO MERCHANT oil spill (Powers and Rummage 1978).

Records of oiled bird sightings from these data indicated that the number of species as well as frequency of oiled individual birds are fewest in summer and greatest in winter and spring (Fig. 41 and 42). The total number of oiled species seen in any month over the 4-year period ranged from zero to nine species. From three to nine species of birds were seen oiled from December to May, with only one month (May) containing less than five species. From June to November, the number of species seen oiled ranged from zero to five, with only one month (October) containing more than three species. Gulls (*Laridae*) were the most frequently observed oiled birds during the winter, which comprised up to 100 percent of the total number of oiled birds during January and February. Other species seen oiled during winter were fulmars, Common Eiders, Razorbills and Dovekies.

There are numerous factors that need to be considered when attempting to determine which species of birds are most likely to be affected by oil pollution. King and Sanger (1979) considered 20 survival factors in an attempt to determine oil vulnerability of marine birds. They found that under certain conditions, virtually any species can be affected by oil pollution. The ARGO MERCHANT oil spill in December 1976 had a dramatic effect on birds off the New England coast, however, the survival of each oiled bird is not known.

Figure 41. Cumulative monthly oiled bird index for pelagic distributions of marine birds on Georges Bank and adjacent waters, 1976-1979.

Figure 42. Monthly oiled bird index for pelagic distributions of marine birds on Georges Bank and adjacent waters, 1976-1979.

The oiled bird/pollution index was seven times greater during the ARGO MERCHANT oil spill than any other period prior or subsequent to that event (Fig. 42).

Concentrations of birds, whether formed during migration, breeding, or wintering periods increase a species susceptibility to oil pollution. Due to the varied habits of the species which occur in the study area, concentrations of birds can be found virtually year-round. In spring, tens of thousands of Red Phalaropes migrate north through the study area. In summer, tens of thousands of shearwaters and storm-petrels have been recorded in the Georges Bank area. Greater Shearwaters probably stage on Georges Bank in fall before their autumn passage to the south (Powers and Van Os 1979). Fulmars, Gannets, large gulls, and kittiwakes occur in flocks in excess of a thousand birds during winter; often in association with foreign fishing fleets. A possible significant wintering area of Razorbills may exist on the Nantucket and Cultivator Shoals areas of Georges Bank. Its importance is heightened by the relative lack of detailed information concerning their distribution away from breeding colonies and their susceptibility to oil spills.

Feeding habits contribute to a species' vulnerability to oil pollution. Birds which dive for food, such as alcids, loons, and ducks, increase their risk of becoming oiled from oil spills; as they generally tend to spend more time resting on the water. In contrast, all species are vulnerable to hydrocarbon pollution through food chain dynamics. In response to the ARGO MERCHANT oil spill Bowman and Langton (1978) and Sherman and Busch (1978) dis-

cussed predator-prey relationships of several fish species and oil-contaminated pathways within marine food webs. These relationships and pathways may be important in long-term assessments of damage from oil pollution. Horn et al. (1970) found evidence of tar ball ingestion by saury in the eastern North Atlantic and discussed its consequences in food chain dynamics. Therefore, better knowledge of the food eaten by marine birds at sea could reveal some important pathways by which bird populations may suffer damage from oil pollution; as well as the effect of direct fouling of their plumages from oil spills.

DATA MANAGEMENT

All MBO seabird data collected prior to DOE funding (February 1976 - December 1977) and subsequent to initiation of the contract (January 1978 to present) were transcribed onto electronic data processing forms. The form and key to the computer codes used in this study were described in DOE quarterly progress report no. 1 (January - March 1978). Data keypunching was performed at the U. S. Fish and Wildlife Service, Migratory Bird and Habitat Research Laboratory (MBHRL) in Laurel, Maryland at no cost to the contractor. In return MBHRL maintains a copy of the seabird file for their coastal and marine bird data bank. Computerized analyses indicated in this report were developed at MBHRL under subcontract to MBO through the DOE contract.

MBO data were collected in three major sets: location, environment, and bird data. More than 20 location and environment variables could be recorded for each 10 minute transect, regardless if any birds were observed. As many as seven associated facts (e.g. color phase, age, behavior) for each individual bird sighted could be recorded. In 1978 and from January to July 1979, we sampled approximately 4500 km² from 4500 transects. A computer-aided analysis of these data was the only feasible way to manage such a data base.

Inherent with large data bases are problems with data transcription, verification, keypunching, reverification, and software program development. MBO lacked keypunching and computer facilities and MBHRL was sought. To date problems from budget and time con-

straints and the remoteness of MBHRL from MBO have not allowed us to develop all essential data retrieval programs needed for this study, nor have they allowed us to keypunch and verify all the data collected during this contract. The data analyzed in this report for various quantitative analyses and species accounts were collected from January 1978 to July 1979. Data from July 1979 to April 1980 should be keypunched at MBHRL by September 1980. Verification of the latter data will be necessary before any analyses are performed. Two software programs still need to be developed: first, a program for regional breakdowns of density estimates with confidence intervals and second, a program to plot abundance values from 1976-1977 data in a form compatible with 1978-1980 data.

SUMMARY

The species composition, distribution and abundance of marine birds on continental shelf waters from Cape Hatteras to the Bay of Fundy were examined. Ships-of-opportunity and volunteer observers were an important part of the sampling effort, which allowed a low-cost means of assessing the composition and structure of the bird community. Four general regions within the study area were determined on the basis of geophysical and oceanographic features. These regions are Gulf of Maine, Georges Bank, Southern New England, and Middle Atlantic. These general regions formed a nucleus from which indices of species structure in the bird community were tabulated.

Northern Fulmar, Cory's Shearwater, Greater Shearwater, Sooty Shearwater, Wilson's Storm-Petrel, Gannet, Red Phalarope, Great Black-backed Gull, Herring Gull, and Black-legged Kittiwake were the most abundant and common species within the study area. These species were ecologically dominant in standing stock and biomass. The Georges Bank and Gulf of Maine regions generally had the greatest estimates of standing stock and biomass. The Middle Atlantic region characteristically had the lowest standing stocks and biomass estimates. The Georges Bank region was particularly important in spring and summer; however, no region or season consistently maintained ecological dominance.

Species diversity or heterogeneity was greatest in spring because of large numbers of species present during this season and a more uniform distribution among species. In contrast, the fall migratory period had lowest diversity values. The Gulf of Maine,

Georges Bank, and Southern New England regions had bird communities which appeared to be similar in structure and collectively different from the Middle Atlantic region. The three northern regions had more species and greater numbers of individuals throughout the year. The Middle Atlantic region consistently had lowest diversity values, although poor sampling effort in this region during fall and winter was noted.

The spatial and temporal distribution of the 10 abundant to common species was described. Although 28 species were recognized as nonabundant or uncommon, an incomplete data analysis allowed us to only partially describe their spatial and temporal distribution. Eighteen species were considered rare to the study area. The study area was primarily concerned with shelf waters and excluded shallow nearshore and deep-water oceanic habitats.

Discussions of factors which apparently influence the pelagic distributions of marine birds were made. Physical oceanographic features, i.e. oceanic fronts, were believed to be important determinants of surface zooplankton feeding birds, e.g. Wilson's Storm-Petrels and Red Phalaropes. Fishing activities were critical determinants of the distribution of Great Black-backed and Herring Gulls. Although fishing activities influenced the distribution of fulmars, Greater Shearwaters, Wilson's Storm-Petrels, Gannets, Pomarine Jaegers, and Black-legged Kittiwakes; these species also appeared to seek natural, but localized concentrations of preferred prey. Pelagic distributions of Cory's Shearwater, phalaropes, Parasitic Jaegers, and alcids apparently were not influenced by fishing activity.

Stomach contents of nine marine bird species were examined for food items. Fish, squid, and euphausiids were the principal groups of prey items identified. Of those bird species examined, fishes were particularly important in the diets of fulmars, Cory's Shearwaters, Greater Shearwaters, and Black-legged Kittiwakes. Sand-lance may provide a staple food for several bird species and marine mammals. Squids were important to the Greater and Sooty Shearwaters, although the availability of squids to the birds may be directly related to fishing activities. Euphausiids were suspected to be important in the diets of Wilson's Storm-Petrels.

A comparison of two principal methods of counting birds at sea was made. Relative abundance and density estimators were found to behave in similar fashions for most species. Whereas the density estimator significantly reduced bias from fishing activity on the survey platform, both estimators must contend with large variances in estimates of species numbers. The large variances were primarily the result of differences in observer abilities to estimate numbers. Neither estimator could adequately resolve problems with chronic ship-following of *Larus* gulls.

Finally, an oiled bird/pollution index was developed. The frequency and number of species of oiled birds was greatest in winter and spring. Gulls (*Laridae*) made up the majority of species recorded with oiled plumages. The index was found to be useful as a baseline indicator of major oil spills, e.g. ARGO MERCHANT. Significant concentration areas for several bird species were identified. Ramifications of long-term effects from oil pollution to bird populations through food chain dynamics was discussed.

ACKNOWLEDGEMENTS

All authors contributed observations at sea during the contract period, but the volume of data collected would not have been possible without the help of former staff and volunteer observers recruited by MBO: E.H. Backus, H.E. Blake, G.C. Burrell, J.D. Cherry, J. Dugdale, S.D. Fitton, A. Frothingham, R.S. Heil, S. Hinckley, D.J. Holcomb, L.K. Jones, M.J. Kasprzyk, C. Kesselheim, W.K. Kremers, M. Litchfield, A. MacLachlan, M. Magner, D.S. Miller, D.M. Moon, A.W. Nickerson, B. Nikula, E.L. Perkins, D.C. Twichell, P.V. Turnbull, and R.R. Veit.

Our pelagic observations were made aboard research vessels of several nations and patrol vessels of the U.S. Coast Guard. We are grateful to their masters, officers, crew, and supporting scientific personnel.

United States: CGC ACTIVE, RV ADVANCE II, RV ALBATROSS IV, CGC BIBB
CGC DECISIVE, RV DELAWARE II, CGC DUANE, RV EDGERTON,
CGC INGHAM, NOAA Ship MT. MITCHELL, RV OCEANUS,
RV SUBSIG II, CGC TAMAROA, CGC TANEY, CGC VIGILANT,
CGC VIGOROUS, CGC UNIMAK.

Union of Soviet Socialist Republics: RV ALIOT, RV ARGUS, RV
BELAGORSK, RV EVRIKA.

People's Republic of Poland: RV WIECZNO

Federal Republic of Germany: RV ANTON DOHRN

Canada: CCGS NARWHAL

We also thank the following organizations for allowing observers to join their cruises: AtlantNIRO Laboratory, Kaliningrad, USSR;

Canadian Coast Guard; EG&G Environmental Consultants, Waltham, MA; Fisheries Ministries of the Federal Republic of Germany and People's Republic of Poland; National Marine Fisheries Service (NEFC); U.S. Coast Guard (1st, 3rd and 5th Districts); Woods Hole Oceanographic Institution.

We are indebted to the following organizations for additional financial, logistical or background data support: AtlantNIRO Laboratory, USSR; Canadian Wildlife Service, Bedford Institute of Oceanography, Dartmouth, NS.; Fund for the Preservation of Wildlife and Natural Areas, Boston, MA; National Marine Fisheries Service (NEFC); and U.S. Fish and Wildlife Service, Migratory Bird and Habitat Research Laboratory (MBHRL), Laurel, MD.

Special thanks are extended to the following individuals: H.C. Boyar (NMFS) and M. Lewandowski (USCG) for arranging passage of observers aboard research and Coast Guard vessels; E.H. Backus for his cartography skills; and D. Dawson (USFWS-MBHRL) for her patience and assistance with data management.

Literature Cited

- Ashmole, N.P., and M.J. Ashmole. 1967. Comparative feeding ecology of seabirds of a tropical oceanic island. Peabody Mus. Nat. Hist., Yale Univ. Bull. 24:1-131.
- Barker, S.P. 1976. Comparative feeding ecology of *Puffinus* (order Procellariiformes) in the Bay of Fundy. M.S. Thesis, Univ. Guelph.
- Beardsley, R.C., and C.N. Flagg. 1976. The water structure, mean currents, and shelf-water/slope-water front on the New England continental shelf. Mem. Soc. Roy. Sci. Liege Ser. 6.10:209-225.
- Belopol'skii, L.O. 1961. Ecology of sea colony birds of the Barents Sea. Israel Prog. for Sci. Trans., Ltd., Cat. No. 125, 346 p. (IPST Press), Jerusalem.
- Biarki, V.V. 1977. Gulls, shorebirds and alcids of Kandalaksha Bay. Israel Prog. for Sci. Trans., Ltd., Cat. No. 612219, 250 p. Keterpress Enterprises, Jerusalem.
- Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wild. Serv. Fish. Bull. 53:1-322.
- Boswall, J. 1977. The use by seabirds of human fishing activities. Br. Birds 70:79-81.
- Bourne, W.R.P. 1963. A review of oceanic studies of the biology of seabirds. Proc. 13th Int. Ornithol. Congr., 1974:716-724.
- Bowman, M.J., and W.E. Esias (ed.). 1978. Oceanic fronts in coastal processes. Proc. of Wkshp. held at Marine Sci. Res. Center, SUNY (May 1977). Springer-Verlag, New York. 114 p.
- Brown, R.G.B. 1970. Fulmar distribution: a Canadian perspective. Ibis 112:44-51.

- _____. 1977. Atlas of eastern Canadian seabirds. Halifax-Bermuda transects. Canadian Wildlife Service. 24 p.
- _____, D.N. Nettleship, P. Germain, C.E. Tull and T. Davis. 1975. Atlas of eastern Canadian seabirds. Canadian Wildlife Service, Information Canada, Ottawa, KIA 059. 220 p.
- _____, W.R.P. Bourne, and T.R. Wahl. 1978. Diving by shearwaters. Condor 80:123-125.
- _____, S.P. Barker, and D.E. Gaskin. 1979. Daytime swarming by *Meganyctiphanes norvegica* (M. Sars) (Crustacea, Euphausiacea) off Brier Island, Bay of Fundy. Canad. J. of Zool. 57:2285-2291.
- Bumpus, D.F. 1976. Review of the physical oceanography of Georges Bank. ICNAF Res. Bull. 12:119-134.
- Burnham, K.P., D.R. Anderson, and J.L. Laake. 1979. On robust estimation from line transect data. J. Wildl. Manage. 43:992-996.
- Buzas, M.A., and T.G. Gibson. 1969. Species diversity: benthonic Foraminifera in the western North Atlantic. Science 163:72-75.
- Cramp, S. (Chief Ed.). 1977. Handbook of the Birds of Europe, the Middle East and North Africa. Vol. I, Ostrich to Ducks. Oxford Univ. Press. 722 p.
- Cromwell, T., and J.L. Reid. 1956. A study of oceanic fronts. Tellus 8:94-101.
- Dement'ev, G.P. and N.A. Gladkov (ed.). 1969. Birds of the Soviet Union. Vol. III. Israel Prog. for Sci. Trans., Ltd., Cat. No. 1121, 1121 p. (IPST Press), Jerusalem.
- de Naurois, R. 1969. Notes breves sur l'avifaune de l'archipel du Cap-Vert. Faunistique, endemisme, ecologie. Bull. Inst. Fondam. Afr. Noire Ser. A 31:143-218.

- Eberhardt, L.L. 1968. A preliminary appraisal of line transects. J. Wildl. Manage. 32:82-88.
- _____. 1978a. Transect methods for population studies. J. Wildl. Magage. 42:1-31.
- _____. 1978b. Appraising variability in population studies. J. Wildl. Manage. 42:207-238.
- E G & G. 1979. Data Report, hydrographic studies, 17-29 March 1979. E G & G, Environmental Consultants, Appendix D of 11th Quarterly Progr. Rept. (BLM Contract AA551-CT8-46).
- Fisher, J. 1952. The Fulmar. Collins, St. James Place, London.
- _____. 1966. The fulmar population of Britain and Ireland, 1959. Bird Study 13:5-76.
- Fournier, R.O. 1978. Biological aspects of the Nova Scotian shelfbreak fronts. pp. 69-77: *In* Oceanic fronts in coastal processes. M.J. Bowman and W.E. Esias (ed.), Springer-Verlag, New York. 114 p.
- _____, J. Marra, R. Bohrer, and M. Van Det. 1977. Plankton dynamics and nutrient enrichment of the Scotian Shelf. J. Fish. Res. Bd. Canada 34:1004-1018.
- Gaskin, D.E., and G.J.D. Smith. 1979. Observations of marine mammals, birds and environmental conditions in the Head Harbour Region of the Bay of Fundy. pp. 69-86: *In* Evaluation of recent data relative to potential oil spills in the Passamaquoddy area. Canadian Fish. Mar. Serv. Tech. Rep. 901, D.J. Scarratt (ed.).
- Gates, C.E. 1969. Simulation study of estimators for the line transect sampling method. Biometrics 25:317-328.
- Gould, P. 1971. Interactions of seabirds over the open ocean. Ph.D. Thesis, Univ. of Arizona.

- _____, C. Harrison, and D. Forsell. 1978. Distribution and abundance of marine birds - south and east Kodiak Island waters. Pg. 614-710: *In* Environ. Assessment of the Alaskan Continental Shelf. Annual Repts. of PI for Year Ending 1978. Vol. II. Receptor - Birds. U.S. Dept. of Commerce (NOAA) and U.S. Dept. of Interior (BLM).
- Grice, D., and A.D. Hart. 1962. The abundance, seasonal occurrence and distribution of the epizooplankton between New York and Bermuda. *Ecol. Monogr.* 32:287-307.
- Grosslein, M.D., B.E. Brown and R.C. Hennemuth. 1978. Research, assessment, and management of a marine ecosystem in the Northwest Atlantic--A case study. 2nd Int. Ecol. Congr. Satellite Prog. in Stat. Ecol. held U. of Parma.
- Harris, M.P. 1970. Differences in the diet of the British auks. *Ibis* 112:540-541.
- Hill, M.O. 1973. Diversity and evenness: a unifying notation and its consequences. *Ecology* 54:427-432.
- Horn, M.H., J.M. Teal, and R.H. Backus. 1970. Petroleum lumps on the surface of the sea. *Science* 168:245-246.
- Howe, M.A., R.B. Clapp, and J.S. Weske. 1978. Marine and coastal birds. MESA New York Bight Atlas Monograph 31, New York Sea Grant Institute (Albany). 87 p.
- Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. *Ecology* 52:577-586.
- Jehl, J.R. 1974. The distribution and ecology of marine birds over the continental shelf of Argentina in winter. *San Diego Soc. Nat. Hist. Trans.* 17:217-234.

- King, J.G., and G.A. Sanger. 1979. Oil vulnerability index for marine orientated birds. Pg. 227-239. In *Conserv. of Marine Birds of Northern North America*. J.C. Bartonek and D.N. Nettleship (ed.) USFWS Wildl. Res. Rept. 11.
- Kovner, J.L., and S.A. Patil. 1974. Properties of estimators of wildlife population density for the line transect method. *Biometrics* 30:225-230.
- Lack, D. 1967. Interrelationships in breeding adaptations as shown by marine birds. *Proc. 14th Int. Ornithol. Congr. 1964*: 3-42.
- Lee, D.S., and J. Booth, Jr. 1979. Seasonal distribution of off-shore and pelagic birds in North Carolina waters. *Amer. Birds* 33:715-721.
- Limeburner, R. 1979. Nantucket shoals upwelling and circulation. 2nd Informal Wkshp. on the Oceanogr. of the Gulf of Maine and Scotian Shelf, held at Dalhousie U., Halifax, N.S., 14-17 May. Unpubl. abstract only.
- _____, and R.C. Beardsley. 1979. Hydrographic station data obtained in the vicinity of Nantucket Shoals, May, July, September 1978. WHOI Technical Rept.-79-30. 88p.
- 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. MS thesis, Dalhousie University.
- MacArthur, R. 1965. Patterns of species diversity. *Biol. Rev.* 40:510-533.

- Mauchline, J., and L.R. Fisher. 1969. The biology of euphausiids. *Adv. Mar. Biol.* 7:1-454.
- Murphy, R.C. 1936. The oceanic birds of South America. *Amer. Mus. Nat. Hist.*, New York. 2 vols.
- Myrberget, S. 1976. Field tests of line transect methods for grouse. *Norw. J. Zool.* 24:307-317.
- Odum, E.P. 1971. Fundamentals of ecology (3rd ed.) W.B. Saunders Co., Philadelphia.
- Overholtz, W.J., and J.R. Nicolas. 1979. Apparent feeding by the fin whale, *Balaenoptera physalus*, and humpback whale, *Megaptera novaengliae*, on the American sand lance, *Ammodytes americanus*, in the Northwest Atlantic. *Fish. Bull.* 77:285-287.
- Palmer, R.S. 1962. Handbook of North American Birds, Vol. I. Loons through Flamingos. Yale Univ. Press, New Haven, CT.
- Parin, N.V. 1963. Scomberesocidae (Pisces, Synentognathi) of the eastern Atlantic Ocean. *Atlantide Rept.* 7:275-290.
- Peet, R.K. 1974. The measurement of species diversity. *Ann. Rev. Ecol. and Syst.* 5:285-308.
- Pennycuick, C.J. 1969. The mechanics of bird migration. *Ibis* 111:525-556.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *J. Theoret. Biol.* 13:131-144.
- _____. 1969. An introduction to mathematical ecology. John Wiley & Sons, Inc., New York. 286p.
- Pingree, R.D., G.R. Forster and G.K. Morrison. 1974. Turbulent convergent tidal fronts. *J. Mar. Biol. Ass. U. K.* 54:469-479.

- Powers, K.D., and W.T. Ramage. 1978. Effect of the ARGO MERCHANT oil spill on bird populations off the New England coast, 15 Dec. 1976 - Jan. 1977. Pg. 142-148. *In Symp., In the Wake of the ARGO MERCHANT*, Center for Ocean Mgmt. Studies, URI.
- _____, and J.A. Van Os. 1979. A concentration of Greater Shearwaters in the western North Atlantic. *Amer. Birds* 33:253.
- Prater, A.J. 1979. Trends in accuracy of counting birds. *Bird Study* 26:198-200.
- Rees, E.I.S. 1961. Notes on the food of greater shearwater. *Sea Swallow* 14:54-55.
- Robinette, W.L., D.A. Jones, and C.M. Loveless. 1974. Field tests of strip census methods. *J. Wildl. Manage.* 38:81-96.
- Rowan, M.K. 1965. Regulation of sea-bird numbers. *Ibis* 107:54-59.
- Rowlett, R.A. 1980. Observations of marine birds and mammals in the northern Chesapeake Bight. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-80/04. 87p.
- Sanger, G.A. 1972. Preliminary standing stock and biomass estimates of seabirds in the Subarctic Pacific Region. Pg. 589-611. *In* Takenouti, A.Y. (ed.), *Biological oceanography of the northern North Pacific Ocean*. Idemitsu-Shoten, Tokyo. 626p.
- Shannon, C.E., and W. Weaver. 1949. *The mathematical theory of communication*. Univ. of Ill. Press, Urbana, IL. 117p.
- Siegel, S. 1956. *Nonparametric statistics for the behavioral sciences*. McGraw-Hill Book Co., New York. 312p.
- Simpson, E.H. 1949. Measurement of diversity. *Nature* 163:688.

- Sokal, R.R., and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco. 776p.
- Stewart, R.E., and C.S. Robbins. 1958. Birds of Maryland and the District of Columbia. N. America, Fauna No. 62, U.S. Govt. Printing Office, Washington, D.C. 401p.
- Tuck, L.M. 1961. The murre. Canadian Wildlife Serv., Ottawa. 260p.
- Veit, R.R. 1978. Some observations of South Polar Skuas (*Catharacta maccormicki*) on Georges Bank. Amer. Birds 32:300-302.
- Wahl, T.R., and D. Heinemann. 1979. Seabirds and fishing vessels: co-occurrence and attraction. Condor 81:390-396.
- Walsh, J.J., T.E. Whitley, F.W. Barveink, C.D. Wirick, S.O. Howe, W.E. Esaias, J.T. Scott. 1978. Wind events and food chain dynamics within the New York Bight. Limnol. Oceanogr. 23:659-683.
- Ward, D.V. 1978. Biological Environmental Impact Studies: Theory and Methods. Academic Press Inc., New York. 157p.
- Warham, J. 1977. Wing loadings, wing slopes, and flight capabilities of Procellariiformes. N. Z. Journal of Zoology 4:73-83.
- Watson, P.S. 1978. Seabirds at commercial trawlers in the west Irish Sea. Ibis 120:107-108, Supplement.
- Wiens, J.A., D. Heinemann, and W. Hoffman. 1978. Community structure, distribution, and interrelationships of marine birds in the Gulf of Alaska. In Envir. Assessment of the Alaskan Continental Shelf. Final Repts. of PI, Vol. 3: Biological Studies. U.S. Dept. of Comm. (NOAA) and U.S. Dept. of Interior (BLM).

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

Wynne-Edwards, V.C. 1962. Animal dispersion in relation to social
behavior. Edinburgh: Oliver A. Boyd.

Zino, P.A. 1971. The breeding of Cory's shearwater *Calonectris*
diomedea on the Salvage Islands. Ibis 113:212-217.

Appendix 1. Diversity Index Formulations.

The Shannon - Weaver Formulation:

$$H' = - \sum_{i=1}^n p_i \text{ LN } p_i$$

where p_i is the proportion of individuals of the i th species
and n is the number of species in the sample.

$$\text{Exp}(H') = \text{antilogarithm of } H'$$

The Simpson Formulation:

$$\lambda = \sum_{i=1}^n p_i^2$$

where p_i is the percentage importance as before and n is the
number of species in the sample.

$$E = \frac{\text{Exp}(H')}{n} = \text{an evenness index}$$

Appendix 2. List of selected rare bird sighting records from Cape Hatteras (c. 35°N) north to Bay of Fundy (c. 44°N) and from the coast east to 65°W longitude from January 1978 to April 1980.

Albatrosses		<i>Diomedea</i> spp.
VII:13:1978	42°19'N, 68°22'W	1
VII: 7:1979	41°09'N, 71°22'W	1
White-faced Storm-Petrel		<i>Pelagodroma marina</i>
VIII:30:1979	37°27'N, 71°55'W	1
IX:19:1979	39°17'N, 72°16'W	1
White-tailed Tropicbird		<i>Phaethon lepturus</i>
IX:5:1979	36°39'N, 70°00'W	1
Long-tailed Jaeger		<i>Stercorarius longicaudus</i>
VI:7:1978	40°49'N, 67°03'W	1
VII:13:1978	41°47'N, 68°34'W	1
IX:1:1979	35°50'N, 74°55'W	1
IX:4:1979	36°56'N, 70°10'W	1
Lesser Black-backed Gull		<i>Larus fuscus</i>
III:7:1979	39°50'N, 73°25'W	1
III:7:1979	37°55'N, 74°49'W	1
XI:23:1979	36°56'N, 76°11'W	1
Sabine's Gull		<i>Xema sabini</i>
VII:25:1979	31°40'N, 80°10'W	1
Little Gull		<i>Larus minutus</i>
XII:3:1979	41°51'N, 70°25'W	1

Black Tern

Chlidonias niger

VIII:29:1979	35°52'N, 74°55'W	1
VIII:29:1979	36°01'N, 74°56'W	4
IX:1:1979	35°51'N, 75°09'W	6
IX:1:1979	35°56'N, 75°17'W	1
IX:1:1979	36°02'N, 75°19'W	4
IX:4:1979	36°59'N, 75°51'W	1
IX:7:1979	36°05'N, 75°03'W	6
IX:7:1979	36°21'N, 75°00'W	3
IX:7:1979	36°27'N, 74°59'W	1
IX:7:1979	36°56'N, 74°53'W	1

Roseate Tern

Sterna dougallii

IX:16:1979	42°51'N, 68°34'W	2
------------	------------------	---

Sooty Tern

Sterna fuscata

XIII:29:1979	35°51'N, 74°55'W	1
IX:4:1979	37°04'N, 70°57'W	1
IX:6:1979	35°36'N, 73°24'W	1
IX:7:1979	36°56'N, 74°53'W	4
IX:11:1979	36°49'N, 73°58'W	5
IX:11:1979	36°42'N, 73°30'W	102
IX:7:1979	41°15'N, 68°57'W	1
IX:7:1979	42°02'N, 68°58'W	1

Least Tern

Sterna albifrons

VIII:20:1979	41°57'N, 69°49'W	1
VIII:21:1979	41°57'N, 69°10'W	1
VIII:26:1979	40°35'N, 67°15'W	1
IX:3:1979	40°16'N, 69°24'W	1
IX:15:1979	41°32'N, 69°00'W	3

Sandwich Tern

Sterna sandvicensis

VI:24:1978	35°44'N, 75°24'W	2
VI:24:1978	35°50'N, 75°29'W	1
VI:24:1978	35°56'N, 75°23'W	1
VIII:23:1979	36°55'N, 75°24'W	1
VIII:23:1979	36°52'N, 75°52'W	3
VIII:23:1979	35°38'N, 75°15'W	1
IX:1:1979	35°56'N, 75°17'W	5
IX:1:1979	36°02'N, 75°19'W	1

Black Guillemot

Cepphus grylle

II:6:1978

42°00'N, 72°00'W

1

II:7:1978

42°00'N, 72°00'W

2