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OBSERVATIONS OF SEABIRDS DURING A CRUISE FROM ROSS ISLAND TO ANVERS ISLAND, ANTARCTICA

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The breeding avifauna of the Sub-Antarctic and Antarctic consists of about 65 species, mostly seabirds. In the antarctic region, which includes the Antarctic continent, Peninsula and adjacent islands, there are 18 breeding species; 8 are restricted as breeders to the Antarctic Peninsula (Watson 1975). These 18 species depend largely on the sea for their existence and most are highly pelagic, only coming to land for breeding during the short austral summer. Sub-adult and foraging adult seabirds from subantarctic islands and the wintering Arctic Tern (*Sterna paradisaea*) are also found in antarctic waters during the austral summer. During the austral spring, under the influence of warming temperatures, wind and water currents, the continuous band of ice which surrounds the Antarctic continent and much of the Peninsula in winter, breaks up into pack ice and open water. Seabirds forage in continuous daylight of the austral summer and exploit plankton-abundant regions of the antarctic oceans.

Most information available on antarctic and subantarctic seabirds has resulted from terrestrial studies of their breeding biology. Although little is known about their pelagic distributions, behaviors and ecologies (Watson 1975, Ainley et al. 1978), these are influenced by prolonged sexual immaturity, nonbreeding periods when sexually mature, absence between bouts of incubation and foraging for food for young. In addition, there is little known about patterns in pelagic seabird community composition and species interactions. Biotic and abiotic determinants of species occurrences are also poorly understood (Watson 1975) although data exist on effects of sea water temperature (Szijj 1967), ice concentration (Cline et

Antarctic Petrel *(Thalassoica antarctica)*. Amundsen Sea, Antarctica, January 1980. Photograph by J.R. Jehl, Jr.

al. 1969, Zink 1978, Ainley et al. 1978) and local plankton blooms (Cline et al. 1969, Ainley et al. 1978) on bird distributions.

Early studies (Gain 1914; Siple and Lindsey 1937; Holgerson 1945, 1957; Bierman and Voous 1950) established the broad patterns of seabird distributions and general pelagic ecology in Antarctica; recent summaries of many aspects of antarctic avian biology can be found in Watson et al. (1971) and Watson (1975). In addition, Watson (1975) provides a useful discussion of the maritime and terrestrial physical environments.

This study contributes information on the pelagic distribution, abundance and habits of 16 species of seabirds obtained during an austral summer cruise aboard the USCGC Glacier, while it traveled through the Ross, Amundsen and Bellingshausen seas, from McMurdo Station (Ross Island) to Palmer Station (Anvers Island). Recent seabird observations from the areas covered herein include those of Erickson et al. (1972) and Darby (1970), and are compared with recent pelagic seabird surveys from the Weddell Sea (Cline et al. 1969, Parmelee 1977, Zink 1978).

ITINERARY AND METHODS

The route and itinerary of the Glacier are shown in Fig. 1. This study was largely opportunistic as the purpose of this portion of the 1976 International Weddell Sea Oceanographic Expedition (IWSOE) was merely to reach Palmer Station, consequently, the route depended mostly on pack ice densities. Of the 136.1 h of observation, 99.1 h were taken in the Ross Sea (170°E–135°W), 23.5 h in the Amundsen Sea (135°W–90°W) and 13.5 h were mostly in ice-free portions of the Bellingshausen Sea (90°W–66°W).

Observations were made from the "flying bridge" of the Glacier, 16 m above the waterline, during periods of various lengths (0.5–4.5 h) throughout the day. A minute by minute account (in GMT) was kept of numbers and behavior of birds and seals sighted within approximately 0.4 km of each side of the ship, providing a census strip width of 0.8 km. The data on seals are discussed elsewhere (in prep.). To determine the transect boundaries a 12.7 × 38.1 cm rectangular board with a line, describing an angle of 2.3°, drawn diagonally from a top corner to a point on the opposite 12.7 cm side was used. While the top (i.e., 38.1 cm) edge of the board was sighted to the horizon (and perpendicular to the ship's course), a simultaneous sighting was taken along the line, which intersected the water 0.4 km from the observer (for details see Cline et al. [1969]). I tried to monitor specific birds following the ship to prevent multiple entries of given individuals. When several individuals of the same species were following the ship, all individuals seen at 5–10 min intervals were counted and the approximate turn-over rate was estimated. Maximum number in sight during any count and turnover rate were used to estimate the number of a given species seen during the transect period. Estimated numbers of birds in large flocks were probably conservative; direct counts of flocks while the Glacier was stuck in pack ice showed that initial estimates were low by as much as 30–40%.

Pack ice concentration during each observation period was recorded in oktas (0 indicating open seas, 8 representing solid pack). Ice concentrations changed rapidly during many censuses and prevented a precise correlation of each sighting with a specific okta value (see discussion of Adélie Penguin [*Pygoscelis adeliae*] for an example). Also, the okta value assigned to a flying bird or one foraging in a relatively narrow zone of several ice concentra-

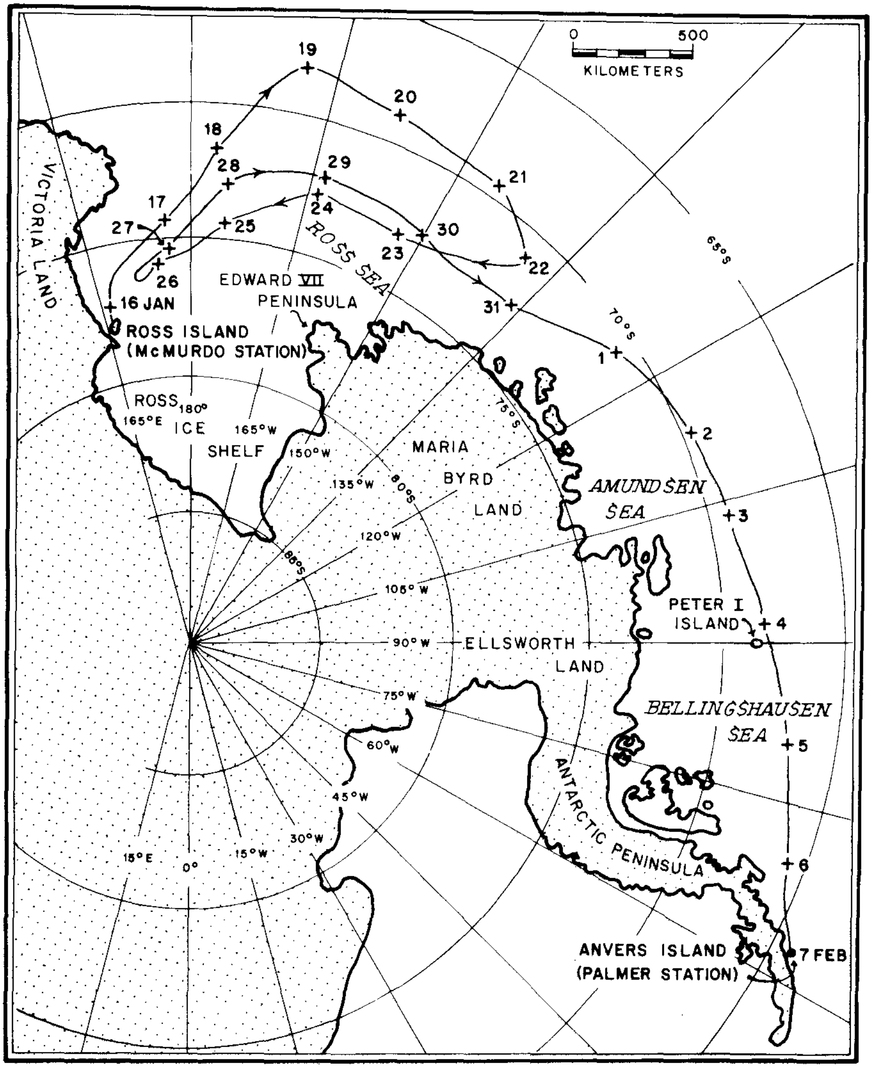

FIG. 1. Approximate route of the Glacier from McMurdo Station to Palmer Station. Numbers refer to dates between 16 January and 7 February 1976. Crosses (+) indicate noon (GMT) positions.

tions was somewhat arbitrary. Because of these factors, and insufficient data for each okta, data were grouped into 1–4, 5–8 oktas and open seas. Large leads (channels of water through ice floes) or polynyas (areas of open water in sea ice, distinguished from leads) were scored as open seas even though they existed within the pack ice, accounting for some of the apparent "open seas" occurrences of pack ice species, as it did in the study by Cline et al.

TABLE 1

SUMMARY OF SHIPBOARD OBSERVATION PERIODS FROM MCMURDO STATION TO PALMER STATION (16 JAN.–6 FEB., 1976)

	Census h	Percent	Km^2 of census	Percent
Open water	14.7	10.8	243.5	12.1
Pack ice (1–4 oktas)	100.2	73.6	1438.5	71.2
Pack ice (5–8 oktas)	21.2	15.6	337.2	16.7
Total	136.1	100.0	2019.2	100.0

(1969). The Glacier followed routes of easiest passage through pack ice and habitats sampled were consequently biased towards open pack, leads and polynyas (Table 1).

Sightings of each species in the 3 habitats were totaled to ascertain general relationships (Table 2). Information on pelagic zonal distribution of each species in antarctic (continental and maritime) and subantarctic (transitional, cold and temperate) waters is given (after Watson 1975). General locations of known breeding sites along the census route are given in Table 2. Density estimates (given as mean ± SD) were computed for the 3 most common bird species by dividing the number of individuals seen during a census by the area censused (Table 3); for some other species only maximum densities are given, and for the remaining species densities were not computed because of low numbers or uncorrected biases in the probability of detection. For instance, although albatrosses were identifiable at 0.4 km, smaller birds, such as prions and storm-petrels, were not. The areas covered during the 69 censuses ranged from 8.6–94.5 km^2 ($\bar{x}$ = 29.3 ± 15.3 km^2). Observation periods were not uniformly spaced, either within or among days, hence there was insufficient basis for a daily comparison of species or abundances. To show general patterns in species pelagic ranges, the days for which each species was observed are given in Table 2. The Glacier often traveled 300+ km per day, thus only approximate range estimates are possible from this presentation; specific locations of important sightings are given in the text.

Data from Erickson et al. (1972) were used to calculate density estimates. They censused birds from 23 January–15 February 1972 in areas of pack ice, from its eastern edge in the Bellingshausen Sea at about 85°W to its western edge in the Amundsen Sea at 135°30′W. Their transects ranged from 68°S–72°S, which represented distances into the pack of from 39–330 km, respectively. Their 23 censuses sampled an area of 1255 km^2 over 88 h; the average census covered 54.6 ± 38.5 km^2 and lasted 3.8 ± 1.9 h. They did not partition their observations according to ice concentrations, hence throughout the present paper, references to their density and abundance figures are for pack ice in general (however, they stated that ice concentrations governed their penetration into the pack, hence their censuses were probably in pack ice of less than 60% concentration).

The densities given by Cline et al. (1969) in their study of birds of the summer pack ice in the Weddell Sea were converted from birds/$mile^2$ to birds/km^2. They related the occurrence of birds to pack ice concentrations as follows: light (10–30%), medium (40–60%) and heavy (70–100%). Parmelee (1977) provided observations of seabirds obtained during a study in the Weddell Sea, primarily in open water, between 23 January and 26 February 1973; there were no density estimates given or derivable from this study. Zink (1978) censused birds in the northwestern Weddell Sea during the austral summer of 1976 and presented data similar to those in the present report, however, pack ice densities represented averages

TABLE 2

NUMBER, DATES EACH SPECIES WAS SIGHTED AND OBSERVED HABITAT PREFERENCES[a]

				Percent within species				Zonal distribution[c]		
Species	Number	Percent	Dates sighted Jan.–Feb. 1976	Open water (0 oktas)	Light pack (1–4 oktas)	Heavy pack (5–8 oktas)	χ^2[b]	Ant-arctic	Sub-Antarctic	Known breeding sites[d]
Antarctic Petrel	3022	38.8	17–6	2.42	95.63	1.95	881.2*	C, M	N	KI, U
Adélie Penguin	2773	35.6	16–19, 22–31	—	54.00	46.00	1878.1*	C, M	N	AP, PI, RI, VL, 75°S/133°W
Snow Petrel	847	10.8	17–20, 22–4, 6	1.42	83.70	14.78	100.4*	C, M	Tr	AP, KI, VL
Arctic Tern	396	5.1	19, 20, 22, 23, 29–4	—	90.66	9.34	81.8*	C, M	Tr, C	N
Southern Fulmar	289	3.6	19, 3–6	22.49	77.51	—	75.6*	C, M	Tr, C, Te	AP, PI
Wilson's Storm-Petrel	116	1.5	22, 25, 27, 31, 3–6	62.07	37.93	—	277.7*	C, M	Tr, C, Te	AP, VL
South Polar Skua	110	1.4	16, 17, 29, 6	0.90	6.37	92.73	456.1*	C, M	Tr, C, Te	AP, KI, PI(?), RI, VL
Blue Petrel	77	1.0	22, 4	100.00	—	—	560.5*	C, M	Tr, C	N
Emperor Penguin	56	0.7	18, 22–1	—	60.71	39.29	24.6*	C	N	AP, KI, RI, VL
Southern Giant Fulmar	25	0.3	18, 19, 23, 27, 31, 2–5	12.00	72.00	16.00	NS	C, M	Tr, C, Te	AP
Black-browed Albatross	18	0.2	5, 6	100.00	—	—	129.2*	M	Tr, C, Te	N
Gray-headed Albatross	17	0.2	5, 6	100.00	—	—	120.6*	M	Tr, C	N
Cape Pigeon	15	0.2	22, 4–6	67.00	33.00	—	42.8*	C, M	Tr, C, Te	AP, PI
Unidentified mollymauk	12	0.2	4–6	100.00	—	—	—	—	—	N
Unidentified petrel	9	0.1	19, 20, 26	100.00	—	—	—	—	—	—
Light-mantled Sooty Albatross	2	0.1	5, 6	100.00	—	—	NC	C, M	Tr, C, Te	N
Wandering Albatross	1	0.1	5	100.00	—	—	NC	M	Tr, C, Te	N
Antarctic Prion	1	0.1	3	100.00	—	—	NC	C, M	Tr, C	N
Total	7786	100.0								

[a] Zonal distribution and known breeding sites are from Watson (1975) and Watson et al. (1971).

[b] Tests the hypothesis that birds were distributed randomly in the 3 habitat categories, based on area censused in each (see Table 1). Chi-square values are not calculated (NC) for species with "expected" values of less than 1 in one or more categories. Degrees of freedom are 2 in each case. An * denotes a $P < 0.005$.

[c] Key for zonal distribution—Antarctic: C = Continental, M = Maritime; Subantarctic: Tr = Transitional, C = Cold, Te = Temperate (from Watson 1975); N = Does not occur in subantarctic zone.

[d] Known breeding sites along route censused. Key: AP = Antarctic Peninsula, KI = King Edward VII Land, PI = Peter I Island, RI = Ross Island, VL = Victoria Land, U = uncertain, breeding possible, N = not known to breed along census route.

TABLE 3
DENSITY ESTIMATES FOR SELECTED SPECIES[a]

Species	Density								
	Open water (N = 11)			Pack ice (1–4 oktas) (N = 46)			Pack ice (5–8 oktas) (N = 12)		
	$\bar{x}$	SD	(range)	$\bar{x}$	SD	(range)	$\bar{x}$	SD	(range)
Adélie Penguin	—	—	—	1.79[b]	± 3.38	(0–18.92)	4.05	± 4.46	(0–11.65)
Antarctic Petrel	0.31	± 0.24	(0–0.74)	1.57	± 4.99	(0–31.87)	0.23	± 0.53	(0–1.78)
Snow Petrel	0.10	± 0.25	(0–0.79)	0.48	± 0.45	(0–2.55)	0.38	± 0.41	(0–1.35)

[a] In birds/km^2.
[b] Based on N = 36; see range in Fig. 2.

over all oktas because of insufficient pack ice census data. Variance in densities, not given in the original report, have been calculated from the original census data.

There was continuous daylight from 16 January–1 February, but by 6 February there were 7 h of darkness per day. The daily mean sea water temperature from McMurdo to Palmer varied from −1.9–2.6°C (3–12 readings per day, N = 193; $\bar{x} = -0.95 \pm 0.88$°C). Because of the narrow range, bird distributions were not compared with sea water temperatures, as was done by Szijj (1967) in Pacific subantarctic waters. Data gathered during periods when visibility was less than 0.4 km were not included in the abundance or density estimates but were used for distributional records and behavioral information.

RESULTS

A total of 7786 individuals representing at least 16 species were sighted and their numbers and general habitat occurrence are given in Table 2. The hypothesis that each species was randomly distributed with respect to area censused, within each habitat category, was tested with Chi-square and rejected ($P < 0.005$) (see Table 2) in all species except the Southern Giant Fulmar (*Macronectes giganteus*). Thus, these arbitrarily chosen divisions do provide indications of general habitat preference.

The occurrence, absolute and relative abundance of each species are functions of census effort per habitat and geographic region studied, as well as of species spatio-temporal distributions and densities. Since most of the census effort was in pack ice (1775.7 of 2019.2 km^2), it is not surprising that 4 species typical of pack ice (Antarctic Petrel [*Thalassoica antarctica*], Adélie Penguin, Snow Petrel [*Pagodroma nivea*], Arctic Tern) comprised 90.4% of the total birds observed; these species often occur in high densities. Many of the infrequently sighted species are characteristic of more open seas and/or lower latitudes. However, of all species observed, only the Black-browed (*Diomedea melanophris*), Gray-headed (*D. chrysostoma*) and Wandering (*D. exulans*) albatrosses typically are not found in continental antarctic waters (see zonal classification in Table 2). A considerable range of latitudes (65°S–77°S) and longitudes (170°E–66°W) were censused, in addition to different habitats, hence the absolute ranking of species; perhaps the relative relationships reflect arbitrary distribution of sampling effort.

Species typical of pack ice.—Antarctic Petrel.—This was the most frequently sighted species during this cruise and occurred mostly in loose pack ice (Table 2). The 73 individuals sighted in open water were in groups of 4 or fewer. The mean density of 1.57 ± 4.99/km^2 in 1–4 oktas was biased by a concentration of 1750 birds sighted during a 3-h period on 27 January at 74°30′S, 179°0′W, in 2–4 oktas of pack ice (Table 3). Several large flocks of 300–400 birds roosting on large tabular icebergs and numerous other smaller flocks and individuals standing on pack ice were observed, accounting for the maximum density of 31.9/km^2. This concentration was unexplained. Without these flocks the mean density was 0.90 ± 2.04/km^2 and was typical of most pack ice (1–4 oktas) areas censused. The mean and maximum densities in 5–8 oktas, 0.23 ± 0.53/km^2 and 1.78/km^2, respectively, were less than those recorded for 1–4 oktas and were less variable. However, while the preference for light pack ice was clear (Table 2), the densities in light and heavy pack ice were not statistically different (t = 1.121, df = 58, NS).

Erickson et al. (1972) sighted this species on all but 2 of their 23 transects and recorded a mean density of 4.31 ± 6.55/km^2 and a maximum density of 23.06/km^2 in the pack ice of the Bellingshausen and Amundsen seas; the 4894 individuals they counted constituted 47.7% of the total birds they observed. Of the 23 density estimates calculated from their data, only 5 exceeded 4.0/km^2 (5.76, 12.49, 15.48, 18.56 and 23.06).

Cline et al. (1969) observed no large concentrations of Antarctic Petrels in the Weddell Sea and recorded a mean density of 0.35/km^2 (no variance given); they noted this species most often in light pack ice. In the pack ice of the northwestern Weddell Sea, Zink (1978) observed this species most frequently in 1–4 oktas and recorded a mean density of 3.0 ± 11.03/km^2 and a maximum density of 58/km^2. Parmelee (1977) also found them common in the Weddell Sea. Present data are insufficient to determine if there are significant differences between densities of Antarctic Petrels in the Weddell Sea and the Ross, Bellingshausen and Amundsen seas, although there is a preference by this species for light pack ice concentrations.

Adélie Penguin.—Occurrence of Adélie Penguins during this cruise is shown in Fig. 2. Erickson et al. (1972) reported this species as rare in the pack ice of the Bellingshausen and Amundsen seas; they observed 24 individuals in 1255 km^2 of pack ice census. A possible reason for this is the apparent lack of breeding sites along the coasts of the Bellingshausen

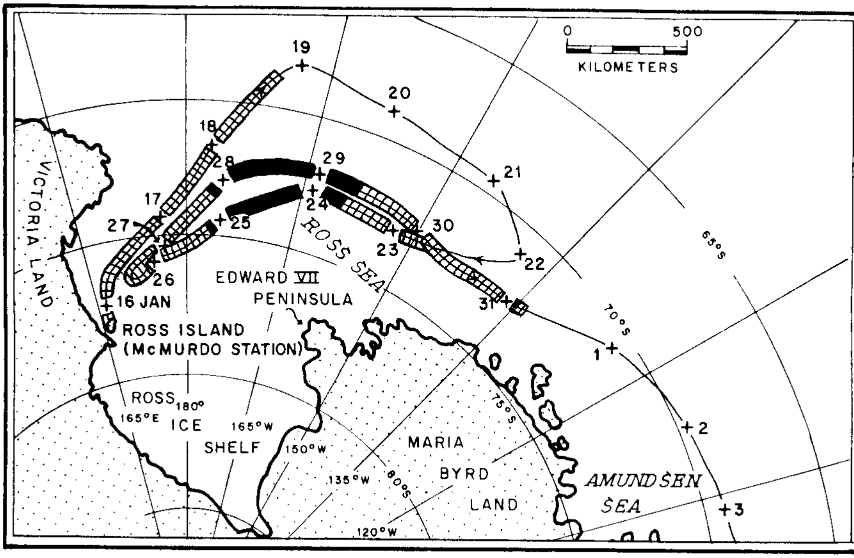

FIG. 2. Occurrence of Adélie Penguins along the cruise track is shown by ⊞⊞. ■ indicates a region where Adélie densities were significantly higher than other areas in which they were sighted.

and Amundsen seas (G. E. Watson, pers. comm.). The absence of Adélies from these areas was substantiated during the present study, as most of the Adélies (2746 of 2773) were observed in the Ross Sea. Twenty-seven Adélies were sighted between 135°W and 127°W in 7.3 h (118.1 km^2) and none was seen east of 127°W during 18.3 h (294.2 km^2) of pack ice census. This species reportedly breeds on Peter I Island (Watson 1975), however, none was observed from the Glacier (see Fig. 1) or during a helicopter seal census covering 65 km^2 at approximately 67°47′S, 90°47′W, which is roughly 100 km north of Peter I. Because of the apparent absence of Adélies from the Bellingshausen and Amundsen seas, censuses in these areas were not used to calculate density estimates. In the Ross Sea, density estimates ranged from 0–18.9/km^2 and the mean densities were $1.79 \pm 3.38/km^2$ in 1–4 oktas and $4.05 \pm 4.46/km^2$ in 5–8 oktas of pack ice (Table 3); the difference between these mean densities was insignificant ($t = 1.85$, df = 48, NS). On several occasions Adélies were observed in 3–5 oktas during 1 census, and it was difficult to assign these observations to either (1–4 or 5–8) pack ice category. Thus, while there appeared to be more Adélies in heavy pack ice (Table 2), the insignificant relationship may reflect consolidation of observations into 1–4 and 5–8 oktas, whereas, possibly Adélies prefer concentrations of 3–5 oktas. Further-more, the distribution of Adélies in the Ross Sea was not uniform. The blackened portion of Fig. 2 represents an area where Adélies appeared to be concentrated. Within these areas a density of 5.60 ± 5.13/km^2 was recorded (N = 15), whereas the density was 1.24 ± 1.78/km^2 for the remainder (N = 25) of the Ross Sea; using a *t*-test for unequal variances and sample sizes (Snedecor and Cochran 1967:114–116) these differences were statistically significant (t = 3.179, df = 40, $0.005 < P < 0.01$). This concentration possibly consisted of nonbreeders attracted to a localized food source.

Cline et al. (1969) found Adélies to be the most abundant bird in the summer pack ice of the Weddell Sea and recorded a mean density of 10.96/km^2 (no variance given) and a maximum of 90.81/km^2; they found them most frequently in heavy pack ice. They noted that the distribution of Adélies was uneven and that the greatest numbers were seen in the northern limits of the pack. Their maximum density estimate consisted of 1360 individuals observed on 15 March 1968, roughly 350 km from nearby breeding sites on the Antarctic Peninsula. They noted that this concentration could have comprised dispersing adults from peninsular breeding colonies. Zink (1978) observed large numbers of Adélies in loose pack ice, at the northern limits of the pack ice in the Weddell Sea, and estimated mean and maximum densities of 7.0/km^2 and 101.75/km^2, respectively. (The mean density was corrected downwards to reduce the effect of several large concentrations; original figure was mean density of 28 ± 30.6/km^2 [Zink, unpubl.].) The apparent occurrence of higher densities in the Weddell Sea, as compared to the Ross, Bellingshausen and Amundsen seas, needs further documentation, as both Cline et al. (1969) and Zink (1978) censused near breeding localities and high densities recorded in these areas could have inflated mean densities.

Adélies usually were seen in groups of 6–20 birds, often on the leeward side of ice hummocks and pressure ridges. Like the Antarctic Petrel, Adélies seemed to prefer older pack ice, especially ice with uneven surfaces providing shelter. Few Adélies were observed in the water except when forced to dive as the Glacier approached to within 100 m. Cline et al. (1969) also observed this behavior in the Weddell Sea and noted that Adélies during their post-breeding molt typically remain out of the water and fast. I observed little direct evidence of molting. That few Adélies were seen in the water could be a result of either restricted feeding periods or the difficulty in seeing swimming penguins. On several occasions, Adélies were seen to approach the ship when it was stuck in ice, hence, curiosity and/or lack of fear may explain their reluctance to flee an approaching ship.

Leopard seals (*Hydrurga leptonyx*) prey on adult Adélies at sea, however, the incidence of this, and adult mortality in general, are thought to be low (Watson 1975). On 25 January, 2 crew members on the bridge of the Glacier observed a killer whale (*Orcinus orca*) lunge out of the water and apparently capture 2 Adélies standing at the edge of a floe. Further observations are needed to document the validity of this claim and extent of this predation.

Snow Petrel.—This species is a common antarctic bird generally restricted to cold continental and maritime waters with pack ice and/or icebergs present (Watson 1975). It was sighted on all but 2 days. Most Snow Petrels (98.58%) were seen over pack ice and their distribution was usually uniform. The densities in pack ice were 0.48 ± 0.45/km^2 in 1–4 oktas and 0.38 ± 0.41/km^2 in 5–8 oktas (Table 3); there was no significant difference between these densities (t = 0.697, df = 56, NS). Of the 847 Snow Petrels recorded, the largest flock had 40 individuals and only 5 other flocks had 10 birds or more (10, 12, 13, 19 and 25). In the pack ice of the Bellingshausen and Amundsen seas, Erickson et al. (1972) recorded 3516 Snow Petrels, which represented 34.2% of the total number of birds they observed. Their mean density was 2.83 ± 3.53/km^2 and the maximum was 15.92/km^2, suggesting that this species is more abundant in the Bellingshausen and Amundsen seas. The pelagic distribution map given in Watson (1975) appears to exclude the southern Ross Sea. In the Weddell Sea, Cline et al. (1969) recorded a mean density of 2.82/km^2 and a maximum density of 46.68/km^2 and noted this species most frequently in light and medium pack ice concentrations. The Snow Petrel was the most common (24.5% of total) volant species sighted by Zink (1978); a mean density of 8.0 ± 5.50/km^2 and a maximum density of 98.69/km^2 (not included in the mean density estimate) were recorded in pack ice, primarily in ice concentrations of from 1–5 oktas. Few birds were sighted in open waters and a maximum density of 5.93/km^2 was recorded. The largest group of Snow Petrels observed by Parmelee (1977) in the Weddell Sea was 47 and a total of 1588 birds was sighted (sightings made on 32 of 35 days).

The specific habitat preference of Snow Petrels during this study was not clear as the observed frequencies in pack ice (83.7:14.9) paralleled the relative areas censused in each habitat (71.2:16.7). Although this difference was significant (χ^2 = 100.23, df = 1, P < 0.005) the preferred habitat may have been masked by consolidating the pack ice observations into 2 categories. As with the Adélie Penguin, perhaps 3–5 oktas is a better approximation of their habitat (ice concentration) preference.

Snow Petrels use 2 types of flight. One was "very erratic, almost batlike" (Watson 1975); the birds flew low over the surface, often exhibiting high maneuverability as they closely followed ice edges. This apparent foraging behavior is consistent with the observation of Falla (1964) that their primary food consists of dead or injured macroplankton. As Ainley et al. (1978) noted, such plankton would be expected to accumulate at the edges of cakes of ice. The other type of flight, steady and direct, was used about 7–10 m above open water and occasionally over pack ice.

Snow Petrels frequently hunted along narrow strips of pack ice while avoiding adjacent open water. Upon sighting a prey item a flying individual quickly veered upwards and then fluttered down to the surface. Feeding motions included pecking at the surface and submerging the head and neck to catch subsurface prey, which, according to Watson (1975), consists mainly of fish and some invertebrates. Birds that remained on the surface for 15 sec or longer folded their wings and swam about after prey. Foraging individuals that alighted on the surface for less than 15 sec usually kept their wings unfolded and held at about 60° to the surface. This was also noted by Ainley et al. (1978) and apparently facilitates more rapid or efficient take-offs.

Arctic Tern.—Adult Arctic Terns migrate annually from their arctic breeding grounds to "winter" in the Antarctic during the austral summer. The Arctic Tern was the fourth most abundant species observed and was seen mostly in loose pack ice (Table 2) along the northern edge of the pack; few were encountered south of the pack edge. The maximum density recorded was 2.72/km^2 on 3 February. Ainley et al. (1978) noted that there are no records of Arctic Terns from the Ross Sea. The westernmost observations of terns were on 22–23 January, when 56 birds were sighted between 72°S–72°50′S and 144°40′W–151°6′W. These observations perhaps establish the limit of Arctic Tern distribution in the eastern Ross Sea. Darby (1970) observed only 1 Arctic Tern in 4 north-south traverses of the Ross Sea and that sighting was (actually in the southern Pacific) at 67°55′S, 174°41′E on 18 January 1968.

Arctic Terns occurred in flocks of 5–20 birds; 5 flocks of more than 20 were seen (60+, 52, 41, 30 and 25); a total of 60 birds was observed in groups of fewer than 5. The flock of 60+ terns was on an iceberg near Peter I Island during a helicopter seal census and was not included in the shipboard census data. Erickson et al. (1972) recorded a mean density of 1.27 ± 1.91/km^2 and a maximum density of 7.95/km^2.

Cline et al. (1969) recorded a mean density of 0.97/km^2 and a maximum density of 13.90/km^2, mostly in light and medium pack ice concentrations. Zink (1978) observed a mean density of 1.4 ± 1.14/km^2 and a maximum of 3.39/km^2 in pack ice, as well as a mean density of 2.67 ± 5.36/km^2 and a maximum density of 27.54/km^2 in open seas. These observations support the conclusion that Arctic Terns are most abundant in the Weddell Sea (Watson 1975, Parmelee 1977).

Arctic Terns often passed the Glacier at the outer limits of the transect strip and it was not always possible to see plumage characteristics clearly. Individuals observed closely were in non-breeding plumage and most appeared to be in heavy wing and tail molt. The few feeding individuals observed plunged headfirst into the water from a height of about 3.5 m. Some birds worked low over brash ice and hovered above prey items before picking them off the surface in flight.

Southern Fulmar (*Fulmarus glacialoides*).—Most (287 of 289) of the sightings of Southern Fulmars occurred between 3–6 February. The 2 birds seen west of 91°W were in loose pack ice on 19 January at 68°30′S, 161°30′W and 68°45′S, 159°0′W. Watson (1975) states that this species is highly pelagic and avoids pack ice, but Johnstone and Kerry (1974) remark that Southern Fulmars occur commonly in pack ice in the Australian sector of the southern ocean. The majority of the fulmars sighted east of 91°W (222 of 287), during the present study, were in loose pack ice (1–2 oktas), and of these, 151 were in groups of fewer than 5 and the remainder were in 9 flocks of fewer than 40. Most birds were sitting on the water or on pack ice and few feeding birds were observed. Some fulmars followed the ship briefly.

Erickson et al. (1972) observed this species on 9 of 23 transects, and of the total of 53 individuals sighted, the maximum density was 0.42/km^2 (25 birds sighted in 60 km^2). The scarcity of sightings west of 91°W might be explained by the relative lack of censuses in more northerly ice-free waters (west of 91°W). In the Weddell Sea, Zink (1978) observed 3 of 709 birds in pack ice and Cline et al. (1969) sighted none in pack ice.

South Polar Skua (*Catharacta maccormicki*).—Watson (1975) states that during the austral summer breeding season, adult South Polar Skuas remain near breeding colonies, while sub-adults are found at sea. Of the 110 skuas observed, 102 were within 75 km of McMurdo Station, either in dense pack ice or along the fast ice in McMurdo Sound. Skuas observed near McMurdo Station were light phase birds. Of the remaining 8 skuas sighted, 6 were seen within 115 km of McMurdo, 1 in the western Ross Sea and 1 in the western Bellingshausen Sea. The skua in the western Ross Sea (at 72°10′S, 157°20′W) was in loose pack ice (1 okta), and was a dark phase bird that showed prominent golden hackles and appeared to be in fresh plumage. Presumably an adult (based on plumage, see Watson 1975), it was some 560 km from the nearest known breeding site.

Skuas are more often found near land, thus, there are relatively few pelagic sightings. Erickson et al. (1972) observed 8 individuals. In the Weddell Sea, Cline et al. (1969) observed 4 and Zink (1978) sighted 10. In spite of the paucity of pelagic sightings, individuals banded in Antarctica have been recovered from temperate seas (Watson 1975) and Greenland (Parmelee et al. 1977).

Emperor Penguin (*Aptenodytes forsteri*).—The largest number of Emperor Penguins seen at 1 time was 4. Most sightings were of groups of 2 or 3, widely dispersed in the pack ice of the Ross and Amundsen seas. Most individuals occurred in light pack ice. Erickson et al. (1972) recorded 30 Emperor Penguins in the Bellingshausen and Amundsen seas. There are no known breeding sites along the coasts of these seas and this species apparently does not range far from its breedings sites, except for wandering young birds. Larger concentrations were noted in the Weddell Sea by Parmelee (1977, maximum number sighted at 1 time was 67, total sightings were 363). Also in the Weddell Sea, Cline et al. (1969) found Emperor Penguins most often in light and moderate pack ice concentrations and recorded a mean density of $0.5/km^2$ and a maximum of $5.33/km^2$. Zink (1978) observed a mean density of $0.14 \pm 0.17/km^2$ and a maximum of $0.50/km^2$.

Southern Giant Fulmer.—Watson (1975) stated that this species is highly pelagic throughout antarctic and subantarctic waters and that young individuals usually are distributed farther north than adults. Fourteen of 17 (82.3%) Giant Fulmars sighted in the Ross Sea were juveniles, based on entirely (or nearly so) dark plumage (Watson 1975). There are both dark and white phases of the Southern Giant Fulmar and the young of each phase resemble the adult condition. The birds sighted during the present study were all dark phase. Siple and Lindsey (1937) and Watson (1975) suggested that the percentage of white phase birds increases to the south or in pack ice; the present observations do not substantiate this. Four of the other 8 Giant Fulmars observed in the Amundsen and Bellingshausen seas were adults. Giant Fulmars appeared to be distributed randomly within the 3 habitat types, although this is inconclusive because of the small sample size (25).

Erickson et al. (1972) observed 65 individuals in 1255 km^2 of pack ice census in the Bellingshausen and Amundsen seas. In the summer pack ice of the Weddell Sea, Cline et al. (1969) sighted 8 individuals. Zink (1978) observed 106 Southern Giant Fulmars in the Weddell Sea and found them randomly distributed between open seas and light and heavy pack ice.

Species typical of open seas.—Wilson's Storm-Petrel (*Oceanites oceanicus*).—Wilson's Storm-Petrels were observed in open water or loose pack ice (Table 2); their occurrence closely followed the pelagic distribution given by Watson (1975). Twenty-nine birds were sighted between 178°27′E and 176°25′W (73°10′S–75°S) and 1 bird was seen between 176°25′W and 97°59′W (at 72°0′S, 145°0′W, on 22 January in 1 okta of pack ice) and the remainder (86) were seen between 97°59′W and Palmer Station. The southernmost sighting was at 76°23′S, 171°53′E, about 150 km from McMurdo Station on 26 January. This is near the southwestern limit of the pelagic range, and is approximately 450 km from a breeding site on the coast line of Victoria Land, at 72°S, 170°E (Watson 1975). Ainley et al. (1978) noted Wilson's Storm-Petrels at Cape Crozier (Ross Island) and therefore the limits of its pelagic range in the Ross Sea are equivocal.

Erickson et al. (1972) observed 7 individuals in the pack ice of the Bellingshausen and Amundsen seas. Cline et al. (1969) observed few birds in the pack ice of the Weddell Sea. Zink (1978) recorded a mean density of 0.44 ± 1.15/km^2 and a maximum density of 4.38/km^2 in the pack ice of the Weddell Sea in addition to a mean density of 1.44 ± 1.97/km^2 and a maximum density of 9.65/km^2 in open seas. These studies indicate that the occurrence of Wilson's Storm-Petrels in pack ice is limited. Once, (about 65°30′S, 67°20′W) approximately 50 birds were in view, mostly astern and following the ship. Otherwise the maximum in view was about 4.

Blue Petrel (*Halobaena caerulea*).—All Blue Petrels seen in this study and in the Weddell Sea by Zink (1978) were in open seas. A flock of 55 Blue Petrels was sighted at 70°40′S, 136°52′W on 22 January as the Glacier passed through an extensive patch of open water in the eastern Ross Sea. This sighting is approximately 300 km south of the previous southernmost record (see Watson et al. 1971, Watson 1975). The other 22 individuals were sighted on 4 February, in several small flocks, in the Bellingshausen Sea.

Unidentified petrels.—Unidentified petrels were seen on 9 occasions in the southern Ross Sea on 19, 20 and 26 January. Poor viewing conditions precluded positive species determination but probably only the Mottled Petrel (*Pterodroma inexpectata*) and/or Sooty Shearwater (*Puffinus griseus*) were involved. All of these sightings are south of the known range of the Sooty Shearwater by at least 400 km. Noteworthy is the sighting on 26 January at 76°10′S, 173°30′E, as this location is about 100 km south of the pelagic range of the Mottled Petrel, but is 1500 km south of the known pelagic range of the Sooty Shearwater. During 4 cruises from New Zealand to McMurdo, between January and March 1968, Darby (1970) recorded her southernmost Sooty Shearwater at 68°22′S, 170°18′E, however, she observed no Mottled Petrels.

Antarctic Prion (*Pachyptila desolata*).—A single Antarctic Prion was seen on 3 February at 68°50′S, 100°20′W over open water. Erickson et al. (1972) did not see this species. In the large leads and polynyas of the Weddell Sea pack ice, Cline et al. (1969) recorded 24 prions and a mean density of 0.04/km^2. Zink (1978) recorded a mean density of 0.21 ± 0.40/km^2 during open water transects in the Weddell Sea and Parmelee (1977) observed 304 prions, which included a single observation of 100+ birds.

Cape Pigeon (*Daption capense*).—On 22 January, at 70°40′S, 136°52′W, a Cape Pigeon was seen over open seas. This sighting represents a southern extension of approximately 200 km based on the map in Watson (1975). However, Ainley et al. (1978) noted records of Cape Pigeons in the Ross Sea at 72°S and 76°54′S. Other records include sightings by Darby (1970) at 73°46′S and by the first Byrd Antarctic Expedition (*in* Siple and Lindsey 1937) in Discovery Inlet, at 78°30′S. From these records it is possible to conclude that only a few Cape Pigeons, perhaps sexually immature individuals, wander through the southern Ross Sea. As noted by Ainley et al. (1978) the observation of Spellerberg (1971) that Cape Pigeons were abundant off the northern tip of Ross Island during March 1964, is suspect. Of the other 14 Cape Pigeons sighted during the present study, 5 were in light pack ice and 9 were over open waters in the Bellingshausen Sea. Erickson et al. (1972) sighted a Cape Pigeon in the pack ice of the Amundsen Sea at 67°47′S, 128°50′W on 11 February 1972. In the northwestern Weddell Sea, Zink (1978) sighted 694 Cape Pigeons in open seas and recorded a mean density of $1.0 \pm 1.22/km^2$ and a maximum density of $4.2/km^2$; few were observed in pack ice. Cline et al. (1969) observed a total of 25 Cape Pigeons and a mean and maximum density of $0.04/km^2$ and $1.70/km^2$, respectively.

Albatrosses.—Four species of albatrosses (Black-browed, Gray-headed, Wandering and Light-mantled Sooty [*Phoebetria palpebrata*]) were sighted during open water censuses in the Bellingshausen Sea from 4–6 February. These species are typically highly pelagic and avoid pack ice (Watson 1975). The largest number of adults of either the Black-browed Albatross or Gray-headed Albatross in view at 1 time was 3. The actual number of albatrosses observed is difficult to determine, because of their well known ship-following habits (except for the gray-headed). Also, 2 or 3 Black-browed or Gray-headed albatrosses were observed (discontinuously) within a short time and there was suspicion as to whether there were 1, 2 or 3 individuals involved. Immature Black-browed and Gray-headed albatrosses are difficult to distinguish at sea, and the records of "unidentified mollymauk" in Table 2 refer to juveniles of these species.

DISCUSSION

Pelagic seabird observations obtained during the austral summer in Antarctica are difficult to interpret because the relative abundances of immatures, unsuccessful breeders and foraging breeders are unclear. Darby (1970) suggested that many birds seen far from land during the breeding season were probably non-breeding or immature individuals. Delayed sexual maturity is typical for most seabirds. Consequently, it is probable that sexually immature procellariids and penguins constitute a high proportion of birds seen at sea, since they evidently avoid regions near breeding sites

(Watson 1975). Because of the short austral breeding season, it is likely that most unsuccessful breeders depart to sea rather than renest. Brook and Beck (1972) discovered nesting Antarctic Petrels, Snow Petrels and South Polar Skuas in the Theron Mountains, 250 km from the nearest foraging grounds in the open waters of the Weddell Sea. Warham et al. (1977) speculated that breeding Mottled Petrels, from colonies on islands south of New Zealand, may range up to 2200 km into the southwestern Ross Sea during off-duty periods. Beck (1969) noted that Cape Pigeons in breeding condition have been collected 350 km from the nearest breeding site. Breeding petrels range considerable distances from nest-sites and undoubtedly contribute to the number of birds seen at sea; this contribution may increase as observations are made nearer to breeding sites. It is not generally possible to distinguish ages or sexes of most species on the basis of sight observations. Therefore, the relative abundance of adults and immatures is uncertain. Sightings of birds hundreds of km from the nearest land (not necessarily breeding sites; see Table 2 for breeding sites of species sighted during this study) provide data for species-level regional distributions and information about species' pelagic ecology and behavior. These data can also be used to ascertain regional patterns in the composition of pelagic seabird communities.

Density estimates are useful for providing a quantitative measure of avian occurrence. Densities (birds/area) are superior in most instances to measures of birds per unit of time or linear distance because of potentially serious biases in observer proficiency and ability, ship speed and uncorrected biases in the nonuniform probability of sighting different species at a given distance. Densities can also be extrapolated to estimate the number of birds in a given region. Erickson et al. (1972) stated that the area circumscribed by the outer limits of their sampling effort was about 250,000 km^2. If the mean density for the Antarctic Petrel (4.31/km^2) is applied to this area, the resulting number of birds is 1,077,500. However, it should be recognized that there is considerable variance (SD = 6.55) about this mean. The Antarctic Petrel often occurs in dense aggregates and additional censuses are probably required. It is necessary to establish the uniformity of the habitat within the bounds of the census effort and to account for such clumped distributions of birds (or at least acknowledge them). Also, because the age structure of this pelagic "population" is unknown, such population estimates are probably area specific and not necessarily applicable to other geographic regions.

In antarctic ecosystems, there are typically few species, but these are often abundant (Watson 1975, Cline et al. 1969). In the present study, most of the census effort (88% of the total census area) was in pack ice. Ten species were observed in pack ice and of these, 4 (Antarctic Petrel, Adélie Penguin, Snow Petrel and Arctic Tern) accounted for over 90% of birds observed in pack ice. Erickson et al. (1972) found the same 10 species in the pack ice of the Bellingshausen and Amundsen seas, although few Adélie Penguins. In order of decreasing abundance, the Antarctic Petrel, Snow Petrel and Arctic Tern accounted for 98.2% of the 10,270 total birds they observed. In the pack ice of the Weddell Sea, the Adélie Penguin, Snow Petrel and Antarctic Petrel accounted for 69.4% of the 14,376 total birds (pack ice and open seas) observed by Zink (1978) even though only 21.6% of the 698 km^2 of census area was in pack ice. Also in the summer pack ice of the Weddell Sea, Cline et al. (1969) found that the Adélie Penguin, Snow Petrel, Arctic Tern, Emperor Penguin and Antarctic Petrel accounted for 98.8% of the 9451 total birds sighted. These studies substantiate the claim that the pack ice environment is dominated by a few, rather abundant species. However, the same species are not equally dominant between areas nor are the relative abundances equal.

Cline et al. (1969) concluded that pack ice concentrations influenced bird distributions and densities and they found the highest densities of most species in ice concentrations of 10–60%. The observations of Ainley et al. (1978) further support this conclusion. During the present study, ice concentrations of 1–5 oktas supported the greatest numbers of birds. However, the type of pack ice also was important. Pack ice varies considerably in thickness, surface and subsurface structure; these vary with age of ice and amount of compacted snow. Different kinds of ice probably offer different potentials to birds, in terms of resources or shelter. Older pack ice (2 years and up) is thicker and generally has a rough, irregular surface that provides wind shelters for resting or molting birds. In addition, its subsurface has usually deteriorated into a matrix of small holes and channels which are often frequented by various invertebrates (Watson 1975) such as krill (pers. obs.). There were qualitative indications that more birds were in areas of older pack ice than in newer (thinner and flatter) pack ice. Future studies should determine the type of ice as well as its concentration for correlations with the occurrence of birds, seals and whales.

Voous (1965) suggested that food availability and abundance are probably the primary factors influencing the distribution of birds in antarctic waters. From the above discussion, it is apparent that the pelagic occurrence of seabirds results from an interaction of food availability and ice concentration and structure.

There was insufficient census effort in open waters to determine, with much certainty, the species characteristic of this environment. Species typical of open, continental antarctic waters are the Southern Fulmar, Wilson's Storm-Petrel, Blue Petrel, Southern Giant Fulmar, Cape Pigeon, Antarctic Prion and Light-mantled Sooty Albatross (Watson 1975). In general, seabird diversity is greater in antarctic maritime and subantarctic waters than in antarctic continental waters (Darby 1970, Szijj 1967, Watson 1975). Darby (1970) thought that the northern limit of the pack ice constituted a barrier to the southward expansion of many species and noted that several species were consistently 80–100 km north of the pack, whatever its northern limit. On 4 February, the Glacier passed out of what was probably the northern extent of pack ice (68°S, 87°W). The species composition changed rapidly (within 2 km) from predominantly pack ice species to species characteristic of open seas. The interface between pack edge and open water potentially supports large numbers of birds because of an accumulation of plankton (Routh 1949). However, no such concentrations of birds were noted.

The interactions and associations of various species at sea are poorly understood. In the Bellingshausen and Weddell seas (Zink, unpubl.) Wilson's Storm-Petrel appeared to be an "indicator" of localized patches of food. Individuals seemed to search independently and were randomly interspersed until a patch of food was located. Others then flocked to the site and fed as described by Alexander (1954) and Murphy (1936). They headed into the wind, pattering their feet on the surface and feeding through the patch of food and then returned downwind and worked through this specific area again. Such a grouping of Wilson's Storm-Petrels often attracted other species such as the Cape Pigeon and Southern Giant Fulmar, and albatrosses in more northerly areas. Both the nature of specific roles in such assemblages and the geographic trends in composition of interspecific flocks are unknown.

SUMMARY

Observations of 16 species of seabirds in antarctic waters were obtained during the austral summer of 1976 while the USCGC Glacier cruised from McMurdo Station (Ross Island) to Palmer Station (Anvers Island). Information on distribution, abundance, habitat (ice concentration) preference and behavior of these species is given and comparisons are made with recent seabird surveys in the Bellingshausen, Amundsen and Ross seas and the Weddell Sea.

The Antarctic Petrel, Adélie Penguin and Snow Petrel were the most abundant species, respectively, in pack ice, where most of the 136.1 h of observation occurred. The Adélie Penguin, which was generally absent from the Amundsen and Bellingshausen seas, and the Antarctic Petrel both occurred in large concentrations, while the Snow Petrel was more uniformly spread throughout the pack ice encountered on this cruise. These species, the Arctic Tern and the Emperor Penguin, probably are the primary species of the antarctic pack ice ecosystem. Antarctic avifaunas are dominated by relatively few species. However, the same species were not dominant throughout all regions examined and in many cases the relative dominances were different. A part of these regional differences may be attributed to the distribution of sampling effort between different regions and habitats. Pack ice con-

centrations of 1–5 oktas appeared to support the greatest numbers of birds. There were indications that older, thicker ice is preferred by birds because its irregular surface provides shelter and its subsurface structure is inhabited by various invertebrate prey items of seabirds.

Because there were few censuses in open seas, only general indications of characteristic species were obtained. The Wilson's Storm-Petrel, Blue Petrel, Black-browed Albatross, Gray-headed Albatross, Cape Pigeon, Light-mantled Sooty Albatross, Wandering Albatross and Antarctic Prion were sighted either entirely or mostly over open waters.

The relative abundance of adults and immatures in pelagic observations is unknown because they are not distinguishable at sea. Also, both sexually immature birds and foraging breeders can be expected to occur long distances from breeding sites.

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COLOR PLATE

The color plate Frontispiece of the Antarctic Petrel (*Thalassoica antarctica*) has been made possible by an endowment established by George Miksch Sutton. Joseph R. Jehl, Jr. provided the photograph.