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BIRD LIFE AT CAPE CROZIER, ROSS ISLAND

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Do birds merely cope with pack ice as a physical barrier restricting access to the sea and its food resources, or are they so adapted to exploit the opportunities it presents that they rely on its presence? The answer to this question would greatly further our understanding of seabird community organization in polar regions. After all, pack ice is unique to polar seas and several seabird species are unique to pack ice regions, particularly in the Antarctic (see Murphy 1936).

The first steps toward understanding the relationship of seabirds to Antarctic pack ice are to document bird occurrence under various ice conditions and to determine whether seasonal changes in ice cause changes in the bird life. Because ice hinders ship travel our knowledge of bird occurrence in the Antarctic is limited, especially in the Ross, Bellingshausen, and Weddell seas where the pack ice is heaviest and most persistent (see summary in Watson et al. 1971). Shipboard censuses have been sporadic and have largely taken place in late summer when ice conditions are lightest. Only the observations by Cline et al. (1969), made during late summer in the Weddell Sea, offer much insight into Antarctic bird/ice relationships, and only those by Parmelee et al. (1977), taken in a relatively ice-free area of the Antarctic Peninsula near the periphery of Antarctica, offer information on seasonal changes in the Antarctic avifauna. The present paper adds to this knowledge by summarizing information gathered during 12 periods, early spring to fall (1962–1976; Table 1), at Cape Crozier, Ross Island, in the Ross Sea at virtually the southernmost reach of the ocean (Fig. 1).

STUDY AREA AND METHODS

Cape Crozier is at the juncture of Ross Island, the Ross Ice Shelf and the most southerly portion of the Ross Sea (Fig. 1). Each year during the periods of 1961–1971 and 1974–1976, we travelled by helicopter or by overland traverse from McMurdo Station about 70 km away. Once at Crozier our stay was continuous, usually from mid-October to mid-February (Table 1). Each season we visited the Emperor Penguin (*Aptenodytes forsteri*) rookery which is about 5 km from the field camp. Until 1970–71 the bird log kept by Wood contained all records of the less common species but only irregular sightings of the common ones. All persons at Crozier were invited to contribute observations and emphasis was placed on recording the first sighting of each species each season. In the last 2 seasons Ainley maintained a daily log of all birds seen as well as the number of hours spent in observation. During the 10 to 12 h spent in the field each day, the sea was searched for birds every 3 to 10 min. Each day that the wind was below 88 km/h at least 1 continuous hour, often more, was spent scanning

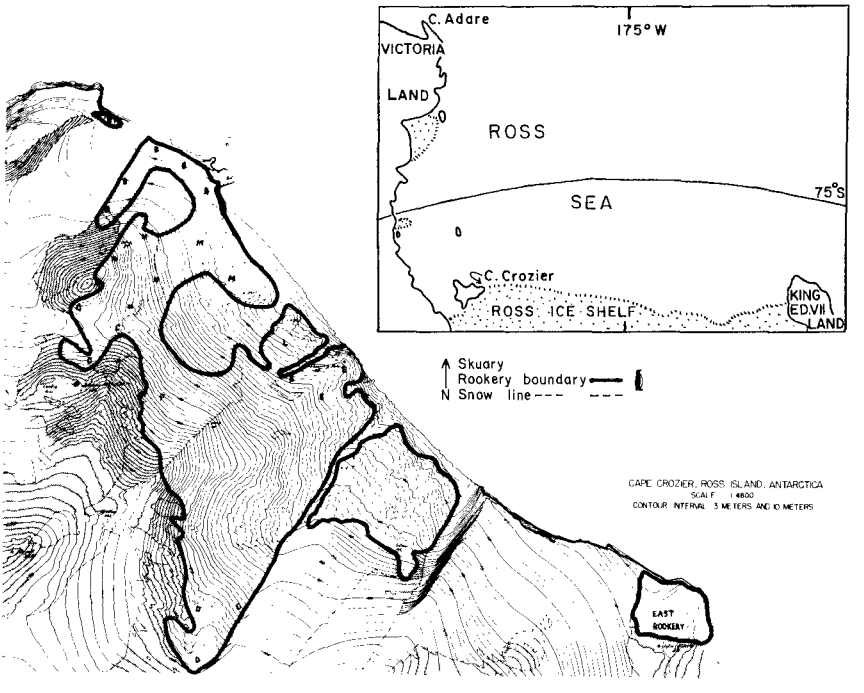

FIG. 1. Map showing breeding areas at Cape Crozier and the location of Cape Crozier in the southern Ross Sea.

the sea from a good vantage point on the beach 10 m above the sea. From there, birds could be detected within about 2 km. Beginning in the 1967–68 austral summer (excepting 1970–71), daily records were kept of wind speed and direction (measured by an anemometer and wind vane) and percent of ice cover on the seas visible from the hut. We could usually see pack ice conditions 40 km out to sea from the hut at 135 m elevation; a new hut replaced the old one in 1974, but ice observations were still recorded from the old site.

SPECIES ACCOUNTS

Emperor Penguin (*Aptenodytes forsteri*).—The Cape Crozier Emperor Penguin breeding colony, the southernmost and the first discovered for this species, is one of the smallest in population size. Adults arrive to nest in late June, eggs laid are incubated from late June through August and chicks hatch in September. This schedule is about a month later than at more northerly rookeries (see summary in Stonehouse 1953). By mid-December the earliest hatched young fledge and by early January all birds have de-

TABLE 1

DATES ON WHICH SPECIES WERE FIRST SIGHTED AT CAPE CROZIER DURING EACH SUMMER PERIOD

Observation Period	Chinstrap Penguin	Snow Petrel	Antarctic Petrel	Southern Fulmar	Giant Fulmar	Wilson's Storm-Petrel	Brown Skua	Southern Black-backed Gull
25 Jan 1962–22 Feb 1962	—	—	—	—	—	—		
16 Oct 1962–2 Mar 1963	24 Feb	17 Nov	26 Dec		8 Jan	23 Dec		
24 Dec 1963–28 Feb 1964	22 Feb	24 Dec	?		8 Jan	6 Jan	9 Jan	
20 Oct 1964–19 Feb 1965	2 Feb	20 Nov	?		16 Jan	4 Dec		mid-Nov
18 Nov 1965–22 Feb 1966	15 Jan	23 Nov	23 Nov		22 Jan	13 Dec	6 Nov	
25 Oct 1966–18 Feb 1967	—	19 Nov	?		4 Jan	20 Dec		
20 Nov 1967–14 Feb 1968	—	?	7 Dec	19 Dec	10 Jan	11 Jan	12 Dec	
20 Oct 1968–16 Feb 1969	—	15 Nov	2 Dec		4 Jan	?		
19 Oct 1969–11 Feb 1970	—	11 Nov	28 Nov	19 Dec	14 Jan	7 Dec	19 Dec	23 Nov
23 Nov 1970–21 Dec 1971	—	(3 Dec)	3 Dec	17 Dec	—	18 Dec		
22 Oct 1974–27 Jan 1975	—	11 Nov	8 Dec		(not seen)	19 Dec		
21 Oct 1975–8 Dec 1975	—	24 Nov	4 Dec		—	—		

— Observation period inappropriate to determine valid first date.
( ) Date possibly affected by period of observation.
? Present but no notes on date of first sighting.

TABLE 2

COUNT-ESTIMATES OF EMPEROR PENGUINS AT CAPE CROZIER, ROSS ISLAND

Year	Number adults	Number chicks[1]	Number breeding pairs[2]	Dates of observation	Comments
1967	500±	0	?	19 Oct	About 200 adults seen wandering in pack-ice off Adélie rookery
1968	1000±	651(60)	711	26 Oct, 16 Nov, 1 & 6 Dec	Two separate breeding groups
1969	1300±	680(17)	697	23 Oct, 11 Nov, 2 & 22 Dec[3]	One breeding group
1974	600±	249(7)	256	14 Nov, 17 Dec,[3] 31 Dec[3]	One breeding group 200 m back from the sea
1975	274	94(24)	108	29 Oct,[3] 18 Nov,[4] 5 Dec[3]	Breeding group 500 m back from the sea. Many adults wandering in pack-ice off Adélie rookery

[1] Numbers in parentheses in chick column are of dead chicks.
[2] Derived by adding number of live and dead chicks; minimum estimate.
[3] Observations made from cliffs above rookery.
[4] Visit made at sea level but no entry made into vicinity of breeding group.

parted. Thus our observations which began in October each year cover only the last third of the Emperor breeding season.

In 1962 and 1963, Stonehouse (1964) estimated 1500 breeding pairs at Cape Crozier, a population 4 to 5 times greater than 60 years earlier (Wilson 1907). He attributed the change to an increasingly favorable breeding environment brought about by movement of the Ross Ice Shelf against the Ross Island cliffs. During October and early November, 1968 and 1969, we estimated a population of 720 breeding pairs based on our counts of chicks (including dead ones; Table 2). In 1974 and 1975, we estimated 260 and 120 breeding pairs, respectively. With the exception of 1967 (see Table 2), every population estimate since 1962 has been lower than the previous count.

Apparently unfavorable nesting habitat contributed to the low numbers in 1975. Other unknown factors such as fewer breeding adults may also have been involved but we were not present at egg laying and can not be sure. The colony was situated 500 m back from the sea and was accessible only over a very tortuous route with many crevasses. The route was so difficult that we quickly gave up attempts to follow it and instead censused chicks

from the cliffs directly above. Although we made a thorough search of more accessible areas, we found no evidence of other nesting birds. Open water occurred right to the edge of the ice shelf instead of, as in other summers, there being fast sea ice upon which the birds reared young. Conceivably they bred on this ice in 1975, but as in 1902 and 1967 (see Wilson 1907, Stonehouse 1964, Sladen et al. 1968) an unusual storm may have broken the ice loose and swept the birds to sea. Unusually large numbers of adults wandered about over the pack ice off the Crozier Adélie rookery during both 1967 and 1975, and during both years far more than usual numbers of Emperors were seen as far away as McMurdo Station. These birds were quite possibly ones that had failed to breed or failed during breeding at Cape Crozier.

Adélie Penguin (*Pygoscelis adeliae*).—The Cape Crozier Adélie Penguin population is among the largest known for this species. An estimate derived from analysis of aerial photographs taken in 1966 placed the breeding population at about 102,500 pairs, 13,500 of which nested in a rookery about 500 m east of the main rookery and separated from it by an ice field and cliffs (Butler and Müller-Schwarze 1977). There are about 166,000 non-breeding birds that also spend time in the rookery each season, mostly during very brief visits in December (Ainley, unpubl. data).

Counts of adults, made in 2 of the few hundred breeding colonies at Crozier during 4 seasons, were continued to late January in 1974–75 (Fig. 2). On 16 October 1962, our earliest date at Crozier, no Adélies were present in the pack ice immediately offshore or in the main rookery. We saw the first in the pack ice on 22 October and in the rookery on 23 October. On our next earliest arrival at Crozier, 19 October 1969, about 200 Adélies were present at the rookery. Most were standing or lying on snow slopes or on the beach, and none appeared in the 2 census colonies until 21 October. During 1968, 1974, and 1975 the maximum number of adult penguins in the rookery was attained by 11 November. In 1969 the maximum occurred on 6 November, an early date presumably related to light pack ice conditions (Ainley and LeResche 1973). Arrival at the breeding grounds thus occurred later at Crozier than at more northern Signy Island where peak numbers occurred on 4 November in 1950 (Sladen 1958) but slightly earlier than at nearby Cape Royds (100 km from Crozier) where peak populations occurred 11 to 15 November in 4 seasons (Taylor 1962, Stonehouse 1963, Yeates 1968). A second but lower peak, composed largely of one member of each pair guarding chicks, failed breeders, and young non-breeders, occurred in late December (31 December in 1974).

In 1968 and 1969 the mean date of clutch completion ranged from 16 to 20

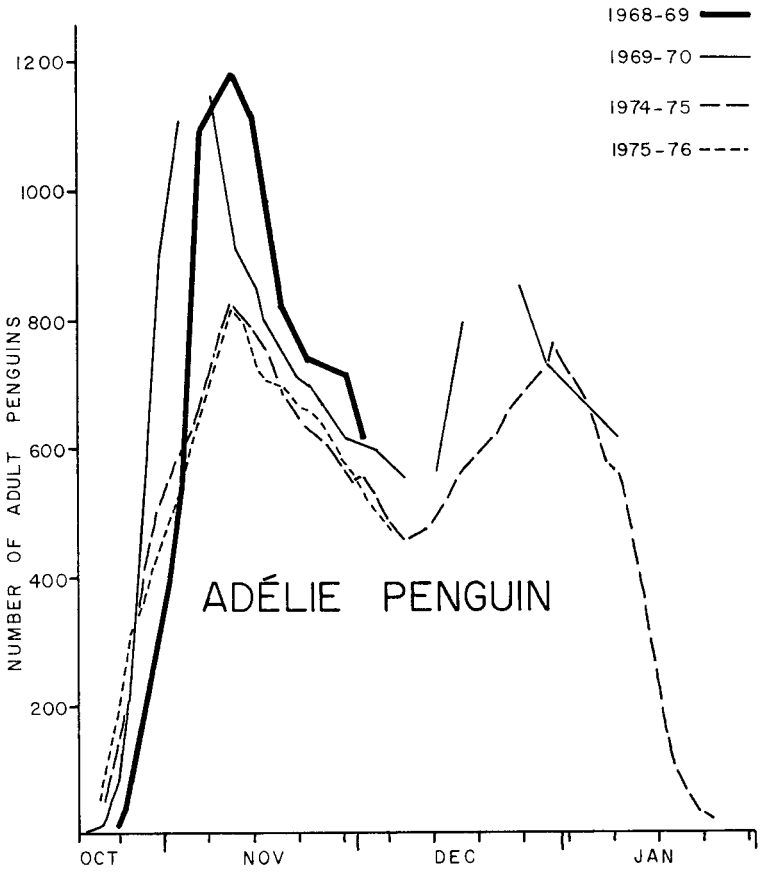

FIG. 2. Census results showing seasonal variation in total number of Adélie Penguin adults in 2 colonies at Cape Crozier, during 4 summers.

November (Ainley and LeResche 1973). First eggs were found on 3 November in 1967, 1968, 1974, and 1975, and on 5 November in 1969. The last eggs were laid during the first week of December but young rarely fledged from them. The first fledglings departed the rookery in late January (29 January 1970; none had departed by 27 January 1975). All chicks and most adults were gone 2 weeks later. A few hundred adults came ashore in late January to begin molt and must still have been there well past the date when the last breeders departed.

Chinstrap Penguin (*Pygoscelis antarctica*).—Nine individuals, most of which were captured and banded (see Sladen et al. 1968), were seen on 15

occasions during 4 years. These records were as follows: 1963—1 bird on 24 February (T. Taylor); 1964—1 bird which began molt on the 27th, present 22 to 27 February (W. Emison); 1965—1 bird on 2 February (D. Thompson) and 2 birds on 17 February, present 15 January to 21 February (W. Sladen and others); 2 birds, 1 of which began molt by the 13th and the other of which began molt on the 20th, present 13 to 21 February (W. Emison); and 1 bird present and molting 20 to 21 February (R. Wood and W. Emison). All but 1 were seen only at the beach and evidently all had come ashore to molt. Since many of the last-dates-seen for these birds were the dates we left Crozier, many of these birds remained much longer than the spread of dates indicate. Because no persons were at Cape Crozier beyond mid-February after the 1965–66 season, Chinstraps, usually seen in late February, were not observed in later years. Watson et al. (1971) include the 1962–64 records in their summary and list only one other record for the entire Ross Sea. Since Chinstraps have begun to breed in recent years on the Balleny Islands (Sladen 1964), several hundred kilometers west of the Ross Sea, one might expect an increase in their visits to the Ross Sea.

Southern Giant Fulmar (*Macronectes giganteus*).—The giant fulmar is another non-breeding member of the Crozier avifauna. Two banded birds captured (run down when winds were calm) originated from Macquarie Island, about 1000 km to the northwest, the closest known nesting colony (see Wood et al. 1967). We recorded this species in all years except 1974–75 on 27 dates between 4 January and 14 February. We have no explanation for their absence during that one season; if they arrived after our departure on 27 January, they were unusually late (Table 1). Several birds were usually present on any day. The average counted per day was 7 to 15 birds ($\bar{x} = 8.5$, n = 50 groups, SD = 12.9) although 83 were present on 17 January 1967, a year when they seemed more abundant than usual (average count for dates that year: 25.6, SD = 26.6, range = 9 to 83). The ratio of light to dark phase birds was 1:6.4 for counts made on 22 days in 6 seasons (n = 238 birds), a ratio similar to that observed by Wilson (1907) in waters of the Pacific Ocean south of the Antarctic Convergence. Giant fulmars, which were never observed feeding in the penguin rookery, were observed feeding on penguin carcasses left floating in the water by leopard seals (*Hydrurga leptonyx*); they were often harassed by skuas interested in the same carcasses. Giant fulmars often roosted on icebergs and on snow slopes at the sea edge.

Southern Fulmar (*Fulmarus glacialoides*).—Southern Fulmars were recorded during only 3 of the 12 years. The first record was of a bird seen on 19 December 1967 (Sladen et al. 1968); another was recorded on 19

December 1969, and individuals were seen 2 or 3 times during the following week, and 1 was observed on 17 December 1970. All were seen as they flew along the beach. This species was not included among records for the southwestern Ross Sea reviewed by Watson et al. (1971). Owing to this local paucity of records, Spellerberg's (1971) comment that they were "often seen" during March 1964 at the mouth of McMurdo Sound, about 110 km west of Crozier, is very interesting. The nearest breeding locality is at the Balleny Islands (Watson et al. 1971).

Antarctic Petrel (*Thalassoica antarctica*).—Antarctic Petrels, recorded in all years except 1963, 1964, and 1966, were seen 21 times on 13 dates between 23 November and 1 January. Sixteen of the observations and 19 of the dates fall between 2 and 23 December. Observations discussed by Spellerberg (1971) indicate that they remain in the southern Ross Sea through February. They rarely occurred as solitary individuals, as also noted by others (e.g. Darby 1970); the largest flocks contained 30 birds on 1 January 1970, 40 on 26 December 1962, and 45 on 23 December 1974. Only 9 of the 21 observations were of single birds. The mean number of birds per sighting was 8.8 ($n = 21$, $SD = 13.8$). Often the flocks flew 50 to 100 m above the sea, and on several occasions they meandered high above the Adélie Penguin rookery.

For 12 of 14 visits from 1967 to 1975 when wind velocity was recorded, Antarctic Petrels were present only during southerly winds of 50 km/h or greater. Under these conditions, the petrels would have had to fly up wind to reach Cape Crozier from the sea (see further discussion under Snow Petrel). Their nearest breeding colony is King Edward VII Peninsula several hundred kilometers to the east (Watson et al. 1971).

Snow Petrel (*Pagodroma nivea*).—Snow Petrels were seen almost daily from late November until late December, but after the first week of January they were seen only 7 times. We recorded them on 49 dates but no doubt they were present on more. The earliest sighting, occurring in 2 different years, was 11 November (Table 1) and the latest was 24 February. Siple and Lindsay (1937) recorded 13 March (1934) as the latest date in the southern Ross Sea. The closest known breeding localities are Cape Hallett and King Edward VII Peninsula (see Watson et al. 1971).

Snow Petrels usually occurred singly or in small, loose flocks. During 1974 the mean number of petrels per sighting was 2.0 (131 sightings, range 1 to 13 birds); single birds were seen on 83 of those occasions. Rarely were they present in large flocks: 17 in one flock on 11 December 1964, 19 on 27 November 1975, 22 on 3 December 1964, and 31 on 24 December 1963. Many times they flew well inland and on several occasions they investigated

the cliffs and talus slopes of Post Office Hill 3 km inland. Twice in 1974 and once in 1975 we saw 3 to 5 individuals flying inland together at an altitude that must have exceeded 600 m.

Analysis of the 1974–75 records revealed that Snow Petrel occurrence at Cape Crozier was related to wind speed and direction and to the extent of pack ice cover. They occurred daily from 11 November to 25 December and the number seen per hour of observation was related directly to the strength of southerly (offshore) winds ($r = 0.68$, $SD = 2.9$, $t = 4.36$, $P < 0.05$). No counts were made during winds higher than 96 km/h that year but, based on observations from the hut window during stronger winds in other years, they appeared to be abundant when wind velocity exceeded that speed. On 27 November 1975, we ventured from the hut when winds were blowing 112–120 km/h with higher gusts. During an hour of observation we counted 68, a figure that fits with the correlation just discussed. They were definitely making headway into the winds, seemingly rather easily. There was no relationship in the 1974–75 data between the number seen and the strength of northerly (onshore) winds ($r = 0.17$, $SD = 0.8$, $t = 0.70$, $P > 0.05$).

The mean number seen per hour of observation during winds that were calm, northerly (onshore), southerly (offshore) but 38 km/h or less, and southerly but greater than 38 km/h, respectively, was 0.02, 0.79, 0.38, and 4.2 petrels per hour. Using a one-way analysis of variance (Steel and Torrie 1960:113) we find these 4 means to be dissimilar ($F = 5.51$, $df = 3$ and 41, $P < 0.05$); but computing the analysis without the value for southerly winds greater than 38 km/h (4.2) gives a set of similar means ($F = 1.86$, $df = 2$ and 24, $P > 0.05$). Hence larger numbers of Snow Petrels at Crozier occurred only when southerly, offshore winds exceeded 38 km/h; as the winds increased so did their numbers. The petrels occurred at about the same rate under all other wind conditions.

The number seen at Cape Crozier was also affected by the pack ice cover. Generally speaking, Snow Petrels were rarely seen earlier than mid-November; before then the pack ice was normally heavy and often covered the sea completely. They were also rare after 1 January when there was usually no pack ice present. During the intervening period when Snow Petrels were present almost daily, the number seen per hour was related inversely to the percentage of the sea covered by ice ($r = 0.442$, $SD = 29.99$, $t = 2.95$, $P < 0.05$). Confusing the issue somewhat, however, was the fact that during that same period the percentage of ice cover was related inversely to the strength of the wind ($r = 0.6865$, $SD = 24.60$, $t = 5.06$, $P < 0.05$). Strong southerly winds, which also attracted petrels, blew the pack ice offshore decreasing the percentage of ice cover; light winds had little effect and northerly winds, which never exceeded 38 km/h, concentrated the pack against the shore. Since we rarely

observed Snow Petrels feeding in the open water (taking advantage of the conditions wrought by strong southerlies), it is difficult to surmise the reason for their marked response to wind and ice conditions. Wilson (1907) noted Snow Petrels feeding on euphausiid crustaceans and occasionally fish, thrown by breaking surf onto the edges of ice floes. The petrels seen at Crozier during strong winds might have been seeking such an opportunity, but under those conditions the pack ice edge was usually pushed too far for us to observe. On a windy day in December 1975, when the ice edge met the land at Crozier, we observed petrels flying along the edge; we were able to view them with 8× binoculars at a distance of 1 km, but none appeared to be feeding.

Snow Petrels tended to fly along pressure ridges in the pack ice and, when ice was sparse, flew back and forth for several minutes from one floe or berg to another. In so doing they were perhaps seeking and taking advantage of updrafts created by the ice, but may have been searching for under-ice organisms available only along exposed edges of ice. We seldom saw Snow Petrels alight. One bird apparently stopped to rest for a few hours on an ice floe (winds were light); another alighted on the edge of the beach ice to investigate a penguin head remaining from a leopard seal kill. On 2 other days (brash ice present, winds calm) they were observed in what was possibly feeding activity; they repeatedly dropped to the water for an instant and, keeping the wings fully extended above the back, pecked at (objects in ?) the water.

Wilson's Storm-Petrel (*Oceanites oceanicus*).—Wilson's Storm-Petrels were seen in all years except 1967 and were recorded 21 times on 18 different dates between 4 December and 8 February. A single bird seen by Halle (1973) on 6 January 1971, is included in the tally. Twelve of the observations and 10 of the dates were between 4 and 23 December, indicating a peak in occurrence during that period. Observations reviewed by Spellerberg (1971) suggest they depart by late February. Only single individuals were present except once when 2 birds were seen flying together; most were observed as they flew along the beach, but 9 times they flew well inland. Twice single birds fluttered about the talus slope of Post Office Hill, seemingly suitable nesting habitat, but they never alighted. Watson et al. (1971) overlooked the occurrence of the species in the southwestern Ross Sea, but both Wilson (1907) and Spellerberg (1971) reported them there. The nearest known breeding site is Cape Hallett, several hundred kilometers to the northwest (Watson et al. 1971).

Brown Skua (*Catharacta lonnbergi*).—Five Brown Skuas have been seen at Cape Crozier. These were identified on the basis of size (see Parmelee et al. 1977:fig. 4), color and voice. Those individuals present on 6 November

1966 (collected: a female, USNM 533558), 12 December 1967, 19 December 1969, and 29 November 1970 have been reported previously (Wood et al. 1967, Sladen et al. 1968, Schlatter and Sladen 1971). The first Crozier record of a single bird present on 9 and 10 January 1964 has not been reported. All Brown Skuas were observed on or very near the beach, usually within clubs (R. P. Schlatter, pers. comm.) of South Polar Skuas. This species has been noted only once previously in the southern Ross Sea (see Watson et al. 1971). The species is suspected to breed on the Balleny Islands, but otherwise the closest known breeding site is Macquarie Island (Watson et al. 1971).

South Polar Skua (*Catharacta maccormicki*).—The South Polar Skua population at Cape Crozier consists of 1900 to 2000 breeding birds and an estimated 200 to 400 non-breeders (Wood 1971). Breeding birds nested in 6 discrete areas. The biology and dynamics of breeders in this population were described by Wood (1971); similar information on non-breeders was presented by R. P. Schlatter (pers. comm.).

In mid-to-late October only 1 or 2 were seen on any day, usually near the beach or over the pack ice. The earliest skua was seen on 19 October in 1962 and 1969. During 1975, nesting area occupation by skuas was observed by censusing birds each morning (ca. 09:00) in a 20 × 100 m plot at the site of the old hut and helicopter landing pad. That season the first skua on the ground was seen on 27 October (the previous season it had been 28 October). They occurred in the study area sporadically for the following week, although increasing numbers were seen flying about near the beach or over the sea. Thereafter the number of territorial skuas increased steadily (Fig. 3). The most spectacular increase in numbers occurred between 7 and 13 November 1975, coincident to the period when Adélie Penguin numbers increased most sharply. A very fierce storm, and consequently an ice-free sea, occurred then too. The sharp increase in penguin numbers was a direct result of the storm and sea conditions (see Ainley and LeResche 1973), but whether skua arrival was also directly related is not known. The maximum number of occupied territories was reached about 21 November and numbers declined in the following week. The peak and decline may have represented birds attempting unsuccessfully to establish new territories in the area. Egg laying began on 25 November when the number of territories leveled off. The earliest and latest known egg laying dates at Crozier are 17 November and 31 December, respectively.

The latest we remained at Cape Crozier was 2 March (1963). Our observations suggest that most skua young probably fledge by late March or early April. Most adults probably depart by then, too; this schedule is supported by the records reviewed in Spellerberg (1971).

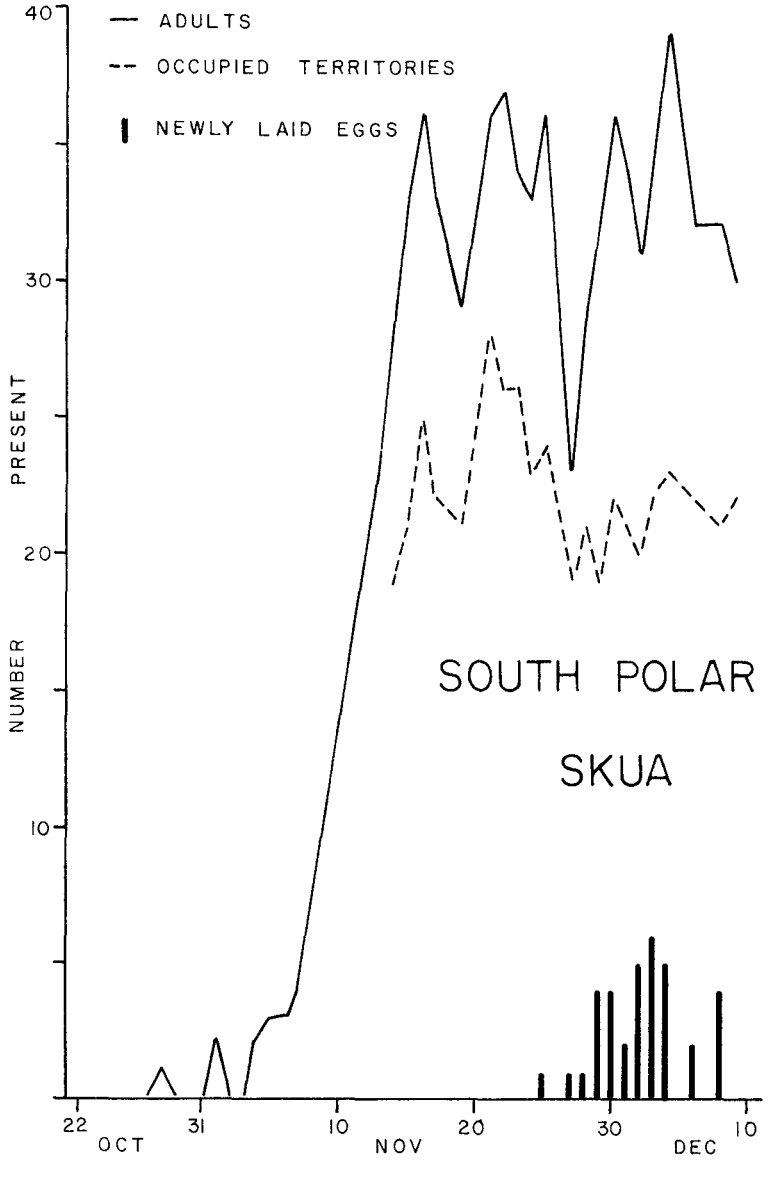

FIG. 3. Census results showing number of adult skuas, number of occupied territories, and number of eggs laid each day for an area near the old hut site at Cape Crozier, 1975–76 season.

Southern Black-backed Gull (*Larus dominicanus*).—An adult Southern Black-backed Gull was seen by R. T. Peterson and Sladen on 15 and 16 November 1965. Another, a second year individual, was present from 24 November until 3 December 1969. It fed with the skuas on remains of Adélie Penguins left by leopard seals. This species had been noted only once before in the Ross Sea (see Watson et al. 1971). The closest breeding locality is Macquarie Island.

DISCUSSION

A continuous belt of pack ice surrounds Antarctica. Vertebrates best adapted for life in that zone should be those found in its interior reaches where the ice is most persistent. The observations from Cape Crozier, deep within the pack ice of the southern Ross Sea, help us to characterize the avian community in that environment. Primary species in the community, in terms of regularity of occurrence and relative abundance, are the Adélie Penguin, Emperor Penguin, Snow Petrel, South Polar Skua, Southern Giant Fulmar, and Antarctic Petrel. Secondary species are Wilson's Storm-Petrel, Chinstrap Penguin, Southern Fulmar, Brown Skua, and Southern Black-backed Gull. The order of listing might well be different had observations been made farther offshore. Particularly interesting in light of the reports by other researchers (see below) is the rare presence of Chinstrap Penguins, Brown Skuas, and Southern Black-backed Gulls, the relative rarity of Southern Fulmars, and the absence of Cape Pigeons (*Daption capense*), prions (*Pachyptila* spp.), and Arctic Terns (*Sterna paradisaea*).

Murphy (1936:598) considered the Southern Fulmar to be second only to the Snow Petrel for its ubiquity in the pack ice. That is probably true, however, only for the periphery of the pack ice zone where the ice is loosely concentrated and where most observations, including Murphy's have been made. Deep within the pack ice of both the southern Ross and Weddell seas fulmars have proved to be quite rare (Cline et al. 1969, Watson et al. 1971, Halle 1973, this study). Cape Pigeons, though not yet observed at Crozier, have been reported in the southern Ross Sea twice: single birds seen by Halle (1973) at 72°S off Cape Hallett in 1971 and by Wilson (*in* Lowe and Kinnear 1930) at 76°54′S in 1912. On the other hand, Spellerberg (1971) mentioned in passing (!) that for waters "off the northern tip of Ross Island" during early March 1964 "the Cape Pigeon . . . was by far the commonest bird sighted." Many other observers have said the same for Antarctic Petrels, a species quite similar in coloration and size (see Darby 1970), in those waters at that time of year. In view of their scarcity in the region in our and others' experience, their superficial similarity to another abundant species,

and the extreme characteristic of Spellerberg's records, one must view the latter with suspicion. Finally, no records exist for the Arctic Tern or for prions at Crozier. Arctic Terns have never been reported in the Ross Sea, although Cline et al. (1969) reported them at least as far as 74°37′S in the Weddell Sea; prions have been seen as far south as 73°38′S in the Ross Sea by Darby (1970) and to 69°36′S in the Weddell Sea by Cline et al. (1969).

The Crozier-area avifauna reached its greatest complexity in terms of population sizes, frequencies of occurrence, and variety of species during December and, to some extent, January (Table 3, Fig. 4). One factor determining that pattern may have been the timing of the plankton bloom which also affects the timing of breeding (see Beck 1970). Balech et al. (1968) found that phytoplankton in the Pacific sector of Antarctica reached peak volume during December and then declined slowly through May (Fig. 4); zooplankton, which feeds upon the phytoplankton and upon which the birds largely feed, should lag slightly behind the phytoplankton in their abundance cycle. The peak in bird occurrence, avian community complexity, and plankton biomass thus corresponded quite closely and were probably related. Why birds did not remain abundant throughout the December to May period of high plankton abundance is discussed below.

An equally, if not more, important factor affecting the birds seemed to be the pack ice conditions. In the Weddell Sea, Cline et al. (1969) found highest concentrations of most avian species where ice was light (10 to 30% cover) to medium (40 to 60%). Few species preferred the extremes of open water and total ice cover. Their observations fit with those averaged over a 5-year period at Crozier where the pack ice began to disappear in late October and was completely gone by January (Fig. 4). The ice cover declined most rapidly during December, from 60 to 10%, precisely the range when the largest number of species and the highest populations occurred. Only the Chinstrap Penguin and giant fulmar arrived after the pack ice disappeared entirely. Even so, Cline et al. (1969) found Chinstraps in the Weddell Sea only where pack ice was light, and giant fulmars mainly where ice was light or absent. The disappearance of the pack ice also corresponded to the disappearance of a Crozier breeding species, the Emperor Penguin, which, after fledging of young in December, requires ice on which to molt. Much earlier in the summer, the presence of 2 other Crozier breeding species (Adélie Penguin and South Polar Skua) also was affected by change in the pack ice: their arrival corresponded to the period when the pack ice first began to lessen. Some open water is beneficial during breeding because it increases the accessibility of food (see Ainley and LeResche 1973) but, when breeding is completed, Adélies, like other Antarctic penguins, are better able to molt in heavy pack ice (Cline et al. 1969).

TABLE 3

THE AVERAGE NUMBER OF BIRDS RECORDED PER DATE DURING "WEEKLY" PERIODS

Weekly Period[1]	Chinstrap Penguin	Southern Giant Fulmar	Southern Fulmar	Antarctic Petrel	Snow Petrel	Wilson's Storm-Petrel	Brown Skua	Southern Black-backed Gull	Total Species[2]
Oct 3									(3)
4									(3)
Nov 1							1		1 (4)
2					2			1	3 (6)
3				4	5			1	4 (7)
4				1	32		1	1	4 (7)
Dec 1				3	41	1		1	5 (8)
2				7	41	1	1		4 (7)
3			1	34	16	2	1		5 (8)
4			1	15	13				5 (8)
Jan 1		1		15	12	2			5 (8)
2	1	4			7	1	1		5 (7)
3	1	31							4 (6)
4	1	25				1			4 (6)
Feb 1	1+	18			4	1			4 (6)
2	1+	17			1	1			4 (6)
3	3				4				3 (5)
4	1+				2				3 (5)
Total Birds	9	460	5	177	991	21	5	2	

[1] Weekly periods (1, 2, & 4) were extended to 8 days to produce 4 periods per month.
[2] Breeding species are included in parentheses only in extreme right column.

Although some open water must be available for Antarctic birds to feed, it seems strange that they apparently preferred water partly covered with ice floes. Except for short term requirements for molting in the penguins and the breeding requirements of the highly specialized and remarkably adapted Emperor Penguin, Antarctic birds should not need ice for resting. They do indeed use it for that purpose but, since their relatives elsewhere do not enjoy the luxury of floating ice islands, it should not be a factor critical to survival in the Antarctic. Possibly the diversity of environment offered by the pack ice is the important factor. Based on what little we know about the feeding

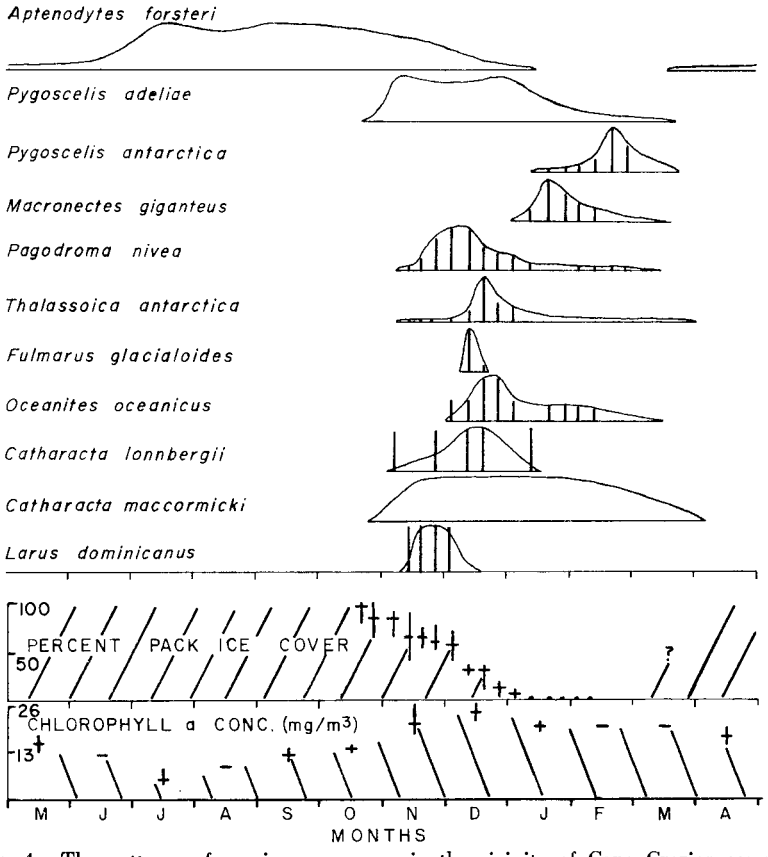

FIG. 4. The patterns of species occurrence in the vicinity of Cape Crozier compared with pack ice cover and phytoplankton standing stock. Pattern for Emperor Penguins based on Stonehouse (1953) and personal observations; pattern for Adélie Penguins and South Polar Skuas based on Figs. 2 and 3, personal observations, and records for late season occurrence reviewed in Spellerberg (1971); patterns for other species drawn from data in Tables 1 and 3 and from Spellerberg (1971): the solid vertical bars represent the relative proportion of birds present compared to the highest weekly total (from Table 3). Ice concentration is shown as the percent cover (mean and range of values) on the sea at Crozier for weekly periods; data are from daily observations taken during 5 seasons: 1967–68 to 1969–70, 1974–75 and 1975–76. Ice cover for March and April are estimates based on information contained in Green (1975). Phytoplankton concentrations (mean and range of values) are taken from Balech et al. (1968, fig. 3).

ecology of these birds, they are conspicuously opportunistic in both feeding behavior and diet. With the exception of the penguins, all scavenge on surface prey or carrion. Light to medium ice cover perhaps provides these birds with several opportunities for feeding not available in open water or heavy ice:

they can feed on open water organisms, ice edge organisms, and under-ice organisms. As Cline et al. (1969) pointed out, they can feed on the many organisms often crushed between rapidly moving floes and, as discussed earlier, can find potential prey thrown up and stranded by wave action upon floes. Thus within light to medium pack ice more kinds of opportunities for food seem available, and this might even relate to our earlier discussions about why winds "attract" birds to Crozier. Wind can rapidly change the configuration and density of pack ice, especially where the ice is relatively loose, and in so doing might rapidly present some of the above opportunities. It would seem worthwhile to observe the avian pack ice community of Antarctica with this idea of habitat complexity and diversity of opportunity in mind.

SUMMARY

Observations of the birds at Cape Crozier, Ross Island, within the southernmost reaches of the Ross Sea in Antarctica were summarized for 12 summers during the period 1961–76. Data on the occurrence of 11 species were presented. The Emperor Penguin breeding colony at Crozier declined in size due to an unfavorable nesting situation and perhaps unknown factors. Wind conditions affected the occurrence of Snow Petrels and Antarctic Petrels; winds under 38 km/h had little effect but offshore winds above 38 km/h attracted significant numbers to the area. Rather interesting were records for Chinstrap Penguins, Brown Skuas, and Southern Black-backed Gulls, the relative rarity of Southern Fulmars, and the absence of Cape Pigeons, prions and Arctic Terns.

The avifauna was most diverse in terms of population sizes and variety of birds during December, the month of peak plankton concentrations and of changing ice cover on the sea. The birds may have responded particularly to the latter because such conditions offer the greatest diversity of habitat and foraging opportunity.

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