SHORT COMMUNICATIONS

THE EFFECTS OF WEATHER AND ICE CONDITIONS ON BREEDING IN ADÉLIE PENGUINS

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Year to year differences in Adélie Penguin (*Pygoscelis adeliae*) egg and chick losses have been reported for Cape Royds, Ross Island, and have been attributed to differences in timing of the pack-ice break-out (Taylor 1962; Stonehouse 1963; Yeats 1968). This paper shows that timing of the pack-ice break-out at Cape Crozier, 90 km from Royds (fig. 1), is related to wind conditions and proposes that the interplay of wind and ice conditions has much more complex effects on Adélie breeding than merely causing differences in egg and chick losses.

METHODS

We report here on data collected during two Adélie breeding cycles, each of opposite extremes in weather. Observations were made in three study areas (B, C, N) that included about 3000 breeding territories. Age-related factors will not be referred to but all observations were made on birds banded as chicks (Sladen et al. 1968), and in both breeding seasons included birds of ages 3 to 7 years. It was not necessary to handle birds since band numbers could be read with binoculars from 6 m away. When a banded bird was sighted, its number, location of territory, and behavior were recorded. Thereafter, we visited them every 1 to 3 days to record status of eggs and chicks. To check nest contents, we approached to within 4–5 m of a parent, making it stand for an instant to shake or stretch. While it stood, we could see eggs or chicks. Mates of banded birds were squirted on the breast with dye from a distance and were eventually banded. We censused three colonies totaling about 1000 territories every few days to determine changes in numbers of penguins at the rookery.

Weather and ice conditions were recorded every evening from our hut, situated on the upper edge of the rookery. The hut was 136 m above sea level and 800 m from the beach. From it we had an unobstructed view of at least 100 km out to sea. Wind speed and direction were read from an anemometer and wind vane. Speed was later converted to Beaufort Scale (fig. 2). The pattern of ice cover was drawn on mimeographed maps of the adjacent Ross Sea, and from these maps we later estimated the per cent ice cover on the sea.

The sea freezes when winds are calm and temperatures are low enough, usually in the late fall, winter, and early spring. The resulting smooth *sea-ice* may stretch unbroken for long distances. High winds and sea swells break this ice into *floes* that range in area from a few meters square to many hectares. The open waters between floes are called *leads*. The broken sea-ice covering on the sea is *pack-ice*. In the pack-ice, wind pushes floes together with such force that they ride up and over each other or where they abut the floe edges buckle and break and pieces of ice are thrust into ridges sometimes several meters in height. In the spring in a movement known as *break-out*, winds aided by higher temperatures move the ice away to leave open water along the coast and hundreds of kilometers out to sea.

WIND AND ICE CONDITIONS

Winds generally blow at Cape Crozier from the polar plateau in the south toward the sea in the north. Winds blowing out to sea for 2–3 days at Force 6 can move the pack-ice temporarily away from Cape Crozier almost to the horizon. However, before actual break-out, the ice moves back when the southerly winds subside. When the wind does blow off the sea from the north, it is of low velocity but does help water currents push the ice toward shore.

The 1968–69 Adélie breeding season, extending from October to February, was unusually calm and the 1969–70 season was unusually stormy. This statement is based on discussions with R. C. Wood who spent ten consecutive summer seasons at Cape Crozier,

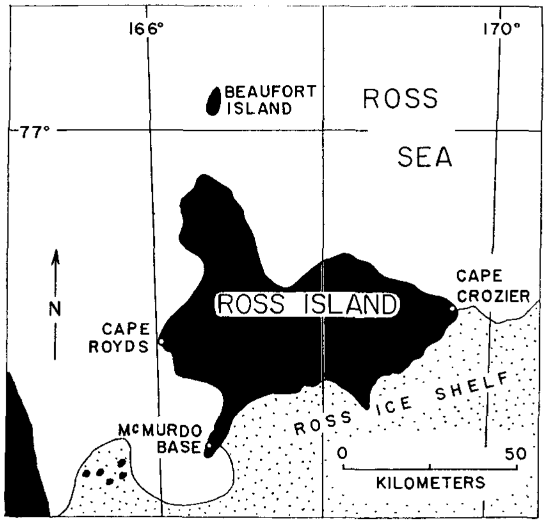

FIGURE 1. Ross Island and adjacent parts of the Ross Sea.

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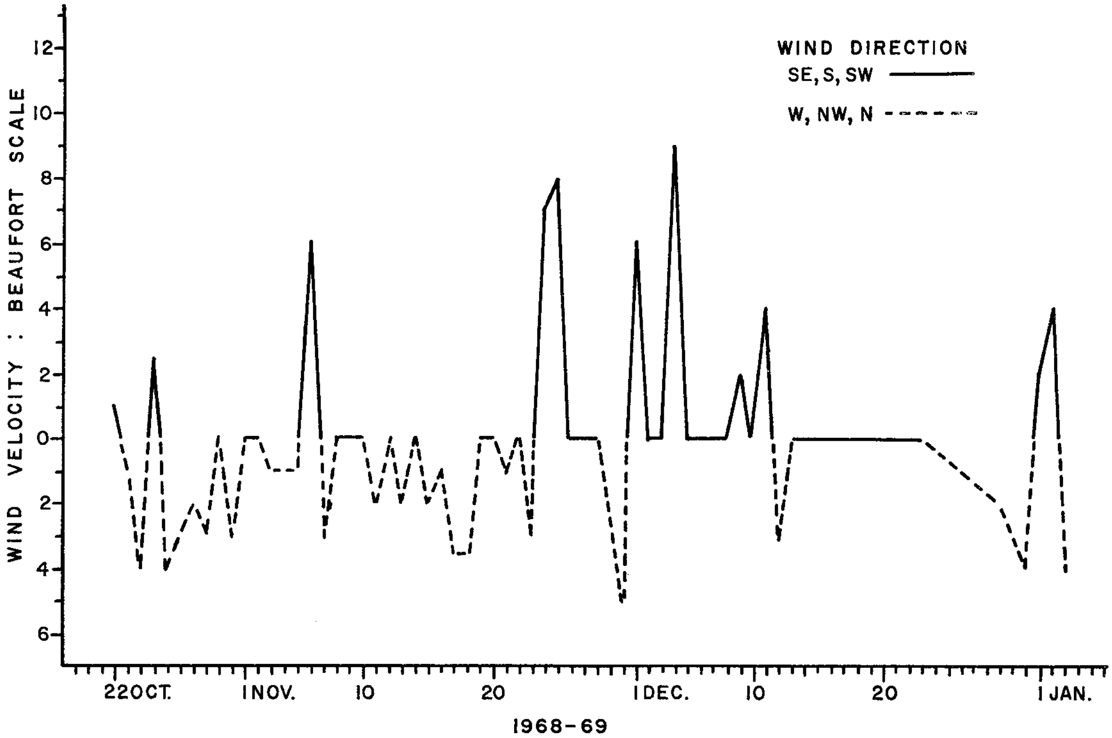

FIGURE 2. The pattern of wind conditions at Cape Crozier in 1968–69. Wind speed is in Beaufort Scale: Force 0 = <1 mph; 1 = 1–3; 2 = 4–7; 3 = 8–12; 4 = 13–18; 5 = 19–24; 6 = 25–31; 7 = 32–38; 8 = 39–46; 9 = 47–54; 10 = 55–63; 11 = 64–72; 12 = 73–136.

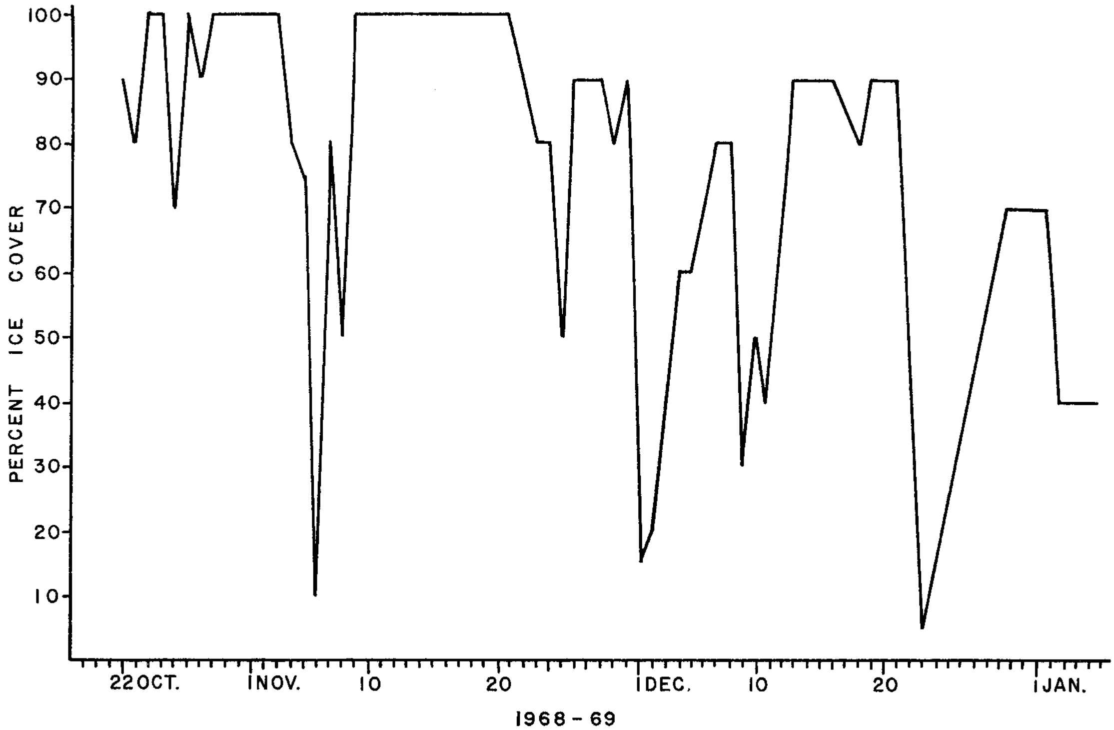

FIGURE 3. Changes in the amount of pack-ice covering the Ross Sea visible from Cape Crozier in 1968–69.

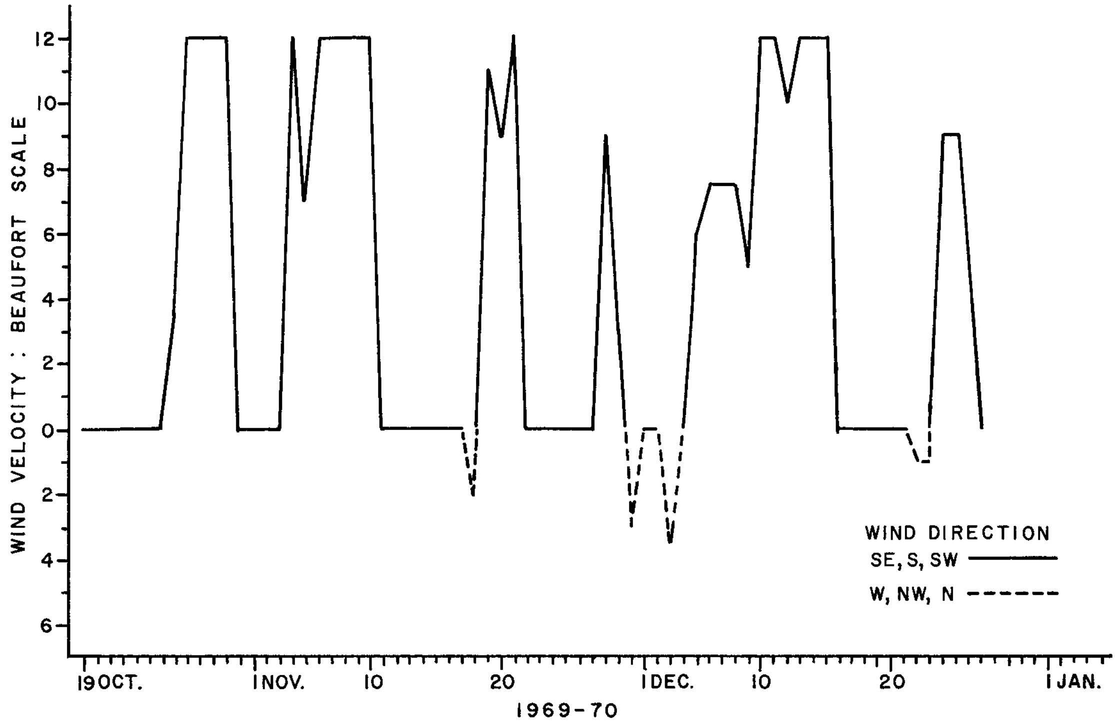

FIGURE 4. The pattern of wind conditions at Cape Crozier in 1969–70. For Beaufort Scale values see figure 2.

1961–62 through 1970–71. The 1969–70 season was the stormiest recorded by the U.S. Navy at McMurdo Base, Ross Island, about 80 km from Cape Crozier, since the beginning of its Operation Deepfreeze in 1957. In 1968–69 (the calm season), offshore winds reached Force 8 on 2 days and Force 6 on one day (fig. 2). During the breeding season, there were also many days when winds were onshore. Con-

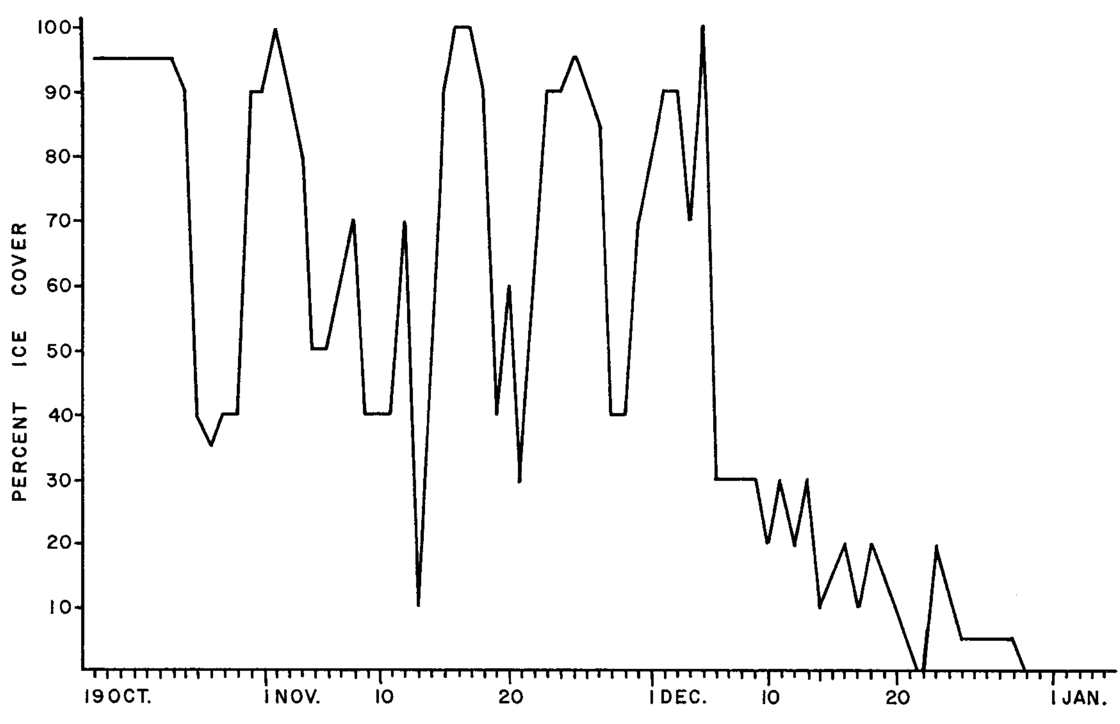

FIGURE 5. Changes in the amount of pack-ice covering the Ross Sea visible from Cape Crozier in 1969–70.

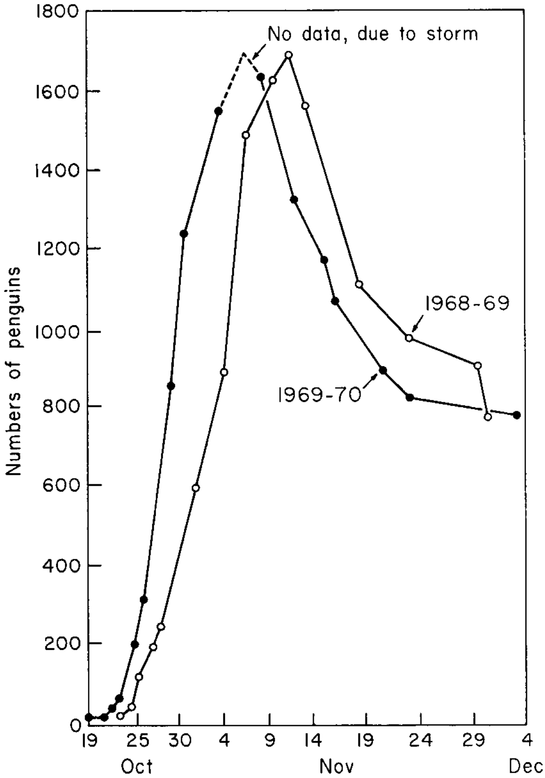

FIGURE 6. The number of Adélie Penguins in three colonies showing the dates of first arrivals and of peak population in the 1968–69 and 1969–70 breeding seasons.

sequently, the ice covered most of the visible sea through the Adélie egg-laying period and break-out did not occur until late December, or after peak egg hatching (fig. 3).

Wind and ice conditions in 1969–70 (the stormy season) were just the opposite (figs. 4 and 5). There were strong southerly winds on many days, including nine during the early breeding season when winds reached over 160 km/hr. The pack-ice moved

TABLE 1. A comparison of breeding for the two seasons at Cape Crozier.

	1968–69	1969–70	P (X^2)
Total birds sighted ages 3–7	638	574	
% birds ages 3–7 attempted breeding	19.5	34.6	< 0.001
% attempted breeders successful	31.2	57.3	< 0.001
% attempted breeders deserted eggs	24.8	10.5	< 0.001
% attempted breeders reversed incubation schedule	9.6	6.5	> 0.4
% reversed incubators successful in hatching eggs	25.0	69.2	< 0.03

TABLE 2. Mean dates of completion for clutches of one and two eggs.

	1968	N	1969	N	P (X^2)
Two-egg clutches	20 Nov	18	16 Nov	91	< 0.001
One-egg clutches	20 Nov	8	20 Nov	22	> 0.7

out early and often and full break-out occurred by early December, or about peak egg hatching.

When ice covers the sea in early spring, penguins must *walk* a great deal while traveling from their wintering areas to the rookery; and later must walk to and from the rookery and feeding grounds. Travel over the rough pack-ice is difficult and time-consuming. Small leads also contribute to slowing the rate of travel since, in response to predatory Leopard Seals (*Hydrurga leptonyx*) hunting in the leads, Adélies wait long periods before crossing from one floe to the next. In contrast, when the sea is clear of ice, Adélies travel normally, swimming rapidly over long distances.

BREEDING

After arriving in the spring, male Adélies fast 5–6 weeks while they establish territories, proceed through courtship, and then incubate for about 2 weeks. Females fast for only 2–3 weeks but also lay one to three (usually two) eggs. Thus Adélies require early season fat stores to breed successfully.

In the windy year (1969–70), spring arrival was about a week earlier than in the calm year (1968–69) as indicated by the differences in dates for first arrivals and the time of peak rookery population (fig. 6). In 1969–70 about 60% of the population arrived during a 5-day storm when winds reached 160 km/hr and over on 4 days. Hence, high winds and rough seas do not hinder Adélie Penguin travel at sea, but indeed aid it by pushing the ice away.

The breeding of Adélies differed in several other respects for the two seasons as shown in tables 1 and 2. (1) In 1969–70, of those birds sighted, significantly more attempted breeding (i.e., were members of a pair that produced eggs). (2) Corresponding to the week difference in spring arrival for the two seasons, there was a 4-day difference in mean date of clutch completion for two-egg clutches: 20 November in 1968 and 16 November in 1969 ($P < 0.001$). There was no difference in mean completion date for one-egg clutches, most of which were laid near the end of egg laying in all years (LeResche and Ainley, unpubl. data). (3) A greater proportion of all clutches were of the maximum size (two eggs) in 1969–70 than in 1968–69 ($P < 0.001$). (4) Of those birds that attempted breeding in 1969–70, a greater proportion successfully raised chicks to the creche stage, within 2–3 weeks of fledging ($P < 0.001$). (5) Correspondingly, fewer pairs deserted eggs or chicks in the stormy year 1969–70.

If a pair was to be successful in hatching eggs, males usually incubated first, the female going to sea to feed soon after laying (Sladen 1958; Taylor 1962). Sometimes, however, early arriving males which had taken an unusually long time to acquire a mate and establish a pair-bond left to feed just as the female was laying her eggs. By the time the eggs were laid, the male's fat reserves had become completely diminished (Johnson et al. 1971). These situations we call reversed incubation schedules. They were successful only if the male could feed and return to relieve the female in less than a week. Otherwise, her fat reserves became diminished and she deserted. When males incubated first, the female normally was away from the rookery for almost 2 weeks. Although for the two seasons there was little difference in the number of reversed incubation schedules attempted, significantly more attempts were successful in 1969–70 (table 1). The ice moved out often enough in that year to allow the males to travel rapidly between rookery and feeding grounds. Once a pair successfully completed a reversed incubation schedule, they were as successful in hatching their eggs as pairs maintaining a normal schedule.

DISCUSSION

Several factors in addition to lowered egg and chick losses contributed to high productivity in 1969–70. Not only was there a greater proportion of successful pairs, but a greater proportion of the population attempted breeding and a greater proportion of breeding pairs laid large clutches. High winds and accompanying blowing snow had no apparent detrimental effects although direct mortality of eggs and chicks might be expected. Thus reports by Yeats (1968) for Cape Royds that egg and chick mortality result from an above normal number of days having winds above 32 km/hr do not seem to apply to Cape Crozier. On the contrary, at Cape Crozier, Adélies are aided by offshore winds as strong as 160 to 190 km/hr. Only as in 1967–68 (Sladen et al. 1968) when winds were of higher velocity (i.e., 225 km/hr) and when they came at critical times such as peak egg laying did they cause losses. Indeed, winds above 210 km/hr make it difficult for Adélies to maintain their footing.

Furthermore, factors just discussed that contributed to high productivity played their part before the pack-ice break-out. Thus reports by Stonehouse (1963) for Cape Royds that early spring break-out results in high productivity are also less applicable to Cape Crozier. Early break-out and high productivity at Cape Crozier seem to be co-results of windy weather rather than being in a cause-effect relationship.

Adélie Penguins have evolved the ability to store large amounts of fat, in part at least, to begin breeding early in spring when ice cover on the sea is usually extensive. Stored fat allows extended travel over sea-ice and long periods in the rookery without having to take time to walk to sea to feed. In the high latitudes, where breeding seasons are usually short, the saving of time is important. High productivity during stormy years results because open sea and quick travel allow Adélies to use fat reserves and food for production of eggs and for fasting during territory establishment, courtship, and incubation rather than for travel itself. In a sense, the wind increases the availability of food resources.

Perhaps one reason Adélies have been so successful in colonizing Cape Crozier is because of its offshore winds during spring. The presence of extensive snow-free land area must also be a major factor. It is estimated that 300,000 Adélies breed at Cape Crozier (Emison 1968). On the other hand, at Cape Royds, which is protected from southerly winds by high mountains, there are only 4000 Adélies even though much nesting area is available (Stonehouse 1963). Perhaps if food were more accessible for Cape Royds Adélies, the breeding population there would be larger.

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RICHARDSON'S ZACATECAS COLLECTION, I

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In 1888 and 1889, W. B. Richardson collected extensively for Salvin and Godman in western México. Some of these bird skins have been studied and published upon several times, but others still remain unrecorded in the literature, yet safe in the drawers of the British Museum. Publication has been meager in the case of species treated in the earlier volumes of the *Catalog of Birds of the British Museum* or of the *Biologia Centrali-Americana* by Salvin and Godman (1879–1904), which were published before 1890. Richardson apparently kept no journal, but an approximate itinerary for the state of Zacatecas was constructed from his labels. Richardson's labels in 1888 ordinarily included sex, locality, and month, but in 1889 he usually added the day of the month. When he wrote exact dates on his labels, Richardson consistently wrote in this order: day, month, year.