—報　告—
Reports

A Note on the Feeding Behavior of the Adélie Penguin

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アデリーペンギンの給餌行動についての一考察

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要旨：クレイシ中期にアデリーペンギンの給餌行動を，24時間連続観察し，以下の4点についてまとめた．

1)　雛が給餌される頻度，2)　給餌のため，親鳥がコロニーに帰る頻度，3)　雛が出てしまった空巣を含むなわばりの識別と利用，4)　雛の生存率と育雛行動の雛数によるちがい．

Abstract: The feeding behavior of Adélie Penguin *Pygoscelis adeliae* was observed from morning till night during the middle crèche stage, and data about the following items were obtained: 1) feeding frequency of chicks, 2) returning frequency of parents, 3) recognition and utilization of the abandoned nesting territories, and 4) difference of survival rate of chicks and parental care due to brood size.

1. Introduction

Many studies have described the physiological and ethological aspects of Adélie chicks; *e.g.*, growing speed (SAPIN-JALOUSTRE and BOURLIÉRE, 1951; SLADEN, 1958; TAYLOR and ROBERTS, 1962), regulation of body temperature (SAPIN-JALOUSTRE and BOURLIÉRE, 1951; GOLDSMITH and SLADEN, 1961), parent-chick recognition (SLADEN, 1953, 1958; PENNEY, 1968; AOYANAGI and TAMIYA, 1981).

During almost the entire crèche stage, both parents are absent from the colony to look for food to feed their chicks. After returning, the parents call the chicks by **LMV** (Loud Mutual Vocalization), and the chicks which respond to the calls are fed. Some are fed at the familiar site, but others outside of such sites after feeding chases.

Feeding frequency may determine the chicks' survival and growth, but a detailed study on this subject has not been done. Our 24-hour observation aimed at collecting information about the following: a) how frequently chicks are fed in a day, b) how many times the parents come to the colony to feed the chicks, and c) how important are the former nesting territories as a place for feeding chicks.

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2. Methods

The B4 colony was selected for this study; it is located at the southern end of the northern rookery at Cape Bird, Ross Island, McMurdo Sound (Fig. 1). This is an almost circular colony and is formed on a sandy flat of foreshore; the longest diameter is 10 m, and the shortest, 9 m. The colony is at the base of a morain mound which is 5 m high and has a vantage point. The whole colony can be viewed clearly from it. All the adult penguins were individually banded on their flippers with aluminum-alloyed flipper-bands (the U. S. Fish and Wild-Life Service) in order to identify them.

The observation was done on January 21, 1979, from the mound. Care was taken not to disturb the penguins as far as possible. All feeding behaviors were watched till the feeding was completed and the following items were recorded: 1) direction from which the parent entered the colony, 2) calling position of **LMV**, 3) duration from the

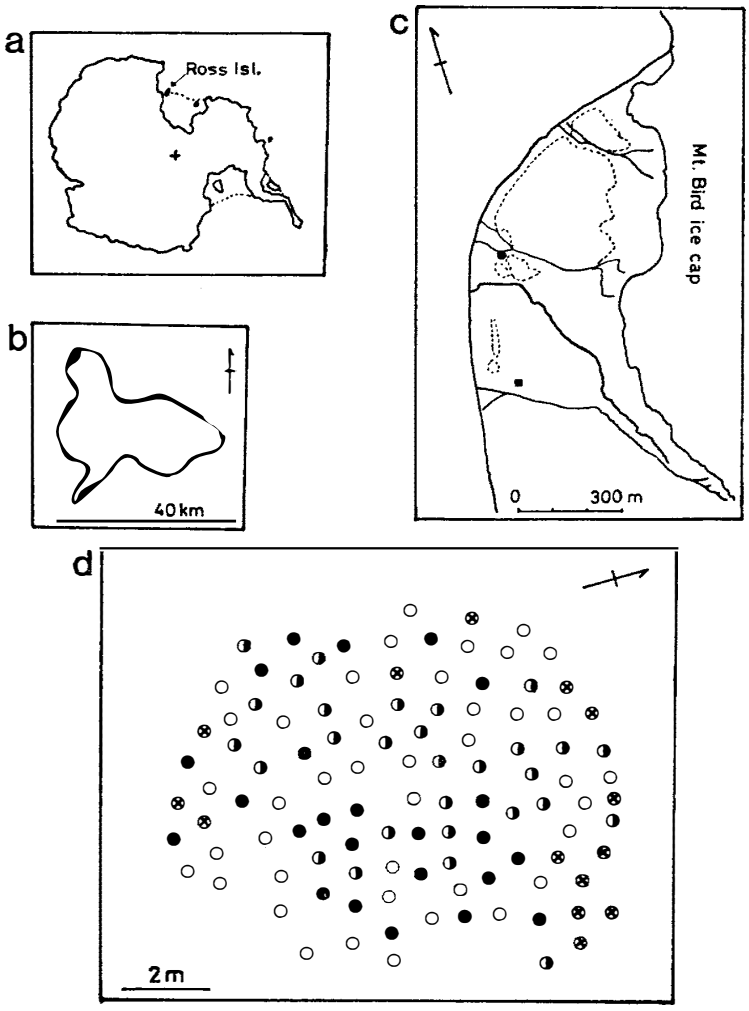

Fig. 1. a. Antarctica. b. Ross Island. Covered: Northern Cape Bird rookery. c. Northern Cape Bird rookery. Closed circle: B4 colony; closed square: laboratory and hut; area enclosed in dotted line: guano area. d. The B4 colony. Closed circles: nests where 2 chicks fledged; circles half open: nests where only 1 chick fledged; open circles: failed nests; circles with cross: unused nest-hollows.

parent's arrival to the last regurgitation, 4) feeding site (on the calling position, some times within the colony and other times outside the colony), and 5) resting site of the parent after feeding.

The detailed map of the colony is shown in Fig. 1d. The sites where the parents made **LMV**, fed chicks and rested after feeding were recognized by their distance and direction from the nearest nest. The position of the nests could be recognized by nest hollows or piled nest-stones even when all the nests were abandoned.

3. Results and Discussions

3.1. Breeding sequence of this season

92 pairs were breeding and their 171 eggs were found on November 21 when we arrived at this rookery. As breeding proceeded, many parents lost their eggs due to predation by the skua and desertion by the parents. The first chick was hatched on December 15, and the last one, on December 30. The first sign of crèche formation was observed on January 1 when two or three huddles consisting of 3–6 chicks were formed in the empty space among the nests. On January 5, more than half of the surviving chicks entered crèches and their parents left the colony to gather food. All the chicks except two in one nest entered crèches on January 10. On January 12 the last two chicks entered the crèche. On January 21, 53 pairs out of the 92 continued breeding successfully, and 75 chicks survived (Fig. 2).

Fig. 2. The B4 colony on January 21.

3.2. Frequency and duration of feeding

Table 1 shows the frequency of arrival of parents. It differed from individual to individual. Two birds (1.9%) returned three times a day, but 28 birds (26.4%) did not return at all. Table 2 shows the frequency of feeding to each brood. Every brood was fed at least once a day, 1.87 times on the average, and 4 times at the maximum. The frequencies of arrival and feeding of parents did not differ significantly with brood size.

Table 1. Frequency of parental arrivals.

	Brood size		Total
	1	2	
Frequency (/24 h)			
0	17	11	28
1	30	29	59
2	9	8	17
3	2	0	2
Total arrivals	54	45	99
No. of parents	58	48	106
Mean arrival	0.931	0.938	0.934

Table 2. Feeding frequency to each brood.

	Brood size		Total
	1	2	
Frequency (/24 h)			
1	14	10	24
2	7	7	14
3	6	7	13
4	2	0	2
Total feedings	54	45	99
No. of broods	29	24	53
Mean frequency	1.862	1.875	1.868

Furthermore, there was no significant relationship between the frequency of feeding and the age of the chicks. However, since the amount of food given in each feeding is not known, we cannot say whether this feeding frequency is enough for a chick to grow.

During this observation, the chicks that were fed only once a day seemed to be starving. Those chicks were wandering around inside of the colony, and some of them gathered on the periphery waiting for the parents' arrivals for a fairly long duration in the day. It seemed that chicks in this period must be fed two or more times per day to grow normally.

Table 3 shows the duration of feeding. It includes not only actual feeding time but also the time elapsed for pauses during feeding chases. The duration of feeding varied

Table 3. Feeding duration.

	Brood size		Total
	1	2	
1– 5 min	6	3	9
6–10	17	18	35
11–15	21	11	32
16–20	6	5	11
21–26	4	3	7
Unmeasured	0	5	5
Total	54	45	99
Av. duration (min)	11.48	12.00	11.69

greatly from 1 to 26 minutes. This result was almost the same as that reported by PENNEY (1968). There was no significant difference between the feeding duration for single chicks and that for two chicks. PENNEY (1968) noted that a parent which had sated its single chick sometimes fed the chick again before it left. In our observations, only one chick was fed again by its parent.

3.3. Significance of the former nesting territories

The calling sites and feeding sites of parents are shown in Tables 4 and 5, respectively. Parents seemed to recognize their former nesting territories when they called and fed the chicks, even though the chicks had already left the nests and gathered in crèches. Of 50 cases in which parents called chicks inside the colony and the calling sites could

Table 4. Calling sites.

Outside the colony	1	
On periphery	14	
peripheral nesters		4
others*		10
Inside the colony	62	
0–1 m from former nests		26
1–2 m		9
2 m<		15
others*		12
Unidentified	22	
Total	99	

* "Others" includes cases that chicks found approaching parents before the parents called by **LMV** and that the parents did not call by **LMV** and found chicks by eyes.

Table 5. Feeding sites.

	Brood size				Total
	1		2		
Inside the colony	45		12		57
without feeding chases		27		1	
after feeding chases		18		11	
Outside the colony	9		31		40
Unidentified	0		2		2
Total	54		45		99

Feeding sites were significantly different due to brood size (χ^2-test, $p<0.001$).

be ascertained, 26 parents (52%) called chicks within 1 m from the nests, and within 2 m in 35 cases (70%). Of 57 cases in which parents fed chicks inside the colony, 29 (50.9%) were done at the sites less than 1 m from the nests, and 40 (70.2%), less than 2 m (Table 6). The brood size had a strong influence on the determination of feeding sites. Most of the parents (45 out of 54, Table 5) with single chicks fed them inside the colony, whereas only 26.7% (12 out of the 45) with two chicks did so. Furthermore, 50% (27 out of 54) with a single chick were fed after feeding chases, and 93.3% (42 out of 45) with two chicks were fed after feeding chases. Therefore, the feeding chase might

Table 6. Distance of the feeding sites from the former nesting territories of the parents which fed chicks inside the colony; a) without feeding chases, and b) after the chases.

	Without chases	After chases	Total
0–1 m	10 (34.48%)	19 (67.86%)	29 (50.88%)
1–2	7 (24.14)	4 (14.29)	11 (19.30)
2–3	3 (10.34)	2 (7.14)	5 (8.77)
3<	5 (17.24)	0 (0.00)	5 (8.77)
Unmeasured	4 (13.79)	3 (10.71)	7 (12.28)
Total	29 (100)	28 (100)	57 (100)

help avoid a struggle for food among chicks during feeding.

The feeding which was done outside the colony might be attended with the danger of predation by South Polar Skua (*Catharacta maccormicki*) when chicks lose contact with their parents. Chicks could not defend themselves from the predation by the skuas. All they could do was to escape from attacking skuas. In fact, throughout the period of our observation one or two chicks were killed every day by a pair of the skuas which occupied the colony in their territory. Therefore, single chicks might receive smaller predation pressure than chicks with siblings.

SPURR (1975) noted that chicks which heard parent **LMV** or lost their way during feeding chase returned to the natal territories. According to PENNEY (1968), a playback of parent **LMV** from outside of the colony caused 7 out of 9 chicks to return to their natal territories. But the same experiments by AOYANAGI and TAMIYA (1981) caused them to come straight from huddling sites to the sites where the parent **LMV** was played back, not to the natal territories. Further, during this observation, the chicks came straight to their parents when they heard the parent **LMV**, and when they lost their way they returned to the colony periphery and waited there to be called again by their parents. Hence, it is doubtful whether the chick recognizes its natal territory and uses it for establishing contact with its parents.

3.4. Resting sites of parent after feeding

The relation between the resting sites and the feeding sites of parents is shown in Table 7; the parents which fed chicks outside the colony tended to rest outside, and the ones which fed inside, rested inside. During the later crèche period, territorial skua pairs around the penguin colony become scavengers rather than active predators (YOUNG, 1963). They ate food spilled by penguin chicks and rarely attacked them.

Table 7. Relationship between feeding sites and resting sites of parents whose feeding sites and resting sites were known.

	Feeding sites	
	Inside the colony	Outside the colony
Resting sites		
inside	22	4
outside	10	27

($\chi^2=20.26$, $p<0.001$)

Therefore, parent resting sites may not be functional for the protection of chicks in the later crèche period, while they might be important in the earlier crèche period when chicks in crèches were young and were attacked actively by skuas.

3.5. Difference of chick survivorship with brood size

Table 8 shows the mortality of chicks in each brood size during the crèche period (January 1–21). The brood size was that recorded on January 1. The survival rate of the single chick was significantly higher than that of sibling chicks. Mean visit time of parents of the single chick nests was almost the same as that for the siblings, though the food required might be half as much for the siblings. As mentioned previously, most of the feeding was done without feeding chases. AINLEY and SCHLATTER (1972) reported that single chicks grew faster than siblings. Hence, singles might get more food than each of the siblings. Furthermore, many parents spent time after feeding beside the chicks. We suppose that the loss of one egg or chick in the earlier breeding can be compensated for by the comparatively faster growth and higher survival rate of the remaining chick.

Table 8. Chick mortality in different brood sizes.

	Brood size		Total
	1	2	
Dead	3	24	27
Survived	23	50	73
Total	26	74	100

($\chi^2=3.99$, $p<0.05$)

3.6. Direction of parent to enter the colony

Figure 3a shows the direction of parents entering the colony. Since many nests in the NW corners had failed their breeding, not many birds selected this direction. Although it was observed that parents came straight to the colony from the landing coast (NW–SW), most of them did not enter the colony from these directions. Parents tend-

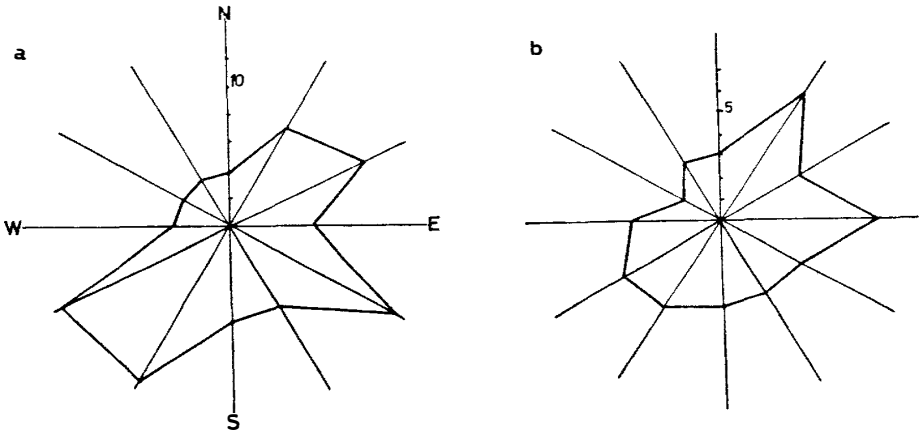

Fig. 3. a. The directions of the point from the colony center where parents entered the colony to feed young. b. Number of the successful nests, in 30°-sectors of the colony.

Table 9. Angles between the directions of nests and of the points of parent entering the colony from the center of the colony.

	Internal nests	Peripheral nests	Total
Angle			
0– 30	16 (32.65%)	30 (60.00%)	46 (46.46%)
30– 60	13 (26.53)	14 (28.00)	27 (27.27)
60– 90	3 (6.12)	1 (2.00)	4 (4.04)
90–120	4 (8.16)	2 (4.00)	6 (6.06)
120–180	7 (14.29)	1 (2.00)	8 (8.08)
Unmeasured	6 (12.24)	2 (4.00)	8 (8.08)
Total	49 (100)	50 (100)	99 (100)

ed to enter the colony from the peripheral point nearest to their nests (Table 9). This tendency is more apparent in parents which had their nests in the periphery of the colony. According to PENNEY (1968), in a large colony birds follow the paths of least disturbance to their nests during the nestling period. It may be certain that even in the crèche period when most birds left their territories and nothing disturbed parental approach they followed the same course of least disturbance.

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