CHICK RAISING ABILITY IN ADÉLIE PENGUINS

DAVID G. AINLEY AND ROBERTO P. SCHLATTER

THIS paper reports the change in weight of Adélie Penguin (*Pygoscelis adeliae*) chicks whose parents were of known age from the creche stage until fledging. Our aim was to assess the abilities of parents of different ages to provide their young with food by comparing the sizes of their broods and the growth patterns of their chicks. We discuss here the implications of delayed breeding and other related factors in Adélie breeding ecology.

Several previous studies of Adélie Penguin chick growth have each emphasized different aspects of this species' biology. Sapin-Jaloustre and Bouliere (1951) and Sapin-Jaloustre (1960) recorded growth to 42 days of age, more than a week before fledging, and correlated weight change to feather and wing growth. Sladen (1958) described general trends of weight change from hatching to fledging. The value of the yolk reserve was investigated by Reid and Bailey (1966), who studied growth in the first week after hatching. Taylor and Roberts (1962) studied the entire chick growth history but discussed mathematical properties of the growth curves rather than their biological significance.

Adélies lay a maximum of two eggs in a clutch and incubate them for 33–35 days. After hatching, chicks are brooded and guarded for 18–27 days (Sladen, 1958; Taylor, 1962). They then enter their phase of most rapid growth (Taylor and Roberts, 1962). Chick food demands are then so great that both parents must forage simultaneously and are with their chicks only when feeding them. When not guarded, chicks of adjacent territories gather in groups called creches. At the start of the creche stage chicks are fed once per day or twice per 3 days. Beginning about day 35 they are fed wtih decreasing frequency so that during the week before fledging they are fed once or twice (Taylor, 1962). They fledge at 46–55 days of age (Sladen, 1958; Taylor, 1962).

METHODS

Johns Hopkins University personnel banded about 35,000 Adélie chicks at Cape Crozier, Ross Island, Antarctica between 1962 and 1968 (Sladen et al., 1968). Banded birds did not have to be rehandled as band numbers could be read from a distance with binoculars. In 1969–70 we located 309 breeding adults 3 to 8 years old that were previously banded as chicks. We banded their unknown-age mates and marked their nest sites. For comparison and as controls on 1 November 1969, a few days before egg-laying began, we dyed 50 unknown-age pairs on their breasts with picric acid dye and marked their nests. These pairs were in the same colonies

(i.e. groups of contiguous territories) and in the same proportion to colony populations as the known-age birds. We selected them for having large, symmetrical nests in the centers of colonies, as Adélies having these nests are usually older individuals (LeResche, MS). We visited all nests every 2–3 days to determine fate of eggs and chicks.

When chicks became so large that brooding parents could not entirely cover them, we marked the down of their backs by squirting dye with a syringe from a distance. They were banded when they entered creches and, when they lost their down, the feathers on the upper breast were dyed. As only 3–4 chicks were marked per colony, these were widely spaced within colonies, and they entered creches on different days, we could easily determine to which parents they belonged. We marked and banded 266 chicks in this way during January 1970.

Of the 266 marked chicks 87 were weighed to the nearest 0.1 kg when first found in a creche and then regardless of age at 6-day intervals until they fledged. To draw growth curves, weights of chicks and fledglings were pooled for age intervals of 4 days. The sample included 55 from 1-chick broods and 16 pairs from 2-chick broods. We defined 1- and 2-chick broods as those having 1 and 2 chicks respectively at the beginning of creche stage. Of 96 marked chicks we located on the beach as fledglings, 62 were from 1-chick broods and 34 from 2-chick broods. Within about a day after fledging, chicks descended the 600 m from the rookery to the beach and then entered the sea. A chick was considered fledged if it was not seen again after being weighed on the beach. Beaches were searched 3–4 times per day from 09:00 to 24:00.

For comparison with chick weights, 24 adult females, sexed by checking cloacal characters (Sladen and LeResche, 1970), were weighed between 7 and 11 January; 13 were unknown-age breeders with empty stomachs that had just fed their creche-age chicks, the remainder nonbreeding 2-year-olds. These females weighed the same at what is close to mean minimum adult female weight (3.8 kg), which is 0.3–0.4 kg less than males of similar breeding status.

RESULTS

The growth curve.—Most chicks from 1- and 2-chick broods averaged 1.9 and 1.6 kg in weight respectively when they entered creches at 18–27 days of age. When 42–45 days old they reached maximum weight (Figure 1) with the young from 1-chick broods weighing 3.3 kg and those from 2-chick broods weighing 3.1 kg. Maximum weight of single chicks at Cape Royds (Taylor and Roberts, 1962) averaged 0.7 kg more than single chicks at Cape Crozier, but the growth curves are similar for both groups.

During the week prior to fledging, weights declined about 15 percent from the maximum. Fledglings from 1-chick broods (2.9 kg) weighed 0.2 kg more ($0.01 < P < 0.02$; t-test) than fledglings from 2-chick broods (2.7 kg). Fledglings from 1-chick broods at Royds (Taylor and Roberts, 1962) averaged 0.5 kg more than single chicks at Crozier. Thus fledglings at Royds were 89 percent and ones from Crozier 75 percent of the adult female minimum weight.

Parents' ages and weight of fledglings.—Our data are correlated to

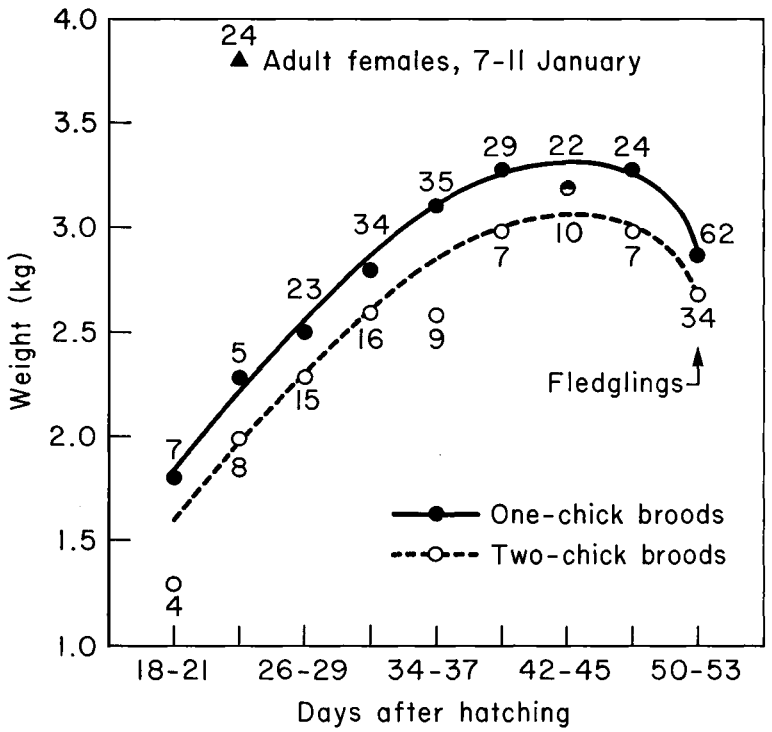

Figure 1. Growth curves of Adélie Penguin chicks from 1- and 2-chick broods at Cape Crozier in 1969–70. Numbers above solid circles are the sample sizes for mean weights of chicks from 1-chick broods at the different age intervals. Similarly the numbers below open circles are the sample sizes for 2-chick broods. The mean weight of 24 adult females during the creche stage is shown for comparison.

the age of only one parent for each nest, the other being of unknown age. However one expects mated Adélies to be nearly the same age. From their 2nd to 6th years Adélies arrive at the rookery earlier each breeding season (Sladen et al., 1968), and they tend to pair, especially females, soon after arrival (Sladen, 1958). Therefore most older, earlier arriving birds are paired before the younger ones arrive.

As parents aged from 3 to 6 years, weight of their fledglings increased from 2.0 to 2.9 kg and remained at the 2.8–2.9 kg level for fledglings of 7- and 8-year-olds (Table 1). Fledged chicks of control parents averaged 3.0 kg, which was not statistically different ($0.3 < P < 0.4$) from the 2.9 kg mean weight of the young of 6-year-olds. The difference in mean weight between fledglings of 3- and 4-year-old parents combined (2.4 kg) and the fledglings of 7- and 8-year-old parents combined (2.8

TABLE 1
MEAN WEIGHT OF FLEDGLINGS RELATIVE TO THE AGES OF THEIR PARENTS

Parent's age	Mean weight of fledglings in kg	No.
3	2.0	1
4	2.4	9
5	2.6	17
6	2.9	18
7	2.8	14
8	2.8	13
Control	3.0	22

kg) was statistically significant ($0.001 < P < 0.01$). Thus older birds raised heavier chicks than did younger ones, with fledgling weight leveling off after parents reached 6 years of age.

Prior breeding experience of the known-age parent regardless of age did not affect the fledging weight of single chicks. Fledglings of a parent that had bred in at least one previous year (i.e. a member of a pair known to have produced eggs) had a mean weight of 2.8 kg ($n = 21$), the same as fledglings ($n = 25$) of parents that had not bred previously.

Parents' ages and number of chicks fledged.—Percentage of 2-chick broods that survived through the creche stage increased from 0 for 3-year-olds to 36 percent for 8-year-old parents (Table 2). The percentage of 2-chick broods among controls was between those for 7- and 8-year-olds. Thus maximum chick raising ability is reached at about 7-8 years of age.

Adélies usually lay two-egg clutches, and in 1969-70 81 percent were two-egg clutches (Ainley and LeResche, MS). Relatively few pairs at Crozier fledge two chicks according to unpublished data collected by

TABLE 2
PERCENT OF 2-CHICK BROODS IN THE TOTAL NUMBER OF BROODS RAISED ALMOST TO FLEDGING TIME (30 JANUARY) BY KNOWN-AGE PARENTS

Parent's age	Percent 2-chick broods	No. of broods
3	0	4
4	8	25
5	20	41
6	18	54
7	24	29
8	36	14
Control	28	43

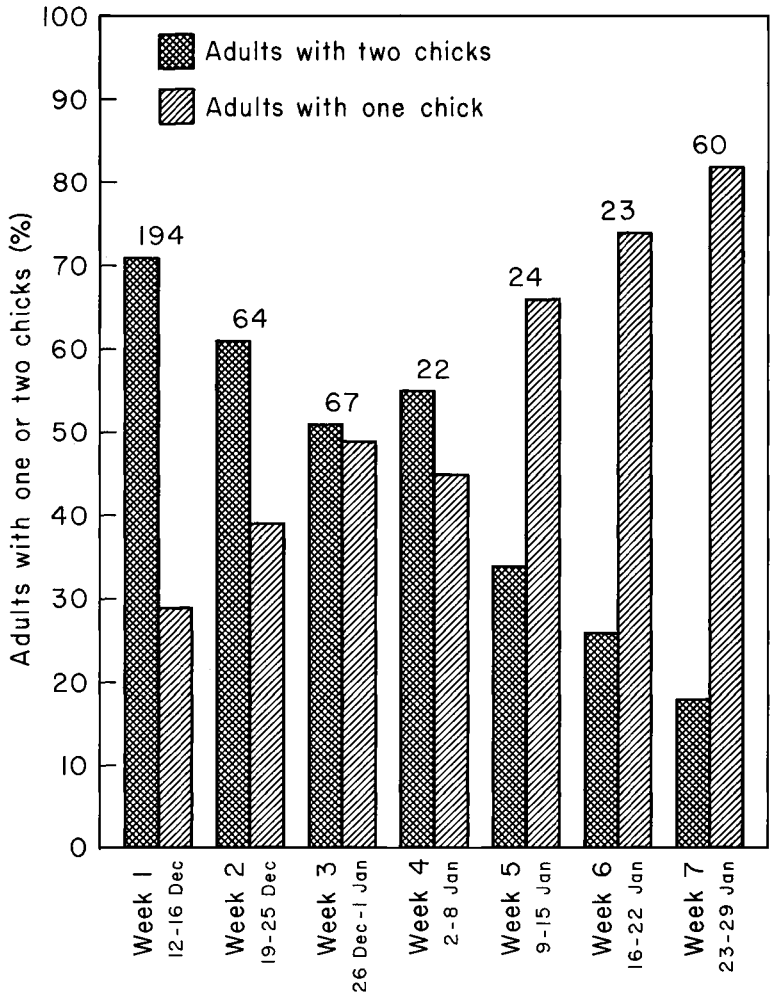

Figure 2. Decline of 2-chick broods as the season progresses. Week 1 began when 50 percent of all eggs had hatched and week 7 ended 1 week prior to fledging. Each week adults were chosen at random as they approached their nest to feed their chicks, and were watched until they finished the feeding. Figures at the top of each column show the number of broods observed per week. Data were taken at Cape Crozier in 1965–66 by W. B. Emison.

W. B. Emison and presented here (Figure 2). In 1965-66 the ratio of 2-chick broods to total broods declined from 71 percent at hatching to 18 percent just before fledging, coincident with an increase in 1-chick broods from 29 to 82 percent. This decline in 2-chick broods in

1965-66 is apparently typical of all years at Crozier. Probably it is more often the younger breeders that lose their second chicks.

DISCUSSION

The chick growth pattern.—The Adélie Penguin growth curve is similar to that of some alcids, especially Common Puffins (*Fratercula arctica*; Karataschew, 1960, *in* Lack, 1968; Belopol'skii, 1961; Myrbeget, 1962, *in* Lack, 1968) and Cassin's Auklets (*Ptychoramphus aleutica*; Thoresen, 1964). Adélie chicks from single broods attain 90–108 percent adult minimum weight and then fall to 75–89 percent of it at fledging. Similarly, Cassin's Auklets reach 90 percent adult weight before falling to 70 percent, and Common Puffins reach 75 percent adult weight and fall to 67 percent. Both alcids have broods of one chick. Less-than-adult maximum chick weights of penguins and alcids suggests that feeding irregularity (see Lack, 1968: 270) is not a great problem for the chicks, compared to those species in which chicks gain fat reserves to weigh significantly more than adults at some stage in development. For example, young Manx Shearwaters (*Puffinus puffinus*) reach almost 150 percent adult weight before losing fat stores prior to fledging at 120 percent adult weight (Harris, 1966).

Fledglings of some other alcids, for example the Razorbill (*Alca torda*) and Common Murre (*Uria aalge*), are less than adult weight (Bent, 1919; Fisher and Lockley, 1954) but they are accompanied to sea by adults. Adélie Penguin and Cassin's Auklet fledglings are not accompanied and therefore must find food on their own. Yet they weigh less than adults and thus do not have extra fat stores. Lack of extra fat is also apparent in dissected individuals. Therefore successful foraging is probably not so great a problem for them as, for example, Manx Shearwater fledglings, which are also independent but which weigh 20 percent more than adults. They thus have fat reserves to protect against initial foraging difficulties.

Decline in 2-chick broods.—Foraging is apparently difficult enough for adult Adélie Penguins that they can raise one chick much more easily than two. This is evident from the facts that chicks from 1-chick broods weigh more than those from 2-chick broods, and that most 2-chick broods lose a chick before fledging time.

Adélies begin incubation with the first egg and thus the second hatches later than the first. This results in chicks of the same nest being of different age, growth stage, and size. Emison (pers. comm.) found that parents with two chicks brought less than twice as much food as those having one chick. As proper weight and nutrition are important for fledgling survival, second chicks survive best in years of plentiful food

when parents can more easily double their food catch. In addition, second chicks in any year have a better chance for survival when they are of older parents.

Delayed breeding.—Adélies raise more and heavier chicks as they age from 3 to 6 years. Furthermore previous breeding experience does not increase a birds' ability to raise heavier chicks. This suggests that as a bird ages the increase in ability to raise heavier fledglings depends more on what is learned with accumulated years of experience at sea rather than the experience in interacting with mates, eggs, and chicks during breeding. Older birds, because they have spent more time at sea, might be better able to catch more food per feeding trip and/or be quicker in catching food so that their chicks are fed more often than those of younger birds. Emison (1968) found that the amount of food different parents brought to their chicks per feeding varied from 300 to 1,100 g, and he suggested that this wide range could be due to a range in age and consequential foraging ability of the parents sampled.

About 3–12 percent of female Adélie Penguins breed for the first time when 3 years of age and a similar percentage of males first breed when 4 years of age. Adélies do not breed when younger (LeResche et al., 1970; Ainley, MS). One factor favoring delayed breeding is that younger birds do not have the foraging skill needed to sustain simultaneously both themselves and a chick. Their foraging ability becomes adequate by 3 or 4 years of age, but perhaps does not reach its peak until 7–8 years of age for it is birds of this age and older that are more likely to raise full-sized broods.

Thus for Adélie Penguins a breeding delay allows them sufficient time to acquire the necessary foraging skill to rear young successfully. Lack (1968) suggested this possible explanation for delayed breeding in several long-lived birds. Additional evidence in support of this hypothesis has been presented for Brown Pelicans (*Pelecanus occidentalis*) by Orians (1969) and for Little Blue Herons (*Florida caerulea*) by Recher and Recher (1969). Immatures of these species were shown to be significantly less successful at foraging than were adults.

ACKNOWLEDGMENTS

We are grateful to D. A. Saunders, R. T. Paul, and W. J. L. Sladen for help in weighing chicks, and to W. B. Emison for his unpublished data. U. S. Antarctic Research Program personnel aided in many ways in support of field work and the U. S. Navy Operation Deepfreeze provided logistics. The seasons of banding and previous work at Cape Crozier were financed by grants to W. Sladen from the National Science Foundation Office of Antarctic Programs. Ainley received a fellowship from the National Institutes of Mental Health and Schlatter received one from NSF. N. Story kindly prepared the figures. R. L. Brownell, W. B.

Emison, C. J. Ralph, W. J. L. Sladen, and R. C. Wood suggested revisions of earlier manuscripts.

LITERATURE CITED

BENT, A. C. 1919. Life histories of North American diving birds. U. S. Natl. Mus., Bull. 107.

BELOPOL'SKII, L. O. 1961. Ecology of sea colony birds of the Barents Sea [Transl. from Russian]. Jerusalem, Israel Prog. Sci. Transl.

EMISON, W. B. 1968. Food preferences of the Adélie Penguin at Cape Crozier, Ross Island. Pp. 191–212 *in* Antarctic bird studies (O. L. Austin, Jr., Ed.). Antarctic Res. Ser., vol. 12. Washington, D. C., Amer. Geophys. Union.

FISHER, J., AND R. M. LOCKLEY. 1954. Sea birds. Boston, Houghton Mifflin Co.

HARRIS, M. P. 1966. Breeding biology of the Manx Shearwater, *Puffinus puffinus*. Ibis, 108: 17–44.

KARATASCHEW, N. N. 1960. Die Alkenvögel des Nordatlantiks. Neue Brehm Bucherei, No. 257. Wittenberg Lutherstadt, A. Ziemsen Verlag.

LACK, D. 1968. Ecological adaptations for breeding in birds. London, Methuen and Co.

LERESCHE, R. E., R. C. WOOD, AND W. J. L. SLADEN. 1970. Antarctic avian population studies, 1968–69. Antarctic J. U. S., 6: 46–49.

MYRBEGET, S. 1962. Contributions to the breeding biology of the puffin, *Fratercula arctica* (L.). Eggs, incubation and young. Pap. Norwegian State Game Res. Inst., 2nd ser., No. 11.

ORIANS, G. H. 1969. Age and hunting success in the Brown Pelican (*Pelecanus occidentalis*). Anim. Behav., 17: 316–319.

REID, B. F., AND C. BAILEY. 1966. The value of the yolk reserve in Adélie Penguin chicks. Rec. Dominion Mus., 5: 185–193.

RECHER, H. F., AND J. A. RECHER. 1969. Comparative foraging efficiency of adult and immature Little Blue Herons (*Florida caerulea*). Anim. Behav., 17: 320–322.

SAPIN-JALOUSTRE, J. 1960. Ecologie du Manchot Adélie. Paris, Hermann.

SAPIN-JALOUSTRE, J., AND F. BOULIERE. 1951. Incubation et development du poussin chez le Manchot Adélie, *Pygoscelis adeliae*. Alauda, 19: 65–83.

SLADEN, W. J. L. 1958. The pygoscelid penguins, parts 1 and 2. Falkland Islands Dependencies Surv., Sci. Rept. No. 17. London.

SLADEN, W. J. L., AND R. E. LERESCHE. 1970. New and developing techniques in Antarctic ornithology, Pp. 585–596 *in* Antarctic ecology, vol. 2 (M. W. Holdgate, Ed.). New York, Academic Press.

SLADEN, W. J. L., R. E. LERESCHE, AND R. C. WOOD. 1968. Antarctic avian population studies, 1967–68. Antarctic J. U. S., 3: 247–249.

TAYLOR, R. H. 1962. The Adélie Penguin, *Pygoscelis adeliae*, at Cape Royds. Ibis, 104: 176–204.

TAYLOR, R. H., AND H. S. ROBERTS. 1962. Growth of Adélie Penguin (*Pygoscelis adeliae* Hombron and Jacquinot) chicks. New Zealand J. Sci., 5: 191–197.

THORESEN, A. C. 1964. The breeding behavior of the Cassin Auklet. Condor, 66: 456–476.

Department of Pathobiology, The Johns Hopkins University, Baltimore, Maryland 21205. Present address of first author: Point Reyes Bird observatory, Box 321, Bolinas, California 94924. Accepted 4 June 1971.