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BREEDING BIOLOGY AND FOODS OF RHINOCEROS AUKLETS ON TEURI ISLAND, JAPAN

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Abstract: The breeding biology and food habits of Rhinoceros Auklets, *Cerorhinca monocerata*, were studied on Teuri Island (44°25′ N, 141°19′ E), Hokkaido in 1984 and 1985. Though the onset of breeding in 1984 was delayed by snow cover, hatching success in 1984 was similar to that in 1985. However, chick survival, chick growth and fledging weight were better in 1985 than in 1984. The better chick conditions characterizing 1985 correlated with the larger food loads and more frequent feedings by parents in that year in comparison with those in the preceding year. Major food items brought to chicks by parents consisted of small pelagic fishes such as Japan Sea greenling, *Pleurogrammus azonus*, sandlance, *Ammodytes personatus*, sardine, *Sardinops melanosticta*, Pacific saury, *Cololabis saira*, and Pacific herring, *Clupea pallasi.*

1. Introduction

The breeding biology and food habits of Rhinoceros Auklets, *Cerorhinca monocerata*, have been recently studied along the west coast of U.S.A. and Canada (RICHARDSON, 1961; VERMEER, 1979; VERMEER and WESTRHEIM, 1984; HATCH, 1984), whereas the breeding biology of this species in Japan, northern Sakhalin and the Kuril Islands has received little attention. VERMEER (1979, 1980), and VERMEER and CULLEN (1979) studied foods, chick growth and reproductive success of Rhinoceros Auklets on Triangle Island, British Columbia and suggested that the annual change in the availability of small pelagic fish (the main diet of the nestlings) influences chick growth and survival.

This paper describes the annual changes in the fish species brought to chicks by parents and in the reproductive success of Rhinoceros Auklets breeding on Teuri Island, Hokkaido.

2. Materials and Methods

2.1. Study area

The study was carried out on Teuri Island (44°25′N, 141°19′E) 28 km off Haboro, Hokkaido (Fig. 1), during the breeding seasons, April to August, in 1984 and in 1985. About 3 km of a total of 12 km of coast line of the island is comprised of rocky cliffs up to 80–100 m in height. Rhinoceros Auklets nest in burrows about 1 m in length

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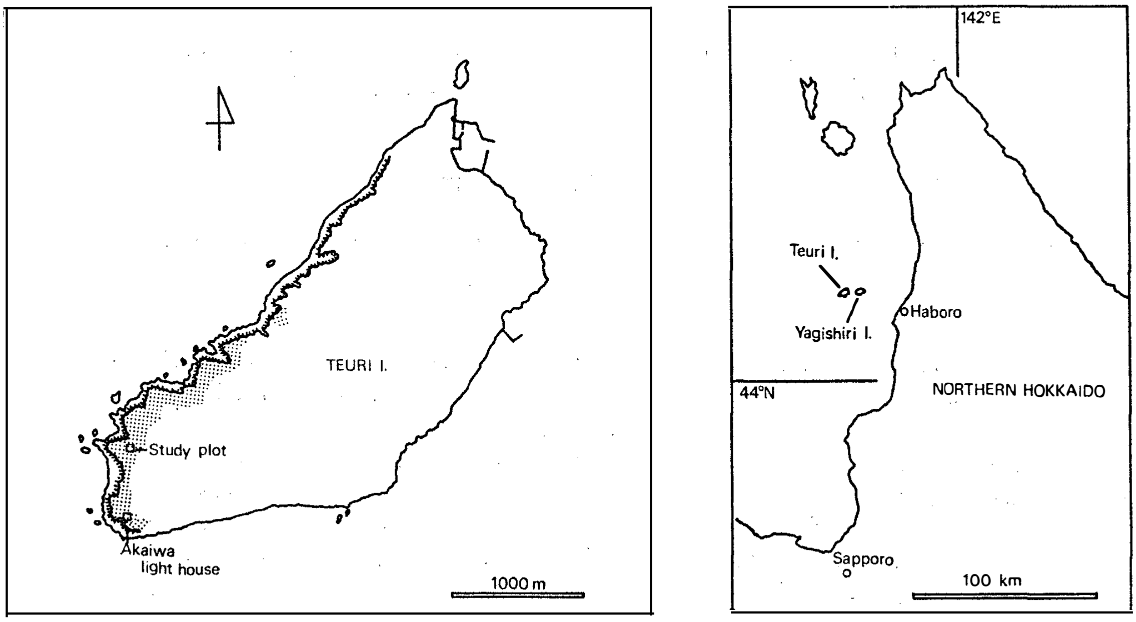

Fig. 1. Map of Teuri Island showing a study plot. Dotted area shows breeding habitats of Rhinoceros Auklets.

on the shoulder slopes of the cliffs. These slopes are covered with dense stands of plants such as *Calamagrostis langsdorffii*, *Polygonum sachalinense*, and *Artemisia montana*. The total auklet breeding population was estimated as 172000 pairs (WATANUKI *et al.*, 1986). A study plot was set on a slope opposite the Byobu Iwa rock stack (Fig. 1). Detailed information on flora and fauna can be found in KURODA (1963).

2.2. *Breeding biology*

I made a small access hole (10 cm in diameter) into the nest chamber, usually located at the rear of the burrow. Each hole was kept plugged by a wedge-shaped piece of sod that could readily be removed. Handling of adults during the incubation period frequently caused desertion of the nests. Therefore, I could not get significant information on egg laying and incubation behavior. However, the time of egg-laying was estimated by back-dating the known hatching time with the mean incubation period of Rhinoceros Auklets. The mean incubation period is 45 days (LESCHNER, 1976). Chicks were weighed to the nearest 1 g by a beam balance every 5 days before 15 days of age, and to the nearest 5 g by a spring balance after that time. A few chicks could not be pulled out of the burrows, being huddled deeply in the nests. Wing and tarsus length were also measured to the nearest 1 and 0.1 mm, respectively.

The chicks were assumed to fledge when they were more than 45 days old and absent from the nest at the following inspection time. The final measurements of these chicks were assumed to be those of the fledglings. In all, 40 nests in 1984 and 45 nests in 1985 were investigated. The weights of 18 eggs, whose status of incubation was unknown, were measured in May 1984. Body weights of 15 adults were also measured on 11 May 1985.

2.3. *Foods*

On Teuri Island, adult Rhinoceros Auklets carry their prey crosswise in their bills back to their chicks in the evening (THORESEN, 1983). I walked in a 10×50 m area near Akaiwa light house (Fig. 1) at a constant speed (about 50 m/15 min) from 1930 to 0200, with the aid of a 6 V light. Adults carrying food were caught by a swooping net or by hand. All the food was placed in plastic bags and preserved in 10% formaldehyde. Whole fish were identified and weighed to the nearest 0.1 g, and their fork-lengths were measured in the laboratory.

Meteorological data were obtained at Yagishiri Island, 10 km east of the study area, by the Japan Meteorological Agency. Significance of the difference in values between 1984 and 1985 was examined by ANOVA or Mann-Whitney U-test. All units are shown as mean±SD with sample size in parentheses.

3. Results

3.1. *Breeding season*

Body weight, wing length, and tarsus length of adult auklets were 544.7±40.2 g

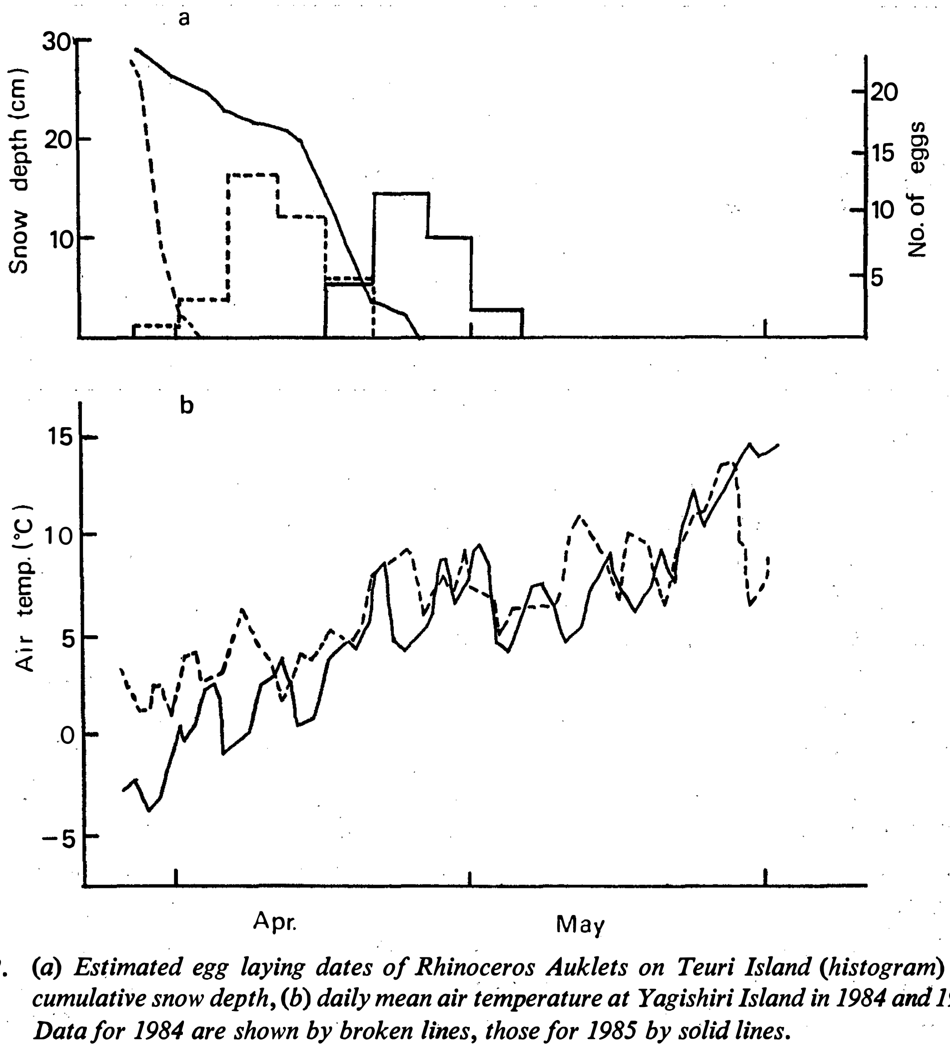

Fig. 2. (*a*) *Estimated egg laying dates of Rhinoceros Auklets on Teuri Island* (*histogram*) *and cumulative snow depth,* (*b*) *daily mean air temperature at Yagishiri Island in 1984 and 1985. Data for 1984 are shown by broken lines, those for 1985 by solid lines.*

(15), 185.6±5.2 mm (15) and 31.4±1.0 mm (6), respectively. The auklet laid one egg whose weight was 83.2±5.0 g (18) in the nest burrow.

The mean hatching date fell on 7.8±4.4 (26) June in 1984 and on 24.8±4.9 (32) May in 1985. Chicks hatched significantly earlier in 1985 than they did in 1984 (F=128.31, dfs=1–56, P<0.01). Egg laying probably started when the snow disappeared, in late April in 1984 and early April in 1985, respectively (Fig. 2). Low air temperatures in early spring in 1984 might have delayed snow melting at that time.

3.2. *Reproductive success*

The hatching success of eggs in 1984 and 1985 was similar (χ^2=0.368, df=1, N.S., Table 1). However, fledging success per egg laid was significantly higher in 1985 than in 1984 (χ^2=5.162, df=1, P<0.05, Table 1). The combined 1984 and 1985 data showed that 15 chicks disappeared before 10 days of age, 8 chicks disappeared between 10 and 40 days of age, and 10 chicks died in their burrows.

Table 1. Reproductive success of Rhinoceros Auklets in 1984 and 1985. Percentage success per egg laid is given in parentheses.

Reproductive parameters	1984	1985
No. eggs laid	40	45
No. eggs hatched	26 (65.0)	32 (71.1)
No. chicks fledged	7 (17.5)	18 (40.0)

Table 2. Growth rate (50–150 g), fledging weight and fledging wing length of chicks of Rhinoceros Auklets in 1984 and 1985 shown as mean±SD (sample size).

Growth parameters	1984	1985
Growth rate (g/5 days)	29.9± 8.1 (6)	48.6±23.9 (17)
Fledging weight (g)	235.0±52.9 (6)	292.4±49.2 (17)
Fledging wing length (mm)	143.0± 8.9 (6)	145.6± 7.7 (17)

3.3. *Chick growth*

Chick growth is shown in Fig. 3. Chicks, which fledged successfully, grew faster in 1985 than in 1984. Growth curves of these chicks were nearly linear between the ages when they attained to 50 g and those when they attained to 150 g (Fig. 3). The growth rate of individual chicks (g/5 days) was determined by calculating the slope of the regression line of growth between these ages. Chick growth rate in 1985 was higher than that in 1984 (U=23, P<0.1, Table 2). In 1984, chicks declined more in weight several days prior to fledging than they did in 1985 (Fig. 3). VERMEER and CULLEN (1979) showed that Rhinoceros Auklet chicks lose more weight in a year of poor growth than in a year of good growth prior to fledging on Triangle Island. Growth of chicks that died later was poorer than that of chicks fledging successfully (Fig. 3). On the other hand, growth curves of tarsus length and wing length were similar for the two years.

The fledging weight of chicks in 1985 was significantly higher than that in 1984 (U=20, P<0.05) but the fledging wing length in 1985 was similar to that in 1984 (U=41.5, N.S., Table 2). The fledging period in 1985, 53.1±4.6 (18) days, was sig-

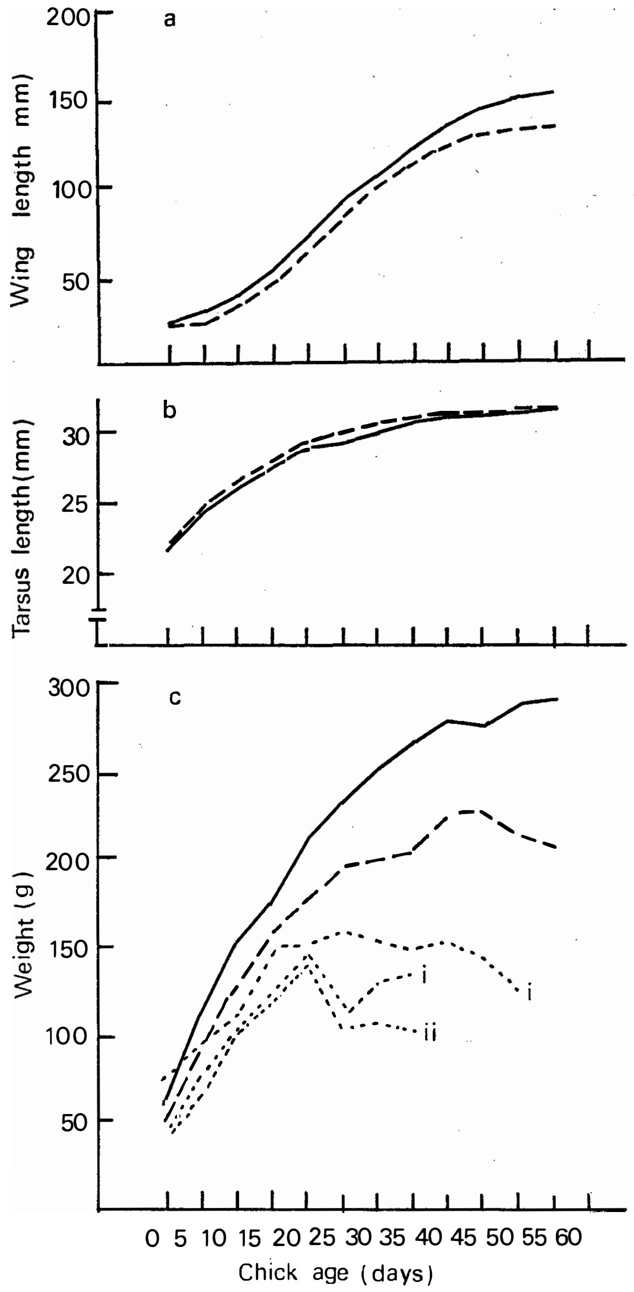

Fig. 3. Mean growth ((a) wing length, (b) tarsus length, and (c) weight) of Rhinoceros Auklet chicks which fledged successfully in 1984 (broken line, n=2–6) and 1985 (solid line, n=2–17). Typical weight changes of chicks died in 1984 (i) and 1985 (ii) also are shown by dotted lines.

nificantly shorter than that in 1984, 58.6±7.5 (7) days, (F=5.091, d*f*s=1–23, $P<0.05$).

3.4. Food

Prey species composition varied with sampling time (Y. Watanuki, unpublished). Percentage (by wet weight) of principal fish species in the food loads brought to chicks is shown in Table 3. Fish species composition in the chick diet varied little between 1984 and 1985, but the percentage of wet weight of Pacific saury, *Cololabis saira*, in 1984 was slightly higher than that in 1985 and those of Pacific herring, *Clupea pallasi*, and Japan Sea greenling, *Pleurogrammus azonus*, in 1985 were higher than those in 1984.

Table 3. Percentage of principal prey (wet weight) brought to chicks by Rhinoceros Auklets in an early (E) and a latter (L) half of a month. Samples were collected between 1930 and 2200.

Fish species	1984				1985			
	E June	L June	E July	L July	L May	E June	L June	E July
Sardine	8.3	40.4	40.3	8.4	—	23.7	29.8	39.0
Pacific herring	—	8.6	0.5	2.2	—	7.1	28.4	26.0
Japan Sea greenling	61.3	4.6	—	—	91.5	46.3	11.3	2.4
Pacific saury	2.2	13.3	35.7	38.4	—	4.6	13.8	6.5
Sandlance	7.4	30.7	18.0	50.7	8.4	11.1	15.4	17.1
Others	20.8	2.4	5.5	0.3	0.1	7.2	1.3	9.0
No. of food loads	15	26	30	30	19	54	43	33

Table 4. Wet weight (g) of food loads, containing one fish species only, brought to chicks by adult Rhinoceros Auklets is shown as mean±SD (sample size). Samples were collected between 1930 and 0200.

Prey species	1984	1985
Sardine	42.7±10.5 (18)	40.1± 6.3 (34)
Japan Sea greenling	22.0± 5.6 (8)	30.1± 8.7 (52)
Pacific saury	31.5± 7.4 (17)	25.5±10.7 (12)
Sandlance	24.3±10.4 (45)	29.5±10.8 (39)

The Japan Sea greenling was an important food for Rhinoceros Auklet chicks early during the nesting season, while the Pacific saury and the sandlance, *Ammodytes personatus*, were important foods later on in the season in both years (Table 3).

A food load usually consisted of a single fish species. Wet weights of food loads with one fish species are shown in Table 4. Food loads with Japan Sea greenling and those with sandlance were significantly higher in 1985 than in 1984 (Japan Sea greenling, $F=6.364$, d*f*s=1–58, $P<0.05$; sandlance, $F=4.924$, d*f*s=1–82, $P<0.05$). Although the food loads with Pacific sauries in 1984 were larger than those in 1985, the difference was not significant ($F=3.206$, d*f*s=1–27, N.S.). The food loads with sardines, *Sardinops melanosticta*, in 1984 were similar to those in 1985 ($F=1.234$, d*f*s=1–50, N.S.). The total food load weight in 1985, 30.4±12.5 (226) g, was significantly larger than that in 1984, 23.2±13.4 (130) g, ($F=26.065$, d*f*s=1–354, $P<0.01$).

3.5. Feeding

Rhinoceros Auklets feed their chicks in the evening and night on Teuri Island. Weights of nine chicks were measured at 0600, 1200, 1800, 2100 and 2400 on 9 June and at 0300 and 0600 on 10 June in 1985. The weight increases of chicks in those intervals suggested that they were fed at least once.

The weights of 4 chicks increased between 1800 and 2100, those of 3 chicks between 2100 and 0000 and those of 2 chicks between 0000 and 0300. Mean weight increase of chicks, which were fed, in those intervals was 38.9±15.9 (9) g. One of them gained 70 g weight between 2100 and 2400. HATCH (1984) suggested that a Rhinoceros Auklet chick is usually fed by one adult each night. Chicks lost more weight during the following 3 hours after being fed, 8.9±4.2 (9) g, than they did during the other 3 hours starvation period, 5.2±5.7 (34) g.

The proportion of food-carrying adults to the total adults observed between 1930 and 2400 on food sampling nights was higher in 1985, 13.0% (or 263/2019), than in 1984, 9.7% (or 92/947) ($\chi^2=6.711$, $df=1$, $P<0.01$). This suggests that parents fed their chicks more frequently in 1985 than they did in 1984.

4. Discussion

4.1. *Breeding season*

Egg laying probably was delayed by snow cover; mean daily air temperature was below the freezing point throughout late March and was at intervals during early April in 1984 (Fig. 2). The surface layer of soil in the breeding area was frozen until mid April, hence it might have been difficult for Rhinoceros Auklets to excavate nest burrows in the early part of the season of 1984. Several studies of ground nesting gulls also show that initial occupation of the colony and egg laying are delayed by ice, snow and low temperatures (VERMEER, 1970; MORRIS and CHARDINE, 1985).

VERMEER (1980) suggested that prey abundance or interference by bad weather with catching prey may have delayed the onset of breeding of Rhinoceros Auklets on Triangle Island in 1976. I have no information on the food (including abundance) of Rhinoceros Auklets during the egg laying period. Mean sea-surface temperature around Teuri Island between mid March and late May in 1984 was about 1°C lower than that in 1985 (Japan Meteorological Agency). Low sea-surface temperature might inhibit the growth of such potential prey as first year sandlance. In fact, catch of sandlance by commercial fisheries around Teuri during May and June in 1984 was smaller than that during the corresponding period in 1985 (K. MIYAGUCHI, personal communication).

Mean of the average daily wind speed during 10 days in March and April was 3.5–6.6 m/s in 1984 and 3.3–6.9 m/s in 1985 and total precipitation during these months was 31 mm in 1984 and 54 mm in 1985 at Yagishiri. Hence, weather condition for catching prey in the pre-laying period could be considered as approximately the same in both years.

4.2. *Food and chick growth*

The nutritional value of each fish species was not measured in this study. Since food intake for Rhinoceros Auklet chicks was higher in 1985 than in 1984, daily energy intake of chicks in 1985 was generally higher than in 1984 (see VERMEER and DEVITO, 1986). The higher daily energy intake in 1985 probably resulted in better growth, shorter fledging periods, larger fledging weights, and higher survival of chicks in that year than occurred in 1984. Annual variations in chick growth and survival have been correlated with size of food loads and feeding frequency for the Tufted Puffin, *Fratercula cirrhata* (VERMEER *et al.*, 1979; VERMEER and CULLEN, 1979) and the Atlantic Puffin, *F. arctica* (HARRIS, 1980). Also, HARRIS and HISLOP (1978) suggested that the increases in feeding frequency and weight of food loads caused improvement in the condition of surviving young puffins later on in the breeding season.

VERMEER and CULLEN (1979) and VERMEER (1980) suggested that unusually large prey (Pacific saury) caused digestive difficulties for young Rhinoceros Auklets in a year when they were fed mostly with sauries and that their survival and growth were poor. On Teuri Island, Pacific saury occurred more frequently in the diet of Rhinoceros Auklets in 1984 than in 1985 (Table 3). The mean fork-length of sauries in food loads of the auklets was significantly larger in 1984 (18.4±5.0 (33) cm) than that in 1985 (15.8±4.3 (38) cm) (F=4.123, dfs=1–69, $P<0.05$). Large Pacific sauries might have caused digestive difficulties in 1984. On Triangle Island in 1976, VERMEER (1980) observed a large number of Pacific saury remained around burrow entrances, and often observed chicks with a saury tail protruding from their mouth. On Teuri Island, two out of three dead chicks dissected in 1985 had a large Japan Sea greenling in their gullets; it appeared that they had choked to death on the fish; however, no such evidence of digestive difficulties was found in 1984.

NETTLESHIP (1972) suggested that the wet and cold summer could affect egg and chick survival in the Atlantic Puffin. At Yagishiri Island, the mean air temperature during the nestling period (June and July) in 1984 at which time the chick growth and survival were poor, was 2–3°C higher than that during the same period in 1985 (Japan Meteorological Agency). The total precipitation during these months in 1984, 101 mm, and the corresponding amount in 1985, 111 mm, were similar. Therefore, weather condition was probably not the cause of poor chick growth and survival in 1984.

In conclusion, small food loads and low feeding frequencies in 1984 probably caused the poor chick condition in that year. These facts might suggest a low availability of small pelagic fish during the chick feeding period in 1984. Another hypothesis that could be put forward: prey availability in both years was similar and decreased in the later part of the season, but the chick-feeding period in 1984 occurred after the time when the food was most abundant, since the onset of breeding was delayed by snow cover in that year. Information on the seasonality of food availability is needed to test this hypothesis.

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