Egg laying, chick growth and food of kittiwakes *Rissa tridactyla* at Hopen, Svalbard

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In 1984, kittiwakes at Hopen laid eggs ca. 14 days later than previously found in North Norway and on the Kola Peninsula. The mean clutch size, egg volume, and hatching success were otherwise very similar to those documented on the mainland. Although feeding trips were very long, a rapid chick growth and high rate of chick survival suggested that food availability was not a limiting factor in 1984. In contrast to other sites at Svalbard where polar cod *Boreogadus saida* and crustaceans dominate kittiwake diets, the diets of chicks at Hopen consisted mainly of capelin *Mallotus villosus* which the adults probably collected at or beyond the polar front southeast of the island.

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Introduction

The kittiwake *Rissa tridactyla* is extremely common throughout the Barents Sea region and breeds in large and small colonies on Svalbard, Franz Josef Land, Novaja Zemlja, the north coast of the Kola Peninsula and and in northern Norway. Of the ca. 900,000 pairs which breed in the region, ca. 270,000 nest on Svalbard (including Bjørnøya) (Mehlum & Bakken 1994; Barrett & Tertiski in press). While the breeding biology of the species has been studied in considerable detail along the coast of North Norway and the Kola Peninsula (summarised in Barrett & Tertiski in press), most effort in the large colonies in the northern part of the Barents Sea has been put into studies of the energetics of the species (summarised in Gabrielsen 1994). Apart from the presentation in Gabrielsen et al. (1992) of a chick growth curve at a colony in Kongsfjord, Spitsbergen (79° N, 12° E), I have been unable to find other data concerning the breeding biology of kittiwakes from this region. This paper presents data from Hopen (76° 35′N, 25° 20′E, Fig. 1), ca. 200 km east of Sørkapp, Spitsbergen, where ca. 40,000 pairs of kittiwakes bred in 1984–1985 on several cliffs around the entire island (Barrett & Mehlum 1989). These data supplement Gaston's (1988) documentation of kittiwake breeding biology in the northernmost part of the kittiwake's arctic range in the North Atlantic. The data are also compared to similar data collected at colonies in North Norway and northeast England.

Methods

The study was carried out during the period 20 June–9 August 1984 in a small colony (2600–2800 nests, pers. obs.) ca. 500 m south of the meteorological station on the southeast coast of the island. Sixty-four nests were individually marked and checked on alternate days beginning on 22 June. Eggs were taken from 16 of these nests (for eating) by the station staff on 14 June. Eggs, and later chicks, in each nest were

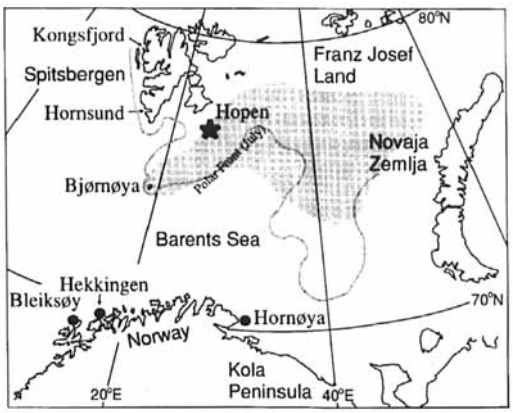

Fig. 1. Barents Sea, showing the position of the localities mentioned in the text, the approximate positions of the polar front in July (from Loeng 1989) and the main distribution of the adult capelin summer feeding grounds (shaded area, from Dragesund & Gjøsæter 1988).

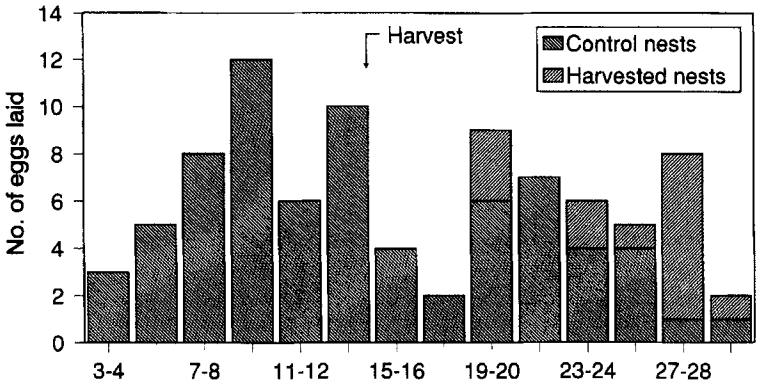

Fig. 2. The distribution of the laying dates of kittiwake eggs laid in 48 control nests, and 16 nests which were harvested on 14 June, at Hopen in 1984.

individually marked and counted at each visit. Laying dates were back calculated from hatching dates using a mean incubation period of 27 d previously documented in the region (Runde & Barrett 1981). Egg dimensions (length L and breadth B) were measured to the nearest 0.1 mm using vernier calipers, and egg volumes (V) were calculated using the formula $V = LB^2 \times 0.4861$ (Runde & Barrett 1981).

Chicks were weighed using Pesola spring balances (±5 g) and their wing lengths (max. flattened chord) were measured to the nearest 5 mm on each nest visit. Logistic growth curves were fitted using Ricklefs' (1967) graphical method. Eighty adults were also weighed (±5 g) during the incubation period, whereas the wing lengths of 112 adults were measured (±1 mm) throughout the season. Any food samples regurgitated by adults or chicks during handling were collected and frozen for later sorting in the laboratory. Each food sample was weighed to the nearest 1 g and the contents identified to the lowest possible taxa by examining otoliths and other recognisable hard parts using Breiby (1985), Härkönen (1986) and Tromsø Museum's reference collection. The contribution of each prey taxa to the overall diet was expressed as the proportion by mass of the total mass of the samples. Capelin lengths (snout to end of tail) were calculated using the equation fish length = otolith length × 48.0 + 25.8 (Barrett unpubl.). All means are given ± one standard deviation.

Results

The mean laying date of 73 eggs of known laying or hatching date in the 48 control nests was 14 June ±7 d (range 3–30 June, Fig. 2). After the 14 June harvest, sixteen eggs were laid in 10 of the 16 harvested nests. Three eggs in two of the clutches were laid only 5–6 days after the harvest.

Table 1. Logistic growth parameters (based on Ricklefs 1967, K = growth constant, KA/4 = maximum instantaneous growth rate) of kittiwake chicks on Hopen compared to colonies in North Norway and England. Hekkingen and North England data from Barrett & Runde (1980), Bleiksøya and Hornøya from Barrett (1983, 1996).

Colony	Year	Asymptote A (g)	Adult mass W (g)	Growth rate			
				R = A/W	K	KA/4(g/d)	$t_{10\text{-}90}$(d)
Hopen	1984	401	419	0.96	0.18	18.0	23.9
Hornøya	1980	418	431	0.97	0.20	20.9	22.4
Hornøya	1981	422	431	0.98	0.18	19.0	24.4
Bleiksøya	1986	396	392	1.01	0.20	19.8	21.9
Hekkingen	1973	414	375	1.10	0.18	18.7	24.2
Hekkingen	1974	405	375	1.08	0.20	20.1	22.1
Hekkingen	1976	410	375	1.09	0.21	21.7	20.7
N. England	1954–57	350	354	0.99	0.21	18.7	20.6
N. England	1961–62	375	330	1.07	0.20	18.4	22.4

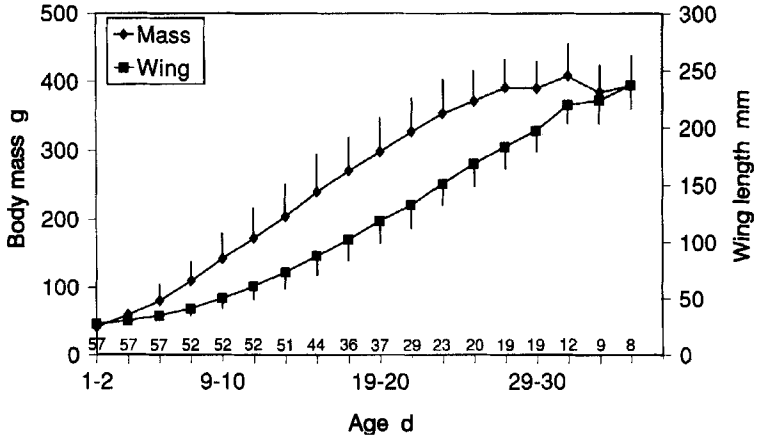

Fig. 3. The growth (mean body mass and wing length in relation to age) of kittiwake chicks at Hopen in 1984. Sample sizes are given above the x-axis and vertical lines indicate standard deviations.

Because replacement eggs are not usually laid until at least a week after the loss of the first clutch (Maunder & Threlfall 1972; Barrett 1978, 1989), these three were considered as eggs of a first clutch, leaving 13 true replacement eggs. The laying dates of two eggs in one of the harvested nests is unknown because they were laid before we started the nest controls and lost before hatching. Eleven of the remaining eggs were laid 13.5 ± 2.3 days after the harvest (range 9–15 days). The mean clutch size in the 48 control nests was 1.7 ± 0.6 eggs (2 × 0, 11 × 1 and 35 × 2 eggs). No three-egg clutches were found. The mean volume of control eggs which could be reached was 45.5 ± 3.4 ml (n = 79) and of replacement eggs was 44.7 ± 5.4 ml (n = 13). The difference was not significant (t = 0.54, p = 0.60).

Sixty-eight (89%) of 74 eggs in 45 of the control nests hatched. Three eggs were lost, three did not hatch and two were abandoned. Eight (62%) of 13 true replacement eggs in the harvested nests hatched. Four eggs were lost in a rock fall and the fifth failed to hatch. The overall hatching success was 85.8% (79/92 eggs).

Two sample t-tests of the mean masses of chicks in 1-chick and 2-chick broods of the same age showed brood size did not affect chick growth. Similarly, chicks hatched early (before 7 July, n = 21) grew at the same rate as those hatched late (after 11 July, n = 27) such that growth data for all chicks were pooled. The overall growth curve of chicks was sigmoidal, logistic in form and reached an asymptote of 401 g (96% of mean adult mass which was 418.7 ± 28.1, n = 80 during the incubation period, Table 1) approximately 30 days after hatching (Fig. 3). The maximum instaneous growth rate was 18.0 g/d. Two chicks reached a maximum mass of 470 g. Wing length increased steadily to ca. 240 mm at day 35/36 (Fig. 3). This was equivalent to 78% of the mean adult wing length (= 321.6 ± 6.9 mm, n = 112).

Fifty three (69%) of the 77 chicks which hatched had either fledged or were still in the nest on the last day of the study (8 August). Of the 24 which died, 12 (50%) were lost within the first week post-hatch, and a further five during the second week.

Of the 54 regurgitations collected, 38 were from chicks and 16 were from adults. Eighty seven percent contained capelin *Mallotus villosus*, 22% contained the hyperiid amphipod *Parathemisto libellula* and 17% contained arctic cod *Boreogadus saida*. Other food items included the

Table 2. Frequency of occurrence and proportion (by mass) of the food items in 54 kittiwake regurgitations at Hopen, Svalbard, July 1984.

	Frequency of occurrence		Proportion by mass	
Prey species/group	Number	%	Mass (g)	%
Mallotus villosus	47	87	811	86
Boreogadus saida	9	17	75	8
Leptagonus decagonus	1	2	8	1
Unidentified fish	3	6	5	0.5
Parathemisto libellula	12	22	37	4
Pandalus sp.	3	1	7	0.5
Nereis sp.	2	1	4	0.4

prawn *Pandalus* sp., polychaetes *Nereis* sp., the fish *Leptagonus decagonus* and unidentified fish. Capelin also dominated the samples gravimetrically, making up 86 % by mass of the samples collected (Table 2).

The mean masses of 31 chick and 14 adult regurgitations were 16.5 ± 7.6 g and 29.6 ± 17.5 g respectively. The difference was significant ($t = 2.7$, $p = 0.02$). Using Galbraith's (1983) findings that kittiwake chick regurgitations weigh 80% of the original feed mass, single chicks were fed ca. 30 g food and chicks and siblings in a two chick brood each received ca. 20 g. The mean length of 56 capelin found in the samples was 130.4 ± 15.9 mm (range 95–162 mm).

Table 3. Breeding success of kittiwakes at Hopen in 1984 compared to other North Norwegian colonies. Hekkingen data from Barrett (1978), Bleiksøya data from Barrett (1989) (– = no data).

	Hopen	Hekkingen				Bleiksøya
	1984	1973	1974	1975	1976	1986
No. eggs laid	92	–	286	91	246	100
% hatched	86	–	56	4	57	79
No. chicks hatched	77	81	146	–	118	79
% fledged	59*	52	77	–	25	76

*Assuming a further 10% loss between the last date of the study and final fledging

Discussion

The laying dates of kittiwakes on Hopen in 1984 were similar to those recorded on Novaja Zemlja in the late 1940s, but, as to be expected in high arctic colonies, they were later (by ca. 14 days) than previously found on the ice-free coasts of Norway and Kola (Belopol'skii 1957; Barrett 1978, 1983). Based on early studies summarised by Løvenskiold (1964) but in which data were not systematically collected, they were probably also later than found at Bjørnøya. They were, however, 10–14 days earlier than those found by Gaston (1988) in the Canadian High Arctic and by Fadley et al. (1989) at Cape Thompson in northern Alaska.

Despite the fact that no three-egg clutches were found, the mean clutch size of Hopen kittiwakes in 1984 was in the upper range of those found on Hornøya, East Finnmark (0.8–1.9 eggs/nest in 13 years between 1980–1995, pers. unpubl. data), where, in some years, up to 20% of the nests contained three eggs. Uspenskii (1956) and Swartz (1966) found three-egg clutches in only 1% of clutches studied on Novaja Zemlja and Cape Thompson respectively, and Gaston found no three–chick broods in the Canadian Arctic in 1982. Furthermore, a three-egg clutch was recorded only once in five studies carried out at Bjørnøra, Kongsfjord and Hornsund at the turn of the century (Løvenskiold 1964). Although Uspenskii and Swartz' sample sizes were small, and Gaston's observations were from late in the season after a certain amount of egg and chick loss, these studies suggest that the normal clutch size of kittiwakes in the northermost part of the species' breeding range is one or two eggs and that the frequency of three-egg clutches is negligible. Further south, in North Sea colonies, the frequency of three-egg clutches has been recorded to be in the range 7–13% (Cullen 1957; Coulson & White 1958; Poluszynski 1979).

The interval between egg loss and replacement and the lack of difference in the egg volumes of first and replacement clutches were also similar to those found in two North Norwegian studies (Barrett 1978, 1989). This and the large clutch size suggest that factors determining kittiwake clutch initiation and egg volume around Hopen were no more limiting than those found in the mainland colonies.

Similarly, the hatching success, chick growth, rate of chick loss and fledging success of kittiwakes on Hopen were similar to those found in North Norwegian colonies (Tables 1 and 3), again suggesting that resources in the northern Barents Sea did not limit production in 1984. This is in contrast to other arctic colonies, e.g. colonies in Alaska which have suffered from poor productivity since the mid-1970s due to low prey availability (Hatch et al. 1993). There was no evidence of Hopen chicks reaching a higher asymptotic mass than chicks in more southerly colonies (Table 1) as was suggested for arctic-breeding kittiwakes by Gaston (1988).

Whereas capelin was an important constituent (up to 93%) of the diet of kittiwake chicks in several colonies in the southern Barents Sea (Belopol'skii 1957; Barrett & Krasnov 1996), only once has it been documented in the northern part of the region as a very minor supplement to the diets of adults collected east of Spitsbergen in spring and summer (Lønne & Gabrielsen 1992;

Mehlum & Gabrielsen 1993). Capelin was not noted in the stomachs of spring- or autumn-feeding kittiwakes in Hornsund, nor amongst the summer diets of kittiwakes collected in Kongsfjord, Spitsbergen or at Franz Josef Land (Lydersen et al. 1989; Mehlum & Gabrielsen 1993; Weslawski et al. 1994). Nor was capelin noted in the diet of auks and fulmars *Fulmarus glacialis* in any of the above studies. In these studies and in nine historical studies of birds collected at Svalbard during the breeding season (summarised by Løvenskiold 1964), arctic cod and crustaceans dominated all the samples. The dominance of capelin in the chick diet at Hopen is thus an interesting supplement to the overall picture of Svalbard kittiwake diets. However, this is doubtless due to Hopen being so far southeast of the main archipelago and very often on the western edge of the main summer feeding grounds of capelin (Fig. 1).

The size distribution and mean length of the capelin caught by kittiwakes at Hopen were very similar to those collected at Hornøya in the 1980s (Barrett & Furness 1990), but larger than those in their diet in southeastern Alaska (median 81–90 mm in 1977, 51–70 mm in 1978, Baird 1990). Capelin of similar size (14–15 cm) were recorded during a fish survey 25–30 miles east of Hopen in 1969 and 1970 (Zaferman 1972).

Although capelin often occur near Hopen during the summer, there are suggestions that in 1984 kittiwakes had to forage further than normal to obtain this capelin. A study of the energetics of kittiwakes in the same colony and season documented adult feeding trips lasting 17–29 hours (mean = 23 hours, n = 17, Gabrielsen et al. 1987). Fourteen of these adults had single chicks and three had two chicks. All chicks were 5–10 days old. However, Gabrielsen et al's (1987) observations of birds were made four times a day only and may thus have missed some feeding bouts. The resulting trip durations were much longer than previously recorded in, e.g., North Norway. At Hekkingen, kittiwakes fed their chicks 4–6 times a day (Barrett 1978), whereas at Hornøya the median feeding trip durations in 1983 were a little over one hour, indicating a foraging range of 27 km (Furness & Barrett 1985). Trip durations recorded at Hopen by Gabrielsen et al. (1987) were also much longer than those recorded at other colonies where feeding conditions were both good (2–4 hours, Pearson 1968; Watanuki et al. 1992; Wanless & Harris 1992; Roberts & Hatch 1993; Hamer et al. 1993) and bad (10–14 hours, Wanless & Harris 1992; Hamer et al. 1993). This suggests that Hopen kittiwakes were either foraging much further afield than is normal for the species, possibly in the order of hundreds of kilometres, or that some of the feeding bouts were missed. As suggested by Gabrielsen et al. (1987), it is also possible that some of the time away from the nest was spent resting, not foraging, thus further reducing the apparent foraging time and range.

Adults colour-dyed in 1984 at Hopen were observed by passing ships ca. 40 km south-east of the island (pers. unpubl. data); this suggests that adults ranged far to the south or east of the island, possibly in or beyond the frontal zone between the Atlantic and Arctic currents (the polar front, Fig. 1) in their search for food. This open-sea site is well beyond the areas covered by the previous studies of kittiwake diet at Spitsbergen in which adult birds were collected in coastal or ice-filled waters. The distant foraging also suggests that 1984 was a year when the main summer distribution of capelin was far east of Hopen. According to Galkin & Ushakov (1977), this is not an uncommon phenomenon. By September, however, capelin had spread northwestwards and were abundant very close to the island (H. Gjøsæter, pers. comm.)

Although the adults may have been foraging very far afield to collect chick food, the mean masses of the adult and chick regurgitates were in the upper part of the ranges of those recorded on three North Norwegian colonies in ten seasons (chicks 6–27 g, adults 9–36 g, Barrett, unpubl. data) and during one season in Scotland by Galbraith (1983). The two heaviest adult regurgitates at Hopen were 72 and 58 g, very similar to Galbraith's 68 and 53 g. Maxima of 50–70 g were also recorded in the above-mentioned studies in North Norwegian colonies. The Hopen and Galbraith's maxima are ca. 18% of the respective adult body masses, suggesting that this is close to the maximum carrying capacity of kittiwakes when feeding their chicks.

Kittiwake chicks have a daily food requirement of ca. 80–100 g capelin when 10 days old (Gabrielsen et al. 1992). If adults carry their food at their maximum capacity, this requirement could easily have been reached at Hopen by adults even when feeding their chicks at the observed rate of a little more than once a day. However, with two chicks in the nest, adults would need to provide

two to three times the maximum and thus increase their feeding frequency accordingly. Unfortunately, no feeding frequency data were collected for a large sample of two-chick nests. The high growth rates and fledging success, and the lack of differentiation in growth rates in relation to brood size suggest, however, that adults did indeed increase the feeding rate above that recorded by Gabrielsen et al. (1987).

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