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Breeding density and population of little auks (*Alle alle*) in a Northwest Greenland colony

Abstract The little auk population of the Thule district in Greenland is generally believed to be the largest anywhere and to comprise more than half of the world population, although published numbers have largely been conjectural. In 1996/1997 we estimated breeding density of little auks at Hakluyt Island in this district by colour-marking a number of birds in three study plots and subsequently counting marked and unmarked birds present in the plots. The density estimate considered most representative of the colony was 1.8 birds/m^2 or 0.73 pairs/m^2 ($\pm 7\%$). From surveys of the inhabited area of the scree slopes, this density implies a total little auk population for the island of 130,000 pairs. An extrapolation to the entire Thule district suggests a population in the area of at least 15 million pairs, which is in general agreement with previously published assumptions.

Introduction

Of the six extant auk species (Alcidae) in the Atlantic region, the little auk (*Alle alle*) is the smallest, and the only one specialised on a diet of planktonic crustaceans. In that respect it appears to occupy an ecological niche divided between several species of auklets in the North Pacific area.

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The little auk is a highly successful species, breeding in huge numbers in the high arctic. The most important populations are those of northwestern Greenland (Thule), the Scoresby Sund area in East Greenland, and Spitsbergen (Svalbard), each with 1 to several million pairs (Kampp et al. 1987; Mehlum and Bakken 1994; Gaston and Jones 1998), while somewhat smaller numbers inhabit the arctic islands of Russia, Jan Mayen and Bjørnøya, and the Upernavik district in West Greenland. None of the major colonies have been accurately estimated, however, owing to the difficulties in censusing burrow-nesting birds and the remoteness of the breeding areas.

The little auk population in the Thule area (Avanersuaq) in Greenland is generally believed to comprise more than half of the world population. Freuchen and Salomonsen (1958) suggested that 30 million birds bred in the area, and Renaud et al. (1982) concluded on the basis of aerial counts that at least 14 million little auks (belonging to the Thule population) were present during spring in western Baffin Bay, and that the total number migrating through this area might be much larger. Recently, the position and extent of little auk colonies in the Thule area were described (Boertmann and Mosbech 1998), improving on earlier reports by Salomonsen (1950) and Roby et al. (1981). An attempt by Boertmann and Mosbech (1998) to convert linear colony extent into population size yielded an estimate of 20 million pairs; it had, however, to be based on the single datum from Roby et al. (1981) that a 140-m-long study colony of theirs held at least 7000 breeding pairs, with no details given.

Estimates of entire little auk populations are important for, for example, quantifying the role of the species in the marine ecosystem. For monitoring purposes, density estimates or sample counts may suffice. Rough indications of breeding density of little auks have been presented by a few authors (Norderhaug 1980; Evans 1981; Stempniewicz 1981; Kampp et al. 1987), mostly based on the number of nests found in a small area in the scree. The only systematic study, however, appears to be

that of Isaksen and Bakken (1995) who colour-marked birds in several study plots in Spitsbergen and based their estimates on numbers of marked and unmarked birds subsequently counted in the same plots.

We applied the technique of Isaksen and Bakken (1995) to estimate densities of breeding little auks at Hakluyt Island in Thule, Greenland. We used these densities and measurements of colony coverage to obtain an estimate of the entire little auk population on the island. The validity of extrapolating the results to the entire Thule area, in the same way as Boertmann and Mosbech (1998), is briefly discussed.

Materials and methods

Hakluyt Island (Fig. 1), at 77°26′N, 72°40′W, is adjacent to the North Water, a great polynya between Thule (Avanersuaq) district in northwestern Greenland and Ellesmere Island, Canada. Hakluyt Island, measuring about 4.8 × 2.2 km and peaking at 421 m, has well-developed talus along the eastern 2 km of the south coast and along the east coast (1 km), forming a huge little auk colony at levels mainly from 50 to 150 m, but occasionally extending to 300 m asl (Falk and Kampp 1997). Some thousands of little auks also breed in talus below steep cliffs along the north coast and in crevices in the cliffs right to the top. The north-facing cliffs are occupied by numerous kittiwakes (*Rissa tridactyla*) and Brünnich's guillemots (*Uria lomvia*), together with a few hundred black guillemots (*Cepphus grylle*), while a few razorbills (*Alca torda*) and puffins (*Fratercula arctica*) inhabit the low cliffs at the western end of the island. About 50 pairs of glaucous gulls (*Larus hyperboreus*) occur along the entire coastline.

Three study plots (1, 2, 3) were laid out in the little auk colony on the south coast. The plots were selected on the basis of their general appearance (apparent representativeness) and accessibility, and the presence of suitable vantage points from which to count them. Plots 1 and 2 were used in 1996, and plot 1 was reused in 1997 together with plot 3. Plots 1 and 2 were distinct, whereas plot 3 was somewhat arbitrarily delimited from a larger, continuous breeding area. The plots were photographed and measured and their areas calculated.

In each plot, little auks were captured using mist nets early in the field season. Captured birds were ringed, measured and inspected for brood patches, and apparent breeders were painted yellow with picric acid on breast and belly. Colour-marked birds

Fig. 1a, b Hakluyt Island. **a** Oblique view showing the three study plots and the approximate delimitations of little auk breeding area along the south coast. **b** Vertical view of the island, with extent of the major little auk colonies indicated by *white lines* (aerial photograph from Ordinary Survey and Cadastre, A. 273–97)
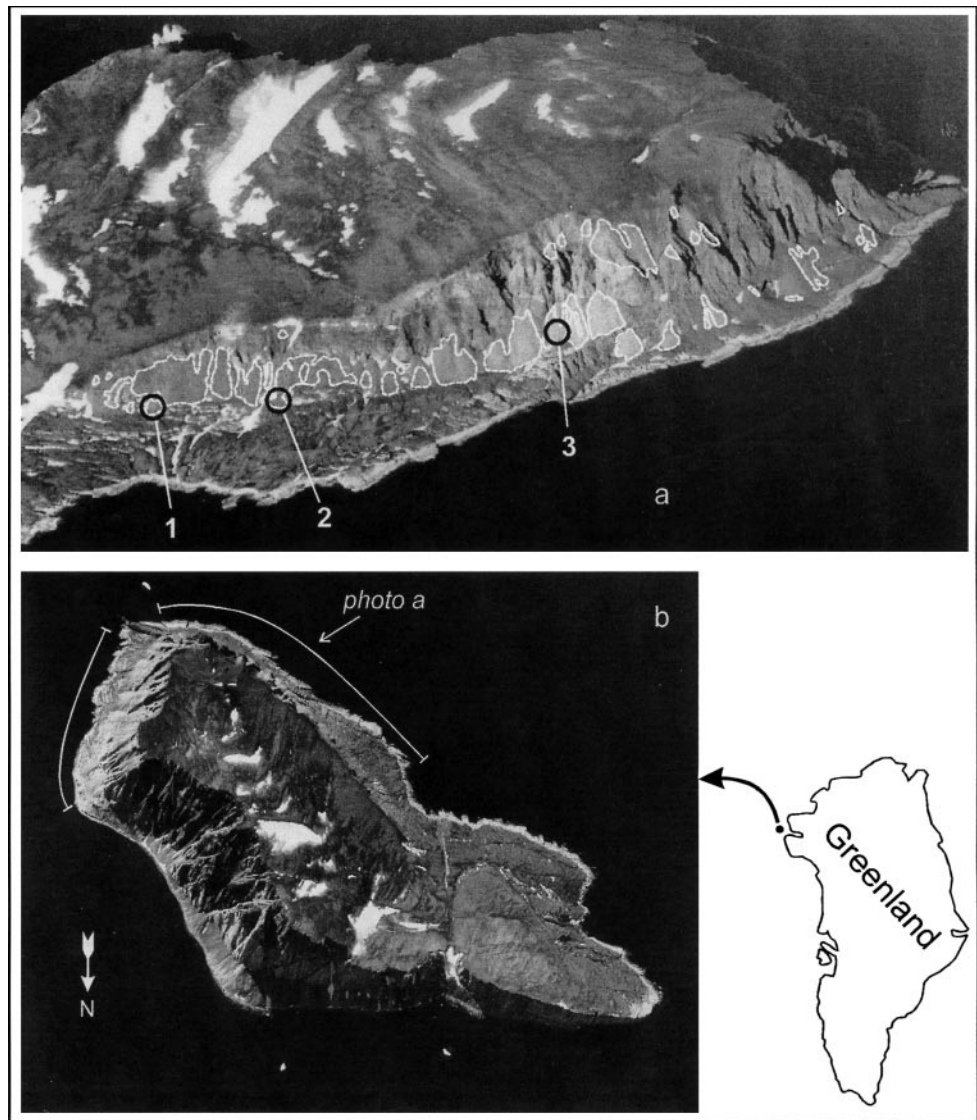
were kept in cardboard boxes for 15 min before being released, to allow the dye to dry.

Trapping and colour-marking took place on 28–30 July in 1996 and 19–25 July in 1997, in the early to mid-chick-rearing period. Colour-marked and unmarked birds visible in the study plots were counted on several occasions during 1–7 August in 1996 and 29 July to 11 August in 1997. Owing to constraints posed by weather and the birds' attendance of the plots, counts were irregularly scheduled but covered most of the 24-h arctic day.

We followed Isaksen and Bakken (1995) in estimating total number of birds associated with the plots by use of the modification of Chapman (1951) to the "Petersen estimate", discarding counts with less than seven marked birds:

$$N = \frac{(M+1)(n+1)}{m+1} - 1$$

where M = total number of birds marked in the plot, m = number of marked birds counted, n = total number of birds counted. All counts from the same plot and season were averaged to a single estimate.

$$\bar{N} = \frac{1}{K}\sum_{i=1}^{K} N_i$$

where K is the number of counts.

The variance of an individual estimate is obtained from Seber (1982):

$$s^2 = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)}$$

which may likewise be averaged, yielding a combined standard deviation:

$$\bar{s} = \frac{1}{K}\sqrt{\sum_{i=1}^{K} s_i^2}$$

The assumptions underlying the method are discussed by Isaksen and Bakken (1995).

The area inhabited by little auks was measured using vertical and oblique aerial photographs of Hakluyt Island, combined with height measurements and averaged GPS positions obtained during the study. However, little auks are not continuously distributed within this area (Fig. 1), so the actual coverage of the colony was estimated by marking inhabited areas on detailed photographs of the talus slopes directly in the field.

Results

The estimated density of birds in the study plots ranged between 1.2 and 3.3/m² (Table 1). To convert bird numbers into breeding pairs, the proportion of apparent non-breeders at plot 1 (1996) was used (23 of 122 birds caught, or 19%). At the other plots, birds with small or missing brood patches were sometimes released without being ringed, owing to time constraints. Breeding densities thus obtained (0.5–1.3 pairs/m²) are also shown in Table 1.

In estimating the breeding population for the south and east coast of the island, we multiplied the density estimate from plot 1 (1996 and 1997 combined), 0.73 ± 0.05 pairs/m², with the area of inhabited scree. The results are given in Table 2, together with an estimate of the minor contribution from the rest of the island, although this is guesswork. The estimated population for the entire island is about 130,000 pairs, with a suggested uncertainty of about 7% originating from the density estimate, provided that we are correct in assuming plot 1 to be representative for the island (see Discussion). The additional uncertainty stemming from the area estimate cannot be quantified.

Discussion

The breeding density estimates for plot 1 in 1996 and 1997 were similar, while the estimate for plot 2 (1996) was somewhat lower, and that for plot 3 (1997) considerably higher, than both estimates for plot 1. In case of plot 2, the difference was probably real, since plot 2, situated at the edge of the colony, did seem to contain areas of low density, while plot 1 had a fairly "normal" appearance. We only managed to count plot 3 three times, so we are less sure of the significance of the high estimate for this plot; the immediate impression was that the density of birds was similar to plot 1 or slightly more, but certainly not twice as much.

Table 2 Population size of little auks at Hakluyt Island, estimated from the given areas by use of a density of 0.73 pairs/m²

	Breeding area (m²)	No. pairs	Coastline (km)	Pairs/km coast
South	100,000	73,000	2.1	35,000
East	70,000	51,000	1.1	46,000
Other parts	–	6000	–	–
Total	–	130,000	–	39,000[a]

[a] South and east only

Table 1 Estimated number of birds and breeding density in the study plots

	Plot 1		Plot 2	Plot 3
	1996	1997	1996	1997
Area (m²)	486	486	917	501
No. of counts	10	6	6	3
Marked birds	99	53	82	93
Total birds	830 ± 69	920 ± 99	1083 ± 106	1656 ± 266
Density (birds/m²)	1.71 ± 0.14	1.89 ± 0.20	1.18 ± 0.12	3.31 ± 0.53
Density (pairs/m²)[a]	0.69 ± 0.06	0.77 ± 0.08	0.48 ± 0.05	1.34 ± 0.21

[a] Assuming 19% non-breeders among the birds (see text)

Isaksen and Bakken (1995) obtained estimates of 0.2–0.5 pairs/m^2 in one Spitsbergen colony, and 1.2–1.9 pairs/m^2 in another. The difference between the two colonies was thought to be connected with the size distribution of stones, being more heterogeneous and having a larger mean value in the high-density colony. Isaksen (1995) applied breeding densities derived from these stone-size distributions in his estimate of the little auk population in the Hornsund area in Spitsbergen. Unfortunately, data on stone size are not available from our study site, except that stones in our (perhaps) high-density breeding plot 3 were somewhat smaller than in plots 1 and 2. However, a threefold variation in breeding density, as between the two study colonies of Isaksen and Bakken (1995), should be detectable even without counts, and few markedly high- or low-density areas were apparent in the Hakluyt Island colony.

Isaksen and Bakken (1995) stressed the importance of the proportion of non-breeders (estimated at 15%, slightly less than the 19% used in this study) as a potential source of error. This problem is equally serious in the present study. The sample size was rather small, and although it was quite easy to see if a bird had a well-developed brood patch even when this was partly re-feathered, brood patches of failed breeders may have re-feathered more or less completely and escaped detection. Moreover, colony attendance of non-breeders apparently varies through the season, and probably also during the time from marking to counting of the birds (cf. Roby et al. 1981).

So, until it becomes possible to reliably correct for the proportion of non-breeders present in little auk colonies, and its variability, breeding density estimates must necessarily be coarse. Nevertheless, published estimates are reasonably consistent, despite the various techniques and study areas involved. In Spitsbergen, Norderhaug (1980) occasionally found more than one nest/m^2, and Stempniewicz (1981) reported 0.5–0.7 pairs/m^2. Kampp et al. (1987) gave a figure of 0.7 pairs/m^2 for a single study plot in East Greenland, based on a similar technique to that applied in the present study. Evans (1981), in the Upernavik district in Greenland, found a mean density of 0.25 nests/m^2 but considered this an underestimate, since some nests were almost certainly missed.

Our estimate for the entire little auk population on Hakluyt Island was based on area of inhabited scree and density of breeding pairs, neither of which were very accurately known. It was not possible to entirely compensate for perspective distortions of photographs or to account for the irregularity of the terrain, which implies some (not quantifiable) uncertainty in area estimates, especially for the east end of the island. It is our belief that the areas adopted (Table 2) are conservative. The given total of 130,000 pairs, therefore, is likely to represent a minimum figure.

If we hazard an extrapolation covering the entire Thule area, we may combine the number of little auk pairs per kilometre of coastline from Table 2 with the total, horizontal extent of little auk colonies in the district, 395 km (Boertmann and Mosbech 1998). The result is a population of at least 15 million pairs. In parts of the district, little auk colonies do have a larger vertical extent than on Hakluyt Island, but in other parts they are shallower, and Hakluyt Island may in fact be fairly representative in this respect. Direct observation and photographs of 25 km of the south coast of the large Northumberland Island just east of Hakluyt Island showed a topography and extent of the little auk breeding area much like that found in our study area (K. Kampp, K. Falk, C.E. Pedersen, unpublished data). So our minimum figure of 15 million pairs may well be fairly accurate and certainly gives the correct order of magnitude.

A significant improvement of the population estimate would, apart from a better estimate of the proportion of non-breeders among the little auks visible at the surface in colonies, require more accurate surveys of breeding colonies and inhabited areas within colonies. This appears to present a rather formidable task, however, and would have to be done from the ground. In our experience, the heterogeneous distribution of the birds in apparently homogeneous scree slopes is not at all obvious from a distance, or at close range at times when no birds are present, since even areas where stones are not overgrown by lichens may be almost or entirely devoid of birds.

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