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Censusing the Thick-billed Murre colonies of Akpatok Island, NWT

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Introduction

The large colonies of Thick-billed Murres (*Uria lomvia*) on Akpatok Island have been familiar to local Inuit for many centuries, giving the island its name, "isle of murres" (*akpa*). The first ornithological exploration of the island was made by an Oxford University expedition in 1931 (Polunin 1932, Davis 1936). However, no attempt was made to census the murre colonies, although their position was mapped. In 1954, L.M. Tuck and J.B. Millar of the Canadian Wildlife Service (CWS) visited the island for 6 weeks in July and August. Tuck estimated that a maximum of 300 000 murres were present on the cliffs at the south end of the island and 900 000 at the north end (Tuck 1954, 1961). These numbers translate into about 150 000 and 450 000 breeding pairs (Brown *et al*. 1975, Gaston and Nettleship 1981, and see below). More recently, an aerial survey of the island by D.N. Nettleship in 1972 confirmed the position of the colony boundaries. Tuck estimated that Akpatok Island had one of the largest concentrations of Thick-billed Murres in Canada.

In 1981 and 1982, a CWS field party, including G. Chapdelaine (GC) and P. Brousseau (PB) conducted studies of breeding biology at the south colony during July and August (Chapdelaine and Brousseau 1982, 1984). In 1982, the colony was photographed in order to make a bird count at a later date. The north colony was visited by A.J. Gaston (AJG) and P. Mineau (PM) in August 1983 and was similarly photographed.

Owing to the size of the north colony and the relatively poor estimates obtained from boat photo-counts where the cliffs are high and the birds therefore a long way from the camera (Gaston *et al*. 1985), we decided not to make the very large investment of time and effort required to count the whole colony. Instead, we elected to sample the colony area. This note describes the census techniques used for both colonies. Each of the major Thick-billed Murre colonies probably needs to be treated according to its own peculiarities. Our methods at Akpatok Island may or may not be appropriate elsewhere. However, they illustrate one possible approach to sampling such a colony and the results that can be obtained.

Description of the colonies

The north colony at Akpatok Island extends over 14 km of cliffs ranging in height from 60 to 260 m (Fig. 1). The highest cliffs are toward the middle of the colony and the lowest are at the southern end (Fig. 2). The sharp promontory known as "Hell Cliff", at the north-east tip of the island, divides the colony into two segments. The north coast to the west of Hell

Cliff is sheer, with only a very narrow cobbled beach. To the south of Hell Cliff, down the east coast of the island, the beach is broader and there is an extensive intertidal platform stretching up to 500 m from the high tide line.

On the north coast, breeding sites for murres are confined to narrow shelves cut into the horizontally bedded limestone, mainly near the top of the cliff. On the east side, there are some broad shelving areas that support compact groups of murres. Although many sites are again situated on horizontal shelves, there is a greater scattering of sites and more occur on the lower half of the cliff. Toward the southern end of the colony, where the cliffs are lowest, the distribution of breeding birds is very patchy, with small aggregations of birds and large unoccupied areas.

The length of the south colony is about 10 km, with the cliffs ranging from 120 to 165 m in height. At the base of the cliffs there is a broad scree and a flat meadow at the southern end of the colony, but the scree contracts northwards, becoming intermittent. Most of the birds breed on long horizontal ledges on the top half of the cliff, with a few irregular patches. The highest density occurs close to the ravine, about one-third of the way from the west end of the colony (Fig. 3). In comparison with other arctic Thick-billed Murre colonies, the density of breeding birds is generally rather low.

Tuck's camp was situated on the meadow area at the south-west end of the colony. He described this as being the densest part of the colony at that time. However, this is no longer so; the perferred area seems to have changed since Tuck's visit, possibly as a result of changes in the cliffs' structure, which may have been caused by the frequent rock-falls.

Methods

South colony

Methods employed for the south colony followed the recommendations of Birkhead and Nettleship (1980). A complete set of photographs was taken by GC and PB from an inflatable boat on 29 June 1982, using a Hasselblad camera with a 250 mm lens and P × P 120 film. Photos were taken between 10:00 and 15:00 EST, the exact time being recorded for each frame. Photos were enlarged to 20 × 20 cm and the birds counted using a counting pencil connected directly to an automatic counter. Photographs were classified into four groups on the basis of their quality.

Numbers of murres counted on the cliffs were converted to numbers of breeding pairs using the conversion factor "*k*" (breeding pairs/individuals present: Nettleship 1976, Birkhead and Nettleship 1980). The conversion factor was derived from counts made over the entire daylight period of 27 July (Fig. 4) at plots where the number of breeding pairs present was known from observations of eggs present (Type 1 method: Birkhead and Nettleship 1980). Counts for each pho-

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Figure 1
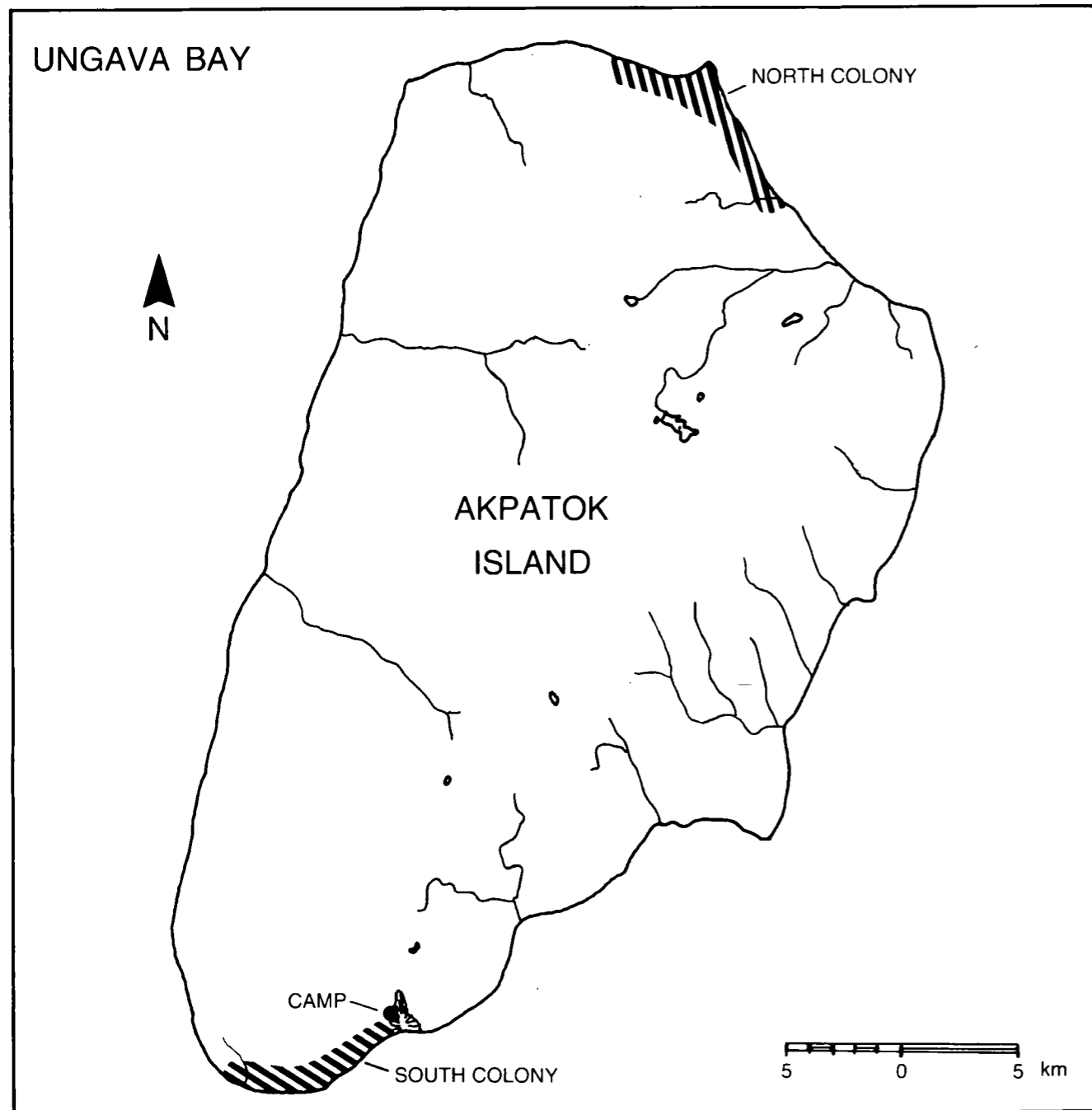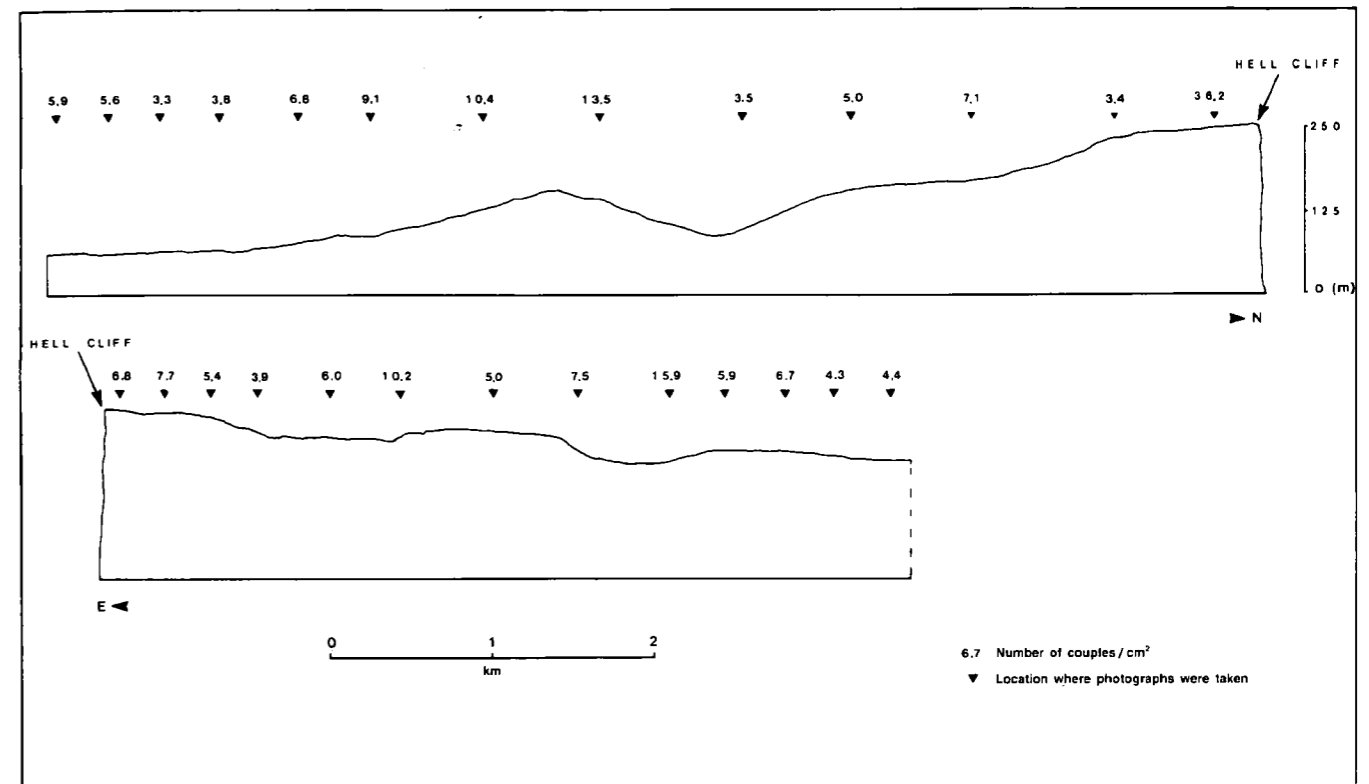Location of Thick-billed Murre colonies at Akpatok Island

Figure 2
Sketch map of the north colony showing the position of photographs counted and the corresponding density of pairs

tograph were corrected by the k value for the corresponding time of day. Weather conditions on 27 and 29 July were similar.

North colony
The set of photographs used to count the north colony was taken with a Pentax 6×7 camera and standard lens, using Plus-X professional film, on 6 August (east coast) and 8 August (north coast) 1983, partly from a Zodiac inflatable boat and partly (on the east side) from the intertidal platform, using a tripod. The total number of photos taken was 130, from which we selected every fifth picture for counting, beginning from Hell Cliff and working outwards in both directions, a total of 13 in either direction. These pictures were enlarged to 35×37 cm. In addition, we counted separately a major concentration of murres on a shelving area just to the south of Hell Cliff on the east side, using pictures taken with a 200 mm lens and enlarged to 25×20 cm.

A mosaic was constructed using all the pictures of the colony made on the same scale (contact size) to measure the total length of the colony on the photographs. Each photograph selected for counting was inspected for quality; edge areas, where birds might have been obscured by reduced sharpness, were excluded. On each photograph we then measured the total length of cliff to be counted. The aggregate length selected amounted to 36% of the total colony length, as measured on

the photographs. The aggregate length exceeded 25% because adjacent photographs overlapped by 20–30%.

Because the birds were distributed mainly in horizontal bands, we chose to sub-sample the photographs selected for counting by dividing the count area into vertical strips 1 cm wide. As the counting strips were at right angles to the axis of maximum variation, the resulting variance among samples was minimized (Savard and Smith 1985). We then counted birds in alternate columns on all enlarged photographs, using the same technique as for the south colony. The total area counted was estimated by measuring the length of the columns counted on the photographs from sea to cliff-top. The position of photographs counted is shown in Figure 2.

Counts for each photograph were converted to numbers of breeding pairs, using the k value for the appropriate time of day, derived from counts made on 3 August 1982 at the south colony (Fig. 5), because no information was obtained on k values at the north colony. We calculated the mean number of pairs per square centimetre for each photograph counted. This figure was distributed normally with a range from 3 to 15 pairs/cm^2 for all except one picture (AK2-1), on which the density was 36.25 pairs/cm^2. Consequently, we calculated the total number of pairs on AK2-1 separately, and added them to the total extrapolated for the remainder of the colony. It is important to note that all areas involved are areas measured from the

Figure 3
Sketch map of the south colony showing the number of birds counted in each section
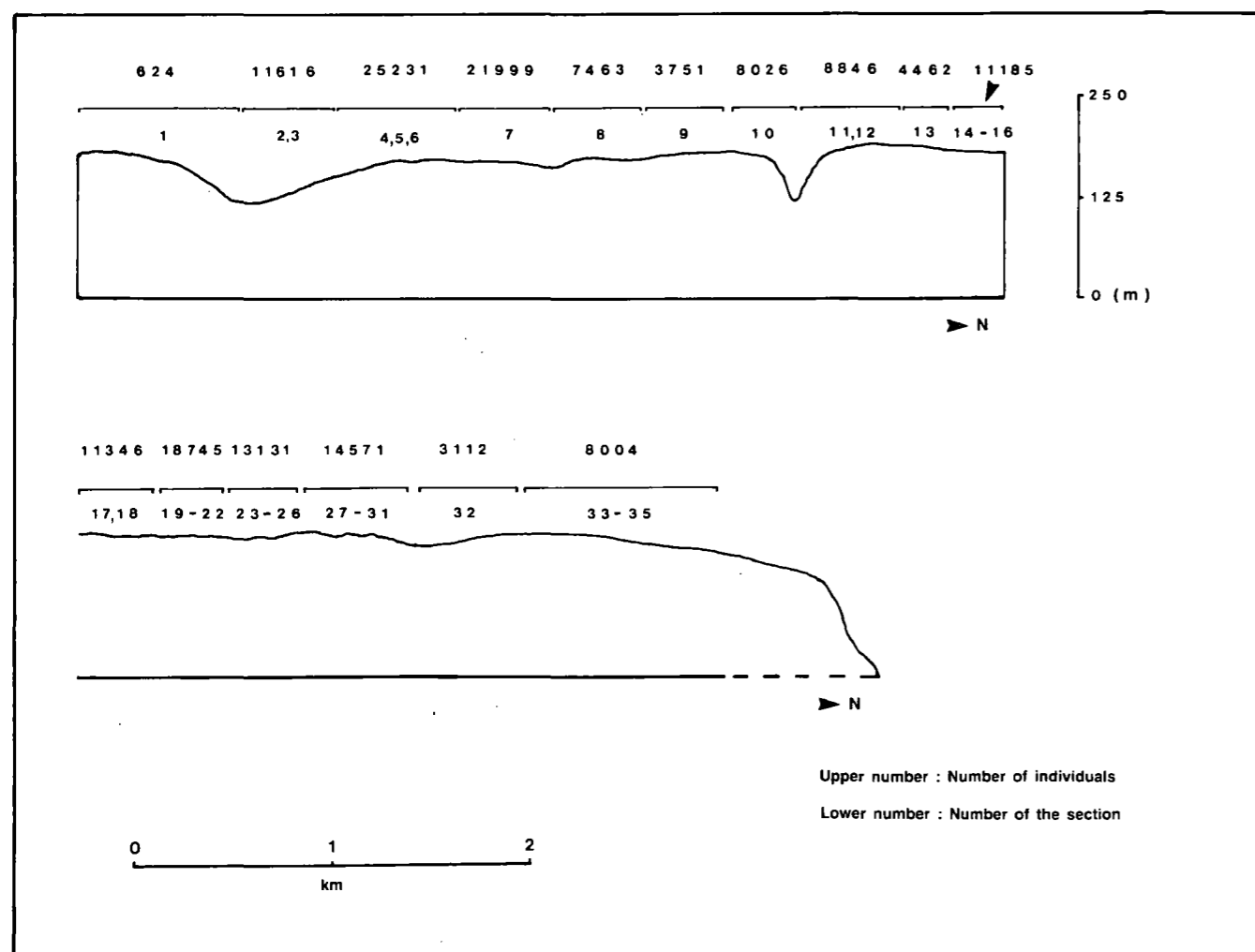
photographs, not actual areas. However, this should not affect the validity of the extrapolation.

Results
South colony
Altogether 172 211 Thick-billed Murres were counted on the photographs, giving an estimate of 119 711 pairs for the entire colony. Details of individual counts and their corresponding k values, ranging from 0.66 to 0.71 based on 390 pairs, are given in Table 1. These figures are certainly underestimates. It is never possible to count all the birds present from photographs because some birds are hidden behind others. This is particularly likely to occur on Akpatok Island, where birds are densely packed on the few major ledges. However, the quality of most photographs was considered adequate and the true breeding population is probably in the range of 120 000–150 000 pairs.

North Colony
We counted 4290 cm² (17.9%) out of an estimated total colony area of 23 839 cm² (8.6%). The total number of birds counted was 45 486, and the estimated number of breeding pairs for the area counted was 28 711, giving a mean density, on the photographs, of 6.7 pairs/cm². This extrapolates to a total of 159 721 pairs for the entire colony except AK2-1. A further 13 065 pairs were estimated for AK2-1, giving a total for the whole colony of 172 756 pairs. Details of count and k values are given in Table 2.

We used Jolly's method (Caughley 1977) to calculate confidence limits for our population estimate, giving a standard error of 4300.8 and 95% confidence limits of ± 5.18% of the estimate (Appendix). To examine the effect of altering the total area counted, we also calculated confidence intervals for the cases where only one column in six and one column in four were counted. These gave, respectively, ± 9.86% and
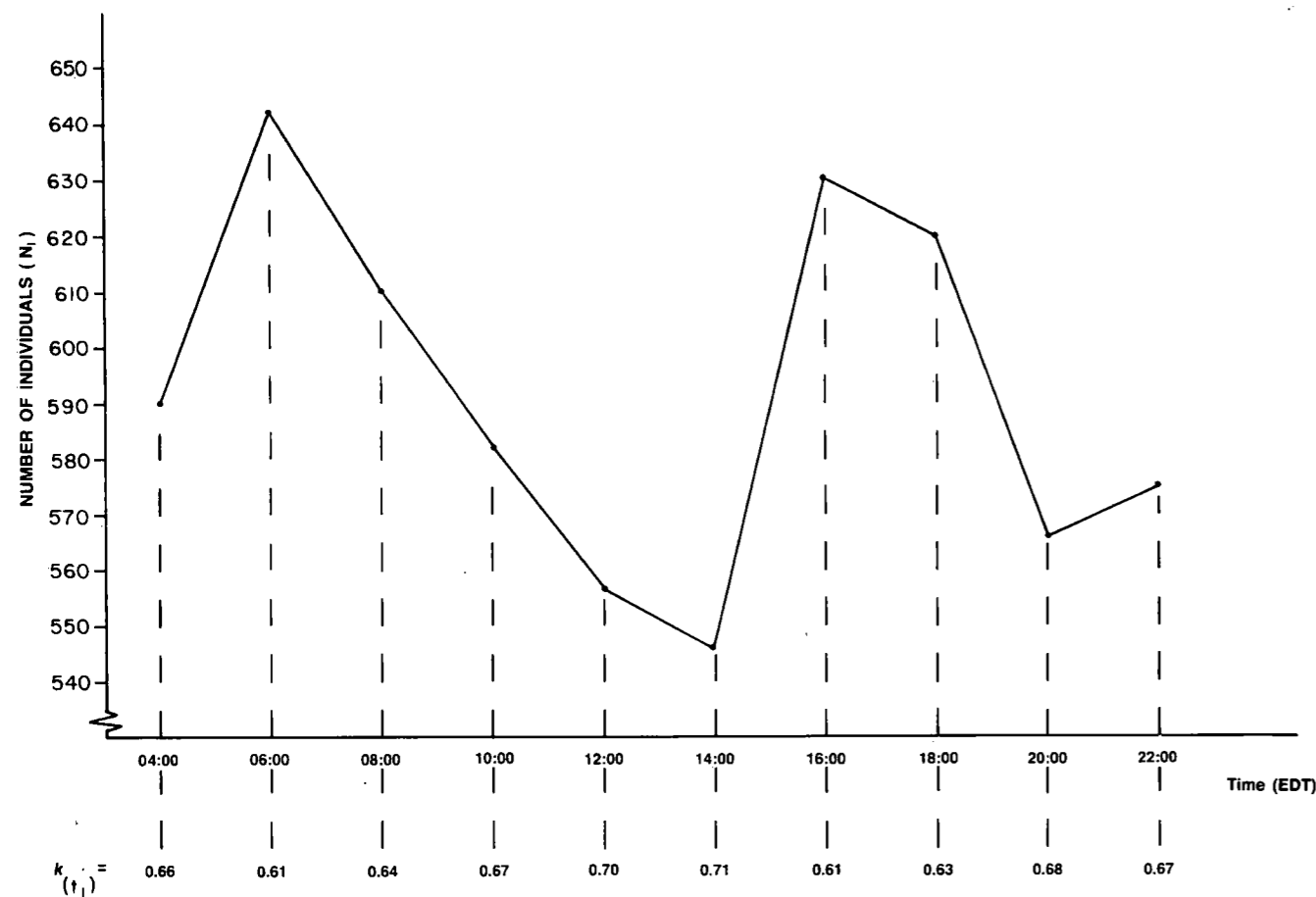
Table 1
Details of photo counts, k ratios and estimates of the breeding population for the south colony in 1982

Section	No. of film	No. of photo	Quality*	No. of murres counted	Time	k	No. of breeding pairs
1	2	12	2–3	624	15:00	0.66	412
2	2	9–11	2–3, 2–3, 2–3	3 934	14:50	0.71	2 793
3	2	6–8	2–3, 2–3, 2–3	7 682	14:45	0.71	5 454
4	2	1–5	3, 3, 2, 2–3, 2–3	7 397	14:35	0.71	5 252
5	1	1, 2, 3, 5, 6, 7, 8	4, 2–3, 3, 4, 4, 3, 2–3	8 470	14:20	0.71	6 014
6	1	4, 9, 10	3, 2–3, 2	9 364	14:15	0.71	6 648
7	1	11, 12	2, 2	5 639	14:10	0.71	4 004
	6	5–12	2, 1, 2, 1, 2–3, 2, 2–3, 2	16 360			11 616
8	6	1–4	1, 3, 2, 2	7 463	14:00	0.71	5 299
9	7	11, 12	2, 1	3 751	13:45	0.70	2 626
10	7	7–10	2, 2, 2, 1	8 026	13:30	0.70	5 618
11	7	3–6	3, 2, 2, 2	6 470	12:40	0.70	4 529
12	7	1	3	2 376	12:40	0.70	1 663
13	7	2	3	3 977	12:40	0.70	2 784
	5	12	3	485			340
14	5	10, 11	3, 3	6 748	12:30	0.70	4 724
15	5	9	3	2 073	12:25	0.70	1 451
16	5	8	2	2 364	12:20	0.70	1 655
17	5	5–7	3, 3, 4	4 370	12:15	0.70	3 059
18	5	1–4	3, 3, 3, 3	6 976	12:00	0.70	4 883
19	5	1	3	2 006	11:45	0.68	1 364
20	16	1, 2	1, 2	2 500	11:40	0.68	1 700
21	16	3, 4, 5, 6, 7, 9 10	1, 2, 3–4, 3, 3, 3, 1	8 767	11:30	0.68	5 962
22	16	8, 11, 12	1, 2, 2	5 044	11:25	0.68	3 430
	17	2	3	428			291
23	17	1, 2	2, 3	1 171	11:15	0.68	796
24	17	5	3	1 045	11:15	0.68	711
25	17	4, 6, 7	1, 2, 3	4 289	11:00	0.68	2 917
26	17	3, 8, 9, 10, 11, 12	1, 2, 3, 1, 3, 3	4 637	11:00	0.68	3 153
	14	11, 10	3, 3	1 989			1 353
27	17	11, 10	3, 3	1 250	10:45	0.67	837
	14	10	3	655			439
28	14	8, 9	3, 2	2 469	10:45	0.67	1 654
29	14	1–7	1, 2, 3, 3, 2, 2, 3	3 013	10:45	0.67	2 019
	15	10, 11, 12	3, 3, 3	1 625			1 089
30	15	4–9	3, 1, 3, 2, 3, 1	4 793	10:45	0.67	3 211
31	15	2, 3	1, 3	766	10:30	0.67	513
32	15	1	1	413	10:30	0.67	277
	13	12–14	3, 1, 2	2 699			1 808
33	13	7–11	1, 1, 3, 1, 1	3 063	10:25	0.67	2 052
34	13	6	1	740	10:15	0.67	496
35	13	1–5	1, 2, 1, 1, 1	4 201	10:00	0.67	2 815
Total				172 211			119 711

*Quality ranking for photographs
1. Excellent — Very good resolution with individual birds easily visible over the entire photograph
2. Good — Mainly as above, but birds difficult to see on some sections of the photograph
3. Medium — Good resolution but the distance involved makes the birds too small to be easily recognizable
4. Poor — Birds practically impossible to pick out

Figure 4
Counts of birds made on 27 July every 2 h at plots where the number
of breeding pairs was known and the corresponding k value

Figure 5
Counts of birds made on 3 August every 2 h at plots where the number
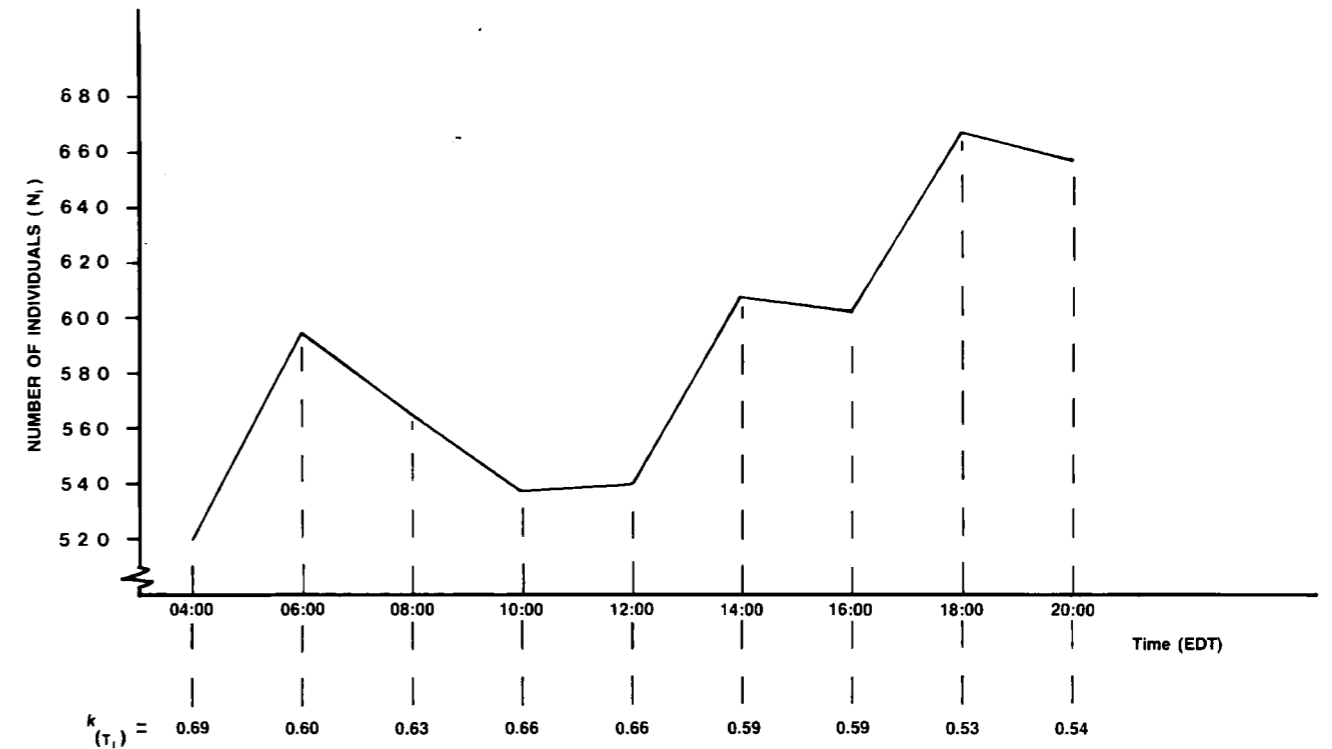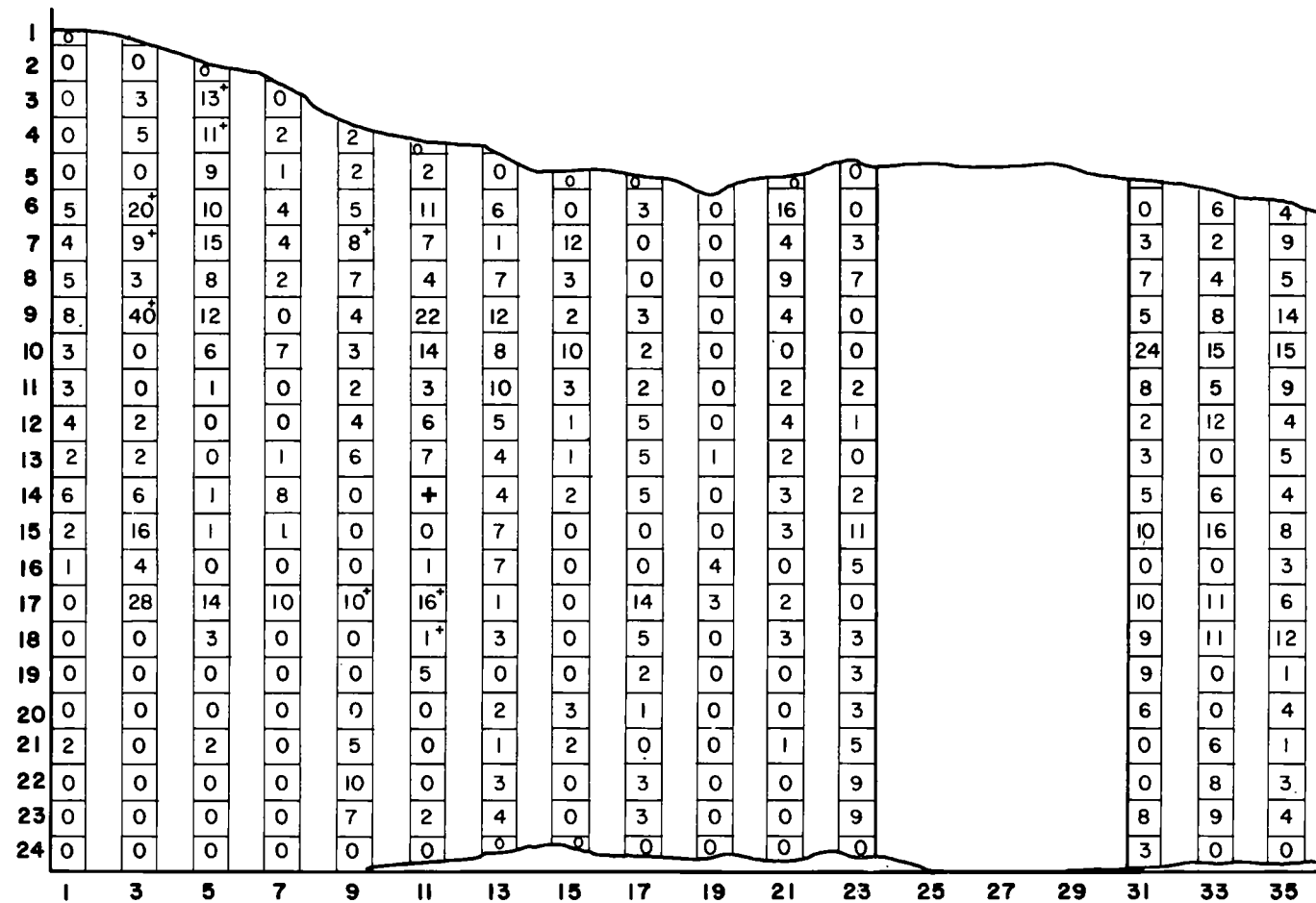of breeding pairs was known and the corresponding k value

Table 2
Details of counts on the sample photos at the north colony

Picture no.	No. of murres	Time	k value	No. of pairs
AK2-8A	8 846	10:10	0.66	558
AK2-13A	1 404	10:20	0.66	927
AK2-18A	1 105	10:40	0.66	729
AK3-4A	648	10:45	0.66	428
AK3-10A	4 951	10:50	0.66	3 268
AK3-15A	4 052	11:15	0.66	2 674
AK4-3	3 478	12:10	0.66	2 295
AK4-9	2 457	12:15	0.66	1 622
AK5-2	1 547	13:30	0.62	959
AK5-8	1 049	13:40	0.62	550
AK6-2	1 129	13:05	0.62	600
AK6-8	1 659	13:35	0.62	1 030
AK7-7A	1 113	15:00	0.59	690
AK7-8A	678	15:00	0.59	400
AK7-9A	516	15:10	0.59	304
AK7-11	1 870	15:00	0.59	1 103
AK8-4/5	2 028	15:05	0.59	1 197
AK8-9	2 366	15:00	0.59	1 396
AK9-2	1 590	15:15	0.59	938
AK9-7	1 416	15:20	0.59	835
AK9-12	1 671	15:25	0.59	986
AK11-12	1 144	11:10	0.66	755
AK12-5	1 300	11:55	0.66	858
AK12-10	1 912	11:55	0.66	1 262
AK13-2	1 783	12:00	0.66	1 177
AK13-7/8	1 061	12:00	0.66	700
AK13-12	713	12:00	0.66	470

±7.59% of the estimate. Considering the other possible inaccuracies in the method, the difference between 95% confidence limits of ±5% and ±10% of the estimate seems fairly trivial. Consequently, we recommend that, if the method is to be applied elsewhere, effort may be reduced by counting only one quarter of the columns.

The above confidence limits do not include underestimation occurring through birds being overlooked and, as in the case of the south colony, our estimate is probably well below the true figure. Birds near the top of the 250-m high cliffs in the centre of the colony were very hard to distinguish on the photographs. On the other hand, those on the 80-m cliffs at the south end of the colony were easily counted. The accuracy of counts at the two colonies was probably similar, and we believe that the true breeding population of the north colony is in the range of 180 000–250 000 pairs.

Discussion
The method adopted at the north colony resulted in a great reduction of printing expense. At $15 each printing, a complete set of pictures would have cost nearly $2000. In addition, the method considerably reduced the amount of time required for counting. It is not possible to measure the level of inaccuracy introduced by the sampling approach, but the evidence from estimates of confidence limits suggests that the level was fairly low in relation to other inaccuracies inherent in such photographic counts (Gaston et al. 1985).

At Akpatok Island, which has very uniform cliff structure and ledge types, the nature of the Murre colonies may lend itself particularly to this type of sampling. At colonies where birds are more densely congregated, such as those of Digges, Hantzsch, and Coats islands, the expense of the photography involved is smaller. For such colonies, a technique where all photographs are printed, but only one column in four counted, might provide the most effective approach.

Our population estimates are considerably smaller than those obtained by Tuck (1954, 1961). However, without better information on Tuck's methods and the proportion of the colonies counted, it is not realistic to speculate about changes in population size. Tuck saw the north colony during a boat trip

Figure 6
Sketch map of photo AK11-12 (north colony) showing the columns sampled and the number of individuals counted in each square centimetre

PHOTO AK 11 - 12

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35
1	0																	
2	0	0																
3	0	3	13*	0														
4	0	5	11*	2	2													
5	0	0	9	1	2	2	0											
6	5	20	10	4	5	11	6	0	3	0	16	0				0	6	4
7	4	9*	15	4	8*	7	1	12	0	0	4	3				3	2	9
8	5	3	8	2	7	4	7	3	0	0	9	7				7	4	5
9	8	40	12	0	4	22	12	2	3	0	4	0				5	8	14
10	3	0	6	7	3	14	8	10	2	0	0	0				24	15	15
11	3	0	1	0	2	3	10	3	2	0	2	2				8	5	9
12	4	2	0	0	4	6	5	1	5	0	4	1				2	12	4
13	2	2	0	1	6	7	4	1	5	1	2	0				3	0	5
14	6	6	1	8	0	+	4	2	5	0	3	2				5	6	4
15	2	16	1	1	0	0	7	0	0	0	3	11				10	16	8
16	1	4	0	0	0	1	7	0	0	4	0	5				0	0	3
17	0	28	14	10	10*	16*	1	0	14	3	2	0				10	11	6
18	0	0	3	0	0	1*	3	0	5	0	3	3				9	11	12
19	0	0	0	0	0	5	0	0	2	0	0	3				9	0	1
20	0	0	0	0	0	0	2	3	1	0	0	3				6	0	4
21	2	0	2	0	5	0	1	2	0	0	1	5				0	6	1
22	0	0	0	0	10	0	3	0	3	0	0	9				0	8	3
23	0	0	0	0	7	2	4	0	3	0	0	9				8	9	4
24	0	0	0	0	0	0	0	0	0	0	0	0				3	0	0

around the island, and it is unlikely that accurate counts could have been made from such a platform. It is equally unlikely that populations have not changed. In any case, both surveys do indicate that the north colony is considerably larger than the south colony. The total population of the island is between 300 000 and 400 000 breeding pairs. This means that Akpatok Island currently supports the largest concentration of seabirds in the eastern Canadian Arctic.

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Appendix
We calculated the estimate (Y) for the number of pairs of Thick-billed Murres and 95% confidence limits using Jolly's Method for unequal sized sampling units.

Let N = the number of columns in the whole set of pictures
n = the number of sample columns
Z = the area of the census zone (in cm^2)
z = the area of any one column (in cm^2)
y = the number of counted pairs in any one column
R = the ratio of pairs counted to area search, i.e. $\Sigma y / \Sigma z$
S^2y = the variance between pairs counted in all the columns

$$= \frac{1}{n-1}\left[\Sigma y^2 - \frac{(\Sigma y)^2}{n}\right]$$

S^2z = the variance between the area of all columns

$$= \frac{1}{n-1}\left[\Sigma z^2 - \frac{(\Sigma z)^2}{n}\right]$$

Szy = the covariance between the animals counted and the area of each column

$$= \frac{1}{n-1}\left[\Sigma zy - \frac{(\Sigma z)(\Sigma y)}{n}\right]$$

Then,
(1) population total, $Y = ZR$
(2) population variance, $Var(Y)$
$= N(N-n)(S^2y - 2RS_{zy} + RS_z^2)$
(3) population standard error, $SE(Y) = var(Y)$
(4) 95% confidence limits of $Y = \pm \tau\, SE(Y)$

To illustrate the method, we give here the calculation of estimates of Thick-billed Murre pairs of picture AK11-12 (Fig. 6). We photographed this sector on August 10 at 11:10. The corresponding k value at this time was 0.66, giving an estimate of 755 pairs for the 1144 individuals counted on the picture (Table 2). The total number of columns on this picture is 35.5, and the number of sample columns is 15. The area of the census zone is 448.6 cm^2, and the area of sample columns is 190.6 cm^2. So, the ratio of pairs counted to area (R) = 3.96.
Substituting these values in equations 1, 2, 3, and 4 we obtain for pictures AK11-12:
Population total, $Y = 1776$
Population variance, $Var(Y) = 858.4$
Population standard error, $SE(Y) = 29.3$
95% confidence limits of $Y = \pm 59$ (3.3%)