A survey of Lesser Snow Geese on Southampton and Baffin islands, NWT, 1979
A survey of Lesser Snow Geese on Southampton and Baffin islands, NWT, 1979

Occasional Paper
Number 61
Canadian Wildlife Service

Disponible également en français

*CWS, Sainte-Foy, Que. G1V 4H5
†CWS, Delta, B.C. V4K 3Y3
Contents

4 Acknowledgements
5 Abstract
6 Introduction
6 Methods
6 1. Review of technique and materials
6 2. The 1979 photo survey
6 3. Analyses of the 1979 photographs and the problem of colour-phase ratios
7 Comparison of the 1973 and 1979 results
7 1. Southampton Island colonies
8 2. Baffin Island colonies
13 Conclusions
13 1. Status of the goose population
13 2. Appraisal of the large-format vertical photographic technique
14 Literature cited

List of tables
7 Table 1. Results of a photographic survey of nesting Lesser Snow Geese in colonies on Southampton and Baffin islands, NWT, in 1979, with comparative results from 1973

List of figures
5 Figure 1. Southampton Island and southern Baffin Island, showing the major Lesser Snow Goose breeding areas surveyed in 1979
8 Figure 2. The Ell Bay colony, Southampton Island
9 Figure 3. The West Boas River colony, Southampton Island
9 Figure 4. The Boas River colony, Southampton Island
10 Figure 5. The Bear Cove colony, Southampton Island
10 Figure 6. The East Bay colony, Southampton Island
11 Figure 7. The Bowman Bay colony, Baffin Island
12 Figure 8. The Cape Dominion and Koukdjuak River colony, Baffin Island

List of appendices
15 Appendix 1. Sampling methodology
15 Appendix 2. Record of photographic coverage of Lesser Snow Goose colonies on Southampton and Baffin islands, 1979, and unadjusted numbers of geese counted
16 Appendix 3. An illustrated guide for the identification of Lesser Snow Goose images on photographs
Abstract

A survey of nesting Lesser Snow Geese (Anser c. caerulescens) was conducted in eight colonies on Southampton and Baffin islands in June and July 1979. The method, following that of a 1973 survey, used large format vertical photography at two scales. Extensive coverage at 1:5000 allowed accurate counts of white-phase geese but not the more cryptic blue-phase birds. To count both colour phases and obtain ratios to apply to the white-phase count from the 1:5000 photographs, subsampling was done at 1:2000. An estimated 453,900 (± 67,000; 95% confidence intervals) breeding pairs were in the area, an increase of 14% from 1973. Most of the increase was in the Southampton Island population, which rose 50% (116,500 nests in 1979, 77,000 in 1973). No significant change was found on Baffin Island.

Both white- and blue-phase individuals were present in all colonies, with blue-phase accounting for 52% overall, similar to the 51% recorded in 1973. Southampton Island colonies contained 28% blue-phase geese and Baffin Island 64% in 1979. It was difficult to identify blue-phase geese on the 1:2000 photographs, and some birds may have been missed or small boulders erroneously identified as blue-phase geese. Some of our estimates of absolute population size or colour-phase ratios may therefore be biased. However, because the methods were similar to those used in a survey during 1973, relative changes between the 1973 and 1979 estimates are probably real. The technique provides reliable results for white-phase geese, but ground-truthing is needed to obtain reliable colour-phase ratios and total estimates in mixed-phase colonies. Escalating costs of aircraft rental, photography, and the personnel required to count goose images on the photographs make the technique most appropriate when it is necessary to census many large and widely separated colonies in the same nesting season. An illustrated guide to the identification of goose images on aerial photographs is presented.

Introduction

The Lesser Snow Goose (Anser c. caerulescens) is an abundant game species of considerable importance to sport hunters in Canada and the United States (Boyd et al. 1982) as well as to native subsistence hunters (Boyd 1977, James Bay and Northern Quebec Native Harvesting Research Committee 1982, Prevett et al. 1983, Reed and Drolet 1985). In order to improve management of the species, Kerbes (1975) devised a special photographic technique to census the geese during the nesting season and applied it to breeding colonies in Hudson Bay and Foxe Basin in 1973. We judged that a repeat inventory in 1979 would be valuable, both to detect changes in breeding numbers of geese and to examine the ease with which the technique could be applied by personnel not involved in its conception. We chose the Southampton Island and Baffin Island colonies (Fig. 1) for re-survey in 1979.

In this report the term "Lesser Snow Goose" designates both white and blue colour phases.

Figure 1

Southampton Island and southern Baffin Island, showing the major Lesser Snow Goose breeding areas surveyed in 1979.

Acknowledgements

Hugh Boyd proposed the study and provided advice and encouragement while it was going on. J.H. Patterson, G.H. Finney, S.G. Cutts, F.G. Cooch, and R.H. Kerbes helped with various logistic and administrative arrangements, the latter two making important technical contributions as well. We are indebted to John P. Rogers and Harvey KeK. Nelson of the US Fish and Wildlife Service for ensuring financial support. We benefited greatly from the experience and competence of A. Golding, photographer, and K. C. Burkhart, pilot, who assisted P.D. in conducting the aerial photographic survey. The Department of Indian and Northern Affairs provided accommodation in Frobisher Bay, as did the Atmospheric Environment Service of Environment Canada in Coral Harbour. J. Letourneau and H. Bernier helped to count and record geese on the photographs. They, in turn, received help at a critical stage of the counting from Pat Angehrn. E. H. Dunn, R.F. Rockwell, and C.D. MacInnes provided constructive comments on an earlier draft. L. Duchesneau and L. Grégoire patiently typed various drafts of the manuscript.
1. Review of technique and materials

We estimated nesting geese by counting geese on negative aerial photographs at two different scales. High-level photographs (scale 1:5000) on which white-phase geese can be readily counted provided the main coverage of the goose colony. Blue-phase geese are not easily detected at that scale. We counted them and the white-phase birds on a sample of low-level (1:2000) photographs and computed the proportion of white geese. We applied that proportion to the high-level photographs.

2. The 1979 photo survey

Flying out of Coral Harbour, our crew surveyed the Southampton Island colonies: Bear Cove and East Bay on 24 June, Boas River on 29 and 30 June, West Boas River and Bowman Bay on 30 June. We first flew over the Plains of the Kooksiidja while moving the aircraft to the Baffin Island base of operation, Frobisher Bay, on 30 June, and we continued to reconnoitre the Kooksiidja, Cape Dominion, Bowman Bay area on 2 July. We carried out the photo surveys on Baffin Island during 3–8 July. On 30 June we noted a nesting concentration at Native Bay, Southampton Island, where geese had been absent in 1975; we surveyed that area on the return trip, 8 July 1979. Poor weather prevented surveys during 25–29 June and on 1, 2, and 5 July. Although no ground checks were possible, we are confident that no additional nests were started after our survey and that none had previously hatched.

We took a total of 3900 photographs and logged almost 25 h of flying time, excluding the time required to ferry the aircraft between its home base and Coral Harbour. Appendix 2 lists by colony the number of photographs taken and the day on which analyses were conducted. White-phase geese were counted as those that were not immediately recognizable as blue-phase geese. Blue-phase geese were recorded as those that were recognized as blue-phase geese. None were later reclassified.

3. Analyses of the 1979 photographs and the problem of colour-phase ratios

Our aim was to derive population estimates accurate to within approximately 20% at the 5% significance level for each colony from a stratified random sample of photographs. We chose an initial sample of photographs and analysed them to provide a preliminary estimate with an indication of its accuracy. From this we judged that only the central 63% of each high-level photograph and the central 84% of each low-level photograph was of sufficient high resolution to yield accurate counts; we therefore excluded the approximate number of outer rows and columns of the overlying grid in our analysis of each photograph. Additional photographs were later added to improve accuracy. Time and budget restrictions even then forced us to accept a level of about 40% accuracy for most colonies individually, but we achieved our objective of ±20% for all colonies combined and for Southampton Island as a whole.

In an initial round of photo-analysis, we relied largely on the written description of goose images given by Kerbes (1975, p. 12, 43, 45). We encountered no problems in identifying and counting white-phase geese on high or low-level photographs. Blue-phase geese were as expected, almost impossible to detect on high level photographs but surprisingly difficult to detect against some backgrounds at low level. In comparison with other Eastern Arctic Lesser Snow Goose colonies, the backgrounds at East Bay, East, and Bowman Bay are particularly good camouflage, especially East Bay, where many goose-sized boulders litter the landscape. The difficulty of detection was compounded by the shadows cast by the geese, though in some situations the shadows were the best evidence of the presence of a blue-phase goose. Because this phase of the study proved the most difficult and time-consuming, P.D. consulted with R. Kerbes and P. Anglin and completed a catalogue of goose images on negative film (Appendix 3).

An accurate blue-white ratio is critical in determining total population of colonies containing blue-phase birds. Even with existing field identifying geese images we could not be confident that all blue-phase geese had been detected, nor that all objects recorded as blue-phase individuals were, in fact, geese. We might also have analysed an insufficiently large sample of low-level photographs or one that was unrepresentative. Hanson et al. (1972) have suggested that colour-phase ratios vary spatially within Lesser Snow Goose colonies in the western Arctic, where the proportion of blue-phase geese is small (Kerbes 1983, 1986). However, on Southampton Island and Baffin Island, blue-phase birds comprise about one-third and two-thirds of the populations respectively.

From ground observations during 1979, Anczyk, Kerbes and Abraham (1979) reported 38.9% blue-phase among 350 nesting adults in the eastern portion of the East Bay Lesser Snow Goose colony; they also found 36.7% blue-phase in 533 adults captured for banding. We recorded 45.4% (75 ± 6700) from a sample of 1187 nesting geese on 14 photographs. It is difficult to test for significant differences between Anczyk and Abraham’s and our estimates since they do not give standard errors for their estimates. A chi-square test cannot be performed since the geese were not randomly sampled. Nevertheless, we have applied their design effect (Cochran 1977, section 4.11) for their survey is the same as ours, 2.07, then their standard errors would be 5.4 and 4.2 for the nesting adult and banding surveys respectively. Comparing these results to ours using a z-test, we obtain z = 1.2 (P = 0.21) and z = 1.7 (P = 0.09) respectively. From this rough assessment, neither difference is significant at 5%. There is, however, evidence to suggest that we may have mistaken some boulders or other objects for blue-phase geese, because their signatures on the photographs are sometimes very similar. Hence our estimates may be high for this colony. On the other hand, at Boas River, Kerbes, and Abraham reported 32.3% blue-phase among 5000 adults, whereas we reported 25.0% (z = 2.64) in 2044 nesters on a sample of 23 photographs. Following the above procedure, the z-test yields z = 1.56 (P = 0.12), which is again not significant at 5%. Given the less prominent background at Boas River, we were probably fairly accurate in our low-level photo counts of blue-phase geese.

At this stage of the analysis, caution must be exercised. We have compared 1979 results with the 1973 survey results because the sample designs differed in some ways. Thanks to the experience and knowledge gained in 1973, the 1979 surveys provided much better coverage and representation of the colonies, and used an improved photographic scale. Despite the possible sources of error pointed out in the previous paragraphs, the 1973 and 1979 results remain the most accurate monitoring data available. Also, because the techniques were similar, any biases seem likely to be in opposite directions and of a similar magnitude, and between-year changes in population size and percentage of blue-phase probably reflect real changes.

Table 1 shows the estimated numbers of nests, along with the computed 95% confidence intervals. A detailed discussion for each colony follows.

1. Southampton Island colonies

1.1. Ell Bay (Fig. 2)

In 1975, Kerbes (1975) found a sparsely occupied colony of 200 nests spread over 37.5 km². In 1979, the colony covered more or less the same area, but nests had increased dramatically to 2600 (statistical significance of difference cannot be tested), mostly in the southern part of the colony.

The proportion of blue-phase geese was 23% in 1975 (Kerbes 1975) and 29% in 1979 (z=0.45, P=0.15). A cluster of approximately 25 nesting pairs, observed 2 km north of the limits of the colony, was not included in the estimates shown in Table 1. Ross’ Geese (Anser rossii) and Tundra Swans (Cygnus columbianus) were observed on lakes within the limits of the colony.

1.2. West Boas River (Fig. 3)

This sparsely colonized colony with 6000 nests on 80 km² in 1975 had only 2900 nests in 1979 (statistical significance of the difference cannot be tested), mostly in two groups on a total area of 49 km². There was an increase from 23% (Kerbes 1975) to 36% (±3.5%, P<0.01) in the proportion of blue-phase geese.

Comparison of the 1975 and 1979 results

Table 1 shows the estimated numbers of nests, along with the computed 95% confidence intervals. A detailed discussion for each colony follows.

<table>
<thead>
<tr>
<th>Colony</th>
<th>1975</th>
<th>1979</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(±56)</td>
<td>(±57)</td>
</tr>
<tr>
<td>Southampton Island colonies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ell Bay</td>
<td>2900 (±2200)</td>
<td>4300 (±2400)</td>
</tr>
<tr>
<td>Bowman Bay</td>
<td>8760 (±10000)</td>
<td>64400 (±12000)</td>
</tr>
<tr>
<td>East Bay</td>
<td>11600 (±6000)</td>
<td>17700 (±16000)</td>
</tr>
<tr>
<td>Bowman Bay</td>
<td>11600 (±6000)</td>
<td>17700 (±16000)</td>
</tr>
<tr>
<td>Total Southampton</td>
<td>343900 (±67000)</td>
<td>301200 (±16000)</td>
</tr>
<tr>
<td>Baffin Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowman Bay</td>
<td>72800 (±27000)</td>
<td>91900 (±23500)</td>
</tr>
<tr>
<td>Cape Dominion</td>
<td>15400 (±5600)</td>
<td>151400 (±16000)</td>
</tr>
<tr>
<td>Total Baffin Island</td>
<td>227400 (±130000)</td>
<td>223280 (±298000)</td>
</tr>
</tbody>
</table>

Table 1

Results of a photographic survey of nesting Lesser Snow Goose colonies on Southampton and Baffin Islands, W. F., in 1979, with comparative results from 1975.

Not fully comparable because of colony boundary redemptions in 1979.
1.3. Boas River (Fig. 4)
This large colony increased from 64,800 nests on 384 km² in 1973 (Kerbes 1975) to 87,600 nests on 540 km² in 1979 (the statistical significance of the difference cannot be tested). Changes in distribution since 1973 included the abandonment of a small area southeast of Unhealing Brook and slight expansion to the north and northwest. Those changes can probably be attributed to different patterns of spring snow cover in the two years. The proportion of blue-phase geese was 23% in 1973 and 25% in 1979.

1.4. Bear Cove (Fig. 5)
The small, sparse colony (400 nests, 1.6 km²) described in 1973 by Kerbes (1975) had increased to 2100 nests in 1979 (z = 2.27, P = 0.02) and expanded to the south and east to occupy 36 km². The proportion of blue-phase geese was 35% in 1973 (Kerbes 1975) and 39% in 1979 (z = 1.00, P = 0.32).

1.5. East Bay (Fig. 6)
This colony, which includes a large southwest extension of sparsely occupied habitat, contained 8500 nests on 247 km² in 1973 (Kerbes 1975). In 1979 the number of nests had increased to 21,300 (z = 3.15, P = 0.002) and the area to 344 km², by expansion to higher ground to the north and west. This included a cluster of about 200 nests along the western boundary of the colony. Kerbes (1975) reported 35% blue-phase geese in this colony in 1973, and we estimated 46% in 1979 (z = 2.36, P = 0.02).

1.6. Summary for Southampton Island
In 1979 about 235,000 nesting adult Lesser Snow Geese were present on Southampton Island. Four of the five colonies showed increases in the numbers of nesting pairs between 1973 and 1979 (statistically significant in the two cases that could be tested), for an overall increase of 56%. Weighted averages of colour-phase ratios indicated 28% blue-phase in 1979, similar to the 24% value computed from Kerbes’ (1975) data (z = 1.53, P = 0.10).

Surface area increased at three of these five colonies between 1973 and 1979, enlarging the occupied area from about 750 km² to 1040 km² (+35.5%). Some of these changes may have reflected a temporary response to spring snow cover and flooding rather than long-term, permanent shifts. Heavy inundation of traditional nesting areas was noted on over-flights on 23–24 June, but the floods had considerably abated by 28–29 June when the photographic surveys were initiated.

2. Baffin Island colonies
2.1. Bowman Bay (Fig. 7)
A proper comparison cannot be made because we did not recognize precisely the same boundaries as Kerbes (1975) in 1973. However, the difference between the 1979 estimate (91,900 nests) and the 1973 one (72,800) is not statistically significant (z = 0.96, P = 0.34). The proportion of blue-phase geese declined from 81% in 1973 to 70% in 1979 (z = 3.92, P = 0.0001).

2.2. Cape Dominion and Koukdjuak River (Fig. 8)
After reconnaissance, we decided to consider this huge breeding area as a single unit due to the lack of distinctly different ecological features (goose density, habitat types, landforms) between the two arbitrary units used by Kerbes (1975) and Coosh (1963). This also offered certain advantages for sampling and analyzing the data.

The number of nests showed no significant change between 1973 and 1979 (z = 0.78, P = 0.44), although the colony boundaries were not identical between years. We estimated 61% blue-phase geese in 1979, greater than the 47% calculated from Kerbes’ (1975) data in 1973 (z = 2.86, P = 0.004).

2.3. Summary for Baffin Island
The number of nests in the Bowman Bay–Cape Dominion–Koukdjuak River area did not differ between 1973 and 1979 (z = 0.11, P = 0.90); the area harboured almost one-quarter million nests in each year. Small numbers of nesting Lesser Snow Geese were also present in 1979 along the coast southwest of Bowman Bay and north of the Koukdjuak River as far as Grant-Sattle Bay (Reed et al. 1980). We recorded somewhat different blue-phase ratios between the various colonies, and these values were in turn different from those reported for the same colonies in 1973 (Kerbes 1975). Nevertheless, the weighted means for the entire Bowman Bay–Cape Dominion–Koukdjuak River complex were similar in both years: 64% blue-phase in 1979, 61% in 1973 (z = 1.45, P = 0.15).

Although some changes in colony boundaries were noted, the entire area occupied by nesting geese remained unchanged between 1973 and 1979 at approximately 2900 km².

Figure 2 The Ell Bay colony, Southampton Island

Figure 3 The East Bay colony, Southampton Island

Figure 4 The Boas River colony, Southampton Island

Figure 5 The West Boas River colony, Southampton Island
Figure 5
The Bear Cove colony, Southampton Island

Figure 6
The East Bay colony, Southampton Island

Figure 7
The Bowman Bay colony, Baffin Island
1. Status of the goose population

In managing the stocks of game species, it is important to distinguish between general population trends and short-term fluctuations. This is particularly important for arctic-nesting geese such as Lesser Snow Geese, whose numbers may fluctuate considerably from year to year. Such fluctuations can largely be attributed to weather conditions, principally in spring on the nesting grounds. In appeasing population trends from counts of nesting geese on the breeding grounds, it is necessary to ascertain whether or not weather conditions had prevented a significant proportion of potential breeders from nesting. Persistent heavy snow cover on the breeding area through mid-June can prevent nesting altogether, and various precipitation and temperature-related variables on breeding, staging, and wintering areas can also prevent a proportion of sexually adult geese from nesting (Boyd et al. 1982). Conditions were close to average on breeding, wintering, and staging areas in 1979 and better than average in all areas in 1973 (Boyd et al. 1982). Thus, the entire potential breeding population probably attempted to nest in both years. The increase from about 301,000 nesting pairs in 1973 to 344,000 in 1979 (14% gain) was due mainly to an increase on Southampton Island. There was a decline of similar magnitude in more southerly colonies along western Hudson Bay during the same period (Boyd et al. 1982, Kerbes 1982).

A thorough analysis of population trends in Eastern Arctic stocks (Boyd et al. 1982), using population indices from summer, fall, and winter as well as survival and kill estimates, showed average annual arithmetic increases in the order of 2–5% during 1964–79. Our data on nest numbers for Baffin and Southampton islands, 1973–79, show a similar annual net gain of 2.2%.

As well as being important for population estimation, colour-phase ratios are of considerable biological interest (Gooch 1965, Cooke and Gooch 1968): monitoring temporal and spatial changes in the colour-phase ratios will provide new insights into the ecology of polymorphism. The values of blue-phase percentage estimated by us and by Kerbes (1975) should not be compared with other studies in which alternative techniques were employed. On the other hand, for large groupings of colonies (all Baffin Island, all Southampton Island, and Baffin and Southampton islands combined), the lack of change in colour-phase ratios recorded between 1973 and 1979 is probably real. For all colonies combined (both islands) we recorded 52% blue-phase geese, which was not different from the 51% value computed from Kerbes’ (1975) data for 1973 (z=0.22, P=0.85). Individual colonies showed more substantial changes between the two years; however, interpretation of changes in these small groupings would best await further research and ground-truthing.

We do not attach great importance to the changes noted in the surface area of certain colonies between 1973 and 1979. Responses by nesting geese to snow cover, flooding, and other variables produce considerable year-to-year fluctuations in the size of the area used for nesting. The long-term spread or shrinkage of the colony would scarcely be evident from only two years’ data.

Our colony estimates do not account for all of the Lesser Snow Geese on Baffin Island, Southampton Island, and adjoining portions of Fove Basin and eastern Hudson Bay. They nest in dispersed fashion in small colonies on Baffin Island north of the Koukdjuak River to about 68°N, on several islands in Fove Basin and northern Hudson Bay, and on the east coast of the Melville Peninsula (Reed et al. 1980, Gaston et al. 1986).

2. Appraisal of the large-format vertical photographic technique

We agree with Kerbes (1975), who developed this technique, that it can provide high-intensity sampling of many large and widely separated Snow Goose colonies in the same year. Within a 16-day period, we obtained extensive photographic coverage of eight colonies, some more than 700 km apart. A permanent record was obtained that can be further analyzed to increase the accuracy of estimates or to study colour-phase ratios, inter-nest distances, nest density in relation to habitat types, and so on.

There is, however, a need for ground-truthing to firmly establish the accuracy of the technique for mixed-phase colonies. We recommend that ground crews be present during the next vertical photo survey to record colour-phase ratios in as many colonies and habitat types as possible. Those crews should also record the reaction of nesting geese to the survey aircraft; Kerbes (pers. commun.) reports that in his extensive experience, nesting geese have remained on their territories when the aircraft flew over the colony, R.F. Rockwell (pers. commun.) recently reported a case in which Lesser Snow Geese flew off their territories at the approach of the aircraft. This was at the southern colony, La Pérouse Bay, Manitoba, where some of the geese nest in the open, in the case of willow scrub, which is not present in the Southampton and Baffin Island colonies. No such reaction was recorded in that same colony during survey flights in earlier years (Kerbes, pers. commun.). Indeed, one of the major advantages of the technique is the small degree of disturbance caused to nesting geese by the relatively high-flying, fixed-wing aircraft.
Counting images on the photographs involved approximately 120 person-days. To this must be added the cost of the contract to the photo-survey firm and various logistic, administrative, and computer costs. Despite this substantial investment of time and money, the derived estimates carry broad confidence intervals. We believe that future surveys could be more economical and accurate if the visual key (App. 3) and people experienced in identifying goose images are used. However, additional funds will be necessary to pay for ground-truthing crews.

The biologist aboard the survey aircraft obtained only a fleeting perception of the survey area and habitat conditions. High speed and altitude of the aircraft and less-than-ideal viewing conditions prevented the observer from obtaining as intimate a view as he might have had from a more versatile aerial survey platform. Oblique, small-format photography from low-flying fixed-wing aircraft is especially that of estimating colour-phase ratios accurately, it is impractical to obtain as satisfactory visual readings as those we obtained from a more versatile aerial platform. A substantial investment of time and money, the derived estimates of the present method, provide a good estimate of the number of white geese of each colony. This survey did not need to be extensive, nor were colonies stratified. The proportion of white-phase geese in the colony was estimated by the formula:

\[ \hat{p} = \frac{a}{a+b} \]

where \( a \) is the number of white-phase geese counted on \( k \)-th low-level photograph, and \( b \) is the total number of geese counted on the \( n \)-th low-level photograph.

This is the standard variance formula for \( 1 - \frac{a}{a+b} \) being the finite population correction.

### Appendix 1

#### Sampling methodology

Estimates of nesting geese were obtained using a refinement of the technique used by Kerbes (1975), which is similar to it.

(a) High-level survey

An extensive high-level photographic survey (photo scale 1:5000) of the colonies provided a good estimate of the number of white geese. Blue geese were not detected at this scale. To improve the precision of the estimate, many colonies were stratified into areas of generally high, medium, and low nesting density; thus, the estimate for the number of nesting white geese, \( \hat{N}_w \), was as follows:

\[ \hat{N}_w = \sum \left( \frac{1}{n} \times n \times \hat{n} \right) \]

where \( n_i \) is numbers of photographs analysed in the \( i \)-th stratum, \( n_i = \frac{1}{n} \times n \times \hat{n} \) is the estimated number of geese in stratum \( i \) that were stratified and \( \hat{n} \) is the number of photographs analysed in the \( i \)-th stratum.

(b) Low-level survey

A low-level survey (scale 1:2500) provided an estimate of the proportion of white geese among all geese. Experience has shown that colour-phase ratios are relatively consistent within a colony. This survey did not need to be extensive, nor were colonies stratified. The proportion of white-phase geese in the colony was estimated by the formula:

\[ \hat{p} = \frac{a}{a+b} \]

where \( a \) is the number of white-phase geese counted on \( k \)-th low-level photograph, and \( b \) is the total number of geese counted on the \( n \)-th low-level photograph.

The variance of \( \hat{p} \) is estimated by

\[ \text{Var} \hat{p} = \left( \frac{n}{n-1} \times \frac{a}{a+b} \times \frac{b}{a+b} \right) \]

Finally, the total number of geese estimated to be on the colony is

\[ \hat{N} = \frac{1}{1-p} \]

which has variance as follows:

\[ \text{Var} \hat{N} = \hat{N}^2 \times \left( \frac{n}{n-1} \times \frac{a}{a+b} \times \frac{b}{a+b} \right) \]

Initially only a few photographs were analysed in each stratum. Based on these results, the remainder were allocated among the strata so as to minimize the variance of \( \hat{N} \).

### Appendix 2

#### Record of photographic coverage of Lesser Snow Goose colonies on Southampton and Baffin Island, 1979, and unadjusted numbers of goose counted

<table>
<thead>
<tr>
<th>Colony</th>
<th>Photos takena</th>
<th>Photos analysed</th>
<th>Goose counted</th>
<th>% white goose</th>
<th>Strata</th>
<th>Photos takena</th>
<th>Photos analysed</th>
<th>Goose counted</th>
<th>White phase goose counted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ell Bay</td>
<td>28</td>
<td>7</td>
<td>333</td>
<td>21.2</td>
<td>3</td>
<td>25</td>
<td>25</td>
<td>2.206</td>
<td></td>
</tr>
<tr>
<td>Bear River</td>
<td>218</td>
<td>25</td>
<td>2274</td>
<td>72.0</td>
<td>5</td>
<td>418</td>
<td>70</td>
<td>10.049</td>
<td></td>
</tr>
<tr>
<td>West Bear River</td>
<td>35</td>
<td>15</td>
<td>360</td>
<td>65.6</td>
<td>2</td>
<td>44</td>
<td>12</td>
<td>813</td>
<td></td>
</tr>
<tr>
<td>Rear Cove</td>
<td>78</td>
<td>21</td>
<td>481</td>
<td>61.0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>East Bay</td>
<td>130</td>
<td>16</td>
<td>1187</td>
<td>54.4</td>
<td>2</td>
<td>164</td>
<td>18</td>
<td>1.654</td>
<td></td>
</tr>
<tr>
<td>Bowman Bay</td>
<td>155</td>
<td>25</td>
<td>790</td>
<td>29.1</td>
<td>3</td>
<td>273</td>
<td>69</td>
<td>4.396</td>
<td></td>
</tr>
<tr>
<td>Cape Dominion</td>
<td>512</td>
<td>65</td>
<td>1522</td>
<td>39.5</td>
<td>2</td>
<td>873</td>
<td>89</td>
<td>3.072</td>
<td></td>
</tr>
</tbody>
</table>

*An additional 590 photographs were taken but not retained for detailed analysis because they fell outside of the colony boundaries; some were, however, scanned to determine colony limits.*
Appendix 3
An illustrated guide for the identification of Lesser Snow Goose images on photographs

Figure 3-1
Schematic representation of Lesser Snow Goose images as they appear on negative film

1. Mixed pair: white-phase goose above, blue-phase below.
2. Atypical blue-phase pair: the left bird has a light body and dark head, the right one a dark body and dark head.
3. Atypical blue-phase pair: only the shadow of the upper bird is evident, whereas the head and the shadow of the lower goose are visible.
4. Typical blue-phase pair.
5. Blue-phase pair: the goose are on the right, their shadows on the left.
6. Key.
7. Typical white-phase pair.
8. Blue-phase pair: only the shadow of the upper goose is visible; the lower bird is probably sitting, because it does not cast a shadow.
9. White-phase goose on right.
10. Atypical blue-phase pair: same as 2.
11. Blue-phase pair: similar to 5, but not casting shadows.
12. Typical white-phase pair.

Figure 3-2
Full-frame negative of a low-level photograph, East Bay, Southampton Island (reduced from original size of 23 × 33 cm). The two boxed-off areas are enlarged in Figures 3-2a and 3-2b. One of the features of this example is the presence of hawkmotors, some of which are difficult to distinguish from geese.
Figure 3-2a
Enlargement from Fig. 3-2
1. To the left of the numeral are three dark-coloured objects. The upper two were identified as white-phase geese (a pair) and the other as a small boulder.
2. To the left and above the numeral is the image of a blue-phase goose; to the right, a white-phase bird is below the numeral.
3. A pair of white-phase geese is to the left of the numeral.
4. A mixed pair of geese is to the left of the numeral, blue phase above.
5. A pair of white-phase geese is to the left of the numeral.

Figure 3-2b
Enlargement from Fig. 3-2
1. A pair of blue-phase geese, one bird is immediately above the numeral.
2. The other is to the left of the numeral, between two boulders.
3. A pair of blue-phase geese is to the left of the numeral.
4. A pair of white-phase geese is to the left of the numeral.
Figure 3-3
Full-frame negative of a low-level photograph, Cape Dorimont, Baffin Island (reduced from original size of 23 x 21 cm). The two boxed-off-areas are enlarged in Figures 3-3a and 3-3b. Note the uniformity of the habitat and the absence of boulders.

Figure 3-3a
Enlargement from Fig. 3-3.
1. A white-phase goose in flight is to the left of the numeral.
2. A pair of blue-phase geese is to the left of the numeral.
3. Four blue-phase geese and one white-phase goose are to the left of the numeral.
4. Two pairs of blue-phase and one pair of white-phase geese are to the left of the numeral.
5. A nest is to the right of the numeral.
6. A pair of blue-phase birds is to the left of the numeral.
7. A nest of white-phase geese is to the left of the numeral.
Other publications in the Occasional Papers Series

No. 18
Gonzalez predation and the possible effects of Gonzanz and Chukotka feeding on the neepaleans composition in some small lakes and ponds in western Canada by R.S. Anstrom and L.C. Reaveley.
No. 19
Aimurnents of DDE and PCB determinations in Canadian birds, 1969 to 1972 by M. Gilbertson and L. Beynon.
No. 20
No. 21
Use of marine specimens in toxic chemical research by A.M. Rick.
No. 22
Impoundments for waterfowl by W.R. Whitting.
No. 23
Motivating the dangers of using studies to cippers and other sensitive species by B.W. Flett and R.R. McDermott.
No. 24
Waterfowl damage to Canadian grain: current problem and research needs by L.G. Sugden.
No. 25
Geese techniques for scours of erratic and eastern Canada by D.N. Neiteichicp.
No. 26
Seas ump the present status of the polar bear in James Bay and Bicbcrs Islands area by Charles Jenkal, Pauline Smith, Ian Silver and Frederick Johnson.
No. 27
Lithological and planktonic studies in the Watem Lakes, Alberta by R. Swain, A. Broom and Derek F. Cones.
No. 28
Birds and mammals of the Bickley, Steepr, Ontario, and King George Islands, Northwest Territories by T.H. Manning
No. 29
Developments in pesticide sampling.—Impact on current research by A.R. Sem.
No. 30
Dynamics of snowshoe hare populations in the Maritime Provinces by Thomas J. Woold and Stanley A. Morine.
No. 31
Migration and population dynamics of the Peace—Athabasca Delta goldie populations by B.B. Wright and A.H. Koyman.
No. 32
The effects of fire on the ecology of the Boreal Forest, with particular reference to the Canadian needs; a review and selected bibliography by John P. Kettle, K.S. Phifer and Thomas B. Wright.
No. 33
The ecology of the polar bear (Ursus maritimus) along the western coast of Hudson Bay by Ian Silver, Charles Jenkal, Pauline Smith, Richard Rehrenm and Dale Linn.