An aerial reconnaissance of the eastern Canadian Arctic, 20-29 July 1969, in search of Greater Snow Geese

By

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Objective

The objective of the expedition was to explore certain areas of the eastern Arctic archipelago and northwest Greenland in order to locate and map the distribution of breeding and non-breeding Greater Snow Geese (Anser caerulescens atlantica).

Personnel

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Introduction

The distribution of Greater Snow Geese on their breeding grounds in the eastern Canadian Arctic is incompletely known. Prior to the summer of 1968 no unified effort had been made to locate these geese throughout the potential breeding range. During late June and early July, 1968, an expedition conducted by the senior author surveyed some 2000 linear miles of habitat and charted the locations of approximately 4000 geese. Some of the routes flown in 1968 were reflown in 1969 in order to confirm that birds seen in 1968 were indigenous to the areas in which they had been observed and were not merely transients. In addition, new areas were explored.

Methods

Observations were made from a de Havilland DHC-2 Beaver aircraft and a de Havilland DHC-6 Twin Otter aircraft. Altitudes from which observations were made varied from 200 feet to 1000 or more feet and were dictated by the terrain and weather conditions. Observations were recorded on tape and later transcribed on to suitable maps.

The routes flown were only roughly pre-determined. Once the aircraft had reached the general area to be explored the lines followed were determined by the apparent suitability of the habitat for snow geese. The pilot of the Twin Otter was able to assist in the selection of possible areas for investigation. In neither 1968 or 1969 was an attempt made to sample the population, but rather we attempted to count every bird.

Acknowledgments

The authors wish to extend their sincere thanks to Messrs John Cesnick and Richard M. de Blicquy, the pilots, respectively, of the Beaver and the Twin Otter. Both pilots, because of their interest in the project, were more than helpful in their suggestions and aid. Without Mr. de Blicquy's intimate knowledge of the areas we were exploring we would have missed a great many geese. His - "I think maybe we should take a look over here..." always seemed to produce positive results.

Itinerary and routes flown

Reconnaissance No. I - July 20.
Resolute to Stefansson Island to Elvira Island to Stefansson Island to Resolute (Fig. 1). Miles flown:
(1) On survey - 184
(2) Dead head - 392

Reconnaissance No. II - July 21.
Resolute to southern Bathurst Island to Little Cornwallis Island to Cornwallis Island to Resolute (Fig. 2). Miles flown:
(1) On survey - 127
(2) Dead head - 111

Reconnaissance No. III - July 22.
(Resolute to Pond Inlet as regular passengers.)
Reconnaissance from Pond Inlet to Bylot Island to Low Point (Baffin Island) to Tay Sound to Paquet Bay to Pond Inlet. Miles flown:
(1) On survey - 288
(2) Dead head - 36

(Pond Inlet to Arctic Bay as regular passengers.)
Reconnaissance from Arctic Bay to Moffet Inlet, and in that general area, to the Steensby Peninsula to Arctic Bay. Remained overnight in Arctic Bay (Fig. 3). Miles flown:
(1) On survey - 55
(2) Dead head - 193

Reconnaissance No. IV - July 26.
Resolute to Croker Bay to Philpots Island to Anstead Point to Grise Fiord to Goose Fiord to Simmons Peninsula to Hoved Island to Vendom Fiord to West Fiord to Eureka to Cape Lockwood to Essayoo Bay to Obloyah Bay to Tanquary Fiord (Fig. 4). Miles flown:
(1) On survey - 648
(2) Dead head - 427

Reconnaissance No. V - July 27.

Tanquary Fiord to Lake Hazen to Alert to Newman Bay (Greenland) to Cape Godfred Hansen (Greenland) to Simmons Bay (Ellesmere Island) to Dodge River to Tanquary Fiord to Essayoo Bay to Schei Peninsula to Eureka.
Miles flown: (1) On survey - 565
(2) Dead head - 270

Reconnaissance No. VI - July 29.

Eureka to Canon Fiord to Bache Peninsula to Inglefield Land (Greenland) to McCormick Bay (Greenland) to Pond Inlet to Phillips Creek to the Gifford River to Bell Bay to Bernier Bay to Resolute. Miles flown:
(1) On survey - 689
(2) Dead head - 800

Total Miles flown on all surveys:
(1) On survey - 2556
(2) Dead head - 2229

In addition to the observations made by the survey party certain individuals contributed observations which they made during the season. These came from parts of Baffin, Bathurst, Devon and Axel Heiberg Islands.

Reconnaissance No. I - July 20

Reports suggested that Stefansson Island was well vegetated, and more lush than similar islands in that part of the archipelago. It was also suggested that the island might support large numbers of breeding birds

including snow geese. The reconnaissance of Stefansson Island showed that the habitat was far from lush, except on the southern tip, but resembled the habitat of Cornwallis Island, i.e. generally devoid of vegetation and made up of shallow sterile-looking ponds and shale-like sedimentary rock. No Snow Geese were observed at any point along the route. Some other birds were seen on Stefansson Island and other islands en route (see Appendix A and B).

Parts of Elvira, Lowther, Prince of Wales, Russell and Griffith Islands were seen during the same trip. No geese were seen in any of these areas.

Reconnaissance No. II - July 21

S.D. MacDonald (pers. comm.) had collected breeding specimens of Greater Snow Geese from the Goodsir Inlet area of southern Bathurst Island. It was therefore considered necessary to inspect other parts of this island. Two problems mitigated against going into more northerly areas of the island; (1) funds were not available to explore areas which Tener (1960) had already shown to be very sparsely populated with Snow Geese and, (2) a team

of scientists in the Goodsir Inlet area were studying certain aspects of Musk-ox biology and had asked pilots to avoid their study area. We respected this request, and confined our reconnaissance to the southern coast of the island.

The area between Allison Inlet and Cape Cockburn appeared to be suitable Snow Goose habitat. It was of low relief, terraced and well supplied with small shallow pot holes. In the area of Cape Cockburn itself, the land was dry and poorly watered.

Little Cornwallis Island was found to be poorly vegetated and of the same light brown sedimentary shales as Cornwallis Island.

No Snow Geese were seen during this reconnaissance though a few other birds were seen (Appendix B).

Reconnaissance No. III - Baffin Island

Much of this route was flown in 1968. The areas were re-examined in 1969 in order to determine that birds seen the previous year, all of them moulters, were part of resident populations.

Bylot Island has been considered as a special case and is discussed in a separate report.

Area	22 July 1969		July 1968	
	Pairs with goslings	Moulting birds	Pairs with goslings	Moulting birds
Baffin Island				
Running River	33	380		
Eskimo Inlet	0	50 (including one blue goose)		
West of Pond Inlet	0	11		
Strathcona Sound	0	30		
Moffet Inlet	4	1562		
Jungersen Bay	16	1238		
Steensby Peninsula	3	56		
Levasseur Inlet	1	0		

Reconnaissance No. IV - Devon and Ellesmere Islands

Much of Ellesmere Island, covered during this flight, was also explored in 1968.

Area	26 July 1969		July 1968	
	Pairs with goslings	Moulting birds	Pairs with goslings	Moulting birds
Devon Island				
Crocker Bay to Lemieux Pt.	3	570		
Philpots Island	40	230		
	43	800		
Ellesmere Island				
Anstead Point (Fram Fiord)	1	0		
Baad Fiord to Sydkap Fiord	1			
Simmons Peninsula	6	170		
Baumann Fiord	10	10		
Vendom Fiord	18	90		
Vendom Fiord to valley south of Stratchcona Fiord	3	150		
Bay Fiord	0	85		
Bay Fiord to West Fiord	2	150		

Area	26 July 1969		July 1968	
	Pairs with goslings	Moulting birds	Pairs with goslings	Moulting birds
West Fiord to Eureka (Fosheim Peninsula)	7	490		
Cape Lockwood	3	35		
Elmerson Peninsula	0	8		
Oobloyah Bay	3	50		

Reconnaissance No. V - Ellesmere and Axel Heiberg Islands

Area	27 July 1969		July 1968	
	Pairs with goslings	Moulting birds	Pairs with goslings	Moulting birds
Ellesmere Island continued				
Lake Hazen	12	220		
Tanquary Fiord Greely Fiord	5	0		
Essayoo Bay	10	90		
West of Atwood Point	1	6		
Eureka to Canon Fiord	1	120		
Axel Heiberg Island				
Schei Peninsula	0	480		

Reconnaissance No. VI - Greenland, Baffin Island

Area	29 July 1969		July 1968	
	Pairs with goslings	Moulting birds	Pairs with goslings	Moulting birds
Greenland				
Inglefield Land	1	0		
Little Island	1	0		
McCormick Bay	25	320		
	27	320		
Baffin Island				
South of Pond Inlet	1	670		
Phillips Creek	12	130		
Inuktorfik Lake area	14	530		
Gifford River Valley	1	0		
Fall River	5	0		
Bell Bay to Berlinguet Inlet	11	130		
Berlinguet Inlet to Bernier Bay	110	3640		

Records of blue phase snow geese in 1969

Bylot Island, July 22: two in a flightless flock of 80 near Polygon Delta.

Baffin Island, July 29: at least one, in a flock of 35 snows on a small lake WNW of Inuktorfik Lake.

One, with three families of swans on a small lake near the inlet on the north shore of Bernier Bay (71.15N, 87.45W)

One or two in a flightless group on a river, a little further west.

Review of results

The foregoing presentation of the 1969 observations in chronological sequence is far from convenient for the purpose of assessing how much is now known of the quantitative distribution of snow geese in the far north. Table I reassembles the data in a briefer form.

Table I. Summary of unadjusted records of snow geese seen July 22-29, 1969.

	Pairs with goslings	Moulting birds	Total adults seen *	%
N.W. Greenland	27	320	370	2.1
Ellesmere I.	94	2,024	2,210	12.7
Axel Heiberg I.	0	480	480	2.8
Devon I.	43	800	890	5.1
Bylot I.	1,032	2,560	4,620	26.5
Baffin I.	211	8,427	8,850	50.8
Total	1,407	14,611	17,420	100.0

* Figures in this column rounded to nearest ten.

The main objections to Table I are that it does not include enough geese and does not suggest how complete and precise the observations may have been. We know, from a set of aerial photographs of snow geese taken on the St. Lawrence River on May 1, 1969, that there were slightly over 70,000 geese present. So far as is known, nearly all of them should have been atlantica and it would be rather unexpected if they had suffered heavy losses between May 1

and July 20. Thus, if we allow a 5% reduction for death, strays and withdrawals of caerulescens, a complete census should have recorded about 66,500 atlantica, ~~rather than less~~ instead of fewer than 20,000. There are potentially two major sources of error: the search may have been much less complete than is necessary, and the number of geese seen may have been under-estimated. As the separate report on the Bylot Island surveys makes clear, in that important concentration area, errors of both kinds occurred.

Some supplementary information on those areas was received after the survey had been completed. R.M. de Blicquy reported 12 families and 85 moulters near Cape Sparbo, Devon Island on July 31. Grey Alexander provided notes on records of geese obtained from geological survey crew flying in helicopters over Axel Heiberg Island: these add at least moulters and families to our records. Finally, from Bathurst Island, and report at least snow geese (moulters and families) from the Goodsir Inlet-Bracebridge Inlet area.

Comparisons of photographic records of moulting flocks on Bylot Island with visual estimates suggest that the observers were usually seriously under-estimating the number in dense flocks. The mean size of the flocks recorded in photographs was 93.0 birds while the mean observed flock size was only 40.4 birds. It is possible that the observer's capabilities improved after July 22 (although a few checks of estimates by H. Boyd against flocks shown on oblique photographs from Baffin Island suggest that he, at least, did not improve) but it may be argued that the recorded number of moulters should be multiplied by a factor of 93.0/40.4 = 2.30 to give a better estimate of the geese seen. There was a reasonably close resemblance between photographic and visual records of pairs with goslings, for which no adjustment for under-estimate is therefore perhaps necessary. As Table II shows, the additions and suggested corrections increase the likely total of geese seen to 36,200. This figure is brought up to 66,500 by the entries in column five of Table II ("hypothetical omissions", which includes allowances for geese in invisible fringe areas

and in parts of Baffin Island we could not reach, as well as for inadequate searches in areas that were visited.

Table II. Provisional allocation of an adult population of 66500 Greater Snow Geese to various parts of the range in late July 1969.

	adjusted counts		additional records		hypothetical	hypothetical	
	parents (pairs x 2)	moulters (reported x 2.30)	parents	moulters	omissions	total (to nearest 00)	%
Greenland	50	740			210	1000	1.5
Ellesmere I.	190	4660			950	5800	8.7
Axel Heiberg I.	0	1100				2000	3.0
Devon I.	90	1840	24	85	160	2200	3.3
Bathurst I.							
other Q. Elizabeth Is.						1000	1.5
Bylot I.	2060	5890			12800	20700	31.1
Baffin I.	420	19380			13500	33300	50.1
other south of N.W. Passage					500	500	0.8
	2810	33410				66500	100.0

Bylot Island, July 22: a group of 5 with about 70 flightless snow geese on a lake close to the shore of Navy Board Inlet, south of Polygon Delta.

Devon Island, July 26: fifteen flying west along the coast between Croker Bay and Dundas Harbour.

Philpots Island, July 26: at least four groups in the northwestern part of the island. Six on a pond with 15 snow geese; 60-70, able to fly, on a pond with 30-40 snow geese; 30 flightless, on a larger lake, and 2 flying. The two largest groups were well inland, perhaps 3 miles or more from the coast.

Ellesmere Island: Simmons Peninsula, July 26 (76°55N, 88°45'W): 50-60, flightless, on a lake at least 8 miles from the shore southeast of Nordstrand Point, 6 with young on a large lake closer to the Point; and three pairs with broods on a lake east of the Point. Vendom Fiord, July 26: about 100 flying along eastern shore, near head of Fiord. Greely Fiord, July 26: six, about 12 miles east of Cape Lockwood.

Axel Heiberg Island, July 27: 40 west of Skraeling Point, near base of Stem leading to Schei Peninsula (about 80°05'N, 87°55'W).

Greenland: Only one uncertain record, of a small group on a pond near the south shore of McCormick Bay (about 77°60'N, 69°40'W), July 29. The absence of brant further north in Greenland was a disappointing, and surprising, feature of the trip.

Brant are often not easy to see. Perhaps we could have found more by altering our pattern of search, to concentrate on lowland areas near the shore, but it seems unlikely that a routine aerial survey would be a useful way of assessing fluctuations in brant breeding populations and annual production. Apart from the birds on Stefansson Island, none were seen clearly enough to give an opportunity to verify what race they might be assigned to.

Canada goose Branta canadensis

The only Canada geese seen during the surveys were a group of six near the south end of Stefansson Island on July 20. They appeared to belong to one of the medium-sized stocks, not to hutchinsii or minima.

Appendix B. Other species of birds noted during the snow goose survey.

A random collection of notes, listed by islands. Only large and obvious birds are seen from aircraft and our time on the ground at airfields yielded little. A few islands on which no birds were seen are noted because they looked worth further study.

Stefansson Island (73°17N, 106°45W) twenty glaucous gulls Larus hyperboreus and a group of about twenty smaller, darker Larus sp., presumably thayeri rather than argentatus; two small flocks of old squaws Clangula hyemalis; one sanderling Crocethia alba and about twenty peeps Erolia sp. Ptarmigan Lagopus sp., probably mutus.

Elvira Island (73.19N, 107.00W) resembles adjacent Stefansson I.: no birds seen.

Russell Island, (73.55N, 98.25W) July 20. A glaucous gull, west of Krabbé Point. Only a barren stretch of coast at southwest examined.

Griffith Island (74.35N, 95.30W) July 20 (mostly shrouded in fog). At least 8 fulmars Fulmaris glacialis and some large gulls flying along the shore near the west end. The nearest fulmar colony noted by Godfrey (1966) is on Prince Leopold Is. with another probably on northern Somerset I.

Lowther Island (74.35N, 97.38W) July 20. Only south end seen - apparently no cliffs suitable for seabirds. One fulmar on water.

Hamilton Island (74.06N, 99.04W) July 20, no birds seen: low, flat, much surface water.

Baker Island (75.00N, 97.45W), in McDougall Sound, July 21: no birds seen, low, with unfrozen lakes.

Bathurst Island July 21, search restricted to south of 75.30N. On southwest cover looked relatively hospitable, with a series of ponds in parallel lines following the coast and a pothole area further inland.

A lake with an island east of Allison Inlet (probably that marked on map at 75.02N, 99.10W) had colonies of terns and small gulls and some shorebirds. There were two glaucous gulls and a tern colony on a grassy island in a lake NNW of Cape Evans. We saw four separate snowy owls Nyctea scandiaca on Bathurst and another on Little Cornwallis Island. There were two groups of King Eiders Somateria spectabilis, totalling about 20 near the inner end of Allison Inlet. Ten murres, presumably Uria lomvia, were seen flying over the sea just north of Truro Island (75.17N, 97.12W). Godfrey (1966) records a probable breeding

site in northwest Somerset Island and breeding at Prince Leopold Island, about 150 miles from Truro Island. Several terns were also seen over the sea there. Presumably these and those at the inland sites were all Arctic Terns Sterna paradisaea, like those nesting near Resolute, and any others within a thousand miles.

Cornwallis Island. July 30. Resolute Village: several fulmars scavenging along the shore, apparently all very dark phase birds.

Beechey Island (74.43N, 91.55W), July 26. We did not see the south side, where there are good cliffs. There was a number of fulmars (tens, rather than hundreds) with gulls off the northwest of the island.

Devon Island, July 26. Several fulmars along the coast between Cape Bullen and Cape Home, and more near Dundas Harbour. In crossing Croker Bay near its mouth we saw 17 Eiders, 5 mollissima subsp. on the water and a group of about 70 males still in fairly full summer plumage and able to fly. There were 25 dark Eiders near Dundas Harbour. Near the outfall of the easternmost glacier coming from the Cunningham Mountains there were about 200 king eiders

and further east towards Cape Sherard a flock of 35 in flight, including at least one full plumaged Northern male. Further east again there were 25 male Northern Eiders. In Bethune Inlet we saw 3-400 grey-plumaged eiders and 120 full-plumaged male Northerns.

Ellesmere Island, South, July 26. Five king eiders, southeast of Grise Fiord. Two fulmars near Cape Stoner. Twenty eiders east of Nordstrand Point. Three snowy owls along the shores of Vendome Fiord. Jaegers at Eureka 26 and 28-29 July were mostly Stercorarius longicaudus with two S. parasiticus.

Axel Heiberg Island, July 27. A small group of eiders flying near the south of the Schei Peninsula, with others on the water (a distant and vague record).

North Baffin Island. July 22. A raven Corvus corax near the promontory (72.45N, 80.17W) north of Alfred Point. A snowy owl near the elbow of Tay Sound (72.00N, 79.15W); another near Morin Point. Single loons were noted on several lakes south of the Jungersen River (71.20N, 84.20W). According to Godfrey only the redthroated loon Gavia stellata breeds on Baffin Island, although G. immer and

arctica have been seen on Bylot Island (Van Tyne and Drury, 1959)

A number of old squaws were seen in Navy Board Inlet, south of Low Point, mostly near the coast of Bylot Island. Their presence was confirmed in the photographs taken on July 24.

Bylot Island, July 22. These sandhill cranes Grus canadensis (two and a single) were seen on the west side, near Polygon Delta.

The number of snow geese on Bylot Island in July 1969

J.D. Heyland and H. Boyd

Abstract

An attempt to count the snow geese in the southwest of Bylot Island on July 22, 1969 revealed major shortcomings in the direct census technique: the completeness of the search was uncertain and the observers seriously underestimated the number of geese in flocks. A partial photographic survey on July 24 showed that there were at least 840 pairs of snow geese accompanied by goslings and 4,800 other moulting adults. Methods of adjusting the visual estimates and of extrapolating from the photographic and visual records to obtain estimates of the number of geese on the entire inhabited area, of up to 500 sq. miles, are discussed. They suggest that there may have been about 1450 successful pairs (range 900 - 6900) with 4500 goslings and 17700 (3200 - 40900) other moulting adults present. Proposals for improving the surveying technique for use on Bylot and Baffin Island in July 1970 emphasize the use of vertical photography and of multi-stage sampling with probabilities proportional

to population density. Most of the technical problems involved require further study.

Introduction

An aerial reconnaissance of large parts of the eastern Canadian Arctic islands and of north-west Greenland was undertaken in July 1969 with the general objectives of: 1) exploring and defining the summer range of the greater snow goose; 2) locating the principal concentrations; 3) assessing the production of young birds and regional variations in production; and 4) improving survey techniques in moving towards efficient methods of predicting annual breeding success and the size of the fall flight number of the entire population of the race. Southwest Bylot Island was a focal point because it was known to hold large numbers of snow geese and has been loosely regarded as the principal home of A.c.atlantica.

The first visit of the survey to southwest Bylot Island was made on July 22, 1969 in a de Havilland Twin Otter aircraft. A low-level flight at 500-1000 ft. above local ground level, lasting from 1210 to 1350 hrs. was made along a route roughly indicated in Figure 1.* The

* Figure 1-4 follows page 29

distance covered was about 140-150 miles and geese were looked for on both sides of the aircraft, to an effective distance of about 1/4 mile on each side, so that some 65-75 sq. miles were inspected, from a total area of 500-540 sq. miles between the shore and the inland edge of the inhabited region, defined by the edge of the central snowfield and glaciers or, in some parts, by steep waterless hills. The flight path was not planned in a formal sense. The first leg, going roughly northwest from near the Aktineq Glacier, was aimed along the inner limits of the terrain that looked green enough and with enough lakes to harbour geese. It yielded more geese far inland than had been anticipated, those remote from the shore being mostly groups of moulters with few families. Approaching the shore at the northwest there were more geese and more families. The second leg, heading southeast, was planned to run roughly parallel to the shore while most of the third and final leg followed the shore closely. It was expected that most of the families would be found near the shore and that was indeed the case.

The party left the island believing that they had seen most of the geese, despite the fact that only a fraction of the hinterland had been closely inspected, because much of the interior had appeared unsuitable, while the belt near the shore had been fairly thoroughly examined. However, as discussed below, there proved to be substantial inconsistencies between the records of individual observers. In an effort to clarify what had gone wrong, Heyland returned to the island on July 24 in a Piper Apaché aircraft, piloted by J. Cesnick, that was equipped with a vertically mounted aerial camera. He set out to obtain photographs of individual flocks or areas containing a number of flocks, without attempting to retrace the route of the survey on 22nd or to make a complete survey of the area. Subsequent examination of the prints demonstrated that the range and mean of the flock sizes recorded on the photographs were far higher than those estimated by the observers. There seems no justification for explaining away the discrepancy by asserting that the geese were aggregated in very different ways on the 22nd and 24th. It is much more likely that the differences were due to faulty estimation of the numbers, particularly in dense

flocks of moulters, seen on 22nd. The purposes of this paper are: 1) to extract the best obtainable estimate of the snow goose population on southwest Bylot Island from the incomplete and inconsistent records obtained on 22 and 24 July 1969; and 2) to use the experience gained in 1969 to improve the design of surveys to be made in 1970 and later years on Bylot Island, Baffin Island and perhaps in other parts of the range.

Collecting and recording of data

The visual gathering of data on the number of geese occurs in five steps: seeking, finding, classifying, counting and recording. All of these steps are liable to error. Our concern is to estimate the magnitude of the errors in the July 1969 survey and to devise procedures to minimize errors in future surveys. By seeking is meant deciding where to look. In 1969 this was not a rigorous process. It involved using all available information on where geese had been seen before and on where else they might occur, as inferred from maps and aerial photographs, and also making rapid, superficial decisions on the suitability of the habitat being inspected. So far as Bylot Island is concerned, we know that in 1969

we did not visit all the areas on the island where geese might occur but our search of the southwest, which prior knowledge suggested would hold most of the geese on the island, was thought to be reasonably thorough. Decisions on suitability were based on Heyland's work on the ground in that area in both 1968 and 1969. Moreover we extended the area of search appreciably beyond the places known to have been occupied in the past, particularly by going further inland, Our search was not curtailed by weather, shortage of fuel or other common limiting factors.

Finding involves flying at an appropriate height, low enough to enable the geese (or at least the adults) to be clearly seen but high enough not to cause the birds to panic or to make it too difficult for the observers to keep track of where they are and what they have already seen. Because much of the area is rolling, the effective searching height must have varied a good deal, but this probably did not cause us to overlook many adults, though it may have added to our difficulties in estimating numbers.

Classifying is a particularly important process by reason of its statistical consequences. It involves large numbers

of decisions by each observer: each goose or group of geese has to be associated with the presence of goslings (showing the adults to be parents) or their absence (when the adults are classed as moulters or non-breeders) and each has to be associated or dissociated from those seen previously and subsequently (is this one group or several?). We established no prior rules to guide us on this and quite probably were not consistent in what we did in the course of the search. The same lack of rigour applied with even greater importance to our decisions about how far out from the aircraft to look for geese and whether we had seen a particular group before on an earlier leg of this flight. It is argued below that the discrepancy between the estimates of moulters made by Heyland and by Boyd must have been due much more to the use of a wider search strip by Boyd than to the undoubted differences in their estimates of numbers within each flock. The use of mechanical means of determining transect width (e.g. markers on the struts) might have been helpful. On the other hand a prior choice of width must have been quite arbitrary and might well have been inappropriate and inefficient (we still do not know what distance would be best at what height).

Counting is an activity we can perform quite well on the fingers so that our estimates of pairs are (comparatively) consistent, but the task was obviously beyond our powers in the case of dense groups of moulters. However, this does not mean that visual observations are useless for determining numbers, because it is possible to allow for individual biases. It is highly desirable to retain some belief in the utility of direct observations, because of the likelihood that many situations will arise in which photographic recording cannot be used, or fails.

Recording received little attention in 1969, with the result that it proved impossible to do much matching of observations to photographs, or of counts by different people in the same sector. More attention should be given in future to using ~~standardized~~ synchronized watches for checking elapsed times, to recording airspeeds and heights, to a simple standard notation for groupings of geese and, if possible, to a prior classification of water types and vegetation zones, so that more rapid progress can be made in describing where geese are seen in ~~our~~ an objective way.

The sequence of steps in a photographic survey differs from that in direct observations, seeking and finding being followed by the photography itself, with simultaneous recording and an anxious period of blank uncertainty before the counting and other analysis of the results. As a hurried improvisation, the photographic flight of July 24 probably yielded more information than we were entitled to expect. There is a need before further flights are made to devise sampling plans so that the photographs can be used in a systematic way to record not only goose numbers but also the extent and distribution of both geese and habitat.

The 1969 data

The observations of July 22 as tabulated by Boyd on the 22nd and 23rd are set out in Table I.* Sections I, II and III correspond to sections AB, BC and CD of the approximate flight paths recorded on Figure 1. The observers were distributed: de Blicquy (pilot) left cockpit, Heyland (navigator) right cockpit, Hermkens left cabin and Boyd right cabin. Each estimated separately the number of adults in flocks and the number

Tables I-IV on pp 24-29

of pair with goslings in his field of vision. With a flight path chosen to cover as much of the likely range as possible, rather than a series of fixed transects, the theoretical expectation is that the numbers seen by the two observers on the right should be approximately equal, as should those recorded by the two on the left; the sum of means from right and left should represent the total seen. Few of the theoretical equalities for families, moulting adults, or the total number of adults are met, even very approximately. We have to decide whether it is possible to select a best set of values that might approach a total count of the geese in the searched part of the island, whether to treat the pooled estimates as a sample count along a transect that could be converted to a regional total by means of an area multiplying factor, or whether, as Heyland has suggested, to abandon the 1969 data as worthless.

The photographic survey of July 24 was made in an attempt to replace the conflicting evidence of the four observers by more objective and permanent records (Table II, from counts by Heyland). The photographs do not constitute a complete record of all the geese in the southwest of

Bylot Island. They comprise a precise determination of a substantial part of the geese present, and provide a very important and useful check on the sources of error in the observational records.

The observers in the cockpit were better placed than those in the cabin, because they could see ahead as well as to the side, and they were also better acquainted with the country being searched and the geese being looked for than the observers in the cabin. Offsetting those advantages, de Blicquy had to give primary attention to piloting the aircraft, while Heyland had to choose and plot the flight path. Table I shows that, for these or other reasons, and contrary to expectation, the observers in the cabin reported more geese than those in the cockpit. In following the path asked for by Heyland, de Blicquy was also attempting to fly in such a way that the observers on the right were given the best opportunities to see geese, leading to the expectation that the number seen on the right should tend to exceed those seen on the left. Table I, again, shows that this seems not to have happened.

On the right hand side of the aircraft, Heyland and Boyd were in relatively close agreement on the number of pairs

but disagreed very widely on the number of moulting flocks they saw. This seems most likely to result from Heyland having applied a consistent transect width for both flocks and families while Boyd achieved an effective width similar to Heyland's in the case of families but also included flocks seen much further out from the aircraft, which he was aware of doing. This raises two queries: 1) did Boyd's flock records involve much duplication, due to overlapping of transects; 2) if not and if therefore his data approach more closely to a complete record of flocks, should we infer that the distribution of families was also much more extensive than the transect data imply? The answer to the second query is fairly certain: relatively few families were scattered inland and their association there with the moulting flocks entitles us to believe that we flew over, and saw, most of them. The doubt about duplicate counting of distant flocks cannot be dealt with in detail, because the sector records cannot be broken down into segments which would enable the frequency of records in areas where overlapping of transects was more likely (e.g. in the northwest and near turning point 'C')to be

compared with those from areas where the flight patterns were widely separated. Certainly an attempt was made to avoid recording flocks twice and some observations were deliberately rejected on that account. However, if duplication by Boyd was unimportant, the discrepancy between Heyland and Boyd adds further weight to the sceptical view that even the latter probably missed an appreciable number of flocks.

On the left hand side of the aircraft an opposite set of biases seem to have been at work. Hermkens and de Blicquy agree on how many flocks they saw, though Hermkens thought that the flocks were larger, but they had substantially different ideas on the numbers of families.

Analysis by Heyland of the family counts from photographs in relation to the comparable observations in the area from Motorcycle Point to Polygon Delta (Table II) strongly suggests that de Blicquy was recording too few pairs, as compared with Heyland himself, but this leaves unresolved the question whether Hermkens was over-estimating, particularly in sector III. Given the evidence from

photographs that Hermkens did better than the other observers in estimating the numbers of moulters in flocks, it seems better to assume that his tally of pairs was nearly complete and correct than to use the mean of his and de Blicquy's figures as an estimate of pairs on the left hand side of the aircraft.

Thus the best estimate of the number of families seen on July 22 is 441 (Heyland) + 591 (Hermkens) = 1032. Heyland's count from the photographs shows that on July 24 there were at least 837 pairs with goslings.

In order to put an upper limit on the number of pairs with goslings it is necessary to consider the relationship between the areas searched on July 22 and photographed on July 24 and the total area in which geese might have been found. The latter has been estimated by Lemieux (1959) as the area between the coast and the edge of the snow-field and the mountains, some 500 sq. miles, which undoubtedly includes some wholly unsuitable country. Heyland estimates that on July 22 the flight path may have traversed 150 miles, with a strip width of 1/4 mile on each side of the aircraft, giving a total searched

area of 75 sq. miles. Boyd's estimate is that the flight path was rather less, about 127 miles, with a searched area of 63 sq. miles (this omits part of the southward travel at the start of section II because of duplication with section I). The total area photographed usefully on July 24 is estimated by Heyland at 5.14 sq. miles. We require a rational procedure for extrapolation, given that the families tend to be highly aggregated near the coast.

One method is to rank the available data in terms of pairs per unit area, then plot the cumulative sum of the number of families against the cumulative sum of the areas searched, using log-log graph paper (Table IV, Figure 2 ~~and 3~~). We find that a straight line can be fitted to the points without the use of too much imagination (if only because the points are few). Extrapolating to an area of 500 sq. miles leads to an estimate of 1900 families based on the observations. The much larger estimates extrapolated from the photographs are probably worthless because the total area photographed was so small and very much concentrated on areas of high density of families. The photographs of inland sites that could

not be related to the observation flight and were not of continuous areas because they were selected to include geese, can only be used here with a correction factor, based on the ratio of area scanned to area photographed in the coastal zone, from Table III.

The utility of such an approach must depend to a considerable extent on whether the chosen flight paths corresponded roughly to sampling by the principle of optimum allocation. What happened on Bylot Island in 1969 was that, on the basis of prior knowledge of the distribution of broods, relatively more effort was put into searching near the shore than further inland. Because the flocks were widely scattered with little concentration near the shore, the searching procedure was probably more appropriate for assessing families than moulting adults.

Similar plotting of the number of flocks seen by Boyd and Hermkens leads to an estimate of 300 flocks on the whole area, compared with their total of 65. The comparable extrapolation from the 34 flocks recorded by Heyland and de Blicquy is only 74.

In order to explore this method further, observations made by Boyd have been analyzed into two segments for each of the three sections, with breaks provided by time checks given in his field notes. For example we flew section I between 12:14 and 12:52 hrs. local time and Boyd recorded a break at 12:44. Assuming a nearly constant flying speed, the estimated length of sector I (60 miles) can be divided into segments before and after 12:44, the first being 60 x 30/38 = 46.8 miles and the second 60 - 46.8 = 13.2. Following the same procedure as before and assuming a strip width of 1/4 mile for observation of families and of 1/2 mile for Boyd's observations of flocks leads to estimates by extrapolation of up to 4,700 families on the entire area, and up to 400 flocks of moulters (Table IV, Figure 3).

The number of moulting geese in flocks

Heyland having demonstrated by counting birds in flocks on photographs that the observers under-estimated the number of moulters in the flocks they saw, we need to find a method for adjusting their estimates. If we assume that the flight of July 22, or any intervening event, had no important effect in changing flock sizes

between 22 and 24 July then, even though we cannot identify photographed flocks with those observed 54 hours earlier, it seems proper to argue that the frequency of flocks of different true sizes within the observed sample should be similar to that found in the photographed samples. Two methods of estimating the total number of moulting adults seen in the flocks are then available: 1) multiplying the estimated number of flocks by the mean size of the photographed flocks, and 2) multiplying the observer's estimates of total number seen by the factor (mean true size of flock, from photographs)/(mean of observers' estimates of flock size). Either estimate needs to be multiplied by some area factor, allowing for the incompleteness of search, to obtain an estimate of the total number of moulters found. The first method is far more straightforward.

One statistical difficulty in using the mean as a multiplier is that the distribution of flock sizes is far from normal, so that the arithmetic mean and the standard deviation do not characterize the distribution very well. Dr. A.R. Sen has suggested using sub-grouping

of the photographic counts, calculating the mean of each successive group of three flocks and then taking the mean of the means. Using $\underline{t}$ to establish 95% confidence limits, we find the values of this mean to be 93.0 and the limits of the mean to be 64.4 and 121.6. Applying these values to the observations of 22 July leads to an estimate of 190 x 93.0 = 17670 moulters in the flocks seen, with limits 12200 and 23100. The photographs of 24 July provide an effective lower limit for the number of moulters present of 4800, as already noted. The upper limits for the number present could conceivably be as high as 121.6 x 400 = 48640 from the extrapolations of Boyd's number flock counts.

An alternative approach to correcting the estimates of numbers in a flock involves using the geometric mean of the counts from photographs to adjust the geometric means of the estimates by individual observers. This may be done very quickly by plotting the percentage cumulative frequency distribution of log (flock size) against log (flock size), as in Figure 4. The straight line relationships found confirm that the use of logarithms effectively transforms the distributions to near-normal.

The similarity of slope between the lines based on observations and that based on counts from photographs (with the probable exception of Heyland's observations) suggests that the observers were under-estimating in a fairly systematic way throughout the range of flock sizes.

Review of results as a guide to further surveys

A selection from the many alternative estimates of numbers is assembled in Table IV. Their diversity goes some way towards justifying the pessimistic conclusion that we shall never know how many snow geese there were in the southwest of Bylot Island in July 1969. Yet several important points emerge. First, photographic records are very much more precise than visual estimates, but photographs need to be taken according to a previously determined sampling plan if the results are to provide estimates of total numbers. The requirements for assessing families and moulting adults are conflicting, since the latter are much more widely distributed and clumped than the families. Complete photographic cover at the height flown in 1969 (which was very suitable for producing clearly identifiable images of goslings as well as adults)

would be too expensive, at least if attempted on Baffin Island as well as Bylot Island: and the results of the extensive reconnaissance, reported elsewhere, make clear that satisfactory estimates for both islands are essential for a proper understanding of the breeding biology of the greater snow goose. A suggested compromise for southwest Bylot and for the vicinity of Bernier Bay and Berlinguet Inlet is to undertake complete strip coverage of a belt one or two miles wide along the coast, supplemented by sample transects flown inland to the limits of suitable habitat, with some overlapping, preferably at readily identifiable sites. For Bylot the pattern could be roughly similar to the 1969 flight path, with the inland transects flown on straight lines. The essential feature seems to be to run continuous lines, rather than to take photographs only where geese are seen, so as to provide a sound basis for extrapolation. The view that in concentration areas such as Bylot the flight path should be partly determined by moving from one flock to the next, as was attempted in 1969, seems to be unsound. Where logistically most convenient, replications of parts of the survey route should be tried at least once, to

provide an estimate of day to day variability in distribution, which would clarify the questions raised by the comparisons of the shore-line counts of July 22 and the photographs of the 24th. Because of the cost of film, the difficulties of examining large numbers of photographs, the likelihood of photographically unfavourable weather and the possibility of technical failure, either of the camera or in processing the films, photographic records should, if possible, be supplemented by observations. The observer should use the same sampling units as the photographer while the latter is in action, and a strip width, determined by prior calculations, coinciding as nearly as possible with that given by the photographs. They should concentrate on detecting and recording groups, and the presence of goslings, rather than give too much attention to trying to count individuals within dense flocks.

In reconnoitring likely areas away from known concentrations, for example along Phillips Creek and the Gifford River, it seems best to retain the observational approach, without fixed transect width, following up with photographic transects in areas where substantial numbers of geese have

been found. This will save both money and effort.

Reverting to the 1969 results, it appears unlikely that the number of successful breeding pairs on southwest Bylot Island exceeded 1,450 or that the total number of adults there, including breeders and moulters, exceeded 21,000. If there were more than 60,000 adults in the population of atlantica at that time, as the photographs from the St. Lawrence River in May and October indicate, Bylot Island is perhaps less important than Baffin Island as their summer home, unless, as is possible, it is more consistently suitable as a breeding place.

Table I. Summary of snow goose records made by observers in flying over southwest Bylot Island on July 22, 1969.

	I	II	III	Total
Number of pairs with goslings				
Heyland (right cockpit)	59	91	291	441
Boyd (right cabin)	69	64	271	404
de Blicquy (left cockpit)	73	45	181	299
Hermkens (left cabin)	98	75	415	591
Number of moulting adults (with number of flocks in parentheses)				
Heyland	411 (8)	165 (4)	15 (1)	591 (13)
Boyd	818 (19)	477 (15)	106 (9)	1,401 (43)
de Blicquy	683 (18)	170 (3)	0	853 (21)
Hermkens	771 (16)	388 (6)	0	1,159 (22)
				4,004 (99)

Table II. Summary of counts of snow geese on southwest Bylot Island by J.D. Heyland, from photographs taken on July 24, 1969.

Number of usable photographs showing geese	79
Area photographed	5.14 sq. miles
Total number of families counted	905
Number of moulting adults	4,821 in 43 flocks
From photographs, mean brood size	3.1 (n
% young birds	

Table III. Comparison of counts of pairs with families seen near the shore on July 22, 1969 by J.D. Heyland and R.M. de Blicquy with counts from photographs of the same areas taken on July 24.

Section	Pairs seen July 22	Area searched (sq. miles)	Counted from photographs July 24	Area in photographs (sq. miles)
A) Motorcycle Pt. - Camp	65	4.30	82	0.85
B) Camp Area	84	1.43	213	0.65
C) Camp - End	383	14.73	241	0.65
D) Polygon Delta	55	6.65	91	0.78
Total	587	27.11	627	2.93

The difference between the area searched and the area photographed reflects the fact that photographs were taken only where geese were seen.

Table IV. Estimates of total numbers of snow geese on southwest Bylot Island, July 22-24, 1969. (Sub-totals rounded to nearest ten, area totals to nearest hundred)

Relevant information: Total habitable area 500 sq. mi., area searched 75 sq. mi., area multiplier (a) 500/75 = 6.67, area photographed 5.14 sq. mi.

Pairs with families F				
highest count - Fh (Heyland & Hermkens)				1030
upper limit (Fh) x a	1030 x 6.67			6880
extrapolations:	from coastal zone photographs	2050		
	upland zone photographs	850	mean (Fc)	1450
	from counts by Boyd			900
	from highest sector counts			1900
Flocks of moulting adults N				
most flocks seen (Boyd 43 & Hermkens 22) 65		Nh upper limit (Nh)a		430
least flocks seen (Heyland 13 & de Blicquy 21) 34		NL lower limit (Nh)a		230
extrapolations:	from all observations	Nc		440
	from Boyd's observations	Nb		220
	from photographs	Np		190

Table IV. (continued)

Mean number of adults in moulting flocks M

		all photographs	all observers	Heyland	Boyd	de Blicquy	Hermkens
arithmetic mean	Mp	93.0	40.4	45.5	32.6	40.6	52.7
geometric mean		66.1		20.9	18.2	14.5	28.8
multiplier (photo/observer)	m		2.30	2.04	2.85	2.29	1.76

Total number of moulting adults NM

from photographs (Np) (Mp) 190x93				17670
from cusums of flock observations (Nc)(Mp) 440x93				40920
(Nb)(Mp) 220x93				20460
individual's (adult counts & multiplier), summed	Co	Cockpit		3160
	Ca	Cabin		6030
C x a		Cockpit		21020
		Cabin		40240

Table IV. (continued)

Total number of geese on southwest Bylot

	Selected value		range of estimates
moulting adults	(Np)(Mp)	17700	3200-40900
parents (pairs x 2)	2 (Fc)	2900	1800-13800
Total adults		20600	
goslings (pairs x 3.1)	3.1 (Fc)	4500	
Total geese		25000	