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Abstract

Estimates of hunting kill, band recoveries, and aerial surveys of wintering places are used to describe the status of Lesser Snow Geese *(Anser c. caerulescens)* breeding in eastern arctic Canada during 1964–79. The population in mid August averaged 2.42 million birds, with a low of 1.35 million in 1966, a maximum of 3.3 million in 1974, and an average annual increase of 130 000 birds. In winter the aerial surveys accounted for an average 1.1 million, with a mean rate of increase of 67 000 birds each year. In the US, hunters killed an average of 356 000 (range: 161 000 – 575 000) geese each season in the Mississippi and Central flyways. In Canada, recreational hunters killed an average 47 000 annually between 1964 and 1979, though from 1975 that annual kill increased rapidly as the geese spent more time in southern Manitoba and southeast Saskatchewan and eastern stocks spent less time around James Bay. The westward shift left Indian subsistence hunters with smaller kills: from 72 000 in 1973–75 to less than 30 000 in 1977–79. The mean annual survival rate of adults banded at three colonies was 77.1% (range: 67.6–93.4%): for geese in the first year after fledging the mean survival rate was 44.2% (range: 23.2–71.2%). The recorded hunting kill amounted to more than half of all adult losses and about 43% of the losses suffered in the first year after fledging. The effects — on goose numbers and breeding — of weather in the breeding, staging, and wintering areas are compared with the impact of hunting and the age structure and behaviour of the goose population. There was a sustained upward trend in numbers which did not seem to be related to weather or other population variables. These variables did, however, predict yearly fluctuations about the trend. Weather in the breeding area at the onset of nesting, represented by mean June temperature, has the most effect on the production of young. Winter precipitation in the Gulf coast states affects the number of adults and their breeding success to a greater extent than spring temperatures and accumulated precipitation in the northern staging areas in the Dakotas and southern Manitoba. The size of the US hunting kill in the previous season also influences population size. There have been substantial changes in the distribution of the geese in fall, winter, and spring, initiated by the geese themselves. The numbers at particular breeding colonies changed considerably from 1973 to 1979 but the effective breeding population remained much the same. The geese are managing themselves with notable success. Wildlife agencies may be able to influence their distribution for the benefit of human users.

Résumé

On a utilisé des estimations des prises des chasseurs, du nombre de bagues récupérées et des relevés aériens des lieux d'hivernage pour connaître la situation de la Petite Oie blanche *(Anser c. caerulescens)* nichant dans la partie est de l'Arctique canadien, entre 1964 et 1979. A la mi-août, la population moyenne a été de 2,42 millions d'oiseaux, le niveau le plus bas ayant été de 1,35 million d'individus en 1966, et le plus élevé, de 3,3 millions en 1974; l'augmentation annuelle moyenne est de 130 000 individus. En hiver, grâce aux relevés aériens, on a compté une moyenne de 1,1 million d'oiseaux et évalué l'augmentation annuelle moyenne à 67 000. Aux États-Unis, les chasseurs ont tué en moyenne 356 000 oies (de 161 000 à 575 000) chaque saison, dans les voies migratoires du Mississipi et du Centre. Au Canada, les chasseurs sportifs ont pris en moyenne 47 000 oiseaux par année entre 1964 et 1979, bien qu'à partir de 1975, le nombre de prises ait augmenté rapidement à mesure que l'oie passait davantage de temps dans le sud du Manitoba et le sud-est de la Saskatchewan, et que les populations de l'est demeuraient moins longtemps dans la région de la baie James. Par contre, ce mouvement vers l'Ouest a réduit le nombre des prises des autochtones qui chassent pour leur subsistance : elles sont passées de 72 000 en 1973–1975, à moins de 30 000 en 1977-1979. Le taux annuel moyen de survie des adultes bagués dans trois colonies a été de 77,1% (de 67,6% à 93,4%); le taux moyen de survie des jeunes un an après qu'ils aient acquis leurs plumes était de 44,2% (de 23,2% à 71,2%). Les prises des chasseurs ont compté pour plus de la moitié de la mortalité chez les adultes et pour environ 43% des pertes chez les jeunes. Le rapport compare les effets, sur les populations et la reproduction, des conditions météorologiques des aires de nidification, de repos et d'hivernage, avec les conséquences de la chasse et la pyramide d'âge et le comportement des populations d'oies blanches. On a remarqué une tendance continue à la hausse dans les populations, laquelle ne semblait pas assujettie aux conditions climatiques ni à d'autres variables de population. Cependant, ces variables ont permis de prévoir les fluctuations annuelles de la tendance. C'est le temps qu'il fait dans l'aire de nidification au début de la période de reproduction, représenté par la température moyenne de juin, qui a le plus grand effet sur la production de jeunes. Les précipitations d'hiver dans les États côtiers du Golfe ont des répercussions plus marquées sur le nombre d'adultes et sur la réussite de la reproduction que les températures du printemps et l'accumulation de précipitations dans les aires de repos des Dakotas et du sud du Manitoba. L'importance des prises des chasseurs américains influe également sur le chiffre de la population de l'année suivante. On a remarqué d'importants changements dans la répartition des oies en automne, en hiver et au printemps, changements provoqués par les oies elles-mêmes. Les populations de certaines colonies ont varié considérablement de 1973 à 1979, mais la population reproductrice s'est maintenue pratiquement au même niveau. Les oies assurent leur permanence de façon remarquable. Les organismes de faune pourraient éventuellement influer sur la répartition de cette espèce à l'intention des utilisateurs.

Introduction

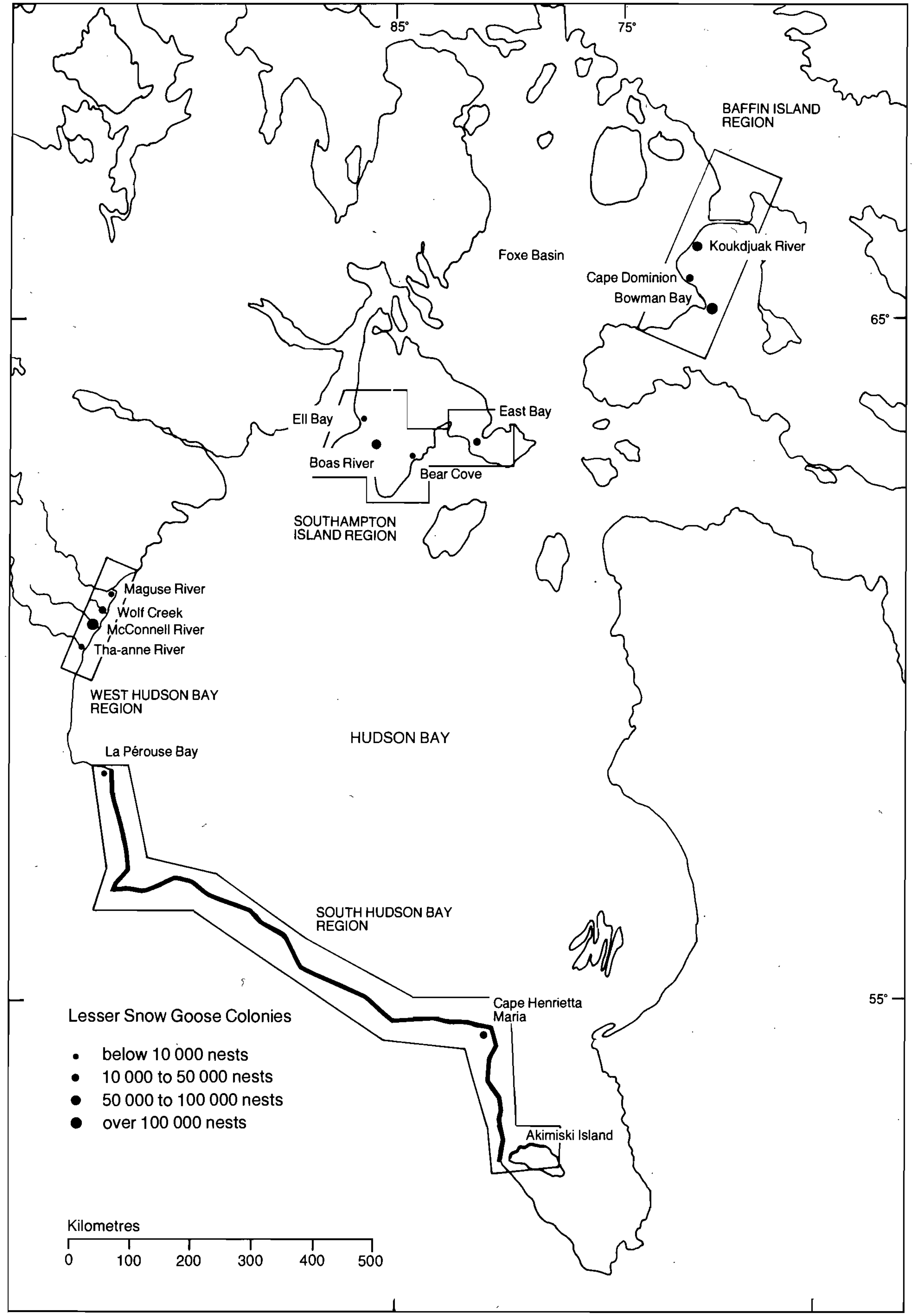
Snow Geese are easier to find and count than most other geese, are abundant, and are growing in popularity as quarry for hunters. They have received a good deal of attention from researchers in northern Canada (see especially Cooke *et al.* 1981) and have been surveyed fairly systematically in Canada and in the US for unusually long periods — over 40 years on the Gulf coast.

This note is a synthesis of some recent appraisals of the eastern arctic stocks of Lesser Snow Geese *(Anser c. caerulescens)* i.e., those breeding in the colonies around Hudson Bay and Foxe Basin (Fig. 1). Boyd (1976*a, b*) described the methods used for estimating total numbers in August. Estimates of numbers in winter are obtained from aerial surveys organized by the US Fish and Wildlife Service (USFWS). The national harvest surveys operated by the USFWS and Canadian Wildlife Service (CWS) provide estimates of kill, which are also used in estimating abundance.

We have tried to convey some feeling for the magnitude of changes in a large, highly mobile population and to explain those changes. In contrast to the proper concern of scholarly biologists with detail and precision, this is a sketch with a broad brush, using unavoidably imprecise data to arrive at general impressions of the well-being of the entire eastern arctic stock, rather than of any particular colony or wintering group.

In this, as in earlier reports, the name "Lesser Snow Goose" is applied to geese of both the white and blue colour phases, for which the data and results are pooled.

Figure 1
Map of breeding colonies of Lesser Snow Geese in the eastern Canadian Arctic



Methods

1. Numbers in August

The August population of Lesser Snow Geese is derived from the relationship:

$$\frac{\text{est. total no. geese, } \hat{N}}{\text{est. geese kill by hunters, } \hat{K}} = \frac{\text{no. geese banded, } B}{\text{direct recoveries of banded geese, } D}$$

$$\text{so that } \hat{N} = \frac{\hat{K}.B}{D}$$

where a "direct recovery" is one obtained in the first hunting season after banding (Lincoln 1930). As not all banded geese which are shot are reported it is necessary to adjust for unreported bands. Here, as in earlier calculations of numbers (Boyd 1976*b*), we assume a constant annual reporting rate of one-third, based on results for several species of geese reported by Martinson and McCann (1966) and Henny (1967). So long as the reporting rate remains nearly constant, even if unknown, $\hat{N}$ can be considered as an index. If the assumed reporting rate is too high the result will be an overestimate of the number of geese in the population.

The US and Canadian national harvest surveys provide the estimates of the goose kill. The kill can be divided into adult and first-year birds according to the proportions found in the samples of tail feathers in the species composition surveys. In previous estimates for 1964–73 only the US kill and US recoveries were used (Boyd 1976*b*). For 1974–79 direct recoveries and kill in both countries have been used. The US kill estimates are limited to those reported from the Mississippi and Central flyways. Few Lesser Snow Geese are shot in the Atlantic Flyway and nearly all those shot in the Pacific Flyway originate from the western Canadian arctic or Wrangel Island (Bellrose 1976). In Canada the kill of Hudson Bay Lesser Snow Geese is virtually confined to the James Bay and eastern Hudson Bay coasts of Quebec and Ontario, and to Manitoba and southeastern Saskatchewan; geese that are taken further west come from the western Arctic (Dzubin, Boyd, and Stephen 1975).

The estimator is $\hat{N} = \hat{K} \times B/d \times ⅓$ where d is the number of direct recoveries reported and ⅓ is the assumed reporting rate mentioned above, i.e., $d = D/3$. Separate calculations are made for adult and first-year birds. $\hat{K}$ is the estimated kill in the relevant parts of Canada and the US. This estimator provides an index of $\hat{N}$, rather than an absolute value. The accuracy and precision of the estimates have not varied significantly apart from some improvement in the Canadian estimates, which have represented only 10% (5–48%) of the total annual kill.

One of the fundamental assumptions of the above (Lincoln Index) method (Seber 1973) is that all animals have the same probability of being caught. During 1963–79 geese were marked at only three colonies — La Pérouse Bay, Manitoba (1969–continuing); Cape Henrietta Maria, Ontario (1970– continuing); and McConnell River, NWT (1964–69 and 1977– 78) — and non-breeders were under-represented because they had moved away from the breeding areas before becoming flightless. However, Dzubin (1974) and Dzubin *et al.* (1975) have shown that extensive mixing occurs away from the breeding areas; therefore, we assume that the sampling of marked and unmarked geese by hunters is random with respect to colony of origin, though biased towards the killing of young birds. The recovery rate of geese wearing highly visible plastic neck collars is greater than that of geese carrying only leg bands. The recoveries of geese collar-marked at the McConnell River in the 1960s have therefore been omitted from the calculations.

Given the uncertainty associated with the estimate $\hat{K}$ of K, an approximately unbiased estimate of the variance of $\hat{N}$ can be shown to be:

$$\text{var } \hat{N} = \frac{(B+1)(B-d)}{(D+1)^2(D+2)} \left[(\hat{K}+1)(\hat{K}-d) + \text{var } \hat{K} \right]$$

This reduces to the estimate given on page 60 of Seber (1973) when $\hat{K}$ is known, i.e., var $\hat{K} = 0$.

The calculated confidence intervals are so wide as to be of little assistance in discerning what may be happening, though they show that little weight should be given to apparent changes from one year to the next.

2. Winter inventory

The winter inventory estimates ($\hat{W}$) are the sum of the numbers found by the USFWS each winter in both the Mississippi and Central flyways. Before 1973, the aerial surveys were made in early January. Since 1973 they have been made in mid December. The earlier count might be expected to lead to increased estimates, as hunting continues into January: yet when counts were made in both months the January count was sometimes higher. The inventories fall short of a census, for the areas to be searched are large and continually changing, and it is hard to avoid underestimating very large aggregations of geese, whether in flight or at rest. Though no details of the searches are published, so we do not know how consistent and comparable they are, the winter inventory is still useful as an index of relative abundance for the detection of trends.

Boyd (1976*b*) used an index of fall flight (F) obtained by adding the estimate of kill ($\hat{K}$) to the winter total ($\hat{W}$) and an adjusted index (F') in which $\hat{W}$ was replaced by $\hat{W}'$, using a correction factor obtained from May censuses in 1973 and 1974 to increase $\hat{W}$. Similar indices have been calculated here for 1974–79 (Fig. 4). Their chief merit is to confirm that in most years the adjusted fall flight is of the same order as, though smaller than, the estimated population size in August.

Photo: R.H. Kerbes, CWS

Results and discussion

1. Kill in Canada

Tables 1 and 2 list estimates of the kill in 1964–79 of eastern arctic Lesser Snow Geese in Canada and the US. When practicable the national totals are split into numbers of adults and of first-winter geese, on the basis of the proportion of young geese found in the samples of goose tails in the national species composition surveys.

The Canadian kill was small and fairly constant from 1969 to 1974. Since 1975, growing numbers have been reported. The upward trend is equivalent to 6000 more geese being shot each year ($r = 0.70$). Table 3 shows a great increase in the kill in Manitoba and southeastern Saskatchewan, partially offset by decreases in the kill in Ontario and western Quebec. Though there is no complete and continuing system for estimating the kill by native people, who are not required to hold a migratory game bird hunting permit, the reported take by the Crees of northern Quebec, which averaged 25 300 in 1973–75, fell to 15 000 in 1977–78, and only 4 800 in 1978–79 (James Bay and Northern Quebec Native Harvesting Research Committee 1976, 1980). The committee estimated that other subsistence hunters took about 40 000 eastern Lesser Snow Geese in 1973–75, the majority in northern Ontario. Recent less complete information suggests that the kill of Snow Geese by native people in Ontario has also fallen, though not as much as in northern Quebec: in 1977–79 native people took no more than 30 000. These reductions appear to be due to smaller numbers of Lesser Snow Geese staging in fall in those parts of the shore of eastern Hudson Bay and James Bay frequented by Indian hunters. That shift may also account for the decreasing numbers and success of visiting sport hunters using the commercial hunting camps along those coasts (Boyd and Wendt, in press).

The changes in kill are related to the estimated numbers of successful goose hunters in the zones where most eastern arctic Lesser Snow Geese are taken (Table 4). Because the information on goose-hunting effort was formerly estimated in a different way it is only practicable to examine data for the six seasons 1974–79, so that the chances of statistically significant correlations with years are reduced (for $n = 6$ and $p < 0.05$, $r > 0.707$). There has been a general increase in successful goose hunters in all four zones, proportionately most evident in Manitoba and southeastern Saskatchewan. Many of these hunters are taking other geese, perhaps exclusively. The average kill of Lesser Snow Geese has increased in Manitoba but decreased in northern Ontario, consistent with the changes in the total provincial kill of this goose.

Table 1
Estimates (in thousands) from the national harvest surveys of the retrieved kill of Lesser Snow Geese in the Mississippi and Central flyways (US kill) and in southeastern Saskatchewan, Manitoba, Ontario, and western Quebec (Canadian kill), 1974–79. Kill partitioned into adults (Ad.) and first-winter (1st w.) on basis of age-ratios in goose tails in the US and Canadian species composition surveys.

Breeding year	US kill			Canadian kill			Combined kill		
	Ad.	1st w.	Total	Ad.	1st w.	Total	Ad.	1st w.	Total
1974	247.8	168.9	416.7	22.5	19.8	42.3	270.3	188.7	459.0
1975	169.0	357.5	526.5	34.3	43.2	77.5	203.3	400.7	604.0
1976	233.8	137.2	371.0	26.4	16.8	43.2	260.2	154.0	414.2
1977	178.4	241.6	420.0	21.4	26.7	48.1	199.8	268.3	468.1
1978	255.6	67.3	322.9	38.6	14.9	53.5	294.2	82.2	376.4
1979	190.5	306.2	496.7	46.1	69.7	115.8	236.6	375.9	612.5
Mean	212.5	213.1	425.6	31.6	31.9	63.4	244.1	245.0	489.0
SE	37.7	108.9	76.0	9.8	21.2	28.7	37.8	126.4	98.1

Table 2
Estimates (in thousands) from the national harvest surveys of the retrieved kill of eastern arctic Lesser Snow Geese, 1964–73. The U.S. estimates here differ from those published by Boyd (1976*b*) which contained several errors. The Canadian kill cannot be separated into adult (Ad.) and first-winter (1st w.) birds.

Breeding year	US kill			Canadian kill	Combined kill
	Ad.	1st w.	Total		
1964	99.3	94.3	193.6	n.a.*	n.a.
1965	104.1	100.0	204.1	n.a.	n.a.
1966	153.6	193.0	346.6	n.a.	n.a.
1967	147.6	119.3	286.9	n.a.	n.a.
1968	118.1	42.6	160.7	n.a.	n.a.
1969	168.1	241.0	409.1	41.1	450.2
1970	268.9	305.7	574.6	29.4	604.0
1971	241.1	145.3	380.4	29.1	415.5
1972	187.2	57.5	245.7	24.4	270.1
1973	148.5	251.7	400.2	39.6	439.8
Mean†	163.6	155.0	318.8	32.7	435.9
SE	57.8	88.9	128.0	7.3	118.7

* Not available.
† The totals may not equal the sum of the parts due to rounding.

Table 3
Estimates (in thousands) of the kill of eastern arctic Lesser Snow Geese in Canada by purchasers of the migratory game bird hunting permit, 1969–79.

Year	Ont. and Que.	Man. and SE Sask.	Total
1969	29.2	11.9	41.1
1970	19.0	10.4	29.4
1971	19.3	9.8	29.1
1972	8.6	15.8	24.4
1973	17.2	22.4	39.6
1974	15.5	26.8	42.3
1975	24.2	53.3	77.5
1976	10.5	32.7	43.2
1977	9.1	39.0	48.1
1978	7.5	46.0	53.5
1979	14.8	101.0	115.8
Mean*	15.9	33.8	47.0
SE	6.9	28.2	29.4
Regression on yrs., r	–0.61	0.79	0.70

* The totals may not equal the sum of the parts due to rounding.

Table 4
Numbers of successful hunters of geese in provincial zones visited by eastern arctic Lesser Snow Geese, 1974–79, and their average season kill of Lesser Snow Geese

	1974	1975	1976	1977	1978	1979	mean	SE	r	Ann. gain
Goose hunters										
Ont., 03(N)	2 752	3 656	2 742	3 951	2 803	4 821	3 454	846	0.57	254
Man., 02(N)	4 050	5 147	5 578	4 749	5 530	6 271	5 221	765	0.80*	326
01(S)	12 469	19 010	14 250	11 199	17 551	21 255	15 956	3 941	0.49	1 043
Sask., 03(SE)	5 687	7 881	7 948	7 278	8 624	8 872	7 715	1 145	0.82*	500
Total	24 958	35 694	30 518	27 177	34 508	41 219	32 346	5 988	0.66	2 126
Av. kill of L. Snow Geese										
Ont., 03(N)	3.46	4.90	3.49	1.47	2.45	1.74	2.92	1.28	–0.75*	–0.51
Man., 02(N)	0.50	1.17	0.41	0.70	1.15	1.45	0.90	0.42	0.63	0.14
01(S)	1.78	2.44	2.08	2.48	1.91	4.13	2.47	0.86	0.66	0.30
Sask., 03(SE)	0.29	0.13	0.09	1.11	0.72	0.35	0.45	0.39	0.42	0.09
Total	1.42	2.00	1.38	1.65	1.53	2.63	1.77	0.48	0.55	0.14

*$p < 0.05$.

Table 5
Estimated kill of Lesser Snow Geese per 100 adult hunters in those states in the Central and Mississippi flyways where substantial numbers of Lesser Snow Geese were taken, 1971–79.

Flyway state	1971	1972	1973	1974	1975	1976	1977	1978	1979	Mean
N. Dak.	116	72	136	167	228	147	200	128	220	157
S. Dak.	90	62	74	64	91	38	85	31	65	67
Kans.	8	7	18	36	13	19	13	8	14	15
Nebr.	19	14	36	37	42	11	22	23	32	26
Tex.	40	55	91	63	106	95	95	49	94	76
Cent. Flyway	–	–	57	57	80	58	69	43	76	63
Minn.	18	12	10	28	9	4	6	3	30	13
Iowa	66	54	48	55	59	24	41	31	77	51
Mo.	41	22	34	48	61	17	29	16	25	33
La.	39	27	75	39	60	47	49	67	39	42
Miss. Flyway	–	–	19	19	18	12	14	16	21	17

2. Kill in the US

Over the 16 years 1964–79 the estimated kill in the Mississippi and Central flyways averaged 356 000, ranging from 161 000 in 1968–69 to 575 000 in 1970–71 and showing a small though significant increase over time ($r = 0.566$, $p < 0.05$), equivalent to 4.0% of the mean annual kill. Most of the increase has been in the Central Flyway (Table 5), and particularly in the north central states, with a marked decline in recent years in the central tier (Kansas, Nebraska, Missouri). On the Gulf coast there have been large fluctuations in the size of the kill, both absolutely and in proportion to the total kill in the two flyways. The decline of the southern harvest due to "short stopping" that was feared in the early 1970s and which prompted much of the US interest in these geese seems to have been prevented.

Though it is not possible to determine from the USFWS harvest surveys how many of the waterfowl hunters in a state were seeking to kill Lesser Snow Geese, it is of some interest to relate the kill to the numbers of adult hunters (Table 5). The five states with the largest kills are also those with the highest kill per hundred hunters in 1971–79. In descending order they are North Dakota (157), Texas (76), South Dakota (67), Iowa (51), and Louisiana (42). If the number of hunters is used as an index of hunting effort, it is notable that none of the states with a substantial kill of Lesser Snow Geese showed a significant trend in yield for effort during 1971–79.

To understand the population fluctuations of the geese it is more important to consider the extent to which the US kill is related to the size of the Lesser Snow Goose population in August. The first column of Table 6 shows that in the west north central region there was a strong correlation between population size and kill ($r = 0.843$), with significant correlations also for several, but not all, individual states. The second column of Table 6 shows that the size of the kill in the west north central region was also strongly correlated with the average temperature in November–December. The partial correlation coefficients (col. 3 and 4) suggest that the kill in Minnesota and Iowa was affected by local temperature rather than by the size of the fall flight. Presumably seasonably high temperatures encourage geese to remain longer in the northern states.

The kill in Louisiana and Texas was not simply related to the size of the population in August, whether or not kill in Canada and the northern states is included. The southern kill does not correlate significantly with temperatures in the Gulf states or in the more northerly fall staging areas. Perhaps this lack of fit reflects the consequences of extending the southern season into late January in recent years, so as to increase hunting opportunities.

Table 6
Correlation of estimated hunting kill (*K*) of Lesser Snow Geese in the northern and central states of the Central and Mississippi flyways, 1971–79, with estimated population size in August (*N*) and with local temperatures in fall (*T*)

State, region	r_N	r_T	$r_{KN.T}$	$r_{KT.N}$
N. Dak.	0.784*	0.584	0.646	0.145
S. Dak.	0.411	0.448	0.284	0.241
Minn.	0.352	0.803†	–0.295	0.812
Iowa	0.095	0.793†	–0.490	0.875
Nebr., Kans.	0.633*	0.372	0.552	0.045
Mo.	0.608*	0.640*	0.617	0.651
West North Central Region	0.843†	0.836†	0.768	0.621

* Significant at level $P = 0.05$.
† $P = 0.01$.

3. Numbers in August

Tables 7 and 8 list estimates of the numbers of adult and young geese in late summer derived from the estimates of kill in Table 2 and records of geese banded and direct recoveries. The estimates derived from banding at McConnell River are listed separately from those based on the pooled results of banding at La Pérouse Bay (LPB) and Cape Henrietta Maria (CHM), because the probability of recovery and the extent of mixing are likely to be different. Figure 2 suggests that the 1964–68 McConnell-based estimates are compatible both with the LPB–CHM estimates for 1969–78 and with the 1977–78 McConnell-based figures. Yet the results from the McConnell banding lead to the inference of a relatively large rate of increase while the LPB–CHM series suggests little growth, if any. The large discrepancies between the alternative estimates for the years 1977 and 1978 seem to result from low recovery rates for the geese banded at the McConnell River colony.

The estimates for adults show much the same trends as those for total numbers. The numbers of young geese show no time trend over the series as a whole ($r = 0.025$) for the LPB–CHM series of 1969–78. From McConnell banding they are negative for 1964–68 ($r = -0.909$), but positive ($r = 0.411$) when the 1977 and 1978 estimates are included.

Yearly variations in the weather at breeding areas seem to have had an effect on breeding, as well as the trend in adult numbers discussed later. Yet it is worth remarking

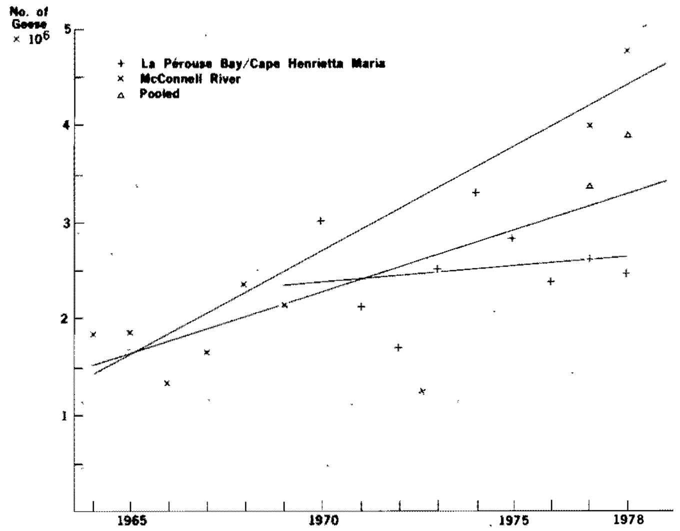
Table 7
Lincoln Index estimates (in thousands) of Lesser Snow Geese in the eastern Canadian Arctic in August, 1974–79, based on samples from banding at La Pérouse Bay (LPB) and Cape Henrietta Maria (CHM), 1974–79. The second estimates for 1977 and 1978 include the data from large-scale banding at the McConnell River.

Banding yr. and place	Adults (more than 1 yr. old)				Young (just prior to fledging)				Total no.
	Banded B_a	Recov'd d_a	Est. no. $\hat{N}_a$	SE($\hat{N}_a$)	Banded B_1	Recov'd d_1	Est. no. $\hat{N}_1$	SE($\hat{N}_1$)	$\hat{N} = \hat{N}_a + \hat{N}_1$
1974	3 014	110	2 469	681	2 451	186	829	173	3 298
1975	1 470	76	1 311	428	3 930	349	1 504	229	2 815
1976	1 858	87	1 851	568	3 778	355	546	82	2 397
1977	2 141	89	1 602	488	3 745	330	1 015	159	2 617
1978	2 213	101	2 149	636	3 010	244	338	62	2 487
1979	5 103	141	2 854	701	8 027	487	2 065	271	4 919
McConnell River & LPB and CHM									
1977	18 164	543	2 283	288	12 846	877	1 310	128	3 593
1978	44 649	1 223	3 580	302	13 803	1 072	353	31	3 933

Table 8
Lincoln Index estimates (in thousands) of Lesser Snow Geese in the eastern Canadian Arctic in August, 1964–73, based on the harvest estimates in Table 2 and on recoveries from samples banded at the McConnell River, NWT, in 1964–68, and at La Pérouse Bay and Cape Henrietta Maria during 1969–73.

Banding yr. and place	Adults			Young			Total
	B_a	d_a	$\hat{N}_a$	B_1	d_1	N_1	$\hat{N} = \hat{N}_a + \hat{N}_1$
McConnell River							
1964	1443	49	975	657	24	860	1835
1965	6745	223	1050	4851	205	789	1839
1966	400	37	554	4052	327	797	1351
1967	2421	103	1156	3427	274	497	1653
1968	8716	154	2228	1217	123	140	2368
Mean 1965–68			1193			617	1811
La Pérouse Bay and Cape Henrietta Maria							
1969	2963	112	1482	1892	228	667	2149
1970	4273	193	1908	5998	590	994	2902
1971	3243	164	1422	1360	124	475	1897
1972	2115	90	1473	3491	304	220	1693
1973	2418	81	1471	3556	291	1028	2499
Mean 1969–73			1551			675	2228

Figure 2
Lincoln Index estimates of the total number of Lesser Snow Geese in the eastern Canadian Arctic in August, 1964–78



the existence of an inverse correlation ($r = -0.486$) between the estimated numbers of adults and of young, just significant at the 5% level.

4. Numbers in winter

The inventory made by searches and counts from light aircraft in the US wintering areas suggests a substantial rate of increase during 1965–80 (Fig. 3 and Table 9), with a peak in 1977, when the numbers recorded in the winter inventory represented about 75% of the Lincoln Index estimates for the preceding August. On average for the entire period the winter inventories account for only about 50% of the estimated numbers in August, a discrepancy too great to be accounted for by hunting between August and December.

5. Numbers in fall

Fall flight indices (*F*) have been calculated for 1974–79 by adding the Canadian and US kill to the winter inventory total. An adjusted fall flight index (F^1) was obtained by multiplying the winter estimate by the factor 1.58 derived by Boyd (1976*b*) from a comparison of winter surveys and inventories along the Hudson Bay coast in May 1973 and 1974. As Figure 4 shows, the numbers were larger in recent years than in 1964–68, reflecting the upward trends in the winter inventories and, to a lesser degree, in the recorded kill.

Another way to estimate an annual index of population size is to use survival rates of banded geese. That method requires the following information about the relative abundance of young birds.

6. Age-ratios

The Lincoln Index estimates of the numbers of adults and nearly-fledged goslings yield estimates of the age ratio: $\hat{J}(\%) = 100\, \hat{N}_y / (\hat{N}_a + \hat{N}_y)$. A second and third set can be derived from the age-ratios in the tail fans of shot geese sent in to the CWS and USFWS species composition surveys, though these are biased by the greater vulnerability of young geese to the gun. There are also field counts made on the US Gulf coast (Lynch and Singleton 1964 and later USFWS

Figure 3
Number of eastern arctic Lesser Snow Geese reported in winter inventories in the Central and Mississippi flyways, 1965–80

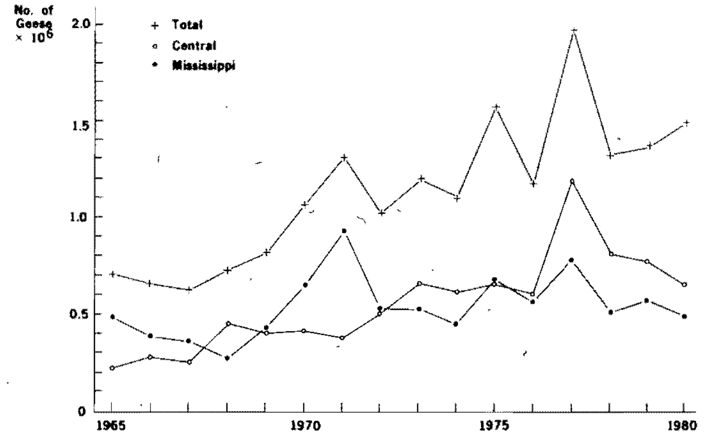


Figure 4
Number of eastern arctic Lesser Snow Geese in fall, estimated from adjusted winter inventory and from hunting kill, 1964–79 (*F*, index of fall flight; F^1, adjusted index)

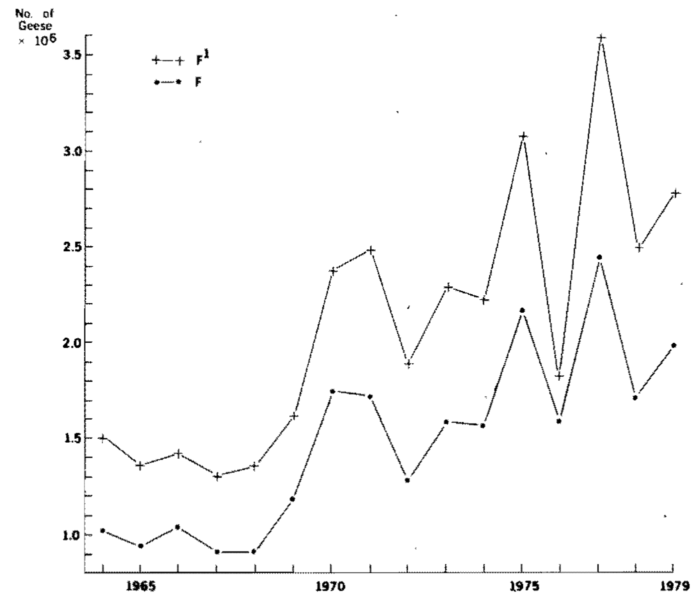


Table 9
Estimates (in thousands) of Lesser Snow Geese seen in winter inventories in Mississippi and Central flyways, 1974–79

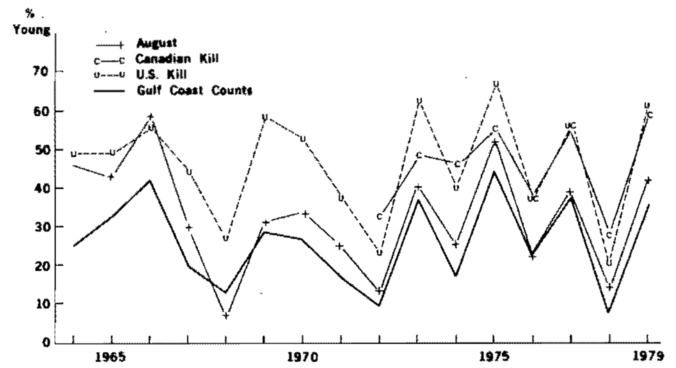
Year	Mississippi	Central	Total
1974	442	681	1123
1975	692	894	1586
1976	571	613	1184
1977	796	1231	2027
1978	573	828	1401
1979	594	834	1428
mean	611	847	1458
SE	121	216	326

reports). Figure 5 compares these four sets of data. The Lincoln Index estimates are not independent of those from the species composition surveys, for it will be recalled that the latter were used to derive $\hat{k}_a$ and $\hat{k}_y$ from the total harvest estimate $\hat{K}$, so that the resemblance between the variations in those age-ratios might be expected. The very strong correlation between the estimated age-ratio in August (Lincoln Index) and the observed ratio in counts of geese flocks on the Gulf coast in late fall ($r = 0.912$) is more useful, helping to confirm the reliability of both measures. The correlations between the observed Gulf coast ratio and those in the Canadian tail samples ($r = 0.900$) and the US tail samples ($r = 0.932$) are of the same high order.

7. Recovery rates and vulnerability

Suppose B_a and B_1 are, respectively, the numbers of adult and juvenile geese banded, and d_a and d_1 are the numbers of adult and juvenile direct reported recoveries from these bandings. These have already been used to estimate $\hat{N}$ but are useful for another purpose, as measures of the extra vulnerability of young geese to the gun, using the vulnerability quotient $V = d_1 . B_1/d_a . B_a$ (Bellrose in Hanson and Smith, 1950). The annual values of such a quotient are susceptible to chance variations in the numbers of banded geese reported so are widely scattered around the period means (Table 10), which themselves vary considerably. This reflects a relative poor correlation between the direct (first-year) recovery rates of geese banded before fledging and of those more than a year old when marked.

Figure 5
Proportion of young eastern arctic Lesser Snow Geese in the Canadian and US kill and in flocks wintering in the Gulf coast states compared with proportion in August obtained from Lincoln Index estimates



8. Mortality and hunting kill

A thorough investigation of the methods of estimating the survival of western arctic Lesser Snow Geese banded since 1964 was made in 1979–80 by G. Butler (unpubl.), who found differences in the reliability and robustness of the methods of estimation, as well as differences between the survival of white- and blue-phase geese from some colonies and rather small differences between the survival rates of males and females. We have made one estimate for all adults and young marked at any one colony in one year (Tables 11 and 12, Fig. 6). Wherever possible we used the "maximum likelihood method" of estimation (Seber 1973, Brownie *et al* 1978), and Ricker's (1975) method to calculate some additional values.

In compiling the data for estimating recovery and survival rates Butler used only records of geese shot in September–March, to avoid heterogeneity; other recoveries are relatively few. There is little correlation between the direct recovery rates and the corresponding mortality rates ($\hat{m} = 1-\hat{s}$): ($n = 14$; $r = 0.212$ for adults, -0.035 for young).

Pursuing further possible relationships between the fate of banded geese and that of the population at large, neither the mortality rates nor the direct recovery rates are significantly correlated with the size of the US kill: for $\hat{m}$, $r = 0.122$ for adults, 0.067 for young; for d, $r = 0.159$ for adults, 0.269 for young ($n = 14$).

The Lincoln Index estimates of population size can be used to derive another crude measure of survival, the ratio of adults in August of year $t+1$ to the total population in August of year t. Those survival indices, which involve a mixture of adult and first-year survival, have a 14-year mean of $74.2 \pm 21.5\%$, falling as low as 39.7% in 1974–75 and apparently exceeding 100% in 1967–68 and 1978–79. The corresponding mean and range for the survival of banded geese can be obtained by weighting the adult and first-year estimates by the numbers of newly-marked adults and young (though this is not equivalent to the ratio of adults to young in the total population). The pooled 14-year mean survival of banded geese is $65.8\% \pm 11.0\%$. Again, there is no fit between the two annual survival estimates obtained in these two different, though not independent, ways: $r = -0.009$. There is no association between "Lincoln Index" mortality rates and the size of the US kill ($r = 0.080$).

9. Numbers of breeding Lesser Snow Geese

Kerbes (1975) reported on a photographic inventory of breeding geese in 1973 and on the recent history of the colonies around Hudson Bay and Foxe Basin. Photographic inventories conducted in 1978–80 are being reported in detail elsewhere by the scientists responsible but Table 13 summarizes the relevant results. The most interesting, yet unexpected, finding is that the total breeding population in 1979 was much the same size as in 1973, about 1.06 million birds. Although the number of geese at the Cape Henrietta Maria colony had nearly doubled, from 59 000 to 110 000 birds (H.G. Lumsden, pers. comm.) and the population on Southampton Island had increased from 156 000 to 214 000, the McConnell River colony declined after 1977. Though no aerial survey of that colony could be made in 1979 it was surveyed in 1977, 1978, and 1980; we interpolated a value of about 283 000 geese for 1979. The reduction of 39% from 1977 to 1980 at the McConnell River group of colonies is the most rapid large decrease yet recorded. R.H. Kerbes, A. Reed, H.G. Lumsden, and others will discuss the reasons for that and other changes in another place.

The aerial photographs taken in June do not provide a total census because large numbers of non-breeding geese are not recorded. These geese tend to fly away at the

Table 10
Relative vulnerability of banded Lesser Snow Geese in their first year after fledging, compared with that of older birds marked in the same year: $V = (d_1/B_1)/d_a/B_a)$.

Year	McConnell V	Year	LPB/CHM pooled V	Year	LPB V	CHM V	Pooled V	McConnell V
1964	1.08	1969	3.19	1974	1.54	1.74	2.08	
1965	1.28	1970	2.18	1975	1.38	2.18	1.72	
1966	0.87	1971	1.80	1976	2.01	1.73	2.01	
1967	1.88	1972	2.05	1977	2.28	1.39	2.14	2.29
1968	5.72	1973	2.36	1978	1.41	2.33	1.78	2.91
Mean	1.21		2.61		1.74	1.99	1.95	2.60

Table 11
Estimated annual survival (%) of adult Lesser Snow Geese (more than 1-year-old at banding), 1965–78. Estimates by G. Butler, using "maximum likelihood models", except for those shown in italic type, which were calculated using Ricker's method. Survival estimate refers to 12 following months, e.g., August 1965 – July 1966.

Banding year	McConnell River $\hat{s}$	McConnell River SE	La Pérouse Bay $\hat{s}$	La Pérouse Bay SE	C. Henrietta Maria $\hat{s}$	C. Henrietta Maria SE	Arithmetic mean $\bar{s}$
1965	69.46	7.18	—	—	—	—	(69.5)
1966	67.47	7.11	—	—	—	—	(67.5)
1967	78.26	6.15	—	—	—	—	(78.3)
1968	76.28	6.21	—	—	—	—	(76.3)
1969	*68.99*	*8.35*	91.37	23.60	*98.58*	*11.07*	86.3
1970	*68.35*	*7.49*	74.27	8.38	60.17	7.16	67.6
1971	—	—	80.64	8.75	102.64	14.13	91.6
1972	—	—	75.57	7.10	67.62	8.61	71.6
1973	—	—	90.63	10.83	96.18	10.05	93.4
1974	—	—	70.98	9.91	64.31	8.23	67.6
1975	—	—	92.17	12.97	88.96	15.26	90.6
1976	—	—	77.41	12.08	64.41	12.02	70.9
1977	*84.84*	*3.58*	59.00	10.60	*96.15*	*17.88*	77.6
1978	—	—	*68.94*	*15.68*	*70.76*	*17.69*	69.9
Arithmetic mean	71.47 (1965–70)		78.08 (1969–78)	2.81	80.98 (1969–78)	3.80	78.7 ± 3.4 (1969–78)

Table 12
Estimated annual survival (%) of young Lesser Snow Geese in first year after fledging, 1965–78. Estimates by G. Butler, using "maximum likelihood models", except for those in italic type, which were calculated using Ricker's method. Survival estimate refers to 12 following months, e.g., August 1965 – July 1966.

Banding year	McConnell River $\hat{s}$	McConnell River SE	La Pérouse Bay $\hat{s}$	La Pérouse Bay SE	C. Henrietta Maria $\hat{s}$	C. Henrietta Maria SE		Arithmetic mean $\bar{s}$
1965	50.80	34.24	—	—	—	—		(50.8)
1966	28.79	2.68	—	—	—	—		(28.8)
1967	23.13	2.44	—	—	—	—		(23.1)
1968	50.34	4.99	—	—	—	—		(50.3)
1969	*35.83*	*4.74*	44.90	6.56	*31.79*	*2.53*		37.5
1970	*52.06*	*7.27*	37.36	4.11	40.66	4.83		39.0
1971	—	—	46.85	5.86	52.49	23.42		49.7
1972	—	—	39.01	3.86	58.24	8.44		48.6
1973	—	—	56.99	6.66	45.70	7.95		51.3
1974	—	—	36.24	5.35	36.12	7.36		36.2
1975	—	—	64.06	7.90	78.34	13.91		71.2
1976	—	—	58.45	8.93	29.08	7.44		43.8
1977	*61.47*	*3.85*	42.96	7.76	73.59	22.54		59.3
1978	—	—	*28.80*	*6.97*	*27.29*	*11.50*		28.0
Arithmetic mean	39.82 (1965–70)	13.00	47.43 (1969–77)	2.18	56.78 (1970–77)	4.67	(1965–78) (1969–78)	44.0 46.5 ± 12.5

Figure 6
Annual survival of adults and first-year Lesser Snow Geese, estimated from recoveries of Lesser Snow Geese banded at McConnell River, 1964–69, and at La Pérouse Bay and Cape Henrietta Maria, 1969–78

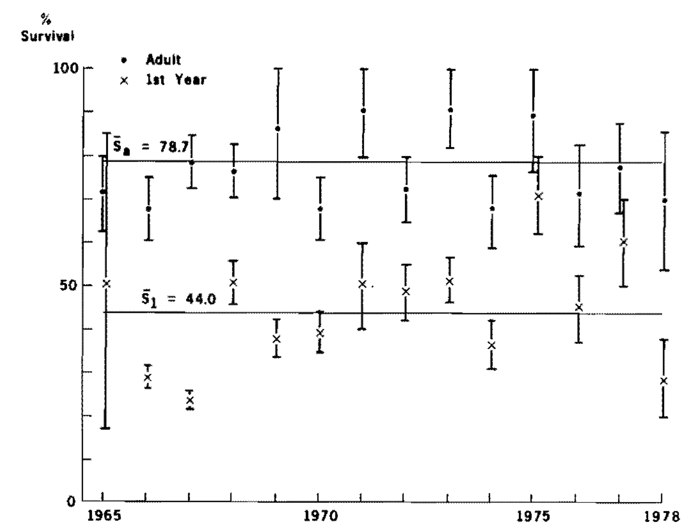


Table 13
Numbers (in thousands) of Lesser Snow Geese in the eastern Canadian Arctic in 1973 and during 1977–80. Counts from aerial photographs of breeding areas in June. 1973 results from Kerbes (1975). Later counts from R.H. Kerbes, A. Reed, P. Dupuis, H.G. Lumsden (pers. comm.).

	1973	1977	1978	1979	1980
S. Hudson Bay	65	—	—	118	—
W. Hudson Bay	390	393	332	283 *	263
Southampton Is.	156	—	—	214	—
Baffin Is.	447	—	—	455	—
Total	1057	—	—	1069	—

* Interpolated value since no survey was done.

approach of the survey aircraft, while the breeders remain. Also, other non-breeders have already moved away from the nesting places. Kerbes (1975) estimated that in summer 1973 there were at least 430 000 non-breeders. We cannot estimate how many non-breeders there were in summer 1979 until reliable estimates of the total numbers that year have been obtained.

10. What is there to account for?

Figure 7 compares four population indices derived from data in earlier sections, using a standardized base, the mean number in each series in 1965–78. Three of the series have already been described. The fourth, labelled "survival," was obtained by starting with a population arbitrarily put at 1 million, using the Gulf coast age-ratios to reflect the proportion of young geese entering each year and using the pooled annual survival rates of banded birds, the rates for adults and young being applied to the appropriate cohorts, to determine the size of the total stock in the following summer.

It is a reflection of the similarity of the trends shown by the four indices, after 1968, that they had to be plotted in pairs, rather than all on one graph, in order to be distinguishable. The resemblance between the plots of winter inventory and fall flight, especially the large fluctuations of 1975–78 is, of course, due to both of them being derived from the winter counts. The high values of the "survival" index in 1965 and 1966, when the other three indices were only around 60, are puzzling. The important general result is that, despite individual deviations, all four indices show an upward trend over most of the period. The annual rates of increase are of the order of 5%, and are arithmetic, rather than exponential.

An alternative way of looking at the changes over the period is by means of a loss-and-recruitment account (Table 14), derived from the Lincoln Index estimates. This suggests an annual net gain of only 2%, clearly not significant in view of the imprecision of the estimates. The point of interest in Table 14 is the repeated alternation between net gains and losses after 1 or 2 years, with no long runs. The same characteristics are exhibited in the production of young (Fig. 5) and by the survival rates of banded geese (Fig. 7).

Figure 7
Comparison of population estimates in summer, fall, and winter, and from survival estimates. Each index uses 100 = period mean

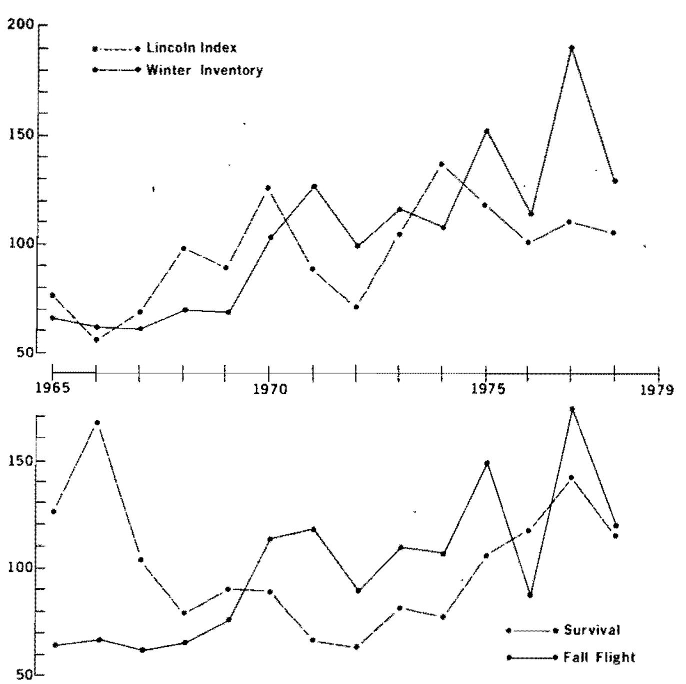


Table 14
Estimates of numbers (in thousands) of eastern arctic Lesser Snow Geese lost from one August to the next and of numbers then recruited to the flying stage, 1964–78.

Year $t \rightarrow t+1$	Initial stock	Losses	Recruits in $t+1$	Net change
1964–65	1835	781	789	+8
1965–66	1839	1265	797	−488
1966–67	1351	195	497	+302
1967–68	1653	−575	140	+715
1968–69	2368	886	667	−219
1969–70	2149	165	1036	+871
1970–71	2902	1431	531	−900
1971–72	1897	654	220	−434
1972–73	1693	208	1025	+817
1973–74	2499	34	829	+795
1974–75	3298	1987	1504	−483
1975–76	2815	964	546	−418
1976–77	2397	795	1015	+220
1977–78	2617	468	338	−130
				+3728
				−3072

Annual net gain = 656/14 = 47 or 2.0% of the mean Aug. stock

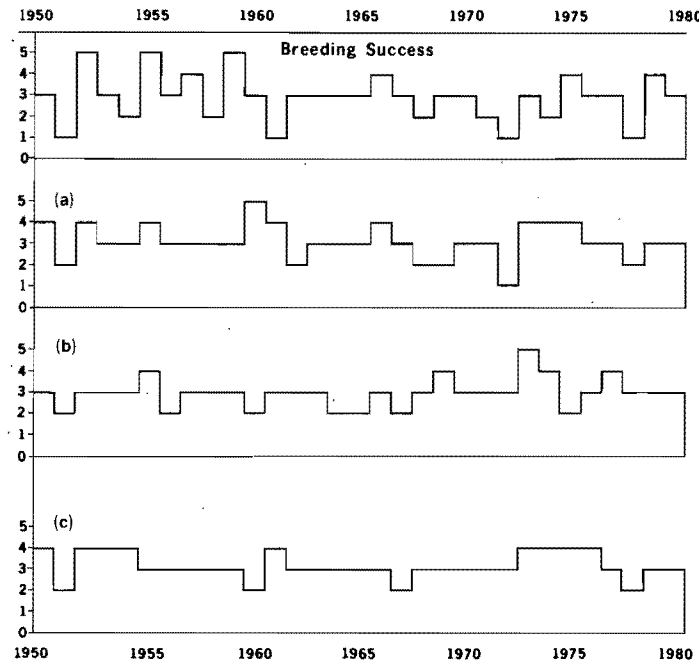
11. Effects of climate on breeding success and survival

The breeding of arctic-nesting geese is adversely affected by persisting snow cover: if extensive snow remains until mid June, nesting may not be attempted at all. Recent evidence suggests that drought in northern spring staging areas lowers the breeding performance of Lesser Snow Geese (Blokpoel 1980, Davies 1981, Owen 1980).

There are no weather stations with long runs of records situated close to northern nesting colonies of Lesser Snow Geese, though the one at Churchill is only about 60 km from the perimeter of the small colony at La Pérouse Bay. The other stations used here are at Chesterfield, Coral Harbour, Hall Beach, and Longstaff Bluff; the two latter began to operate only in 1958 and 1961 respectively. As there are few detailed records of the dates of first laying or full occupation at the northern colonies there is little point in trying to use daily weather data. Pooled monthly mean temperatures for May and June, together with the depth of snow cover on May 31, are used here as indices of the severity of conditions. For conditions on the spring staging areas in southern Manitoba and the northern midwest states and in the winter quarters the indices are derived from monthly records of temperature and precipitation.

There is no reason to expect a strong or a linear relationship between these area weather indices and the performance of the geese, such as emerges from the long-continued study of the geese at La Pérouse Bay (Cooke *et al.* 1981). As the data summarized in Table 1 and Figure 5 have shown, substantial year-to-year variations in breeding success can be inferred from field observations in the following fall and winter. In Figure 8*a* the data on brood-size and on the percentage of young birds in wintering flocks are combined into a single index, taking values from 1 to 5. Production in seasons close to the mean values is given a score of 3; higher proportions of young and larger mean brood-sizes are scored 4 to 5 and poor output 2 or 1. Figure 8*a* shows good breeding seasons in 1952, 1955, and 1959 but none since. The four poorest seasons were 1951, 1961, 1972, and 1978. Figure 8*b* depicts conditions at the four weather stations nearest to the Foxe Basin colonies; Figure 8*c* summarizes temperature and snow cover in the West North Central Region in March and April and 8*d* the precipitation and temperature in Louisiana and Texas in December–March.

Figure 8
Breeding success index compared with weather parameters, 1950–80. Summaries are presented of breeding success; (*a*) temperature and precipitation at the four weather stations nearest to the Foxe Basin colonies; (*b*) temperature and snow cover in the northwest central regions in March and April; and (*c*) precipitation and temperature in Louisiana and Texas in December–March



While there are some obvious correspondences between the annual indices of breeding success and of the weather to which the geese had been subjected, most notably in 1951 (poor), 1955 (good), 1972 and 1978 (both poor), at other times there are none. The high production in 1952 and 1959 and poor production in 1961 do not reflect unusually favourable or inclement weather, either around Foxe Basin and Hudson Bay or in the staging and wintering places.

Much of the lack of fit may simply be the consequence of the oversimplification involved in expressing production and weather variation by means of single annual index numbers. The possible relationships can also be explored by means of correlation and regression using five parameters to describe the goose population, eight to describe the weather in the Gulf coast states in winter, in the Dakotas and Manitoba in March, April, and May and in Foxe Basin in May and June, and two for the sport hunting kill in Canada and the US. The data are tabulated in Appendix 2, which also includes the statistically significant correlation coefficients between pairs of variables, including parameters for previous years as well as current years, so that lagged responses can be detected.

Table 15
Models relating the total number of eastern arctic Lesser Snow Geese expected to be found in mid December (the winter inventory) to previous and current population states and to climatic variables: (*a*) the best three-variable model and (*b*) the best six-variable model.

a. Three variables: $r^2 = 0.828$ $F = 17.63$ $P(F_{3,11} > 17.63) = 0.0002$

	b value	SE	*F*	$P(F_{1,11} > F)$
Intercept	−3713.02			
Year	45.52	15.57	8.55	0.0138
DST	106.37	46.02	5.34	0.0412
ENA1	0.29	0.127	5.31	0.0417

b. Six variables: $r^2 = 0.981$ $F = 69.67$ $P(F_{6,8} > 69.67) < 0.0001$

	b value	SE	*F*	$P(F_{1,8} > F)$
Intercept	−2112.31			
Year	82.02	4.718	302.21	0.0001
PJA	22.49	2.348	91.75	0.0001
MBW	−1257.78	146.05	74.16	0.0001
PJW1	−20.59	2.872	51.38	0.0001
DWP	−5.93	0.840	49.75	0.0001
DST	85.98	16.938	25.77	0.0010

Many observers have had difficulty finding and counting Lesser Snow Geese and identifying the broods and the proportion of young birds (see Voelzer 1980). The Lincoln Index method of estimating population size has rarely been used on this scale, either because the assumptions of the model were not met or because the data were incomplete or biased. Thus it is encouraging to find that the estimated proportions of young geese in mid August correlate closely with those found in the field from October to December, and to find that the relationship between pairs of total population estimates is reasonably constant.

The significant correlation coefficients help to identify the parameters most likely to have affected the numbers and production of Lesser Snow Geese in 1964–79. We have used stepwise multiple regression analysis to obtain models describing the relationships of the number of geese, in August and in December, to the previous population size and composition and to some of the weather variables. As the longest runs of data are no more than 16 years in most cases, it is appropriate to use models with few variables.

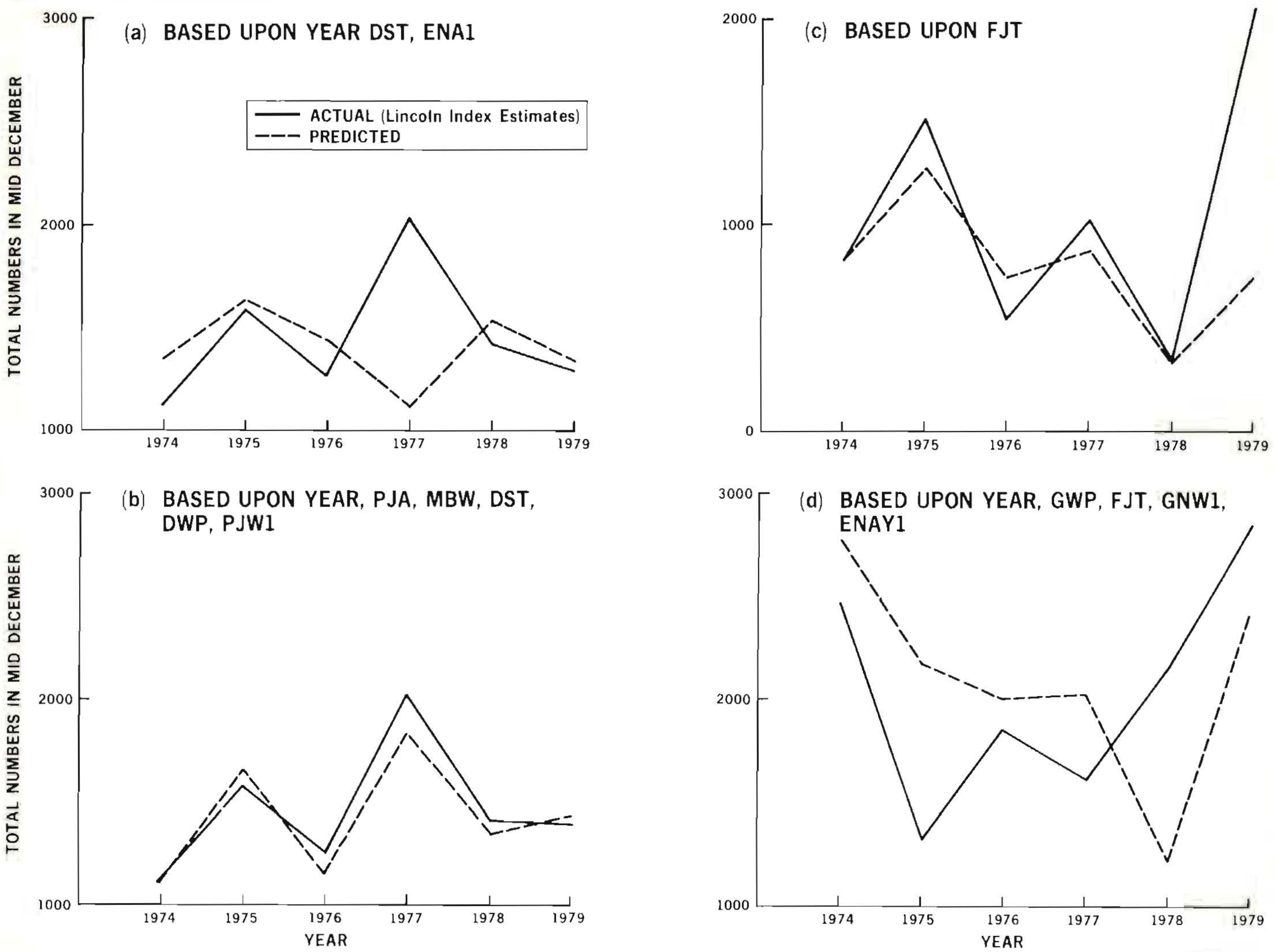
After obtaining suitable models by ordinary least squares (OLS), i.e., standard regression techniques, we tried to refine the estimates using autoregressive series of orders one and two to allow for dependencies among years in the error term. However, the autocorrelations were generally not significant, and there was little difference in the parameter estimates. The significance levels for the parameters tended to be somewhat higher using an autoregressive series, but the tests in this case are only approximate. Because much of the data is derived from rough measurements, the series of data is rather short, and in the interest of simplicity, we present the results of the OLS procedure. We used the statistical package, SAS, (SAS User's Guide, 1979 Edition) to perform the calculations.

Taking the total number of geese found in mid December as the dependent variable and maximizing r^2, two simple models are of particular interest (Fig. 9*a* and *b*, Table 15). The appearance of "year" as an independent variable reflects the presence of a trend which was not explained by other independent variables. "Year" was inserted so that variability due to unexplained long-term trends would not mask short-term fluctuations in numbers of geese caused by similar fluctuations in other dependent variables.

In the best three-variable model (Fig. 9*a*) the other two variables, with nearly equal effect, are the spring temperature in the Dakotas (DST) and the total numbers in August of the previous year (ENA1 — "1" after the abbreviation identifies a variable for the preceding year). The latter perhaps serves as an index of the number of potential breeders in the current summer, since the survivors of the "adults" present in August of the previous year would now be mature.

The six-variable model (Fig. 9*b*, Table 15*b*) is outstanding ($r^2 = 0.980$, $F = 69.67$, prob. $(F_{6,8} > 69.67) < 0.0001$. The largest contribution is again made by the year. The population variables identified as affecting the number in December are the proportion of juveniles in August (PJA) and, in a negative way, the mean brood size in November

Figure 9
Comparison of predictions from models with numbers of geese recorded in winter inventories (*a*, *b*) and estimates of August numbers (*c*, *d*)



(MBW), and the proportion of juveniles present in the preceding winter (PJW1). The latter would be responsible for the presence of immature birds in the summer. The negative effect of MBW reflects the fact that the larger the mean brood size the smaller the number of successful parents required to correspond to the observed proportion of young geese. The influential weather variables in this model are the spring temperature in the Dakotas (DST) having a positive effect, and the accumulated winter precipitation in the Dakotas (DWP) having, surprisingly, a negative effect.

Two other simple models (Fig. 9*c* and *d*) account for much of the variation in goose numbers in August, as estimated by the Lincoln Index technique. Some 75% of the variation in size of the estimated fledging population (ENAY) is determined by the June temperature around the Foxe Basin (Fig. 9*c* and Table 16*b*). The three-variable model (Table 16*c*) estimating total numbers draws on factors reflecting events in the US in the previous winter: the cumulative precipitation in Louisiana and Texas (GWP), the mean brood size (MEW1), and the US harvest (USKIL). The numbers of adults in August are harder to predict. A five-variable model yields $r^2 = 0.65$ and a small F value (Table 16*a*). It is of interest chiefly because it would enable a prediction to be made as soon as the June temperature was known, as the other variables are from the previous winter.

Table 16
Number of adults (ENAA) and young (ENAY) as dependent variables, using current year weather variables: (*a*) best five-variable model for adults; (*b*) best one-variable model for young; (*c*) best three-variable model for total population in mid August

a. Adults, five variables:	$r^2 = 0.650$	$F = 2.98$	$P(F_{5,8} > 2.98) = 0.0826$	
	b-value	SE	*F*	$P(F_{1,8} > F)$
intercept	−14367.26	—	—	—
year	223.62	82.45	7.36	0.0266
FJT	−263.27	93.212	7.98	0.0223
ENAY1	1.379	0.588	5.50	0.0471
GNW1	−2.222	0.980	5.14	0.0531
GWP	4.77	2.177	4.80	0.0598
b. Young, one variable:	$r^2 = 0.756$	$F = 37.28$	$P(F_{1,12} > 37.28) < 0.0001$	
	b-value	SE	*F*	$P(F_{1,12} > F)$
intercept	491.64	—	—	—
FJT	145.50	28.83	37.28	0.0001
c. Total number, three variables:		$r^2 = 0.876$	$F = 23.49$	$P(F_{3,10} < 23.49) > 0.0001$
	b-value	SE	*F*	$P(F_{1,10} < F)$
intercept	−6510.94	—	—	—
GWP	9.63	1.292	55.53	0.0001
USKIL	4.41	0.632	48.75	0.0001
MBW1	1957.75	425.98	21.12	0.0010

12. Comparison of predictions of goose numbers with observations and estimates

It is interesting to compare the August population of Lesser Snow Geese as predicted from the linear models with the number of adults and juvenile geese in August calculated by means of the Lincoln Index and to see how well the three- and six-factor models predict numbers in December. Because those other estimates are themselves imprecise we are not comparing the predictions with actual numbers. Further, in calculating the predicted values, we omitted the values for the latest years, one at a time, so that, for example, the prediction for 1979 was derived from data for 1964–78 (in practice only 14 years because of missing values) while that for 1974 was based on only nine years of data. Thus, although the same dependent variables are used, the parameter estimates (*b*-values) will differ from one year to the next. This was done to help reduce the tendency to get a good but spurious fit between actual numbers and numbers predicted by the model. (We would be using all the data to estimate parameters and then comparing using the same data.)

The above procedure does not eliminate a spurious fit since, initially, all the data were used to choose the independent variables. Normally, a better method of testing a model would be to use a subset of years, say up to 1973, choose variables using a stepwise regression, then proceed to make yearly predictions using all available data. However, the run of data was not long enough to do this. The acid test of the models will be their future success. In Figure 9 the predicted numbers of adults and juveniles in August in the 6 years 1974–79 are each plotted against the Lincoln Index estimates. As might be expected from the relatively low r^2 in the five-factor model (Fig. 9*d*) for adults in August the fit between the values for adults is poor for 1975 and 1978. In 1975 the predicted value was more than the number calculated from direct recoveries. In 1978 those values were reversed. The model for juveniles in August based solely on the June temperature in Foxe Basin (Fig. 9*c*) fits the Lincoln Index estimates remarkably closely. The exception was in 1979, for which the Lincoln Index estimates seem to be wild, due to a shortage of recoveries. This will be re-examined when the reports of recoveries in 1980 and 1981 are available for analysis.

The three-factor model for total numbers in December (Fig. 9*a*) yields values close to the winter inventories in 5 of 6 years, except in 1977 when the winter inventory was much higher than in the other years but the prediction was low. The predictions for the six-factor model (Fig. 9*b*) correspond very well with the observed numbers, supporting the occurrence of a high value in 1977.

These results emphasize the necessity for sustained monitoring of the principal parameters year by year. Until data for at least 10 years are available the degrees of freedom are so few that only very simple models can be used, with a serious reduction in the confidence with which predictions can be made for the forthcoming August and December.

Photo: R.H. Kerbes, CWS

What needs to be done?

Although the Migratory Birds Convention requires the federal governments of Canada and the US to manage Lesser Snow Geese, the birds regulate themselves effectively without intervention by management agencies at the national or international level.

The self-regulation of the geese is not effective from the point of view of hunters, who are so much less mobile. Are agencies under any obligation to maintain hunting opportunities in particular areas at specified levels? If so, how might that be done, given the freedom of the geese to choose where and when to travel or stay?

Only the 1979 James Bay and Northern Quebec Agreement imposes such an obligation on the federal government. Section 24.6.5. of the agreement (reproduced as App. 1) requires the determination of the "present levels of harvesting" in the territory by native hunters, the kill by other hunters in the territory, and "the total kill figures for each migratory bird population", so that "the percentage of the total kill from each population now being taken in the Territory" can be calculated. Section 24.6.5. states "This percentage figure shall constitute a guarantee so that in any given year the Territory would be guaranteed at least the same percentage of the total kill from each population as is presently hunted and harvested." The implications of this undertaking have yet to be worked out in numerical detail, although the James Bay and Northern Quebec Native Harvesting Research Committee has now collected data for a 5-year period.

Supposing that the arithmetic of the James Bay case with respect to Lesser Snow Geese will soon be argued, the major practical question may well turn out to be what can the CWS do to check or reverse the very recent tendency of Baffin Island geese to spend less time on the Quebec coasts of Hudson Bay and James Bay in the fall? (They have long made comparatively little use of the Quebec coast in spring.) This paper provides no more than an indication of how the distribution is changing. Why is it happening and what, if anything, can be done about it will require more intensive studies, chiefly, though not exclusively, in northern Quebec.

While it appears that the recent level of exploitation of this stock of geese is too low to be having a detrimental effect at the continental level, if the intensity of exploitation continues to increase, locally or continentally, more intensive monitoring of hunting, as well as the resources of the geese, will be needed. The rapidly growing harvest in the Atlantic Flyway (Reed, Boyd and Wendt, 1981), since 1975 when hunting of the Greater Snow Goose (*A. caerulescens atlanticus*) was resumed, is providing a test case.

Because of the greater abundance and geographic range of the Lesser Snow Goose, many states and provinces must be involved in its management. Their local interests are often conflicting — more geese at A means fewer at B, or more crop damage at A. The decisions on distribution made by the geese themselves largely preempt the tasks that managers might wish to undertake. That is surely a good thing.

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Appendices

Appendix 1
Section 24.6.5. of the James Bay and Northern Québec Agreement of November 1976.

24.6.5. Subject to the principle of conservation and where populations of these species permit, the principle of priority of Native harvesting shall be applied to migratory birds in a manner similar or equivalent to the procedures hereinafter set forth:

a) In conformity with the procedure provided in paragraph 24.6.2, the present levels of harvesting of migratory birds shall be established.

b) The present level of harvesting shall be combined with the present level of non-Native hunting of such birds in the Territory to establish the total present kill for the Territory.

c) Based upon the total kill figures for each migratory bird population and the total kill in the Territory for each migratory bird population, there shall be a determination of the percentage of the total kill from each population now being taken in the Territory.

d) This percentage figure shall constitute a guarantee so that in any given year the Territory would be guaranteed at least the same percentage of the total kill from each population as is presently hunted and harvested.

e) Within the Territory itself, the principle of priority for Native harvesting shall apply to the allocation of quotas or use of other management techniques in such a way as to ensure that the Native people are guaranteed a harvest based on present levels of harvesting of migratory birds.

f) In any given year when populations permit a kill for the Territory higher than the guaranteed allocation equal to present levels of harvesting, the Native people shall be allowed a harvest equal to the guarantee based on present levels of harvesting, and the remainder of the permissible kill for the Territory shall be divided in such a way as to ensure primarily the continuance of the traditional pursuits of the Native people and secondarily so the non-Native people may satisfy their needs for recreational hunting.

g) In any given year when the populations permit a kill for the Territory lower than the guaranteed allocation for the Native people equal to present levels of harvesting, the entire kill for the Territory shall be allocated to the Native people, who shall have the right in turn to allocate a portion of this kill to non-Native hunting through recognized outfitting facilities.

h) This guarantee shall not operate to endanger migratory bird populations.

i) This guarantee in itself shall not operate to prohibit or reduce hunting of migratory birds elsewhere in the flyway or in Canada.

Appendix 2
Relationship between Lesser Snow Goose breeding and weather variables

(a) Identifier, means, standard deviation, and range of descriptive parameters

Variable	No. of yrs, *N*	Mean	*SD*	Range
Year	16	71.5	4.76	1964–79
GNW – midwinter count, x10³	16	1108.8	359.11	633.0 – 2027.0
ENA – no. in Aug., x10³	15	2278.5	541.71	1351.0 – 3298.0
PJA – % juvs. Aug.	16	32.5	15.30	5.9 – 59.0
PJW – % juvs. winter	16	26.4	11.75	7.5 – 44.6
MBW – mean brood size, winter	16	1.96	0.30	1.49 – 2.59
GWT – mean temp. Jan.–Mar. La. to Tex., °C	16	9.1	1.43	6.1 – 11.3
GWP – precip., Oct.–Feb. La. to Tex., mm	16	360	82.3	201 – 525
DST – spring temp. W. N. central, °C	16	8.47	1.17	6.9 – 11.8
DWP – precip., Oct.–Mar. W.N. central, mm	16	184	46.8	121 – 288
MSM – Manitoba soil	16	159	24.9	104 – 191
FMS – snow cover, Foxe Basin 31 May, mm	16	359	144.4	170 – 571
FSI – Foxe Basin, spring index (see text)	16	–230	1015	–2233 to 1558
FJT – June temp. Foxe Basin, °C	16	1.42	2.08	–2.7 to 6.3
CDNKIL – sport kill, Can., x10³	11	49.4	26.28	24.4 – 115.8
USKIL – kill in US x10³	16	658.8	120.81	160.7 – 574.6

(b) Parameter values

Year	GNW	ENAA	ENAY	PJW	PJA	MBW	GWT	GWP	DST	DWP	MSM	FMS	FJT	CDNKIL	USKIL
	x10³			%	%		°C	mm	°C	mm	mm	mm	°C	x10³	x10³
64	796	975	860	25.8	46.9	2.09	8.7	312	8.8	121	191	330	0.3	—	193.6
65	698	1050	789	33.7	42.9	2.11	8.6	342	7.1	150	143	330	0.7	—	204.1
66	642	554	797	42.7	59.0	2.49	8.2	322	8.3	155	161	171	1.4	—	346.6
67	633	1156	497	20.2	30.1	1.92	10.7	201	8.5	132	165	482	0.7	—	266.9
68	718	2228	140	12.7	5.9	1.88	8.3	406	9.1	151	148	571	0.3	—	160.7
69	826	1482	667	29.1	31.0	1.98	8.8	402	7.9	239	151	546	0.7	41.1	409.1
70	1077	1984	1036	26.7	34.3	1.84	9.4	398	7.6	178	178	362	2.0	29.4	574.6
71	1341	1589	531	17.2	25.0	1.58	9.9	250	8.1	204	176	211	2.0	29.1	386.4
72	1037	1466	220	9.7	13.0	1.63	10.9	365	8.8	221	174	565	–2.7	24.4	245.7
73	1202	1478	1025	37.8	41.0	1.94	8.9	525	9.2	288	121	247	4.4	39.6	400.2
74	1103	2469	829	17.6	25.1	1.64	11.1	413	9.0	225	158	235	2.4	42.3	416.7
75	1585	1311	1504	44.6	53.4	2.05	9.5	449	6.9	215	183	241	6.3	77.5	526.5
76	1263	1851	546	22.7	22.8	2.00	11.3	265	9.1	122	165	398	1.5	43.2	420.0
77	2027	1602	1015	38.3	38.6	2.13	8.6	375	11.8	157	104	550	2.6	48.1	420.0
78	1401	2149	328	7.5	9.0	1.49	6.1	310	8.3	197	131	330	1.4	53.5	322.9
79	1391	2854*	2065*	36.5	42.0	2.59	7.1	432	7.1	188	191	170	1.5	115.8	496.7

*Over-estimates due to incomplete reporting of direct recoveries; not used in calculations, though shown in Figure 9*c* and *d*.

(c) Correlation coefficients of current year parameters:
*significant at $p < 0.05$; † $p < 0.01$; ‡ $p < 0.001$

	Year	GNW	ENA	PJW	PJA	MBW	GWT	GWP	DST	DWP	MSM	FMS	FSI	FJT	USKIL
Year	—	0.836‡	0.820*												0.566*
GNW		—	0.560*												0.575*
ENA			—					0.520*						0.499*	0.636*
PJW				—	0.913‡	0.781†							0.623†	0.707†	
PJA					—	0.732†						0.532*	0.681†	0.585*	
MBW						—									
GWT							—								
GWP								—		0.671†					
DST									—		0.626†				
DWP										—					
MSM											—				
FMS												—	–0.690†		
FSI													—	0.809‡	
USKIL														—	0.621†
ENAA	0.581*		0.722†		–0.741†	–0.710†									
ENAY				0.832‡									0.697†	0.840‡	0.666†

(d) Correlation coefficients involving parameters from previous year: *significant at $p < 0.05$; †$p < 0.01$; ‡$p < 0.001$

	Year	GNW	ENA	PJW	PJA	GWT	GWP	DST	DWP	USKIL
GNW1	0.848‡	0.637*								
ENA1	0.620*	0.669†								0.552*
PJW1							–0.741†		–0.586*	
MBW1							–0.715†		–0.642†	
USKIL1		0.531*								
PJA1							–0.756†		–0.679†	
GWT1								0.535*		
DST1						–0.542*				
DWP1			0.612*							
FMS1						–0.604*				
FSI1						0.564*	–0.515*		–0.573*	
FJT1						0.525*				
ENAA1	0.581*	0.652†					–0.631*			0.632*
GNW1	0.848‡									

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