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Estimates of total numbers in the Hudson Bay population of Lesser Snow Geese, 1964–1973

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Abstract
The finding of very large numbers of Lesser Snow Geese (*Anser c. caerulescens*) along the Hudson Bay coast in May 1973 (1 650 000 ± 131 000) and 1974 (2 109 500 ± 73 000) confirmed that the midwinter inventories in the US have seriously underestimated the population size: the corresponding winter counts were 1 037 000 in December 1972 and 1 202 000 in December 1973.

Lincoln Index estimates of the numbers in August can be obtained from estimates of the US hunting kill and the proportion of direct recoveries of banded geese, adjusted for non-reporting. Using a reporting rate of one-third, the August population estimates for 1973 and 1974 were 2 499 000 and 3 410 000 respectively and the mean values for the quinquennia 1964–68 and 1969–73 were 1 928 000 and 2 228 000.

Estimates of the fall flight into the US can be obtained by combining published estimates of the US kill with results of the winter inventories, adjusting the latter upwards by the ratio number seen in May 1974/number seen in December 1973 to allow for incomplete detection in winter. The adjusted fall flight estimates for October 1972 and 1973 are 1 884 000 and 2 299 000, with quinquennial means of 1 400 000 in 1964–68 and 2 134 000 in 1969–73.

Although neither method of retrospective estimation is comparable in reliability with the May surveys, these results suggest that the population was tending to increase in the decade 1964–73, despite an increasing kill in the US and fears that the total numbers were diminishing. The increase seems to have been due to a decline in mean annual losses of full-grown geese, not to an increase in recruitment.

Introduction

Until recently, the only information on the population size of the stock of Lesser Snow Geese breeding around Hudson Bay was provided by the long series of midwinter inventories made for the US Fish and Wildlife Service (USFWS) in Louisiana and Texas by J.J. Lynch and others (see, especially, Lynch and Singleton 1964, Lynch 1972, Lynch and Voelzer 1974, and Dzubin, Boyd and Stephen 1975 for the data used in this paper). These indicated a population, in mid-January, *i.e.* late in the US hunting season, averaging 750 000 (range 525 000 to 1 015 000) in the years 1950 to 1959; and 722 000 (range 576 000 to 799 000) in 1960 to 1969. Subsequently, counts in December rose from 826 000 in 1969 to 1 341 000 in 1971, 1 032 000 in 1972 and 1 202 000 in 1973.

Lynch's suspicions that the winter inventories seriously underestimated the total population size have recently been confirmed by two types of surveys in Canada. Vertical aerial photography of the twelve Hudson Bay Snow Goose colonies has demonstrated that in June 1973 there were 528 700 ± 43 600 nests of Snow Geese in those colonies (Kerbes 1975), corresponding to a late August population of about 2.6 million full grown and first-year geese. Aerial surveys of geese scattered along 2660 km of the coast of Hudson Bay and James Bay in late May led to estimates of 1.65 ± 0.13 million Lesser Snow Geese present on 19 May, 1973 and 2.11 ± 0.07 million on 22 May, 1974 (Curtis 1976).

If in recent years there have been far more Lesser Snow Geese than previously realised, it is obviously of practical importance to determine whether this is a result of genuine increases in abundance or solely of the use of more complete or more accurate surveying techniques. The principal purpose of this note is to derive an independent set of estimates of the number of Lesser Snow Geese by reviving the method proposed by Lincoln (1930), using information from recoveries of banded birds in conjunction with estimates of hunting kill. The results are of unknown reliability. However, they are sufficiently plausible and raise enough points of interest to suggest that with attainable refinements the method could be of use as a supplement to and check on other methods.

The Lincoln Index estimates are compared with a second set of estimates referring to the 'fall flight' into the US obtained by combining published estimates of US harvest with the results of winter inventories, adjusted for incompleteness of detection. These estimates are also of unknown reliability, affected by some arbitrary assumptions and perhaps biased.

Throughout this report the name Lesser Snow Goose is applied to geese of both the white and blue colour phases, the latter often referred to by other authors as Blue Geese and sometimes treated by them as a separate form as, for example, in USFWS reports. That practice is unfortunate. It adds to the seeming complexity of the situation by increasing the number of entities being considered, while reducing the sample sizes, and encourages the idle belief that not enough is yet known to permit firm management decisions to be made.

Methods

Numbers in late summer

In 1930 Lincoln pointed out that an estimate of the total number of waterfowl in the United States could be made using the relationship

$$\frac{\text{total no. waterfowl}}{\text{no. waterfowl killed by hunters}} = \frac{\text{no. waterfowl banded}}{\text{no. direct recoveries of banded birds}}$$

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At that time any estimate of the kill was no more than a guess and the proposed procedure was not followed up, although a great deal of attention has since been given to methods of estimation based on live recaptures of previously-marked animals, comprehensively reviewed by Cormack (1969) and Seber (1973).

With the introduction of national surveys of waterfowl hunting in the US which sample total hunter activity, specific composition of the kill, and age-ratios in the kill, it is now possible to obtain seasonal estimates of Snow Goose kill, K, reassembled in Table 1 from data presented in USFWS reports. I have combined data from the Central and Mississippi Flyways and for 'Lesser Snow' and 'Blue' Geese, and used the published Flyway-weighted age-ratios. No study of the reliability of specific estimates of US goose-hunting kill obtained from the mail- and parts-surveys seems to have been published. Some State agencies are sceptical of the estimates for their states, at least where the FWS estimates differ substantially from those obtained by local surveys, but there seems to be some confidence in the results at the level of an entire Flyway.

Estimates of Snow Goose kill in Canada have also been obtained in a rather similar way by the Canadian Wildlife Service since 1967, but these are relatively small and are known to be incomplete, so that it is better at present to use only the US harvest in arriving at population estimates.

The number of Snow Geese banded each year, b, is known quite accurately, although it is likely that appreciable losses of young geese between banding and fledging have occurred on two occasions since 1964. What is much less certain is whether the location of banding has an important effect on the representativeness of the banded sample in relation to all the geese in the population. The direct recovery rates of geese banded in the eastern Hudson Bay colonies (on Baffin Island and at Cape Henrietta Maria, Ontario) are generally less than those of geese banded at colonies on the west side of Hudson Bay; but the estimated mortality rates do not differ significantly (Boyd 1976). At the level of approximation appropriate to a preliminary survey of the entire population it seems at least as useful to group all bandings, ignoring colony of origin, as to attempt to weight the samples of bandings and recoveries by colony size or in other ways.

The difference in recovery rates just referred to is undoubtedly related, though probably in complex ways, to an important limitation on the use of the reported direct recoveries d as a measure of the number of banded geese killed. Not all the bands found on shot geese are reported. As no experimental assessments of the reporting rates appropriate to Lesser Snow Geese have been made, I have assumed a constant annual reporting rate of one-third, based on results for several species of geese found by Martinson and McCann (1966) and Henny (1967). There may well be substantial local variations and trends in reporting rates, though these are less likely to be serious sources of bias where the birds involved were banded in the Canadian Arctic than when they were marked in southern Canada or the US, close to the site of recovery.

Thus the estimator used here is $N = K \times b/d \times 1/3$. Separate values have been calculated for geese in their first year and for all older geese, because young geese are substantially more vulnerable to hunting than birds more than a year old. The seasonal values of K are given in Table 1 and of b and d, with the estimates of N, in Table 2.

Size of fall flight

An estimate of the fall flight (F) into the US can be obtained as the sum of the midwinter inventory (W) and of the harvest (K) in the Mississippi and Central Flyways. Table 3 includes two sets of such estimates. The second ($F' = K + W'$) includes an upward adjustment of the winter count to allow for incomplete detection and/or underestimation of the number in large flocks. The correction factor uses the counts made in May 1973 and 1974 (mentioned in the introduction) as estimators of the complete population size in the preceding December, with an arbitrary adjustment for losses between December and May. Such a device assumes that the midwinter inventories, while incomplete, nevertheless included a constant proportion of the geese alive at the date of the count. Clearly this assumption is most unlikely to be wholly justified.

Results

Given the crude nature of the data and estimating procedures it would be inappropriate to attach much weight to particular numerical values. The Lincoln Index estimates include two absurd values: (1) the adult population in August 1968 is estimated to have been much larger than the entire population in August 1967, and (2) the adult population in August 1974 was slightly larger than that of the entire stock in August 1973. At the other extreme, the apparent large reduction from 1965 to 1966, involving the deaths of nearly 3/4 of the stock, seems likely to be an exaggeration. The general impression, however, is of a growth in total numbers between the first and second quinquennium, due to an increase in the number of geese more than a year old. That increase was apparently not due to an increase in the mean number of young produced but to a reduction in the mortality rate of full-grown geese. The fall flight estimates (Table 3) similarly suggest an increase from the first to the second quinquennium, both the average harvest and the average midwinter count increasing substantially—the former by 31.1%, the latter by 26.7%, as compared with the 23.5% increase in the mean size of the population in August indicated by the Lincoln Index estimates.

The somewhat paradoxical result that a rise in mean population size has been accompanied by a greater rate of increase in the US kill can be explored more fully by means of Tables 4–6, which deal with estimates of losses and mortality rates, the relative magnitude of the August, fall and midwinter estimates and the US harvest as a proportion of the August and fall populations. Table 4 includes estimates of annual mortality rates for geese banded at Hudson Bay colonies for the years 1966 to 1973 (after Boyd 1976).

As with the estimates of total numbers, the year-by-year estimates of losses and mortality fluctuate widely and inconsistently, yet the generalised picture given by the quinquennial means is remarkably consistent. From Table 4, average yearly losses from all causes were down from

604 000 in 1964–69 to 442 000 in 1969–74 (a reduction of 26.8%) while the average US hunting kill rose from 270 400 to 438 200 (Table 1), an increase of 62.1%. Corresponding to the apparent drop in total losses, the average annual mortality rate of full-grown geese fell from over 30% in 1964–69 to under 20% in 1969–73.

Implications for management

What seems to have been happening is a substitution of kill by US sport hunting for other causes of deaths. That the average kill in the US in 1969–73 comes very close to the average total losses over the same period perhaps suggests that the capacity to absorb increasing losses to hunting in the US without impact on total numbers has nearly, if not entirely, been exhausted.

The lack of resemblance between the annual rates of mortality calculated in different ways is troubling. It emphasises the great need to develop better techniques and more appropriate models for measuring survival and/or loss.

Although the estimated sport hunting kill of Hudson Bay Snow Geese in Canada (Table 7) is still only a small fraction of the total, it has been growing rapidly in Manitoba. Moreover, the still incomplete information on the subsistence hunting kill, chiefly on both the Ontario and Quebec shores of James Bay, shows it to be large enough to call for its inclusion in any population model for the use of managers.

It would be rash for the USFWS and the CWS, or State and Provincial game agencies, to assume that because the Hudson Bay Snow Geese flourished between 1964 and 1973 they will continue to do so without any serious attempt to manage them on the basis of sound biological information. This note shows just how uncertain we still are of some of the elementary and key facts from year to year. In such uncertainty it would be easy to let things go too far.

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Table 1

Estimates (in thousands) of the kill of Lesser Snow Geese in the Mississippi and Central Flyways, 1964–65 to 1974–75, partitioned by age-ratios (immature/adult) found in samples of goose tails in US harvest surveys. Data from USFWS Special Scientific Reports and Administrative Reports, combining published figures for 'Lesser Snow' and 'Blue' geese, already adjusted for unretrieved kill (after Table 7 in Dzubin, Boyd and Stephen 1975)

	US harvest ($\times 10^3$)					
Breeding yr	K	=	K_a	+	K_i	K_i/K
1964	227.3		116.6		110.7	0.487
1965	238.0		121.4		116.6	0.490
1966	403.4		178.9		224.5	0.557
1967	289.1		160.9		128.2	0.444
1968	194.0		142.7		51.3	0.265
Mean 1964–68	270.4		144.1		126.3	0.467
1969	477.1		196.0		281.1	0.589
1970	675.5		316.5		359.0	0.532
1971	392.3		244.8		147.5	0.376
1972	245.7		188.1		57.6	0.234
1973	400.2		147.8		252.4	0.631
Mean 1969–73	438.2		218.6		219.5	0.472
Mean 1964–73	354.3		181.4		172.9	0.470
1974	384.9		240.4		144.5	0.375

Table 2
Lincoln Index estimates (in thousands) of number of Lesser Snow Geese in the eastern Canadian Arctic in August, 1964–73. Estimates of K are given in Table 1

	Adults (more than 1 yr old)			Young (just prior to fledging)			Total
Breeding yr	Banded b_a	Recovered d_a	Estimated No. N_a	Banded b_j	Recovered d_j	Estimated No. N_i	population $N = N_a + N_i$
1964	1443	49	1145	657	24	1010	2155
1965	6745	223	1224	4851	205	920	2144
1966	400	37	554	4052	327	797	1351
1967	2421	103	1163	3427	274	494	1659
1968	8716	154	2195	1217	123	138	2333
Mean 1964–68	–	–	1256	–	–	672	1928
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	–	–	677	2228
Mean 1964–73	–	–	1404	–	–	674	2078

Table 3
Estimates (in thousands) of 'fall flight' of Lesser Snow Geese into the Mississippi and Central Flyways, 1964–73, obtained from sum of hunter kill in those flyways and winter inventory counts by USFWS (latter from Table 8 in Dzubin, Boyd and Stephen 1975)

Breeding yr	Hunter kill K	Winter inventory W	Fall flight $F = K + W$	Adjusted* winter inventory W'	Adjusted fall flight $F' = K + W'$
1964	227	796	1023	1285	1512
1965	238	698	936	1127	1365
1966	403	642	1045	1036	1439
1967	289	633	922	1022	1311
1968	194	729	923	1177	1371
Mean 1964–68	270	700	970	1127	1400
1969	477	720	1197	1138	1615
1970	676	1081	1757	1708	2384
1971	392	1328	1720	2098	2490
1972	246	1037	1283	1638	1884
1973	400	1202	1602	1899	2299
Mean 1969–73	438	1074	1512	1696	2134
Mean 1964–73	354	887	1241	1412	1767

*Adjustment based on observations (after Curtis and Lumsden, in prep.) that in May 1973 there were 1 650 000 Lesser Snow Geese on the Hudson Bay coast and that in May 1974 there were 2 110 000. These correspond to winter inventories of 1 037 000 and 1 202 000 respectively. The numbers of deaths from January to May in each year are not known but are probably at least 50 000 and not more than 80 000, including late season kills in Texas and Louisiana, spring kills by native subsistence hunters and deaths from natural causes. Using the arbitrary addition of 70 000 to each December inventory total since 1969, we arrive at a correction factor of

$$\frac{1650 + 2110}{1107 + 1272} = \frac{3760}{2379} = 1.580$$

by which each yearly value of W should be multiplied to arrive at W'. For the years 1964 to 1968, when the counts were made in mid-January and there was no late US hunting season, we add only 45 000 to the recent winter mean of 1 119 500 to yield a multiplier of 1880/1164.5 = 1.614.

Table 4
Estimates of losses (in thousands) and gross mortality rates (in %) of Lesser Snow Geese in 1964–73 obtained by subtracting estimated number of geese more than one year old in year (t + 1) from total population in year (t). L, losses; N, total population in August or October

	Estimated losses		Mortality rate (%)		Mortality rates for banded geese		
Year	(Lincoln Index) Aug.–Aug. L	(Fall flight) Oct.–Oct. L'	(Lincoln Index) L/N	(Fall flight) L'/F'	Adults m_a	1st year m_i	Weighted mean* m
1964–65	931	644	43.2	42.6			
1965–66	1590	592	74.2	43.4			
1966–67	188	463	13.9	32.2	64.8	74.3	69.2
1967–68	(-538)	142	(-32.5)	10.8	21.7	76.3	35.7
1968–69	851	369	36.5	26.9	21.5	44.4	24.9
5 yr mean	604	442	31.3	31.6	–	–	–
1969–70	241	47	11.2	2.9	24.4	53.5	35.4
1970–71	1480	401	51.0	16.8	38.8	61.3	46.5
1971–72	424	822	22.4	33.0	15.2	47.8	21.8
1972–73	222		13.1		39.0	50.1	40.3
1973–74	155		(-6.2)		7.9	37.9	
5 yr mean	442		19.6				
Period mean	523		25.2				

*Mean weighted by estimated age-ratio in adjusted fall flight

$$m' = \frac{m_a F'_a + m_i \cdot F'_i}{F'}$$

Table 5
Comparison (in thousands) of Lincoln Index estimates of the population of Lesser Snow Geese in eastern Arctic Canada in August with estimates of the fall flight into the US and with the midwinter counts (adjusted for incomplete search) for the breeding years 1964–73

Breeding yr	No. in August N	No. in fall F'	No. in winter W'	F'/N	W'/N	W'/F'
1964	2155	1512	1285	0.702	0.596	0.850
1965	2144	1365	1127	0.637	0.526	0.826
1966	1351	1439	1036	1.065	0.767	0.720
1967	1657	1311	1022	0.791	0.617	0.780
1968	2333	1371	1177	0.588	0.504	0.858
Mean 1964–68	1928	1400	1127	0.726	0.585	0.805
1969	2149	1615	1138	0.752	0.530	0.705
1970	2902	2384	1788	0.822	0.589	0.716
1971	1897	2490	2098	1.313	1.106	0.843
1972	1693	1884	1638	1.113	0.968	0.869
1973	2499	2299	1899	0.920	0.760	0.826
Mean 1969–73	2228	2134	1696	0.958	0.761	0.765
Mean 1964–73	2078	1767	1412	0.850	0.679	0.799

Table 6
Estimated harvest of Hudson Bay Lesser Snow Geese in the Mississippi and Central Flyways in proportion to estimated total population size in August (N) and fall (F') and total annual losses, 1964–65 to 1973–74

Breeding yr	K/N %	K/F' %	K/L %	K/L' %
1964	10.5	15.0	24.4	35.3
1965	11.1	17.4	15.0	40.2
1966	29.9	28.0	(214.6)	87.1
1967	17.4	22.1	–	(203.6)
1968	8.3	14.2	22.8	52.6
Mean 1964–68	14.0	19.3	44.7	61.1
1969	22.2	29.5	(198.0)	(1015.1)
1970	23.3	28.3	45.6	(168.5)
1971	20.7	15.8	92.5	47.7
1972	14.5	13.0	(110.7)	
1973	16.0	17.4	(258.2)	
Mean 1969–73	19.7	20.5	99.1	
Mean 1964–73	17.0	20.0	67.7	

Table 7
Estimates (to nearest hundred) based on national migratory game bird harvest surveys of the kill by sport hunters in Canada of Lesser Snow Geese from the eastern Arctic, 1969–74

	Estimated sport kill in			
Breeding yr	Manitoba	Ontario	Quebec	Total
1969	11 900	21 600	7 600	41 100
1970	9 600	12 600	6 400	28 600
1971	8 600	12 300	7 000	27 900
1972	15 500	6 300	2 300	24 100
1973	21 500	12 500	4 700	38 700
1974	25 200	13 800	1 700	40 700