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IMMIGRATION IN A SMALL POPULATION OF SNOW GEESE

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ABSTRACT.—The Lesser Snow Goose (*Chen caerulescens caerulescens*) colony on Howe Island, near Prudhoe Bay, Alaska, is the only established nesting colony of this species in the United States. A study was initiated to follow the dynamics of this small population in 1980 when it became clear that oil development would proceed near the nesting colony and in nearby brood-rearing areas. Virtually all brood-rearing Snow Geese in the study area were banded in late July of 1980 through 1993 to determine return rates of banded birds and to determine whether immigration contributed significantly to the maintenance and growth of the population. This was a critical question if, in the future, a local catastrophe (e.g. foul cholera, oil spill) were to affect most or all of the birds in this small population. During this 15-year study, the Snow Goose population expanded from 39 to 412 nesting pairs. Based on mark-recapture data from the banding programs, the immigration rates for females and males are estimated to be 12.8 ± SD of 4.39% and 60.7 ± 12.85%, respectively. Exceptionally high immigration rates for males were recorded in 1990 and 1993, when large numbers of two- and three-year-old females (banded as goslings) returned with unbanded mates from other populations. Many females apparently immigrated when they were juveniles. The origins of immigrants is still unclear because of limited banding at neighboring colonies. Resightings of neck-banded Howe Island geese indicate emigration of primarily males to Wrangel Island, Russia, and Banks Island and the Anderson River Delta, Northwest Territories, Canada.
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THE LESSER SNOW GOOSE (*Chen caerulescens caerulescens*) nesting colony on Howe Island, near Prudhoe Bay, Alaska (Fig. 1), is the only established colony of this species in the United States (Johnson and Troy 1987, Johnson and Herter 1989, Johnson et al. 1993), and it is the only colony of Snow Geese nesting in proximity to an active oil field (Johnson and Troy 1987). The Howe Island colony has been studied since 1980. The geese nest during June, rear broods in the Sagavanirktok River Delta during July through mid-August, migrate eastward and stage on the North Slope of Alaska and the Yukon during late August through mid-September, and migrate south through the Mackenzie Valley to Alberta and Saskatchewan in late September through October. Most winter resightings and band recoveries of Howe Island Snow Geese are from the Central Valley of California, the Rio Grande and Pecos river valleys of New Mexico, and the highlands of Chihuahua, Mexico (Johnson in press). In these overwintering areas they mix with Snow Geese from the much larger Western Arctic (Canada) and Wrangel Island (Russia) populations (Bellrose 1980).

A major objective of this study was to determine whether the Howe Island Snow Goose population is maintained through: (1) internal production supplemented by immigration; or (2) internal production with little or no immigration, as postulated for the La Perouse Bay Snow Goose population in Manitoba, Canada (Cooke and Sulzbach 1978). This was an important question if a major catastrophe were to occur, such as an oil spill or foul cholera outbreak, that could affect the size, growth, and structure of the colony.

METHODS

Since 1980, Howe Island Snow Geese have been monitored annually to determine their numbers, productivity, and distribution in brood-rearing areas after they leave the nesting colony in late June or early July. Except in 1992 and 1994, when complete nesting failures occurred, all Snow Geese in brood-rearing areas in the study area were captured and banded during late July. All captured and recaptured geese were examined to determine sex, age, and band number, as well as whether they were recaptured or newly captured.

Daily observations of Snow Geese were conducted from 26 May through 5 June 1993 and 1994 when the geese were aggregated in family groups or feeding flocks in snow-free areas of the outer Sagavanirktok River Delta. Based on plumage and body shape, I was able to estimate the number of geese in different age and sex classes that were banded (returning geese) and unbanded (immigrants).

During years when most breeding-age adults in the

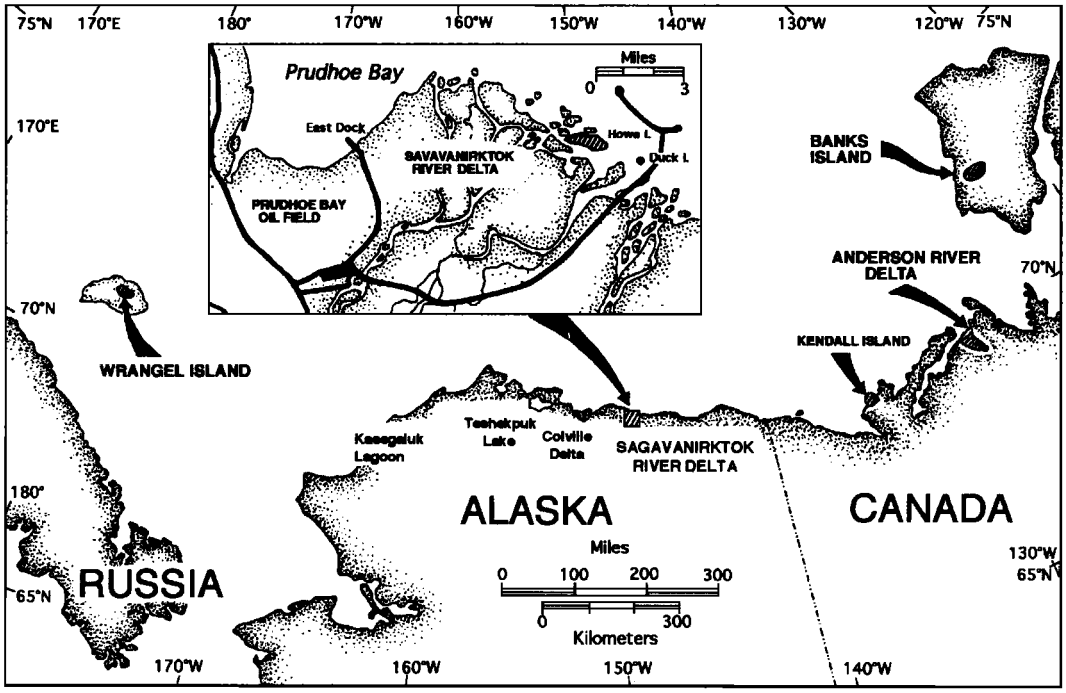

Fig. 1. Locations of Snow Goose colonies in the Western Arctic. Inset shows the Sagavanirktok River Delta study area, Howe Island, and the Endicott Development Project road and causeway.

population nested successfully (1980, 1981, 1983, 1985, 1986, 1988, 1990, 1993), gosling production was relatively high. During years of severe weather and/or heavy predation during the nesting period (1982, 1984, 1987, 1989, 1991, 1992, 1994), fewer breeding-age adults in the population nested successfully and, consequently, fewer goslings were produced. Nevertheless, during all years, all productive adults and all goslings in the population were captured and banded during the brood-rearing period. Most nonbreeding or failed-breeding adults left the study area and travelled to distant molting areas. This segment of the population was not banded during most years, but over the 15-year study most adults eventually nested successfully and were captured, inspected, and classified.

Immigration estimates were based on the assumptions that: (1) all brood-rearing groups in the population were captured and banded each year; and (2) loss of aluminum leg bands was insignificant (i.e. $\leq$0.06%/year, as recorded for La Perouse Bay Snow Geese; Seguin and Cooke 1982).

RESULTS

The Howe Island Snow Goose population grew from 39 to 412 adult females from 1980 through 1993 (Table 1). During the same period, the percent of recaptured females increased: 0% in 1980; 20.5% in 1981; and 75.5% in 1984. It reached an equilibrium thereafter (Fig. 2 shows percent immigrants). It was hypothesized that the percent recaptured eventually would increase to 100% if the population was maintained solely through internal production (i.e. no immigration). In fact, the proportion of banded females reached an asymptote notably less than 100% after 1984. The average difference between 100% and the asymptote during 1985–1993 (i.e. the average proportion of unbanded females) was considered to be the proportion of immigrants from neighboring populations.

The average percentage of recaptured females during 1985–1993 was 87.2 $\pm$ SD of 4.39%. This corresponds to an average annual immigration of new females into the Howe Island population of 12.8 $\pm$ 4.39%. The percentage of immigrant males during the same period was much higher (60.7 $\pm$ 12.85%; Fig. 2). Exceptionally high immigration rates for males were recorded in 1990 and 1993 (Fig. 2), when large numbers of two- and three-year-old females, originally banded as goslings in 1988 and 1990 (Table 1), returned with unbanded (immigrant)

TABLE 1. Total number captured and percent immigrants in the Howe Island Snow Goose colony, Sagavanirktok River Delta, Alaska, late July 1980–1994.

Banding year[a]	No. geese captured					No. (percent) immigrant adults captured	
	Goslings		Adults				
	Female	Male	Female	Male	Total[b]	Female	Male
1980	39	45	39	38	161	—	—
1981	104	128	83	78	393	66 (79.5)	71 (91.0)
1982	25	15	78	74	192	35 (44.9)	52 (70.3)
1983	152	145	145	129	571	48 (33.1)	98 (76.0)
1984	115	107	94	93	409	23 (24.5)	52 (55.9)
1985	141	130	161	151	583	24 (14.9)	99 (65.6)
1986	158	165	161	155	639	9 (5.6)	85 (54.8)
1987	42	39	163	154	398	29 (17.8)	89 (57.8)
1988	258	222	247	200	927	33 (13.4)	114 (57.0)
1989	87	97	103	98	385	14 (13.6)	51 (52.0)
1990	441	463	341	340	1,585	36 (10.6)	260 (76.5)
1991	2	4	11	12	29	2 (18.2)	5 (41.7)
1993	402	434	412	414	1,662	35 (8.5)	333 (80.4)

[a] No Snow Geese banded in 1992 or 1994 because of complete breeding failures.
[b] During 1980–1993, 68 subadult females and 52 subadult males also captured in study area.

mates from other populations. Immigration rates were more consistent for females than males, but exceptionally low rates for females were recorded in 1986 and 1993 (Table 1).

Overlooked brood-rearing groups and unbanded goslings in one year would appear in future years to be immigrants. Band loss similarly would result in some birds being wrongly classified as immigrants. Both of these biases would inflate immigration estimates. Comparisons of aerial counts of brood-rearing Snow Geese in the study area during 1985–1989 (ABR Inc., unpubl. data) and counts during our banding programs in the same years indicated that virtually all brood-rearing Snow Geese (adults with goslings) present in the study area were captured each year. The mean percentage of goslings, and of adults and subadults counted in 1985–1990 during aerial surveys of brood-rearing areas, relative to the numbers counted during the banding programs in these same years, were: 100 ± 3.3% for goslings, and 99 ± 1.9% for adults and subadults. These two values are not markedly different from 100%; thus, the immigration estimates are not biased by incomplete sampling.

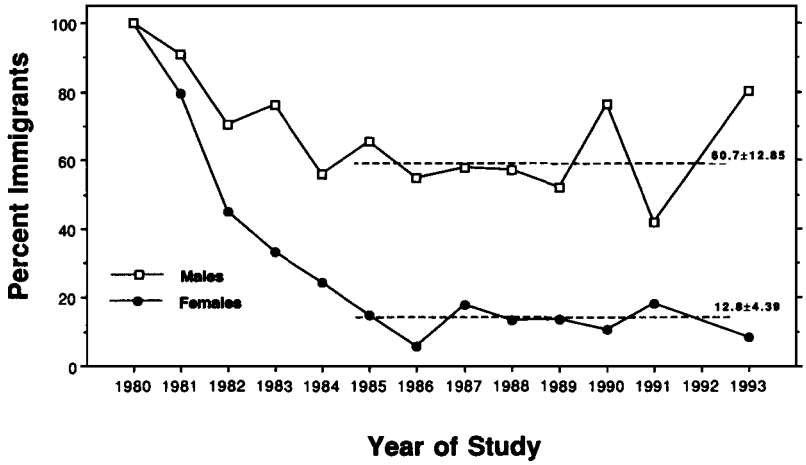

Fig. 2. Proportions of female and male Snow Geese immigrating into Howe Island population. Dashed lines and associates values indicate means ± SD for each sex for 1985–1993.

TABLE 2. Emigration histories of 17 Lesser Snow Geese from the Sagavanirktok River Delta, Alaska.

Original banding date	Recapture, resighting or recovery	
	Location	Date
	Female (banded as gosling)	
21 July 1985	Sagavanirktok R. Delta, AK	28 July 1987
	S of Banks Island, NWT	26 May 1988
29 July 1986	Banks Island, NWT	1 June 1988
	Female (adult)	
27 July 1982	Yukon R. Delta, AK	7 May 1984
22 July 1984	Wrangel Island, Russia	14 June 1987
19 July 1985	Wrangel Island, Russia	27 June 1986
	Wrangel Island, Russia	14 June 1987
28 July 1988	Wrangel Island, Russia	19 June 1991
	Male (banded as gosling)	
26 July 1981	Wrangel Island, Russia	15 July 1984
21 July 1985	Banks Island, NWT	3 August 1987
29 July 1989	Sagavanirktok R. Delta, AK	20 July 1990
	Wrangel Island, Russia	16 June 1991
	Male (adult)	
25 July 1980	Wrangel Island, Russia	15 July 1984
25 July 1981	Sagavanirktok R. Delta, AK	27 July 1982
	Wrangel Island, Russia	15 July 1984
27 July 1982	Sagavanirktok R. Delta, AK	20 July 1983
	Yukon R. Delta, AK	7 May 1984
19 July 1985	Wrangel Island, Russia	27 June 1986
20 July 1985	Wrangel Island, Russia	21 June 1986
21 July 1985	Sagavanirktok R. Delta, AK	29 July 1986
	Sagavanirktok R. Delta, AK	27 July 1987
	Anderson R. Delta, NWT	29 July 1988
	Sagavanirktok R. Delta, AK	29 July 1989
28 July 1986	Wrangel Island, Russia	15 June 1989
28 July 1986	Anderson R. Delta, NWT	30 July 1987

Only one leg band on a Snow Goose was replaced because of band wear during the 15 years of this study. In addition, 1,431 adult Snow Geese from the Howe Island population were double marked with plastic neck bands and aluminum leg bands during 1980–1993, and there was no evidence that leg bands were lost from neck-banded geese during this time (Johnson et al. 1995). Thus, the immigration estimates are not biased by band loss.

Snow Geese from Howe Island also have been reported at other Western Arctic Snow Goose colonies, mainly on: (1) Wrangel Island in Russia; and (2) Banks Island and in the Anderson River Delta in the Northwest Territories, Canada (Table 2). Notably, 3 of 5 emigrants from Howe Island banded as goslings (2 females, 1 male) were reported on Banks Island, whereas 9 of 12 emigrants banded as adults (3 females, 6 males) were reported on or migrating to Wrangel Island (Table 2). Only two emigrants from Howe Island (both adult males) were reported in the Anderson River Delta (Table 2).

DISCUSSION

Immigration and emigration also have been described for Barnacle Geese (*Branta leucopsis*; Larsson et al. 1988, Larsson 1992), but no other studies have documented age- and sex-specific annual variation in immigration and emigration in wild geese. Immigration estimates in this study are consistent with the premise that turnover (immigration and emigration) of males within Snow Goose colonies is high (Cooke and Sulzbach 1978). However, the estimates are not consistent with the supposition that turnover of adult females is rare (Cooke and Sulzbach 1978:279). Although Geramita and Cooke (1982: 2055) showed over a decade ago that fidelity by female Snow Geese to their natal breeding colony is not absolute, the high rate of immigra-

TABLE 3. Mean percent (±SD) of unbanded juvenile and adult Snow Geese observed in feeding areas in outer Sagavanirktok River Delta, Alaska, 26 May to June 1993–1994. Unbanded geese were considered immigrants.

	Juveniles		Adults	
Year	No. groups	$\bar{x} \pm$ SD	No. groups	$\bar{x} \pm$ SD
1993	7	16.2 ± 3.37%	36	15.0 ± 2.19%
1994	23	42.6 ± 4.75%	30	15.5 ± 2.99%

tion found in this study is a significant discovery.

The origin of immigrants to the Howe Island population is unclear. Scattered pairs or small groups of Snow Geese sporadically nest in areas adjacent to the Sagavanirktok River Delta, such as in the Colville River Delta (J. W. Helmericks, pers. comm.), in the Teshekpuk Lake area (R. D. King, National Biological Service, pers. comm.), and along the Chukchi Sea coast adjacent to Kasegaluk Lagoon (Fig. 1; Johnson et al. 1993). Some of these geese may occasionally immigrate to the Howe Island population. However, it has been assumed that most immigrants to Howe Island originated from the much larger (500,000+ birds) nesting colonies on Banks Island and the Anderson River Delta, Northwest Territories, Canada, and on Wrangel Island, Russia. Relatively few Banks Island Snow Geese have been banded during the period of this study, and none have been recaptured in the study area. Larger numbers of Anderson River Delta and Wrangel Island Snow Geese have been banded during the study period, and three adult males from Anderson River Delta, and one adult male (1983) and one adult female (1994) from Wrangel Island have been recorded in the Sagavanirktok River Delta study area. Without a significant banding and recapture program on Banks Island, however, it has not been possible to determine the origins of most immigrants to the Howe Island colony.

In 1992, virtually all Snow Geese in the Howe Island colony failed to nest and no adults or goslings were banded, (i.e. all geese left the study area for distant molting areas prior to mid-July 1992; Table 1). It was assumed, however, that some immigration probably had occurred in 1992, and that these new birds would return in 1993 and, if they nested successfully, would be captured along with any 1993 immigrants. Thus, the proportion of immigrant females and males was expected to be high in 1993 compared to earlier years because of the presumed accumulation of immigrants over two years. Although the proportion of immigrant males was high in 1993, the proportion of immigrant females was among the lowest recorded since 1985 (Table 1).

A possible explanation for the low female immigration rate in 1993 may be related to the number of juvenile females that return to the colony in years immediately following major breeding failures, such as in 1992 following the partial failure in 1991, and in 1993 following the complete failure in 1992. If juvenile females from family groups broken during winter (Ely 1993) and during migration are adopted by intact family groups, especially family groups with juveniles, then the number of immigrant juveniles may be directly related to the number of intact families (pairs with young from previous year) that return to the colony in a given year. Such a mechanism has not been documented in Snow Geese (Prevett and MacInnes 1980) or White-fronted Geese (*Anser albifrons*; Ely 1993), but it is plausible considering the small number and proportion of unbanded juveniles recorded in the study area in late May 1993 compared to 1994 (Table 3).

Another possible hypothesis explaining the low immigration rate of females in 1993 is that, during years of heavy predation and low gosling production (as in 1991 and 1992), potential immigrants may not remain associated with the Howe Island population (i.e. they may emigrate by reassociating with Banks Island or Wrangel Island geese). Cooke and Sulzbach (1978) suggested that emigration of female Snow Geese from one colony to another was uncommon. In contrast, Larsson et al. (1988) found that up to 7.4% of adult Barnacle Geese from a nesting colony in Sweden may have emigrated to other nesting populations in a single year. Although some emigration has been shown from Howe Island to neighboring colonies in arctic Russia and Canada, in the absence of large-scale systematic resighting and banding programs at

neighboring colonies during the study, this second hypothesis remains untestable.

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