THE GREATER SNOW GOOSE

REPORT OF THE
ARCTIC GOOSE HABITAT WORKING GROUP

A Special Publication of the Arctic Goose
Joint Venture of the North American
Waterfowl Management Plan
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EXECUTIVE SUMMARY

The spring population of the greater snow goose has increased from less than 50,000 birds in the late 1960s to about 700,000 in the spring of 1997. The growth rate of the population is approximately 9% per year, about twice the rate of the mid-continent lesser snow goose. The population is doubling about every eight years and there are no signs to indicate any slowing of this pattern. At this rate, numbers of greater snow geese should reach 1,000,000 by 2002 and 2,000,000 by 2010.

The geese heavily use traditional spring and fall staging areas along the St. Lawrence River. The numbers of birds have far exceeded the carrying capacity of the natural marshes and the birds have expanded their use of habitat into surrounding farmlands. The long-term integrity of the marshes is threatened with continuing degradation but these changes are not believed to be permanent or irreversible if the impact of the geese could be reduced. Wintering habitat on the Atlantic Coast is severely impacted at a few traditionally used sites. However, this damage is limited in relation to the total amount of salt marsh available and these damaged areas are likely to recover if management practices can be implemented to redistribute the birds to other unused salt marsh areas.

On wintering areas, the increased numbers of geese is also being sustained by their use of agricultural habitats. Some localized crop damage occurs but it is not extensive. However, damage to hayfields near spring staging areas along the St. Lawrence River is severe, widespread and of considerable economic significance. This is a major management problem for wildlife agencies and will worsen as the greater snow goose population continues to grow. However, even if population growth is arrested, the birds have adapted so thoroughly to these agricultural habitats that the impacts by the geese will remain very extensive and will require innovative corrective measures.

Studies on the high Arctic breeding habitats do not indicate that extensive damage to that ecosystem is currently occurring as a result of over-abundant goose use. The population is estimated to be at about one-half the carrying capacity on the areas studied on Bylot Island, the largest breeding colony. This is likely near an ideal and long-term sustainable level. Over the last 19 years, body mass, size and condition measured on fall staging areas along the St. Lawrence River have all declined indicating density dependent factors operating during the brood-rearing period to reduce gosling growth. We believe these effects are likely real at the level of the whole population. However, survival and growth rate measurements over the recent 8-year period on the Bylot Island nesting colony have not discovered a similar pattern.

A comprehensive population model was developed using recent and historical demographic data from breeding and staging areas. It was then used to explore the effect on population growth rate of changing the survival of the birds during several life history stages. Adult survival (approximately 83%) was determined to be the most important variable, accounting for 60% of population growth rate in good breeding years compared to 98% in poor years. Survival of young birds was the second most important variable, accounting for up to 20% of variability in population growth in good breeding years.

The Working Group believes that continued growth of the population will soon threaten the long-term integrity of the Arctic ecosystem upon which the birds depend as has occurred elsewhere on habitats used by mid-continent lesser snow geese. The lesser snow goose population serves as a relevant and timely model for the greater snow goose and provides managers with an unambiguous warning as to where the current trend will likely lead. Continued growth of the population will also result in some expansion of salt marsh degradation on the U.S.

Atlantic Coast and along the St. Lawrence River as well as increased damage to the already ravaged farmlands in parts of southern Québec.

The Working Group recommends that management intervention be implemented as soon as possible to arrest the growth of the greater snow goose population and stabilize it, by the year 2002, at between 800,000 and 1,000,000 birds. Stabilization should occur if harvest rate is doubled to 24% from the current rate of 12%. Specific suggestions of practices that will increase harvest rates are offered and we point out that experience gained from programs designed to reduce the size of the mid-continent population of lesser snow geese will provide extremely relevant guidance for managers.

Any new management practices should be implemented under an Adaptive Resource Management scenario, thus requiring that current data collecting programs be reviewed and then continued, modified, or expanded where needed. Again, experience gained with management and evaluation of mid-continent lesser snow geese will be very helpful in developing the Adaptive Management program needed for these geese. Changes in future management paradigms will also require effective communications programs to inform, and gain the support of, all the relevant stakeholders.

INTRODUCTION

BRUCE BATT, Ducks Unlimited, Inc.

Waterfowl managers have become increasingly concerned about the dramatic increases of some populations of North American Arctic nesting geese. The basis for their concern is the widespread habitat degradation that is occurring on many Arctic nesting colonies and staging areas as reviewed by Abraham and Jefferies (1997a). This damage is threatening to the snow geese themselves and to the myriad other species that share the same ecosystem with them. The extent of the damage has been quantified especially well for Hudson and James Bay coastal habitats used by mid-continent lesser snow geese (*Anser caerulescens caerulescens*) Abraham and Jefferies (1997b). However, biologists at many locations across the Arctic have noticed increased degradation of areas used by most of the "white" geese, including other lesser snow goose populations, greater snow geese (*A. caerulescens atlantica*) and Ross' geese (*A. rossii*).

Managers have been responding to increasing white goose numbers for at least the last decade through liberalized bag and possession limits and longer hunting seasons. These changes generally have increased the kill but harvest rates have been inadequate to overcome the rate at which some populations are growing (Rockwell *et al*. 1997, Chapter 4).

The Arctic Goose Joint Venture (AGJV) of the North American Waterfowl Management Plan recognized these issues as needing special attention beyond what can be done under typical management guidelines and protocols. Their establishment of the Arctic Goose Habitat Working Group in 1996 initiated a series of reports and actions that have elevated the awareness of problems and potential management actions for the mid-continent lesser snow goose population. The publication of the report *Arctic Ecosystems in Peril* (Batt ed. 1997) provided the scientific underpinning that resulted in a "call to action" for increased management attention to bring the population back to a level that can be sustained by its Arctic ecosystem.

Public agencies and private conservation groups have rallied to support the management objective with a great variety of workshops, planning exercises, public consultations and communications initiatives. The media have been heavily engaged in covering the issue from a multitude of angles. Two pieces, which provide the general reader with a solid background of the main issues, were provided by Rockwell *et al*. (1997) and Ben-Ari (1998). A documentary video that describes the biological basis for the problem has been produced and can be obtained from Ducks Unlimited, Inc. (One Waterfowl Way, Memphis, TN 38120).

In 1997, the AGJV charged the Working Group with conducting a similar review for the greater snow goose which many scientists believe are on a similar path to what was determined for the mid-continent lesser snow goose. This report is a product of that action. It is similar in approach and content to what was produced in the earlier report. Again, the Working Group took it as their mandate to provide the Joint Venture with a solid scientific analysis of the situation with the greater snow goose followed by a modeling exercise designed to clarify the likely population impacts of a range of possible future management actions. The report also includes recommendations for management consideration by the AGJV and the responsible public agencies.

The report was presented to the AGJV in March of 1998 in Orlando, Florida. It was approved in general but the writing team still had many editorial and peer review steps to take. That work was accomplished and led to the preparation of this final report.

Members of the Joint Venture Management Board, other Writing Team members, other Working Group members, the AGJV Technical Committee, the Atlantic Flyway Snow Goose Committee and a selection of other peers were asked to provide critical review of the March 1998 document. The Writing Team acknowledges the comprehensive reviews received from Dr. Jean Bédard (Université Laval), Paul Castelli (New Jersey Division of Fish, Game and Wildlife), Dr. Evan Cooch (Simon Fraser University), Mike Johnson (North Dakota Game and Fish Department), Dr. Mark Lindberg (Ducks Unlimited), and Dr. James Nichols (U.S. Fish and Wildlife Service). Other useful comments on the March draft were received from Dr. Ken Abraham (Ontario Ministry of Natural Resources), John Dunn (Pennsylvania Game Commission), and Dr. Robert Jefferies (University of Toronto).

The Writing Team met together once, in February of 1998 in New Jersey. Since then, vigorous and effective communications between team members have been conducted through e-mail. Interruptions occurred because of fieldwork and other work priorities but we thank our employers for allowing us the time to be engaged in this project. The Canadian Wildlife Service provided travel funds for the three university-based team members but each other individual's expenses were provided by his employer. Brenda Carlson of Ducks Unlimited, Inc. had the burden of pulling all the various versions and formats together through a series of drafts and revisions that sometimes seemed endless. Nevertheless, she prevailed and the authors thank her for hanging in there. Ducks Unlimited provided office support, express mail and graphic design support for several drafts and for the final production.

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CHAPTER 1

POPULATION SIZE, PRODUCTIVITY, HARVEST, AND DISTRIBUTION

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POPULATION SIZE

Total Population

Population management of most North American geese is based on trends detected from mid-winter aerial surveys. These surveys do not provide estimates of total waterfowl numbers. Rather, the wintering habitat is sampled in a consistent way each year by flying standardized flight lines in small fixed-wing aircraft and using experienced observers to visually estimate the size of flocks encountered. No attempt is made to correct for error in visual estimation, nor to extrapolate for areas outside the flight lines. Assuming that a more-or-less equal proportion of the population is counted each year, these surveys can be expected to show trends that are similar to those occurring in the overall population.

Snow geese (*Anser caerulescens*) do not lend themselves well to such an approach. Firstly, they are very gregarious and range widely and unpredictably over large expanses of coastal marshes and agricultural fields; this clumped and unpredictable distribution makes it unlikely that mid-winter surveys flown along standard routes would encounter an equal proportion of the population each year. Secondly, individual flocks are often so large as to defy the capabilities of even experienced observers to estimate numbers accurately.

On the other hand the white plumage of snow geese contrasts with most backgrounds, making it relatively easy to detect flocks at great distances and to conduct exhaustive aerial surveys over large areas. The same contrasting plumage also allows the use of aerial photography as a means of markedly increasing the accuracy of estimating flock size. Since the mid-1950s, various types of aerial surveys (some using photography) have been conducted on wintering flocks of greater snow geese (*A.c. atlanticus*) in the United States (Serie 1996), and with staging flocks during spring and fall migration in the St. Lawrence valley, Québec (Heyland 1972, Bourget 1974, Gauvin and Reed 1987). A routine survey has evolved from these earlier surveys and now serves as the basis for greater snow goose population monitoring in the Atlantic Flyway (Anon 1981). This survey undoubtedly includes some lesser snow geese (*A.c. caerulescens)*, but because they compose such a small proportion of the flock (judged to be less than 3%: Anon 1981) no attempt is made to correct for this factor.

This routine survey is conducted in spring while the geese are staging in the St. Lawrence valley (Fig.1-1) and involves exhaustive aerial coverage and photography to estimate the size of the entire population. In the 1960s through the 1980s, all flocks were photographed and all geese on each photograph were counted. By the late 1980s, with increased numbers of geese ranging over a larger geographic area, two problems were recognized. Firstly, the conducting of total counts on photographs became increasingly fastidious and costly, and caused delays in producing estimates. Secondly, with geese occupying a much larger portion of the St. Lawrence valley and making daily flights to farm fields well inland from the river, it became more difficult to be sure that all flocks were encountered during a single survey flight.

Figure 1-1. Range of the greater snow goose.

In response to these problems, a re-designed survey was initiated in 1991, involving two main changes: 1) the counting of geese from photographs was conducted using sampling procedures rather than total counts (although full photographic coverage was maintained), and 2) replicate surveys were conducted each spring to examine within-year variability in population estimates and to assess the likelihood of flocks being missed during individual surveys. The sampling procedure for photographic counts is conducted in two stages. Firstly, each photographed flock is assigned to one of three size classes or strata (small, medium, large) based on a visual estimate of the size of that flock recorded during the survey (refined, if necessary, from a second visual estimate from the photograph). A random sample of flocks (photographs) is chosen to be counted from each size-class stratum. Each photograph chosen for counting is overlaid by a squared grid, and a systematic sample of squares containing geese are counted. Estimates and their variances are generated from these sample counts, and if the variance exceeds the chosen value of CV = ±7%, additional photographs are selected and counted. During 1991-1995, three surveys were conducted each spring (late April, early May, mid-May); in both 1996-1997 two surveys were conducted, all in May (Appendix A). For the purposes of this study, we have used for each year the highest of the three (1991-95, or two in 1996-97) survey estimates, assuming that it was the most complete (i.e. likely to have missed the least number of flocks, if any).

The estimated population sizes for spring 1965-1997 are given in Appendix B and plotted in Fig. 1-2. The data show a strong increasing trend over the three decades, with rapid growth rates evident for the periods 1968-1974 and 1983-1997. There was, however, a period of relative stability with little increase between 1974 and 1982. The overall annual growth rate (1965-1997) averaged 8.9%, and has remained high during the most recent growth phase (9.7% for 1983-1997). This rapidly increasing trend, since about 1965, is also evident from 5-year averages of the mid-winter survey indices (Appendix B, Table 6) although those surveys record only about one half (52% over the decade 1988-1997) of the population estimated from the St. Lawrence surveys.
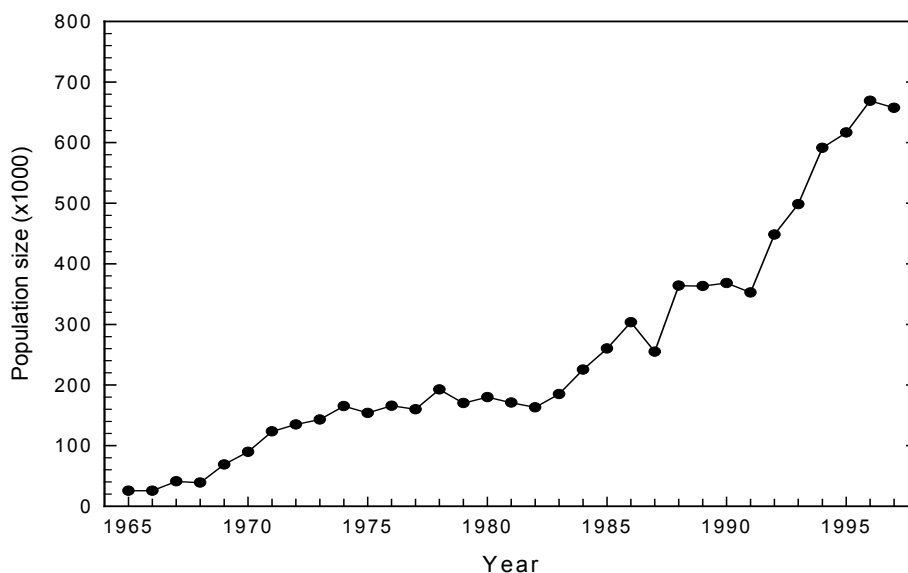
Figure 1-2. Greater snow goose populations in spring, 1967-1997, from photographic surveys in the St. Lawrence estuary.

Tracking population change through years prior to 1965 is difficult because the only systematically recorded data are U.S. mid-winter indices going back only to 1950. Nevertheless, examination of historical records from early explorers suggest that population levels were probably much lower than present from the 1500s through to the end of the 1800s (Bent 1962, Anon 1981). The few available estimates from the first half of the 1900s (Lemieux 1959, Anon 1981) suggest a gradual increase from about 2,000 to 20,000 by 1941. In 1950 and 1951, the first two years of mid-winter aerial surveys in the U.S., slightly more than 40,000 geese were recorded; from 1952 to 1964 these U.S. aerial surveys recorded numbers fluctuating between 34,800 and 67,100 (Anon 1981) and showing no apparent trend. No information has been found to suggest that excessive harvest by aboriginal peoples or early European settlers could have been the cause of low populations in the 16th to 19th centuries. Perhaps a more severe climate in the Arctic during this period (the so-called Little Ice Age) may have kept populations low because of frequent breeding failures.

Breeding Numbers on Bylot Island

Because of the huge expanse of the breeding range (Figs. 1-1 and 1-9) and the high costs of travel in the Arctic, it is not feasible to conduct regular surveys of the entire breeding population. Reconnaissance surveys conducted in the late 1960s through the1980s (Heyland and Boyd 1970, Reed *et al*. 1980, A. Reed unpubl. data) showed, however, that a high proportion of the total population bred in an area encompassing northern Baffin Island and adjacent Bylot Island. Because Bylot Island has the largest and densest nesting concentration (about 15% of the total breeding population; Reed *et al.* 1992) and is centrally located in the range, events occurring there are likely typical of those happening elsewhere in the range. Quantitative aerial photographic surveys have been conducted on Bylot Island once every five years since 1983 (Reed and Chagnon 1987, Reed *et al*. 1992, A. Reed unpubl. data). The survey covers the 1600 km^2 south plain of the island during the brood-rearing period. A stratified random sample of 2x2km quadrat plots, stratified in relation to habitat features reflecting potentially high, medium or low brood densities, are selected. Each of the selected quadrats is searched intensively from a helicopter and all geese recorded; in small groups the geese are counted individually whereas in larger groups an oblique 35mm photograph is taken to be counted later in the lab. Further details on the method are given in Reed and Chagnon 1987 and Reed *et al*. 1992.

Table 1-1 Estimated densities of greater snow goose broods on Bylot Island, 1983-1993, in relation to habitat quality.

Habitat quality*	Mean number of broods/km^2					
	1983	**SE**	**1988**	**SE**	**1993**	**SE**
Good	16.4	1.6	14.9	1.7	29.9	3.3
Moderate	5.6	0.9	7.8	2.1	16.0	3.3
Poor	0.8	0.3	6.1	2.8	12.1	2.2
Total	5.2	0.5	8.2	1.6	17.0	1.6

* Predicted capability of habitat to support broods: Good = areas with abundant ponds and abundant graminoid vegetation (High-density stratum); Poor = areas with very few wet areas and little graminoid vegetation (Low-density stratum).

The estimated numbers of greater snow geese and brood densities on Bylot Island in 1983, 1988 and 1993 are presented in Table 1-1 and Fig. 1-3. The total number of geese (breeding adults, moulters, and goslings) increased threefold from 52,000 in 1983 to almost 155,900 in 1993, as did the number of breeding adults which passed from 16,600 to 55,000. The number of non-breeding (moulting) adults fluctuated from 8,900 in 1983 to 5,400 in 1988 and to 14,473 in 1993 (Fig. 1-3). Overall, brood densities also increased threefold from 1983 to 1993, with densities increasing in all strata, especially in that stratum judged to represent poorest quality habitat within the study area (Table 1-1).
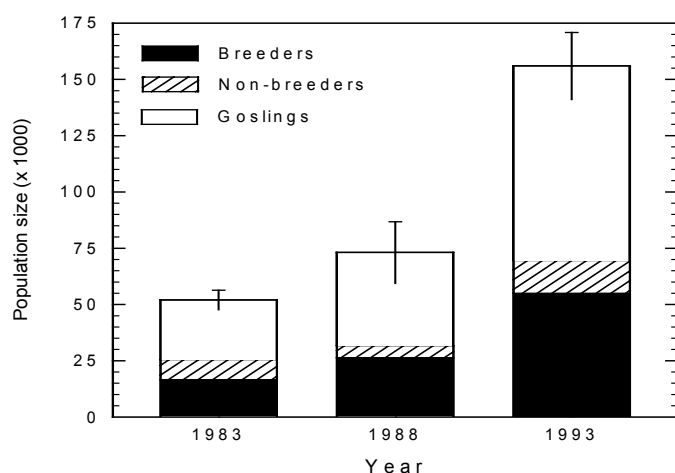
Figure 1-3. Numbers of greater snow geese on Bylot Island, in 1983, 1988, and 1993.

PRODUCTIVITY

Productivity has been documented on a regular basis by field surveys aimed at determining the proportion of young-of-the-year (juveniles) in the fall flight (Lynch and Singleton 1964). The longest record, covering 1956 to 1997, comes from surveys (mainly in Nov.) on the wintering grounds (Gauvin and Reed 1987, Voelzer 1986, Walter 1987-1995, Bidwell 1996; see Appendix C). There is also an uninterrupted series from the St. Lawrence (in Oct.) spanning 1973-1997 (Gauvin and Reed 1987, Reed unpubl. data; Appendix C). In addition to these ground surveys, aerial photography was used on the St. Lawrence River during 1969-1984 (Appendix C).

An inherent bias in many productivity surveys stems from the fact that they are conducted during or after hunting has occurred; because hunting removes juvenile birds from the population at a greater rate than for adults, such counts can underestimate true productivity. We have sought to minimize this bias by using the St. Lawrence ground data (1973 to present) which were collected much earlier in the hunting season (mostly prior to 15 October) than were the U.S. data (mostly in November); however, in the absence of consistent Canadian data for years prior to 1973, we have used U.S. data for the earlier years 1965 to 1972 (Fig. 1-4). The data showed considerable annual fluctuation, varying from 0.4 to 47.8%, averaging 24.2% but, most importantly, showing no long-term trend (1965-1997: $r^2 = 0.04$, $P = 0.26$; 1973-1997: $r^2 = 0.01$, $P = 0.78$).
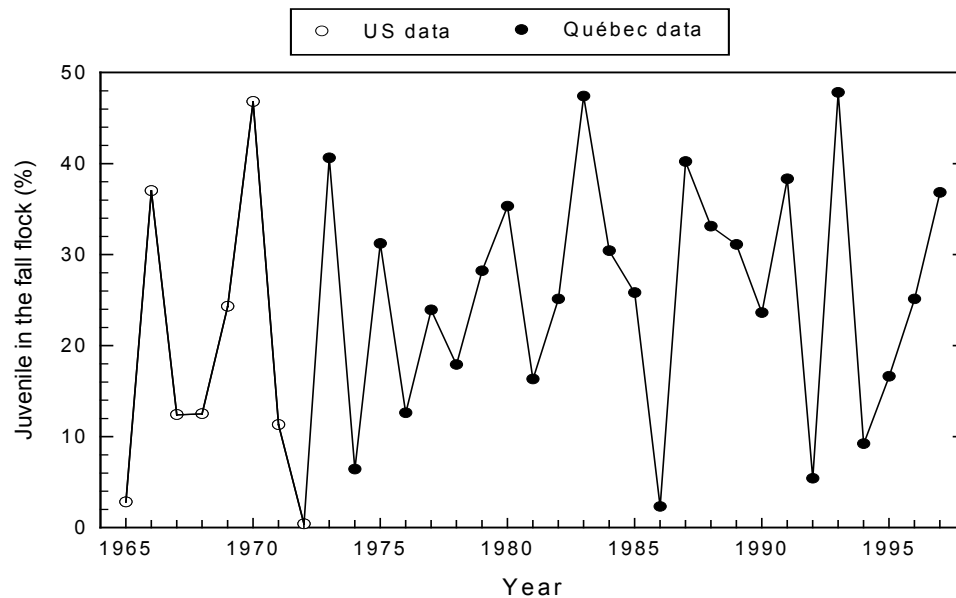
Figure 1-4. Greater snow goose productivity data, 1965-1997.

Concurrently with the ground surveys to determine the percentage of young in the fall flight, observers also recorded average brood size for « normal » families (i.e. broods accompanied by two parents). These data are presented in Appendix D, using U.S. data for 1971and earlier, and St. Lawrence data from 1973 onward. They show annual fluctuations between extreme values of 1.65 to 2.94 young per brood with a slight increasing trend for the period 1965-1997 ($r^2 = 0.12$, $P = 0.055$) but not for the period 1973-1997 ($r^2 = 0.01$, $P = 0.84$). Annual mean brood size was highly correlated with the proportion of young in the fall flight (1973-1997: $r = 0.89$, $P < 0.001$).

HARVEST

Recreational Harvest

The recreational harvest has been estimated in Canada since 1967, and in the U.S. since 1975 (the year in which hunting was re-opened on this subspecies in the U.S.), from the regular national harvest surveys in both countries (Appendix E). The Canadian data used in this report include all snow and blue geese for Zone 1 in Québec (CWS National Harvest Survey files). The U.S. data relate to all snow and blue geese for the Atlantic Flyway States (extracted from annual USFWS Administrative Reports). The data for both countries includes some lesser snow geese, but because the proportion of lessers in Atlantic Flyway staging and wintering areas is very small (Anon 1981), and because no consistently reliable way has been found to distinguish between the two subspecies using the tail fans turned in by hunters, no correction is attempted.

Since 1975, the Canadian harvest has fluctuated between 9,700 and 92,700, averaging approximately 39,000, and showing an increase over time (1967-1995: $r^2 = 0.46$, $P = 0.001$; 1975-1995: $r^2 = 0.18$, $P = 0.06$; Fig. 1-5). The average yearly harvest increased from about 28,240 during the period 1975-1979 to 49,480 in 1991-1995. Also since 1975, the U.S. harvest has fluctuated between 8,900 and 40,400, averaging 21,600, but showing no trend (1975-1995; $r^2 = 0.01$, $P = 0.90$; see also Appendix E). However, more recent data not available to us at the time of this analysis, indicated that the opening of late (Feb - Mar) seasons in 1996 in several northern states, especially

Pennsylvania, resulted in large increases in harvest in these states. The combined harvest has fluctuated between 18,500 and 121,800, averaging 60,500 since 1975. The large annual variations in the harvest largely reflect annual variation in productivity (see below). Although the combined harvest increased between 1967 and 1995 ($r^2 = 0.50$, $P < 0.001$), the increase since the opening of hunting in the U.S. was not significant (1975-1995: $r^2 = 0.11$, P = 0.15). Overall, the total harvest averaged 47,360 during the period 1975-1979 compared to 70,100 during 1991-1995.
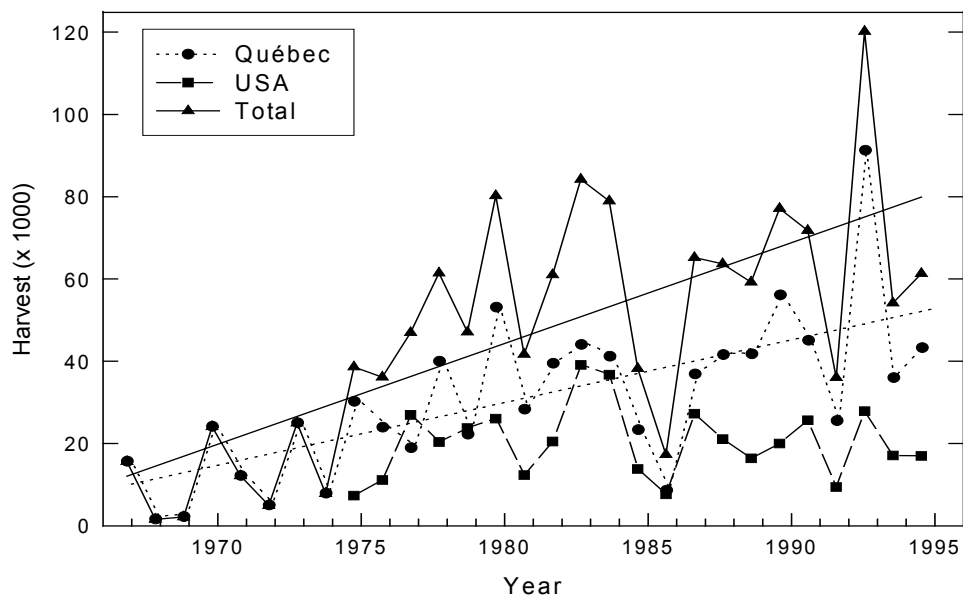
Figure 1-5. Greater snow goose harvest in Québec, U.S. Atlantic Flyway (only since re-opening of the season in 1975) and total (Québec + U.S.), 1967-1995.

Age Ratio in Recreational Harvest

Age ratios (juveniles:adult) in the kill have been estimated each year from tail fans sent in by recreational hunters participating in national harvest surveys in both Canada and the U.S. (Table 1-2). Although juveniles always accounted for less than a half of the goose population at risk in the fall (Appendix C), they outnumbered adults in the harvest in almost all years (Table 1-2), averaging 3.4: 1 in the Canadian harvest (1968-1995) and 1.2: 1 in the U.S. harvest (1976-1996). Annual variation was, however, considerable. This variation partly reflects low sampling intensity in some years, and, especially, the large annual variation in productivity, the age ratio in the kill being much higher in years of high productivity. The increased vulnerability of young geese to the gun, in comparison with adults, is explained in large part by their lack of experience in avoiding hunters. Similarly, juvenile geese show less vulnerability to the gun in the U.S. in comparison to Canada because of experience gained by those surviving the earlier hunting season in Canada. The age ratio in the Canadian harvest is nonetheless strongly correlated to that in the U.S. harvest (1977-1995: $r^2 = 0.79$, $P < 0.001$).

Table 1-2 Age ratios in the harvests of snow geese, juveniles: 1 adult (no. of tail fans or geese examined), in southern Québec and the Atlantic Flyway states, 1967-1996.

Year	Can. NHS (Qué.)	U.S. NHS (Atl. Flyway)	Bag check – Cap Tourmente NWA
1967	no data	season closed	
1968	1.77 (25)	season closed	
1969	2.21 (77)	season closed	
1970	4.95 (101)	season closed	
1971	2.05 (116)	season closed	
1972	0.15 (61)	season closed	
1973	12.33 (255)	season closed	
1974	0.67 (80)	season closed	
1975	5.85 (130)		
1976	1.28 (82)	0.33 (77)	
1977	10.63 (58)	1.59 (156)	
1978	3.26 (98)	0.66 (165)	
1979	2.79 (106)	0.74 (209)	
1980	4.38 (345)	1.83 (185)	12.28 (2152)
1981	1.85 (74)	1.05 (70)	1.79 (681)
1982	3.03 (121)	0.78 (148)	10.62 (1255)
1983	6.75 (225)	2.76 (348)	10.96 (2645)
1984	2.98 (435)	1.17 (384)	6.93 (2555)
1985	2.03 (97)	0.88 (131)	14.22 (1613)
1986	0.35 (46)	0.17 (57)	1.63 (701)
1987	5.80 (238)	2.53 (338)	18.96 (2795)
1988	3.10 (373)	2.00 (309)	16.59 (2849)
1989	1.73 (328)	1.30 (221)	9.55 (2838)
1990	1.74 (318)	0.70 (254)	10.41 (3182)
1991	4.78 (249)	1.86 (287)	26.94 (1816)
1992	0.32 (187)	0.14 (172)	1.37 (521)
1993	6.14 (616)	2.26 (465)	25.71 (3712)
1994	0.54 (196)	0.73 (201)	3.10 (1077)
1995	2.56 (267)	0.56 (233)	6.70 (1502)
1996		0.55 (405)	9.66 (2581)

Subsistence Harvest

Greater snow geese are also harvested by native subsistence hunters in northern Québec, the eastern Canadian Arctic and Greenland, but the kill is not well documented. Both geese and eggs are harvested. The most recent harvest data available for northern Québec and the eastern Arctic were collected in the late 1970s and early 1980s and did not distinguish between greater and lesser snow geese. Presently a harvest survey is underway in Nunavut (eastern Arctic) but results are not yet available. It seems probable that the bulk of the native harvest in Canada comes from hunters from those villages closest to the heart of the breeding range, namely Pond Inlet, Arctic Bay, Clyde River, Resolute Bay, Grise Fiord, and possibly Spence Bay. Undoubtedly others are killed during migration through more southerly areas of the eastern Arctic and through northern Québec (e.g. Cape Dorset, Hall Beach, Igloolik, Saluit, Povungnituk, Inukjuak) but we have no way of separating out greaters from the assumedly more-abundant lessers in their reported kill of snow geese.

Harvest statistics for the five main locations within the Canadian breeding range of greater snow geese (and where very few lessers would be present) are presented in Table 1-3. The average estimated harvest for these five sites for the years 1981, 1982, and 1984 was 1,185 geese. Egg harvest, recorded only in 1984, totaled 1,414 for the same five locations. Although we are unable to account for any changes in harvest since the early 1980s, or for additional harvests near other native settlements, it appears likely that the subsistence harvest of greater snow geese is less than 5,000 geese which represents a relatively small proportion of the total harvest.

Table 1-3 Estimated subsistence harvest of snow geese in five locations in the northeastern Canadian Arctic, 1979-1984.

Location	Geese 1979[1]	Geese 1981[2]	Geese 1982[3]	Geese 1984[4]	Eggs 1984[4]
Pond Inlet	642	280±48	1470±45	658	427
Arctic Bay/Nanisivik	no data	185±33	371±45	245	340
Clyde River	18	19±2	91±5	85	647
Resolute Bay	no data	50±29	0	6	0
Grise Fiord	20	28±10	53±6	13	0
Total 1981-1984		**562**	**1985**	**1007**	**1414**

[1] Finley and Miller 1980
[2] Donaldson 1983
[3] Donaldson 1984
[4] Pattimore 1985

Harvest Rate

A knowledge of hunting mortality is essential in order to evaluate the effect of various harvest management scenarios on population growth (see Chapter 4). When the estimated total number of birds killed by recreational hunting is expressed as a ratio of total population size, the resulting statistic (harvest rate) can provide an estimate of hunting mortality. This statistic is often calculated from band recovery data, but incomplete banding data for the early decades of the study period and the absence of information on band reporting rates for greater snow geese prompted us to use a different approach. The total number of young and adults killed each year was estimated by applying age ratios estimated by the national harvest surveys in Canada and the U.S. (Table 1-2) to

14

the estimated total harvest in each country (Appendix E). The size of the adult population in fall was estimated by adjusting the population size obtained by the spring census (Appendix B) for natural mortality occurring between the spring and fall. To do this we used a spring-to-fall survival of 94.6%, a value proposed by Gauvin and Reed (1987) in an earlier study. An improved estimate of spring-to-fall survival using neckband resighting data will soon be available (Stéphane Menu, unpubl. data), which will allow a more refined analysis. To estimate the size of the juvenile population in fall, we multiplied the estimated fall population size for adults by the proportion of juveniles estimated in the fall flight along the Saint Lawrence estuary (Appendix C), divided by the proportion of adults in the fall flight (100 -% juvenile).

The average harvest rate during the period 1968-1995 was 15.6% (young and adult combined). However, as indicated earlier by Reed (1990), the data show three distinct periods with markedly different harvest rates (Fig. 1-6): 1) from 1968 to 1974, harvest rate averaged 8.0%; 2) after re-opening of hunting in the U.S., it jumped to 25.0% during 1975-1984, 3) finally, harvest rate dropped abruptly after 1984 and has stabilized around 11.8% since then. The drop in harvest rate after 1984 affected both young (67.3% 1975-1984 vs 32.9% after 1984) and adults (11.1% 1975-1984 vs 6.0% after 1984). It should be pointed out that there are some obvious inaccuracies in the age specific data during the 1970s, as shown by harvest rate estimates of 156% and 101% for young in 1972 and 1978.
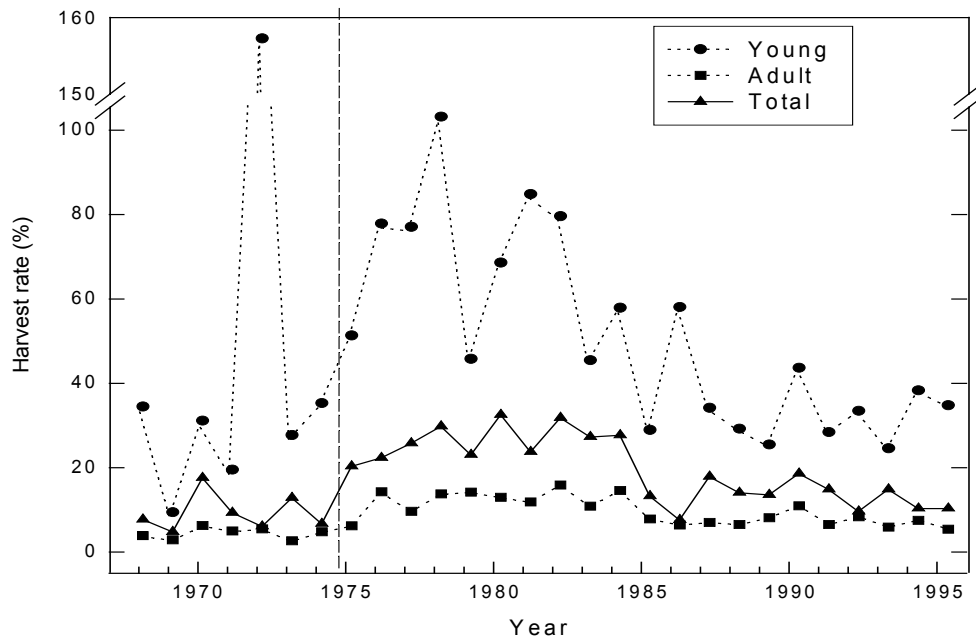
Figure 1-6. Greater snow harvest rate (number killed/estimated fall population size) for young, adult and total (combined young and adult), 1968-1995. Vertical dashed line indicates re-opening of hunting in the U.S. (1975).

Table 1-4 Mid-winter indices of greater snow goose numbers in the Atlantic Flyway: 5-year averages by state, 1955-1996 [1]

State	Period							
	1955-60	1961-65	1966-70	1971-75	1976-80	1981-85	1986-90	1991-96
New York	0	0	0	15	1	1	18	285
Pennsylvania	0	0	20	9	9	10	4	2076
New Jersey	4230	1660	2340	21661	13136	8058	37900	77400
Delaware	0	220	240	3798	17893	45640	72839	63809
Maryland	1707	520	940	2578	17893	45640	56339	68192
Virginia	6759	21960	22040	12535	32022	21055	18090	11472
North Carolina	30652	33160	23500	31620	37730	25480	21660	18433
South Carolina	6	60	140	400	996	485	659	427
Flyway Total [2]	43377	57580	49220	72655	119775	146419	207527	242103

[1] Data from Serie (1996). Note that the first and last columns (1955-60 and 1991-96) indicate 6-year averages.
[2] Includes total for above 8 states as well VT, NH, RI, WV, GA and FL; none of these additional 6 states had any 5-year averages exceeding 70 geese.

DISTRIBUTION

Wintering Range

The wintering range extends along the Atlantic coast from New Jersey to South Carolina, with main concentrations in New Jersey, Delaware, Maryland, Virginia and North Carolina (Anon 1981). The main concentration areas and a current estimate of the approximate numbers of geese at each site are shown in Fig 1-7. Note that there are a few small concentration areas harboring a few thousand lesser snow geese within this range, notably at Black Water NWR in Maryland, at Presquile NWR in Virginia, and at Mattamuskeet NWR in North Carolina (Fig 1-7). Mid-winter survey indices over 40 years since 1955 (Table 1-4) show general increases in 5-year averages in Delaware, Maryland, and New Jersey, a decline in North Carolina, and no clear trend in Virginia and South Carolina; New York, Pennsylvania and New Jersey all showed marked increases in 1991-1996. Indeed, the build up of winter flocks in Pennsylvania since 1995 is greater than indicated by the mid-winter surveys because of late-winter arrivals in the interior part of the state. Thus more geese, both numerically and proportionately, are now wintering in the central and northern portion of the range. This trend is only partially reflected in the hunting kill in the main five harvest states (Table 1-5) with only Delaware showing a general increase since 1976, New Jersey and North Carolina showing decreases, and Maryland and Virginia showing fluctuations.

PENNSYLVANIA

MARYLAND

EAST SHORE CHESAPEAKE BAY (MD)
Ca. 75-100,000 in mid-winter.

NEW JERSEY

DELAWARE

FORSYTHE NWR
Peak number
ca. 30,000 in Nov.,
dropping off in
winter.

DELAWARE BAY MARSHES (NJ)
Numbers build up over winter
reaching ca. 50,000 in Jan.,
and ca. 145,000 in mid-March.

■ SUSQUEHANNA NWR

BOMBAY HOOK & PRIME HOOK NWRs
DELAWARE BAY MARSHES (DEL) &
ADJACENT FARMLAND
Peak numbers >250,000 in Oct./Nov.,
dropping to ca. 150-200,000 in Dec./Jan.

■ BLACK WATER NWR

CENTRAL DELMARVA
Ca. 25,000 in MD,
10,000 in DEL.

CHINCOTEAGUE NWR
ATLANTIC COAST MARSHES
Ca. 30,000 in MD, 10,000 in VA
during mid-winter.

■ PRESQUILE NWR

VIRGINIA

BACK BAY, KNOTTS ISLAND, MACKAY ISLAND NWRs
Ca. 5,000 in VA, 10-15,000 in NC.

■ MATTAMUSKEET NWR

PEA ISLAND NWR

NORTH CAROLINA

PUNGO LAKE AREA
Ca. 5-10,000

SOUTH CAROLINA

■ CAPE ROMAIN NWR

GEORGETOWN AREA

■ Small wintering flocks
of Lesser Snow Geese

0   150 km

Figure 1–7. Wintering range of greater snow geese.

Table1-5: Estimated snow goose harvest in the Atlantic Flyway states: 5-year averages by state, 1976-1995 [1]

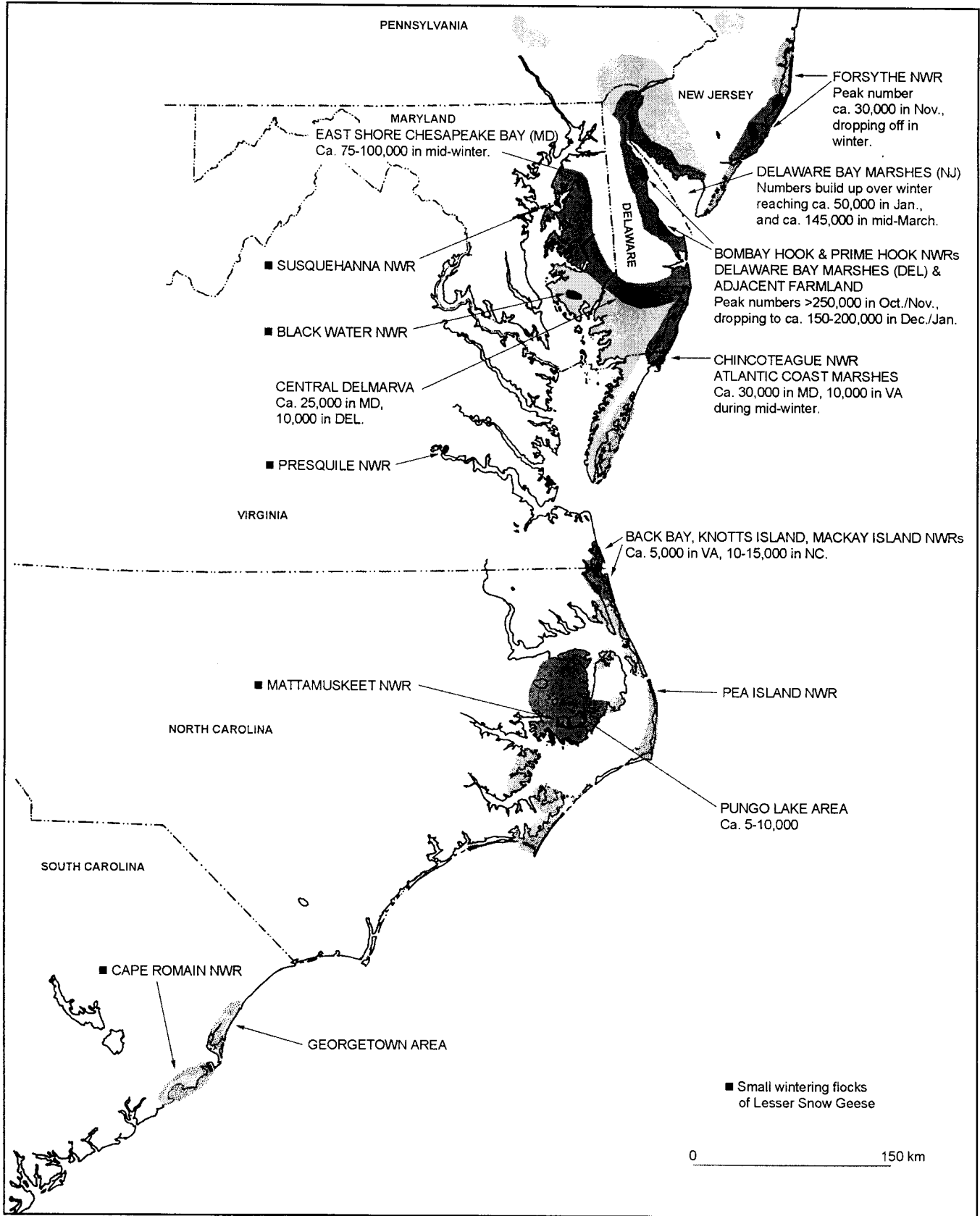| State	Period			
	1976-80	**1981-85**	**1986-90**	**1991-95**
Vermont	80	120	1020	1340
New York	380	80	520	360
Pennsylvania	160	20	80	280
New Jersey	9600	9280	6840	3820
Delaware	1020	6700	7880	7880
Maryland	2260	4680	2220	4380
Virginia	940	640	320	820
North Carolina	7220	3920	780	1520
South Carolina	140	0	0	0
Flyway Total [2]	21940	25600	19920	20420

[1] Data from Serie (1996). Note that hunting was re-instated in the Atlantic Flyway in 1975; in that year (not included in table) the estimated total flyway harvest was 9,200 Snow Geese.

[2] In addition to the above 9 states, total includes harvests from ME, NH, MA, CT, WV, and GA; none of these additional 6 states had 5-year average harvests exceeding 100 geese.

Spring Staging Areas

The traditional staging area along the St. Lawrence estuary extended along 80 km, from Québec City to Saint-Roch, and coincided with the major bulrush tidal marshes (Lemieux 1959); until the early 1960s, this was the only area of the St. Lawrence used by the geese in both spring and fall, and where they fed almost exclusively on bulrush (*Scirpus pungens,* formerly *S. americanus*) rhizomes. By 1975-1980 the geese had extended an additional 100 km downstream to the cordgrass marshes near Kamouraska and Isle-Verte, and 100 km upstream to include Lac Saint-Pierre, an enlargement of the St. Lawrence River (Anon 1981, Reed 1992); field feeding began to build up throughout that spring range, especially near the newly occupied cordgrass marshes and Lac Saint-Pierre. The spring staging area now extends along >400 km of the St. Lawrence River and estuary, as well as along at least three of the main tributaries, especially the Richelieu River through to its source in Lake Champlain (Fig.1-8), and field feeding has become commonplace.

Formerly greater snow geese flew non-stop from Delaware Bay to the traditional bulrush marshes immediately downstream from Québec City (Lemieux 1959), but now many stop off first in Lake Champlain, along the Richelieu River, and in Lac Saint-Pierre before moving downstream to the traditional tidal marshes. In 1997, several large flocks also flew north along the Hudson River and through the Finger Lakes region of New York (B. Swift and P. Hess, pers. comm.) before arriving in the St. Lawrence. The Baie-du-Febvre area along the south shore of Lac St. Pierre is characterized by the presence of many corn fields and has now become the most important spring staging area with concentrations up to 500,000 birds and 12 millions goose-days (A. Béchet *et al*. UQAM, unpubl. data); this represents almost half of the cumulative goose-days during spring staging. Based on a telemetry study conducted in 1996-97, all marked geese in the population staged at Baie-du-Febvre for periods varying between 2 and 40 days; only one bird (in 1997) did not subsequently move to the estuary to complete spring staging. This exception is consistent with the observation that in 1997, for the first time, a flock of 10,000 birds stayed at Baie-du-Febvre for the entire staging period before departing for the Arctic breeding grounds. Nevertheless, large numbers of geese continue to congregate in the traditional estuarine area during much of the spring staging period.

Early 1960s

Baie-Comeau

Lake St-Jean

St.Lawrence River

Rimouski

Use restricted to the tidal
Scirpus marshes "traditional" area

Québec

Trois-Rivières
Lake St-Pierre

Chaudière River

Montréal

Richelieu River

Lake Champlain

50 km

Early 1990s

Baie-Comeau

Lake St-Jean

St.Lawrence River

Rimouski

Use of traditional area expanded
to include adjacent hayfields

Expanded downstream where
most feeding occurs on hayfields.
Some use of adjacent Spartina marshes

Québec

Chaudière River

Trois-Rivières
Lake St-Pierre

Massive early-spring
use where most feeding
occurs in cornfields
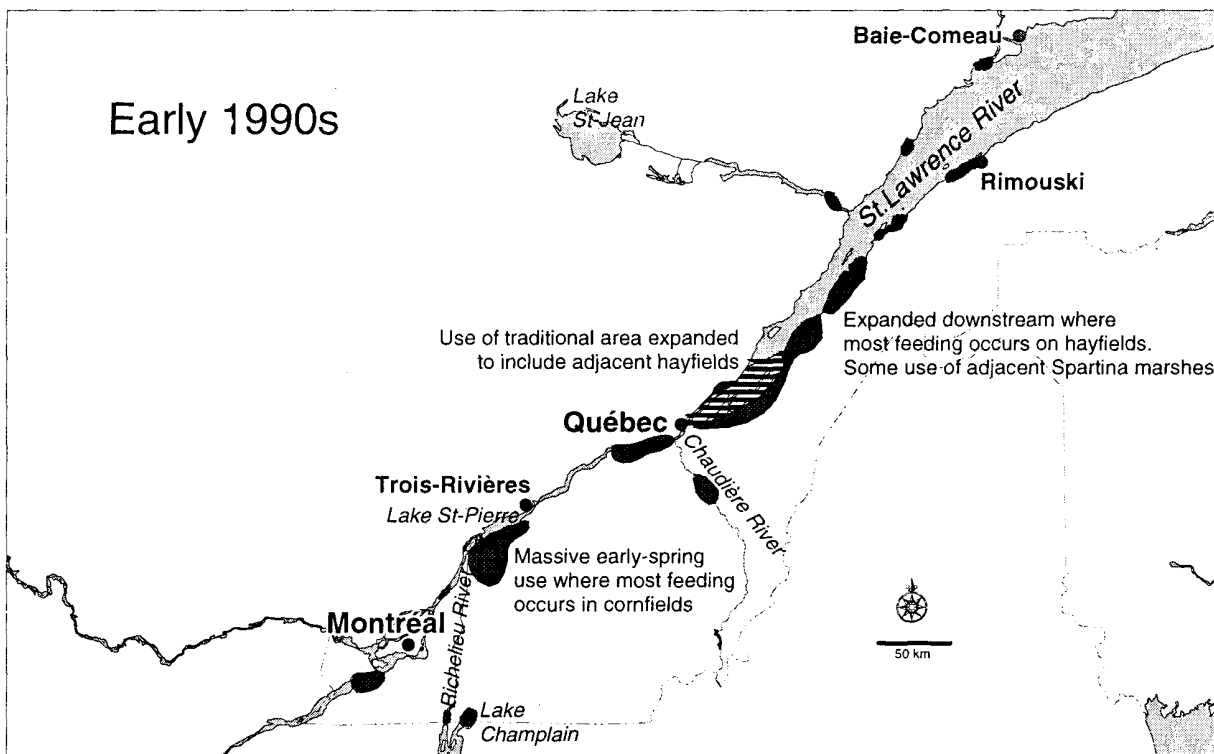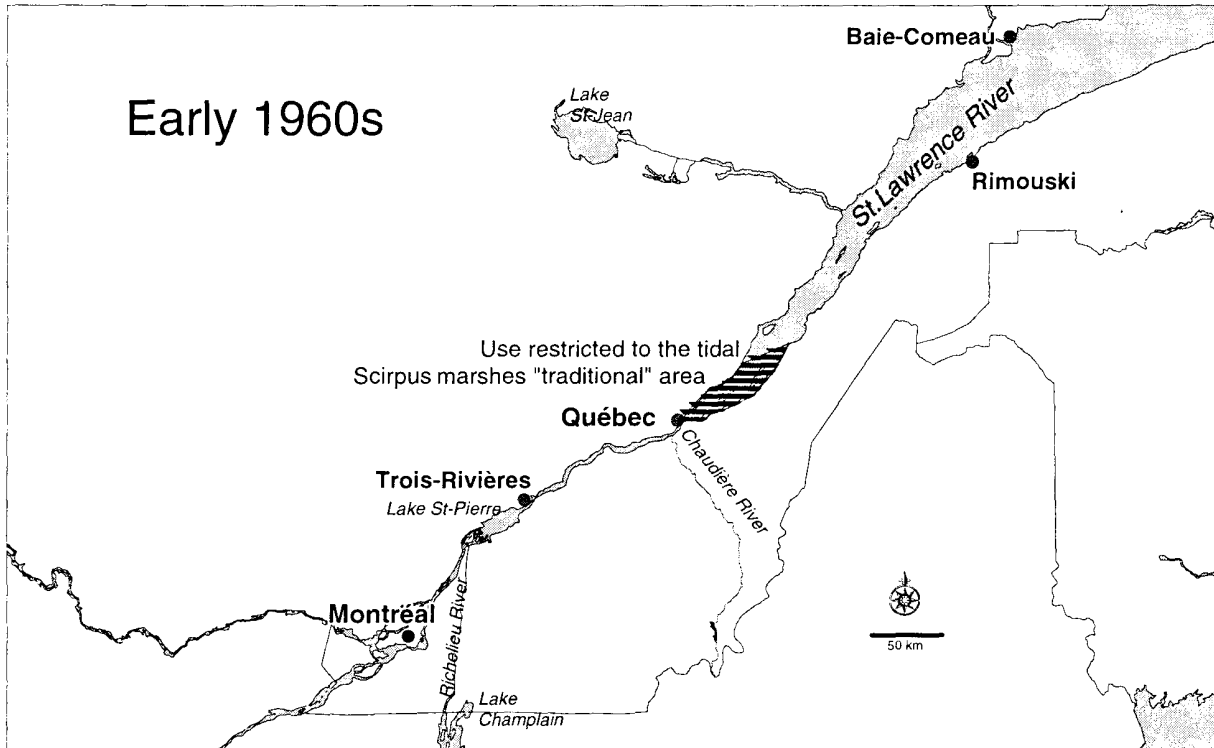
Montréal

Richelieu River

Lake Champlain

50 km

Figure 1-8. Use of the St.Lawrence staging area by greater snow geese
in spring : 1960s versus 1990s.

The existence of a staging area for snow geese in Ungava (Fig. 1-1) was first noted by Manning (1949) whose observations, based on the proportion of blue phase geese, were referred to the lesser subspecies. The presence of greater snow geese in Ungava was first brought to light in the early 1970s following reconnaissance surveys and questionnaires with local residents and bush pilots (J.D. Heyland, P. Dupuis unpubl. data), and from incidental sightings during caribou (*Rangifer tarandus caribou)* surveys (Le Hénaff *et al*. 1995). It is now known that a vast area of the tundra portion of the Ungava peninsula is used by both lesser and greater snow geese during both spring and fall migration. No large, dense concentration areas are known; rather, the geese appear to move through the area on a broad front. Greater snow geese appear to use mainly the central and eastern portion of the Ungava Peninsula, especially near its southern boundary just north of the treeline (see also below under fall migration). Staging during spring migration by greaters occurs early (mainly the last week of May) and is undoubtedly of short duration (Gauthier and Tardif 1991); as a result, the geese are probably unable to supplement nutrient reserves to any significant amount at this time (Gauthier *et al*. 1992).

Breeding Range

Reconnaissance surveys conducted from the late 1960s to the late 1970s showed the breeding range to extend from about 69° N in Foxe Basin northward through northern Baffin Island, Bylot, Somerset, Prince of Wales, Bathurst, Devon, Ellesmere, and Axel Heiberg islands, and in the Thule district of northeastern Greenland, with the bulk of the population occurring on northern Baffin Island and Bylot Island (Heyland and Boyd 1970, Anon 1981). What little new information has emerged since indicates no major changes or shifts; recent data suggest only the addition of a few areas of sparse breeding within the known range (e.g. Boyd 1989, Forbes *et al*. 1992), and a few other areas extending the range westward to Melville Island (Maltby 1978) and eastward on northern and western Greenland beyond the traditional breeding area near Thule (Boertmann 1994). An updated map of the breeding range is provided in Fig 1-9.

Fall Staging

Two main staging areas are used during fall migration. The first is located on the Ungava Peninsula and the second along the St. Lawrence River (now including portions of the Richelieu River and Lake Champlain).

Satellite tracking of greater snow geese marked on Bylot Island has recently provided detailed information on the fall migration route (Giroux *et al*. 1998). Fall migration started from Bylot Island in late August with an initial long migration bout (> 1000 km) which took them rapidly southward across Baffin Island and then along the north-east shore of Foxe Basin and across Hudson Strait to the central portion of the Ungava Peninsula. They staged several days in Ungava, moving 5 to 7 times over distances of 20 to 300 km between many scattered sites with no apparent dense concentrations. An earlier investigation revealed that during this stopover in Ungava, the geese occupied both rocky heathland, where they fed on berries (*Empetrum, Arctostaphylos, Vaccinium* spp.), and small shallow wetlands, where they fed on the basal portions of sedges (A. Reed and N. Dignard unpubl. data). By the time of departure the radio-marked geese were close to the treeline. From there they undertook a second long migration flight (>1000 km) following a corridor between 72° and 74° W of longitude across the boreal forest to the St. Lawrence River. Overall, between Bylot Island and the St. Lawrence River, the migration pattern consisted of 8-10 (8.8 ± 0.4) bouts lasting 1-5 (2.1 ± 0.1) days with intervening staging periods lasting 1-7 (2.8 ± 0.1)

days. Fall staging in Ungava is probably of particular importance for juvenile birds to rest and refuel just before they depart on the long flight to the St. Lawrence.

An important change has occurred in the way the St. Lawrence staging area is used during fall migration. Formerly (into the 1970s), the geese staged throughout the month of October almost exclusively in the *Scirpus* marshes in the restricted portion of the St. Lawrence between Ile d'Orleans and St. Roch before leaving on a direct non-stop flight to Delaware Bay (Lemieux 1959, Blokpoel *et al*. 1975). In more recent years, many geese have been dispersing from this restricted traditional area earlier in October and moving southwesterly to Lake Saint-Pierre or northern Lake Champlain where they have fed in cornfields, and where some have remained well into November or December. This southwestern shift in the fall distribution of geese in Québec is also demonstrated by tail fan receipts from the National Harvest Survey (Fig. 1-10), and by decreasing numbers of goose-days at Cap Tourmente since 1989 (A. Reed unpubl. data). The lower estuary (Kamouraska and Isle-Verte) has been used only sporadically in fall in recent decades. Increasing use of the Lake St. Jean area has been noted since fall 1995 but not quantified. More importantly, however, some geese are now overflying the St. Lawrence altogether. In the mid-1980s, Maisonneuve and Bédard (1992) used repeated observations of neck-collared geese to estimate that 11-20% of the geese were flying directly to the U.S. without stopping in southern Québec and that the average staging period of individuals that did stop off in the estuary was 15-19 days. Based on satellite and conventional telemetry conducted in 1995-96, Giroux *et al*. (unpubl. data) confirmed that 20-22% of the geese did not stop off in southern Québec and those that did remained in the estuary for an average of 11 days; furthermore, about 25% of the geese that staged in the estuary subsequently moved to southwestern Québec (the corn-growing area) to stage for an additional 14 days, on average.

Interactions with Atlantic Population Canada Geese

There is a growing concern that greater snow geese may be displacing Canada geese in southern Québec, Ontario and some coastal states. During the last 30 years, the increasing use of some regions of southern Québec (St-Vallier, Isle-Verte, Lake St-Pierre) by greater snow geese during spring migration has coincided with a concomitant decline of Canada geese in these regions (A. Reed, pers. obs.). Increased use of the Ottawa River region in recent years by Canada geese in spring has also been attributed to a displacement of birds from the Lake St-Pierre area since the arrival of greater snow geese in the mid 1980s but this has not been demonstrated through scientific studies.

At a local scale, detailed studies have been conducted in the Lake St-Pierre area where the two species stage in sympatry during spring migration. Competitive exclusion of Canada geese by greater snow geese at roosting sites (temporary floodplains) likely occurred in 1990 when limited run-off reduced the total flooded area. This did not happen the following year because of extensive flooding and no longer occurs because of creation of temporary impoundments by Ducks Unlimited (J.-F. Giroux, pers. obs.). On the feeding grounds, both species consume the same plant species when foraging on a given type of fields (Giroux and Bergeron 1996). However, little competition likely occurs because greater snow geese are more mobile and move to corn fields that are up to 40-60 km from the roost whereas Canada geese feed on hayfields within about 10 km from the roost (Cazelais 1992, DeKoster 1992). Canada geese have changed their habitat use from corn fields to hayfields in this area during the last 20-25 years (Reed et al. 1977, Cazelais 1992), probably more in response to changes in agricultural practices (more fall plowing of corn fields) than the arrival of greater snow geese.

Recent studies using satellite telemetry suggest that Canada geese marked in southern Ungava Bay and George River area in Labrador may overlap the current migration route of greater
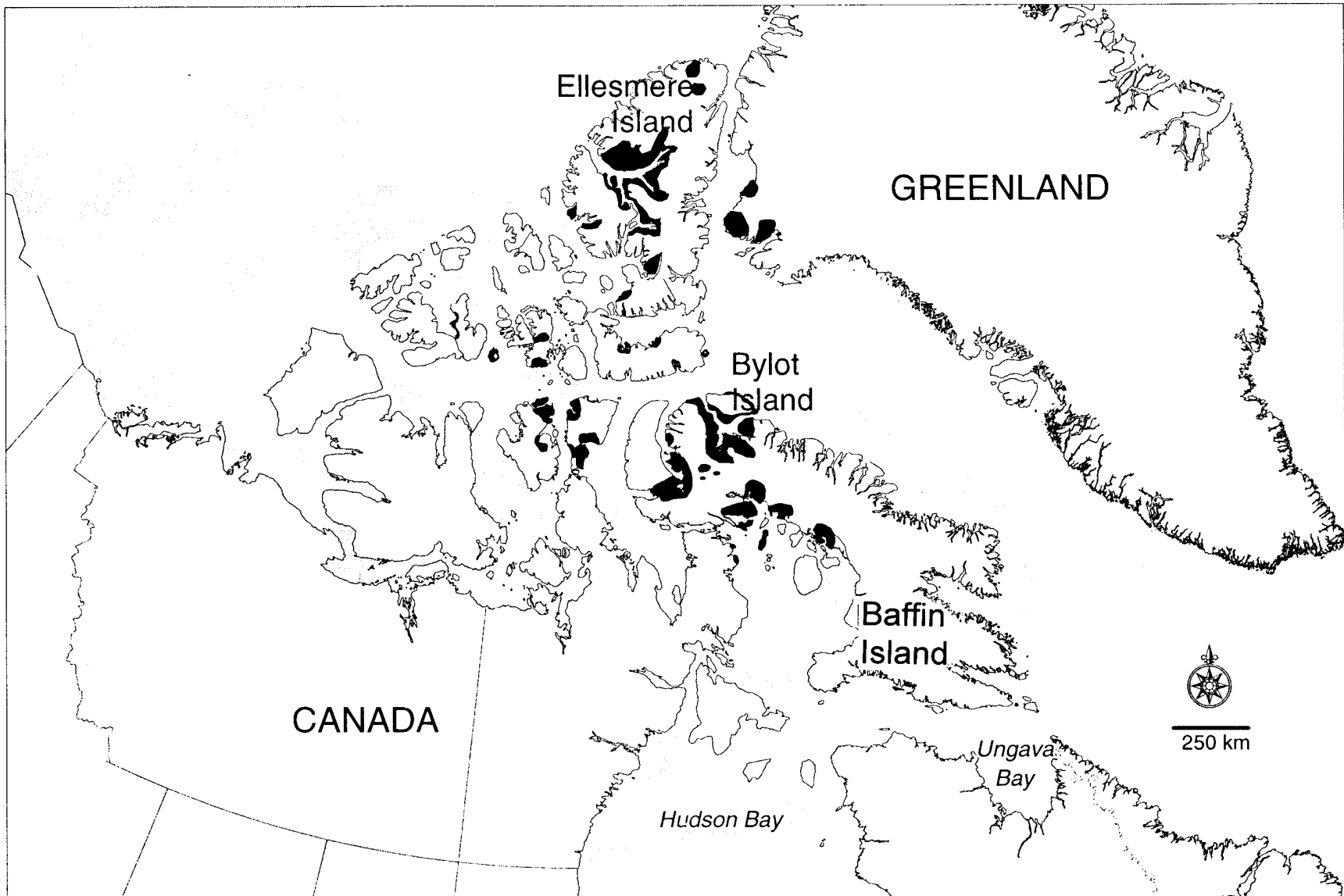
Figure 1-9. Breeding range of the greater snow goose.

Lake St-Jean

St.Lawrence River

Québec

1970s - 78%
1990s - 62%

Lac Saint-Pierre

1970s - 2%
1990s - 10%

Richelieu

1970s - 4%
1990s - 13%

50 km
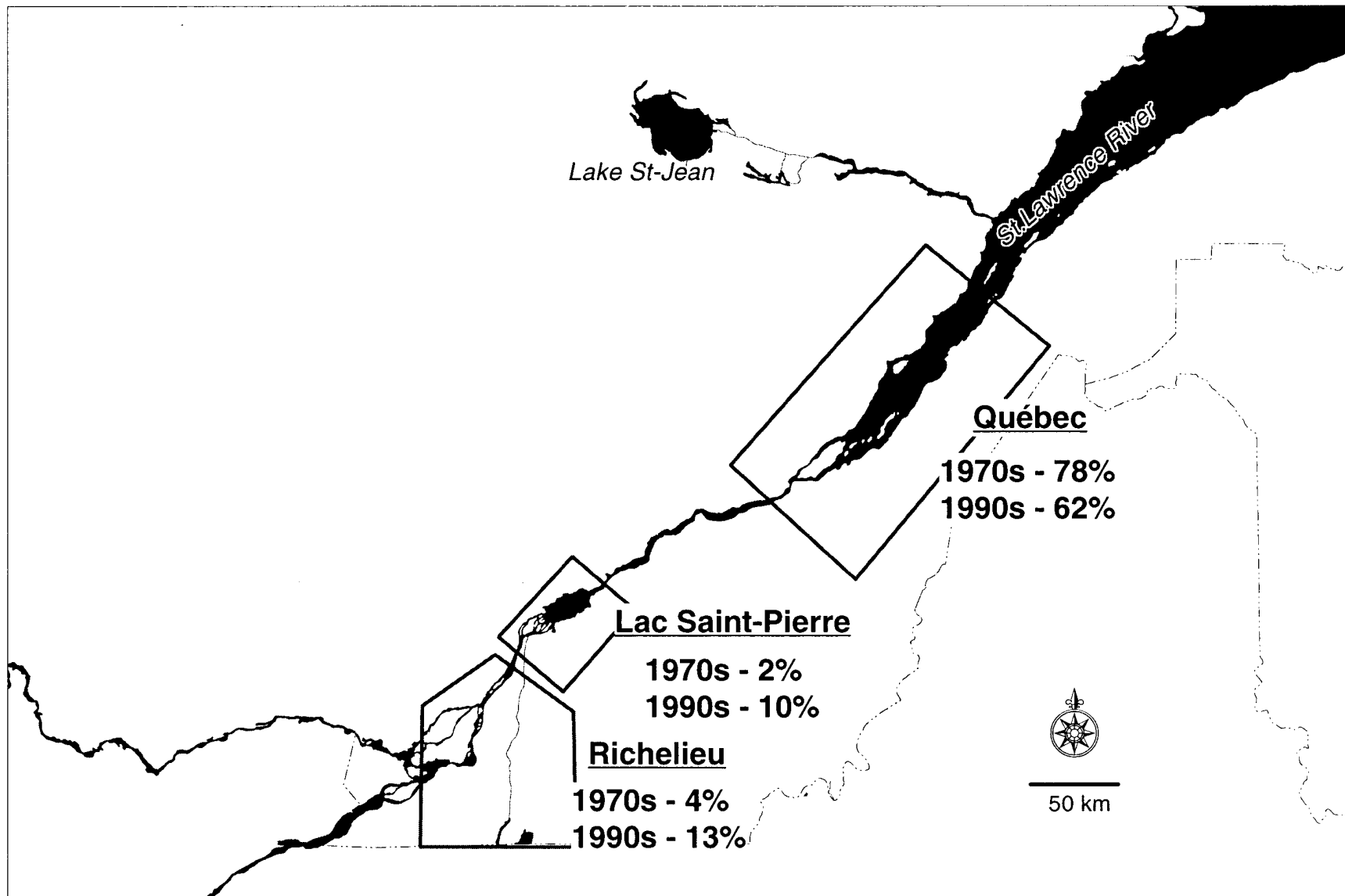
Figure 1-10. Changing patterns of fall distribution in the St. Lawrence staging area as shown by receipts of tail fans in the National Harvest Surveys : 1970s versus 1990s (through 1995).

snow geese in southern Québec in fall (Malecki et al. 1998). However, these birds do not represent a large proportion of the total population. On the other hand, birds marked on the Hudson Bay side of Ungava Peninsula where the greatest concentrations of AP Canada geese nest have a more westerly fall migration route (west of Lake Champlain) than greater snow geese. No concentrations of Canada geese have been regularly reported on staging areas used by greater snow geese in fall. The potential for competitive exclusion of AP Canada geese by greater snow geese in fall is thus currently limited.

In conclusion, despite anecdotal evidence, there is little scientific evidence of a direct interaction between the two species. However, further increase of the greater snow goose population and/or further expansion of its distribution especially in spring could influence the staging distribution of AP Canada geese. It presently appears unlikely that habitat management for snow geese in southern Québec could short-stop AP Canada geese, but this subject deserves further study.

SUMMARY

1. The greater snow goose population has increased from <50,000 geese in spring 1965-1968 to more than 650,000 in 1996-1997. After re-opening of the hunt in the U.S. in 1975, there was a short period of apparent stability (1975-1982). However, the average growth rate since 1982 has exceeded 9%.

2. Productivity, as measured by age ratios (% juveniles) in the fall flight, has averaged 24.2% over the period 1965-1997, showing no long-term trend. Productivity has, however, fluctuated considerably, reflecting the climatic harshness of their high Arctic breeding range.

3. Total recreational harvest increased during the period 1967-1995. A large part of this increase resulted from re-opening of hunting in the U.S. in 1975. From 1975 to 1995, the annual harvest increased in Canada (Québec), but not in the U.S.

4. The harvest by native subsistence hunters is poorly documented but is believed to be relatively unimportant in comparison to recreational harvest.

5. Some recent expansion of wintering range has been recorded, but the main result of population growth has been a build up of numbers in Delaware and Maryland, and since 1991 in New Jersey, New York, and Pennsylvania. Numbers have declined in the southern portion of the winter range (e.g. North Carolina). Field feeding has become widespread on the wintering grounds.

6. As the population has increased over the past three decades, the main staging area along the St. Lawrence has expanded from a 40-km portion of the river to more than 400-km, and now extends along the Richelieu River to northern Lake Champlain. This has been accompanied by increased field feeding on adjacent farmland.

7. Recent study has revealed the presence of a staging area in Ungava which may be especially important in fall for geese migrating between breeding areas and the St. Lawrence staging area.

8. During the last three decades, only a few new breeding areas have been discovered and the overall breeding range has expanded only slightly. The most important result of the increase in population appears to be increasing densities at main breeding colonies. This has been substantiated at the largest known colony, Bylot Island, where the numbers of breeding geese increased threefold between 1983 and 1993.

9. A factor contributing to continued population growth since the mid-1980s is the fact that the hunting kill has increased more slowly than the goose population, resulting in reduced harvest rates. Harvest rate is now about one half of the rate that prevailed during the period of near-stable population in 1975-1983. Non-hunting mortality during the non-breeding season may have remained low or even decreased as the geese have gradually discovered a supplementary food supply on agricultural land.

10. Productivity has not declined, despite increasing densities on breeding areas where no agricultural food supplements are available. Nevertheless, some density dependent effects are showing up (see Chapter 2), but these are not presently preventing population growth nor reducing age ratios in the fall flight.

11. Changing patterns of fall migration and distribution (e.g. more stop-offs, shorter flight distances between the traditional staging area in the St. Lawrence and the wintering grounds) could partly reflect increased pressure on food resources in natural habitats (see Chapter 2) resulting in possible decrease in body condition of the geese while staging in the St. Lawrence (Reed and Plante 1997). However, geese now have access to an abundant supply of high quality food in agricultural fields, especially in wintering areas and during spring staging, and there is evidence that this has lead to improved body condition in spring (Gauthier *et al.* 1992).

12. The gradual shift in fall staging from the traditional *Scirpus* marshes of the upper St. Lawrence estuary to the cornfields of southwestern Québec may result in a decrease in the harvest rate because: 1) the tradition of hunting this species is less well developed in this area, and 2) the long, unpredictable daily feeding flights from roosting sites to cornfields make the geese more difficult to hunt than in the marshes of the St. Lawrence estuary.

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Appendix A: Results of spring surveys of greater snow geese in the St. Lawrence valley, 1991-1997. The first value is the population estimate derived from the photo counts, followed by the coefficient of variation (in parentheses), followed by the number of geese not included in the photo count, followed by the grand total, rounded to the nearest hundred.

		Period	
Year	late April	early May	mid-May
1991	259900 (6.4) + 12090 = 272	342100 (4.6) + 10487 = 352	287500 (4.8) + 11910 = 2994
1992	417600 (6.0) + 16235 = 433	428400 (4.6) + 5615 = 434	436100 (4.6) + 11980 = 448
1993	349200 (4.5) + 7570 = 356	417400 (5.2) + 165 = 417	496000 (4.2) + 2365 = 4984
1994	403900 (6.3) + 1748 = 405	418100 (4.3) + 1916 = 420	587900 (4.5) + 3450 = 5914
1995	501300 (6.2) + 3210 = 504	563900 (4.3) + 4039 = 567	611800 (4.1) + 4820 = 616
1996	no sur	579700 (4.3) + 5443 = 585	664500 (5.1) + 4586 = 669
1997	no sur	586800 (4.8) + 8902 = 595	650800 (4.2) + 6745 = 657

Appendix B: Greater snow goose population indices from mid-winter surveys in the Atlantic Flyway states and population size in spring (from aerial photographic counts in the St. Lawrence valley).

Mid-winter survey in the U.S.[1]		Spring survey in Québec	
Year	Number of geese	Year	Number of geese
1964/65	46 500	1965	25 400
1965/66	43 400	1966	25 400
1966/67	59 900	1967	40 900
1967/68	50 500	1968	38 900
1968/69	62 800	1969	68 800
1969/70	29 500	1970	89 600
1970/71	48 500	1971	123 300
1971/72	81 100	1972	134 800
1972/73	60 000	1973	143 000
1973/74	98 300	1974	165 000
1974/75	75 400	1975	153 800
1975/76	117 500	1976	165 600
1976/77	152 900	1977	160 000
1977/78	87 000	1978	192 600
1978/79	112 200	1979	170 100
1979/80	129 400	1980	180 000
1980/81	95 600	1981	170 800
1981/82	107 100	1982	163 000
1982/83	122 500	1983	185 000
1983/84	133 500	1984	225 400
1984/85	273 400	1985	260 000
1985/86	137 700	1986	303 500
1986/87	143 700	1987	255 000
1987/88	241 400	1988	363 800
1988/89	283 600	1989	363 200
1989/90	231 200	1990	368 300
1990/91	199 000	1991	352 600
1991/92	276 000	1992	448 100
1992/93	181 700	1993	498 400
1993/94	219 600	1994	591 400
1994/95	353 500	1995	616 600
1995/96	222 900	1996	669 100
1996/97		1997	657 500

[1] Data extracted from: Serie, J. (compiler) 1996. Atlantic Flyway: Waterfowl Harvest and Population Survey Data. U.S. Fish and Wildlife Service, Laurel, Md. Mimeo 80pp.

Appendix C: Productivity surveys of greater snow geese in Canada and the U.S., 1956-1997.

Year	U.S. visual	Québec visual	Québec aerial photo
1956	33.8		
1957	34.4		
1958	3.1		
1959	42.7		
1960	34.1		
1961	1.2		
1962	28.4		
1963	33.9 (2728)		
1964	20.5 (8179)		
1965	2.8 (2524)		
1966	37.0 (5516)		
1967	12.4 (5236)[1]		
1968	12.5 (3613)		
1969	24.3 (5004)		30.0
1970	46.8 (6930)		45.6
1971	11.3 (8334)		29.7
1972	0.4 (3214)		
1973	41.1 (4900)	40.6 (800)[1]	46.6
1974	2.0 (6148)	6.4 (7282)	
1975	37.3 (11460)	31.2 (17579)	32.7
1976	9.8 (34892)	12.6 (20847)	9.5 (120755)
1977	23.8 (7531)	23.9 (10297)	21.6 (132425)
1978	14.7 (16159)	17.9 (9679)	20.1 (205419)
1979	23.2 (8041)	28.2 (20849)	22.5 (179002)
1980	36.3 (12140)	35.3 (12120)	40.1 (164453)
1981	17.0 (17229)	16.3 (10683)	16.8 (86039)
1982	23.8 (12773)	25.1 (9577)	10.5 (65436)
1983	48.9 (19206)	47.4 (12353)	41.6 (100910)
1984	27.4 (11133)	30.4 (39781)	37.6 (103000)
1985	31.0 (14972)	25.8 (33700)	
1986	2.3 (13109)	2.3 (22998)	
1987	37.9 (17467)	40.2 (33278)	
1988	31.2 (14467)	33.1 (40246)	
1989	30.1 (17735)	31.1 (29191)	
1990	17.2 (24439)	23.6 (20313)	
1991	26.2 (27805)	38.3 (15102)	
1992	4.5 (10501)	5.4 (32252)	
1993	44.6 (23082)	47.8 (24163)	
1994	13.4 (19726)	9.2 (16444)	
1995	13.3 (13221)	16.6 (19519)	
1996	30.5 (23728)	25.1 (22595)	
1997		36.8 (17586)	

[1] Percentage values in bold print were used in Fig.1- 4 (see text)

Appendix D: Annual mean brood size of greater snow geese, recorded on staging (Québec, October) or wintering (U.S., November), 1965-1997.

Year	Where recorded	Sample size (no. Broods)	Mean brood size	SE
1965	U.S.		1.71	
1966	U.S.		2.16	
1967	U.S.		2.37	
1968	U.S.		1.65	
1969	U.S.		2.23	
1970	U.S.		2.89	
1971	U.S.		2.21	
1972	U.S. - Québec		no data	
1973	Québec	49	2.94	
1974	Québec	119	2.19	
1975	Québec	1294	2.71	
1976	Québec	419	2.46	
1977	Québec	396	2.28	
1978	Québec	309	2.34	
1979	Québec	1226	2.65	
1980	Québec	651	2.76	0.053
1981	Québec	229	2.30	0.081
1982	Québec	661	2.48	0.047
1983	Québec	1246	2.86	0.043
1984	Québec	2434	2.63	0.029
1985	Québec	1682	2.49	0.033
1986	Québec	74	1.89	0.105
1987	Québec	1882	2.77	0.031
1988	Québec	2444	2.76	0.029
1989	Québec	2014	2.59	0.033
1990	Québec	830	2.54	0.047
1991	Québec	1247	2.69	0.038
1992	Québec	404	2.06	0.048
1993	Québec	2743	2.75	0.028
1994	Québec	242	2.44	0.091
1995	Québec	665	2.47	0.049
1996	Québec	1247	2.34	0.035
1997	Québec	1222	2.69	0.041

Appendix E: Recreational harvests of snow geese in southern Québec and the Atlantic Flyway states, 1967-1997.

Year	Québec	Atlantic Flyway	Total
1967	16800	season closed	16800
1968	2700	season closed	2700
1969	3300	season closed	3300
1970	25300	season closed	25300
1971	13300	season closed	13300
1972	6100	season closed	6100
1973	26200	season closed	26200
1974	9000	season closed	9000
1975	31400	8500	39900
1976	25100	12300	37400
1977	20100	28200	48300
1978	41200	21600	62800
1979	23400	25000	48400
1980	54400	27300	81700
1981	29500	13500	43000
1982	40700	21700	62400
1983	45300	40400	85700
1984	42400	38000	80400
1985	24500	15000	39500
1986	9700	8800	18500
1987	38100	28500	66600
1988	42800	22300	65100
1989	43000	17600	60600
1990	57400	21200	78600
1991	46300	26900	73200
1992	26700	10600	37300
1993	92700	29100	121800
1994	37200	18300	55500
1995	44500	18200	62700
1996	62900	32000	94900
1997	55200	35100	90300

CHAPTER 2

IMPACT OF GEESE ON NATURAL HABITATS

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INTRODUCTION

Greater snow geese are strict herbivores, i.e. they only eat plants, but they use several foraging modes. It is important to understand the difference between these foraging modes because their effects on plant communities will differ greatly. Foraging behavior of greater snow geese can be divided into two main categories: feeding on aboveground and on belowground vegetation.

The main foraging mode of birds feeding on aboveground vegetation is grazing, which involves the removal of leaves, flowers or entire shoots. This is the predominant foraging mode used by geese in farmlands (e.g. in hayfields) or in the tundra during the summer. Feeding on cereal grains is another foraging mode used by geese in farmlands. This involves gleaning waste cereal grains such as oats or corn after the harvest.

Belowground feeding is also very important in Greater snow geese and they are extremely well adapted to this activity. They have a very strong bill, much stronger in fact than most other goose species including lesser snow geese, which suggests that belowground feeding has always been a dominant foraging behavior in this species (Bolen and Rylander 1978). Grubbing is the most common foraging mode of geese feeding on belowground vegetation. Grubbing involves digging in the ground to extract rhizomes, bulbs or roots of plants (Smith and Odum 1981, Bélanger and Bédard 1994a). This activity is restricted to natural habitats such as tidal marshes in southern Québec and the United States, or in early spring in the Arctic. Geese rarely grub in farmlands (except perhaps in flooded fields). Shoot pulling is another foraging mode used by geese feeding on belowground vegetation. This behavior involved the removal of white basal stems of sedges buried in the ground while discarding dead or senescing aboveground parts. This occurs mostly in early spring or late summer in the Arctic (Gauthier 1993) or early fall in tidal marshes of southern Québec (Giroux and Bédard 1988a).

ST. LAWRENCE RIVER

Use of Natural Habitats by Greater Snow Geese along the St. Lawrence River

Greater snow geese have traditionally used bulrush marshes during their spring and fall staging periods along the St. Lawrence estuary (Lemieux 1959). With the demographic expansion of the population in the mid-1970s, they started to spread into cordgrass salt marshes during their spring migration (Gauthier *et al.* 1988). These marshes are located in the La Pocatière, Kamouraska and Isle-Verte regions where geese depend to a great extent on the adjacent agricultural fields for feeding. Although no studies on the effects of geese on cordgrass marshes have been conducted in this area, no degradation comparable to eat-outs observed along the U.S. Atlantic coast has been noted. If goose grazing affects salt marshes, it is probably localized and at very small scale (few m^2). The rest of this chapter will therefore deal with the effect of geese on bulrush marshes.

Distribution and Area of Bulrush Marshes along the St. Lawrence River

Marshes dominated by three-square bulrush (*Scirpus pungens*)[1] cover approximately 4000 ha along the St. Lawrence river (Anon. 1980, Jacques 1986). One fourth of the acreage of these marshes are located in the freshwater non-tidal portion of the river (specially around Lake St. Pierre) and their use by geese is limited. The remaining portion is found east of Québec City and consists of freshwater and brackish tidal marshes characterized by an upper and lower portion separated by a 30-70 cm high micro-bluff. The upper marsh is 20- to 100-m wide and is flooded by equinoctial tides. It is dominated by prairie cordgrass (*Spartina pectinata*) and saltmarsh sedge (*Carex paleacea*) and is mostly used by geese for resting. The lower marsh located below mean high water mark is characterized by a mixed semidiurnal tide with two complete oscillations per day, unequal in height and duration. Tidal amplitude reaches 4 to 6 m. The lower marsh which is the main feeding area of geese consists of a 100- to 1,000-m band of vegetation dominated by *Scirpus pungens* with sparse growth of wild rice (*Zizania aquatica* var. *brevis*), arrowhead (mostly *Sagittaria latifolia*), Torrey bulrush (*Scirpus torreyi*), and spikerush (*Eleocharis* spp.) (Giroux and Bédard 1988b). It is also bordered by bare mudflats extending 200 to 1,000 m from the vegetation down to the lowest low tide.

This section of the estuary is characterized by high natural turbidity resulting in sedimentation of tidal marshes from June to mid-September (Sérodes and Troude 1984). Accretion of sediments along the south shore can be up to 14 cm (Giroux and Bédard 1988b) and 30 cm at Cap Tourmente (Sérodes and Troude 1984). Two periods of rapid erosion (October-November and April) bring the mud flat surface back to its approximate original level. From December to April, these marshes are covered by a 1.0- to1.5-m layer of ice.

In the last 50 years, approximately 15% of the marshes of the estuary have disappeared through reclamation for agriculture, road construction or other developments (Anon. 1981). Several of the bulrush marshes used by geese are now part of the Migratory Bird Sanctuary network or located within the Cap Tourmente National Wildlife Area.

Feeding Behavior of Geese in Bulrush Marshes

Greater snow geese feed in bulrush marshes during both their spring and fall migrations (Giroux and Bédard 1988c, Reed 1989). In the early 1980s, Gauthier *et al.* (1988) estimated that, in spring, geese spent approximately 90% of their feeding time in those marshes and the remaining in adjacent agricultural fields. In 1997, preliminary observations of radio marked birds revealed that this is probably less than 50% (A. Béchet, Ph.D. candidate, UQAM, unpubl. data).

In fall, the relative use of marshes varies among sites depending upon the amount of hunting activities in adjacent agricultural fields. At Cap Tourmente where large tracts of fields are available for geese, Reed (1989) estimated that only 30% of fall usage recorded between 1980 and 1985 occurred on the tidal marsh. Part of the remaining 70% occurred in fields, and over the years this has probably remained stable (A. Reed unpubl. data). Along the south shore during the mid-1980s, geese were totally dependent upon marshes for feeding because of the presence of hunters in nearly all-adjacent fields (Giroux and Bédard 1988c). In recent years, however, a greater proportion of feeding time is spent in agricultural fields thus reducing the relative use of marshes by geese (J.-F. Giroux and G. Gauthier, unpubl. data).

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[1] Based on his taxonomic review, Schuyler (1974) proposed that plants usually treated as *Scirpus americanus* Pers. should be called *Scirpus pungens* Vahl and those identified as *Scirpus Olneyi* Gray be treated as *Scirpus americanus* Pers.

Despite these changes, marshes located within the migratory bird sanctuaries are still used to a greater extent than adjacent marshes because of their greater use in fall attributed to hunting pressure. Marshes outside the sanctuaries are used in spring and during nighttime in fall, a situation prevailing in the mid-1980s (Giroux and Bédard 1988c).

In fall, three-square bulrush represents approximately 75% of the diet of geese feeding in marshes (Giroux and Bédard 1988a). Wild rice, arrowhead and spikerush account for another 20% while the rest of the diet is composed of several less important species. Juveniles feed to a greater extent on the above- and belowground stems of bulrush while adults feed more on rhizomes. The proportion of stems in the diet decreases during the season with depletion of this resource and possibly with the increased efficiency of juveniles in grubbing.

Dead plants are either exported by tide in late fall or ultimately removed at spring break-up when large ice floes plowed and scoured the marsh surface (Bélanger and Bédard 1994a). Aboveground vegetation has therefore completely disappeared when the geese return to the marshes in spring. Bédard and Gauthier (1989) estimated that 97-99% of the diet of geese feeding in spring in marshes was constituted by bulrush rhizomes. Bélanger and Bédard (1994b) reported that geese also grazed on the emerging shoots of bulrush in late spring but their relative importance in the diet has never been established. They speculated that this grazing strategy compared to grubbing was best explained by a lower foraging cost since the nutritive value of emerging shoots was comparable to rhizomes (Bélanger and Bédard 1992).

When the birds arrived in fall, they used the stems of bulrush as a cue to get to the rhizomes 10-25 cm below the surface (Reed 1989, Bélanger and Bédard 1995). Stems disappear quickly through trampling, clipping or eating and the marsh surface is then covered by a layer of soft sediment. Digging is done more or less randomly at that time. When sediments eroded in late fall and spring, geese concentrate their activity in or at the edge of ice-scoured depressions to extract rhizomes (Bélanger and Bédard 1995). They avoid any undisturbed and/or hardened rocky marsh surface. As the ebb tide exposes the marsh, geese spread out and move continuously from one depression to another. Feeding activities remain high until low tide when it drops to nearly 50%, and remains moderate through flood tide (Gauthier *et al.* 1988). It is believed that foraging geese follow the tide to take advantage of a softer substrate.

Effect of Geese on Bulrush Production

Based on the number of goose-hours recorded at the Montmagny sanctuary and on the ingestion rate calculated by Bédard and Gauthier (1989), Giroux and Bédard (1987a) estimated that up to 62 g/m^2 of rhizomes were eaten annually (fall + spring). This represented 23% of the belowground biomass available and 59% of the net belowground primary production. Using a series of exclosures established at Cap Tourmente, Reed (1989) estimated that geese removed 55 g/m^2 during their fall staging period which represented 32% of the belowground biomass available. By comparing seasonal changes in belowground biomass, Reed (1989) also measured a decrease of 112 g/m^2 or 74% between September (before goose arrival) and early June (after goose departure). This last figure, however, may be slightly overestimated because losses attributed to plant die-off, reserve translocation to shoots, erosion and ice-scouring were not considered (Reed 1989).

In the heavily used marshes at the Montmagny sanctuary, Giroux and Bédard (1987a) observed a 62% difference in plant production between grazed and ungrazed plots after 2 years of goose exclusion (Fig. 2-1). The higher biomass in the ungrazed plots was related to both a greater number of shoots and a greater shoot biomass. Belowground biomass was not assessed in this study because a non-destructive sampling technique in permanent plots was chosen for this short-term evaluation. Nevertheless, there is a strong positive relationship between aboveground biomass and

belowground biomass that can be used to estimate net belowground primary production (Giroux and Bédard 1988d). The difference in aboveground biomass between grazed and ungrazed plots therefore represented 410 g/m^2 of belowground biomass. Similar results were obtained at the Cap St-Ignace sanctuary, a nearby marsh less used by geese. The difference between grazed and ungrazed plots was 28% after 1 year of goose exclusion (Giroux and Bédard 1987a). No difference was found, however, between grazed and ungrazed plots outside the sanctuaries at Montmagny and Cap St. Ignace reflecting the limited use of these marshes by geese compared to sanctuaries (Giroux and Bédard 1988c).
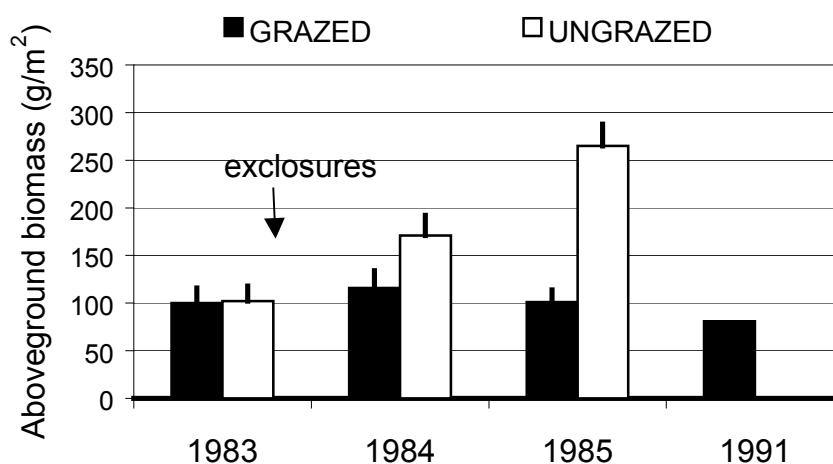

Figure 2-1 Aboveground biomass of three-square (mean + 1 SE) in grazed and ungrazed plots at the Montmagny sanctuary, 1983-1985, 1991. Note: exclosures were put up after the growing season in 1983 just before goose arrival. Non-destructive sampling of the same 45 paired plots was conducted from 1983-85. In 1991, plots (excluding exclosures) were located at approximately the same place as in 1983-85 (Data from J.-F. Giroux, UQAM and A. Reed, CWS).

At Montmagny, the aboveground biomass in the grazed plots was stable between 1983 and 1985 and averaged 106 g/m^2 or 267 g/m^2 of belowground biomass (Fig. 2-1). Giroux and Bédard (1987a) concluded that geese maintained the system at a low-level steady state while Bélanger and Bédard (1994b) argued that this resulted from a shift by geese of their foraging sites within the marsh when a minimal threshold of food was reached. Based on their study of the foraging behavior of geese, Bélanger and Bédard (1994b) suggested that this level was approximately 220 g/m^2 of belowground biomass. In 1991, the aboveground biomass was still at the same level than during the previous sampling period supporting the idea of a steady state (Fig. 2-1).

A unique long-term data set is available for the Cap Tourmente marshes where bulrush stem density has been determined annually between 1971 and 1984 and every second year since. Annual variations between 1971 and 1996 were important and may be attributed to the growing conditions prevailing during the summer as shown by Giroux and Bédard (1987b). Nevertheless, stem density declined by 40% during the last 25 years (Fig. 2-2; n = 18 years, r2= 0.28, t =-2.67, P = 0.02).

These evaluations on the effect of goose grubbing on plant production conducted at Montmagny and Cap Tourmente are supported by an experimental study that showed that even a low intensity of simulated feeding can reduce subsequent production of bulrush (Giroux and Bédard 1987c). This is consistent with the role of nutrient reserves played by the belowground parts of bulrush which does not allow for compensation as has been observed for aboveground herbivory (Cargill and Jefferies 1984).

Unlike alkali bulrush (*Scirpus robustus*), three-square bulrush does not respond to removal of its belowground reserves by increasing its sexual reproduction (Smith and Odum 1981, Giroux and Bédard 1987a). Giroux and Bédard (1995) speculated that this was related to the poor seedling establishment due to the important sediment accretion occurring in these marshes at that time.
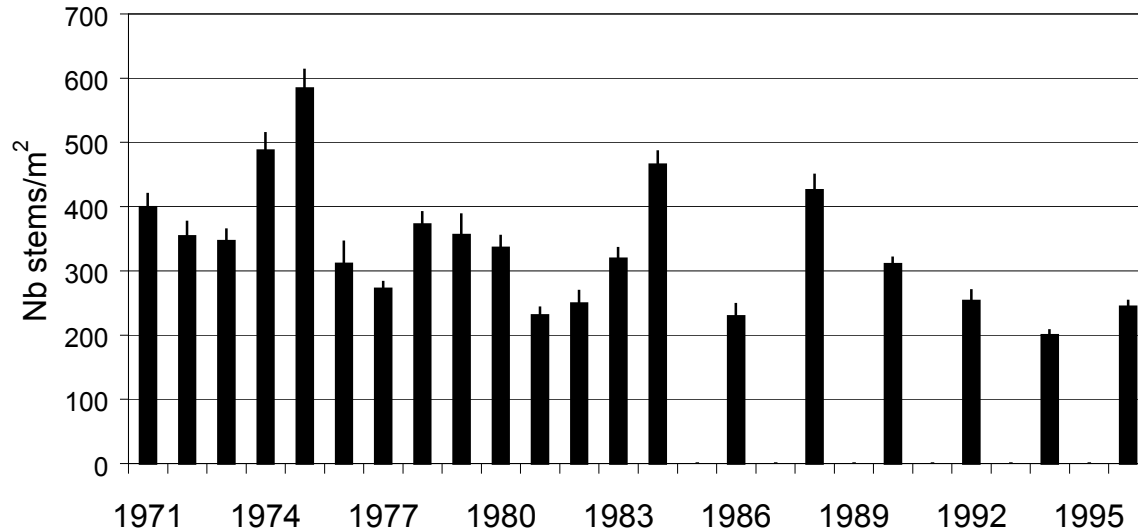

Figure 2-2 Stem density of three-square bulrush (mean + 1 SE) at the Cap Tourmente National Wildlife Area, 1971-196. Sample size was 375 plots/year although in some years it varied between 297 and 382 (Data from A. Reed, CWS).

Effect of Geese on Plant Species Composition

During his long-term study, Reed (1989, unpubl. data) recorded an inverse relationship between three-square bulrush and wild rice stem densities (r = -0.51, n= 18, P = 0.03). At the Montmagny sanctuary, Giroux and Bédard (1987a) found a greater production of wild rice in grazed than in ungrazed plots. They suggested that the small depressions created by geese when grubbing for rhizomes of bulrush offer a good substrate for the germination of wild rice because they are filled with unconsolidated nutrient-rich sediment. Moreover, the decreased biomass of bulrush in the grazed plots decreases the shading effect and increases light availability for the seedlings of wild rice. This suggestion was supported by the results of Bélanger and Bédard (1994a) who observed a greater production of wild rice in grazed disturbed patches (ice-made depressions) than in undisturbed patches.

Giroux and Bédard (1987b) suggested that competitive interference was occurring between three-square and Torrey bulrush but did not observe an increase of Torrey bulrush in their grazed plots (Giroux and Bédard 1987a). Bélanger and Bédard (1994a), however, found a greater production of Torrey bulrush in grazed patches disturbed for at least 2 years and suggested that grubbing by geese facilitates colonization by Torrey bulrush. This species lacks the white belowground stem of three-square bulrush and its rhizomes are much smaller making it an unattractive food source for geese. During a visit of the Montmagny sanctuary in August 1997, J.-F. Giroux noted that the relative abundance of Torrey bulrush appears to have considerably increased in recent years at the expense of three-square bulrush. It is interesting to note that Torrey bulrush is candidate to be considered a vulnerable plant in Québec (Gratton and Dubreuil 1990). We believe that its abundance at Montmagny and in nearby marshes does not warrant such consideration anymore.

Effect of Geese on Bulrush Quality

In several Arctic ecosystems including Bylot Island, goose grazing improves forage quality (nitrogen content) by keeping plants at an early growth stage (Gauthier *et al.* 1995). Bélanger *et al.* (1990), however, found no difference in plant quality (fiber and nitrogen) between belowground parts of three-square bulrush extracted from grazed and ungrazed plots where geese had been excluded for 3 years. The only difference was a lower proportion of roots attached to rhizomes in grazed plots (12.2±2.2%) compared to ungrazed plots (34.0±6.0%). Less roots may facilitate extraction of rhizomes and this can be considered an improvement of the feeding sites following grubbing by geese.

Deposition of secondary metabolites possibly acting as deterrents to herbivores is a common evolutionary response of plants in many plant-herbivore systems (Rhoades 1985). Such an antiherbivory mechanism does not appear to have evolved in three-square bulrush because no difference in total phenols was observed between rhizomes from grazed and ungrazed plots (Bélanger *et al.* 1990).

Effect of Geese on Marsh Erosion

Dionne (1985) predicted that grubbing by geese at the surface of bulrush marshes in the estuary would result in vertical erosion. Quantitative data are not available and the exact role of geese have not been established either. Nevertheless, casual observations by local people and J.-F. Giroux confirm that marsh elevation at least in the Montmagny sanctuary is now lower than in the mid-1980s.

Dionne (1985) also claimed that removal of aboveground vegetation by geese in fall was contributing to erosion of the micro-bluff that separates the lower and upper marsh at Montmagny by increasing wave action. He measured annual retreats up to 1 m but the relative contribution of geese to this phenomenon is unknown because similar retreats were measured in other marshes where geese are absent (Dionne 1986). Nevertheless, snow geese may exacerbate a natural problem of erosion associated with a recent sea-level rise that increases ice and wave action and results in bare mudflats at the upper end of the lower marsh (Dionne 1986). These bare mudflats, however, are colonized by three-square bulrush through sexual reproduction (Giroux and Bédard 1995).

Although published quantitative data are limited and the relative role of geese unknown, a marked retreat of the micro-bluff occurred between the mid-1980s and 1997 at Montmagny and possibly in nearby marshes (J.-C. Dionne, pers. comm., J.-F. Giroux, pers. obs.). Associated with the geo-morphological changes observed at Montmagny, the plant community characterized by three-square bulrush, spikerush, Torrey bulrush, nodding beggarticks (*Bidens cernua*), arrowhead, burreed (*Sparganium* spp.), and waterparsnip (*Sium suave*) located at the upper end of the lower marsh (Community 4 of Giroux and Bédard 1988a) has been replaced by a community dominated by three-square and Torrey bulrush (J.-F. Giroux, pers. obs.). The significance of this increase of potential feeding habitats for geese has not been established.

Sérodes and Troude (1984) have established a relationship between the amount of sediments accreting in marshes and the number of bulrush stems that act as trap to sediments. Reduction in stem density following grubbing by geese (Reed, unpubl. data, Giroux and Bédard 1987a) may thus contribute to changes in the annual sedimentation rate of these marshes influencing the equilibrium between erosion and sedimentation.

Effect of Geese on Other Species

No detailed information is available regarding the consequences of goose grubbing on other species. These marshes are used by ducks and the traditional concentrations of fall staging northern pintails (*Anas acuta*) at the Montmagny sanctuary, and pintails, green-winged teal (*A. crecca*) and American black ducks (*A. rubripes*) at Cap Tourmente, are still observed (J.-F. Giroux and A. Reed, unpubl. data). The greatest abundance of wild rice following goose grubbing may even enhance the attractiveness of these marshes for waterfowl in late summer and early fall. Large numbers of gastropods and invertebrate larvae have been observed on mudflats covered by algae (in the mid-1980s) at Montmagny and Cap Tourmente (J.-F. Giroux and A. Reed, pers. obs.) but their abundance and distribution have not been monitored. The fish community of these marshes has received little attention and the effect of goose grazing on the sites used by fishes in the lower and upper marshes has not been studied.

Restoration of Bulrush Marshes

Restoration of bulrush marshes is very difficult. The limited contribution of sexual reproduction precludes seeding and therefore requires the transplantation of rhizomes or pieces of sods including rhizomes with or without shoots. This is very laborious and expensive. The best strategy that has been recommended for many years is the rotation of the sanctuaries in an attempt to equilibrate goose use (Giroux and Bédard 1987a, Bélanger and Bédard 1994b). This has not been done so far.

Conclusions - St. Lawrence River

Studies on the effect of geese on bulrush marshes conducted in the mid- and late 1980s along the estuary concluded that geese and marshes were at equilibrium but at a low-level steady state (Giroux and Bédard 1987a, Reed 1989). Giroux and Bédard (1987a) also claimed that three-square bulrush had a good ability to withstand high, chronic grazing because it recovered rapidly once geese were removed. They based their suggestion on the fact that bulrush production in the Montmagny sanctuary exclosures reached levels comparable to the ungrazed portions of the marsh outside the sanctuary after only 2 years of goose exclusion. These studies, however, took place when the population was less than half of what it is now. The decreased number of goose-days recorded in fall at Cap Tourmente during the last 10 years (A. Reed, unpubl. data), the declining productivity of three-square bulrush at Cap Tourmente and possibly at Montmagny, changes in plant species composition in several marshes and erosion of marshes along the south shore are all indications that the carrying capacity of these marshes may have been reached and that they can no longer accommodate the increasing number of geese.

Based on the fall use of the Montmagny marshes by geese during the mid-1980s (4,316 goose-days/ha) when the system was believed to be at equilibrium (Giroux and Bédard 1987a, 1988b) it is estimated that the 3,000 ha of bulrush marshes present along the estuary could theoretically accommodate the 1 million birds of the 1997 fall flight for only 13 days (Giroux, unpubl. data). This illustrates the potential value of increasing the carrying capacity of this fall habitat. It is therefore urgent that rotation of sanctuaries be implemented to equilibrate bird use. Management of agricultural habitats near sanctuaries is also essential to lessen the grazing pressure in the tidal marshes and to retain more birds for longer periods in order to benefit from this resource.

Bulrush marshes play an important role in the St. Lawrence estuary ecosystem. Deschênes and Sérodes (1986) demonstrated that three-square bulrush can assimilate heavy metals and large quantity of nutrients such as phosphorous indicating an important purification role of these marshes. Moreover, all the plant material exported in fall to the lower estuary and the Gulf contributes to

trophic chains of these ecosystems. The overall functions of bulrush marshes should therefore be considered when evaluating the impact of geese on these marshes. Costanza *et al.* (1997) recently produced an interesting analysis on the nature capital and ecosystem services that help appreciate some of the externalities not usually considered in assessing environmental impacts and socio-economic benefits or losses related to man-made developments. Wildlife damage to natural ecosystems, especially when human induced, also have their hidden costs.

Summary - St. Lawrence River

1. During their spring and fall migrations along the St. Lawrence estuary, greater snow geese feed in approximately 3,000 ha of bulrush marshes by grubbing for rhizomes.

2. Most studies on the effects of geese on marshes were conducted in the mid-1980s when the population was less than half of what it is now. These studies concluded that the marshes and the geese were at a low-level steady states and that marshes quickly recover when goose grazing is reduced.

3. In recent years, changes in plant species composition, declines in plant production and marsh erosion indicate that the carrying capacity of bulrush marshes may have been reached. It is concluded that bulrush marshes cannot accommodate the increasing number of geese.

4. No eat-outs comparable to those reported along the U.S. Atlantic coast have been observed along the St. Lawrence river but actions should be taken to prevent further deterioration of the St. Lawrence bulrush marshes by geese.

U.S. ATLANTIC COAST

Greater Snow Goose Use of Coastal Marshes

The effects of snow goose feeding activities on coastal wintering habitats have been recognized for a long time (Griffith 1940, Lynch *et al.* 1947). Prior to the 1960s, however, overall impacts from snow geese on coastal marshes appeared relatively small. As the snow goose population began to increase in the late 1960s and early 1970s, these impacts became more apparent. During the 1970s and 1980s, areas of denuded marsh (referred to as marsh "eat-outs") could be found from New Jersey to North Carolina. As the population continues to grow, there is increasing concern about the ecological effects that snow goose are having on coastal marshes.

Coastal salt marshes used by Greater snow geese in the Mid-Atlantic region are dominated by smooth cordgrass *Spartina alterniflora* and salt meadow cordgrass (*Spartina patens*). These Spartina grasses are perennial species that reproduce predominantly by vegetative means and less so by seed or sexual reproduction (Smith and Odum 1981). They store considerable amounts of energy in their roots and tubers (Gallagher 1983). Removal of large amounts of these root reserves will affect plant regeneration and the amount of subsequent vegetative cover on the marsh. *Spartina alterniflora* marshes grazed heavily by snow geese have been found to produce ten times less vegetative cover than ungrazed marshes (Widjeskog 1977). Estimates of belowground biomass in grazed Spartina marshes are also significantly lower than those for undisturbed Spartina marshes (Smith and Odum 1981, Young 1985). Other marsh types, such as freshwater and brackish-water bulrush (*Scirpus robustus*) marshes appear to recover more rapidly because they rely to some extent on sexual reproduction (Smith and Odum 1981).

The degree to which *Spartina* marshes are affected or the length of time required for *Spartina* marshes to recover from grazing may vary. Factors including the extent of the vegetation

removed, the size of the area impacted, degree of tidal circulation, associated wind and wave action, and other environmental variables are important in influencing the severity of the impacts and the recovery of the marsh. Some marshes denuded of standing vegetation may be able to recover relatively quickly if sufficient belowground biomass remains (Smith and Odum 1981). Marshes with little below ground biomass will recover slower if they must depend on seeds to generate new plants. In North Carolina, exclosures placed in a heavily grazed marsh had 60% greater plant cover than unprotected areas after one year (Smith and Odum 1981) (Fig. 2-1). Exclosures in heavily grazed marshes in Delaware also produced greater aerial plant cover than unprotected areas (Young 1985). In addition, the *Spartina* production in the grazed areas was stunted and seed production was reduced. Widjeskog (1978) noted that in New Jersey, some marshes along the Delaware Bay appeared able to recover in 2-3 years when grazing pressure was removed. In other areas, mostly seaside coastal marshes, recovery appeared slower, possibly because restricted tidal flow did not provide an ample seed source (Lee Widjeskog, NJ Fish, Game and Wildl., pers. commun.). In large eat-out areas, marsh recovery may progress through stages of colonization by *Cladophora* spp. (algae) and *Salicornia* spp. (glassworts) before *Spartina* becomes reestablished (Widjeskog 1978).

Areas that are grazed year after year may be maintained as mud flats. Young (1985) noted that in Delaware, impacted sites often regenerated to some extent each year, yet large amounts of once densely vegetated marshes stood as patchy growths of *Spartina alterniflora* plus mudflats. Annual vegetation sampling at Bombay Hook National Wildlife Refuge (NWR) in Delaware from 1989 through 1997 show consistently lower vegetative cover in marshes that are grazed annually as compared to marshes that are not grazed (USFWS 1997). In the coastal marsh at the Forsythe NWR in New Jersey, a large eat-out has been maintained by continued annual grazing. The lack of marsh vegetation at this site has resulted in a large area of open water at higher tides. Wind and wave action across this open water is causing further marsh erosion and may be preventing plant re-establishment.

Extent of Snow Goose Eat-outs Along the Atlantic Coast

Marsh eat-outs have been found around most refuges on the Atlantic Coast where greater snow geese stage or winter (Fig. 1-7). The amount of salt marsh habitat impacted by snow geese increased throughout the 1970s and into the 1980s, paralleling the increase in snow goose numbers. In recent years, however, the impacts on the marsh have not increased in proportion to the size of the snow goose population. The extent of damage appears to depend upon the number of geese feeding, the length of time they are present, and the availability of alternative food resources such as agricultural crops. Traditionally, snow geese fed almost exclusively on marsh vegetation in coastal marsh habitats. As the population has grown over the past 20-30 years, the birds have made greater use of green grain fields such as winter wheat, barley and rye, and harvested corn and soybean stubble fields. In areas where snow geese have taken advantage of agricultural crops, their impacts on coastal marshes appears to have stabilized.

At Bombay Hook NWR in Delaware, 539 acres of *Spartina alterniflora* marsh were lost or reduced to bare mud from 1980-1984 (Young 1985). Other areas of the marsh have been impacted to a lesser degree (less than 50% of the vegetation removed) but this damage has not been quantified. Estimates of the area denuded by snow geese (eat-out area) for the past 8 years (1989-1997) have been relatively stable between 510-600 acres each year (USFWS 1997), and are similar to the estimate made in 1985. This represents about 5% of the salt marsh habitat available on the refuge (~12,000 acres) and a smaller percentage of the amount of salt marsh available in the state (67,000 acres). During the same period, the number of snow geese using the Refuge vicinity has increased from around 65,000 in the late 1980s to over 130,000 in the last two years. In addition to feeding in the marsh, many of the snow geese using the Refuge now fly inland to agricultural fields in Delaware or Maryland, or even across Delaware Bay to fields in southern New Jersey. This has

taken some of the feeding pressure off of the marsh. Most of the feeding activity on the Bombay Hook marshes had been confined to the same areas each year. Little pioneering into new areas was noted until the past two years when record numbers of snow geese have been using the refuge. During this time, snow geese have moved to a new site but have denuded only a few additional acres (<5) thus far.

Snow goose numbers have also increased at the Prime Hook NWR, located 30 miles south of Bombay Hook NWR along the Delaware coast. Peak numbers increased from 3-4,000 in the early 1980s to around 120,000 birds in the mid-1990s. The Prime Hook refuge contains about 6,000 acres of marsh, of which 1,500 acres is tidal salt marsh and 4,500 acres is freshwater impoundments. Some minor impacts of snow goose feeding activities to coastal salt marshes have been noted in this area but they have not been quantified (Annibel Larsen, USFWS, Prime Hook NWR, pers. commun.). Snow geese have been found feeding to a greater extent in the freshwater impoundments on the refuge and in cattle feedlots on private farms off the refuge. Feeding activities in the freshwater impoundments are not thought to be detrimental but instead may have some beneficial effects. Snow geese may help open up areas of dense vegetation and maintain early successional wetland plants (annuals) that are beneficial to other waterfowl (Annibel Larsen, USFWS, Prime Hook NWR, pers. commun.).

In New Jersey, an estimated 20% (~ 1,700 acres) of the *Spartina* salt marsh in the vicinity of the Forsythe NWR (Brigantine Division) was severely impacted (>40% denuded) by snow geese between 1971-1978 (Widjeskog 1978). Snow goose numbers on the refuge had expanded rapidly at that time from around 2,000 in the late 1960s to a high of 60,000 in some years during the 1970s. Numbers have fluctuated over the past 20 years but have generally remained between 20-40,000 (USFWS, Forsythe NWR, unpubl. data). Snow goose numbers on the refuge generally peak during November and decline when colder winter weather arrives in December. These geese remain closely associated with the refuge and its surrounding marshes and do not use other Atlantic coastal marshes to any great extent despite the fact that there are >70,000 acres of additional salt marsh habitat further south along the New Jersey coast. There is little agricultural food in the vicinity of the refuge and the geese have continued to feed predominantly on the salt marsh vegetation. It appears that the area of marsh impacted has increased gradually over time and this has led to further marsh erosion (Paul Castelli, NJ Fish, Game and Wildl., pers. commun.). Because of the loss of the vegetation, wind and wave action has severely impacted the dike on the north side of the refuge impoundments (Paul Steblein, USFWS, Forsythe NWR, pers. commun.). Work to repair the dike over the past two years has cost over $150,000. Forsythe NWR is among the best bird watching sites in eastern U.S. and there are concerns that marsh degradation by Greater snow geese could affect the potential of the area.

Snow geese have also impacted marshes along the Delaware Bay coast of New Jersey. The number of snow geese in this area generally range from 20,000-40,000 in the fall. Similar to the geese at the Forsythe NWR, most birds move out with the onset of colder weather in December. Numbers increase again in late winter and early spring when as many as 175,000 snow geese may use the area during the northward migration (Perry, Obrecht and Goldsberry unpubl. rep.). Between 1,000-3,000 acres of *Spartina* spp. marsh, approximately 2% of the cordgrass marshes along the Delaware Bay shore of New Jersey, were impacted in the 1970s and 1980s. Snow geese still use these marshes but the extent of damage appears to have stabilized or even decreased in recent years (Lee Widjeskog, NJ Fish, Game and Wildl., pers. commun.). These geese have not been as restrictive in their use of habitats and have dispersed inland to use agricultural fields in southwestern New Jersey and inland in Pennsylvania.

Snow goose numbers have been increasing in Pennsylvania since the early 1990s. Few birds are present in the fall. They begin arriving in mid-December when up to 20,000 have been counted

the last several years. Their numbers increase substantially in late winter (mid-February to March) at the start of the northward migration. Up to 150,000 snow geese have been using the southeastern part of the state during this time period in the past couple years (John Dunn, PA Game Comm., pers. commun.). The geese have generally been using agricultural fields for feeding and little impact on marshes has been noted.

In Maryland, damage to salt marshes dominated by *Spartina alterniflora* has occurred near Newport Bay at the north end of Chincoteague Bay, and on several marsh islands in Chincoteague Bay. Although snow geese feed in agricultural fields during the day, wetland damage results when birds return to the salt marsh at night. Impacts have been most severe on Big Bay Point and Robbins Tump, two marsh islands in lower Chincoteague Bay. Snow geese have lowered the marsh elevation, causing nine ponds to become incorporated into three large ponds, and increasing the size of the open water area by >300% (L.J. Hindman, Maryland Dept. Nat. Res., Wye Mills, pers. commun.). Property owners have proposed a project to use either dredge spoil or excavated material from existing ponds to restore the marsh level to where it will support *Spartina alterniflora*. Damage to salt marsh has also been noted on the lower end of an adjacent island, Tizzard Island, in Chincoteague Bay. If this foraging activity continues, it is likely that these coastal islands will be converted to mud flats as erosion accelerates. Overgrazing was noted for the first time in October 1997 on the north end of Assateague Island (Dave Brinker, Maryland Dept. Nat. Res., Annapolis, pers. commun.). However, severe damage by snow geese has not been recorded on Assateague Island National Seashore.

In Virginia, there is anecdotal information about minor impacts on coastal salt marshes in the early 1970s, but there is little documented information. A small area of marsh eat-out (only 1-2 acres) was noted in the early 1980s in the salt marsh around the Chincoteague NWR. In the past 5 years, two other areas, one about 5-7 acres and another 1-2 acres, have been created in the refuge vicinity. These eat-outs have occurred during late winter-early spring just prior to or during the northward migration (Irv Ailes, USFWS, Chincoteague NWR, pers. commun.). The number of snow geese using the Chincoteague area from the late 1970s through the early 1990s was generally between 5-15,000. In the last 5 years (1994-1998), larger numbers of geese (between 20-50,000) have been using the refuge area in late fall to early winter. These geese have been found feeding in both salt marsh habitats and inland agricultural fields in Virginia and Maryland. Snow goose numbers decrease to around 5,000 in mid-winter (January) as birds disperse from the refuge area and move further south.

The Back Bay/Mackay Island area of Virginia/North Carolina is a fresh-to-brackish water system located inland of the coastal barrier dune. The area generally winters from 10-15,000 greater snow geese. An annual cyclic pattern of *Scirpus americanus* marsh denudation was observed in the 1970s in which snow geese would rotate around the marsh over a period of years. Geese would denude one section of the marsh one year, then move to another area of the marsh the following year. This allowed impacted areas to recover over the course of several years (Atlantic Flyway Council 1981). It was noted that heavy grazing in some portions of *Scirpus* marsh could result in the invasion of less desirable vegetation such as *Cyperus* spp. or *Juncus* spp. Snow geese began using agricultural fields in the Virginia/North Carolina area in the late 1960s and early 1970s as evidence from the complaints by farmers at that time (Otto Florschutz, USFWS, Washington NC, unpubl. rep.). Currently, snow geese use both marsh and agricultural fields in the area and do not appear to have long-term negative impacts on either habitats.

In coastal North Carolina, snow goose eat-outs were evident in the early 1970s in the vicinity of the Pea Island National Wildlife Refuge (Bob Nofsinger, USFWS, pers. commun.). Different habitat types including freshwater, brackish-water, and coastal salt marsh habitats were impacted (Smith and Odum 1981). The fresh and brackish-water marshes were able to recover

quicker than the *Spartina* marsh, which required several years without grazing to fully revegetate. The number of snow geese using the Pea Island area has declined from around 5,000 birds in the 1970s and early 1980s to between 1-2,000 over the last 10 years. Little damage to coastal salt marshes have been noted during this time. Snow geese have, however, fed in a restored freshwater wetland mitigation site that was created in the mid-1990s. Along with Canada geese, they have denuded this 35 acre wetland of vegetation during the last two years (Dennis Stewart, USFWS, Pea Island NWR, pers. commun.).

Mattamuskeet and Pocosin Lakes NWRs in North Carolina are predominantly freshwater marsh systems that winter both lesser and greater snow geese. Only small numbers of snow geese were found on these refuges in the 1960s and early 1970s (Bob Nofsinger, USFWS, unpublished data). At Mattamuskeet NWR, the number of lesser snow goose increased to between 3-6,000 during the 1970s and 1980s. In the past two years 5,000 lesser snow geese have been using the Lake Mattamuskeet area joined occasionally for short periods by flocks of greater snow geese from adjacent refuges. At Pocosin Lakes NWR, mid-winter numbers of snow goose increased to 2-5,000 from 1975 through 1985, peaking at 12,000 in 1990. The number of greater snow geese has stabilized at 6-8,000 since then. Little impact on habitats in and around these refuges had been noted in the past. A Ph.D. study is now underway to evaluate the impacts that snow geese and other waterfowl are having on the vegetation in portions of Lake Mattamuskeet.

Ecological Significance of Snow Goose Feeding Activities

Snow goose feeding behavior has a number of detrimental effects on coastal salt marsh systems. Overgrazing and grubbing activities can lead to the loss of marsh vegetation, an increase in erosion, and a decrease in marsh primary productivity. Species that depend on these habitats for nesting or foraging, such as the clapper rail, black duck, willet, sharp-tailed sparrow and northern harrier will be affected (Ferrigno 1976). Grazed marshes in New Jersey were unsuitable for clapper rail nesting and the number of rails declined in these areas (Widjeskog 1978). Invertebrates associated with the salt marsh vegetation including the salt marsh snail (*Melampus bidentatus*), ribbed mussel (*Geukensia demissa*), and fiddler crabs (*Uca* spp.) also declined in eat-out areas. Invertebrates are a major component of the black duck diet and the loss of marsh invertebrates can negatively affect the winter carrying capacity for black ducks (Atlantic Flyway Council 1981). Invertebrate populations did not fully recover until a year after the recovery of the marsh vegetation (Widjeskog 1979).

Although greater snow geese can have significant negative impacts on salt marshes, they may also have beneficial effects. Eat-outs create openings that provide habitat diversity in monotypic stands of *Spartina* marsh. These openings can provide habitat for shorebirds and wading birds, and roosting and loafing sites for other waterfowl. Grazing and grubbing activities may aid in recycling nutrients and providing resources for other marsh consumers (Smith and Odum 1981). Goose grazing may also lead to a greater diversity of plant species and prevent the invasion of woody species in certain areas (Smith 1983).

The ecological significance of snow goose feeding behavior depends upon the magnitude of their impacts in relation to available habitats, and how they affect other species using these habitats. Short-term effects on salt marsh habitats have been demonstrated, but long-term impacts on coastal ecosystems are harder to identify and interpret. In areas where snow geese have adapted to feeding in agricultural habitats, their winter range has expanded and their relative impacts on coastal marshes appear reduced. Yet, the nutritional subsidy provided by agricultural grains has likely contributed to the snow goose population increase (Abraham and Jefferies 1997). Increased damage to coastal habitats during the last 5-10 years has occurred in areas where agricultural foods are less available or

where large increases in snow goose numbers have occurred rapidly. Continued growth of this population will likely present additional challenges for wildlife managers.

Summary - U.S. Atlantic Coast

1. Impacts to Mid-Atlantic coastal marshes from greater snow goose feeding activities appeared to increase in the 1970s and early 1980s along with the general increase in snow goose populations.

2. Damage to coastal salt marshes in the 1990s does not appear to have increased in proportion to population size in areas where agricultural fields are used. However, in traditional snow goose concentration areas along the coast, areas of salt marsh eat-outs have been maintained or expanded.

3. The amount of salt marsh habitat impacted by greater snow geese is relatively small in comparison to the total amount of coastal salt marsh habitat available. However, extensive damage does exist in some areas and can have detrimental effects on the environment and other wildlife species.

4. Depending upon a number of variables including the degree, extent, timing, and location of impacts, some habitat changes resulting from snow goose feeding activities could be considered beneficial.

ARCTIC BREEDING HABITATS

Habitat Use by Geese

The breeding range of greater snow geese extends over a vast area of the Canadian Arctic archipelago, and data on habitat use and impact of geese on the vegetation is available from very few sites. Published information on the habitat use is available only from two sites: Jungersen Bay which is located at the base of Admiralty Inlet on northern Baffin Island, and Bylot Island.

Giroux *et al.* (1984) studied habitat use by greater snow geese during the brood-rearing period at Jungersen Bay in summer 1981. Habitats most heavily used by geese at this site included a tidal marsh dominated by *Puccinellia phryganodes* and *Carex subspathacea*, and wet sedge meadows around freshwater ponds dominated by a mixture of sedges (*Carex* spp, especially *C. aquatilis*, and *Eriophorum* spp.) and grasses (*Dupontia fisheri, Arctagrostis latifolia*). Mosses were also a dominant feature of wet sedge meadows. They also reported a small amount of old grubbing (presumably from the spring) and shoot pulling. Although they made no direct measurements of the impact of grazing by geese on the vegetation, they estimated that the amount of Arctic habitat available for greater snow geese was more than an order of magnitude greater than what was required by the total population at that time (170,000 geese in 1981). This conclusion was reached by combining information on plant production estimated at other high Arctic sites, the amount of tundra habitat available (estimated from the Arctic Ecology Map Series of Canadian Wildlife Service) the proportion of habitat suitable for geese at their study site, and known daily food requirement of geese.

Since 1990, Gauthier and collaborators have conducted detailed studies on plant production, grazing impact, habitat use and gosling growth at the Bylot Island snow goose colony. Tidal marshes are very restricted on Bylot Island and, although used by geese, account for a negligible fraction of habitats available to them. This situation appears common in many areas used by greater snow geese in the summer as the rugged and steep coastline of many Arctic islands is not suitable for the formation of large tidal flats. Wetlands used by geese on the south plain of Bylot Island are thus inland, freshwater habitats. Many of these wetlands result from the action of permafrost which

creates topographic features such as patterned grounds (polygon) or thermokast pits that impede drainage and favor water retention.

On Bylot Island, Hughes *et al*. (1994b) described 12 habitat types used by geese grouped in three main categories: pond/lake, wet meadow and upland. Pond/lake are small to large permanent water bodies with a narrow band of rich graminoid cover and mosses along the edge. Wet meadows (often called sedge meadows) are shallow basins (e.g. polygons) that do not retain standing water permanently. These wetlands are essentially fens and are covered by a thick carpet of mosses and graminoid plants. Upland habitats are a mixture of moist to dry habitats located mostly on sloping terrain and are characterized by sparse vegetation but may also contain isolated wet patches (e.g. along seasonal streams). Wet habitats are dominated by sedges (*Carex aquatilis, Eriophorum scheuchzeri* and *E. angustifolium*) and grasses (*Dupontia fisheri, Pleuropogon sabinei* and *Arctagrostis latifolia*). Moist upland habitat has a diverse but variable vegetative cover depending of the amount of soil moisture. Common plants include shrubs such as *Salix* spp and *Vaccinium uliginosum*, forbs such as *Cassiope tetragona, Oxytropis maydelliana* and *Polygonum viviparum* and graminoids such as *Arctagrostis latifolia, Alopecurus alpinus, Poa glauca* and *Luzula confusa* (Gauthier *et al*. 1996).

Habitats used by geese on Bylot Island vary seasonally. To better characterize habitat use, the summer period can be divided into four periods: arrival and pre-laying, nesting, brood rearing and fledging. Geese generally arrive on the island in late May, when most wetland habitats located in lowland areas are still frozen and covered by snow. At many lesser snow goose colonies (e.g. west Hudson Bay), damage to the vegetation can occur at snowmelt because large number of birds nesting further north will stage at more southerly colonies and heavily grub before moving on. This does not appear to be the case on Bylot Island where we never observed large flocks of birds passing through in late May or early June. Use of the island at snowmelt appears to be largely restricted to birds breeding on the island or in the immediate vicinity. Arriving geese will initially feed in snow-free sloping areas. Their diet in these upland habitats is diverse and includes leaves, roots and bulbs of several species of grasses and forbs (Gauthier 1993). Grubbing can be locally intensive as belowground vegetation accounts for about 50% of their diet. As snowmelt progresses and lowland areas become snow-free, geese concentrate their foraging on the edge of ponds and flooded wet meadows. They feed mostly on basal stems and roots of *Eriophorum* and *Carex* (shoot-pulling). Belowground vegetation is still important, accounting for >50% of the diet.

During the nesting period, food intake by geese is limited and their foraging activity concentrated in the immediate vicinity of the nest (Reed *et al*. 1995). Nesting habitats include upland habitat and polygon rims on the edge of wet meadows or ponds (Lepage *et al*. 1996). Diet of geese during this period is also diverse as they often take advantage of temporary available food items such as opening buds, emerging leaves and catkins of willows, horsetail shoots or flowers of *Oxytropis* (Gauthier 1993, Gauthier and Hughes 1995, Reed *et al*. 1995). Belowground vegetation still accounts for up to 30% of the diet of early incubating geese but decreases thereafter as shoot-pulling of *Carex* is gradually replaced by grazing of graminoid plants.

After hatch, goose families settle mostly in pond/lake and wet meadow habitats, although upland is also used to some extent, especially late in the season (Hughes *et al*. 1994a, b). During this period, foraging mode is almost exclusively grazing on leaves. *Dupontia fisheri*, a grass, and *Eriophorum scheuchzeri*, a sedge, are the principal plants grazed by geese at that time (Manseau and Gauthier 1993, Gauthier *et al*. 1995). With the addition of growing goslings to the population, this is the period when grazing is most intensive. A small number of non-parental birds (failed or non-breeders) are also present on the island during the summer. During molt, these flocks of birds are largely restricted to pond/lake habitat (especially the larger lakes) where they also graze grasses and sedges in these wetlands (Hughes *et al*. 1994b).

Shortly before fledging in late summer, broods tend to disperse away from wet lowlands to upland habitats (Hughes *et al*. 1994a, b). Casual observations suggest that use of upland habitat increases further after fledging and before departure for the southward migration, which occurs in the last days of August. Little information is available on the diet of geese at that time although they appear to revert again to feeding on belowground vegetation (grubbing and shoot-pulling of *Carex* and *Eriophorum*) in addition to grazing. Feeding on berries in some areas is also possible.

Annual Impact of Grazing on Vegetation

Information on the effect of grazing by greater snow geese on plants is available only from the intensive work that G. Gauthier has been conducting on Bylot Island. All the measurements of impact on the vegetation have been made in wetlands (pond/lake and wet meadows) because these are clearly the preferred and most heavily used habitats, especially by brood-rearing geese, even though they account for only about 10% of the total area of the south plain of Bylot Island (Massé 1998). Every year since 1990, a series of 1x1 m exclosures are erected in wetlands of the largest glacial valley of Bylot Island to monitor production of graminoid plants and grazing impact of geese. Exclosures are set up in mid June, shortly after snowmelt. The area sampled is mostly exposed to grazing by brood-rearing geese although a variable but small amount of early spring and/or late summer grubbing and shoot-pulling also takes place in some areas.

Plant production is variable among years on Bylot Island. For instance, aboveground biomass of graminoid plants in annual exclosures at the end of the growing season was half of normal in 1994, a drought year (Fig. 2-3). We detected an impact of grazing by geese on aboveground plant biomass in all years, but the effect was also variable among years (Fig. 2-3). The highest grazing impact occurred in 1993: Gauthier *et al*. (1995) estimated that geese consumed 78% of the annual production of *Dupontia fisheri* and 100% of the production of *Eriophorum scheuchzeri* in preferred brood-rearing habitats that year. There is no evidence of long-term increase in grazing impact despite the increase in population size on Bylot Island (Chapter 1). Annual variation in grazing impact largely represents annual variation in the intensity of use of the area by brood-rearing geese. In 1993, faeces counts suggested that use of the lowland areas was the largest ever recorded on Bylot Island (Fig. 2-4). This resulted from an unusually large reproductive effort by geese that year due to the early snowmelt, and a high nesting success (Lepage *et al*. 1996). Other factors such as nesting phenology, the timing of dispersal by broods from lowlands to uplands or weather conditions could also explain some of the annual differences in grazing impact.

Herbivores can sometimes have a positive impact on their plant food. For instance, grazing often results in an increase in plant quality (higher nitrogen concentration) and in enhanced plant production (overcompensation). Such positive feedbacks on the vegetation have been reported at moderate levels of grazing by lesser snow geese at La Pérouse Bay (Cargill and Jefferies 1984, Hik and Jefferies 1990). On Bylot Island, nitrogen concentration of grazed plants is generally higher than ungrazed plants (Gauthier *et al*. 1995), though not always (Piedboeuf 1996). However, in contrast to the situation prevailing in the coastal marshes of Hudson Bay, we failed to detect any evidence of overcompensation in plants grazed by snow geese in wetlands of Bylot Island as regrowth following grazing was not higher than in ungrazed swards. On the contrary, annual production of *Dupontia fisheri* in grazed areas was slightly lower than in ungrazed areas.

An increase in the availability of nitrogen to plants via the deposition of goose faeces was a key factor in explaining the positive response of graminoids to moderate grazing at La Pérouse Bay (Bazely and Jefferies 1985, Hik and Jefferies 1990). However, controlled experiments on Bylot Island showed that goose faeces did not have any fertilization effect on graminoid plants (Beaulieu *et al*. 1996), even though fertilization experiments showed that nitrogen was limiting plant growth
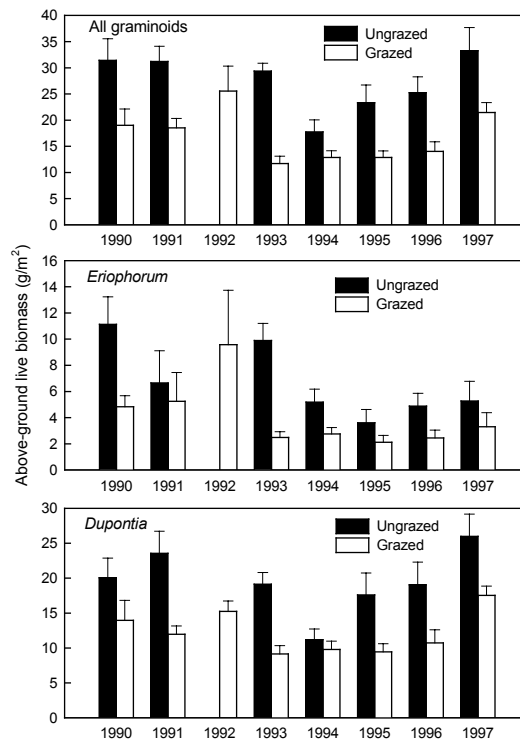
Figure 2-3. Live aboveground biomass (dry mass) of graminoids on 15 August in grazed and ungrazed areas (n = 12) on Bylot Island (mean $\pm$ SE), 1990-1997. No data from ungrazed area in 1992 because grazing was negligible following the almost complete breeding failure of geese.
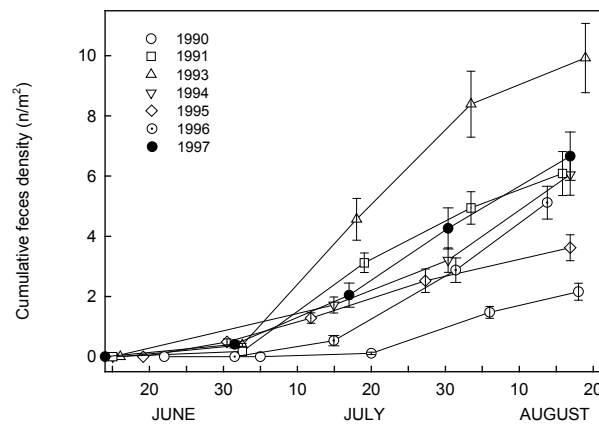

Figure 2-4. Cumulative faeces density showing the use of the Base-camp Valley by greater snow goose families on Bylot Island (n = 12 transects of 1 x 10 m), 1990-1997.

(Pineau 1998). One important difference, however, with coastal marshes of Hudson Bay is the presence of a thick layer of moss in wet meadows used by snow geese on Bylot Island. It is possible that most nutrients leaching from goose faeces are absorbed by mosses rather than graminoids because mosses have a higher ion exchange capacity than vascular plants. Preliminary results from fertilization experiments showed that mosses absorbed nitrogen at a lower level of fertilization than graminoids (Pineau 1998). This suggests that mosses act like a sponge, soaking up most of the nutrients released from faeces. It thus appears that nitrogen cycling in this ecosystem is more complex and involves three levels (graminoids, mosses and herbivore) rather than only two.

Impact on Gosling Growth

The growth rate of greater snow geese is exceptionally high for a self-feeding precocial bird of that size, undoubtedly an adaptation to the short Arctic summer (Lesage and Gauthier 1997). In order to achieve optimal growth, goslings must have access to abundant and high quality food. Lepage *et al*. (1998) showed that the total amount of nitrogen available in plant food during the summer could explain a large proportion of seasonal and annual variations in gosling growth. Because gosling growth rate is likely to be the first parameter to be affected by a decline in food supply, that rate could be used as an index of habitat quality and to detect possible habitat deterioration related to population expansion. At La Pérouse Bay, Cooch *et al*. (1991) showed a long-term decline in gosling mass and size near fledging in response to a gradual deterioration of brood-rearing habitats due to overgrazing.

In greater snow geese, Reed and Plante (1997) showed a significant decline in mass, size and condition of goslings measured during the fall hunt in southern Québec over a 19-year period (1975-1994). They suggested that this could be a consequence of density dependent factors occurring during the brood-rearing period in the Arctic: as the population expanded, increasing numbers of goslings may be encountering a reduced per capita availability of food, and thereby experiencing lower growth rates and reduced final size. Annual monitoring of gosling mass and size near fledging at Bylot Island over a 7-year period (1991-1997; Fig. 2-5) failed to substantiate the findings of Reed and Plante (1997): based on large sample sizes obtained during our annual banding operation, we found no evidence of long-term decline in gosling growth. However, in accordance with the previous study, we found large annual variation in gosling growth. For instance, very poor growth was observed in 1994, a year with relatively low brood density but with very low plant production due to drought conditions (Fig. 2-3). In the year of highest brood density (1993), gosling mass near fledging tended to be low (though not size). Our inability to detect long-term decline in gosling growth at Bylot Island may be related to the large annual variability in growth and the relatively small number of years (7) compared to the data set of Reed and Plante (1997).
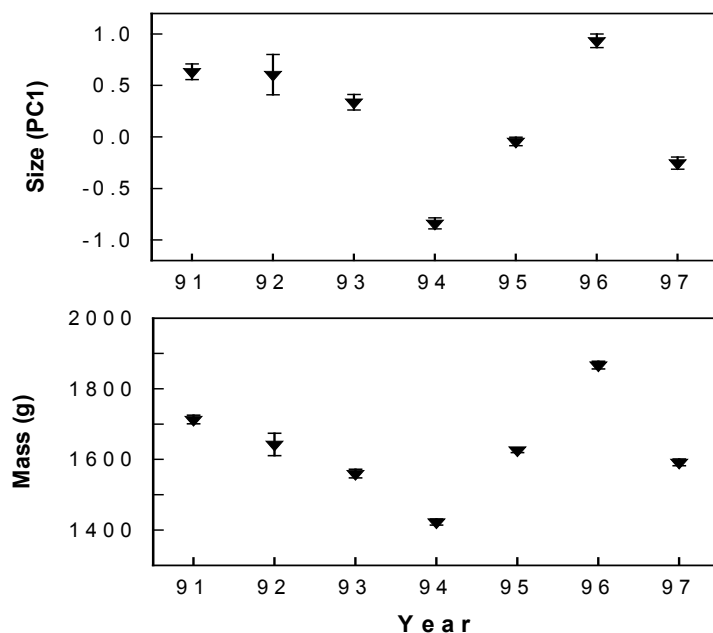
Figure 2-5. Annual body size and mass (g) of goslings measured during banding at Bylot Island, 1991-97 (n = 11,632). Measurements are standardized at 35 d of age (Least-square means $\pm$ SE). The first axis of a principal component analysis including culmen, head and tarsus length (PC1) was used as an index of body size. Regression of mass or size on year were not significant ($P > 0.05$).

Long-term Impact of Grazing

Annual plant production at Bylot Island (range: 20-35 g/m^2) tends to be at the lower end of the range for wet Arctic graminoid communities (Gauthier *et al*. 1996). This could partly reflect site-specific differences in net primary production, or could be a consequence of the intense, chronic grazing by geese on Bylot Island. We found that accumulation of soluble carbohydrates in rhizomes was lower in grazed than in ungrazed plants (Beaulieu *et al*. 1996). As belowground reserves are important to sustain production of new tillers in Arctic graminoids, chronic grazing could eventually lead to a decrease in tiller density and thus overall production. The shoot-pulling habit of geese in early spring and late summer is another factor that may contribute to the decrease in tiller numbers in grazed areas.

Preliminary results from the monitoring of long-term goose exclosures showed that, indeed, both the production and composition of the community is affected by geese. In 1994, we resampled 13 1x1m exclosures that had been left standing after our annual sampling in 1990 or 1991. After 4 to 5 years of goose exclusion, biomass of *Eriophorum*, the preferred food plant of geese, was 3 times higher at the end of the summer than in sites protected from goose grazing only in the current year (23 vs 8 g/m^2, respectively; Fig. 2-6a) and the number of tillers was twice as high (2048 vs 1081 tillers/m^2; Fig. 2-6b). Although *Eriophorum* was less abundant than *Dupontia* in the first year of goose exclusion (37% of total graminoid biomass), it had become the dominant species 5 years later (55% of biomass). The standing litter (dead aboveground vegetation) had also increased by more than two fold (Fig. 2-6c). These results suggest that chronic, intense grazing by geese leads to a low-level production equilibrium between geese and the plants similar to the situation documented

in some *Scirpus* marshes along the Saint Lawrence estuary (Giroux and Bédard 1987a). However, they also show that when grazing is stopped, plant biomass increases rapidly within a few years.
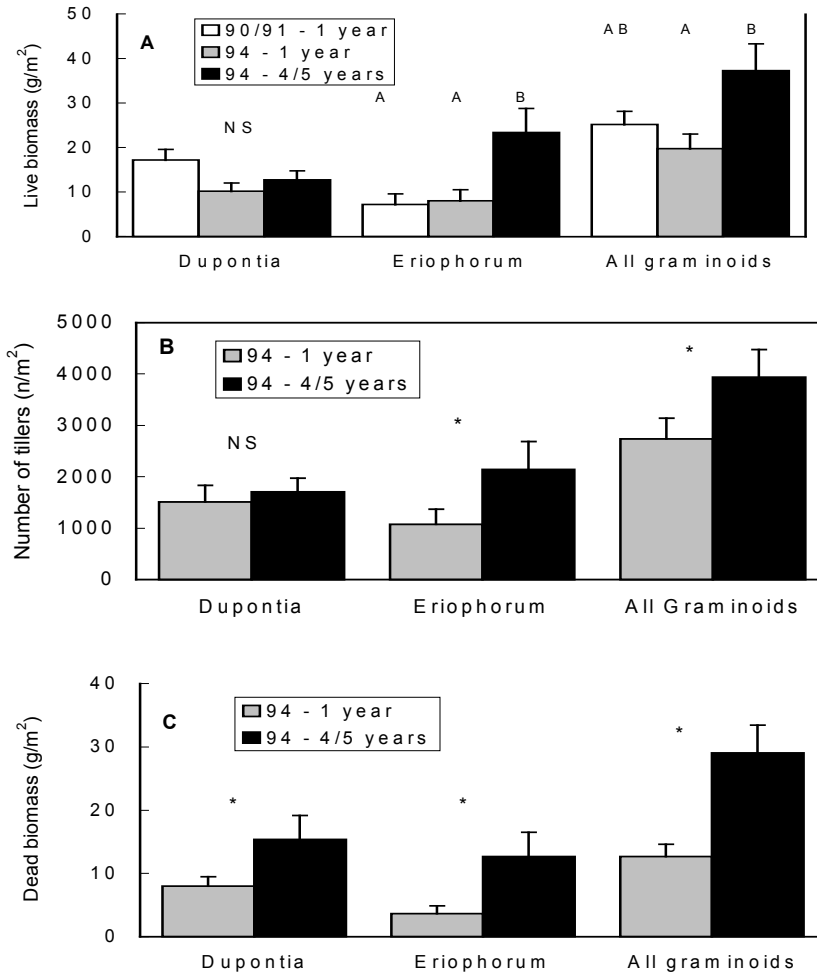

Figure 2-6. Live aboveground biomass (A), number of tillers (B) and dead aboveground biomass (C) of graminoid plants at the end of the summer (dry mass; Mean $\pm$ SE) after one year and 4 or 5 years of goose exclusion in preferred wetlands used by brood-rearing geese on Bylot Island (n = 13 1x1 m exclosures). Bars with * or different letters within each categories differ significantly (P < 0.05; NS = not significant).

A more complete set of larger exclosures (4x4 m) was set up in 1994 to monitor long-term changes to the vegetation on Bylot Island at sites where only grazing occurs, and others where both grazing and shoot-pulling is common. Results for the graminoid plants after 3 years of exclusion mirror those obtained with the smaller size exclosures. Moss production is also monitored because increase in biomass and litter of vascular plants could adversely affect mosses.

Grubbing, which is much more devastating for the vegetation than grazing, is not yet extensive on Bylot Island although it occurs regularly at snowmelt. Even though the island is not used as a staging areas for geese migrating further north in spring, grubbing is likely to increase with the continuous increase in the population. In lesser snow geese, even colonies which are at the terminus of migration and receive little staging birds such as Queen Maud Gulf are suffering from

habitat degradation caused by locally breeding birds (Abraham and Jefferies 1997). This process is likely to occur as well in areas used by greater snow geese in the future.

The Carrying Capacity of Bylot Island for Brood-rearing

Extensive damage done by lesser snow geese to the salt-marshes of Hudson Bay suggests that geese have exceeded the carrying capacity of their habitat (Abraham and Jefferies 1997). The carrying capacity can be defined as the number of individuals that a given habitat can sustain at equilibrium. Estimating the carrying capacity of a habitat can be a useful step when attempting to set population goals for a species. Estimating the carrying capacity of the Arctic islands for greater snow geese is impossible at this stage. However, because Bylot Island is one of the most important breeding colonies for this species and since growth rate of the colony has been as rapid as the population as a whole (Chapter 1), estimating the carrying capacity of the island for geese may be used as an index for the whole population.

The study of Hélène Massé (1998) recently estimated the carrying capacity of freshwater wetland habitats used by greater snow geese on Bylot Island during brood-rearing. The approach that she used was to evaluate in detail food availability and to compare it to the requirement of the birds. This involved: 1) mapping the different wetland types available to geese on the 1600-km^2 south plain of the island, 2) estimating plant production of these habitats at several sites on the island, 3) comparing total food availability with estimated total nutrient requirement of growing goslings and adults, and 4) validating the model by comparing the predicted amount of plant biomass consumed with the intensity of goose grazing measured at several sites. As a first step, she limited her estimate of the carrying capacity only to wetland habitats. Although additional food resources can be found by geese in upland habitat, this habitat is of marginal quality for them and it is unlikely that geese could rely exclusively on this habitat throughout the summer. As this work is still in progress, only preliminary results will be presented here.

Five types of wetland habitats were retained for mapping purposes: wet polygon, polygon channels, lake polygons, stream banks and lake shores. Stream banks, wet polygons and polygon channels were the most widespread habitats, accounting for 92% of all wetland habitats on the island (Table 2-1). However, a large proportion of some wetland habitats (e.g. polygon channels) was unsuitable for goose feeding because of the presence of deep water or patches of dry upland habitat. The total availability of food for geese per habitat was assessed by combining data on habitat area covered by suitable forage plants and the associated production. The vegetation of stream banks represented up to 70% of the total food supply available on the island wetlands (2,004 tonnes), followed by the vegetation of wet polygons which accounted for 24% of all suitable forage.

Food requirements of geese were calculated from data derived from the literature. Requirements of individual birds were multiplied by the population size estimated during the last census of Bylot Island (Chapter 1) to obtain annual food consumption of geese on the island. The total amount of food that would have been consumed by the 1993 population was estimated at 1,182 tonnes of vegetation (Massé 1998) which represented 59% of the estimated carrying capacity of the south plain of Bylot Island (2,004 tonnes of forage). Although the total population has increased since 1993, the abundance of birds on the island during the years that the carrying capacity was estimated (1996-1997) was probably comparable since 1993 was a year of very high brood density for geese on Bylot Island.

Table 2-1. Area covered by wetland habitats, area covered by suitable forage plants within habitats, aboveground plant production and total availability of suitable forage plants for geese in wetland habitats on the south plain of Bylot Island (Massé 1998; *do not cite this table without permission of the author*).

Habitat type[1]	Total area (km²)	Area covered by suitable forage plants (km²)	Production (g/m²/yr)	Total availability of suitable forage plants (kg x 1000)
SB	44.6	41.5	33.6	1,394
WP	30.2	17.4	27.8	484
PC	30.0	1.9	54.1	103
LP	8.4	0.6	32.0	19
LS	0.3	0.2	20.2	4
Total	113.5	62.7		2,004

[1] SB = Stream-bank, WP = Wet polygon, PC = Polygon channels, LP = Lake polygons, LS = Lake shores

To validate the model, Massé (1998) compared the proportion of consumed biomass predicted by the model with actual measurements of grazing impact. In 1996-1997, grazing impact in the five habitats was measured at 7 sites throughout the south plain of Bylot Island (N = 154 exclosures). These measurements yielded an average value of 35% of aboveground biomass removed by geese by 15 August. If we only consider the food requirement of the geese up to the time that exclosures were sampled (15 August), the model estimated that geese should have consumed about 45% of the total food available in the Bylot Island wetlands by then. These two values agree reasonably well considering the error associated with each of them. The higher value predicted by the model may be because food available in isolated wetlands in upland habitat, and in the marginal upland habitat itself was not measured (Hughes *et al*. 1994b). It is also important to remember that this is a crude estimate of the carrying capacity of the south plain of Bylot Island because several sources of error could affect these calculations. This value could also fluctuate over time because of weather related variation in annual plant production as shown before. These calculations nonetheless suggest that, although the carrying capacity of Bylot Island for snow geese is not yet reached, it could be in the near future with the continuous increase in the population.

Summary – Arctic Breeding habitats

1. In contrast to other snow goose populations breeding in the low Arctic, salt marshes are rare in the high Arctic and are thus little used by greater snow geese. Wetlands used by geese in the high Arctic are thus largely inland, freshwater habitats. The most important habitats include small to large permanent water bodies (pond/lake) and wet meadows (often called sedge meadows). These wetlands are essentially fens and are covered by a thick carpet of mosses and graminoid plants, of which *Dupontia fisheri, Eriophorum scheuchzeri* and *Carex aquatilis* are the most important forage species for geese.

2. Also in contrast to the situation prevailing along the southern and western coasts of Hudson Bay, Bylot Island is not used by waves of migrating geese en route to nesting grounds further north. Use of the island in spring appears to be limited to those breeding in the area. However, spring grubbing by locally breeding birds already occurs on a small scale and is likely to increase with the continuous increase of the population.

3. Although grazing level can be very high in some years on Bylot Island, we have not yet seen evidence of damage to the vegetation in terms of absence of regrowth following grazing. Evidence from other sites in the high Arctic are virtually non existent. Several researchers have visited greater snow goose colonies elsewhere in the Arctic islands (e.g. Doug Heyland, Hugh Boyd, Austin Reed and Jean-François Giroux) since the 1970s but none reported goose-related damage to the vegetation at these colonies.

4. Lepage *et al*. (1998) showed that variation in food availability during the summer could explain a large proportion of seasonal and annual variations in gosling growth. Reed and Plante (1997) reported a decline in mass, size and condition of goslings measured during the fall hunt in southern Québec over an 19-year period, and suggested that this was consequence of density dependent factors occurring during the brood-rearing period in the Arctic. Annual monitoring of gosling mass and size near fledging at Bylot Island over a 7-year period did not reveal similar trends although large annual variations may obscure long-term trends.

5. Monitoring of long term goose exclosures showed that the composition of the community is modified by geese, and annual production is reduced in heavily grazed areas. After 4-5 years of goose exclusion, biomass and tiller density of *Eriophorum*, the preferred food plant of geese, increased three-fold. Chronic, intense grazing by geese apparently leads to a low-level production equilibrium between geese and the plants in Arctic wet meadows. However, when grazing is stopped, plant biomass increases rapidly within a few years.

6. A recent survey estimated the total amount of forage plants available to snow geese in all wetlands of the south plain of Bylot Island at 2,004 tonnes. Two independent estimates of the total amount of food consumed by geese on the island was also obtained based on food requirements of individual birds and estimated population size, and the actual differences in biomass removed between paired grazed and unpaired plots across the island. Both methods suggested that almost 60% of total available forage plants in wetland habitats were consumed by geese at current population size. These calculations nonetheless suggest that, although the carrying capacity of Bylot Island for snow geese is not yet reached, it could be in the near future with the continuous increase in the population.

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CHAPTER 3

IMPACT OF GEESE ON FARMLANDS

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SOUTHERN QUÉBEC

Introduction

Contrary to the waterfowl depredation occurring on small cereal grains in western Canada during the fall, crop depredation by greater snow geese in Québec occurs in the spring. Depredation takes place mainly in hayfields devoted to forage production (mixtures of grasses and legumes), particularly east of Québec City along the St. Lawrence River estuary. However, the spring staging distribution of geese is gradually shifting toward southwestern Québec and the north shore of the St. Lawrence River west of Québec City. This shift as well as a longer stay in these areas could mean increasing depredation problems within these areas in the near future. Reasons for these changes are unknown but coincide with the rapid increase in the greater snow goose population (Chapter 1).

Until the 1960s, greater snow geese staged in their traditional bulrush marshes of the upper St. Lawrence River estuary. They gradually started field feeding along the south shore in the late 1960s (Anon 1981, Reed 1992) and early 1970s at the Cap Tourmente National Wildlife Area (Laperle pers. comm.). This was initiated when the population reached approximately 100,000 birds. Concurrently, the geese invaded the cordgrass marsh in the lower St. Lawrence River estuary, and were well established there by the end of the 1970s (Chapter 1). During the springs of 1979 and 1980, Gauthier *et al.* (1988) observed that geese staging in the cordgrass marsh spent 28% of their time field feeding as compared to 10% for those staging in the traditional bulrush marsh. In the springs of 1993 and 1994, geese staging near cordgrass marshes spent 59% of the daylight period in fields and 41% in marshes (UPA 1995). Bédard and Gauthier (1989) further determined that the salt marsh cordgrass was of low nutritional value for snow geese in the spring. This could explain the more important field feeding activity of geese staging in the lower estuary compared to those using the traditional bulrush habitat.

The impact of geese is markedly different between spring and fall. In October and early November, the birds converge on a small number of areas where hunting is prohibited. These are located in the traditional bulrush marshes of the St. Lawrence estuary. They visit hayfields to some extent but cause little damage since the plants are dormant at this time. April and May however, the geese are widely distributed throughout the St. Lawrence River valley where they may stage for up to 7 weeks in some areas. Goose displacements are not restricted by hunting activities in the spring and field feeding is much more intensive. This also corresponds to the onset of growth of the hay, a period when plants are vulnerable to grazing.

Studies of Goose Damage to Farmlands

Geese feeding in agricultural fields of the lower St. Lawrence estuary in the spring showed a strong preference for new hayfields with young grass growth and abundant grains leftover from the harvest of the previous year (Gauthier *et al.* 1988; Reed and Cloutier 1990). In the Montmagny agricultural area, 50 km east of Québec City along the south shore of the estuary, hay crop loss due to goose grazing increased from 0.47 to 0.78 metric ton/ha between 1980 and 1985 (Bédard *et al.*

1986, Bédard and Lapointe 1991). Goose numbers in the study area only rose by 11.5%; the spring population was around 200,000 birds. However, grazing pressure went up as shown by the density of goose droppings which increased threefold between 1980 and 1985. Bédard (1988) noted that even if the behavior and distribution of snow geese were continuously changing, some elements remained constant. The areas intensively used in 1984 remained the same in 1988. Also, while the number of geese using the Montmagny area did not increase markedly, the time spent feeding in farmlands increased considerably. Bédard and Lapointe (1991) predicted that an increase in grazing pressure due to a rapid goose population growth would soon lead to unacceptable damage. They surmised that in the spring of 1989 when the snow goose population was 363,000 birds, some 5,000 ha of agricultural land were affected in southern Québec at levels similar to the ones measured around Montmagny in 1985 (Chapter 1).

In 1994, a large-scale on-farm research project was launched by Ducks Unlimited Canada at Isle-Verte, 200 km east of Québec City. The objective of the study was to determine the effect of goose grazing on various seeded forage mixtures, grasses and legumes, established with or without a cover crop. First year results in 1995 confirmed an average yield loss of 24% or 1 metric Ton/ha for the first cut, and a 7 to 10 day delay in plant maturity (Filion 1998).

Crop damage occurs from the onset of vegetative growth in the spring, in early May, until the geese leave for the Arctic during the last week of May. However, damage intensity is not uniform throughout this period. Because forage growth in spring is closely linked to the accumulation of growing degree-days, crop damage is proportional to the accumulation of degree-days from the beginning of the growing season until the departure of the geese. This suggests that damage by geese occurs when geese graze during the growing season and that maximum damage will occur when geese graze intensively in the last few days preceding their departure (Filion and Allard in preparation). This also suggests that protecting fields only at the end of the spring staging period could be more cost effective in terms of reducing damage. This issue is currently being addressed by a study at Isle-Verte.

In addition to grazing in hayfields, geese staging in southern Québec also feed on waste grain. Along the St. Lawrence estuary, around Montmagny and eastward, they feed on small grain cereals such as oats or barley (Bédard and Gauthier 1989, Reed 1974). Expansion in the distribution of the geese in southwestern Québec occurred mostly in corn-growing areas where they feed heavily on waste corn in both spring and fall (Giroux and Bergeron 1996). Feeding on these cereal grains does not cause any damage because it occurs after the harvest is completed.

Evaluation of Goose Damage and Compensation to Farmers

The Québec Farmers Union (UPA) is asking for a control of the goose population as well as equitable compensation for farmers who suffer a yield loss. In some agricultural areas, compensation is not sufficient as some farmers no longer want to see geese in their fields. The burden of hazing large goose flocks from large tracts of land from dawn to dusk is certainly overwhelming for many farmers in the spring, a period of the year when their work load peaks.

In Québec, unpredictable and randomly occurring damage is usually covered by crop insurance, for farmers that have paid their premium. As goose damage is more predictable in time and space, farmers cannot be covered by insurance because the premium would be too high. Therefore, a compensation fund corresponding to 80% of the loss incurred by farmers was set up in 1992 following a non-recurrent five-year federal-provincial government agreement. Agricultural departments and wildlife agencies contributed to it from 1992 to 1994. Since then, the agricultural departments have been the sole contributors to the compensation fund but have claimed that wildlife agencies should pay for the damage.

To obtain compensation on areas larger than 1 ha, farmers must advise the Québec Crop Insurance Board of suspected damage as soon as the geese depart the area in May. At that time, the Board initiates an evaluation process based on a collective assessment rather than an individual one in order to reduce the cost of the evaluation. Damages are determined on a regional basis using 30 fields in each agricultural zone exposed to goose grazing. Early in the spring, a variable number of 1x1m goose exclosures are set up in each field, as reference plots that will not be grazed. When the geese leave for the Arctic, an initial visual inspection is carried out, both in fields with exclosures and in those of individual farmers that reported damage, in order to confirm the extent and the intensity (rated as high, moderate and low) of grazing, and taking into account other factors such as winterkill or spring flooding. Prior to the first and the second hay cuts, two paired 1x1m plots (inside and outside exclosures), are clipped in each field in order to evaluate the loss in forage yield due to goose grazing. Average yield loss is estimated separately for fields rated high and moderate grazing intensities within each agricultural district. The average loss is used to compensate individual farmers according to the initial visual assessment of damage on their property by the Board.

The most severe damage was determined in 1995, with 900,000 Can$ being claimed by 369 producers farming 6,500 ha (Table 3-1). However, only 62% of that year's claim was paid due to a lack of funds, and the farmers had to assume the difference. From 1992 to 1996, only about 70% of the estimated loss was compensated due to lack of funds. Furthermore, according to many farmers these losses are only one aspect of the problem. Yield losses could mean feed shortages for dairy producers who will have to buy replacement feed. Goose grazing has also been blamed for increasing the abundance of weeds and decreasing stand vigor which leads to more frequent reseeding and increased production costs. Results of the long-term study carried out at Isle-Verte should shed more light on these issues.

Table 3-1. Compensation paid by the Federal / provincial plan since 1992.

Year	Producers	Ha affected	Estimated losses	Paid ($CDN)	% compensated losses
1992	251	8,176	466,589	373,271	80
1993	136	3,526	211,514	169,211	80
1994	309	10,348	534,891	399,970	74
1995	369	16,081	904,043	560,000	62
1996	293	11,940	844,213	560,000	66
1997	283	11,411	485,312	485,312	80

With the recent shift of geese towards the upper estuary (Lake Saint-Pierre) and their later departure from these regions, damage to forage production could increase and new crops such as winter cereals could be affected as well. In the St. Lawrence floodplain, some wet agricultural fields may also be susceptible to goose grubbing in the spring. In these situations, newly established crops could suffer severe losses. Whether or not they occur at random and could be covered by the crop insurance program remains unknown. Nevertheless, recent changes in the duration and staging pattern of snow geese in the St. Lawrence River valley, including along major tributaries such as the Richelieu River, need to be closely monitored.

Summary – Southern Québec

The agricultural industry is subject to a growing number of constraints and a more competitive world market. Farmers cannot be expected to sustain alone recurrent economic losses for the benefit of wildlife. On the other hand, the geese have become largely dependent on agricultural areas during their wintering and staging periods. Therefore, wildlife agencies must work hand-in-hand with agricultural agencies to develop and implement sustainable management measures to prevent or compensate damage due to wildlife. This is essential to maintain the social, cultural and economic benefits offered by the greater snow geese as a natural resource. In this respect, it is urgent that wildlife managers and farmers jointly design and implement measures that have the potential to reach these objectives as well as improve the economic benefits to affected farmers. To this end, government agencies will need to adapt their management programs to the dynamics of the snow goose population.

MID-ATLANTIC STATES

The widespread use of agricultural lands for feeding by greater snow geese is a relatively recent adaptation. Small groups of greater snow geese were first observed feeding in agricultural fields in southeast Virginia and northeast North Carolina during the early 1960s (Anonymous, 1981).

The first reports of agricultural depredations in the U.S. portion of the Atlantic Flyway occurred during the winter of 1971-72. By the winter of 1973-74 large numbers of the birds were invading fields of winter wheat (*Triticum aestivum*) in northeast North Carolina and southeast Virginia (Findley, J.D., Atlantic Flyway Council, unpubl. rep., 1975). This activity resulted in increased complaints from local farmers. In New Jersey during the winter of 1975-76, snow geese used in excess of 1,500 acres of wheat, rye, sod, and pasture crops (Hall, R., NJ Fish, Game, and Shell Fish., unpubl. rep., 1976). Hall described the New Jersey farmers as being "relatively unconcerned".

Fear of economic loss caused added interest in reopening hunting seasons on snow geese in the U.S. portions of the Atlantic Flyway. It also caused state and federal wildlife agencies to begin to quantify and deal with the damage. During the winter of 1973-74 the FWS undertook an effort to haze snow geese out of fields lying within a 20x40-mile section of land, near Currituck Sound and Back Bay (Florschutz, O., U.S. Fish and Wildl. Serv., unpubl. rep., Washington NC, 1974). The hazing was discontinued because it was not considered by participating biologists to be effective in reducing goose usage on target fields and required a large commitment of personnel and aircraft. A subjective follow-up survey at the time of wheat harvest concluded that yields were reduced in fields which received heavy goose usage, but that the decrease was not as large as anticipated. Hartke (U.S.D.A., APHIS, unpubl. rep., Raleigh NC, 1986) reported over $5,000,000 in cumulative damage resulting from snow geese and tundra swans (*Cygnus columbianus columbianus*), in 7 counties in northeast North Carolina, during 1980-86. Wildlife managers at the time believed that this estimate of dollar loss, was inflated because it was based on unsubstantiated reports from the farmers themselves.

The effect of grazing by related waterfowl species on the vegetative parts of small grain crops has been studied. Conover (1988) concluded that grazing of rye by Canada geese reduced subsequent biomass of leaves and roots and reduced its value as a cover crop. Allen *et al.* (1985) noted that the yield and plant height at harvest, of winter wheat fields heavily grazed by Canada geese, was reduced, and maturity was delayed. This occurred even if the heavy grazing occurred in a single episode. Kahl and Sampson (1984) observed that in some cases grazing by captive Canada geese reduced yield and plant height, of winter wheat. Light and moderate grazing of winter wheat

by tundra swans, near Mattamuskeet NWR, had little effect on yield and in some cases of light grazing, served to increase yield (Crawley, 1997). Crawley observed that heavy grazing decreased yield slightly.

Greater snow geese are also making increased use of corn and soybean stubble fields to feed on waste grain. As would be expected, this feeding activity has not resulted in damage complaints. The preference of grain over traditional marsh foods by greater snow geese in the Mid-Atlantic states is a relatively recent event. During the late 1970s, corn, wheat, and rice were not effective in attracting snow geese to rocket nets at Pea Island NWR (R. Brame, N.C.S.U.,pers. comm). By 1985 however, snow geese seeking corn began to monopolize several banding sites in North Carolina, and interfered with the capture of Canada geese and other waterfowl. Hill and Frederick (1997) observed that radio-tracked greater snow geese near Bombay Hook NWR feed heavily in cornfields in the early (Oct.-Nov.) and mid (Dec.-Jan.) seasons. Use of cornfields declined in the late season (Feb.-Mar.) as waste grain became less available and new growth of green vegetation resumed. Conversely the leaves of winter wheat and barley were used little in the early season but became the most important feeding habitat in the late season. Lesser snow geese at Desoto NWR spent more of their time feeding in corn stubble fields in the fall than they did in wheat fields (Frederick and Klaas, 1982). The wheat fields were used primarily for loafing and sleeping.

The use of waste grain may also reduce the species dependence on traditional marsh habitat as evidenced by declining use of some areas having mostly marsh and estuarine habitats, such as the Outer Banks of North Carolina. It also may have resulted in movement of geese into locations, where marsh resources are limited but agricultural land is abundant. Such areas include Middle Creek, Pennsylvania, Pocosin Lakes refuge in North Carolina, and portions of the Delmarva peninsula. Snow geese may leave marshland habitat used for early season feeding and roosting on refuges and move to farm ponds or other water bodies closer to cropland feeding areas (Hill and Frederick, 1997, D. Luszcz, NC Wildl. Res. Comm., pers. obs.). One developing concern over the increasing use of corn by greater snow geese is that the birds might interfere with management targeting other waterfowl species. In Maryland (W. Harvey, MD DNR, pers. comm.) and in northeast North Carolina, flocks of snow geese are successfully competing for standing corn, purchased by state agencies and set aside for diminished wintering populations of Atlantic Population Canada geese (*Branta canadensis*).

Recent literature on greater snow goose depredations on agriculture in the Mid-Atlantic states is lacking. Therefore, an informal questionnaire survey was sent to wildlife agencies of states with wintering populations of the birds. Pennsylvania, New Jersey, Maryland, Delaware, Virginia, and North Carolina responded. We asked state personnel to indicate the average annual number of damage complaints submitted from farmers for the last three years. Less than 35 complaints annually were indicated from all 6 states. Pennsylvania (15) and Maryland (10) received the most snow goose complaints, followed by Delaware (5), and New Jersey (3, 1996-97 only). Virginia and North Carolina indicated only occasional complaints, while New York reported none. Damage occurred most often to winter wheat and barley. A few reports of damage to rye (PA) and clover (NJ) were also mentioned. In New Jersey, farmers growing salt hay (*Spartina patens)* are concerned about damage but have apparently learned to prevent it by using propane cannons throughout the winter (L. Widjeskog, NJ Div. of Fish, Game, and Wildlife, pers. comm.). Damage was reported to be on the increase in Pennsylvania, Maryland, and Delaware, and stable in the remaining states. Virginia and North Carolina reported that damage complaints were relatively high in the 1970s, but had dwindled to nearly none in recent years. Damage mechanisms include clipping of leaves, uprooting and trampling of plants, and soil compaction, particularly under wet conditions. Only Pennsylvania and North Carolina respondents feel that hunting snow geese alleviates damage to agricultural crops but Delaware and Maryland indicate that persistent harassment may be helpful.

Depredation problems arising from feeding greater snow geese are currently not a serious problem in the U.S. portion of the Atlantic Flyway. This is evidenced by the small number of complaints relative to the number of farmers accommodating the birds on their land each winter. Initially, farmers reacted in alarm as large numbers of the birds started using wheat fields. They have apparently learned to live with the damage and/or are dealing with it on their own. Damage complaints may not be as prevalent in the Mid-Atlantic states as they are in Québec due to the relative size of the farmed area in each location. In Québec the farmland acreage adjacent to roost sites is relatively small. In the states, farmland blocks in those areas used by snow geese may cover tens of thousands of acres. This may result in less intense use of individual ownership than in the more restricted northern farms. Also, in the U.S., farmers are not traditionally reimbursed for wildlife damage and thus have less incentive to report damage to the government. Timing of grazing may also be a factor since in the spring the tender growing plants may be far more vulnerable to damage than are the dormant plants of winter. In Delaware, Maryland, and portions of the other states which have a history of leased hunting, snow geese provide economic incentives to farmers to tolerate the limited damage received. As the greater snow goose population continues to increase however, we can anticipate increased agricultural depredations in some areas of the flyway.

Summary – Mid-Atlantic States

1. Snow geese were first seen feeding in farmlands in the Mid-Atlantic states around 1960 and the first depredation complaints were received in 1972.

2. Snow geese in farm lands feed primarily on the leaves of winter wheat, barley, and rye, and on waste grain in corn and soybean stubble fields. In recent years grain has become the preferred food.

3. Feeding by snow geese on winter wheat plants seems to reduce grain yield.

4. Gauged by the low number of complaints received from farmers, snow goose have not yet caused serious unacceptable damage to crops in the Mid-Atlantic states. This could become a serious problem as snow goose numbers increase and the tolerance level of farmers is exceeded.

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CHAPTER 4

POPULATION MODEL OF THE GREATER SNOW GOOSE: PROJECTED IMPACTS OF REDUCTION IN SURVIVAL ON POPULATION GROWTH RATE

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INTRODUCTION

The rapid and continuous increase of the greater snow goose population has brought some concerns about possible over-abundance problems similar to those observed in the mid-continent population of the lesser snow goose. We therefore undertook this modelling exercise to accomplish two objectives. First, we built a matrix-based model of the greater snow goose population using the most accurate demographic information currently available. Second, we explored the effect of a reduction in survival rate through projected increase in harvest rate on population growth rate.

The data on greater snow goose population size obtained from the annual spring photo count along the Saint Lawrence estuary since 1965 (see Chapter 1) is by far the most accurate estimates for this population, and probably one of the most accurate estimate of population size of any goose population in North America. Although there is evidence of density dependent effects on some population traits (e.g. body size of birds; Reed and Plante 1997, Chapter 2), so far we have failed to detect any such effects on survival or fecundity (Chapter 1, Menu 1998). Moreover, the graph of population size (Chapter 1) strongly suggests that over the 1965-97 period, the growth rate of the population has been exponential. We have therefore estimated the growth rate of the population using an exponential model ($N_t = N_0 e^{rt}$).

Adjusting an exponential model for the whole period yielded an estimated growth rate, λ ($\lambda = e^r$), of 1.089 (95% CI: 1.078-1.102; Fig. 4-1). Although the fit of the model is rather impressive ($R^2 = 0.893$), the distribution of the residuals along the regression line tends to be non-uniform with all data points for the period 1965-1968 falling below the line whereas those for the period 1970-1980 all falling above. This is a consequence of the near stabilization of the growth rate of the population during the mid and late seventies, as pointed out in Chapter 1. However, this had little effect on the estimate of the overall growth rate of the population. Indeed, if we restrict the model to the most recent period (1982-1997), the estimated growth rate is very similar ($\lambda = 1.097$; 95% CI: 1.085-1.108) even though the fit is improved ($R^2 = 0.964$) and the distribution of the residuals is uniform (Fig. 4-1).

This analysis shows that the greater snow goose population is growing at a very rapid rate which has been sustained over most of the last 30 years. An average annual growth rate of 9-10% is twice as high as the growth rate of the mid-continent population (5%; Rockwell *et al*. 1997). This means that the greater snow goose population is doubling every 8 years on average. If this growth rate is maintained, the spring population will have reached 1 million birds in 2002 and 2 millions birds in 2010. With the annual production of young, the fall population size will exceed these values much sooner. In this chapter, we examine the effect of changes in harvest rate on the growth rate of the population under various scenarios. More specifically, we ask by how much harvest rate should be increased to stop the population increase ($\lambda = 1.0$) or to reduce population size at an annual rate ranging from about 5 to 20% (i.e. $\lambda = 0.95$ to 0.80).
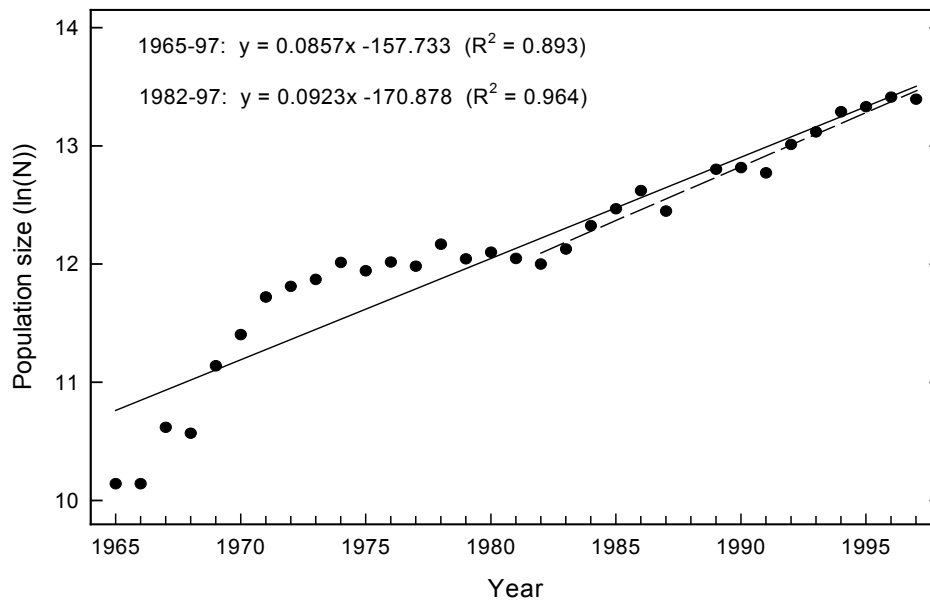
Figure 4-1. Growth of the greater snow goose population, 1965-1997. The slope of the relationship is an estimate of r, the annual rate of increase. The regression is calculated for the whole period (1965-1997) and for the period of most recent increase (1982-1997).

THE MODELLING APPROACH

For the purpose of the model, we have chosen to reduce the life cycle of the geese to 4 stages, which correspond to 4 reproductive classes (Fig. 4-2). Following the approach of Brault *et al.* (1994) and Rockwell *et al.* (1997), we used a birth-pulse matrix projection model that corresponds to the synchronous breeding patterns of the birds. We used the production of fledgling at the end of the summer as our measure of "fecundity". As this was the starting point of the year in our model, the model had a post-breeding census formulation (Caswell 1989). Stage 1 of the model (Juvenile) thus extended from fledging in year t (~1 month of age) until the end of summer $t+1$ (~1.1 years old). Stage 2 extended from the end of summer $t+1$ to the end of summer $t+2$ (2.1 years old). Because snow geese can start to breed at 2 year of age, some birds could have non-zero fecundity already in the 2nd stage. However, because fecundity occurred at the very end of the stage, a survival term had to be included in the estimation of fecundity. Stage 3 extended from the end of summer $t+2$ to the end of summer $t+3$. Finally, stage 4 included all subsequent reproductive classes ($t+4$, $t+5$, ...etc.).
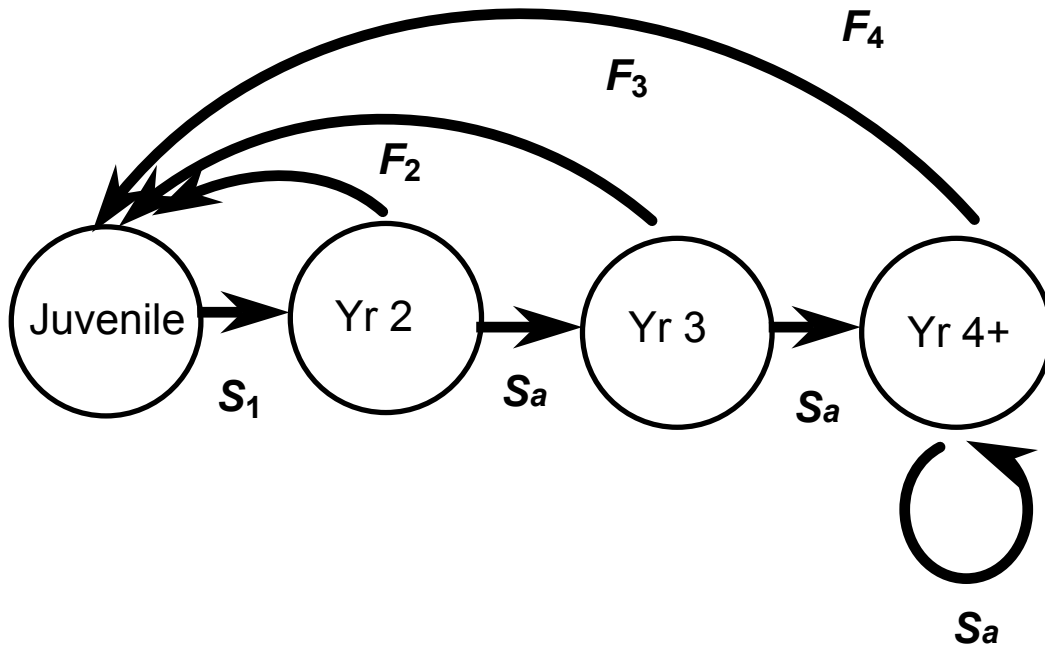
Figure 4-2. Life cycle of the greater snow goose used for the model. F = fecundity, S = survival. Numbers refer to stage, each stage referring to an age class (or year), starting at 1 month of age (i.e. at banding). Thus, Stage 1 of the model (Juvenile) extends from fledging (~1 month of age) until ~1.1 years old. See text for details. ($S_1 = 1^{st}$ year survival, S_a = adult survival).

This model can be cast into a Leslie style matrix where demographic parameters are included into matrix **A** and the population size in a vector **n**. In matrix **A**, the first row contains the fecundity terms (Fi) for each stage i, and subsequent rows contain the transition probabilities (Si), i.e. the probability of passing from one stage to the other (= survival). In vector **n**, each row corresponds to the number of individuals in stage (i.e. age-class) i. For a 4 stages model, the matrix is:

$$\mathbf{A} = \begin{bmatrix} 0 & F_2 & F_3 & F_4 \\ S_1 & 0 & 0 & 0 \\ 0 & S_2 & 0 & 0 \\ 0 & 0 & S_3 & S_4 \end{bmatrix} \qquad \mathbf{n} = \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{bmatrix}$$

The population was modelled or "projected" through time as: $n_{t+1} = A \bullet n_t$, and the projection interval was of one year. The population growth rate (λ) was calculated analytically as the largest positive eigenvalue of the transition matrix A. This growth rate is the asymptotic rate, i.e. the rate that will dominate the growth pattern of the population once it reaches a stable stage distribution. Given that the greater snow goose population has been increasing at a relatively steady rate in the last decade, this growth rate value should be a good estimate of the current rate.

Parameters F (fecundity) and S (survival) were estimated as follows. For the fecundity, we used the fitness component model of Rockwell to estimate this parameter (see Lepage 1997 for details).

$$F_i = BP_i \bullet (TCL_i/2) \bullet NS_i \bullet P1_i \bullet P2_i \bullet P3_i \bullet S_a$$

$$S_i = S_1 \quad \text{for } i = 1$$

$$S_i = S_a \quad \text{for } i > 1$$

where i = stage, BP = breeding propensity, TCL = clutch size, NS = nesting success, $P1$ = egg survival in successful nests, $P2$ = hatching success, $P3$ = gosling survival from leaving the nest until banding, S_1 = 1st year survival, S_a = annual adult survival (age > 1). A full definition of these variables can be found in Table 4-1. We divided clutch size by 2 because we modelled only the female component and assumed a 1:1 sex ratio at hatching.

Table 4-1. Definition of reproductive and survival parameters.

Parameter	Definition
Breeding propensity (BP)	Probability that a female alive at time t will attempt to breed.
Total clutch laid (TCL)	Total number of eggs laid by a nesting female (clutch size).
Nesting success (NS)	Probability that a nest will be successful, i.e. that at least one egg will hatch.
Egg survival ($P1$)	Probability that an egg will survive to hatching in successful nests.
Hatching success ($P2$)	Probability that an egg that reached hatching stage in successful nests will produce a gosling leaving the nest.
Gosling survival ($P3$)	Probability that a gosling leaving the nest survives until banding, which occurs just prior to fledging.
1st year survival (S_1)	Probability that a bird will survive from banding at ~1 month to the next banding period, at ~1.08 years.
Annual adult survival (S_a)	Probability that an adult bird (> 1 year old) will survive from one banding period to the next.

CHOICE OF MODEL PARAMETERS

There are no published demographic data for greater snow geese. The only available data comes from the ongoing population study conducted by Gilles Gauthier, Austin Reed and their students at the Bylot Island colony since 1990. One disadvantage of having only one data set is that it comes from a single colony whereas the breeding range of the species covers a vast area of the Canadian Arctic islands (Chapter 1). Thus, one should keep in mind that parameters estimated at this one site may not always apply throughout the breeding range of the species. A second potential problem with the data set is that the demographic parameters were estimated over a relatively short time frame (5 to 7 years in most cases) for a long-lived species. However, we have shown earlier that growth rate of the population has been fairly stable at least since 1982, which includes the period during which demographic data were collected. Finally, censuses conducted every 5 years at the Bylot Island colony since 1983 suggest that the growth rate of this colony has kept pace with that of the population as a whole during this period. Thus, all these considerations suggest that the Bylot Island data should be fairly representative of the population as a whole.

Most of the estimates of demographic parameters coming from the Bylot Island study can be found only in theses. They come from the Ph.D. work of Denis Lepage (1997) and Stéphane Menu (1998), and from some analyses conducted by Gilles Gauthier and Austin Reed. For these reasons, methodological details will be provided where appropriate. Although the best available parameter

estimates were used for the model, some of these analyses are still underway, and thus these estimates should be viewed as preliminary. As more data continues to accumulate from the Bylot Island banding program, new analyses will result in revised values for some of the parameters. Parameter values used in the current model can be found in Table 4-2. For one parameter (breeding propensity), no estimate is yet available from the Bylot Island project. We therefore used the values estimated for the Lesser Snow Goose at LaPérouse Bay (Rockwell *et al*. 1997).

Table 4-2. Estimates of reproductive and survival parameters for greater snow geese. All values are estimated from Bylot Island except breeding propensity which are values taken from LaPérouse Bay (Rockwell *et al*. 1997). Note that breeding propensity and adult survival were set equal in good, average and bad years.

Parameter	Stage (age class)	Good year	Average year	Bad year
Breeding propensity (*BP*)	1		0	
	2		0.35	
	3		0.77	
	4		0.85	
Total clutch laid (*TCL*)	2 – 4	4.44	3.81	3.39
Nesting success (*NS*)	2 – 4	0.89	0.71	0.14
Egg survival (*P1*)	2 – 4	0.956	0.905	0.885
Hatching success (*P2*)	2 – 4	0.960	0.930	0.879
Gosling survival (*P3*)	2 – 4	0.759	0.705	0.529
Survival (*S*)	1	0.50	0.35	0.12
	2-4		0.83	

One characteristic of the greater snow goose population is that it nests in a high Arctic environment where conditions are highly variable among years. This has a considerable effect on annual production of young which can vary by more than one order of magnitude between a "good" and a "bad" year, with periodic breeding failures (see Chapter 1; also, Lepage *et al*. 1996, Lepage 1997). Because of this variability, we have selected 3 sets of parameters, corresponding respectively to a "Good", "Average" and "Bad" year of reproduction. Our analyses suggest that all fecundity parameters will be enhanced or reduced in a good or a bad year, respectively. First-year survival will also differ between a good, average or bad year because environmental conditions prevailing during breeding may have a strong influence on survival immediately after fledging, especially during fall migration (Menu 1998). In contrast, adult survival appears little affected by variable conditions in the Arctic. Data for a good year come mostly from 1991 and 1993 whereas data for a bad year come mostly from 1992 and 1994.

Details on the estimates of total clutch laid, nesting success, egg survival and hatching success can be found in Lepage (1997). Gosling survival was estimated with SURGE at 30% using recaptures of web-tagged goslings by Lepage (1997). However, this estimate is unrealistically low and is not supported by field observations of change in brood size during the summer. We suspect the presence of some sources of heterogeneity in the estimation of the recapture probability, which would cause an underestimation of survival with this method. We preferred to use another estimate of gosling survival which can be obtained from direct observations of brood size and young:adult ratio at banding. Change in brood size between hatch and banding gives an estimate of loss of goslings in broods that are not totally lost. Over the period 1991-1995, the apparent probability of

survival of goslings was 0.835 ± (SE) 0.040 (annual range: 0.734 – 0.960). This estimate, however, has to be corrected for broods that lost all their goslings. The proportion of broods that lost all their goslings (*TBL*) can be calculated as follows:

$$TBL \ = \ 1 \ - \ \frac{N_G / N_A}{BS / 2}$$

where N_G/N_A is the gosling:adult ratio in banding catches and *BS* is the average brood size observed at the time of banding. Over the period 1990-1997, total brood failure was estimated at 0.177 ± 0.049 (annual range: 0.0 – 0.290). Combining these two estimates yielded an average estimate of gosling survival (*P3*) of 70.5%, a value considerably higher than the one estimated by recapture of web-tagged goslings. The former estimate assumes that 1) all young are accompanied by two parents, 2) non-breeders or birds that lose their clutch before hatch are not captured at banding, and 3) birds that lose all their young after hatch have an equal chance of being captured at banding than those that retained some young. Assumption 1 is likely to be true most of the time. Assumption 2 is also largely true on Bylot Island. Indeed, telemetry data and observations of flock of non-breeders show that these birds leave the island or have regained flight abilities before our banding. Assumption 3, however, may not always be true: birds that lose all their young tend to molt together and may be less likely to be caught at banding. Thus, total brood failure may be slightly underestimated and gosling survival overestimated with this method.

First year survival was estimated using band-recovery analyses for birds banded on Bylot Island between 1990-1996. Analyses using SURVIV suggested that 1st year survival was time dependent with large annual variations (Menu 1998; Table 4-2). During that period, average survival was 0.35 and did not differ between sexes except in one year. There was no evidence of consistent temporal trend (i.e. long-term decrease or increase). Adult survival was estimated using several methods. The first one used resightings of neck-banded females. Using this method, survival of females was estimated at 0.83 ± (SE) 0.06. Band-recovery analyses of females only yielded an almost identical survival estimate (0.82 ± 0.09). Finally, band-recovery analyses of male and females simultaneously yielded an estimate of 0.79 ± 0.03 while accepting the hypothesis of equality of survival rates between sexes (Menu 1998). All these analyses accepted the hypothesis of constant survival rate over time and none of these values differed significantly. For modelling purpose, we retained the value of 0.83 (females only).

Selection of a constant survival rate for adults in the face of a declining harvest rate has been a contentious issue in the population model of the mid-continent lesser snow geese (Cooke and Cooch 1998). However, contrary to lesser snow geese, harvest rate of greater snow geese has been fairly stable since an abrupt decline in the mid-eighties (Chapter 1). Harvest rate has remained stable in recent years because total harvest has increased steadily in Canada. Thus, the hypothesis of constant adult survival rate over the last 10-15 years appears reasonable.

THE MODEL

When we used the values for a year of average reproduction (Table 4-2) in the model, we obtain a $\lambda_A = 1.009$, i.e. an almost stable population. Clearly, this suggests that average values do not describe very well the population, which currently has a $\hat{\lambda} \approx 1.09$. In contrast, using values for a good year yielded a λ_G of 1.174, a value much higher than the current growth rate. Finally, parameter values for a bad year yielded a λ_B of 0.840, indicating a declining population. We calculated the proportion of good, average and bad years of production based on the proportion of young estimated in the fall flock (Chapter 1). Good years were defined as years with ≥30% young in the fall flock, average years had ≥10% and < 30% young, and bad years (i.e. years of breeding failure) had <10% young. Since 1982 (i.e. during the most recent period of sustained population growth; Fig. 4-1), there were 8 good, 5 average and 3 bad years, for a ratio of 5:3:2 over a 10-year

period. Combining good, average and bad years using this ratio, we obtained through simulations[2] an average λ of 1.061 (0.995-1.124 95% CI; geometric mean = 1.049), which is still below the actual growth rate of the population. A ratio of 6:3:1 (good:average:bad years) was required to obtain an average λ of 1.104 (1.043-1.156 95% CI; geometric mean = 1.085), a value close to the actual growth rate of the population.
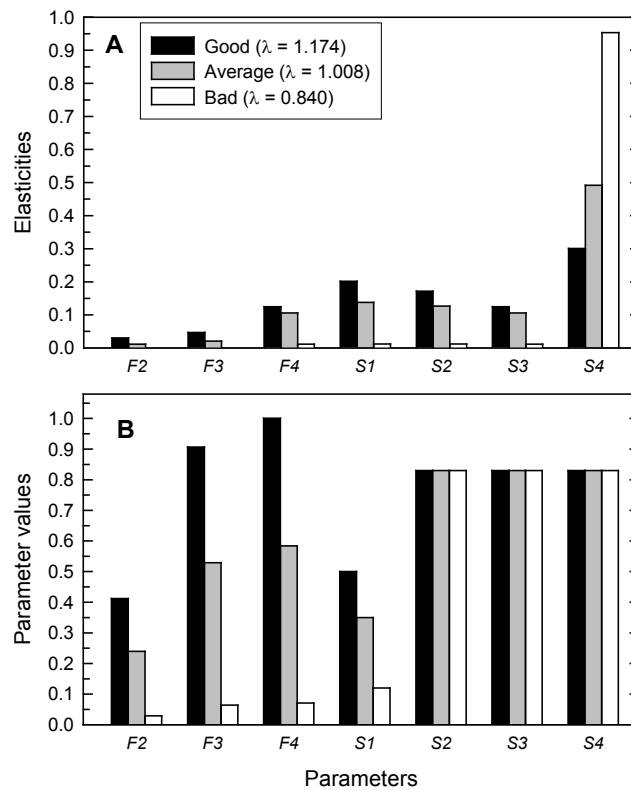
Elasticity Analyses

The elasticity of any element in a Leslie matrix is its proportionate contribution to the growth rate of the population (they sum to 1). Each elasticity can also be viewed as the proportional change one would expect in the growth rate given a proportionate change in that element. Changing elements with higher elasticity will alter the growth rate more than changing those with lower elasticity.

The elasticity of the 7 elements of each matrix (good, average and bad years) is shown in Fig. 4-3a, along with each parameter value (Fig 4-3b). As usual in long-lived animals, elasticities of survival are much higher than the ones of fecundity. Even in a good year of reproduction, combined elasticities of all fecundity elements (F_2 to F_4) sum up to only 0.202, compared to 0.202 for 1st year survival (S_1) and 0.597 for adult survival (S_2 to S_4). This means that all fecundity parameters and 1st year survival contribute in about the same proportion to the population growth (20% each) but adult survival by itself contributes for 60% of the population growth. When reproductive success is reduced (average and bad year), the elasticities of all fecundity elements and survival of younger age classes (S_1 to S_3) are reduced whereas the elasticity of older adults (S_4) is increased. For an average year, fecundity and 1st year survival contribute for 14% of the population growth each compared to 72% for adult survival. Differences are much more extreme in a year where reproductive success is very poor. Under these conditions, adult survival contributes to as much as 97% of the growth of the population.

The contribution of the survival elements of the matrix to population growth is actually slightly underestimated because the variable adult survival (S_a) is also included in the estimation of fecundity (see fecundity equation above). This occurs because we used a post-breeding census model (Caswell 1989). It is possible to estimate the exact contribution of adult survival to the elasticity of λ by partial differentiation (Rockwell *et al*. 1997). These contributions are termed "lower level elasticities" and, while they do not sum to 1 (as do higher level elasticities), they provide a relative measure of the impact of a proportionate change of a given parameter on population growth. The same procedure can be used to estimate the lower level elasticity of each parameter entering in the calculation of fecundity (see fecundity equation and Table 4-2).

Results from this analysis clearly show that adult survival makes by far the largest contribution to population growth (Fig. 4-4). For example, a 10% reduction in adult survival in a good year of reproduction would result in more than a 4-fold greater reduction in λ than a 10% reduction in any component of fecundity. The difference would even be greater in average or bad years of reproduction. Contribution of the various components of fecundity to population growth is about equal although breeding propensity of experienced breeders appears to be the most important

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[2] We ran 1000 simulations of 30 years each. At each yearly iteration, one of the three matrices was randomly selected based on probabilities equal to the chosen ratio of good:average:bad years. For each simulation, the mean growth rate (λ) was calculated as $[\ln(N_{30})-\ln(N_1)]/29$. The λ values from the 1000 simulations were used to calculate mean λ and the approximate 95% confidence limits, defined as the 2.5th and 97.5th percentiles of λ values sorted from the lowest to the highest value. We used this method to calculate the average and confidence intervals of λ whenever we used a ratio of good, average and bad years, unless mentioned otherwise in the text.

Figure 4-3. Elasticities (A) and values (B) of parameters used in the model for good, average and bad years of reproduction. F = fertility, S = survival. Numbers refer to stages (= age classes; see Fig. 4-2).

Proportion of Good, Average and Bad Years

One could argue that the proportion of good years used in the model (60%) to adequately describe the current growth rate is too high. This may be true and may in fact point out to some limitations of the data. A first problem may be that we simply don't have enough years of data available from the Bylot Island study, especially considering that we have a relatively long lived bird which breeds in a highly variable environment. A second problem may be related to the imprecision of some parameter estimates, especially adult survival and breeding propensity. Because of the very high elasticity of S_a, a slight error in the estimation of this parameter will have a large impact on our estimate of λ. To illustrate this, we have increased S_a by 1 standard error (0.83+0.06). Doing this results in substantially higher λ (λ_G = 1.239, λ_A = 1.070 and λ_B = 0.900). Mean λ then becomes 1.154 (1.092-1.207 95% CI; geometric mean = 1.148) for a ratio 6 good:3 average:1 bad, a value higher than the observed population growth, and 1.107 (1.046-1.166 95% CI; geometric mean = 1.112) for a ratio 5:3:2, a value close to the observed one. This illustrates the importance of estimating S_a with high precision, something that can only be achieved with long-term banding program, and requires large samples of banded and resighted birds.
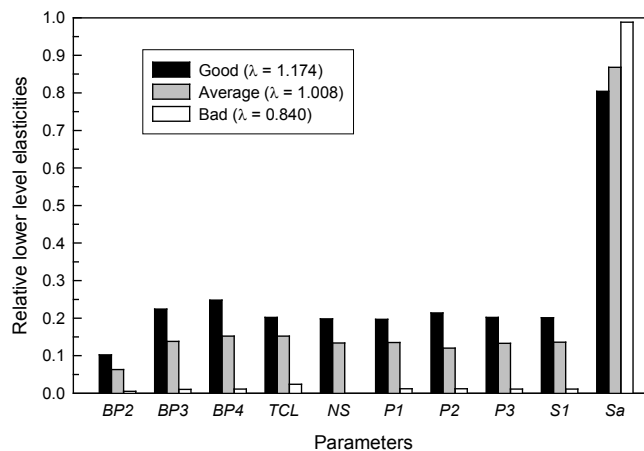
Figure 4-4. Relative lower level elasticities of the reproductive and survival parameters for good, average and bad years of reproduction. See Table 4-1 for definition of parameters. For *BP*, numbers refer to age-classes.

The estimation of breeding propensity (*BP*) is also problematic because no estimate is available for the greater snow goose (remember that we used the values for the lesser snow goose at LaPérouse Bay). We suspect that in a good year, *BP* may be higher than the values used, and this could have a large effect on λ_G. To illustrate this point, assume that in a good year, *BP* for 2, 3 and 4+ years old are 0.7, 0.85 and 0.95 (compared to values of 0.35, 0.77 and 0.85). Under this scenario, λ_G is 1.234, a substantial increase over the original value (1.174). Conversely, we can suppose that *BP* will also decrease in a bad year. However, even if BP is reduced by 50% in a bad year (values of 0.175, 0.385 and 0.425 for 2, 3 and 4+ years respectively), λ_B will suffer only a slight reduction to 0.835 (vs 0.840 previously). This, of course, is a consequence of the large difference in the elasticity of *BP* between a good and a bad year (Fig. 4-4): in a bad year, a decrease in *BP* has little effect on λ because the reproductive success is already very low. In contrast, in a good year, even a slight increase in *BP* can have a large effect in λ. Good breeding years will therefore have a disproportionate effect on the overall growth rate of the population. If we used these adjusted *BP* values (i.e. enhanced in good years, reduced in bad ones), the ratio of good:average:bad years observed in the population (5:3:2) then yields an average λ of 1.129 (1.057-1.211 95% CI; geometric mean = 1.074), a value closer to the observed population growth.

At this stage, we have chosen to retain in the model the three sets of parameters (good, average, and bad) in a proportion 6:3:1 to explore the effect of change in harvest on population growth. We felt that using different values of survival or breeding propensity without further quantitative data was too speculative at this stage, and therefore not warranted.

ANALYSIS OF THE EFFECT OF SPORT HUNTING ON POPULATION GROWTH

The previous analysis showed that the most important variable affecting growth rate of the greater snow goose population is adult survival, followed by 1st year survival and fecundity. Because of the low elasticity value of fecundity and the difficulty of directly affecting this parameter through management action (e.g. large scale egg harvesting), we do not believe that such action is a viable option. Although egg harvesting can contribute to a reduction of population growth, its overall effect on growth will be small even with a large-scale program (Rockwell *et al*. 1997). Furthermore, the remoteness and widespread dispersal of greater snow geese breeding areas (see

Chapter 1) would make large scale egg harvesting even more prohibitive than in the lesser snow goose. Therefore, we chose not to examine the effect of reducing fecundity, and to concentrate on the effect of reducing survival through an increase in sport hunting in fall, winter and spring on population growth.

Estimation of Hunting Mortality

In order to examine the effect of harvest through sport hunting on population growth, we first have to determine what is presently the contribution of sport hunting to the annual mortality of young and adult greater snow geese. Hunting mortality can be estimated from two sources: the regular national harvest surveys in Canada and the US, and band recovery analyses. Both sources of information can be biased. We did not use data band recovery analyses because: 1) band recovery data are available for only a small number of years (since 1990) and, 2) reporting rate of banded birds that are shot is poorly known, especially in Québec where it could be different from the U.S.

We chose to use data from the harvest survey to estimate hunting mortality. An estimate of hunting mortality is provided by the harvest rate (*HR*), which is the ratio between the total number of birds killed by recreational hunting and the total fall population size. In Chapter 1, we estimated annual harvest rate for young and adults for the period 1968-95. Our analysis showed that harvest rate has been relatively stable since 1985, following an abrupt drop in 1984-85. We therefore used harvest rate data since 1985 as an index of hunting mortality. Rockwell *et al*. (1997) did not use harvest rate to estimate hunting mortality in lesser snow geese because they argued that both population size (obtained from mid-winter counts) and harvest were merely indices, and therefore poor estimators of true values (see also Cooke and Cooch 1998). However, we believe that these limitations do not apply to greater snow geese. First, we used population size data from the annual census conducted every year in the St. Lawrence estuary, Québec, which is a total population count much more accurate than the mid-winter counts (see Chapter 1). Second, the accuracy of harvest estimates through the national harvest surveys has increased over the years. Third, because the range of the greater snow goose is restricted to the Atlantic Flyway and overlaps little with other snow goose populations, harvest estimate is not likely to be contaminated by other populations.

Annual survival (*S*) of birds from one banding period to the next (i.e. from late summer to late summer) can be seen as the product of three independent events:

$$S = S_{NA1} \bullet S_H \bullet S_{NA2}$$

where S_{NA1} is the probability of surviving to natural mortality (M_{NA1}) occurring during the fall migration (i.e. before the hunting season), S_H is the probability of surviving to hunting mortality (M_H), and S_{NA2} is the probability of surviving to natural mortality after the fall migration, i.e. during and after the hunting season (M_{NA2}; this assumes that hunting mortality is additive to non-hunting mortality). In adults, we assumed that mortality during the fall migration is negligible and we set this value equal to 0 ($S_{NA1} = 1$). Over the period 1985-95, the average annual harvest rate (= M_H) of adults has been 0.06 (Chapter 1). Using our estimate of annual survival ($S_a = 0.83$), we estimated natural mortality in adults at 0.12 (Table 4-3), suggesting that hunting mortality accounts for about a third of annual mortality of adults.

In contrast to adults, assuming that mortality of young is negligible during the fall migration is clearly inappropriate because natural mortality during this period can be very high (Menu 1998). We estimated hunting mortality of young separately for good, average and bad years because of large annual differences in fall migration survival and, to a lesser extent, in harvest rate (Table 4-3). Data for fall migration survival is available for 4 years (1993-96) and we used the lowest and highest value for our estimate of good and bad years. Harvest rate (= M_H) of young was 0.28 in good years (about 47% of total mortality), 0.32 in an average year (37% of total mortality) and 0.37 in a bad year (21% of total mortality). However, values of post-migration natural mortality for young appear

to be too low (Table 4-3). We suspect that fall migration mortality and/or the hunting mortality are biased high although we have no means to correct for this potential bias.

Table 4-3. Estimation of hunting mortality in young (1st year) and adult greater snow geese for years of good, average and bad production of young based on harvest rate data calculated from national harvest surveys in Canada and the U.S.

Year	Annual mortality	Fall migration natural mortality	Hunting mortality (Harvest rate)	Post-migration natural mortality	Total natural mortality
Adult					
All years	0.17	0.00	0.06	0.12	0.12
Young					
Good	0.50	0.28	0.28	0.04	0.31
Average	0.65	0.45	0.32	0.07	0.49
Bad	0.88	0.81	0.37	0.03	0.81

Annual Mortality (M): from Table 4-2.
Fall migration natural mortality (M_{NA1}): data are from Menu (1998). To contrast mortality during the fall migration in a good, average and bad years we used data for the 1995 (good), 1996 (average) and 1994 (bad) fall migration.
Harvest rate (HR): data are from Chapter 1, for the period 1985-1995. For young, harvest rate was calculated separately for years of good ($\geq$30% young in fall flock), average ($\geq$10% and < 30%) and bad (<10%) production during the period 1985-95.

Post-migration natural mortality (M_{NA2}):
$$M_{NA2} = 1 - \left(\frac{1-M}{(1-M_{NA1}) \bullet (1-HR)} \right)$$

Total natural mortality (M_{NA}):
$$M_{NA} = 1 - \left[(1-M_{NA1}) \bullet (1-M_{NA2}) \right]$$

Scenarios for Increased Harvest

We simulated three scenarios of increased harvest through sport hunting on the greater snow goose population growth:

A. Increase in hunting mortality of adults only
B. Increase in hunting mortality of young only
C. Increase in hunting mortality of adults and young simultaneously

To achieve this, we increased hunting mortality by increments of 25% from 0 to 200%. This corresponds to multiplying hunting mortality by a factor ranging from 0 (no increase) to 3.0 (200% increase). This factor is referred to as the "Proportional increase in hunting mortality". Because hunting mortality varies between good, average and bad years, we repeated the simulations for each of these matrices. We also combined the results of the good/average/bad matrices in a ratio 6:3:1, the ratio that best explained the current population growth (see above).

For adults, increasing hunting mortality by a factor of 3 (i.e. from the current value of 0.06 to 0.18) meant that S_a in the Leslie matrix model was reduced from 0.83 to 0.72 (Table 4-4; we set natural mortality constant at 0.12, i.e. we assumed that hunting mortality was completely additive). Because the fecundity terms included adult survival (i.e. post-breeding census, see equation for fecundity above), we had to adjust the F_2, F_3 and F_4 values each time S_a was modified, taking the different fecundity values in good/average/bad years (Table 4-2). For young, we increased hunting mortality from 0.28 to 0.84 (3-fold increase) in a good year (1st year survival, S_1 = 0.50 to 0.11, Table 4-4), from 0.32 to 0.96 in an average year (S_1 = 0.35 to 0.02), and 0.37 to 1.00 in a bad year (S_1 = 0.12 to 0.0). One should note that increasing the current hunting mortality by a similar factor

in young and adults results in a greater reduction in the 1st year survival than in adult survival (Table 4-4). This is because the hunting mortality is up to 6 times higher in young than in adults. Indeed, we showed in Chapter 1 that the average annual kill for the last 5 years is 44,500 young and 25,500 adults, almost a ratio 2:1 (Y:A). In essence, scenario C (similar increase in hunting mortality for adult and young) assumes that this age ratio is maintained in the harvest, in contrast to scenarios A (increase in hunting mortality of adults only) or B (increase in hunting mortality of young only) which assume that this ratio declines (scenario A) or increases (scenario B). Therefore, increasing hunting mortality by a similar factor in young and adults (scenario C) will result in a much higher increase in absolute number of young birds killed compared to adults.

The effect of increasing hunting mortality on population growth rate (λ) is presented in Table 4-4 and Fig. 4-5. We note that an increase in hunting mortality of young causes a larger reduction in population growth rate than a similar increase in adult mortality for good and average years (Fig. 4-5; this does not occur in a bad year because production of young is so low that increasing their hunting mortality will have little impact on population growth). This surprising result appears in contradiction with our earlier statement that adult survival is the parameter that contributes the most to population growth because of its high elasticity. This difference stems from the fact that hunting mortality is about 4 to 6 times higher in young than in adults. Therefore, increasing hunting mortality by the same factor in both groups will result in a much more substantial decrease in survival of young compared to adults, and hence will have greater impact on λ.

We believe that a liberalization of hunting regulations for greater snow geese will likely affect both adult and young and that it will be difficult to achieve a disproportionately large increase in hunting mortality of adults. Therefore, scenario C, which assumes that any liberalization in hunting regulation will affect young and adult equally (and thus maintain the current hunting bias in favor of young) is probably the most realistic. Under the model that best describes the current population growth of greater snow geese (i.e. combination of good/average/bad years in proportion 6:3:1, Fig. 4-5), a stabilization of the population (i.e. $\lambda = 1.0$) may be achieved by increasing hunting mortality by about 60% (i.e. 1.6x on the *x* axis; see also Table 4-4). Similarly, a doubling of the current hunting mortality would lead to a $\lambda = 0.938$, or a population decreasing at about 6%/year. These values would reflect the actual situation over a long time period. However, because good, average and bad years of reproduction can occur in a random fashion, in the short term (i.e. over a 3 or 4-year period), greater snow geese could experience a run of "good" reproduction years just by chance. If this was the case, then scenario C for the good reproduction years should also be considered. Under these conditions, a stabilization of the growth of the population ($\lambda = 1.0$) would require that harvest be increased by a factor 2.1 (i.e. at least a 100% increase).

Until now, our discussion has focused on the increase in hunting mortality required to reduce current population growth. However, our estimation of hunting mortality is based on a data set (national harvest survey) that may be subject to biases; it also requires additional assumptions (e.g. that hunting mortality is additive) and the estimation of additional parameters (e.g. survival during the fall migration, Table 4-3). Although we believe that our estimate of hunting mortality is the best value that can be obtained, given the information available, its precision is probably low and it may be biased. However, an alternative way to look at this problem may be to directly examine the relationship between survival rate and λ (Table 4-4). This will tell us by how much we have to reduce adult and/or young survival to achieve targeted population growth rate. This approach could be especially useful if one wants to monitor the success of our management actions, i.e. by how much survival rate has actually been reduced once harvest regulation have been liberalized.

Table 4-4. The effect of increase in hunting mortality (multiple) on total survival of adult and young greater snow geese, and on the population growth rate (λ) if only adult mortality (scenario A), only young mortality (scenario B) or both (scenario C) are increased. The analysis is repeated for good,

average and bad years of reproduction, and for the combination of these 3 years (in ratio 6 good : 3 average : 1 bad) that best describes the current growth of the population.

Increase in hunting mortality	Survival		λ		
	Adult	Young	Scenario A	Scenario B	Scenario C
Good year					
x1	0.830	0.500	1.174	1.174	1.174
x1.25	0.817	0.451	1.160	1.151	1.137
x1.5	0.804	0.403	1.146	1.126	1.099
x1.75	0.790	0.354	1.131	1.100	1.058
x2	0.777	0.305	1.117	1.072	1.017
x2.25	0.764	0.257	1.103	1.043	0.975
x2.5	0.751	0.208	1.088	1.011	0.931
x2.75	0.737	0.160	1.073	0.977	0.883
x3	0.724	0.111	1.059	0.939	0.833
Average year					
x1	0.830	0.350	1.009	1.009	1.009
x1.25	0.817	0.308	0.995	0.992	0.978
x1.5	0.804	0.267	0.982	0.974	0.948
x1.75	0.790	0.226	0.968	0.956	0.916
x2	0.777	0.185	0.955	0.937	0.883
x2.25	0.764	0.144	0.941	0.916	0.850
x2.5	0.751	0.103	0.928	0.894	0.815
x2.75	0.737	0.062	0.914	0.870	0.778
x3	0.724	0.021	0.900	0.844	0.739
Bad year					
x1	0.830	0.120	0.840	0.840	0.840
x1.25	0.817	0.102	0.827	0.839	0.826
x1.5	0.804	0.085	0.814	0.837	0.811
x1.75	0.790	0.067	0.800	0.836	0.796
x2	0.777	0.049	0.787	0.834	0.781
x2.25	0.764	0.032	0.774	0.833	0.767
x2.5	0.751	0.014	0.761	0.831	0.752
x2.75	0.737	0.000	0.747	0.830	0.737
x3	0.724	0.000	0.734	0.830	0.724
6 Good : 3 Average : 1 Bad years					
x1	0.830	0.417*	1.104	1.104	1.104
x1.25	0.817	0.373*	1.071	1.069	1.052
x1.5	0.804	0.330*	1.053	1.046	1.015
x1.75	0.790	0.287*	1.042	1.025	0.976
x2	0.777	0.244*	1.019	1.000	0.938
x2.25	0.764	0.200*	1.006	0.974	0.896
x2.5	0.751	0.157*	0.990	0.948	0.854
x2.75	0.737	0.114*	0.971	0.919	0.810
x3	0.724	0.073*	0.957	0.889	0.767

* Unlike adult survival, young survival differs among good, average and bad years. Therefore, the weighted average under a combination of 6 good: 3 average: 1 bad is only given as a general indication since survival is here time dependent.
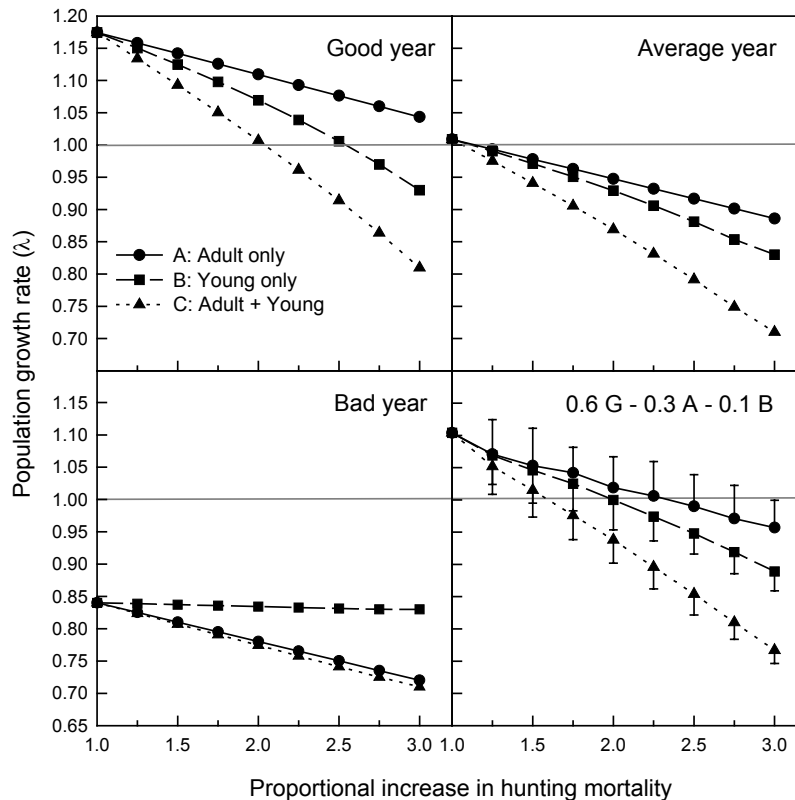
Figure 4-5. The effect of increase in hunting mortality (multiple) on growth rate (λ) of the greater snow goose population in good, average and bad years of reproduction, and for the combination of these 3 years (in ratio 6 good : 3 average : 1 bad) that best describes the current growth of the population. Three scenarios are presented: increase in hunting mortality of adult only (A), young only (B) and both adult and young at the same time (C). For the combination 6:3:1, the 95% confidence interval of each estimate is presented.

SUMMARY

1. A model of exponential growth rate fitted well the greater snow goose population size data over the last 30 years. The average growth rate of the population over this period is estimated at about 9-10% (1965-1997: $\lambda = 1.089$; 1982-1997: $\lambda = 1.097$). This means that the greater snow goose population is doubling about every 8 years.

2. To model the population, we used a birth-pulse matrix projection model (i.e. Leslie-style matrix) using the production of fledglings at the end of the summer as our measure of "fecundity" (i.e. post-breeding census formulation). We defined 4 stages (i.e. age classes). Parameter estimates for the model all came from the on-going population study of greater snow geese on Bylot Island, except for breeding propensity for which we used values from the lesser snow goose at LaPérouse Bay. Some of these estimates, however, should be viewed as preliminary.

3. To adequately describe the current population growth rate, we had to define 3 matrices, each corresponding to conditions prevailing in a good, average and bad years of reproduction. All

fecundity parameters and 1st year survival differed among these 3 matrices, but not adult survival. A ratio of 6 good: 3 average: 1 bad years was required to obtain a λ of 1.104, a value close to the actual growth rate of the population. This corresponded relatively well to the proportion of good:average:bad years of reproduction observed in recent years in this population (ratio of 5:3:2), though not perfectly, probably reflecting the imprecision of some parameter estimates.

4. The elasticity analyses showed that the most important variable affecting growth rate is adult survival, followed by 1st year survival and fecundity. Adult survival was estimated at 0.83 (constant over time) and young survival at 0.5 (good year), 0.35 (average) and 0.12 (bad).

5. We used data from the national harvest survey in Canada and the US to estimate hunting mortality. We estimated that hunting mortality of adults was 0.06, about a third of total annual mortality (0.17). For young, we estimated hunting mortality at 0.28 in a good year (about 47% of total mortality), 0.32 in an average year (37% of total mortality) and 0.37 in a bad year (21% of total mortality).

6. Under the model that best describes the current population growth of greater snow geese (i.e. combination of good/average/bad years in a ratio of 6:3:1), a stabilization of the population (i.e. λ = 1.0) should be achieved by increasing hunting mortality by about 60% (i.e. 1.6x actual harvest). However, if greater snow geese were to experience a run of "good" years of reproduction, a stabilization of population growth would require that harvest be increased by a factor 2.1 (i.e. at least a 100% increase).

7. During the period of stabilization of population growth (1975-85), harvest rate was estimated at 25%, compared to 12% now. This "natural experiment" suggests that a 2-fold increase in hunting mortality is required to bring stability. Our model predicted that stabilization could in theory be achieved by increasing hunting mortality by a factor of 1.6. On the other hand, under good breeding conditions, the model also predicted that a 2-fold increase in harvest rate is required. However, we should be cautious in this comparison because: 1) harvest data may have some biases (which may have been larger in the earlier years compared to later ones), and, 2) demography of the population (i.e. natural mortality, fecundity, etc) may have changed.

8. Our analysis emphasizes the importance of long-term studies to obtain reliable estimates of demographic parameters. At the same time, it points out the limitations of some of the current estimates (e.g. breeding propensity, hunting mortality), and underlines the need to improve the quality of these estimates. For instance, as additional banding data accumulate, it may be possible to obtain a better estimate of hunting mortality using recovery rates instead of harvest surveys. Finally, monitoring adult and young survival through a continued banding program may be the best way to monitor our success in increasing mortality, and thus reducing population growth, through a liberalization of hunting regulations.

ACKNOWLEDGMENTS

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CHAPTER 5

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CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

CONCLUSIONS

1. Under current management strategies the greater snow goose population will soon exceed 1 million birds and continue to double every eight years.

The average growth rate of the greater snow goose population since 1982 has exceeded 9% which is nearly twice the rate observed for mid-continent lesser snow geese (Rockwell et al. 1997). The population has increased from less than 50,000 geese during the springs 1965-1968 to more than 650,000 in 1996-1997. At this rate, the spring population could reach 1 million birds by 2002 and 2 million by 2010. Productivity, as measured by age ratios (% juveniles) in the fall flight, has averaged 24% over the period 1965-1997, showing no long-term trend.

Reduced harvest rates have been the main factor contributing to continued population growth since the mid-1980s. The current 12% harvest rate is about one half of the rate that prevailed when the population was near stability during the 1975-1983 period. Non-hunting mortality during the non-breeding season may have remained low or even decreased as the geese have gradually discovered a supplementary food supply on agricultural land. Another factor in continued population growth is that supplemental agricultural foods in spring improve body condition, thereby improving snow goose recruitment.

2. Expansion of greater snow geese into new habitats has not kept pace with increases in the population in some portions of the range.

During the 1960s and 1970s the adaptation to exploit agricultural lands for feeding significantly expanded snow goose wintering habitat. More recently, some additional expansion of wintering range has been recorded, but the main result of population growth has been a build up of numbers in Delaware and Maryland, and since 1991 in New Jersey, New York, and Pennsylvania. Numbers have not increased in the southern portion of the winter range in North Carolina.

The main spring staging area along the St. Lawrence valley has expanded from a 40-km portion of the river to more than 400-km, and now extends along the Richelieu River to northern Lake Champlain. Similar expansion has been observed in fall but the most important change has been the increasing number of birds that are now flying directly to the U.S. without stopping in southern Québec. The fall staging period of individual birds along the St. Lawrence estuary is also shorter now than 15 years ago.

During the last three decades, only a few new breeding areas have been discovered and the overall breeding range has expanded only slightly. The most important result of the increase in population and the failure to colonize new breeding areas has been increasing densities at main breeding colonies.

3. **Greater snow goose populations have reached carrying capacity in some marshes within staging and wintering areas and could exceed it in Arctic breeding areas in the near future under current management. This may be detrimental to the snow geese themselves and to other wildlife with which they share these habitats.**

The feeding activities of large numbers of greater snow geese have a significant influence on wetland communities throughout their range. Habitat change caused by snow geese may favor some species of wildlife but are probably harmful to others. There is a growing concern that greater snow geese may displace Atlantic Population Canada geese on some staging areas. Over-abundant greater snow geese may interfere with management of other waterfowl species by monopolizing winter banding sites and feeding sanctuaries developed for other species.

Arctic breeding habitats are likely the most limiting of any used by the geese during their annual cycle. Actual estimates at Bylot Island, the largest breeding colony, indicate that the population is already over 50 percent of the carrying capacity. Significant declines in body mass, structural size, and condition of goslings during the fall in southern Québec over a 19 year period (1975-1994) indicate that density dependent effects on growth are likely occurring during the brood rearing period. Extensive damage to arctic habitats, such as those resulting from lesser snow geese feeding along the Hudson Bay coast has not yet been observed for greater snow geese. However, as carrying capacity is reached and exceeded, long-term, even irreversible damage to these fragile habitats will likely occur.

Greater snow geese are affecting marsh habitats in migration and wintering areas. Along the St. Lawrence River, recent observations of bulrush marshes used by geese during their fall and spring migration have shown that the carrying capacity of some of these marshes has been reached. The most deteriorated marshes occur within bird sanctuaries where geese concentrate their feeding activities in fall. Plant species composition changes, declines in plant production, and marsh erosion have occurred. These marshes, however, could recover within a few years if the distribution of geese was modified by periodically changing location of sanctuaries. Snow geese have not had a significant effect on cordgrass marshes along the St. Lawrence River.

Cordgrass marshes used by wintering geese along the U.S. Atlantic coast appear to be more affected. Eat-outs have been reported for a long time and it may take several years before these marshes become fully vegetated again. The effect of eat-outs on other wildlife species is a major concern in some refuges, which are among the best bird-watching spots in the eastern U.S. The loss of some marsh invertebrates that support wintering American black ducks is also a concern. Nevertheless, areas of eat-outs have not increased proportionally with the demographic expansion of the population because geese are not utilizing additional salt marsh habitats in proportion to their increasing numbers. Rather they are increasing in density on their traditional sites, exerting even greater grazing pressure on already damaged habitats. Snow geese are making greater use of agricultural habitats, in most parts of the wintering range.

4. Increasing numbers of greater snow geese feeding in agricultural fields causes economic losses for farmers and will increasingly interfere with wildlife management programs for other species.

The increasing tendency of greater snow geese to feed on agricultural crops has undoubtedly been the primary reason for the rapid increase in numbers since 1960. Food supplies, during the spring migration and wintering periods, are less likely to be limiting factors and breeding geese now have advantages in body condition, probably not realized by previous generations of the birds limited to marsh feeding during winter. One other consequence of increasing numbers of field feeding greater snow geese is crop depredation problems in southern Québec, and to a lesser extent in the U.S.

Damage to hay fields in early spring is the most serious problem in Québec. Somewhat less than 1 million dollars of damage is recorded annually along the St. Lawrence estuary but these losses affect individual farmers who are only partially compensated. The problem seriously affects a non-negligible number of farmers who have been unable to recuperate losses by renting out hunting rights, and cannot (for climatic reasons and because of specific forage requirements) grow other types of crops.

Farmers in the Mid-Atlantic states suffer losses to winter wheat, barley, rye, and salt hay. However, recent complaints to government have been minimal. U.S. farmers are not compensated for such losses, and apparently accept or have learned to cope with the losses. Fees for hunting leases may be a mitigating factor in some areas.

A concern of wildlife agencies in both countries is the affect that overabundant geese have on relationships with the farming community. These relationships are essential for the proper management of waterfowl, other game, and non-game wildlife in agricultural habitats. Moreover, part of the solution to manage greater snow geese requires the participation of farmers.

MANAGEMENT RECOMMENDATIONS

The Arctic Goose Habitat Working Group recommends that the population be stabilized by 2002 at a population level of 1 million or less.

With a 9% annual increase, the Arctic Goose Habitat Working Group recommends that the growth of the population of greater snow geese be stopped by the year 2002. In their population model, Gauthier and Brault (Chapter 4) calculated that increasing hunting mortality by 75% could attain a stabilization of the population. This was based on a scenario of 6 good, 3 average and 1 bad year of reproductive success over a 10-year period. To stabilize the population by 2002, we have in fact only 3 years to control the population (1999-2001). Based on the 6:3:1 scenario, we could expect by chance to get 2 good and 1 average years during our initial attempt. We believe that we should be less optimistic and take the worst scenario, namely a succession of 3 good years. According to the Gauthier and Brault model, stopping growth during good years requires a doubling of hunting mortality, or an increase of harvest rate from 12 to 24%. This means harvesting approximately 143,000 birds each year compared to the annual average of 71,500 recorded since 1990. By the time this is achieved, hopefully in the next 3-4 years, the size of the spring population should be between 800,000 and one million birds.

Following this short-term objective and based on an adaptive management process, reduction of the population could become a mid term objective if natural habitats continue to deteriorate or if measures taken to reduce crop depredation do not achieve the desired results. The

target population should be based on a scientific evaluation of habitat carrying capacity. We believe that breeding habitats, which are the most fragile, should get the first attention. We recommend that the carrying capacity of the spring staging grounds also be estimated, especially along the St. Lawrence estuary where crop depredation is important. Finally, the carrying capacity of wintering salt marshes should also be evaluated. These estimates should be determined during the period of population stabilization. The lowest carrying capacity estimates among the three habitats should then guide the establishment of the target population.

If the spring population is permitted to become greater than 1,000,000 birds, the Working Group believes that adverse ecological effects will be an inevitable result and that population control will be increasingly difficult. It is therefore imperative to initiate the proposed measures as soon as possible. Recognizing that hunters alone may not be able to control greater snow goose numbers, other methods to increase mortality and decrease productivity of adult geese should be simultaneously explored.

SUGGESTED STRATEGIES

1. Implement a greater snow goose communication program.

A comprehensive communication plan aimed at informing all potentially affected interests about the greater snow goose problem and the need for action should be developed and implemented immediately. The experience gained from the successful communications and public review efforts with the mid-continent lesser snow geese will provide excellent guidance for a communications effort with greater snow geese. In Canada, such information would be required in both official languages and special care should be taken to make the information available to the Nunavut Inuit.

2. Increase the interest and effectiveness of recreational snow goose hunters.

Snow geese have proven to be much less vulnerable to traditional waterfowl hunting techniques than most other species of waterfowl. As a result, harvest success has declined to the point where many hunters have lost interest in the sport, or if they have continued to hunt snow geese, harvest fewer birds. In response, both countries have greatly liberalized harvest regulations for greater snow geese, but the desired increase in hunter interest and success has not occurred.

The U.S. harvest is low despite a much longer annual period when geese are available to U.S. hunters in comparison to Canadian hunters. Moreover, the increasing number of geese over-flying southern Québec directly to the U.S. has not improved the U.S. harvest which has remained constant since 1990. Expansion of areas used by geese during migration in southern Québec may have contributed to a slight increase in harvest in that province. The proportion of the total kill in Québec compared to the U.S. has increased from 66% in 1988-92 to 70% in 1993-97.

Efforts should be made to encourage current and former goose hunters to be active and to encourage new recruits to the sport. Greater hunting success may also help to achieve these objectives. Some hunters and parts of the general public have expressed concern over the ethics of using some hunting practices, particularly those heretofore illegal, to harvest more snow geese. This is a serious issue that must be addressed by the communications program. We believe that the larger ethical question relates to our responsibility to protect the ecosystems that will almost definitely undergo near irreversible damage if goose population growth is not arrested. A

distinction should be made between regular snow goose hunting seasons under traditional basic regulations, and conservation hunts which would take place when no other waterfowl hunting is allowed.

Some suggestions for increasing hunter interest include reciprocal licenses between states and provinces for snow goose hunters, programs to increase access to private and public hunting areas, and distribution of information on successful hunting techniques. Bag limits should remain liberal and information on better use of harvested geese (recipes etc.) would be an incentive. A promising measure might be to allow hunting of snow geese in/near fields where portions of crops are left after harvest. It should be only allowed during some periods at special designated hunting areas for snow geese. This would get general support among hunters and may help sustain interest in snow goose hunting. The use of live decoys should also be considered. Less controversial techniques, like electronic callers and extension of shooting hours should be immediately allowed in tightly controlled snow goose hunts on public lands or after other waterfowl seasons have closed. In Québec, ways should be explored to make sneaking (sometimes called creeping) legal and more acceptable to hunters. Hunter support of these programs is essential. It is crucial to clarify for hunters and the general public how important their participation is in solving this problem of overabundant snow geese.

3. Promote and facilitate subsistence harvest.

There is potential for an increased impact from egging or subsistence harvest on the greater snow goose population, although only a few small communities are located near breeding colonies. Programs should be developed to encourage and assist Inuit communities of the Nunavut to increase their harvest of snow geese. These programs might include subsidies for travel and equipment, transport of harvested geese to other communities for barter, or perhaps even development of programs to commercially produce and export snow goose meat products under strict guidelines. The harvest on the fall staging grounds in northern Québec might also be increased, but is hampered by the birds stopping in the central portion of the Ungava Peninsula, far from communities which are generally on the coast.

4. Initiate conservation hunts that utilize hunting periods and techniques distinct from traditional recreational hunting.

Conservation hunts should be implemented to allow hunters to harvest greater snow geese after the period when normal waterfowl hunting seasons have been closed. This is an important law enforcement consideration because it must be unambiguous that the hunters only have the right to pursue snow geese during this period and that the harvest of any other wildlife species is illegal. A variety of special measures, such as those mentioned in Section 3 above, could be allowed during these hunts. Conservation hunts could occur during the regular season frameworks which end on March 10th or beyond that date by special understanding between Canadian and American officials responsible for the Migratory Birds Treaty. The critical issue is that no other species could be harvested.

5. Manage snow goose use of public and private lands to increase hunter success, minimize impacts of natural wintering and staging habitats and reduce agricultural depredation.

Sanctuaries, particularly federal, provincial, and state wildlife areas and refuges, and adjacent private lands are heavily used by greater snow geese within the Atlantic Flyway. An evaluation should be made of each sanctuary complex to assess the impacts of management on regional snow goose harvest. Management strategies should be developed which make

sanctuaries useful tools for increasing harvest of snow geese rather than simply providing resources which boost snow goose condition and productivity. Management programs that provide for non-disturbed feeding or otherwise restrict movement of snow geese to hunted areas are undesirable and should be revised. Systems of small sanctuaries that are alternatively hunted may be useful to enhance movement of snow geese. Managers could provide further encouragement to hunters by making available decoys and other equipment or making improvements that facilitate access to hunting locations.

Management should strive to maintain traditional migration patterns between regions and actions designed to increase local harvest should not be made at the expense of harvest in other areas. In southern Québec, for example, managers are especially concerned with recent increases in the proportion of birds that bypass the region and fly directly to the U.S.

Active management of snow goose movements and habitat use should also be used to minimize the impacts of large numbers of snow geese on natural marshes and agricultural crops. More frequent movements of geese, whether caused by purposefully applied disturbance, or hunting activities, will reduce habitat and crop damage by preventing localized long-term use of individual areas and will limit, to some extent, the accumulation of nutrient reserves. Monitoring of marsh condition in areas of high snow goose numbers will indicate where management actions can help shift goose use from highly or over-used areas to marshes able to withstand additional feeding activity.

Achievement of this strategy will require development of well-coordinated programs in individual provinces, states, and regions to influence snow goose movements and use of habitats. The actual management programs may involve rotation of hunting pressure, the use of lure crops, other modifications to farming practices, hazing, and similar means. There presently is some uncertainty on whether or not habitat management for greater snow geese in southern Québec could short stop Canada geese. This subject deserves further discussion.

6. Explore the feasibility, logistics and effectiveness of non-traditional means to reduce numbers of snow geese.

Since there is great uncertainty as to whether or not the previous strategies will be completely successful in controlling greater snow goose numbers, alternative methods should be simultaneously considered as the initial management actions are taken by hunters. Culling of molting adult snow geese from within the most populated breeding colonies may, for example, be an effective technique. The population model indicates that reducing adult survival will have a much greater influence on snow goose numbers, than alternatives which reduce recruitment. However, because of the extreme difficulty and cost of working in remote Arctic areas, opportunities to reduce the population should also be explored in more accessible staging and wintering areas.

We recognize that measures such as culling of large numbers of snow geese, even in remote breeding areas, may be unpopular with animal rights and humane groups, many waterfowl hunters and maybe the Nunavut Inuit. However, the risk of serious ecological damage will increase in parallel with increasing numbers of greater snow geese. We believe that it is prudent and responsible to have such a program ready to implement in case methods, more acceptable to the public, fail. Planning should include, monitoring habitat condition of major breeding colonies, staging and wintering marshes, estimating funding and logistic needs, and selection of techniques for trapping, humane euthanasia, and use of the geese. Commercial hunting is another practice that could be considered if the initial methods are not effective. Needless to say, if

strategies of this type prove necessary, success will depend on excellent public education and relations programs.

GETTING THE JOB DONE

Achievement of the management objectives will absolutely require a high level of cooperation and coordination between federal, provincial, and state wildlife agencies, private conservation organizations, and the many sportsmen's, farmer's and other groups with a stake in the future of the greater snow goose. The high rate of increase in the greater snow goose population and associated problems demands that work on each independent strategy or related group of strategies begin immediately and go forward concurrently.

We suggest that several management teams be established to plan and implement each group of related tasks. Leadership of these teams and international coordination should be managed within each country by representatives of the U.S. and Canadian Federal agencies responsible for migratory bird management.

The experience being gained from the lesser snow goose management initiative will be crucial to the progress and success of the greater snow goose issue. Wildlife agencies and governments are learning a lot from that exercise which will help guide the implementation of programs to deal with the greater snow goose problem.

EVALUATION AND THE ROLE OF ADAPTIVE MANAGEMENT

The Arctic Goose Habitat Working Group believes that the management of the greater snow goose population should be based on an adaptive process (Lancia et al. 1996). This will be feasible only if proper scientific monitoring programs are also implemented along with the various management practices. Some components of the monitoring program already exist and should therefore be maintained and improved whereas other components should be established as population control is started. We offer the following guidance for those who will be more integrally involved in developing an effective adaptive management approach to this program.

1. Population Monitoring

a) Maintain the annual spring census of the entire population in southern Québec and design a method based on capture-recapture using telemetry to obtain error values on the estimate of the population size. The greater snow goose is probably one of the best monitored populations and this should be a priority of the monitoring program.

b) Maintain the survey of the Bylot Island breeding colony and additional new sites if necessary every 5 years. It is essential to determine if changes in population numbers are also reflected on the current breeding grounds or if expansion into new areas is occurring.

c) Maintain the mid-winter inventory for greater snow geese in the U.S. to provide as a measure of distribution.

c) Maintain harvest monitoring and improve the National Harvest Survey and the Species Composition Survey for greater snow geese. Since harvest is expected to be the main tool, dependable estimates of harvest both in Canada and U.S. are needed.

e) Maintain the banding program on Bylot Island to monitor population demographic parameters. Initiate new banding programs at a few other colonies. A main objective of the management strategies are to reduce adult and, to a lesser extent, juvenile survival through harvest. We therefore need to estimate these parameters with the greatest accuracy before and during the implementation of the management plan. We hypothesize that harvest is dominantly an additive process and not compensatory for greater snow geese. Knowledge of the harvest rate/survival relationship is required for adaptive management. A band reward study may be required to get more precise estimates of reporting rates specially for French speaking hunters.

f) Maintain monitoring of productivity (% of juveniles) in fall and early winter to determine annual variation in production (good, average and bad years).

g) Maintain goose measurement operations in fall at the Cap Tourmente NWA to assess if the reported density-dependent effects on size and condition of the birds will still operate after population stabilization.

2. Habitat Monitoring

a) Maintain habitat monitoring in the Arctic especially on Bylot Island and expand it to other sites where deemed necessary. The core concern of the Working Group is the maintenance of the integrity of the natural habitats, especially the Arctic breeding grounds.

b) Continue the monitoring of bulrush marshes at Cap Tourmente every 2 years.

b) Initiate a monitoring program of the main St. Lawrence bulrush marshes every 5 years.

d) Initiate an assessment of the extent of damage to salt marsh habitats along the Atlantic coast, especially at refuges with large snow goose concentrations.

d) Continue and improve monitoring of crop depredation wherever it occurs.

f) Establish the carrying capacity of the various habitats used during the wintering, spring staging and breeding periods in order to establish a target population.

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