Patterns of distribution and abundance of Greater Snow Geese on Bylot Island, Nunavut, Canada 1983-1998

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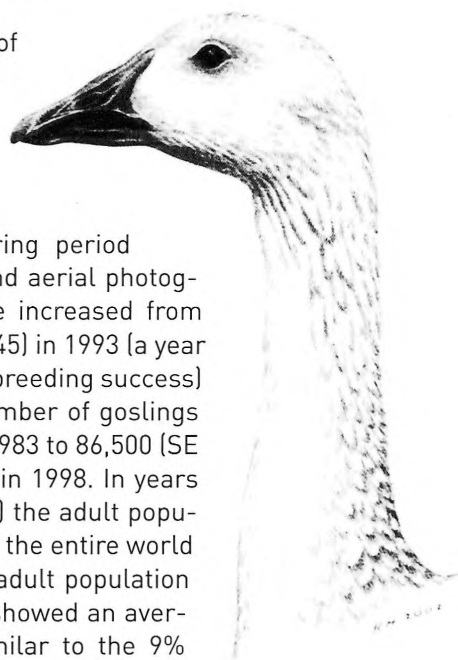

To monitor the numbers and distribution of Greater Snow Geese at the largest breeding colony in the eastern Canadian High Arctic, surveys were conducted on Bylot Island at five year intervals from 1983 to 1998. The surveys were conducted during the brood-rearing period using a stratified sampling procedure and aerial photography. The total number of adult geese increased from 25,500 (SE 2582) in 1983 to 69,500 (SE 8645) in 1993 (a year of exceptionally high breeding effort and breeding success) before dropping slightly in 1998. The number of goslings also increased from 26,500 (SE 2320) in 1983 to 86,500 (SE 8147) in 1993, and also dropped slightly in 1998. In years of high breeding success (1983 and 1993) the adult population on Bylot Island represented 14% of the entire world population of Greater Snow Geese. The adult population on Bylot Island between 1983 and 1998 showed an average annual rate of increase of 7%, similar to the 9% increase recorded for the entire population. Brood densities varied from a low of 0.8 broods km^{-2} in the poorest quality habitats in 1983 to 29.9 broods km^{-2} in the best habitats in 1993, but an increasing trend was evident in all habitat strata over the course of the study. A large proportion (63%) of the surface area of the colony accommodated only very low brood densities in 1983, but by 1993 the proportion occupied by such low densities had been reduced to 29%. It is concluded that the increase in goose numbers and the spread of higher brood densities over a larger portion of the colony are indications that the carrying capacity of the Island has not yet been reached.

Key Words : Colony survey, brood distribution, population change.

The study of population change in wildfowl relies heavily on survey data. To examine the numbers and trends of wildfowl, many wildlife agencies have placed emphasis on surveys conducted when the birds are concentrated on wintering or staging areas (Eggeman & Johnson 1989). As useful as they are, such surveys do not tell the entire story. Decisions on management and conservation issues require a broader base of knowledge, including information on numbers and trends in other areas of the range, on population dynamics, and on bird-habitat relationships. Recent concerns about expanding populations of Snow Geese *Anser caerulescens* have highlighted the threats of overpopulation on fragile Arctic habitats (Batt 1997, 1998). With 'northern' geese, the remoteness of their breeding areas and the high costs of Arctic survey operations have made it difficult to conduct breeding surveys. As a result, few studies have been able to track population changes at large breeding colonies over extended periods of time. However, information of this sort is critical for effective management when vulnerable Arctic habitats are threatened by large and expanding populations. For Snow Geese in North America, the governments of Canada and the United States (with the collaboration of the provinces and states), under the Migratory Bird Treaty of 1917, effectively managed populations by regulating autumn and winter hunting seasons, and by creating refuges and other protected areas. Through these actions, large populations were built up or maintained, but over the last few decades of the 20th century many of these populations expanded dramatically as a result of increasing use of agricultural land during winter where an abundant food supply ensured improved survival. Currently, several Snow Goose populations are causing damage to, or are threatening the integrity of certain arctic ecosystems through intensive grazing (Batt 1997, 1998). The conservation challenge has now shifted from ensuring more geese, to reaching levels where the destruction of natural habitats in the arctic (and elsewhere) will be halted. This means either arresting population growth or reducing numbers. Arriving at meaningful population goals requires information on goose numbers and densities at vulnerable arctic sites, and on the carrying capacity of those habitats. In this paper, the results of four surveys conducted between 1983 and 1998 at the largest known colony of Greater Snow Geese *A. c. atlanticus* in the Canadian High Arctic are presented. Changes in goose numbers that have occurred at the study colony are compared with those occurring in the subspecies' population, and changes in numbers and distribution are examined in relation to habitat types.

Study area and methods :

Bylot Island (73°N, 79°W), located near the northeast edge of Baffin Island, covers 10,750 km^2, of which more than a half is composed of high mountains covered with glaciers, ice-fields and permanent snow. Terrain suitable for geese is found in low lying areas near the coast, especially in the 1,600 km^2 rolling plain along the southwest coast (**Figure 1**).

The southwest plain constituted the survey zone, and was divided into 400 2x2km plots. The surveys were conducted during the brood-rearing period (between July 21 and August 8) when all geese were flightless, and involved comprehensive helicopter-based searches in sample plots. All groups of geese encountered were photographed during these surveys. The survey zone

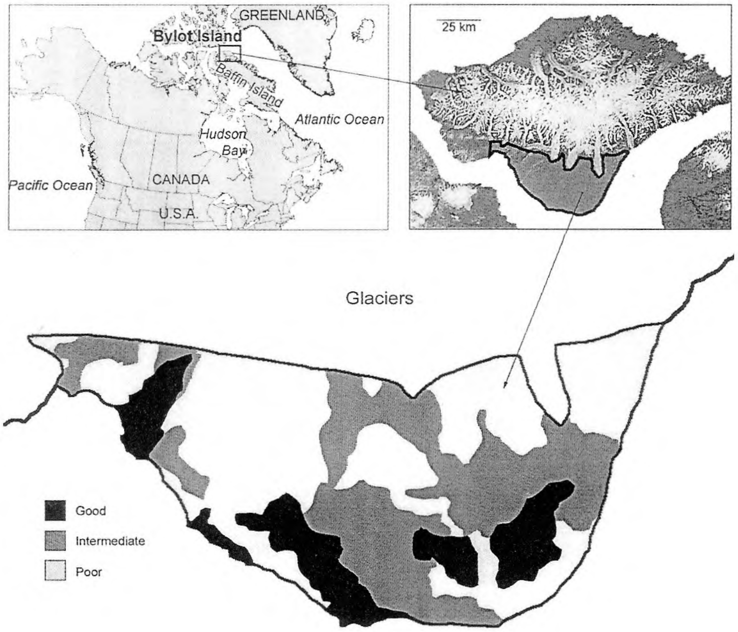

Figure 1. Bylot Island, showing its location (inset, upper left), the entire island with the southwest plain study area outlined (upper right), and the habitat stratification of the study area (bottom map).

was divided into three strata (**Figure 1**), representing suitability of the habitat for brood-rearing (good, poor and intermediate), based mainly on a vegetation map (Zoltai *et al.* 1983). Areas with abundant food (high degree of graminoid plant cover) and escape cover (numerous ponds or streams), were considered 'good', whereas those with little food (non-vegetated or low abundance of graminoids) or escape cover (little or no open water), were considered 'poor'. Initially, 71 plots were classified as good, 134 as intermediate and 195 as poor. For the 1998 survey, based on an improved knowledge of the terrain, some plots were re-classified, yielding 83 good, 129 intermediate, and 188 poor plots. The optimal allocation method (Cochran 1977) was used to select a random sample of plots to be surveyed. Survey coverage varied from 21% of the total area in 1983 and 1988 to 27% in 1993 and 19% in 1998.

The surveys were conducted using a helicopter (Bell 206B in 1983 and 1988, Bell 206L in 1993 and 1998), with one person navigating and recording, and a second person photographing geese. Navigation was aided by aerial photographs with the boundaries of each survey plot drawn on an acetate overlay. In 1993 and 1998, a Global Positioning System was also used to facilitate the location of plots and to determine boundaries where landmarks were indistinct. An exhaustive search of each plot was conducted and all groups of geese recorded. Generally, groups of 10 or fewer adult geese were counted visually, whereas larger groups were photographed and geese counted from projected images. Adults and goslings were counted separately, except in some small flocks for which only the adults were counted; the number of goslings accompanying these adults were estimated from a regression model based on the ratio of adults to goslings in flocks where both age groups were counted. The estimation of total numbers of adults and goslings was made using the standard stratified estimator of Cochran (1977). Most goose groups, at the time of recording, included family groups in a tight flock, making it impossible to identify single families or to distinguish between adults accompanied by young (parents) from those without young (non- and failed-breeders, hereafter referred to as non-parental geese). In order to distinguish between these two groups of adults, each year a number of individual broods were observed from the ground under undisturbed conditions to determine the average brood size. By dividing the number of goslings in a group by the average brood size the expected number of parents in that group could be determined; any excess adults were considered to be non-parental geese. Further details of survey methods can be found in Reed & Chagnon (1987) and Reed *et al.* (1992).

Results

Population estimates and trends

The total number of adult geese increased from 25,500 (SE 2582) in 1983, to 69,500 (SE 8645) in 1993, before dropping to 60,700 (SE 7981) in 1998. The number of goslings also increased from 26,500 (SE 2320) in 1983 to 86,500 (SE 8147) in 1993, and dropped to 59,100 (SE 6658) in 1998 (**Table 1**). The mean brood sizes used to subdivide the adult population into parental and non-parental components were 3.20 goslings per family (n=165, SE 0.09) in 1983; 3.15 (n=265, SE 0.07) in 1988; 3.14 (n=284, SE 0.08) in 1993; 3.03 (n=303, SE 0.064) in 1998.

There was an increasing trend in the total number of geese (average rate of increase = 6.5% per year), of parental adults (6.4% per year), of total adults (6.8% per year) and of goslings (6.3% per year), although for all of these categories the highest number was obtained in 1993 (**Figure 2**). The number of non-parental geese also increased (7.7% per year), with the highest value occurring in 1998 and the lowest in 1988 (**Table 1**). The proportion of non-parental geese in the adult population varied from 17% to 38%, but showed no apparent trend. The growth rate of the adult population on Bylot Island paralleled that of the entire Greater Snow Goose population, as determined from spring surveys on a staging area (**Table 2**, **Figure 3**). Productivity surveys in the staging area during autumn showed that all four surveys were conducted in years when breeding success was above the long-term average (**Table 3**).

Brood densities and distribution

Brood densities varied among years, showing an overall increasing trend. They also varied between habitat types, reaching the highest density (29.9 broods km^{-2}) in the best habitats in 1993 (**Table 4**). Density in the low-quality habitat increased from 0.8 broods km^{-2} in 1983, to levels >6 broods km^{-2} in sub-

Table 1. Population estimates of Greater Snow Geese on Bylot Island 1983-1998. SE in parentheses.

Year	Breeding adults	Goslings	Non-parental adults	Total geese
1983	16,600 (1,520)	26,500 (2,320)	8,900 (1,062)	52,000 (4,308)
1988	26,300 (4,990)	41,400 (7,810)	5,400 (950)	73,100 (13,676)
1993	55,000 (5,238)	86,500 (8,147)	14,500 (3,407)	155,900 (14,912)
1998	37,600 (4,260)	59,100 (6,658)	23,100 (3,721)	119,800 (14,242)

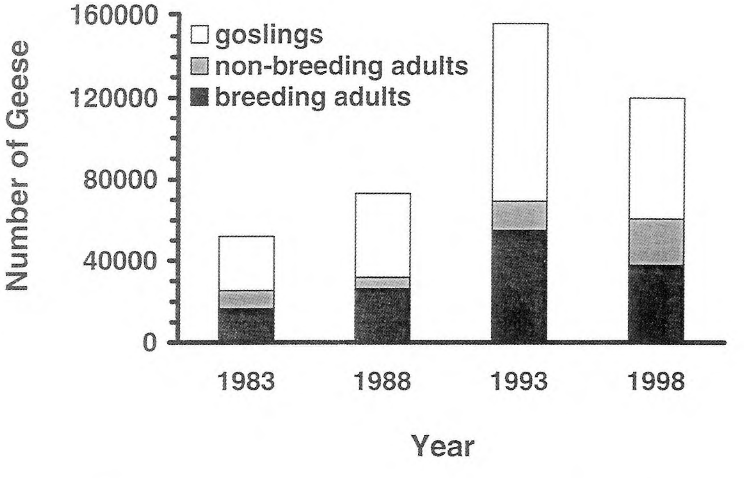

Figure 2. Estimated numbers of Greater Snow Geese on the southwest plain of Bylot Island, 1983-1998.

Table 2. Number of Greater Snow Geese recorded on Bylot Island in summer and in southern Québec in spring, 1983-1998.

Year	Total geese in southern Québec[1]	Adults on Bylot Island	Adults on Bylot as % of total population
1983	185,000	25,500	13.8
1984	225,400		
1985	260,000		
1986	303,500		
1987	255,000		
1988	363,800	31,700	8.7
1989	363,200		
1990	368,300		
1991	352,600		
1992	448,100		
1993	498,400	69,500	13.9
1994	591,400		
1995	616,600		
1996	669,100		
1997	657,500		
1998	741,200	60,700	8.2

[1]Data from Reed *et al*., 1998 and A. Reed, unpublished.

Table 3. Breeding success and productivity of Greater Snow Geese, 1983-1998.

Year	% young in fall flight[1] (entire population)	% nest success on Bylot Island[2]	Ratio young:adult at fledging on Bylot island
1983	**47.4**		
1984	30.4		
1985	25.8		
1986	2.3		
1987	40.2		
1988	**33.1**		
1989	31.1	70	
1990	23.6	79	1.15:1
1991	38.3	72	1.46:1
1992	5.4	70	0.81:1
1993	**47.8**	**89**	**1.55:1**
1994	9.2	40	0.79:1
1995	16.6	14	1.10:1
1996	25.1	65	0.83:1
1997	36.8	83	1.06:1
1998	**33.1**	**79**	**1.09:1**
Mean	*27.9*	*66.1*	*1.09:1*

[1]Data from Reed *et al.* 1998 and A. Reed, unpublished.
[2]Data from Gauthier *et al.*, 1999

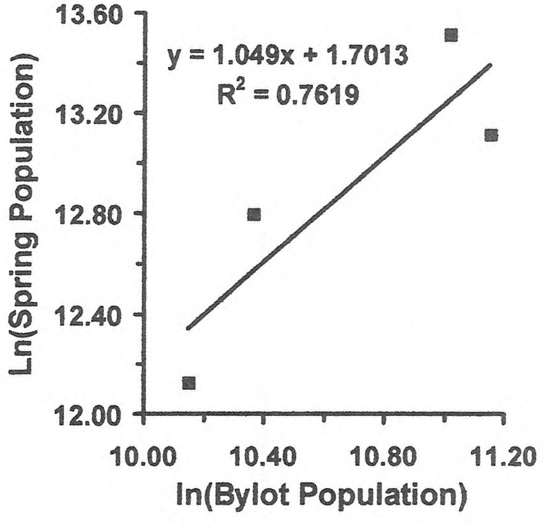

Figure 3. Comparison of growth rates of the numbers of adult Greater Snow Geese on the southwest plain of Bylot Island (ln N Blot) and of the entire population (in N total) using logarithmic values for 1983, 1988, 1993 and 1998: b(slope)=1.049; SE=0.415; *P*=0.127.

Table 4. Densities of Greater Snow Goose broods in relation to habitat quality, Bylot Island, 1983-1998. Densities given in broods km^{-2} (SE).

Year	Good habitat	Intermediate habitat	Poor habitat	Total
1983	16.4 (1.6)	5.6 (0.9)	0.8 (0.3)	5.2 (0.5)
1988	14.9 (1.7)	7.8 (2.1)	6.1 (2.8)	8.2 (1.6)
1993	29.9 (3.3)	16.0 (3.3)	12.1 (2.2)	17.0 (1.6)
1998	22.9 (3.2)	10.6 (2.0)	7.7 (2.0)	11.8 (1.3)

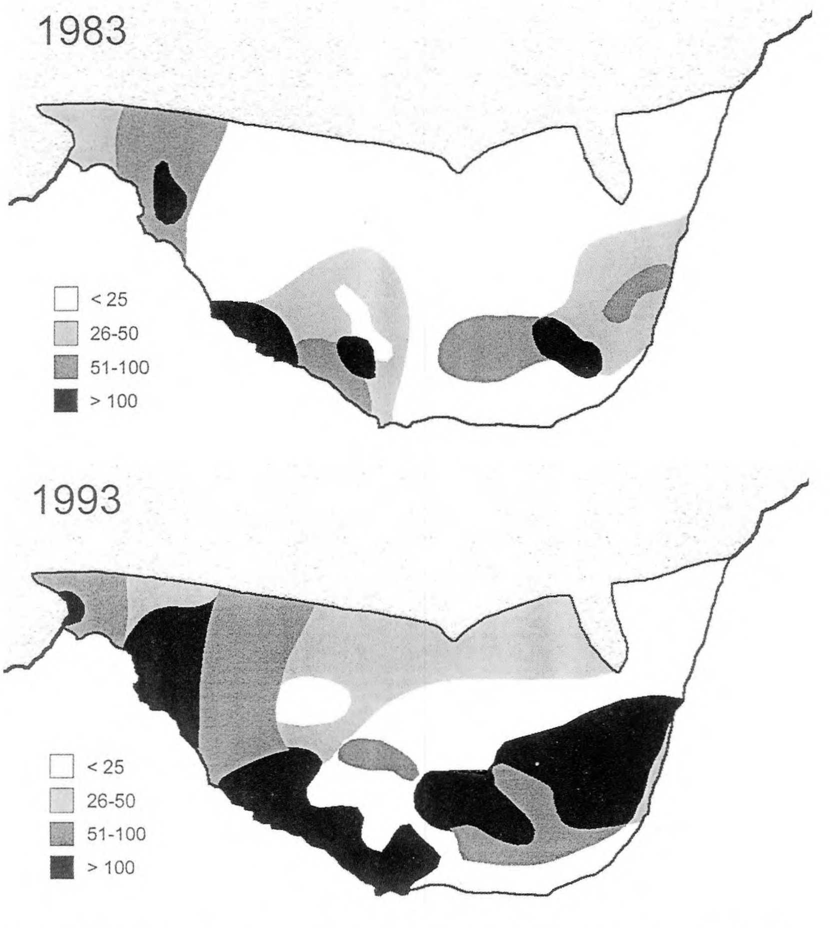

Figure 4. Distribution of Greater Snow Geese broods (number of broods/2x2km plot) on the southwest plain of Bylot Island in 1983 (above) and 1993 (below).

sequent surveys. The spatial distribution of broods in 1983 was characterised by the presence of three small areas of high to moderate density (37% of 400 plots had densities >25 broods/plot or approximately six broods km^{-2}) and one large area of low density (63% of plots with <six broods/plot). By 1993, the three areas of high to moderate density had expanded substantially around their initial epicentres (71% of plots with ≥ six broods/plot) (**Figure 4**) .

Discussion

Quantification of the size of the potential breeding and non-breeding goose populations of the island is of considerable value for management and conservation purposes. To estimate relevant parameters, an assessment is needed of whether all potential breeders and non-breeders are present on the island at the time of the survey. Recent studies by Reed *et al.* (in press), have demonstrated that most local breeders unable to nest, or those that lose their nest in an early stage of breeding, leave the study area to moult elsewhere, and this occurs prior to the survey dates. Furthermore, there are large annual variations in breeding success, which is a function of weather conditions and predator pressure (Reed 2002; Bêty *et al.* 2001). As a result, nest success and nesting effort (the percentage of potential breeders that attempt to nest), is variable. Evidence of breeding effort and success over the study period were examined to detect any such possible biases.

Annual monitoring of breeding success on Bylot Island began in 1989 (Gauthier *et al.* 1999), and the last two colony surveys overlapped with this work. Monitoring of breeding success of the entire Greater Snow Goose population has, however, been conducted during the entire 16-year period of 1983-1998, using age ratio counts in the autumn flight in southern Québec (**Table 3**). Over the 12 years during which monitoring occurred at both sites, the indices of success rates on Bylot Island were similar to those for the entire population. The age ratios recorded in southern Québec varied from 2.3% to 47.8%, average 27.9% (Reed *et al.* 1998, A. Reed unpublished data). All four of the surveys described here were conducted in years when the age ratios were above this average. None of the surveys were conducted in years of widespread breeding failure (eg 1992 and 1994) when many geese either did not nest or failed in their attempts. In two of the four survey years (1983 and 1993), the proportion of young reached the highest levels, not only for the 16-year study period, but for the entire 28 years of available data. Thus, in all four survey years, it is likely that the proportion of potential breeders present in the study area at the time of the survey was high, but probably slightly higher in 1983 and 1993 than in 1988 and 1998.

The data do not allow correction of the four estimates of adult geese to a common index of potential breeders.

However, errors or biases that may have occurred through annual variability in reproductive success (ie through variability in rates of emigration by non-breeders and failed breeders), are likely to have been minor, and the trends detected for adult segments of the population probably reflect true changes in the potential breeding population. It would be desirable to correct for emigrating non-breeders and failed-breeders in order to better estimate the potential population, and to provide more accurate estimates of rate of change. The capability to make such corrections would be particularly useful in years when breeding success was low. Such corrections may become possible with continued monitoring of breeding success and colony surveys, and with further study of breeding propensity and emigration of non- and failed breeders.

The colony survey results were compared to those from the annual spring surveys of the entire Greater Snow Geese population on their staging area in southern Québec over the same time period (**Table 2**). Both sets of data show an increasing trend over the study period. The estimates from Québec indicate an annual average rate of increase of 9% (Menu *et al.* 2002), close to the 7% computed for the adult population on Bylot Island. Logarithmic values of data from these two sets were compared for 1983,1988,1993 and 1998. This gave a slope of 1.049, close to the predicted value of 1.0 for two populations changing at the same rate (**Figure 3**). It was concluded that the breeding population on Bylot Island has increased at a similar rate to that of the entire population.

Despite the rapid increase of the overall population (a four-fold increase between 1983 and 1998), Bylot Island has continued to be used by a similar proportion of the population. This is consistent with the findings of Massé *et al.* (2001) who concluded that the carrying capacity of the island's wetland brood-rearing habitats had not yet been reached. It cannot, however, be ruled out that density dependent effects may be a factor. Although the main reason for the decline in numbers of breeding geese between 1993 and 1998 may have been due to a higher rate of absence of failed breeders (through emigration prior to the survey), it is possible that part of the decline was due to fewer potential breeders. Also, mean brood size on Bylot Island showed a regular but non-significant declining trend of about 5% overall between 1983 to 1998, which could reflect deteriorating feeding conditions for goslings. Present levels of grazing pressure by geese have reduced the annual production of food plants on Bylot Island but have not led to long term habitat degradation (Gauthier *et al.* 1996).

In both years of very high breeding success, 1983 and 1993, Bylot Island accommodated about 14% of the entire adult goose population, and between 8% and 9% in the other two years (**Table 2**). The lower values recorded in

1988 and 1998, when breeding success was lower, probably reflected departures of non-breeders and failed-breeders between arrival in spring and the time of the survey. In 1983 and 1993 it is probable that nearly all of the potential breeders were still present at the time of the survey. Thus the potential breeding population of the southwest plain of Bylot Island is probably close to, but somewhat greater than 14% of the entire adult population of Greater Snow Geese.

Brood densities generally increased at similar rates in all habitat types over the course of the study. Although very low densities were recorded in habitats judged to be of poorest quality ('poor' stratum) during the first survey, densities reached moderate levels in later surveys. These poorer quality habitats occurred on upland sites with reduced availability of graminaceous food plants and with a lack of large ponds or lakes to serve as refuge from terrestrial predators. Competition for the preferred lowland (wetland) habitats (mainly 'good' stratum), where food and refuge were more available (Hughes *et al.* 1994) may have reached a threshold after 1983, forcing more geese to make this shift. Also, a larger goose population may have led to increased sizes of brood flocks which, by virtue of a larger critical mass of adult geese, may have been more effective in reducing predation by Arctic Fox *Alopex lagopus*. This interpretation is consistent with observations over the course of the study showing increased use of mesic (drier) upland sites by large multi-brood flocks. This increased use of poorer quality habitat is especially evident from a comparison of distribution maps showing densities of broods in 1983 and 1993 (**Figure 4**). This shows that the area occupied by low densities (<6 broods km^{-2}) covered >10,000 km^2 (63% of the study area) in 1983 but only 4,600 km^{-2} in 1993.

The Greater Snow Goose population has increased continuously over recent decades reaching springtime levels of >800,000 by 1999 (Reed *et al.* 1998, A. Reed unpublished data). In response to potential threats to the integrity of habitats throughout the range, a special spring hunting season was proposed (Giroux *et al.* 1998) and initiated in Québec in 1999. It was thought that this special hunt, combined with the continuing traditional autumn hunt, could halt population growth and stabilise the population. Given the seriousness of the problem and the sensistivity of the conservation issues, it is imperative that scientists continue and enhance efforts to monitor the population and examine relationships between goose density and habitat integrity, especially on fragile Arctic ecosystems. These efforts should include continuation of the survey on the Bylot Island colony every five years, annual monitoring of breeding success, further study of breeding effort and emigration of non- and-failed breeders.

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References

Batt, B.D.J. (ed.) 1997. *Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group*. Arctic Goose Joint Venture Special Publication. U. S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario. 120 pp.

Batt, B.D.J. (ed.) 1998. *The Greater Snow Goose : report of the Arctic Goose Habitat Working Group*. Arctic Goose Joint Venture Special Publication. U. S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario. 88 pp.

Bêty, J., Gauthier, G., Giroux, J-F. & E. Korpimäki, E. 2001. Are goose nesting success and leming cycles linked? Interplay between nest density and predators. *Oikos* 93: 388-400.

Cochran, W.G. 1977. *Sampling techniques*. Third edition. New York. John Wiley and Sons. 428 pp.

Eggeman, D.R., & Johnson, F.A. 1989. Variation in effort and methodology for the midwinter waterfowl inventory in the Atlantic Flyway. *Wildlife Society Bulletin* 17: 227-233.

Gauthier, G., Rochefort, L. & Reed, A. 1996. The exploitation of wetland ecosystems by herbivores on Bylot Island. *Geoscience Canada* 23: 253-259.

Gauthier, G., Reed, A, Rochefort, L., Giroux, J-F. & Lévesque, E. 1999. *Population study of Greater Snow Geese on Bylot Island (Nunavut) in 1999 : a progress report*. Unpublished report to the Arctic Goose Joint Venture. 16pp.

Giroux, J-F., Batt, B., Brault, S., Costanzo, G., Fillion, B. Gauthier, G. Luszcz. D. & Reed, A. 1998. Conclusions and management recommendations. In: B.D.J. Batt (ed.) *The Greater Snow Goose : report of the Arctic Goose Habitat Working Group*. Arctic Goose Joint Venture Special Publication. U. S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario, pp. 81-88.

Hughes, R.J., Gauthier, G. & Reed, A. 1994. Summer habitat use and behaviour of Greater Snow Geese *Anser caerulescens*. *Wildfowl* 45: 49-64.

Massé, H., Rochefort, L. & Gauthier, G. 2001. Carrying capacity of wetland habitats used by breeding Greater Snow Geese. *Journal of Wildlife Management* 65: 271-281.

Menu, S., Gauthier, G, & Reed, A. 2002. Changes in survival rates and population dynamics of Greater Snow Geese over a 30-year period : implications for hunting regulations. *Journal of Applied Ecology* 39: 91-102.

Reed, A & Chagnon, P. 1987. Greater Snow Geese on Bylot Island, Northwest Territories, 1983. *Journal of Wildlife Management* 51: 128-131.

Reed, A., Boyd, H., Chagnon, P. & Hawkings, J. 1992. The numbers and distribution of Greater Snow Geese on Bylot Island and near Jungersen Bay, Baffin Island, in 1988 and 1983. *Arctic* 45: 115-119.

Reed, A., Giroux, J-F. & Gauthier, G. 1998. Population size, productivity, harvest and distribution. In: B.D.J Batt, (ed.) *The Greater Snow Goose : report of the Arctic Goose Habitat Working Group*. Arctic Goose Joint Venture Special Publication. U. S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario, pp 5-31.

Reed, E.T. 2002. *Couts des soins parentaux et effets des conditions environnementales sur la reproduction de la Grande Oie des neiges*. PhD thesis, Université Laval, Québec, Canada.

Reed, E.T., Bêty, J., Mainguy, J., Gauthier, G. & Giroux, J-F. In press. Molt migration in relation to breeding success in greater snow geese. *Arctic*.

Zoltai, S.C., McCormick, K.J. & Scoter, G.W. 1983. *A natural resource survey of Bylot Island and adjacent Baffin Island, Northwest Territories*. Parks Canada, Ottawa, Ontario, Canada.