Arctic Ecosystems in Peril

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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(Second Printing)

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The publication costs of this report were provided by:

Ducks Unlimited, Inc.
Canadian Wildlife Service
U.S. Fish and Wildlife Service
North Dakota Game and Fish Department
Texas Parks and Wildlife Department

SUGGESTED CITATIONS

Batt, B. D. J., editor. 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. l2Opp.

Abraham, K. F., and R. L. Jefferies. 1997. High goose populations: causes, impacts and implications. Pages 7-72 in B. D. 3. Batt, ed. 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.

Library of Congress Catalog Card Number 97-65274
Printed in the United States of America

ISBN: 0-9617279-3-4

Printed by Paulsen Printing, Memphis, Tennessee

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Executive Summary

In some Arctic areas, over-abundance of several populations of Arctic-nesting geese in North America is causing extensive damage to habitats used by these geese and other wildlife. Mid-continent white goose populations are expanding at an average rate of 5%/year. Most of the major mid-continent white goose nesting colonies are being impacted and the damage is expanding annually. The prime causes of these population increases are human-induced changes to the agricultural landscape and changes in refuge provision during wintering and staging periods that lead to high winter survival and recruitment. The birds have effectively been released from winter carrying capacity restraints that sustained populations at lower levels before agriculture changed the North American landscape.

Over-grazing and over-grubbing by geese causes changes in soil salinity and moisture levels that lead to severe environmental degradation of the affected Arctic landscapes, conditions that will alter plant community structure and succession and prohibit the original plant communities from being restored. Large portions of the Arctic ecosystem are threatened with irreversible ecological degradation. Plant communities associated with goose breeding habitat are finite in area and distribution and will likely be permanently lost unless there is effective human-induced intervention to reduce the size of certain goose populations.

The Working Group recommends that the Canadian Wildlife Service and the U.S. Fish & Wildlife Service assign full-time coordinators to oversee implementation and evaluation of effective strategies to reduce mid-continent white geese to about half their current population. This major program could be advanced under an Arctic Goose Management Initiative overseen by the Arctic Goose Joint Venture. A crucial component of the initiative is the development and delivery of an effective communications strategy to inform the public at-large of the problems caused by over-abundant mid-continent white goose populations. The Arctic Goose Habitat Working Group should be retained as expert consultants and reviewers of the progress of the Initiative.

Population modeling, using mid-continent lesser snow goose data, indicates that the most effective interventions should be focused on reducing adult survival as it is the main demographic parameter driving population growth rates. The Working Group adopted the principle that any interventions should respect the birds as valuable components of the environment in general and as game animals and food. Population reduction methods that did not allow geese that were killed to be used as food were rejected. Interventions to reduce recruitment can only be effective if delivered on a massive scale that is not seen to be practical or cost effective. Reductions in adult survival is the most important demographic component to be addressed on breeding, staging and wintering areas.

The Working Group recommends that the goal of the Arctic Goose Management Initiative be to reduce mid-continent white goose numbers by 5 - 15% each year. Several control methods are described in the report, all of which can remove adult geese from the population and all of which should be considered in some places at some times. Most of them have been used in the past by hunters but were regulated against to provide the birds extra protection during an earlier era when

the management goal was to increase populations. All of them involve the participation of traditional hunters who we view as being a highly motivated, well-equipped and economical labor force with an already widely-demonstrated commitment to waterfowl conservation.

We urge that the following practices be implemented by the fall of 1997 in time for the 1997/1998 mid-continent lesser snow goose hunting season: 1) legalize the use of electronic calling devices for snow goose hunting; 2) legalize baiting in special snow goose population reduction seasons, and; 3) provide additional snow goose hunting in and around state, provincial and federal refuges

Additionally, we urge the Federal agencies to extend the harvest of snow geese for southern hunters beyond the current restrictions (March 10) in the Migratory Bird Treaty. This should be done as soon as possible - we would hope within a year of the delivery of this report. Northern native residents already have the right to harvest geese for the remainder of the year as prescribed by the Canadian Constitution. Native Canadians should be contacted and recruited, as soon as possible, to seek their participation in the management of mid-continent white geese.

This report includes an outline for an evaluation strategy which should be further developed and implemented as soon as possible. However, changes in regulations controlling white goose harvest should not be held up until an evaluation program is fully in place. It is important for managers to gain experience with the implementation of the Arctic Goose Management Initiative and there will undoubtedly be a time lag between promulgation of new regulations and the effective involvement of hunters who have limited experience with some of the new tools and time frames for hunting. There is virtually no risk of a management error causing over-harvest of mid-continent white geese within the next several years, even if all the above practices were implemented within the very near future. At the same time, it is important that the numbers of mid-continent white geese be reduced, as soon as possible, to a level that can be sustained by their Arctic habitats.

Part I: INTRODUCTION

BRUCE BATT, Ducks Unlimited, Inc., Memphis, TN 38120

Waterfowl managers have achieved considerable success with goose populations over the past several decades. Although a few populations remain problematic, most are near, or above, long-term numerical goals. These successes have come about as a result of several factors inherent to the biology of geese that allow them to be more easily managed and because of preadaptations that have allowed geese to successfully exploit human modified landscapes.

Most goose populations have fairly definitive breeding, migration and wintering ranges where harvest and habitat management strategies and refuges can be targeted for the benefit of the birds. Also, since geese are grazers, the quality of their feeding habitats throughout most of their migratory and wintering ranges has actually improved with agricultural and urban development. Most goose species have adapted to feeding on waste agricultural grains or on newly planted crops. A few species, especially some Canada geese, have adapted to feeding in urban areas where they exploit fertilized and manicured corporate lawns, golf courses and public parks, as well as nearby agricultural areas.

During the past two decades, several populations have exceeded management goals and, even in the face of increased bag limits and longer season lengths, have continued to increase in number. This has been most conspicuous for some Arctic-nesting white geese (lesser snow geese, greater snow geese, Ross' geese) and Canada geese that are resident in areas of southern Canada and the lower 48 states. Management goals have also been exceeded for other populations but have not yet gained much attention from managers or the public. There is an emerging pattern of many goose populations having moved beyond waterfowl managers' ability to affect population size using traditional methods of controlling bag limits and season lengths.

Waterfowl managers have typically been motivated to maintain breeding populations at numbers that provide some sustainable harvest. Most management paradigms relate to protecting, building or restoring the size of breeding populations. There are few management programs to deal with overabundant populations of waterfowl other than for problems in local situations where birds cause damage to agricultural crops or where they are a nuisance in some urban areas. Indeed, there is no well- developed consensus on whether higher than targeted populations of waterfowl are good, neutral or problematic, such as there is for wildlife like white-tailed deer. There has been little debate on bigger ecological concerns such as the carrying capacity of breeding, wintering or staging areas or long-term ecosystem impacts of excessive grazing and grubbing by geese.

There is a growing body of literature on the effects of excessively high numbers of geese which reduce habitat integrity and gosling survival, growth rates and adult body size of lesser snow geese (e.g. Cooke *et al*. 1995). A series of papers delivered at the Eighth North American Arctic Goose Conference and Workshop in Albuquerque, New Mexico in February 1995 identified the occurrence of these observations on several different colonies, including other species, across the Arctic. Subsequent discussions, popular press articles in Ducks Unlimited Magazine (Young 1993) and American Hunter Magazine (Bourne 1995), correspondence between Working Group member Dr.

Dave Ankney and officials in the Canadian Wildlife Service and the publication of Ankney (1996) heightened scientists' and public officials' awareness of possible problems with overabundant goose populations.

The upshot was an ad hoc workshop of about 50 scientists and managers on the topic at the Arctic Goose Joint Venture Technical Committee and Management Board Meetings at Oak Hammock Marsh, Manitoba in October 1995. The charge to the workshop was to review what was known about the extent of the problem, particularly as it related to impacts on habitats and other species, and to advise the AGJV on what future actions should be undertaken. That group concluded that over-abundant goose populations could well be a serious long-term management problem and advised the AGJV Management Board that a working group should be established "to develop a scientific approach to the problem of habitat degradation". They recommended that the group should consist of about 16 individuals representing government and non-government conservation organizations in the U.S. and Canada. The AGJV took this advice and formed the group that is responsible for this report.

The Arctic Goose Habitat Working Group met for the first time at the Ducks Unlimited Symposium in Memphis, Tennessee in February 1996. At that time, the general plan for this report was established. The approach was endorsed by the AGJV Management Board in March, 1996 at Tulsa, Oklahoma. The Working Group agreed to complete the report by the end of October, 1996 for review by the AGJV Management Board.

The Working Group operated under two guiding principles. Foremost, was that the Group's work would be guided by traditional standards of scientific scrutiny and objectivity. Our charge was to provide the AGJV Management Board with a strong biologically-based report, free from bias imposed by political pressures, or by any predispositions that individual Group members might have had as the process started. The second principle was adopted as the process unfolded and we reviewed possible management actions that might be taken to reduce the size of mid-continent white goose populations. We decided that any management action recommended by the Group would be based on the principle that the birds are valuable natural resources, as game animals and as food. Thus, we did not consider any recommendations that advocated slaughter and destruction of birds followed by their being wasted in landfills or some similar fate.

Part II presents a comprehensive analysis of the published and unpublished information on the growth of several populations of geese, the causes of these changes and the impacts on habitat and the birds themselves. Lastly, it comments on the long-term implications of these changes to the future of Arctic and sub-Arctic habitats used by breeding geese. This section, compiled by Drs. Kenneth Abraham of the Ontario Ministry of Natural Resources, and Robert Jefferies of the University of Toronto, provides the technical background that confirms the scope and implications of allowing some goose populations to continue to expand in size and distribution. This information established the basis for the Working Group's core conclusion that some measures must be taken to reduce populations back to a more sustainable level.

Part III was developed by Drs. Robert Rockwell of the American Museum of Natural History, Evan Cooch of Simon Fraser University and Solange Brault of the University of Massachusetts. It presents a population model, based on best estimates of parameters from a long-term study of lesser snow geese nesting at La Pérouse Bay (see Cooke *et al*. 1995) on the west coast of Hudson Bay. It develops several scenarios of possible interventions that management might take to reduce the mid-continent snow goose population. Several explicit assumptions are made and explained including the current size of the population, a desired time span for reducing it and a target population of approximately 50% of the current size. The major conclusion is that the most effective management measures must be directed towards reducing adult survival.

Part IV, by Michael Johnson of the North Dakota Game and Fish Department, describes a collection of possible management interventions that might be used to reduce the size of mid-continent snow goose populations. It has been the subject of several reviews by the Working Group and has had additional input from waterfowl managers across the U.S. and Canada. Some measures that were originally included were deleted after the Working Group formally adopted the principle of respect for the birds as game animals and as food. Biologists from the Mississippi and Central Flyway Technical Sessions provided very helpful advice on the content and organization of Part IV.

Part V was prepared by Dr. Don Rusch of the Wisconsin Cooperative Wildlife Research Unit, and Dale Caswell of the Canadian Wildlife Service. It recommends that a combination of four population and habitat components should be monitored to evaluate progress towards the goals of the Arctic goose management initiative called for in this Working Group report. These are: harvest rates, adult survival rates, goose population status and the status of coastal tundra habitats.

Finally, Part VI represents the Working Group's conclusions and recommendations. All Working Group members had opportunities to contribute to all portions of the report throughout its development.

The Working Group acknowledges the encouragement and interest of AGJV Management Board Chairmen, Gerald McKeating of the Canadian Wildlife Service, and Paul Schmidt of the U.S. Fish & Wildlife Service. These individuals provided on-going encouragement that the Working Group's advise would be taken seriously in the development of federal agency action programs to resolve problems caused by over abundant mid-continent snow geese. They kept the group free from bureaucratic and political restraints and provided travel support for some academically-based members who would not have been able to participate without this help.

This report was presented to the Arctic Goose Joint Venture Management Board on October 30, 1996 in Smyrna, Delaware. The Management Board endorsed the report and forwarded it to the Secretary of the Interior in the U.S., the Director of the U.S. Fish and Wildlife Service, the Minister of the Environment in Canada and the Director General of the Canadian Wildlife Service. They recommended that the two federal agencies take action to reduce mid-continent snow goose populations to the levels suggested by the Working Group. They further recommended that a task force be established by March of 1997 to develop an effective management program, to be

implemented by the fall of 1998, that would reduce populations and reverse the destruction of Arctic goose habitats caused by over-abundant mid-continent snow geese.

The group received input at two meetings from representatives of communities in northern Canada, namely from: Ginette Lajoie and Kenny Blacksmith of the Grand Council of the Crees, and; Noah Muckpau of the Arviat Hunters and Trappers organization. CWS representatives, Kathy Dixon and Steve Wendt attended one meeting and provided valuable perspectives. Scott Stephens of the Conservation Programs Group (CPG) at Ducks Unlimited provided extensive logistic and technical assistance in assembling this report. Paula Booker and Marvin Coleman, of the CPG, Chuck Petrie of DU Magazine and Cecille Birchler and Karen Almand of DU's Creative Services staff provided other valuable assistance. Other acknowledgements by individual writing team members are included in each part of the report, however, one individual, Dr. Austin Reid of the Canadian Wildlife Service, provided an especially valuable critique of the last draft.

We also extend our appreciation to the organizations for which we work as they allowed time (and travel expense for many members) for our participation in this effort. This amounted to a considerable commitment for several individuals and organizations. We hope the comprehensiveness and timeliness of this report vindicate that their trust was well placed and that we contribute meaningfully to the reversal of the current path to habitat destruction in large portions of the Arctic ecosystem.

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Part II: HIGH GOOSE POPULATIONS: CAUSES, IMPACTS AND IMPLICATIONS

Kenneth F. Abraham and Robert L. Jefferies

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INTRODUCTION

Many species of Arctic breeding geese have increased significantly over the last thirty years (Ogilvie and St. Joseph 1976, CWS, USFWS and Atlantic Flyway Council 1981, Boyd and Pirot 1989, Owen and Black 1991, Fox *et al*. 1992, Abraham *et al*. 1996). In North America, these include lesser snow geese (*Anser caerulescens caerulescens*), greater snow geese (*A. c. atlantica*), Ross' Geese (*A. rossii*), greater white-fronted geese (*A. albifrons*), and some populations of Canada geese (*Branta canadensis*), e.g., B.c. *interior* of the Mississippi Valley Population and *B.c. parvipes* of the Short Grass Prairie Population. In addition, some temperate breeding Canada geese (*B.c. maxima*) have also increased (Rusch *et al*. 1995, Allan *et al*. 1995). Most increases are the direct or indirect result of human activities; their combined effects represent biomanipulation of goose populations on a massive scale. The mid-continent population of lesser snow geese, for example, now exceeds three million birds, and the population is increasing at a rate of at least 5% per annum (Abraham *et al*. 1996) (Fig. 2.1).

The intense foraging activities of lesser snow geese, greater snow geese, Ross' geese and some Canada goose populations, have altered plant communities in both natural and agricultural ecosystems (Lynch *et al*.1947, Smith and Odum 1981, Giroux and Bédard 1987, Jefferies 1988a,b, Kerbes *et al*. 1990, Belanger and Bédard 1994, Didiuk *et al*. 1994, Ryder and Alisauskas 1995). Most species of geese feed in flocks on migration and wintering grounds. Many, including lesser snow geese, also feed in groups on the breeding grounds following hatch, hence it is not only the large numbers of birds, but also their colonial or gregarious behaviour and locally high densities that cause substantial changes to plant assemblages.

The chronic effects of disturbance by geese to different types of vegetation and soils are cumulative. Females display a high degree of philopatry to breeding grounds (Cooke *et al*. 1995) and in response to overall population growth, individual nesting colonies expand outward to occupy all suitable habitat and/or increase in density within suitable habitats (e.g. Ross' geese, Alisauskas and Boyd 1994, Kerbes 1994). The sustained use of a breeding site over a number of years allows little opportunity for recovery of the vegetation from the effects of foraging. The intensity of foraging, particularly in spring, varies from year-to-year and is dependent on the number of birds and on the prevailing weather conditions. In late springs, the prolonged cold and the presence of ice and snow delays the northward migration of birds, and at sites in the sub-Arctic and southern Arctic both local breeding populations and staging birds have considerable impact on vegetation (Jefferies *et al*. 1995).

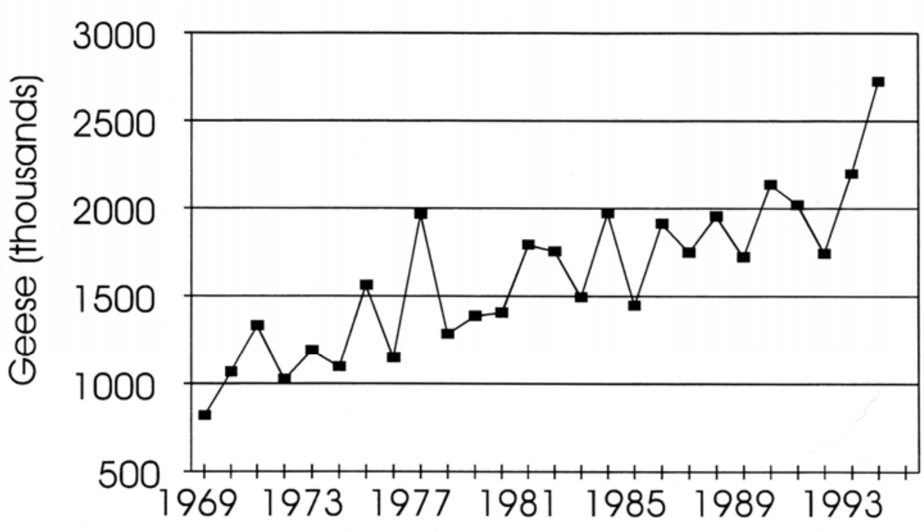


Figure 2.1. Number of lesser snow geese in the mid-winter index of Mid-Continent Population, 1969-1995. Mississippi and Central Flyway data, courtesy of K. Gamble and D. Sharp.

Most damage to vegetation, so far recorded, has occurred in habitats along the western and southern coasts of Hudson Bay and in James Bay. These localities, which are major staging and breeding areas for both lesser snow geese and Canada geese, are undergoing isostatic uplift (ca. 1 cm/yr) and plant community development in these early successional environments is strongly dependent on coastal geomorphology. The destruction of vegetation which occurs at sites frequented by geese is the direct result of foraging and feedback processes that lead to further destruction of vegetation and desertification of landscapes (Srivastava and Jefferies 1996). The rate of loss of vegetation is rarely linear, once a threshold associated with the intensity of the feedback processes is passed, destruction is rapid (see later).

The effects of this cumulative damage on the geese and other fauna, on wetland and agricultural ecosystems, and on migratory bird management are significant and complex. Arctic coastal wetlands and their biological processes and components, in particular, are at risk from sustained high goose populations. The biology and well-being of individual geese have been affected (e.g., reduced body size, reduced gosling survival). Ducks, shorebirds and passerines suffer direct habitat loss, particularly nesting birds that are less mobile. Degraded soils alter the conditions for invertebrate and microfaunal growth. Aquatic systems in coastal areas are affected by eutrophication, increased water temperature, salinity, and increased evaporation, with probable consequences on the structure of invertebrate communities. In areas long-occupied by geese, faecal droppings have accumulated, and conditions may favour the spread of parasites and diseases, (e.g., renal coccidiosis, Gomis *et al.* 1996).

There are few precedents for dealing with problem (high) populations of migratory game birds. For harvestable wildlife in general, the wildlife conservation profession has focused on ensuring stable or increasing populations consistent with wise use. For non-harvested wildlife it has emphasized protection or halting declines of rare species; it has dealt relatively little with population reduction or control of abundant native vertebrates (Garrott *et al*. 1993) except where rare or endangered species recovery is limited (Goodrich and Buskirk 1995). The dilemma posed by high populations of geese present new challenges (Ankney 1996, Rusch *et al*. 1996) made more difficult because many of the negative impacts occur far away and unseen by the general public, whose understanding and support will be needed for action.

In this background report, we review status and trends of selected goose populations, the contributory causative factors, the biological impacts of high populations, the likelihood of recovery of affected systems, and some of the human interactions. In companion reports, the effects of various population manipulations is considered (Rockwell *et al*. 1997) and possible management actions are reviewed (Johnson 1997).

POPULATION STATUS AND TRENDS

In the following accounts, eastern Arctic refers to the area east of approximately longitude 95° W; the central Arctic refers to the area between 95° W and approximately 115° W, and the western Arctic refers to the area west of 115° W (Fig. 2.2a, 2.2b).

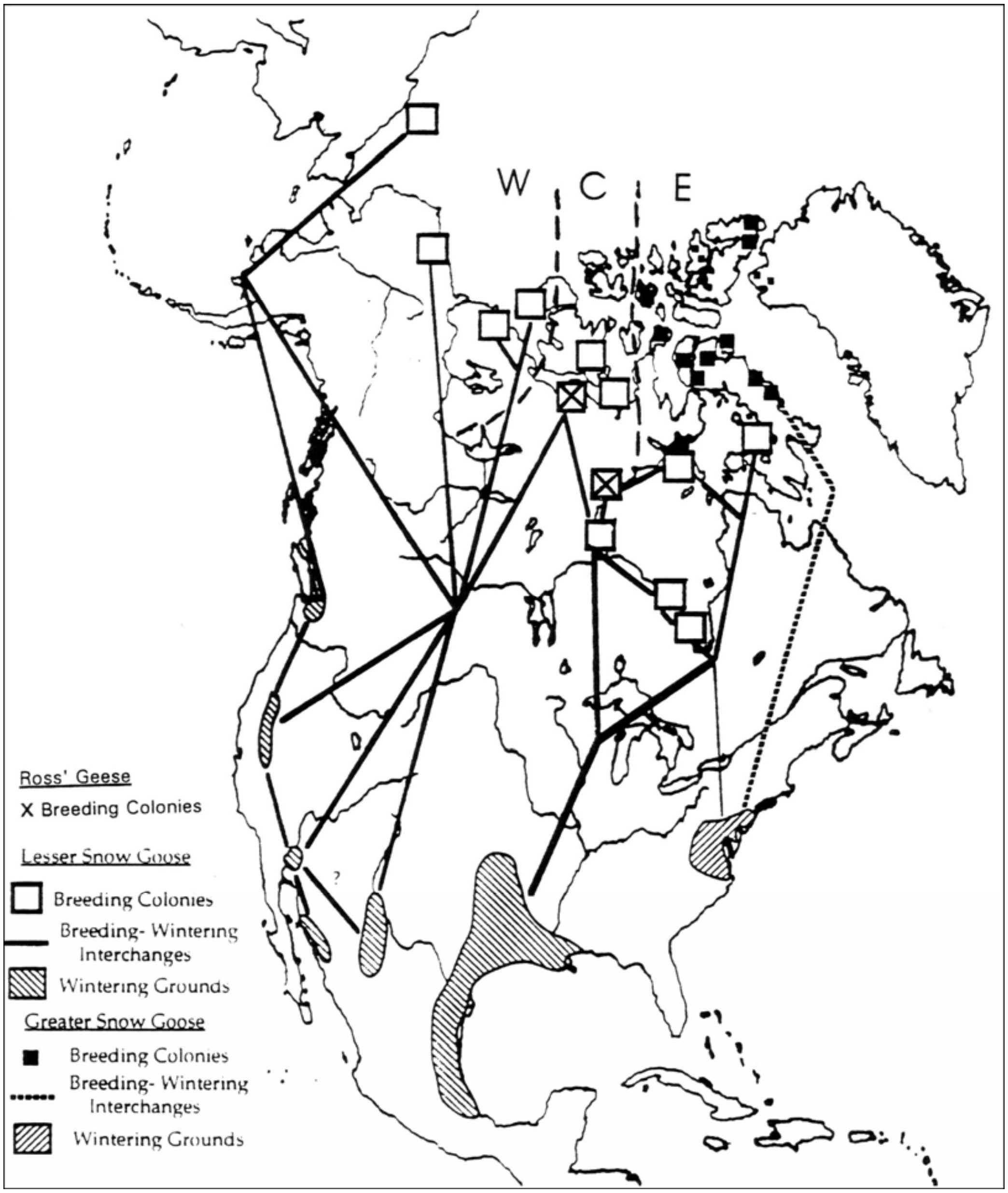


Figure 2.2a. Locations of breeding colonies and linkages to wintering areas for lesser snow geese, greater snow geese, and Ross' geese in North America. Dashed lines separate western, central and eastern Arctic areas (after Cooke et al. 1995)

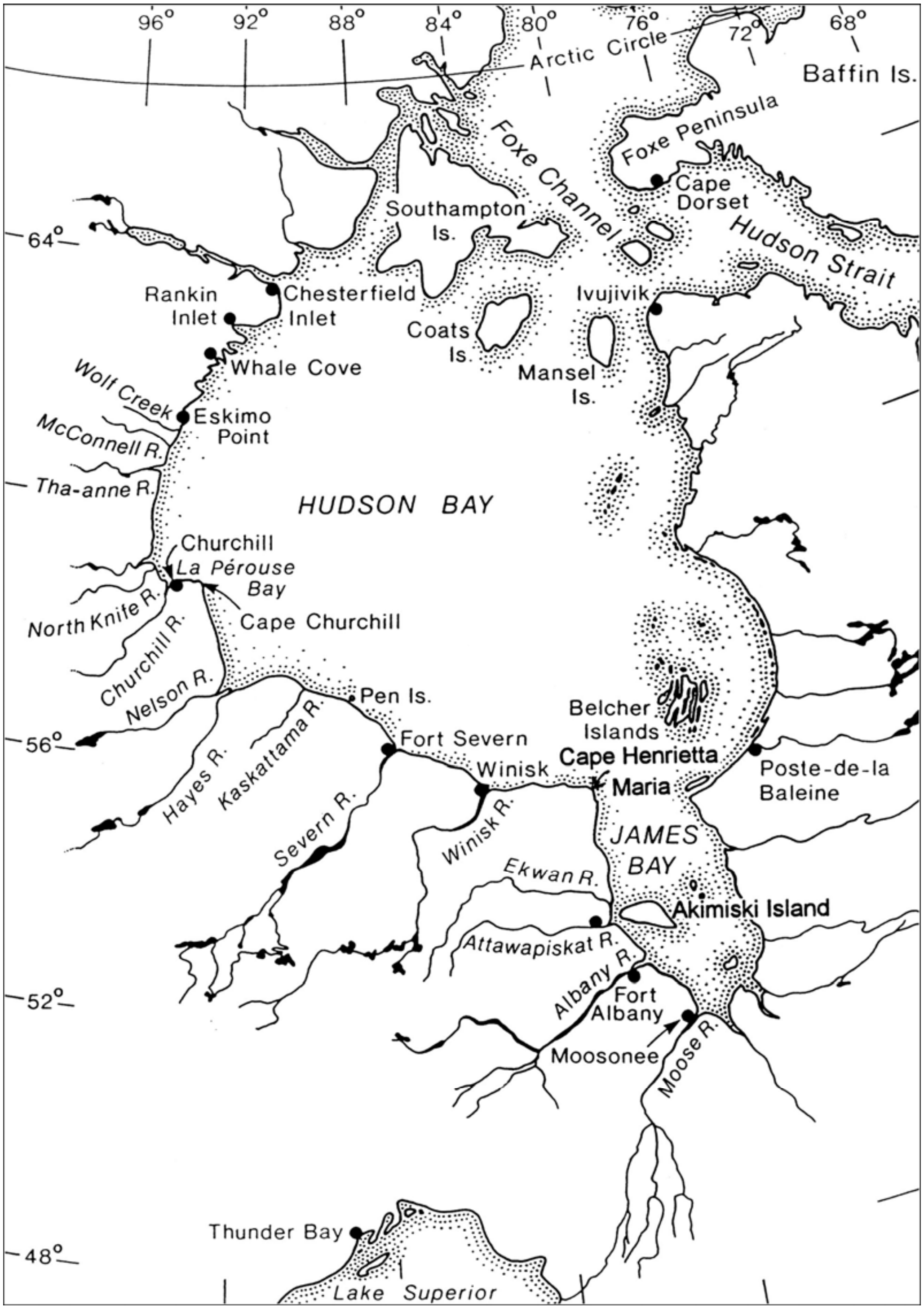


Figure 2.2b. Map of Hudson Bay region showing place names mentioned in text.

Lesser Snow Goose (LSGO)

LSGO populations in the mid-continent have been indexed annually during winter since mid-century. The mid-winter index (MWI) rose 300% from 0.8 million geese in 1969 to 2.7 million in 1994 (Mississippi and Central Flyway Councils, unpublished data) (Fig. 2.1). A complete photographic inventory of eastern Arctic nesting colonies by Kerbes (1975) suggested that winter indices averaged about half the actual spring number (e.g., when MWI was 0.8-1.0 million geese, he estimated 1.9 million at nesting colonies); Boyd *et al*. 1982) corroborated this underestimation and used a factor of 1.6 to adjust MWI. The probability of mid-winter index counts under-estimating the real population size has probably increased as the population has grown, due to the daunting task of monitoring the expanding wintering area used by geese, and the limitations of survey techniques for large clustered populations. The current actual population of mid-continent LSGO geese is probably between 4.5 and 6 million.

Recent breeding ground surveys in the eastern and central Arctic have confirmed substantial growth at several colonies and establishment of new colonies (Fig. 2.3a-d) (Reed *et al*. 1987, Alisauskas and Boyd 1994, Kerbes 1994 and unpublished data, Cooke *et al*. 1995, Hudson Bay Project, unpublished data). D. Caswell, personal communication, conducted surveys on southwestern Baffin Island that revealed 1.2-1.4 million breeding adults in 1994 and 1995. LSGO populations in central and western Arctic Canada apparently grew more gradually (than those of the eastern Arctic) before the 1980's but now (the last decade) appear to be on a similar track. Central and western Arctic nesting areas now each contain more than 500,000 breeding birds (*cf*. Alisauskas and Boyd 1994 in ROGO account below). The Egg River, Banks Island colony experienced extremely rapid growth from 1985 to 1995 (Dzubin 1979, Kerbes 1983, R. H. Kerbes, unpublished data). An Alaskan nesting population established in the late 1960s has grown gradually, partly through immigration (Johnson 1995).

<u>Some exceptions.</u>-- Unlike most LSGO populations, the total population returning in spring to Wrangel Island, Russia declined recently to 70,000 birds from 150,000 in 1970 (Pacific Flyway Management Plan, 1992) (Fig. 2.4a). Lesser snow geese that breed on Wrangel Island are composed of two different sub-populations that winter in separate locations, either in the Fraser-Skagit Delta system of British Columbia and Washington, or in California and Oregon (McKelvey *et al*. 1989, Syroechkovsky *et al*. 1994). An Asian population, thought to nest on the Arctic coast of the Russian Far East as far west as the Lena River and to winter in Japan, was eliminated due to human harvest (V.V. Baranyuk, pers. comm.).

The complex of nesting colonies on the West Hudson Bay coast, centered at McConnell River, grew exponentially from the 1940s to late 1970s to a high of 215,000 breeding pairs but has declined since 1985 to less than 75,000 breeding pairs (Kerbes 1982, MacInnes and Kerbes 1987, Kerbes *et al*. 1990, R. Kerbes, pers. comm.) (Fig. 2.4b). Habitat destruction by geese and emigration of adult geese to other nesting areas are implicated as causes of the decline.

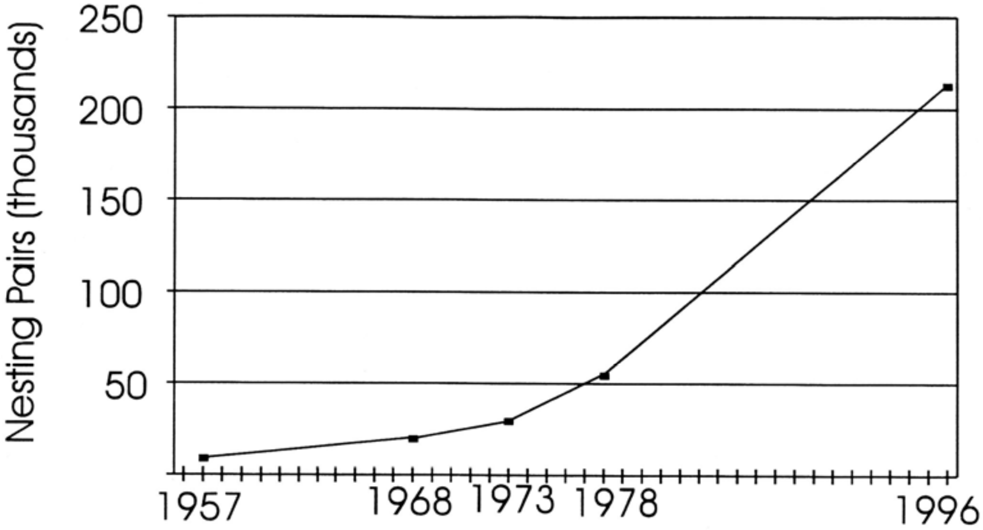


Figure 2.3a.Growth of lesser snow colony at Cape Henrietta Maria, Ontario, 1957-199

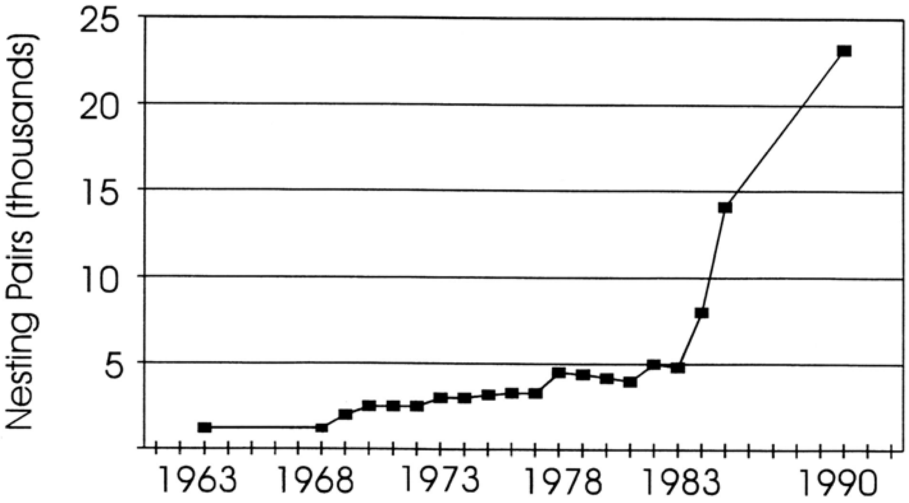


Figure 2.3b. Growth of lesser snow goose colony at La Pe'rouse Bay, Manitoba, 1963-1990. Cooke et al. 1995, R. Kerbes, unpublished data.

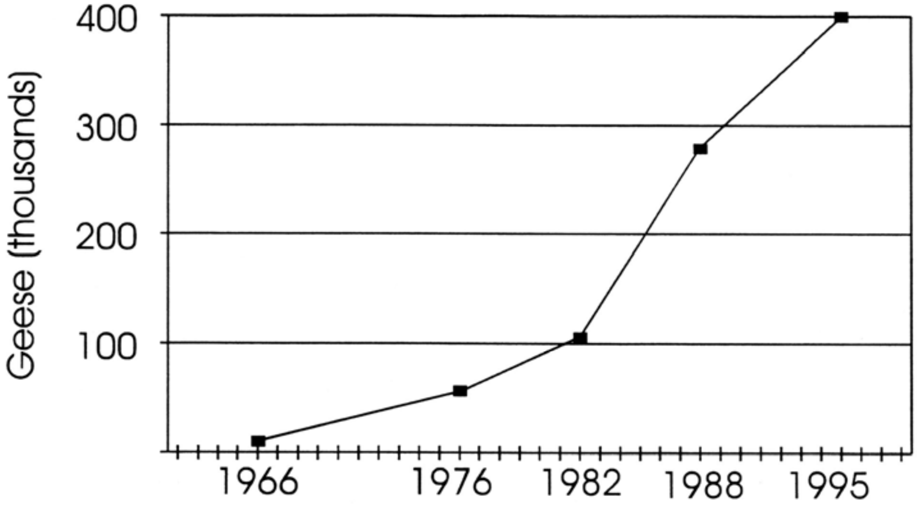


Figure 2.3c. Number of nesting lesser snow geese in the Central Arctic, 1965-1995. Unpublished data courtesy of R. Kerbes.

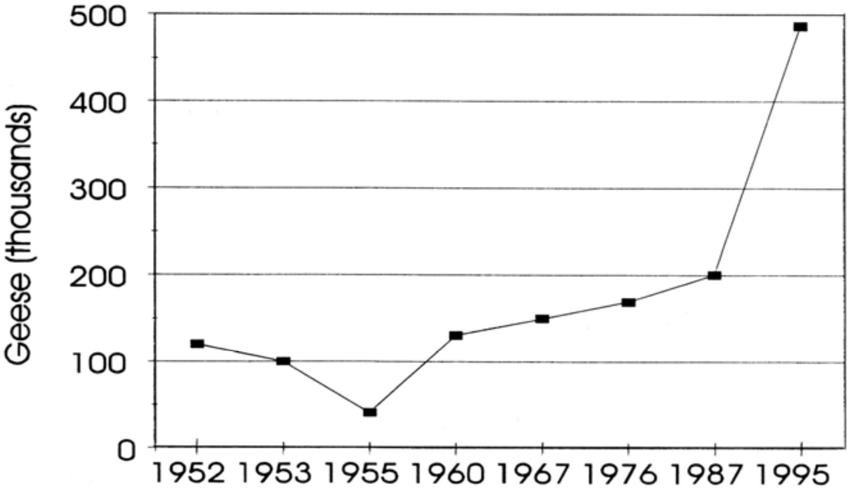


Figure 2.3d. Number of nesting lesser snow geese in the Western Arctic, 1950-1995. Source in text, and R. Kerbes, unpublished data.

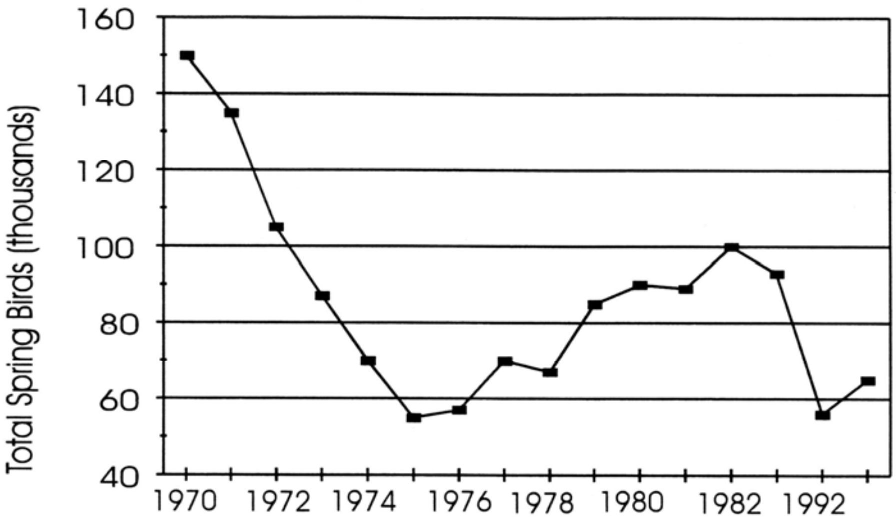


Figure 2.4a. Number of lesser snow geese in spring (nesting and non-nesting birds) at Wrangel Island, Russia, colony. Data courtesy of R. Kerbes.

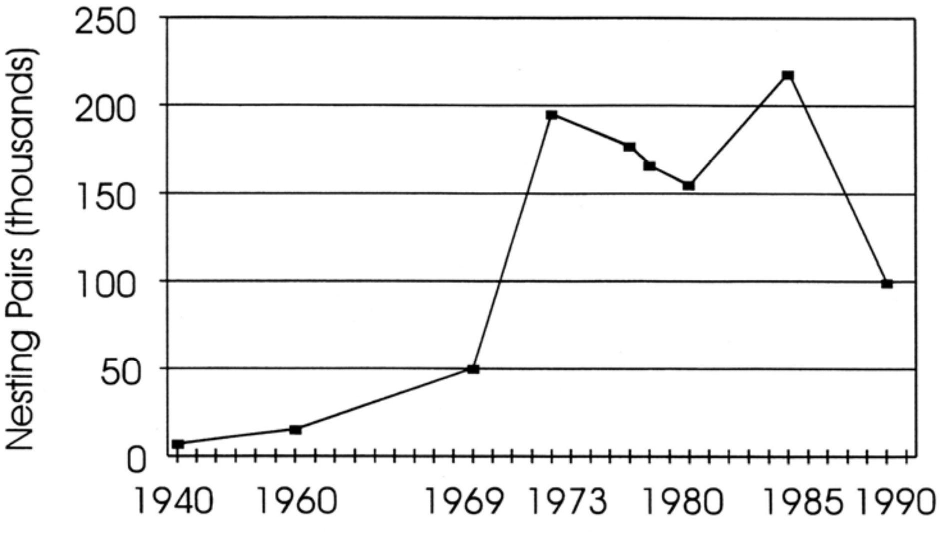


Figure 2.4b. Number of nesting pairs of lesser snow geese at McConnell River and west Hudson Bay colonies, 1940-1990. MacInnes and Kerbes, 1987, R. Kerbes, unpublished data.

Ross' Goose (ROGO)

ROGO are difficult to index because of mixing with LSGO in both winter and at nesting colonies. However, a technique using late winter surveys (when ROGO are somewhat isolated from LSGO) showed an increase in numbers from 8,000 in 1957 to over 38,000 in 1968 (Bellrose 1980). McLandress (1979) estimated a 7% per annum growth rate from 1964 to 1976, at which time the winter population index was 107,000 birds. Nesting birds in the Queen Maud Gulf region increased from about 2,000 in 1949 to 34,000 in 1965-67 to 188,000 in 1988 (Kerbes 1994) (Fig. 2.5a). Thus, almost 400,000 ROGO migrated from the breeding grounds in the early 1980s. Alisauskas and Boyd (1994) documented further growth of existing colonies and establishment of new ones. They suggested the nesting population at the 2 major colonies doubled between 1988 and 1990-91. They estimated a population of over 900,000 adult ROGO and LSGO combined in the Queen Maud Gulf area in 1990-91; ROGO make up about 42% (210,000) of the largest colony at Karrak Lake, which contained an estimated 500,000 total "white" geese in 1995 (R. Alisauskas, unpublished data).

A few nesting ROGO were present in most LSGO colonies in the eastern Arctic in the early 1970s (MacInnes and Cooch 1964, Prevett and MacInnes 1972, Prevett and Johnson 1977). Since that time, the population has exploded to an estimated 40,000 birds at the McConnell River colony, NWT in 1995 (R. Forsyth, Canadian Wildlife Service and R. Bromley, Government of Northwest Territories, unpublished data), and to 1,000 on western Baffin Island (D. Caswell, Canadian Wildlife Service, unpublished data). In addition, up to 14% of "white" geese within sections of the Boas River nesting area on Southampton Island, NWT are ROGO (T. Moser and K. Abraham, unpublished data). If most individuals from these eastern subpopulations migrate in fall to the mid-continent area, the overall number of ROGO there may exceed 100,000 birds. B. Sullivan (Texas Parks and Wildlife Department, unpublished report) provided an estimate in 1995 from Texas alone of 70,000 ROGO which supports this suggestion (see also Kerbes 1994).

Greater Snow Goose (GSGO)

The population with the best documented growth data among all white geese is the GSGO. A single population of this subspecies exists in eastern North America. It grew from a few thousand in the 1930s to 50,000 by the mid 1960s, to over 500,000 in fall migratory flights in the late 1980s (Gauvin and Reed 1987, Reed 1990). Spring migratory populations (measured by the use of complete photography on staging areas) reached 612,000 in 1995 (Reed 1996) (Fig. 2.5b). Following 7 decades of slow growth, the population increased seven-fold from 1965 to 1985 and it has nearly doubled between 1985 and 1995. Surveys of breeding numbers on the largest colony (Bylot Island) have been made every 5 years since 1983. They have showed an increase from 16,000 breeding adults in 1983, to 26,300 in 1988, to 55,000 in 1993 (Reed and Chagnon 1987, Reed *et al.* 1992, Reed, pers. comm.). In addition to the excellent long-term population monitoring, the geographic expansion of the breeding grounds, spring staging areas, wintering grounds, reproductive success and annual harvest have been recorded carefully (Reed 1976, Reed 1990, Gauthier *et al.* 1988, Bédard and Gauthier 1989). These data provide an excellent example of the information necessary to determine the causes of population increase of geese (Gauvin and Reed 1987, Reed 1992).

The rapid population growth phases of the mid-continent LSGO population, the ROGO and LSGO populations in Queen Maud Gulf, and the GSGO population all occurred at about the same time (Boyd, Cooch and Smith 1982, Kerbes 1994, Gauvin and Reed 1987). In the period between 1966/1967 and 1974/1975 all of these populations doubled. Since that time, LSGO have nearly doubled again, and GSGO and ROGO populations have achieved even higher growth rates.

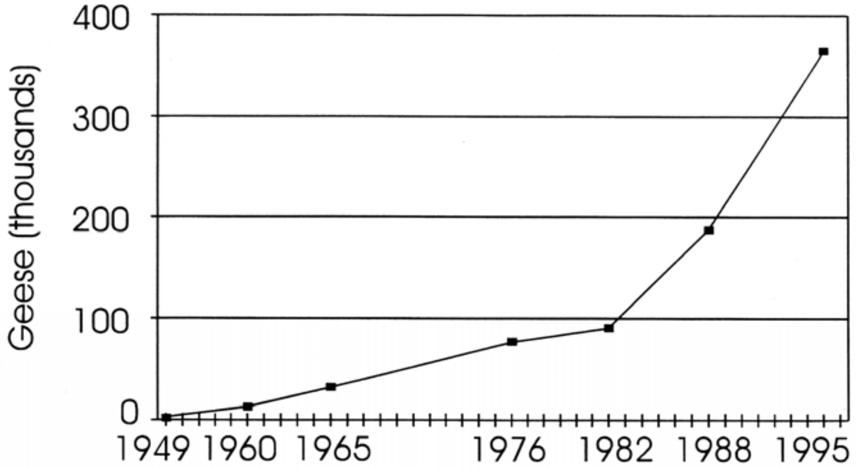


Figure 2.5a. Number of nesting Ross' Geese in Central Arctic, 1950-1995. Source in text and unpublished data courtesy of R. Kerbes.

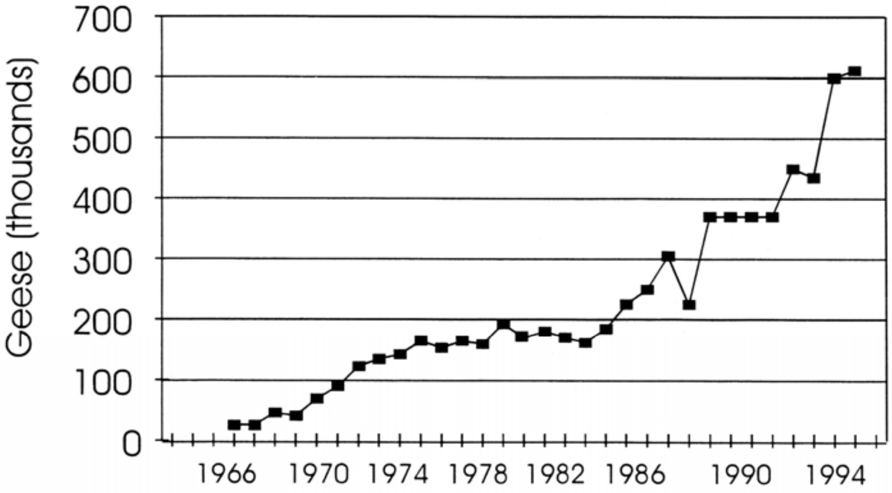


Figure 2.5b. Census of greater snow geese staging in spring in St. Lawrence River, Quebec. Data courtesy of A. Reed.

Greater White-fronted Geese (GWFG)

Mid-continent Greater White-fronted Geese have, like other geese, increased dramatically over the past 40 years. In the Mississippi Flyway, only 12,000 were counted in the first coordinated aerial surveys of the mid-1950s (Yancey *et al*. 1958). They have increased over ten-fold to a 1996 MWI of 145,100 (K. Gamble, Mississippi Flyway Council, unpublished data); the increase has been similarly dramatic in the central flyway (D. Sharp, Central Flyway Council, unpublished data) (Fig. 2.6a-b). GWFG that winter in these flyways have been managed and monitored as two groups: Western and Eastern Mid- continent. However, Kraft and Funk (1991) cited evidence that this distinction might not be valid and recognized an urgent need for better information to delineate and monitor populations. Since then, coordinated September surveys in Saskatchewan and Alberta and the northern states of the Central and Mississippi Flyways have been conducted (from 1992 to 1995). These surveys tallied 625,847 geese in 1992, 677,489 in 1993, 727,726 in 1994 and over 1 million in 1995 (Canadian Wildlife Service, D. Neiman, unpublished data, Zenner 1996).

Krapu *et al*. (1995) studied the spring staging ecology of mid-continent GWFG, particularly the use of habitat, nutrient accumulation, and agricultural food contributions to energetics of pre-breeding birds. They believe that GWFG now "arrive on Arctic breeding grounds with larger and less variable fat reserves than before modern agricultural development". They attribute this to increased corn availability and use, beginning in the 1940s when corn harvesting techniques provided waste grain, but accelerating in the 1960s and 1970s when corn yields increased. They suggest that increased fat deposition in spring positively affects recruitment.

GWFG in portions of the Central Flyway where wetland loss is >90% (Krapu *et al*. 1995, Friend and Cross 1995) are vulnerable to disease epizootics, especially avian cholera. High concentrations on the relatively few remaining roosting wetlands allow for easy transfer of the disease. Population growth as exhibited in recent years likely exacerbates these problems.

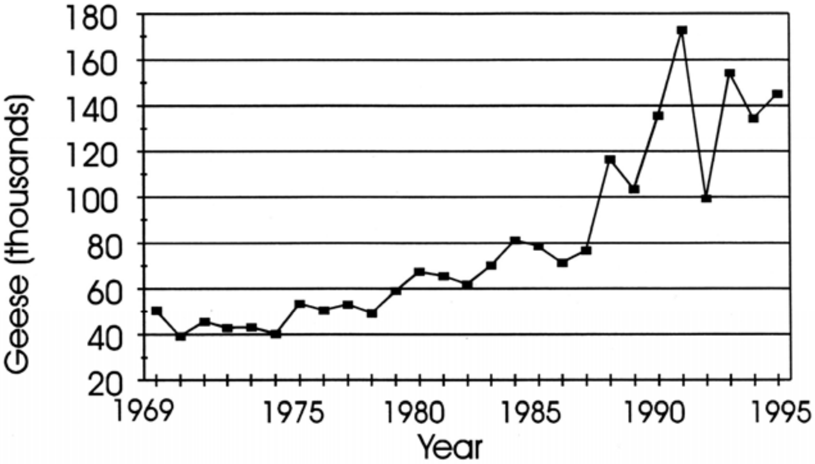


Figure 2.6a. Number of greater white fronted geese in the Mississippi Flyway, 1969-1995. Mississippi Flyway data, courtesy of K. Gamble.

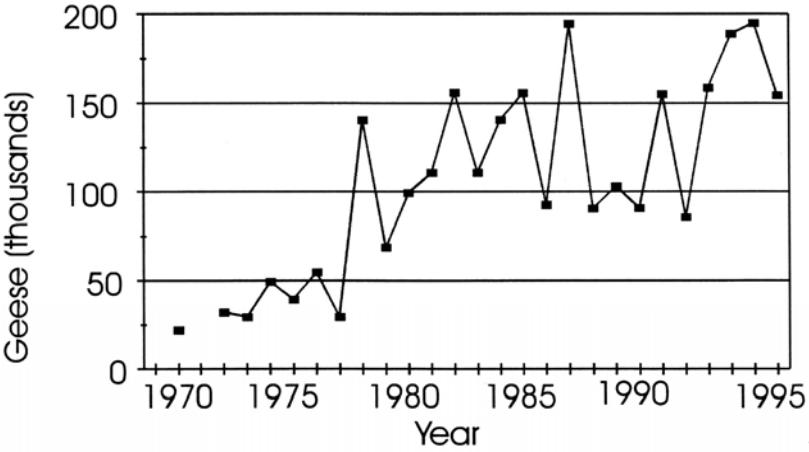


Figure 2.6b. Number of greater white fronted geese in the Central Flyway, 1970-1995, in winter. Central Flyway data, courtesy of D. Sharp.

Giant Canada Geese (Giant CAGO)

Populations of Giant Canada geese have grown from near extinction to nuisance levels over the past 40 years; from an estimated 55,000 birds in 1965, the various populations of temperate breeding birds now contain an estimated 2 million geese, with over 1 million in the Mississippi Flyway alone (Rusch *et al.* 1995, Rusch *et al.* 1996) (Fig. 2.7a). Much of this growth is directly attributable to planned management actions of agencies and private sponsors, including restoration and introduction programs, closed hunting seasons, and restricted harvest expressly intended to increase populations. Equally, however, this growth is an outcome of the species adaptability and colonization of unoccupied habitats under protection. This has occurred in an urban and rural landscape much altered since they were extirpated from many jurisdictions, which offered countless unintentional sanctuaries. The agricultural energy subsidy evident in the growth of white goose populations is similar in effect for Canada geese and is in part responsible for the growth of these goose populations. (Fig. 2.7b).

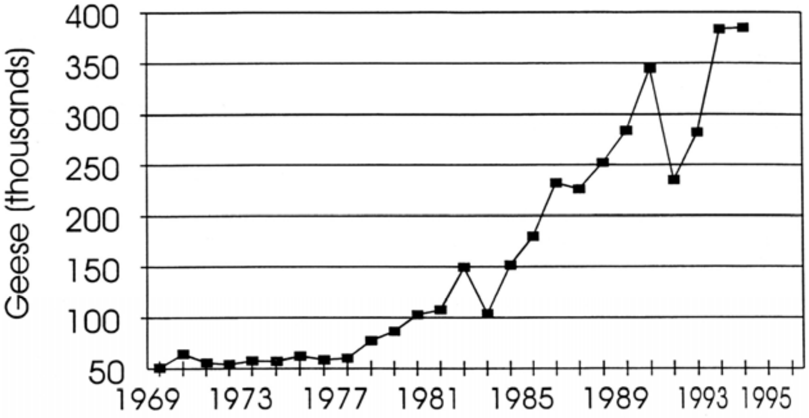


Figure 2.7a. Number of mid-winter Giant Canada geese in the Mississippi Flyway, 1969-1993. Mississippi Flyway Council data, courtesy of K. Gamble.

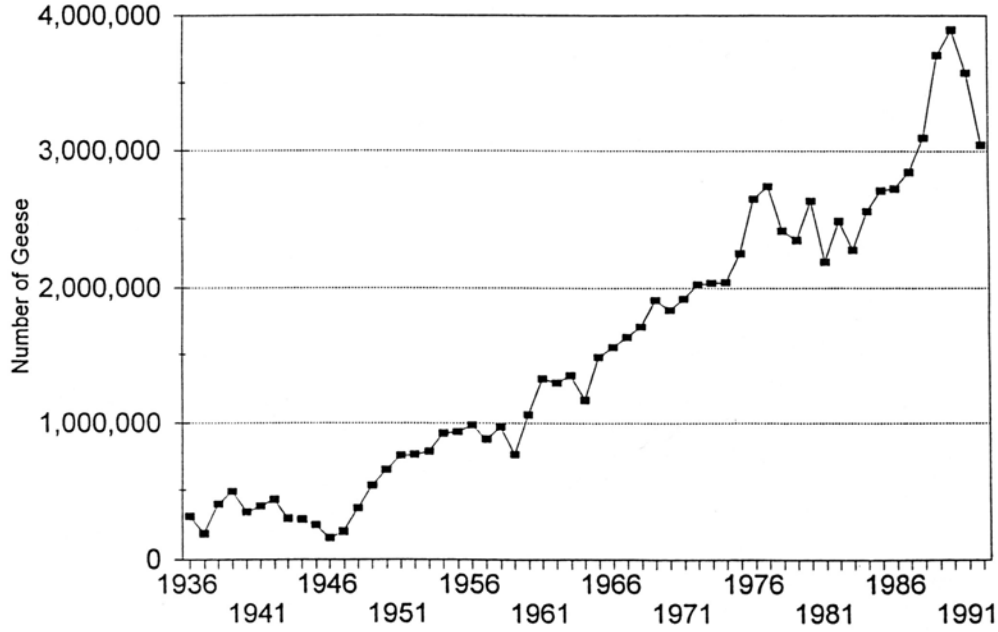


Figure 2.7b. Number of Canada Geese in North America in winter, 1936-1992. From Rusch, Malecki and Trost 1995.

Mississippi Valley Population Canada Geese (MVP CAGO)

The Mississippi Valley Population of Canada geese is the largest population of the *interior* subspecies. Management through harvest regulations and habitat programs have had the objective of increasing its size to 300,000 in winter (USFWS 1979) and later to 900,000 in spring (Tacha 1991). Sustained increases have occurred over the past 40 years, from less than 40,000 birds in winter to a current MWI of over 900,000 (Rusch *et al.* 1995, Mississippi Flyway Council, unpublished data) (Fig. 2.8). A period of rapid growth from 1964 to 1975 was followed by an erratic pattern until 1983, during which time the annual count reached an unprecedented peak of 576,000, but the mean MWI did not change significantly. The counts were possibly confounded by undetected growth of giant populations at that time. Since 1983, the population has rapidly and steadily increased, resulting in a tripling of the MWI. However, debate about the accuracy of the MWI and the inclusion of giants led to initiation of comprehensive breeding ground surveys in 1989. These show a spring population of 700,000 to over 900,000 from 1989-1996 and a fall flight of 1 to 1.5 million varying annually depending on current and recent years' production (J. Leafloor, unpublished data).

One of the consequences of the sustained growth in numbers is the change in nesting density and occupation of new range. Before about 1975, few nesting or brood-rearing Canada geese occupied the near coast (10 km) zone of Hudson Bay or northwest James Bay (H. Lumsden, pers. comm.). Annual photographic surveys from 1958-1970 made during the brood-rearing period covered the coast from Moosonee, Ontario to Eskimo Point, Northwest Territories (Hanson *et al.* 1972). A special effort to photograph broods for early assessment of reproductive success became possible only in the early 1980s. In addition, banding of coastal breeders was difficult and limited until the early 1980s. This suggests, at the least, an increase in use of coastal brood rearing areas, possibly a result of increased population density. Numbers of breeding pairs have tended to decline over the 1991-1996 period (J. Leafloor, pers. comm.), which may be an early signal of the population nearing its carrying capacity. A complicating factor is the increase of nesting lesser snow geese in the coastal zone of the MVP range from 1970 to the present; two small colonies (<2500 pairs) have been established and the major colony at Cape Henrietta Maria has nearly quadrupled in number, and doubled in area of coastal range occupied (Hudson Bay Project, unpublished data).

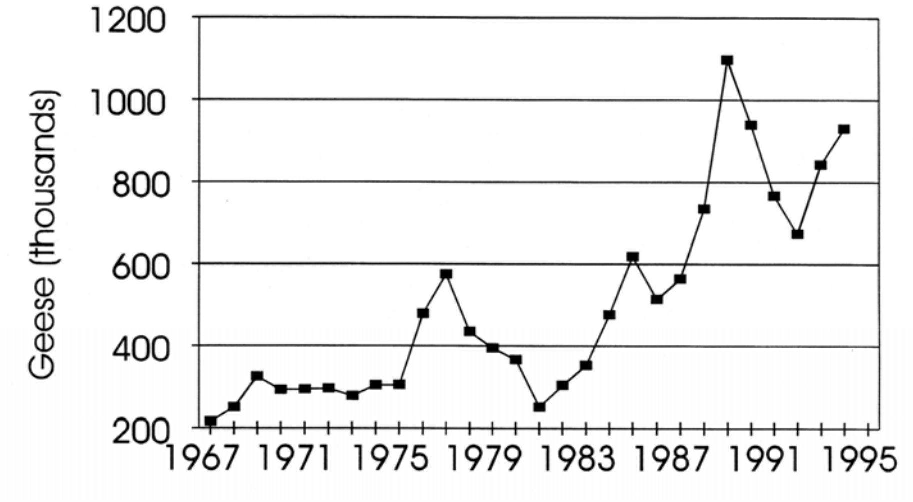


Figure 2.8. Number of mid-winter Mississippi Valley Population of Canada Geese, 1967-1994. Mississippi Flyway data, courtesy of K. Gamble.

HOW LARGE WERE WHITE GOOSE POPULATIONS BEFORE THIS CENTURY?

Before this century, accounts of abundance are narrative and anecdotal. None of the estimates was documented or quantified for comparison with modern methods. All of them precede the era of aerial surveys and none involved a coordinated, simultaneous air or ground survey. We summarize these below, but urge caution in interpretation because methods of numerical estimation are usually anecdotal and not statistically reliable.

LSGO

Bent (1962) writes of the "astonishing abundance" of lesser snow geese and blue geese (then described as two species) in the first decades of this century, particularly on the Gulf Coast and in Manitoba (i.e., what we now call the mid-continent population). The number of mid-continent LSGO in the 1930s was judged to be up to "3.5 million on the Gulf Coast in winter" (McIlhenny, in Gresham 1939), and "4-5 million in Manitoba in spring" (Soper, in Johnsgard 1974). McIlhenny (1932) estimated 1.25-1.5 million geese in a single flock. Johnsgard (1974) commented that these early estimates were "either wildly optimistic" or "mid-continent snow geese have declined greatly in recent decades". Yet Bent (1962) does not mention declines, nor does McIlhenny (1932) during his 50 years of close association with blue geese on the Gulf Coast.

Evidence of LSGO nesting colonies of sufficient size to corroborate these large migration and winter estimates of LSGO is lacking. Nesting areas were first visited by non-natives in 1928-30 (Soper 1930, Sutton 1931). Manning (1942) suggested hesitantly that there were 100,000 (presumably nesting) birds of each color on southwestern Baffin Island and 30,000 on Southampton Island (calculated from his counts and color ratios), but Kerbes (1975) termed Manning's estimates "minimum" because of the technique used (a coastal boat survey). Although these records suggest a fall flight of about 0.5 million birds in the late 1930s (similar to the first coordinated winter surveys in the Mississippi Flyway which estimated 440,000 (average of 1954-56) (Yancey *et al*. 1958), they are far short of 3.5-5 million! If there were that many birds during the first third of the century, what happened to them between then and the first coordinated winter surveys in the mid-1950s? We know of no evidence of massive disease outbreaks or die-offs, nor is there any hint of a massive hunting harvest (this was relatively early in the Migratory Bird Convention era and enforcement was strict).

ROGO

According to Bent (1962), ROGO were "the rarest of the geese which regularly visit the United States" by the 1920s. However, he mentions some evidence of their abundance prior to 1886, such as several thousand present each spring on the Missouri River (Montana). In California in winter, ROGO were "often quite common" and because of tameness "many are shot for the market". Ryder and Alisauskas (1995) cite Grinnell *et al*. (1918) as support for the suggestion that open market hunting may have contributed to the rarity of Ross' Geese at the beginning of the century.

GSGO

Concerning numbers of GSGO, early explorers wrote about "many thousands of white and grey geese" near present Québec City in 1535 (Jacques Cartier) and "many wild white geese" in the same area in 1663-64 (Fr. Paul Lejeune and Lalement) (Anonymous 1981, 1992). However, they “could not be called common” on the Atlantic coast by the late 1800s according to Bent (1962). The GSGO population was only 3,000-4,000 from the 1880s until the 1930s, and although it was suggested they were formerly more common, we found no specific statement of reasons for a possible decline (e.g., no evidence of decrease due to market hunting). A. Reed (pers. comm.) studied the ancient literature and gained the impression that GSGO were never abundant in the 1500s through 1900. Although hunting on the small population may have helped check population growth, he too found no evidence of excessive exploitation. He posed the question of whether a more severe climate in the Arctic during that period (the so-called Little Ice Age) may have kept numbers low because of frequent breeding failures.

Summary

What can we conclude about current versus former populations sizes? In the case of LSGO, abundance itself may have masked any trends; the difference between 0.5-1 million and 4-5 million would have been difficult to detect before consistent survey methods, as it is even now. Indeed, despite their abundance, contact with humans was infrequent because of the remoteness of breeding areas, and the limited number of staging areas along migration routes. In the case of ROGO and GSGO, migration concentrations and wintering sites overlapped with areas of early settlement which subsequently developed as human population centres in North America. Although their suggested former abundance apparently did not equal current population levels, a real decline appears to have occurred before this century and but only ROGO may have resulted from human activities.

EXPECTED WHITE GOOSE POPULATION EVENTS

If current agricultural and goose management practices are maintained, we expect continued growth of all populations for the foreseeable future, except the Wrangel Island LSGO. The western Arctic and western Central Flyway LSGO populations will escape from control by hunting (i.e., adult survival will increase). Western Arctic spring staging areas and nesting areas, which are predominantly fresh-water environments, should then experience increasing degradation similar to that already documented in these habitats in the Hudson Bay and central Canadian Arctic resulting in a decrease in survival of flightless young and other condition-related effects. More nesting colonies are likely to be established where suitable habitat exists. However, Alisauskas and Boyd (1994) speculate that prime nesting sites of Central Arctic Ross' and Snow Geese (shallow lakes with islands preferred as colony sites) are now in short supply and these geese must exploit other habitats. They appear to be spreading westward and northward into favoured range of small Canada Geese and White-fronted Geese. In southern Hudson Bay, most areas of extensive salt marsh capable of sustaining large colonies are now occupied (K. Abraham, R. Jefferies and A. Jano, unpublished data). Use of other habitats, particularly *Carex aquatilis* fens, is expected to increase.

Populations of all three white geese may experience an increase in the frequency of disease outbreaks in wintering and migration areas, but the mid-continent LSGO population, at least, appears to have the capacity to absorb many such small events without the overall population growth being slowed. Disease mortality effects on populations of other birds sharing these areas may be more detrimental.

FACTORS CONTRIBUTING TO HIGH POPULATIONS OF WHITE GEESE

Several factors coinciding in time and location have contributed to the observed population growth rates of white geese.

Agricultural food resource subsidy in winter and migration

Snow goose population size was once thought to be limited by over-winter survival, due to the species' apparent narrow definition of suitable winter habitat (salt marsh) and destructive foraging (grubbing) of vegetation resulting in depletion of food resources (Lynch 1975). Wintering habitats along the Gulf of Mexico (LSGO) and Atlantic coast (GSGO) were primarily restricted to coastal bulrush (*Scirpus* spp.) and cordgrass (*Spartina* spp.) salt marshes (McIlhenny 1932, Bellrose 1980, Anonymous 1981, Smith and Odum 1981). The area of habitat available for wintering LSGO on the coasts of Texas and Louisiana was somewhat more than 200,000 ha. After the 1940s, LSGO expanded their foraging range (Lynch 1975) by incorporating rice prairies immediately adjacent to coastal marshes. Overall, there was nearly 400,000 ha of land in rice production at that time. Although coastal marsh habitat loss or change has been implicated (e.g., oil and gas development, urban expansion, dredging and filling; Bent 1962, Robertson and Slack 1995). Lynch (1975) argued that these anthropogenic effects were a minor factor in the changing pattern of land use by the birds, particularly because refuges were established in coastal marshes to protect such habitats. Louisiana and Texas had 223,000 ha (550,000 acres) of protected marshes in the early 1970s (Lynch 1975). The reliance of LSGO on rice prairies has increased further since the mid 1960s (Bateman *et al*. 1988, Hobaugh *et al*. 1989, Widner and Yaich 1990). Agricultural and hunting management practices that provided large areas of shallow water suitable for night roosting played an important role in expanding this use to interior rice prairies. The increase in the area of rice cultivation and the use of nitrogenous fertilizers have been dramatic since that time, and LSGO and ROGO now forage in over 900,000 ha of rice fields in Texas, Louisiana, and Arkansas. Although the harvested rice area has declined in the last decade, the yield per hectare on the upper Texas coast has continued to increase due to second cropping and more efficient harvesting (Hobaugh, Stutzenbaker and Flickinger 1989, Robertson and Slack 1995).

Further north in the mid-continent region and in the mid-Atlantic coast, geese exploit other cereal grains (Alisauskas *et al*. 1988, Anonymous 1981, Hill 1992, Reed 1992). A major impact of this conversion of natural grassland and bottom land forest habitats to agricultural use is that the former depletion of winter food resources in salt marshes, which presumably resulting in mortality or sublethal effects on body condition, has been removed as a factor limiting survival and population growth.

Corn, wheat. barley, oats and rye cultivation in the mid-western and northern prairies provide additional nutrient and energy subsidies for LSGO. Snow goose preference for corn in Manitoba in spring minimizes the historical influence that drought in natural habitats may have had on condition of pre-breeding geese (Alisauskas and Ankney 1992, Davies and Cooke 1983). Due to the important role of stored reserves in determining breeding success (Ankney and MacInnes 1978), this more reliable food source would lead to higher average reproductive potential. In fall, availability of waste grain in harvested fields has delayed the southward fall movement of geese and blurred the definition of "winter" range (Alisauskas *et al*. 1988). This effect is additive to the effects of refuges (see below).

On the Atlantic coast, GSGO formerly wintered in a restricted area of coastal salt marsh. Compared with LSGO, their use of habitats other than coastal marshes is more recent and more limited (Anonymous 1981, Reed 1992), but GSGO have fed in winter in agricultural cropland since about 1970 (Hill 1992). Historically, spring staging was limited to the tidal brackish *Scirpus* spp. marshes of the St. Lawrence River. In the late 1960s GSGO began to forage in agricultural land in Québec during spring (Reed 1992) as a result of a growing population and the cumulative annual depletion of *Scirpus* spp. plants (Gauthier *et al*. 1988).

Refuges placed in close proximity to traditional feeding areas and the loss of salt marsh as a consequence of development (Hindman and Ferrigno 1990) apparently assisted this shift. Ironically, concentrations of GSGO feeding intensively on refuge impoundments may have pushed marsh plants beyond their threshold of regeneration. Geese may have been forced to seek off-refuge foods in agricultural lands. In addition, industrial and urban development limited available salt marsh food supplies, and where forage was available, hunting pressure was high. In effect, a positive feedback was established between broadened habitat use and the population increase of LSGO and GSGO on both wintering grounds and staging areas.

The effect of refugia on migration routes

National Wildlife Refuges, state refuges and other wildlife areas were established throughout the United States, especially from the mid 1930s to the 1970s to protect and restore wetland habitat for breeding and migrating waterfowl and other wetland-dependent birds (Bellrose 1980). The attractiveness of these protected environments to waterfowl was quickly evident. The subsequent interruption of migration of LSGO and northward shift in the fall was particularly rapid and dramatic in the central United States from North Dakota to Louisiana and Texas. This eventually led to a reduction in traditional long distance flights from northern staging areas to Texas (Johnsgard 1974), and from James Bay to Louisiana (Cooch 1955).

Hunters were also attracted to some refuges which provided hunting opportunities, and in these places mortality increased (Johnsgard 1974). High local harvest rates near some refuges, as a result of both anticipated and unforeseen events (e.g., firing lines at refuge boundaries) may have led to poorer survival of birds using refuges than those that fed and roosted elsewhere. However, during the 1970s, changes in hunting practices near refuges included a reduction of firing lines, creation of no-hunting zones, manipulation of croplands to provide food, and a restricted harvest of geese on refuges and off refuges. The management practice of half-day hunting (Schroeder 1963) was initiated to hold migrant geese longer to increase hunting opportunities and local harvest, but its success also appears to have influenced distribution. These factors led to such migration sites functioning as true refugia (Frederick and Klaas 1982). Long-term reduction in the hunter harvest is consistent with the hypothesis of disproportional growth of population units using refuges (Raveling 1978). These refuges may thus function as loci for population growth and exploitation of surrounding "new" agricultural foods. Note that these events took place in the mid 1970s, the same time as the other factors contributing to the overall population increase of white geese appear to have taken effect.

Lower harvest rates

Annual survival of LSGO adults from Hudson Bay increased from about 78% in 1970 to about 88% in 1987 (Francis *et al.* 1992). The principal cause of mortality of adult geese in recent decades is hunting (Owen 1980). The expansion of the winter range of mid-continent snow geese and the lengthening of fall migration stopovers at northern latitudes has had a significant effect on dispersion of geese, hunter access and exposure to hunting. Harvest in the central US has declined along with hunter numbers over the past 25 years (Fig. 2.9a). More importantly, harvest rates (measured as proportion of mid-winter indexed population) declined from near 40% to under 8%

annually (Fig. 2.9b) (see Rockwell *et al*. 1997). Increases in harvest per hunter (Fig. 2.9c) have not compensated. Canadian harvests of lesser snow geese have also declined in recent decades (Fig. 2.9d). The increase in survival may have been due, therefore, to a reduced overall harvest rate. If so, the beginning of LSGO population "escape" from constraining effects of annual harvest occurred in the early 1970s.

GSGO harvest rates from the 1880s to the 1930s are not recorded but presumed to be high. Hunting of this subspecies was prohibited in the United States from 1931 to 1975 (Gauvin and Reed 1987) in order to increase survival and population growth. The population grew at a slow rate from 1910 to 1960. Significant growth did not occur until 1950 which suggested that hunting mortality alone was not responsible for low population growth. There is no evidence that habitat was in short supply (Reed, pers. comm.). Perhaps periodic weather related failures were in part, responsible for checking growth. Additionally, traditional use of coastal marshes (i.e., behaviour), lack of development pressure, and the low population numbers (i.e., little density dependent foraging competition) may have kept them from finding agricultural foods.

From 1967 to 1988, three distinct periods were recognized: the first (1967-1974) was characterized by legal seasons in Canada only, by variable but generally low harvest (mean 12,800 geese/yr) and a mean kill rate of about 10%; during the second (1975-1981) hunting occurred in both countries and mean harvest (51,600/yr) and mean kill rate (23.9%) increased; in the third (1982-1988) the mean harvest rose to 59,000 but the kill rate decreased to 18.5%. A more recent analysis covering 1989-1993 (Reed, pers. comm.) showed a continued increase in harvest (mean 74,500 geese/yr) and a further decrease in kill rate (mean 13.5%). The addition of a U.S. hunting season in 1975 resulted in larger harvests and, initially, in increased harvest rates but this was insufficient to stop steady population growth. Since the early 1980s, harvest rates have been decreasing, and the spring population has increased by an average of 10% annually (1980-1996) (Reed, pers. comm.). This inability of hunting to control numbers of GSGO occurred about the same time it ceased to control population size of mid- continent LSGO.

Climate amelioration in the Arctic

A general warming trend from 1961-1990 has occurred in the central and western Canadian Arctic regions (Cohen *et al*. 1994) which include major breeding areas of LSGO and ROGO. MacInnes *et al*. (1990) showed that LSGO nesting occurred progressively earlier in the Hudson Bay region from 1951 to 1986. They suggested it was, in part, due to climate amelioration. As reproductive success in Arctic geese is positively correlated with early spring melts (reviewed by Owen 1980), warming of nesting areas could have led to higher annual population growth rates of mid-continent LSGO. Long term trends in decadal climatic patterns have shown the decade from 1970 to 1980 to be an anomalous warm period in the southern Hudson Bay region (W. Skinner, unpublished data) during which time spring melt occurred almost 15 days earlier than in the previous and succeeding decades. Thus, rather than a steady climatic improvement, there may have been a brief window of more favourable conditions that reduced the frequency of reproductive failures (the "boom-bust" pattern) typical of Arctic goose productivity up to 1980 (Owen 1980). Boyd *et al*. (1982) were not able to relate the upward trend in numbers to weather patterns between 1964-79, but qualified this finding because of the measures of breeding success that they used. However, with the exception of poor or bust production in 1972 (LSGO, GSGO), 1974 and 1976 (GSGO) and 1978 (LSGO) they had periods of sustained good reproductive success, as measured by proportion of goslings to adults in fall flights and on the wintering grounds (Boyd *et al*. 1982, Gauvin and Reed 1987). Years of poor reproduction do not always coincide between low and high arctic areas. GSGO showed decreasing frequency of "bust" years (<10% juveniles in fall) up to 1988 (Reed 1990); three times in the decade 1956-65, twice in 1966-1975 and once in 1976-1988. But in the last eight years (1989-1995) there have been two bust years (Reed, pers. comm.). The striking feature of this long term data set is the eleven year stretch from 1975 through 1985 in which there were no bust years and in which juveniles in fall averaged 27%.

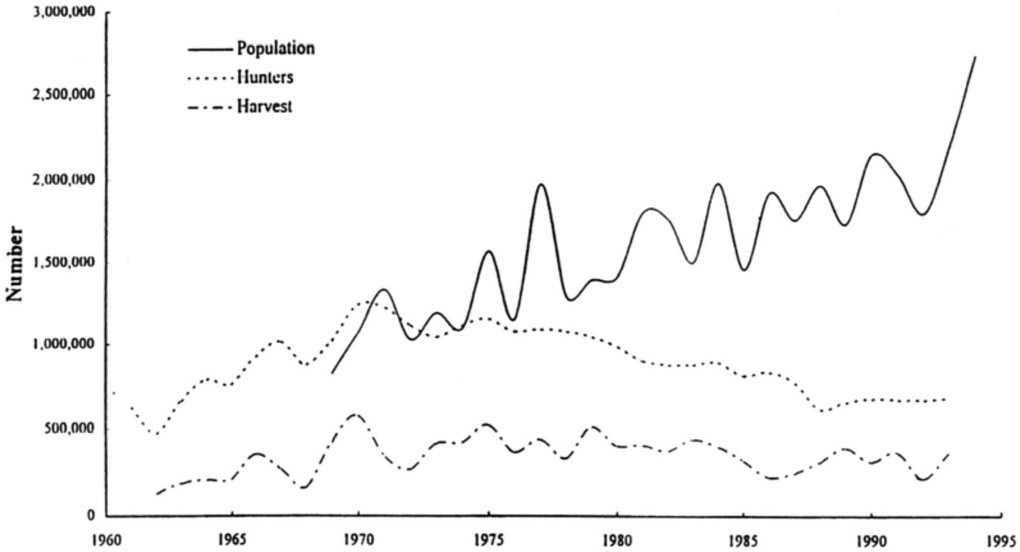


Figure 2.9a. Number of lesser snow geese, hunters and harvest in the Central and Mississippi Flyways. Central and Mississippi Flyway; graph courtesy of B. Sullivan.

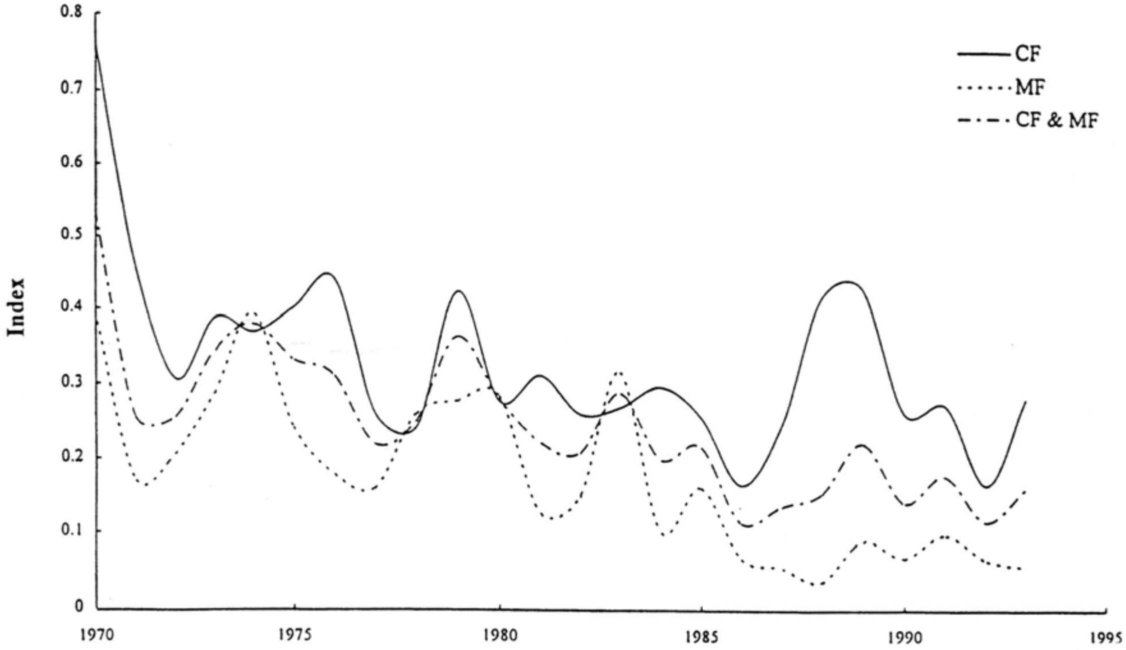


Figure 2.9b. Index to lesser snow goose harvest rate (harvest/population index) in the Central and Mississippi Flyways. Central and Mississippi Flyway data; graph courtesy of B. Sullivan.

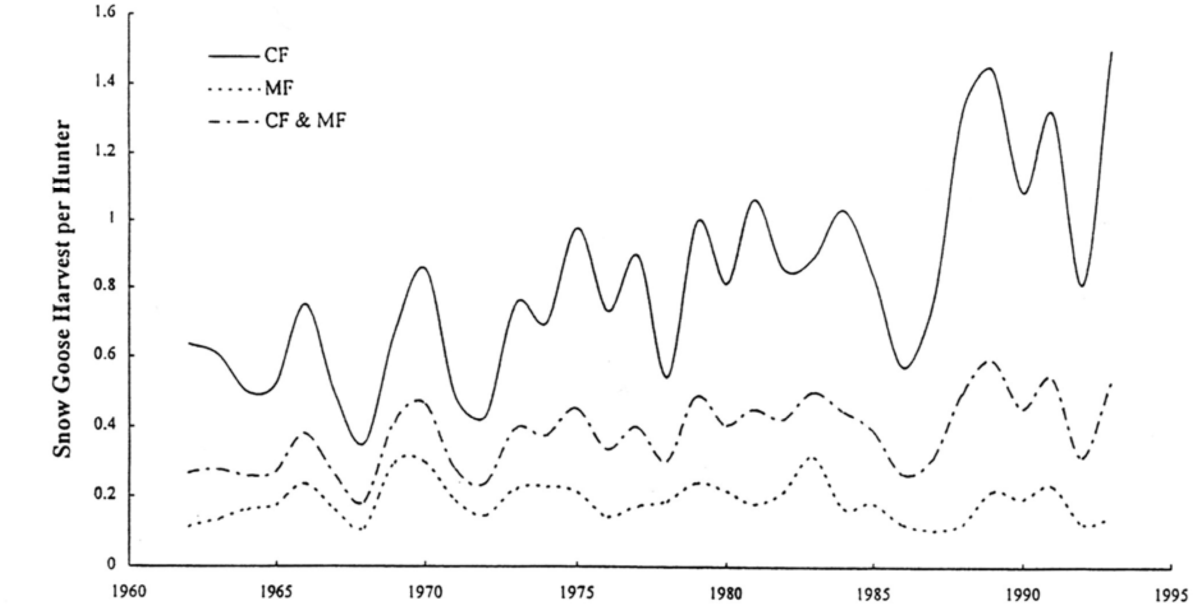


Figure 2.9c. Lesser snow geese harvest per hunter in the Central and Mississippi Flyways. Central and Mississippi Flyway data; graph courtesy of B. Sullivan.

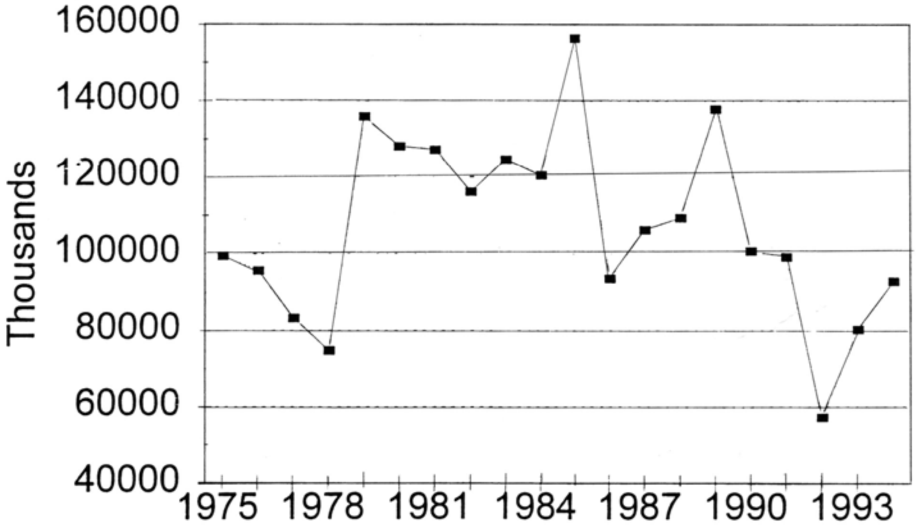


Figure 2.9d. Harvest of lesser snow geese in Canada, 1975-1994. Canadian Wildlife Service data, courtesy of K. Dickson.

The southern shift of nesting range of LSGO

The distribution of breeding birds has changed dramatically since the late 1920s. As a result, the centre of LSGO breeding range in the eastern Canadian Arctic geese has moved south to areas with a less severe climate (i.e., rather than climate change *in situ*). Snow clearance, on average, is 2 weeks earlier at Cape Henrietta Maria than at Baffin Island (Kerbes 1975). Before 1940, all known nesting colonies of lesser snow geese in the eastern Arctic were north of 60 ·N (Cooch 1958, 1961), whereas by 1973, 40% of the entire population was nesting south of that latitude as far as 55 ·N (Kerbes 1975).

MacInnes *et al*. (1990) suggested that with an earlier average start to nesting and a longer growing season, higher average annual production would result in population growth of these southern colonies. Evidence from Cape Henrietta Maria (Hudson Bay Project, unpublished data) and La Pérouse Bay (Cooke *et al*. 1995) (Fig. 2.3) supports this assertion. However, the slow growth of each colony in the first 2 decades following establishment argues against this as the sole mechanism to account for growth. Northern colonies continue to experience occasional weather-related "busts" in production (e.g., 1972, 1978; Boyd *et al*. 1982, and 1983, 1992; Kerbes, pers. comm.). Some birds which would normally nest in northern colonies may be induced in some years to nest at southern latitudes by these late melt conditions (Hanson *et al*. 1972, Geramita and Cooke 1982, Hudson Bay Project, unpublished data).

LSGO populations have also expanded their breeding range in the central Arctic, both on islands and interior mainland (McCormick and Poston 1988, McCormick 1989, Alisauskas and Boyd 1994, Kerbes 1994, B. Bromley, pers. comm.) where the long-term climate trend has been a gradual warming (Cohen *et al*. 1994).

SUMMARY OF CAUSATIVE FACTORS

A nutrient and energy subsidy derived from foraging in agricultural croplands in several seasons and an expanded migration and winter range have been the major influences enabling geese to increase in numbers in recent decades. Climate warming on breeding areas and expanded breeding range are likely secondary causes. Reduced harvest rate appears to be an effect rather than a cause, even if harvest rate was limiting population size before the 1970s. While there are population density-dependent effects, such as decreases in body size in LSGO (Cooch *et al*. 1991, Cooch *et al*. 1991) and GSGO (Reed and Plante 1997) and poorer body condition/higher gosling mortality in LSGO (Cooch *et al*. 1993, Williams *et al*. 1993), these adverse effects are more than offset, at the population level, by increased adult survival (Francis *et al*. 1992) and by "cheating" (see below).

Once the nutrient-energy subsidy was established on migration and wintering grounds, the overall landscape use by geese became inherently unstable. The geese are recipients of an increasing nutrient and energy subsidy and as such they represent an output of the agro-ecosystem at the landscape level. Expected density-dependent effects such as declining natality and increasing mortality fail to operate because of this subsidy.

Geese also "cheat" density-dependent regulation by their dispersal behavior on the breeding grounds both within seasons and between years. Increased nesting at the edges of existing colonies leads to colony expansion (MacInnes and Kerbes 1987, Reed and Chagnon 1987, Alisauskas and Boyd 1994, Kerbes 1994, Cooke *et al*. 1995). Dispersal of family groups after hatch to areas distant from nesting sites ensures that the birds do not forage in the most severely degraded areas (Cooch *et al*. 1991, Hudson Bay Project, unpublished data, R. Alisauskas and S. Slattery, unpublished data). In addition, new nesting colonies establish away from traditional sites that have been degraded (Alisauskas and Boyd 1994, Kerbes 1994). The apparent decline of the McConnell River and west Hudson Bay nesting complex can be interpreted in this context. It may be an example of how local carrying capacity was exceeded as the population grew and occupied new areas, but that at some point further dispersal took the form of emigration to a distant habitat (e.g., to the Rasmussen Basin lowlands, McLaren and McLaren 1982 and perhaps to Queen Maud Gulf, *cf*. Kerbes 1994). It may appear that, if the birds can disperse, the problems of habitat destruction are less urgent. However, as we discuss below, under the continued pressure of expanding populations of geese, the rate of destruction is accelerating, the total area affected is large and significant, and the habitats remaining undamaged are non-preferred and even marginal and ultimately, finite.

The Wrangel Island LSGO population decline is real and appears to be related to density-independent factors, including weather conditions on the breeding grounds and the length of their migration route. A series of late summers in the early 1970s virtually eliminated recruitment of new breeders. A long-term cooling trend is also evident for the high latitudes of the Russian Far East (Cohen *et al*. 1994), unlike most other LSGO breeding areas. Harvest rates have also been higher for Wrangel Island birds than others until very recently (S. Boyd, pers. comm.). Historically, harvest on the breeding grounds was also very high.

Currently, both winter subpopulations have access to extensive agricultural lands (i.e., they should both benefit from the agricultural subsidy effect). Spring migration routes differ, however, with the California-Oregon group following an interior route coincident with western Arctic LSGO and central Arctic ROGO through the grain producing areas of Saskatchewan, Alberta and western Montana. At least part of the Washington-British Columbia wintering group migrates in steps from one natural river estuary/coastal marsh to another (e.g., Stikine River) where they feed principally on *Carex lyngbyei* (S. Boyd, pers. comm.). Thus, they differ in spring diets and may not benefit from the spring energy subsidy.

IMPACTS OF HIGH POPULATIONS ON ARCTIC AND SUBARCTIC HABITATS

Foraging Methods

The different foraging activities of the geese are described based on observations made mostly in coastal areas of Hudson and James Bays or reported in the literature. Understanding these differences is essential to a clear perception of impacts at different times of the year and in different habitats that geese have on vegetation and soil processes.

Grubbing of below-ground biomass

This refers to the digging and uprooting of roots and rhizomes of plants, in general, and graminoids (grasses and sedges), in particular (Fig. 2.10). The grubbing which takes place mainly in spring (but not exclusively) is dependent on the upper layers of sediment thawing for at least some hours each day. It is restricted to snow-free sites where the layer of vegetation and plant litter is thin and where seasonal above-ground growth of vegetation has not started. Where these conditions occur the birds are able to break open the turf and forage on below-ground biomass. Greater and lesser snow geese and Canada geese grub extensively immediately after snow melt. Some further grubbing may occur at the end of the season in late July and August, when above-ground tissues are senescing and reserves are being transported to below-ground organs. We have observed only lesser snow geese foraging in this manner in late summer, but in degraded environments with a shortage of food resources it may be practised by other species as well. Grubbing is a major foraging technique of LSGO on migration routes and in winter in the Gulf of Mexico coastal marshes, and of GSGO on the Gulf of St. Lawrence tidal marshes, and in east coast tidal marshes of the United States.

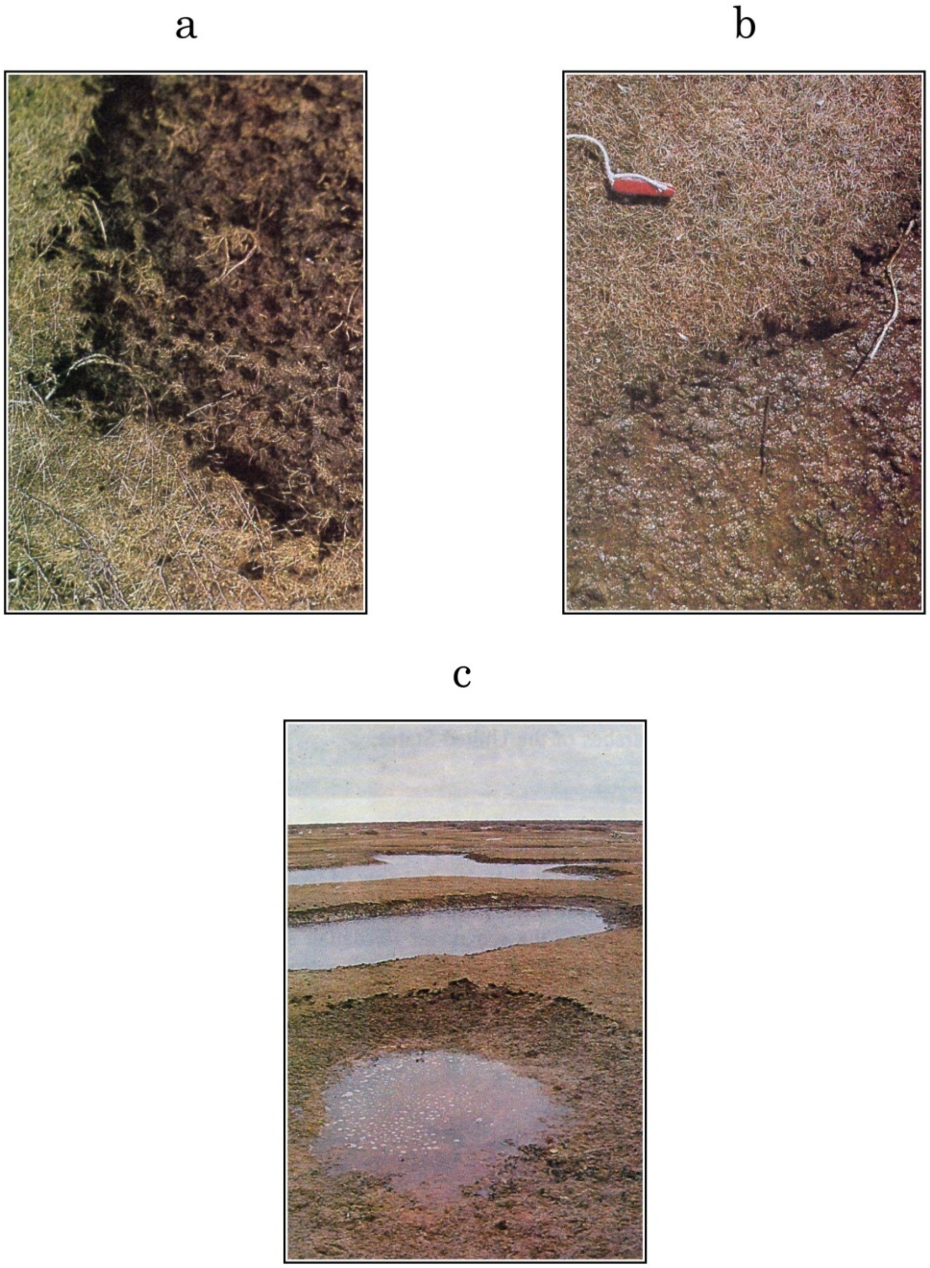


Fig 2.10. Grubbing by Canada and lesser snow geese: (a) grubbing by Canada geese showing small tufts of turf removed by the geese, (b) grubbing on along edges by lesser snow geese, (c) removal of turf by lesser snow geese and the creation of small ponds in intertidal salt marsh.

Shoot pulling of sedges

This type of foraging occurs in spring and is restricted to fresh-water mires (wetlands with an organic substratum). Lesser snow geese pull individual shoots of large sedges (>20 cm in height from a tussock) (Fig. 2.11). They eat the white basal portion of the shoots which is rich in soluble nitrogen compounds and carbohydrates and discard the remainder (Gadallah and Jefferies 1995a). Removal of shoots by geese can occur in oligotrophic, mesotrophic and eutrophic sedge communities. *Carex aquatilis, Eriophorum angustifolium* and *Carex X flavicans* are examples of preferred forage species. The only grass species in wetlands from which shoots are pulled frequently are *Dupontia fisheri* and *Arctophila fulva*. However, in sandy or gravel areas the geese pull up shoots of lyme grass (*Elymus arenarius*).

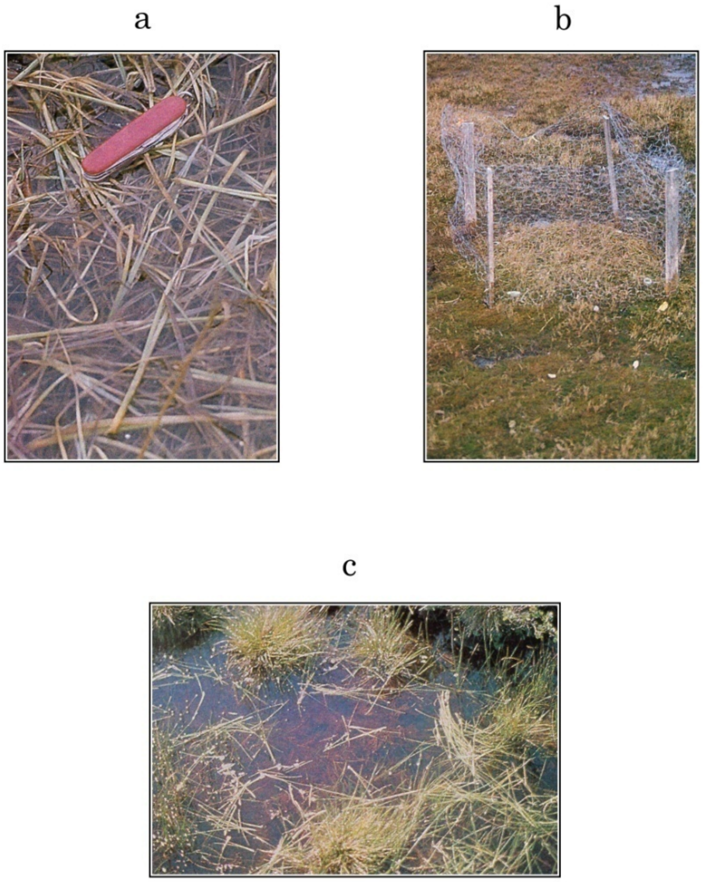


Fig 2.11. Shoot pulling by lesser snow geese: (a) discarded shoots of Carex aquatilis. The basal portion has been eaten by the geese, (b) development of moss carpet following removal of sedge shoots by lesser snow geese. In the exclosure shoots of sedges are intact, (c) discarded shoots of sedges growing oligotrophic mires.

Grazing

A large number of species are grazed on different occasions during the snow-free season (Fig. 2.12). The selectivity of different species appears to be linked to plant phenology and nutritional quality (Jefferies *et al*. 1994, Gadallah and Jefferies 1995a). Some coastal salt-marsh graminoids show enhanced compensatory shoot growth following defoliation and are subject to multiple defoliations throughout the season (e.g. *Puccinellia phryganodes*) (Cargill and Jefferies 1984, Hik and Jefferies 1990, Hik *et al*. 1991). In contrast, other species either show only limited compensatory growth or no growth following defoliation (Zellmer *et al*. 1993). Under conditions of intense grazing, the pseudostem of grasses such as *Puccinellia phryganodes* may be damaged and the regrowth of swards severely impaired. Ross' geese may be able to graze swards of *P. phryganodes* lower than lesser snow geese, because of the shape of their bills. In damaged, heavily grazed swards the former species may be capable of obtaining some forage, unlike lesser snow geese.

In addition to the salt-marsh graminoids described above, the following species are grazed at different times of the season in the Hudson Bay region: *Senecio congestus*, catkins of *Salix* species (early spring); *Potentilla egedii*, *Plantago maritima*, *Stellaria humifusa*, *Triglochin palustris*, *Triglochin maritima*, *Carex aquatilis*, *Eriophorum angustifolium* (all of these species in early to mid-summer); *Festuca rubra* and *Calamagrostis deschampsioides* (mid-summer). In fall birds eat *Potamageton filiformis*, the seed heads of *Triglochin* species, as well as the shoots of *Equisetum* and a range of *Carex* species (Prevett *et al*. 1979).

Berry-feeding occurs on ericaceous tundra during migration (Reed, pers. comm.). Baffin Island LSGO and Atlantic Canada geese appear to feed heavily on the berry crop on the Ungava Peninsula in both spring and fall. Similarly, LSGO feed on berries on tundra ridges along the Hudson Bay coast (K. Abraham, pers. obs.).

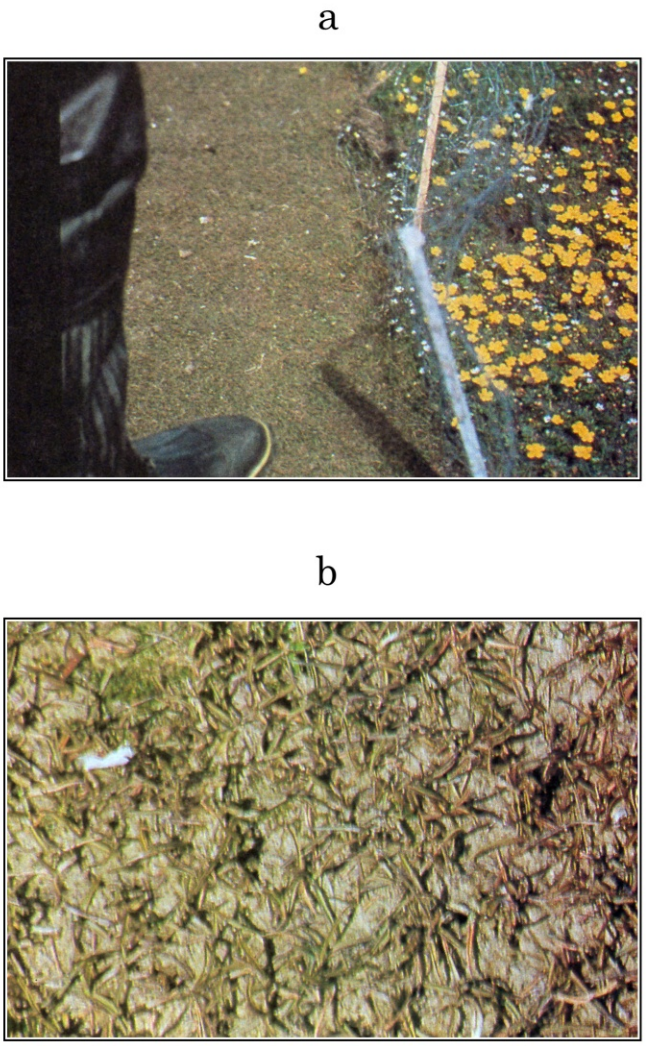


Fig 2.12. Grazing by lesser snow geese: (a) intensive grazing to the left of the exclosure which is 2 years old and plants are Potentilla egedii (yellow cinque foil) and Stellaria humifusa (chickweed), (b) close-up of an intensively grazed salt-marsh sward of Carex subspathacea (sedge) and Puccinellia phryganodes (grass).

Prime Forage Species

Plant species selected by greater and lesser snow geese as prime sources of forage differ depending on the geographical location of the breeding colony (see below). The prime forage species from Wrangel Island and Bylot Island grow at sites where there is a well developed peaty substratum that may have a high water content and which is mesotrophic or oligotrophic. In contrast, the forage species from the Hudson Bay lowlands grow either on mineral soils or where there is only a thin veneer of organic material. Because of the different tolerances of species to foraging, and the different intensities of foraging, the effects of the geese on plant communities at the various geographical locations are not necessarily similar. Most breeding colonies of snow geese are coastal in distribution in the Arctic and sub-Arctic, and much of the damage to vegetation described below is based on changes that have occurred to vegetation in the coastal zone of the Hudson Bay lowlands. The mid-continent population of lesser snow geese breeds in this region.

Experimental field evidence from feeding trials at La Pérouse Bay with captive goslings, as well as evidence of the correlation between amounts of standing crop and gosling weight, indicate that in early life the salt-marsh graminoids meet the nutritional requirements of goslings more successfully than other types of forage (Gadallah and Jefferies 1995b; Cooch *et al*. 1993). Elsewhere in the Arctic, other species such as *Dupontia fisheri* and *Eriophorum* species are a source of high quality forage (Gauthier *et al*. 1995) and meet the nutritional demands of goslings. These species grow on an organic substratum rather than in mineral sediments.

Isostatic Uplift and Development of Salt-Marsh Plant Communities in the Hudson Bay and James Bay Region

The Hudson Bay region is undergoing isostatic uplift at approximately 1 cm/yr. The actual rate has been estimated to be between 0.5 and 1.2 m per century, depending on the proximity of sites to epicentres of uplift (Andrews 1973). The present-day coastal zones have emerged within the last 1000 years. The rate of uptake and associated modifications of the soil environment influence plant successional processes. Although grazing by geese of salt-marsh vegetation retards the development of dicotyledonous plants (the apical meristem is destroyed by grazing, whereas in graminoids the meristem is basal and clipped leaves continue to grow, (e.g., a lawn) and maintains the *Puccinellia phryganodes* - *Carex subspathacea* grazing lawn, so that the successional "clock" is being reset each year, eventually the effects of isostatic uplift modify the physical environment and result in the replacement of *Puccinellia* and *Carex* by *Calamagrostis deschampsioides*, *Festuca rubra* (grasses) and dicotyledonous plants. The interaction between the grazer and the vegetation maintains the *Puccinellia* - *Carex* community, as long as it can overcome the environmental constraints imposed by isostatic uplift.

Although this type of vegetation is well developed at the seaward end of the marsh and is renewed continually by uplift even in the absence of grazing, its continued presence in the upper salt-marsh is strongly dependent on the foraging activities of the geese. In their absence, rapid vegetational changes occur within 5 years leading to the development of a *Calamagrostis* - *Festuca* grassland in which herbaceous plants and willows grow. These swards are not as heavily grazed as swards of *Puccinellia* and *Carex*. The nutritional quality and digestion efficiency of the forage are lower than comparable data for *Puccinellia* - *Carex* forage (Gadallah and Jefferies 1995a,b).

Damage to Coastal Habitats

Coastal salt marsh plant communities

The coastal zone of the Hudson Bay lowlands and vicinity consists of a large number of salt marshes, the most notable of which are the marshes on the north shore of Akimiski Island (Northwest Territories); Cape Henrietta Maria-Sutton River, Shell Brook, and Pen Islands (Ontario); Cape Churchill - La Pérouse Bay and the estuaries of the Knife and Seal Rivers (Manitoba); and the McConnell River - Wolf Creek system (Northwest Territories). However, most river estuaries have small areas of salt marsh adjacent to the mouth of the rivers and there are many small fringe salt marshes landward of barrier beaches. The marshes are dominated by two species, the stoloniferous grass, *Puccinellia phryganodes* and the rhizomatous sedge, *Carex subspathacea*, both of which are prime forage species of the lesser snow goose. Large breeding colonies are located at the geographical locations mentioned above where there is the strongest evidence of damage to vegetation. Some of these localities, such as the Cape Henrietta Maria-Sutton River salt marsh system are over 120 km in length.

All of these marsh systems show evidence of grubbing, although the scale of damage varies. Grubbing on Pen Island marshes is restricted, probably because they are covered by ice and snow until late in the spring, whereas at La Pérouse Bay, Cape Henrietta Maria, Akimiski Island and the McConnell River-Wolf Creek system grubbing is extensive (Fig. 2.13). At these localities the size of the grubbed patches increases each year and the graminoid vegetation fails to recover. Measurements of abundance of species based on 805 metres of transects across the salt marshes at La Pérouse Bay indicate that since 1985 approximately 70% of the salt-marsh graminoid swards have been severely damaged or destroyed by geese. On 5 of the 12 transects no vegetation remains (R. Jefferies, unpublished data).

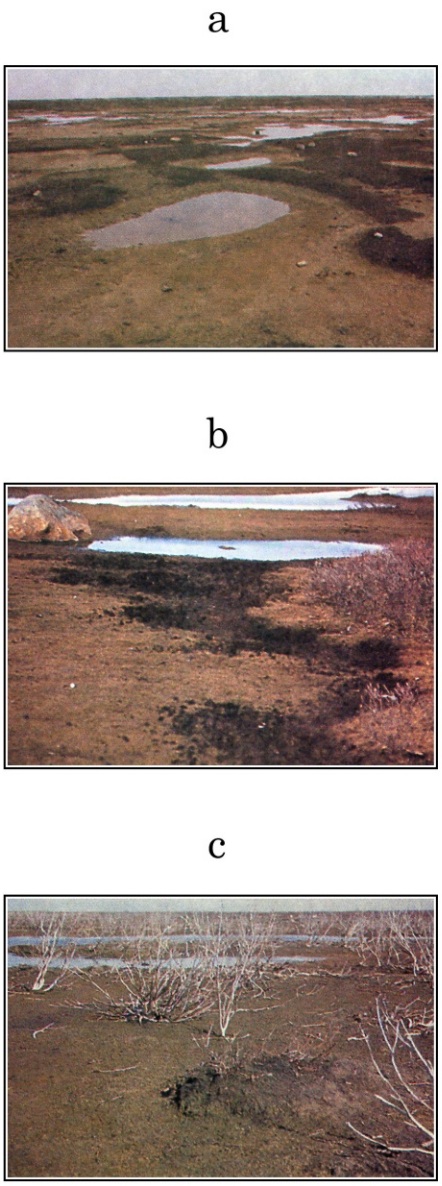


Fig 2.13. Grubbing by geese: (a) removal of short graminoid turf over a large area, (b) broad front type grubbing by lesser snow geese, (c) dead willows and the absence of turf; the surface of the sediments is hypersaline.

The change in the state of the vegetation initiated by the geese acts as a trigger for a further series of changes that leads to increased destruction. The reduced area of salt marsh vegetation and the high numbers of goslings and adults result in intense foraging during the post-hatch period. The above-ground biomass of the heavily grazed swards may be only 10-15 grams dry weight (g dwt) per square metre (40 g dwt in undamaged grazed swards) (Cargill and Jefferies 1984, Williams *et al.*

1993). The effect of these foraging processes is to reduce the thickness of the vegetation mat (live and dead material) that insulates the underlying marine sediments from the air. These sediments were laid down when the Hudson Bay lowlands were part of the Tyrrell Sea. Rates of evaporation from the surface sediments increase and inorganic salts from the marine clays produce hypersaline conditions ranging from 32-120 g of dissolved solids per litre (32-120 $^{0}/_{00}$) (Iacobelli and Jefferies 1991, Srivastava and Jefferies 1995a,b; 1996). Experimental studies have shown that salinities above 32 $^{0}/_{00}$ (oceanic sea water) reduce the growth of the preferred forage plants, *Puccinellia phryganodes* and *Carex subspathacea*. This, together with the intense foraging, maintains open swards and hypersaline conditions and results in a positive feedback producing increased destruction of salt-marsh swards and desertification of the landscape (Srivastava and Jefferies 1996) (Fig. 2.14).

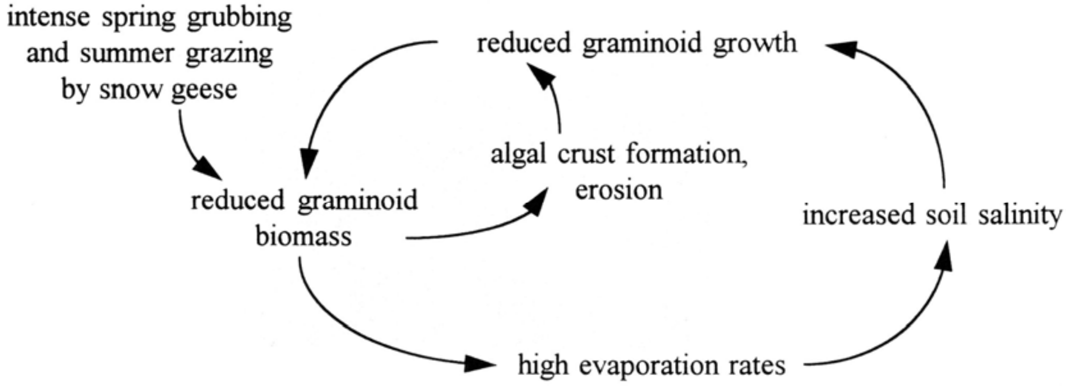


Fig 2.14.Positive feedback in salt marsh desertification.

A group of species that may invade these grubbed sites are good ecological indicators of disturbance of swards by geese. *Salicornia borealis* and *Atriplex patula* var. *hastata* colonize bare sediments which are highly saline. These species do not grow in some localities such as the McConnell River-Wolf Creek system, but they are present at others, (e.g., Walker Bay, Central Arctic, B. Bromley, pers. comm.). Neither species is eaten by the geese; about 45% of the dry weight of plants of these species consists of salt. In late summer large areas of marsh appear reddish-purple in colour as *S. borealis* produces anthrocyanin pigments at this time of year.

Within intertidal marshes a number of measures described above indicate ecosystem dysfunction. They include a low level of above-ground biomass, damage to pseudostems of graminoids and the presence of indicator species such as *Salicornia borealis*. At sites where the vegetation has been killed, bare mud flats remain. At some sites, such as on the foreshore between the north and south arms of the McConnell River, the remains of below-ground biomass of former *Puccinellia* swards are visible. Elsewhere the sediments are eroded, exposing underlying glacial till and marine gravels.

Damage to sand dunes and beach ridge plant communities

Beach ridges and dunes are widespread in coastal zones around the Bay. Lyme grass (*Elymus arenarius*) is an active colonizer of these dunes and ridges. Shoot pulling of developing shoots of this grass is widespread in early spring. The grass is no longer a common species at La Pérouse Bay. Some beach ridges where the grass was formerly abundant are now devoid of the species (B. Ganter, pers. comm.). In early spring these ridges are roosting sites for geese and dung heaps are deposited by the birds. The same scenario has developed where spring migrant Interior Canada geese and moult migrant giant Canada geese congregate near Cape Duncan, Akimiski Island, Northwest Territories (K. Abraham and R. Jefferies, pers. obs.). A flora characteristic of the overall disturbance by geese has colonized these degraded sites. *Senecio congestus*, *Matricaria ambigua* and *Rumex maritimus* invade; the leaves of the first species are eaten by the geese in very early spring. In addition, moss carpets (mainly *Bryum* species) are common on the tops of frost-heave hummocks, where the higher plant vegetation has been removed. In summer, the carpets dry out and the moss mat is blown away, exposing the underlying sand and gravels.

Damage to coastal meadow grassland and willow communities

In dry sites, immediately inland from the intertidal salt marshes, meadow grassland is widespread along the southern coast of Hudson Bay and in James Bay. The grassland is often colonized by *Salix brachycarpa* and *Salix myrtifolia*. The most common grass species include *Festuca rubra*, *Calamagrostis deschampsioides*, and to a lesser extent *Elymus arenarius*. These sites are covered by tidal water on rare occasions. Grubbing of these grasslands, which have a thin veneer of organic matter on the surface of sediments, is common in spring. Both lesser snow geese and Canada geese grub the turf and remove grass roots and rhizomes. Where the grubbing of turfs extends to the base of willow bushes, the bushes die as a result of the hypersalinity and exposure of roots (Iacobelli and Jefferies 1991) (Fig. 2.13c). In some areas where the thin veneer of soil organic matter has been removed *Puccinellia phryganodes* and *Carex subspathacea* colonize the exposed saline sediment. Patches of these graminoids inland from the intertidal marshes are often indicative of secondary succession following goose disturbance. Further grubbing of these secondary swards can be expected.

Overall Comment

The descriptions given above indicate that the effects of the geese on vegetation development are not symmetrical. The geese interact with physical processes (i.e., the positive feedback described above)(Fig. 2.14), so that discontinuous and irreversible transitions in the serial stages of plant succession may occur (Hik *et al.* 1992). Intense grazing of the *Puccinellia-Carex* intertidal swards results in removal of apical meristems of leaves and shoots of dicotyledonous plants (*Plantago maritima*, *Potentilla egedii* and *Ranunculus cymbalaria*). This precludes further shoot growth for the remainder of the season. In effect, the geese reset the successional clock each year and delay successional processes. The species diversity (number of species per unit area) may be used as an indicator of intense goose foraging, particularly at sites close to the mean high water mark of spring tides. In the absence of grazing the plant assemblage switches to one dominated by *Festuca rubra* and species diversity increases rapidly (Bazely and Jefferies 1986).

Long-term destruction of sub-Arctic freshwater wetland vegetation by lesser snow geese

The Hudson Bay lowlands is one of the largest wetlands in the world. It provides food resources for several million migrating waterfowl, including the mid-continent population of lesser snow geese, the Eastern Prairie, Tall Grass Prairie, Mississippi Valley and Southern James Bay populations of Canada Geese, half of the Atlantic Brant population, and significant populations of pintails, black ducks, green- winged teal and mallards (Ross 1982, Thomas and Prevett 1982). When snow geese migrate north in spring they follow the coastline of Ontario, Manitoba and Northwest Territories northwards, staging just south of the retreating snowline. They feed primarily in fresh-water sedge meadows adjacent to coastal habitats. One of the most conspicuous types of damage that occurs in spring is shoot pulling. The birds forage intensively on the shoots of fresh-water sedges, particularly *Carex aquatilis*, but also *C. atrofusca*, *C. x flavicans* and *C. vaginata*. Later, during nesting, breeding birds also remove large numbers of shoots. At some localities shoot pulling has been intensive and the effect is accumulative. In shallow ponds, where dense stands of *Carex aquatilis* were formerly present, the death of stands has created open ponds of standing water devoid of vegetation in which large amounts of organic matter and peat debris are mixed by surface winds (Fig. 2.15). The system is dysfunctional and the depth and mobility of the debris appear to restrict germination and seedling establishment of wetland species. The muds are anoxic and some ponds have remained in this state for a decade or more (Kotanen and Jefferies 1997). In saturated mossy areas, where sedge assemblages formerly occurred, the disappearance of sedges produces extensive moss carpets in which only scattered shoots remain (Fig. 2.16). Again the thick moss carpets, composed of *Drepanocladus uncinatus* and *Aulacomnium* species, appears to restrict seedling establishment of sedges (Kotanen and Jefferies 1997). Close to frost heave mounds, *Salix reticulata* and *S. arctophila*, together with *Potentilla palustris* and *Petasites sagittatus*, have grown across the moss carpet creating a new plant assemblage. The four latter species and the mosses are not eaten by the geese (Jefferies 1988a,b). This type of assemblage and moss carpets can be recognized at a number of goose colonies where sedges have been removed by geese (Kerbes *et al*. 1990; Kotanen and Jefferies 1997, K. Abraham, pers. obs.). Community development appears to have been altered irreversibly by the geese.

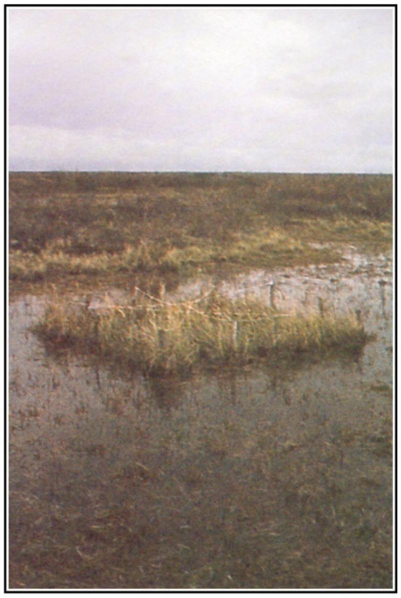


Fig 2.15. Depletion of sedge shoots in a small pond. The exclosure shows shoot growth of sedges in the absence of foraging by geese.

Figure 2.16. Extensive banks of moss carpets at Cape Henrietta Maria.

The large scale destruction of sedge meadow communities and the exposure of peaty sediments, or peat, can be seen in the McConnell River-Wolf Creek area (Kerbes, Kotanen and Jefferies 1990). In much of the coastal hinterland of string and flark (ridges and intervening wet zones) bogs and fens (oligotrophic / eutrophic mires), the geese have grubbed vegetation, exposing underlying peat over large areas. These dysfunctional systems have been called peat barrens (Kerbes *et al*. 1990) (Fig. 2.17). Plants of woody species, such as *Betula glandulosa* and *Empetrum nigrum*, which are confined to the strings, also die. At some sites erosion of the peat has occurred as a result of water movement (spring run-off) and chemical oxidation of peats as they dry-out in summer. Where this has occurred, the underlying glacial gravels and till are exposed. At present, examples of this kind of habitat damage along the west coast of Hudson Bay occur from the Tha-anne River north to the Maguse River, a distance of almost 200 km. The area is used by both breeding and staging birds (lesser snow geese).

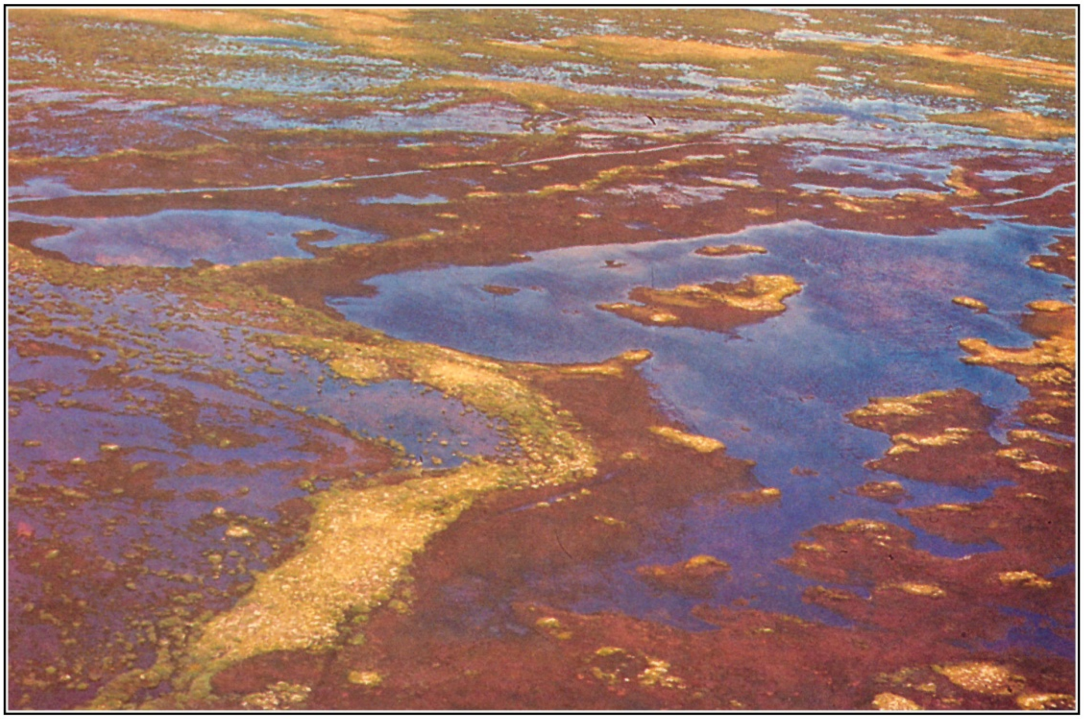


Figure 2.17. Peat barrens north of the McConnell River, N.W.T. A large area of black peat (c. 500 m in length) from which sedges have been removed by the geese. Photograph taken by A.B. Didiuk.

Rates of destruction of vegetation

Most of the changes described in the above sections have occurred at La Pérouse Bay, Manitoba since 1978 when intensive studies of plant-herbivore interactions began there. Based on our knowledge of the changes in the vegetation, it is clear that this is an on-going process and that there are sites at La Pérouse Bay and elsewhere which show comparable changes in vegetation that occurred much earlier than 1978. How much earlier is very difficult to determine. Although the present colony at La Pérouse Bay was established in the late 1950s (Cooke *et al*. 1995), the area may have been a major staging location prior to those years. What is different today compared to earlier times, is that the scale of destruction associated with the increase in the population size of lesser snow geese has increased in magnitude. Similar changes have occurred elsewhere along the coastline in response to the foraging activities of large numbers of birds (e.g., McConnell River, Cape Henrietta Maria, and Akimiski Island).

The damage to vegetation and soils of these coastal habitats is cumulative, although the same amount of damage does not occur each year. Prevailing weather conditions throughout the Hudson Bay region determine both migration rates of geese and which sites serve as staging areas in a given year. One approach that offers considerable promise for measuring rates of destruction of vegetation is the application of remote-sensing techniques, particularly the use of LANDSAT imagery. This approach has been used to detect vegetational changes since the 1970s at La Pérouse Bay and the north shore of Akimiski Island, and a similar study is underway to examine vegetational changes along the coast between the Knife and Seal Rivers. At La Pérouse Bay LANDSAT imagery based on spectral differences in the red and far-red bands between 1973 and 1993 indicates that the vegetation has been destroyed or severely damaged over an area of approximately 2400 ha (Jano, unpublished data) (Fig. 2.18). Much of the initial damage was on the beach ridges, dunes and in the salt marshes, but in the last 10 years the damage has extended to the fresh-water sedge meadows, as the birds seek alternative sources of forage. As a result, we are beginning to see an early stage in the development of peat barrens there, as described for the McConnell River-Wolf Creek area.

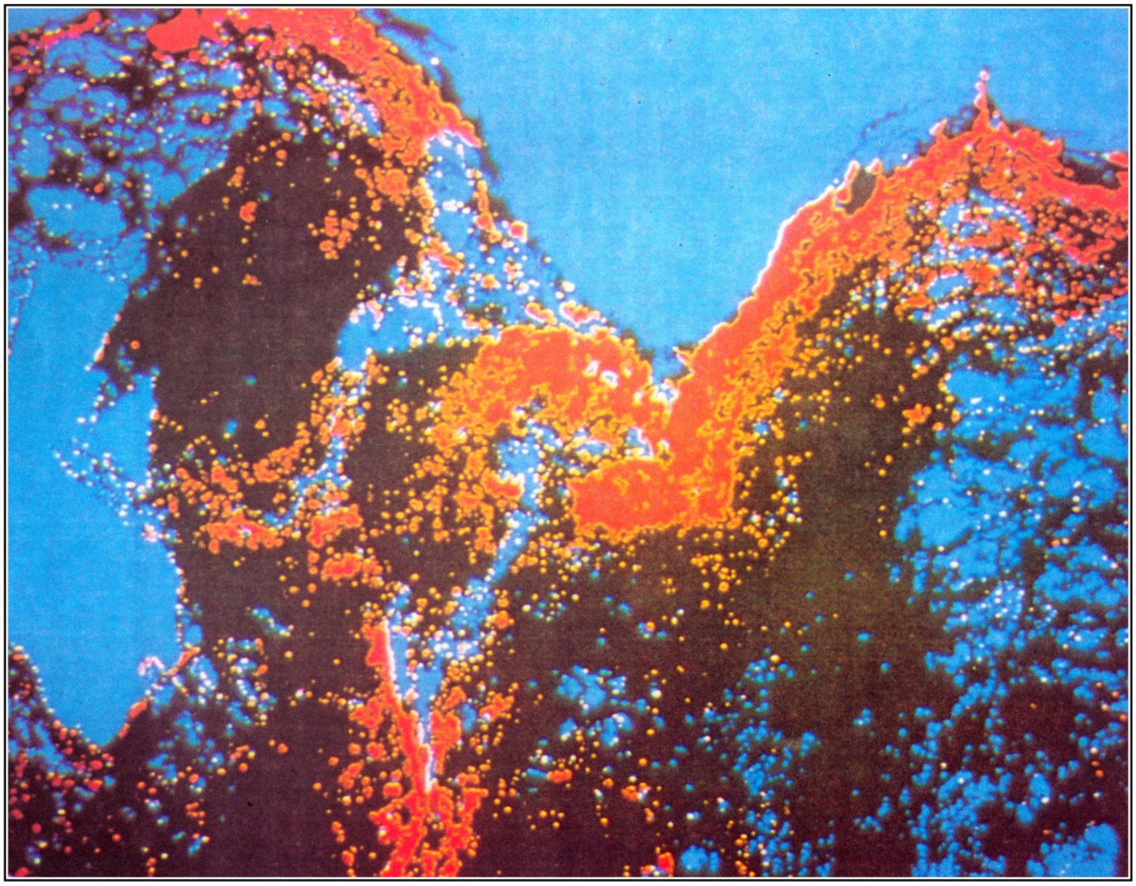


Figure 2.18 LANDSAT imagery of the cumulative damage at La Pe'rouse Bay, Manitoba between 1973 and 1993 largely caused by lesser snow geese. On the image, water appears blue, intact vegetation cover green, and damaged areas where there is bare soil or incomplete plant cover appears red. In 1973 these areas had complete vegetation cover (after Jano, A. unpublished data).

Estimates of damaged areas of coastal marshes

No formal estimate has been made of the total area of destroyed coastal marsh, or of the area of vegetation swards that have been partially damaged by the foraging activities of the geese. Such an analysis requires the following minimum information: (1) LANDSAT remote-sensing imagery of changes in vegetation from 1973 to the present along the entire Hudson Bay coastline; (2) the necessary ground- truthing of the vegetation and the preparation of a classified vegetation map; (3) calculation of damaged areas and ground-truthing of partially damaged areas in order to calculate this area; (4) Measurements of above-ground biomass at all sites.

Given that these data are unavailable at this time, the following, tentative estimates of the scale of destruction have been made. Long-term monitoring of ground transects in the inter-tidal marsh at

La Pérouse Bay indicate the changes that have occurred to the vegetation since 1985. Approximately 35% of the vegetation swards have been destroyed and another 30% are so badly damaged, that they no longer provide a source of forage for the birds (because geese are present each summer recovery is impossible). In effect, two-thirds of the land base monitored in inter-tidal marsh is now non-productive. The remaining 35% is "overgrazed", such that damage to grass shoots is occurring. Independently, the results from the remote-sensing imagery show that approximately 2400 hectares of vegetation have been destroyed, or very badly damaged between 1973 and 1993 at La Pérouse Bay. Some of this area includes supra- and inland salt-marsh vegetation and sedge meadow vegetation. However, as most damage has occurred in intertidal areas (salt marshes and dunes/gravel ridges), an approximate estimate of 2,000 hectares of vegetation have either been destroyed, or so badly damaged that the vegetation is unproductive. This is equivalent (approximately!) to 65% of the former area of inter-tidal vegetation at La Pérouse Bay, as indicated above.

Observations of the state of inter-tidal salt marsh swards of *Puccinellia phryganodes* and *Carex subspathacea* along the entire coastline from Attawapiskat, Ontario to the Maguse River, NWT, together with measurements of above-ground standing crop (g m^{-2}) give no reason to doubt that the estimates for La Pérouse Bay are applicable to other sites where snow geese feed during migration and breeding. In short, the "35%-30%-35%, pattern" discussed above can be applied to other sites. Major exceptions include the Pen Island marshes on the Ontario/Manitoba border where there is little damage and at river estuaries (e.g., Nelson, Albany) where large volumes of fresh water discharge, reducing the salinity and producing tall growth forms of both *Puccinellia* and *Carex* which are little grazed. Additional exceptions are small patches of salt marsh fringing beach ridges which are heavily grazed by Canada geese during brood rearing but remain productive. Andrew Jano (Ontario MNR, unpublished data) has estimated the area of intertidal marsh from the Kettle River (Ontario/Manitoba border) to Attawapiskat (Ontario, James Bay) in contiguous 5 km segments of coastline. The total area is 35,329 hectares, including 2,000 hectares for the north coast of Akimiski Island. Figures for supratidal marsh of the same area are also available but comparable figures have not been calculated from remote sensing imagery yet for Manitoba and NWT. In Manitoba, the area of grazed *Puccinellia-Carex* (i.e., intertidal) salt marsh is estimated to be 14,500 hectares and for the NWT as far north as the Maguse River, the estimate is 5,000 hectares (R. Jefferies, unpublished data). Hence, out of a total of 54,829 hectares of intertidal salt marsh for the entire coastline it is estimated that approximately 35,638 hectares are no longer productive and the majority of the remaining areas of salt-marsh swards are heavily utilized. It should be emphasised that these figures for the area outside La Pérouse Bay are very provisional and they do not include supra-tidal marshes.

Similar estimates of damage to sedge meadow-fen vegetation cannot be made at this time as the extent of damage is very poorly known.

POTENTIAL FOR RECOVERY OF DAMAGED HABITATS IN THE HUDSON BAY REGION

General comments

As long as the mid-continent population of lesser snow geese is expanding at the conservative estimate of 5% per annum, there is little likelihood that habitat recovery will be possible. As mentioned above, direct and indirect effects of grubbing are cumulative. Even though full restoration trials have not been undertaken, exclosure experiments of unassisted re-vegetation in the absence of geese have indicated that at badly damaged sites where the soil is hypersaline, it takes at least 15 years for swards to begin to develop. This length of time is beyond the life expectancy of a single age cohort of lesser snow geese; after 8 years, 95% or more of a given cohort are dead (Cooke *et al*. 1995). Hence, the effects on habitat outlive the geese. In intact but damaged swards, exclosure experiments indicate that recovery in the absence of geese can be rapid (Hudson Bay Project, unpublished data). However, without eliminating geese from the site, any recovery is transitory. Although restoration may be possible on an experimental basis, it is unlikely that such assisted re-vegetation of damaged sites designed to accelerate the rate of sward development will be practical; the continued presence of geese, the costs and logistic difficulties, and other priorities preclude full restoration schemes.

Given that unassisted, natural re-vegetation processes are the only means by which these damaged areas can be recovered, the potential for recovery among the various plant assemblages is examined below. This discussion and the views expressed are tentative, as re-vegetation trials are still in progress.

Coastal salt-marsh plant communities

Puccinellia phryganodes, the prime forage grass of lesser snow geese, is a sterile triploid which has never been known to set seed (Jefferies and Gottlieb 1982). Although it is widespread in salt marshes throughout polar regions, it establishes at sites by clonal propagation. Individual leaves, shoots and tillers have the ability to root in soft sediment (Chou *et al*. 1992). Although *Carex subspathacea* sets seed, it is an irregular event, and many plants flower but fail to set seed. Plants spread by clonal growth, and leaves, shoots and tillers also root in soft sediment (Chou *et al*. 1992). Hence, the two main forage species of lesser snow geese in the Hudson Bay region depend heavily on clonal propagation for establishment and growth. Most of the dicotyledonous plants appear to establish from a small, but persistent seed bank in sediments (Chou, unpublished data).

Patches of the *Puccinellia-Carex* sward that are lightly grubbed are capable of recovering within the season when exclosures are erected to exclude geese. New shoot systems develop by stoloniferous or rhizomatous growth and by the end of the first growing season, graminoid plant cover is uniform across exclosed plots (Jefferies and Abraham, unpublished data). Where exclosures are maintained for five growing seasons substantial changes in plant assemblages occur (Bazely and Jefferies 1986). The grasses, *Festuca rubra* and *Calamagrostis deschampsioides*, increase in abundance at the expense of the prostrate graminoid species, *Puccinellia phryganodes* (Fig. 2.19). In addition, dicotyledonous species increase in abundance. Plots when initially exclosed had 7 species present, five years later the number of species had increased to 18, most of which were dicotyledonous plants.

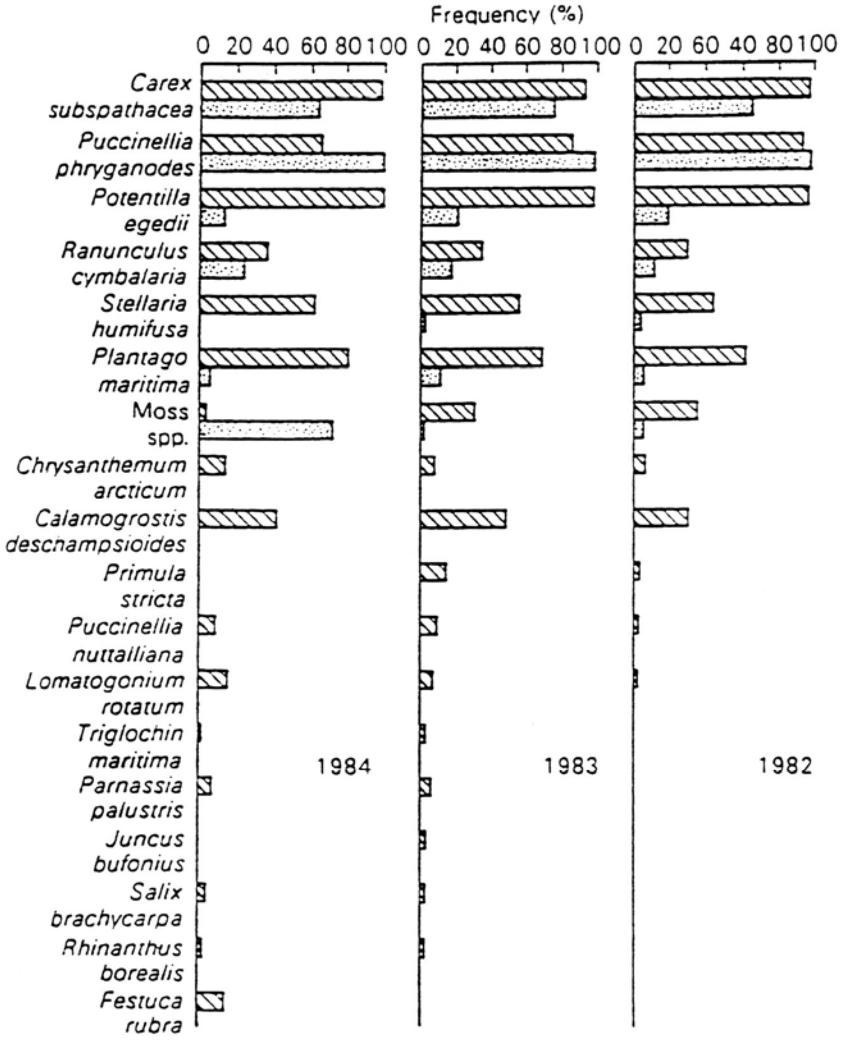


Figure 2.19. Percentage frequencies of species in a salt marsh at La Pérouse Bay, Manitoba in 1982-1984; ▨ , in an exclosure (5 m x 5 m) erected in 1979; and ░ , in an adjacent plot where the vegetation is grazed by lesser snow geese. Results based or presence of absence of species in 200 quadrats (5 cm x 5 cm).

All indications are that if swards are only lightly grubbed so that shoots remain in grubbed patches, rapid recovery is possible as long as no further grubbing occurs. In the absence of grazing, changes in plant assemblages are particularly rapid, indicating that natural regeneration processes respond quickly to change.

Sand dune and beach ridge plant communities

No exclosures have been established where sand and gravels are now devoid of vegetation, but where plants were present formerly. Heagy and Cooke (1979) established a single exclosure on an old sand dune dominated by *Elymus arenarius* in the vicinity of a nesting area used by lesser snow geese. Prior to the establishment of the exclosure, breeding geese pulled out shoots of this grass on the old dune, but individual plants survived. After the exclosure was established growth of *Elymus* was considerable and the entire stand was dominated by the grass. We anticipate that these communities can re-establish, but as in the case of the salt-marsh, the time interval is likely to be long (> 10 years), even in the absence of goose grazing.

Coastal meadow grassland and willow communities

Although there have been no formal re-vegetation trials in these communities, exclosures were established by R. Harmsen in about 1985. They were placed at different locations in these communities at sites where grazing was heavy, but where no grubbing had occurred. The exclosures are still in place, but monitoring of the vegetation has not taken place on an annual basis. Although, the amount of above- ground biomass has increased inside the exclosures, there is no evidence of significant changes in species assemblages over the 10 year period. Individual species may have increased in abundance, such as *Triglochin maritima* (heavily grazed by Canada geese), but the exclosures are still dominated by *Festuca rubra* and *Calamagrostis deschampsioides* and *Salix brachycarpa*.

At sites which have been grubbed, so that gravels and marine clays are exposed, no natural revegetation has occurred during the last 10 years. The upper layers of sediment dry out in summer and are hypersaline. Erosion of sediments has resulted in increased exposure of glacial gravels. Exclosures established in these areas have remained unvegetated for over a decade. In one exclosure wind-blown plant litter has collected in one corner of a plot and provided a mulch above the hypersaline soil on which plants have established. In effect, it is an artifact of the method in that the chicken-wire exclosure traps plant litter.

Freshwater Wetland Vegetation

In 1995, a series of fully replicated exclosures were placed in sedge meadows on the Cape Churchill peninsula, both where moss carpets or bare peat were present and where there was little evidence of damage to vegetation. Changes in the vegetation will be monitored, but it is too early to indicate likely changes in plant assemblages.

Field observations made over a number of years indicate that two herbaceous species, *Potentilla palustris* and *Petasites sagittatus* invade the moss carpets and form a mat or stand of vegetation. Additionally, prostrate willow species (*Salix arctophila*, *S. reticulata*) grow by clonal propagation across the surface of the moss. None of these species is eaten by the geese and this plant assemblage is common where sedges have disappeared.

As mentioned earlier, peat barrens are widespread in some areas of the Hudson Bay lowlands. Re-vegetation of this system depends very much on the prevailing water regime. The hydrology precludes moss development, although in wet years when the surface of the peat is moist, grasses such as *Dupontia fisheri* establish, together with liverworts on the bare surface. In dry years, or where sites are well drained, the surface dries out and either chemical or physical processes lead to erosion of peat and ultimately to exposure of clays and gravels. If this occurs, there is little possibility of reestablishment of the original vegetation.

Where pools have developed in place of stands of *Carex aquatilis* and related species the mobility of peat debris appears to preclude successful plant establishment. Around the edges of the more shallow ponds (c. 20 cm of water) moss carpets have invaded the ponds, so that some former ponds are now covered with a blanket of mosses.

GREATER SNOW GEESE IN BREEDING, STAGING AND WINTERING AREAS

The single population of this sub-species breeds from northern Baffin Island and northwards and birds feed predominantly on sedges and grasses growing in moss-covered fens and in uplands during the summer. There is evidence of changes in habitat use by snow goose families, possibly in response to food depletion in the grass and sedge fens which are their preferred habitat. These are habitats where there is a well developed organic substratum, unlike the situation on the intertidal flats of the Hudson Bay coast. Parallels can be made between the two subspecies and their effects on vegetation, but there are also differences, primarily related to the use of different species as a prime source of forage.

Damage to Coastal Habitats in the Wintering and Staging Areas

Prior to the 1960s the geese fed almost exclusively in freshwater tidal marshes dominated by the bulrush, *Scirpus americanus*, particularly in the marshes of the St. Lawrence River (Giroux and Bédard 1987, Reed 1989). Smith (1983) reported that greater snow geese altered the species composition of salt marshes on the wintering grounds in North Carolina. The birds grazed intensively on *Spartina alterniflora* and on *Spartina patens* and the above-ground biomass was severely reduced (Smith and Odum 1981, Fig. 2.20). However, the vegetation was not eliminated and full recovery of the latter species occurred in exclosures which were protected for two growing seasons after grazing ceased. *Scirpus robustus* invaded heavily grazed patches of *Spartina alterniflora*. Stands of *Scirpus americanus* were unaffected by grazing, the percentage cover in grazed and ungrazed areas was not significantly different. *Eleocharis* species were only present in grazed sites. Of course, the geese grazed only during the period when the marsh plants were dormant, hence the effects of grazing and rhizome grubbing were not likely to be as severe as when active growth was occurring. Nevertheless, grazing/grubbing led to a decrease in net below-ground production and a change in species composition.

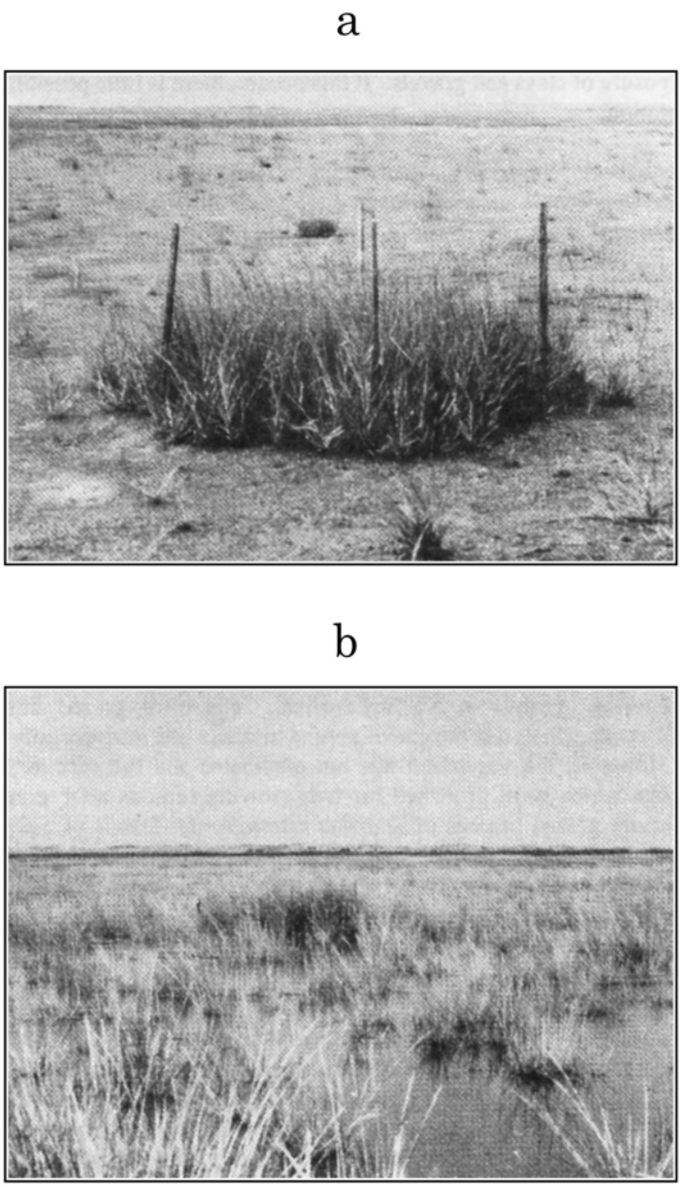


Figure 2.20. (a) view of a typical exclosure and surrounding marsh at Salt Flats in early July 1978; midway in the growing season 8 months after grazing by greater Snow Geese. Note very dense spartina alterniflora growing within the exclosure and relatively little growing outside it. (b) the same exclosure approximately 7 weeks later. Grass outside the exclsoure had grown taller, but not denser (after Smith & Odum 1981). Printed with permission.

Formerly, staging in the St. Lawrence estuary occurred almost exclusively in the *Scirpus americanus* marshes, and even today, with many more geese and an expanded range, those marshes are of critical importance. Vigorous grubbing by the geese removed an estimate 74% of the underground biomass of *Scirpus* in one year in a major marsh area, however, no long term trend in abundance of the plant occurred (Reed 1989). In another marsh, it was demonstrated that net above ground primary production of *Scirpus* was lower in areas exposed to heavy grubbing by geese than in areas protected from grubbing (Giroux and Bédard 1987) but the heavily grubbed areas were maintaining their production (albeit at a lower-than-potential level) over the long term (Reed and Giroux, unpublished data). Expansion of the staging area downstream led to geese feeding on salt-marsh vegetation, including *Spartina alterniflora* and *Spartina patens*. Although marshes continue to be used as roost sites (Gauthier *et al*. 1988), the low abundance of *Scirpus americanus* and the high extraction cost and low energy return associated with *Spartina* roots has led to the birds feeding in agricultural land (Bédard and Gauthier 1989). The rhizomes of bulrush (*S. americanus*) are still an important component of the diet, but there are indications that demand is outstripping the regrowth potential of stands of bulrush, and that soft mudflats are replacing former stands of bulrush. A similar situation exists in the Fraser Delta in British Columbia, where lesser snow geese eat a substantial proportion of the total rhizome of each plant of *Scirpus* (Burton 1977). In addition, the geese there are increasingly foraging for waste crops on agricultural land (potato fields, corn and wheat stubble fields).

Damage to Agricultural Crops

Most of the reported damage to agricultural land in the USA by greater snow geese is associated with small grain crops, particularly winter wheat. Damage can result from a variety of causes but it includes removal of seedlings, grazing of plants, and the loss of seed heads (Anonymous 1981, Hindman and Ferrigno 1990). In some areas, the persistent foraging by geese has led to reduced wheat yields. The birds also glean grain from old fields of corn (*Zea mays*) and soybean (*Glycine max*) (Reed 1991). A crop damage insurance program began in Québec in 1992. Costs of reported damage to hay crops by GSGO in Québec from 1992-1995 are shown in Table 2.1.

Most agricultural land adjacent to the marshes in the St. Lawrence River is managed for hay production based on a 4-6 year rotation system with oats/barley, *Phleum pratense*, *Trifolium pratense* and *Medicago sativa*. In spring, geese graze the new green growth which is mostly *Phleum* (timothy grass). Heavy grazing on this growth and that of other forage species can significantly reduce hay yields at first harvest (Bédard *et al*. 1986, Reed and Cloutier 1990) which occurs from mid- to late-June (Reed 1991). This is approximately 3 to 6 weeks after the northward migration of geese from the area. In the Montmagny area where the grazing is particularly intensive, a mean loss of 14% in hay yield was recorded in old and new hay fields in 1980. By 1985 goose usage had tripled and hay losses at harvest had doubled (Bédard and Lapointe 1991). Yield loss is not uniform across the entire area but is concentrated in a few individual fields, hence the loss is disproportionately high for a small group of farmers. Gauthier and Bédard (1991) have experimented with forage mixtures which are less palatable to the geese. Among legumes, *Trifolium pratense* ranked highest and *Lotus corniculatus* lowest in preference. Among grasses, *Phalaris arundinacea* (canary grass) was the preferred species followed by *Dactylis glomerata*, *Bromus inermis* and *Phleum pratense*. They conclude that the substitution of *Trifolium* with *Lotus* would reduce the attractiveness of hay fields to snow geese.

	1992	1993	1994	1995
Claims for goose damage	$ 466,600	$ 211,500	$ 500,000	$700,000
Compensation paid	$ 373,270	$ 169,200	$400,000	$ 560,000
Administrative cost	$ 139,200	$ 72,700	$ 193,200	$ 186,600

Table 2.1. Crop damage by greater snow geese in Québec (data courtesy of Michel Lepage, Ministère de l'Environnement et de la Faune du Québec).

Preferred Forage Species on the High Arctic Breeding Grounds

Much of the information discussed below is based on the results of G. Gauthier and his group working on Bylot Island, NWT, where there is a large breeding colony of greater snow geese numbering 27,500 breeding pairs in 1993 (Reed and Chagnon 1987; Reed *et al*. 1992, and A. Reed, unpublished data).

Grazing by geese has had a major impact on the above-ground biomass of forage graminoid species and the effect of the geese on the vegetation has increased in recent years (Gauthier *et al*. 1995). Although *Dupontia fisheri* is the dominant plant in moss covered fens in which family groups of greater snow geese feed, the impact of goose grazing was more severe on *Eriophorum scheuchzeri/angustifolium* than on *Dupontia*. Peak above-ground biomass in ungrazed areas averaged 33 g dwt/sq m. In all years of a three-year study, it was estimated that geese consumed from 65-113% of the cumulative net above- ground primary production (NAPP) of *Eriophorum* species and 30- 78% of the cumulative NAPP of *Dupontia*. Grazed plants were able to grow new foliage, but grazing did not enhance NAPP, unlike at La Pérouse Bay where swards of *Puccinellia phryganodes* show increased NAPP following defoliation (Cargill and Jefferies 1984).

It is likely that this pattern of grazing is common in the high Arctic. Again, there are indications that with the increasing number of birds the swards may not be able to regenerate and foraging areas will become moss carpets. On the Tundra of the Academy on Wrangel Island this has occurred in the vicinity of shallow, thermokarst lakes (R. Jefferies, per. obs.). However, in general, there does not appear to be the level of damage in the high arctic that characterizes the coastal areas of the subarctic Hudson Bay lowland.

STATUS OF HABITAT AT SELECTED BREEDING AND STAGING SITES

The above accounts of the damage are necessarily based on longer term studies of systems where both observational and experimental evidence are irrefutable. Studies are now under way on a wider scale, yet there is an immediate need to answer questions about the magnitude and distribution of the problem of high populations and damaged Arctic and sub-Arctic coastal ecosystems (i.e., how much habitat is there and in what condition is it?).

The range of geese in Arctic North America is vast and a comprehensive inventory of the status of habitat at all the important sites is unavailable. Here, we briefly describe conditions at several major breeding or staging sites, with histories of visitation spanning 30-40 years, and all visited within the last 5-10 years. The order of presentation is arbitrarily from south to north and east to west (Fig. 2.2b).

Akimiski Island, NWT

Vegetation damage to the intertidal area along much of the north shore of Akimiski Island is extensive. Mudflats have replaced swards of *Puccinellia phryganodes* and *Carex subspathacea* and only patches of vegetation remain. The *Festuca rubra* and *Calamagrostis deschampsioides* swards in the upper intertidal zone also are being increasingly grazed and grubbed. Brackish and fresh-water graminoid vegetation immediately inland from the upper limit of spring tides is grazed heavily in summer and shoot pulling is common in spring. Bare peaty areas occur as a result of foraging activities by both lesser snow geese and Canada geese. Dead willow stands occur locally in grubbed areas. Extensive areas are now covered by non-forage plant species, including *Glaux maritima* and *Senecio congestus*. Fresh-water sedge meadows show limited signs of damage, but no close examination has been made.

The vegetation in the south-east coastal zone of the island also has been badly damaged by migrating and molting Canada geese. The graminoid cover there has been removed and an extensive moss carpet together with *Senecio congestus* and *Spergularia marina* has replaced much of the brackish intertidal vegetation. Large areas of hypersalinity are marked by extensive stands of *Salicornia borealis*. The south shore of the islands has a steeper gradient, and hence less marsh. In general, it appears to be in good condition, but goose use is limited compared to the north shore.

West coast of James Bay, Ontario

Damage to vegetation as a result of grubbing is localized in salt marshes which occur in embayments or landward of barrier beaches. In general, grubbing is more evident north of Attawapiskat River than south of it. Intensive spring foraging by staging snow and Canada geese has been documented for areas north of Ekwan Point as far as the Lakitusaki River (Wypkema and Ankney 1979, Prevett *et al*. 1985, Hudson Bay Project, unpublished data). The brackish / freshwater marshes are dominated by *Carex aquatilis*, *C. paleacea* and *Hippuris tetraphylla*. The presence of ice and deep melt water in spring along the shoreline, the extensive spring and autumn hunting carried out by people from coastal settlements and the absence of large breeding colonies of lesser snow geese has resulted in only localized damage to vegetation.

Cape Henrietta Maria, Ontario

The Cape Henrietta Maria region contains an extensive area of intertidal salt marsh that has been severely grubbed and heavily grazed. Inland from the intertidal zone are extensive moss carpets, particularly in the region of the Cape itself. The conditions prevail on the James Bay coast as far south as Hook Point. Between the Cape and the Sutton River to the west, large grubbed areas, degraded salt marsh swards and moss carpets dominate the coastal zone. The salt marshes immediately west of the Sutton River are in relatively good condition, although there are indications of increased grubbing of these marshes. In 1996, the western perimeter of the breeding colony was east of the Sutton River. Tundra areas inland of the inter-tidal areas have extensive fresh-water sedge meadows dominated by *Carex aquatilis*. These show moderate to heavy grazing by older broods up to 8-10 km from the coast. However, intensive damage, such as the development of peat barrens, has been noted only near the core of the large breeding colony.

The Hudson Bay Coast of Ontario

The stretch of coastline from Sutton River west to the Ontario - Manitoba border shows a diverse geomorphology. Much of the coastline consists of barrier beaches, landward of which are small fringe salt marshes that are both grubbed and heavily grazed by Canada geese and lesser snow geese. Relatively small, but high density colonies of nesting lesser snow geese occur in the vicinity of the more extensive salt marshes east of Winisk River, at Shell Brook and at the Pen Islands. The vegetation at the latter site which is large (20 km x 5 km) is in good condition, possibly protected by deep snow and ice in spring. At the other locations and at the estuaries of the rivers which drain the Hudson Bay Lowlands some damage to the *Puccinellia - Carex* swards is evident.

The Hudson Bay Coast of Manitoba

The coastline of Manitoba between the Black Duck River in the east and Rupert Creek at the southern end of the Cape Churchill Peninsula has no large colony of breeding lesser snow geese. The area is a major staging region for lesser snow geese and Canada geese in spring. Between the border with Ontario and Cape Tatnum, the coastline consists largely of barrier beaches with heavily grazed/grubbed fringe salt marshes. The vegetation along the remainder of the coastline is dominated by the outflow and mineral sedimentation from the Nelson and Hayes Rivers. This produces freshwater/brackish conditions and rank growth of vegetation which is ungrazed. Staging birds pull shoots in the sedge meadows inland from the coast. There is some moss carpet development and many bare areas in which loose sediment is present on the surface.

The Cape Churchill Region and La Pérouse Bay, Manitoba

The expanding population of lesser snow geese at La Pérouse Bay has resulted in substantial changes to all intertidal habitats. No extensive *Puccinellia-Carex* swards remain and large areas of dead willows are present in the coastal zone. In addition, nearly all shoots of *Carex aquatilis* are grazed up to 10 km from the coast. In the vicinity of the coast extensive moss carpets are present. Indicator plants of severe disturbance and hypersalinity, such as *Senecio congestus* and *Salicornia* *borealis* are widespread. In 1996, birds nested from Rupert Creek to Christmas Lake beach ridge and densities of nests at some sites exceeded 2500 km^{-2}.

Knife and Seal Rivers, Manitoba

The extensive braided estuaries of the Knife and Seal Rivers have staging, breeding and post- hatch populations of lesser snow geese and Canada geese. There are a number of *Puccinellia-Carex* marshes that are badly grubbed and damaged. Moss carpets have developed where *Carex aquatilis* shoots have been removed.

Tha-Anne River to the Maguse River in the NWT on the west coast of Hudson Bay, NWT

The coastal inter-tidal salt marsh has been replaced by mudflats throughout the entire coastal strip, except at Wolf Creek. Eutrophic, mesotrophic and oligotrophic sedge communities have either been heavily grazed or replaced by peat barrens for distances up to 10 km inland from the coast. At some sites, the peat has been eroded to expose glacial gravels.

Southampton Island, NWT

Although quantitative vegetation surveys have not been carried out on Southampton Island in relation to the effects of foraging by geese, reports from biologists who have visited the breeding colonies of lesser snow geese indicate that there is widespread shoot-pulling of sedges, heavy grazing of shoots of *Carex aquatilis / stans* and *Arctophila fulva* and the presence of bare peat areas and moss carpets. At Boas River, formerly extensive salt marshes reported by T. Barry are badly grubbed and reduced to remnant areas. These changes in the vegetation are of particular interest as breeding colonies of Brant, Canada and lesser snow geese are in close proximity to each other. There are virtually no graminoid areas on the southern two-thirds of the island that are not used by broods of snow geese and the other three goose species. Snow goose broods now travel from the East Bay nesting areas all the way westward to the village of Coral Harbour itself, a distance of up to 60 km (K. Abraham, pers. obs).

Southwestern Baffin Island, NWT

This area along the shores of Foxe Basin contains the locations of the first documented lesser snow geese nesting (in the 1920s) and has been occupied continuously since. Several large colonies of lesser snow geese that breed in the coastal marshes and move inland along river valleys to forage on fresh-water graminoids. Again formal vegetation studies of this area have not been done, but damage to salt marshes is evident (D. Caswell, pers. comm.). Examination of photographs indicates widespread destruction of coastal vegetation by geese (grubbing) and the development of moss carpets in the river valleys of the uplands. The lack of quantification is unfortunate because the area may hold as many as one-third of the mid-continent breeding population (D. Caswell, unpublished data).

Bylot Island, NWT

In some areas, there has been deterioration of vegetation in recent years as a result of the foraging activities of a colony of greater snow geese. The birds forage on a range of graminoids, in particular, *Dupontia fisheri*, *Eriophorum angustifolium* and *Eriophorum scheuchzeri* that grow on an organic substratum rather than a mineral substratum. The death or poor growth of individual tussocks/shoot systems following intense foraging has led to the development of sparse growth of graminoids, and the increase of moss. The studies of G. Gauthier and associates show, in prime brood rearing areas: 1) a high impact of grazing, 2) regrowth of plants after grazing and 3) lower production of plants in heavily grazed habitats (Gauthier *et al*. 1995, Gauthier *et al*. 1996). However, the long-term ability of the plants to recover is not yet affected because, when geese were excluded, production of *Eriophorum* tripled after four years (Gauthier *et al*. 1996).

Queen Maud Gulf, NWT

Extensive studies of the growth and geographical expansion of the colonies of Ross' and lesser snow geese in this region indicate that the birds have expanded beyond prime nesting colony sites, especially where lakes occur, to marginal mainland fresh-water tundra sites. The birds forage in both coastal and inland marshes and travel large distances (over 60 km, R. Alisauskas and S. Slattery, unpublished data) to suitable brood rearing habitats. A number of the vegetation changes reported for the west coast of Hudson Bay occur here, including extensive areas of peat barrens that can be detected from satellite imagery (LANDSAT).

Banks Island, NWT

Formal vegetation studies in relation to the effects of goose grazing are absent. However, the types of changes to vegetation indicated above as a result of goose grazing are expected to occur and can be seen on recent photographs of the area.

North Slope of Alaska, USA

The relatively small breeding colony of lesser snow geese on Howe Island, Sagavanirktok River (<250 pairs) is unlikely to have deleterious effects on the vegetation at this point. However, fall staging of snow geese from the western Canadian Arctic occurs in fresh-water tundra wetlands on the coastal plain. No assessment of damage has been made.

Wrangel Island, Russian Federation

Damage to vegetation at the nesting site in the uplands is minimal and confined to local grubbing. On the coastal Tundra of the Academy there is very heavy grazing of shoots in the vicinity of lakes (<250 m) and moss carpets or swards of *Petasites sagittatus* (arctic coltsfoot/heliotrope/ butterbur) are common.

IMPACTS OF HIGH POPULATIONS ON GEESE AND OTHER FAUNA

Effects on the Geese Themselves

Lesser snow geese from Hudson Bay have experienced declines in adult and gosling body size, gosling survival (Cooch *et al*., 1991a,b; Williams *et al*. 1993) and increases in parasites (Rockwell *et al*. 1994). Greater snow geese have declined in body size (Reed and Plante 1997). J. Leafloor (unpublished data) and M. Hill (unpublished data) have found that adult and gosling *interior* Canada goose from Akimiski Island, NWT exhibit morphological variation from area to area that is consistent with the hypothesis of reduced forage resources resulting from high populations of geese.

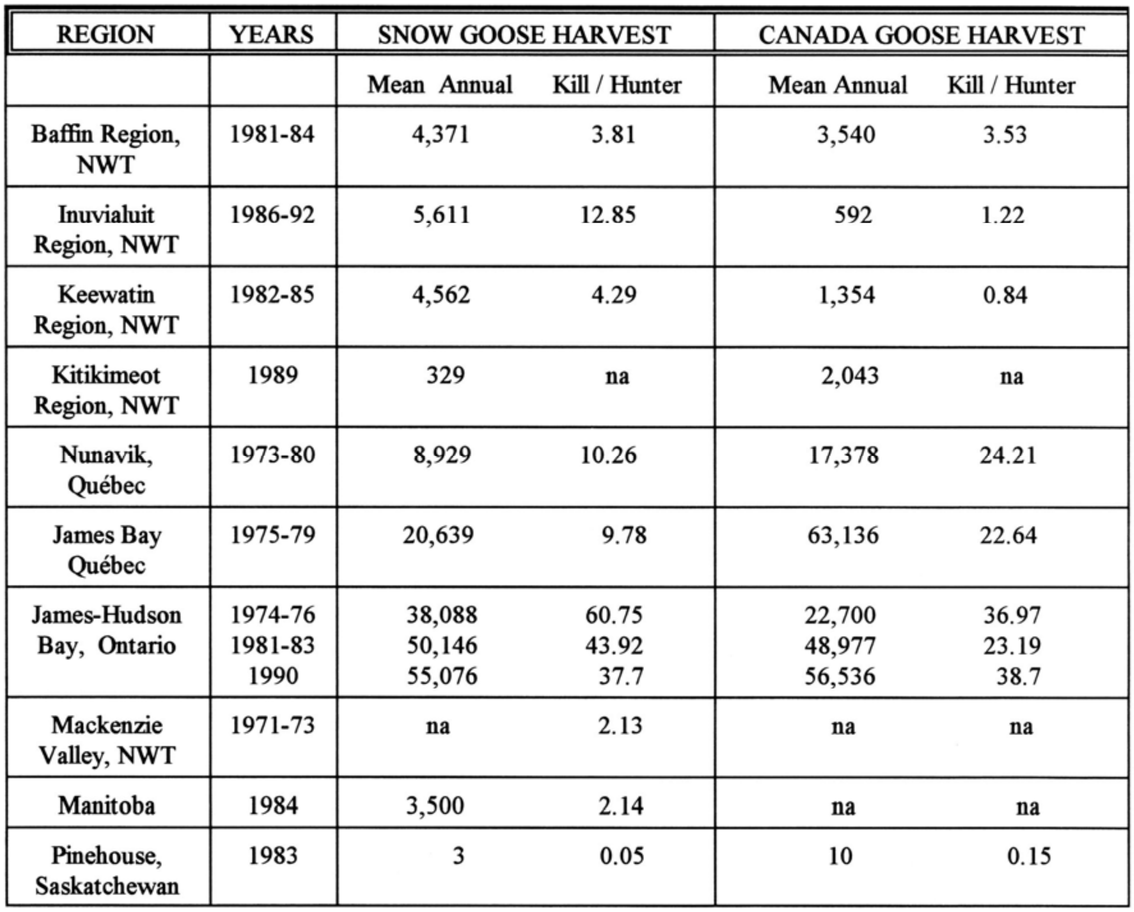
Effects on Other Birds

The effects on other birds have not been studied. Nesting birds in the vicinity of goose colonies where severe damage has occurred experience direct loss of nesting habitat through the destruction of sedge, grass and low shrub associations. In addition, the changes to soil salinity and decomposition processes likely result in significantly altered microfaunal changes resulting in a loss of forage resources. Preliminary findings (B. Milakovic and R . Jefferies, unpublished data) suggest that aquatic invertebrates may be less diverse and less abundant in ponds in areas of degraded vegetation.

Gratto-Trevor (1994) monitored local nesting populations of Semipalmated Sandpipers (*Calidris pusilla*) and Red-necked Phalaropes (*Phalaropus lobatus*) at La Pérouse Bay, Manitoba. Nesting pairs of both species have declined dramatically in habitats traditionally occupied by relatively high densities of lesser snow geese for nesting and brood rearing over the last 30 years. Impacts of the growing snow goose colony on habitat quality of these shorebirds was cited along with weather and predation rates as possible explanations. The Yellow Rail (*Coturnicops noveboracensis*) was formerly abundant at La Pérouse Bay, but has not been encountered there recently (R. Rockwell, unpublished data). Other shorebirds, ducks (e.g., American Wigeon, *Anas americana*, and Northern Shoveler, *Anas clypeata*) and passerines, (e.g., Lapland Longspurs, *Calcarius lapponicus*) are likely candidates for similar negative interactions because they share either nesting or brood rearing habitats. Some species appear to be utilizing degraded environments. For example, where willows have died and little vegetation remains, Semipalmated Plovers (*Charadrius semipalmatus*) breed. The scale of the problem and associated level of risk to the broader populations requires intensive study, including some calculation of the proportion of total range of the species affected by goose damage. It is clear, however, that the interaction is dynamic, and the rapid occupation of new areas by geese increases the threat to other species even as the effects are being calculated.

GEESE IN RELATION TO PEOPLE

A full review of human interactions with growing populations of geese is beyond the scope of this report. Here we discuss consumptive uses of geese, primarily lesser snow geese and Canada geese by aboriginal people in Canada (Table 2.2, Fig. 2.21, K. Dickson, CWS data). Waterfowl in general are important in the provisioning of aboriginal communities with meat. Snow geese and Canada geese are particularly important over a broad area. Clearly, however, the importance numerically is greatest among Cree communities of the Hudson Bay Lowland in southern Hudson Bay. The communities in the Ontario portion have been surveyed periodically for over four decades (see below).



REGION	YEARS	SNOW GOOSE HARVEST		CANADA GOOSE HARVEST	
		Mean Annual	Kill / Hunter	Mean Annual	Kill / Hunter
Baffin Region, NWT	1981-84	4,371	3.81	3,540	3.53
Inuvialuit Region, NWT	1986-92	5,611	12.85	592	1.22
Keewatin Region, NWT	1982-85	4,562	4.29	1,354	0.84
Kitikimeot Region, NWT	1989	329	na	2,043	na
Nunavik, Québec	1973-80	8,929	10.26	17,378	24.21
James Bay Québec	1975-79	20,639	9.78	63,136	22.64
James-Hudson Bay, Ontario	1974-76	38,088	60.75	22,700	36.97
	1981-83	50,146	43.92	48,977	23.19
	1990	55,076	37.7	56,536	38.7
Mackenzie Valley, NWT	1971-73	na	2.13	na	na
Manitoba	1984	3,500	2.14	na	na
Pinehouse, Saskatchewan	1983	3	0.05	10	0.15

Table 2.2. Reported estimates of snow goose and Canada goose harvests by aboriginal people in Canada (Data compiled by K. Dickson, CWS, from various harvest surveys, 1971-1992).

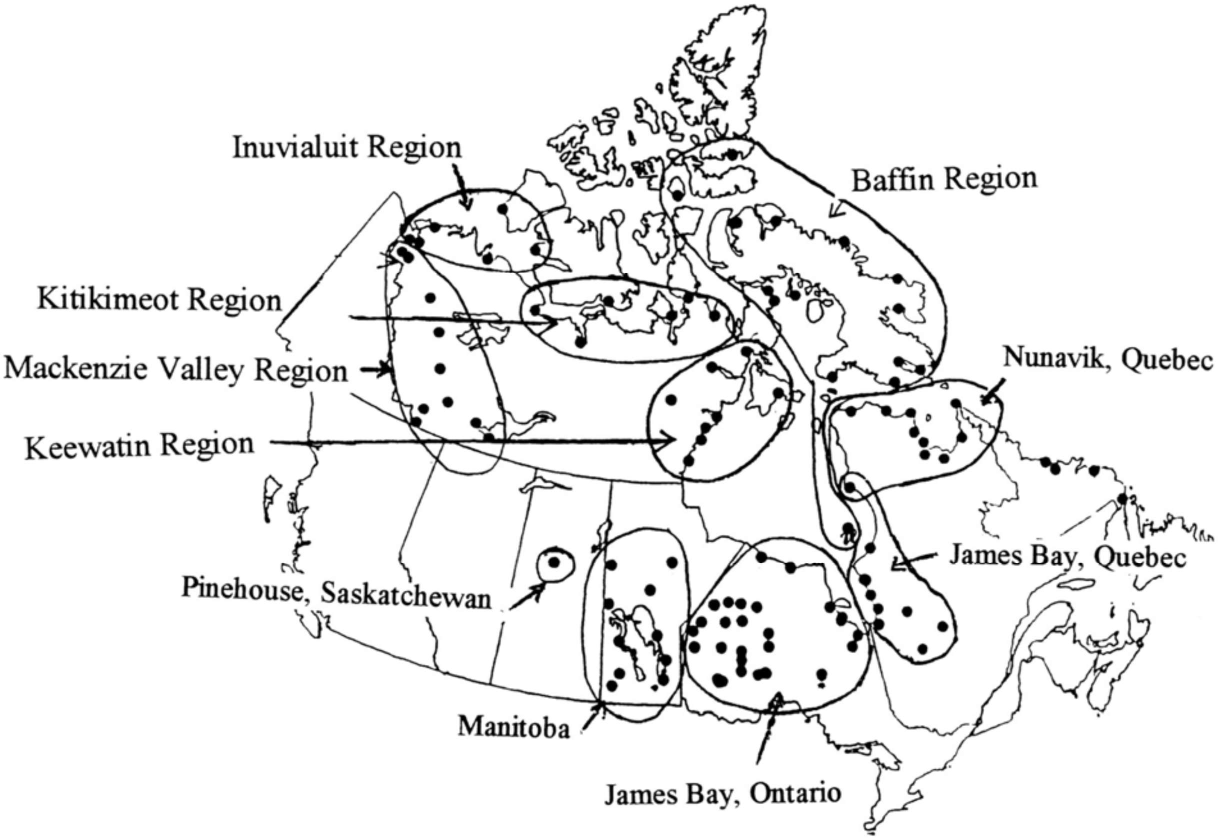


Figure 2.21. Aboriginal communities and areas where harvest surveys were conducted in 1971-1992 (from K. Dickson, Canadian Wildlife Service, unpublished data). See Table 2.2.

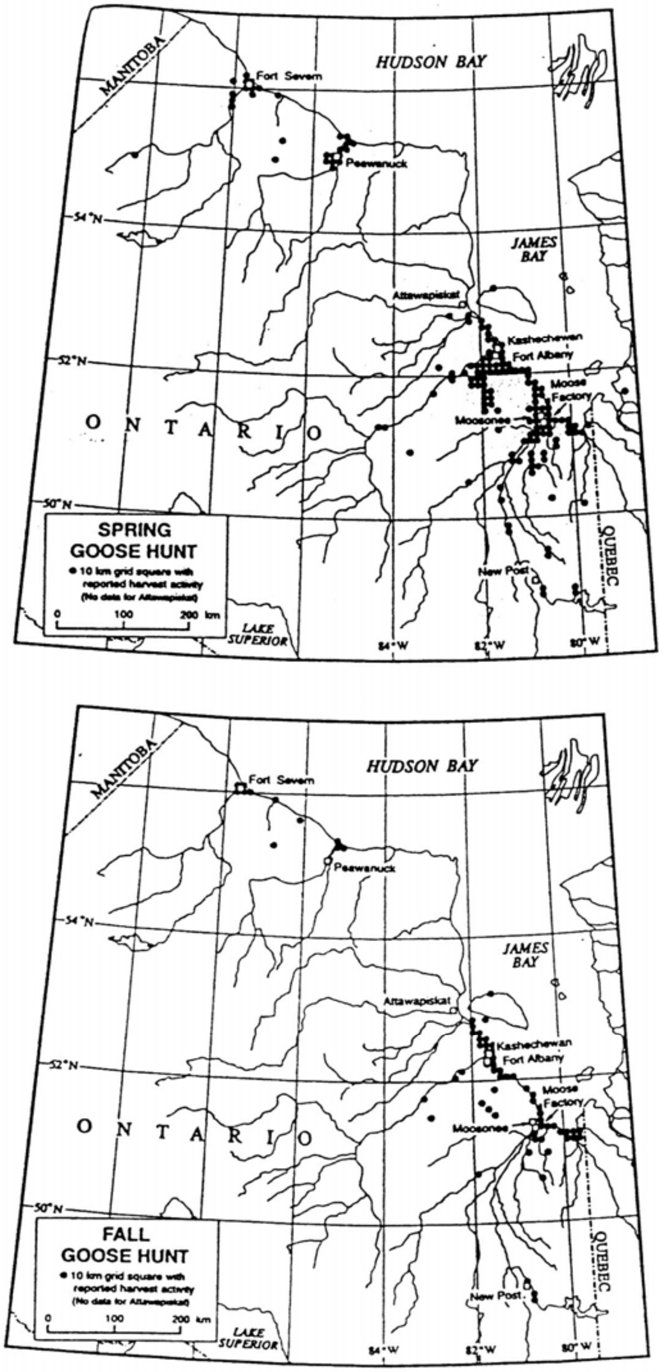


Figure 2.22. Harvesting areas in the Hudson Bay Lowland, Ontario, used in 1990, by season, for aboriginal goose hunting (after Berkes et al. 1995)

Aboriginal Land Use in the Hudson Bay Lowland

A land-based economy remains a major component of the mixed economies of most aboriginal communities in the lowlands of southern Hudson Bay and western James Bay region (Berkes *et al.* 1994, 1995). Within this region of Ontario, the Cree place considerable emphasis on land use in relation to self-governance, and for strengthening land use and hunting traditions in communities. The population there is concentrated in Moosonee and eight First Nation Communities, Moose Factory, Mocreebec, New Post, Fort Albany, Kashechewan, Attawapiskat, Peawanuck and Fort Severn (Fig. 2.22). All settlements are members of the Mushkegowuk Harvesters Association who share the coastal region and use the same wildlife populations (Berkes *et al.* 1995). In addition, in the Manitoba portion of the Hudson Bay lowlands, the town of Churchill has a Cree population with its own Council, and the First Nation community of Shamattawa has a history of seasonal use of coastal areas for wildlife harvesting. In Québec, the Cree communities of eastern James Bay share many of the cultural traditions of the Ontario James Bay Cree, including heavy reliance on waterfowl, and their regional economies are similar (James Bay and Northern Québec Native Harvesting Research Committee 1976, Boyd 1977).

The information given below is based on mapping of harvest sites and the collection of data from hunters among the resident aboriginal population in the Ontario portion of the region (Prevett *et al.* 1983, Thompson and Hutchison 1989, Berkes *et al.* 1994, 1995) and does not include Manitoba and Québec portions of the Lowland.

Major harvesting activities

Of the major wildlife harvesting activities, the spring waterfowl hunt attracted about 14,000 person-days of harvesting effort in 1990 and the fall waterfowl hunt about 10,000 person-days, the most recent year for which data are available (Berkes *et al.* 1994). Most harvesters spent 10 to 50 days per year hunting. Harvest of Canada geese dominates the spring hunt and harvest of lesser snow geese dominates in the fall, with some variation between localities. In spring, geese are hunted along inland drainage basins as well as on the coast and the season is shorter compared to that in late summer and fall. Hunters from Kashechewan, Fort Albany and Attawapiskat stay close to the coast in spring but range more extensively in fall. There is considerable overlap in community hunting areas. Overall, two communities, Moose Factory and Kashechewan, accounted for over half of the hunting effort and most communities spent more time waterfowl hunting than any other hunting activity.

Native Goose Harvest in the Hudson Bay Lowland of Ontario

The reported number of Canada geese killed in 1990 was 40,676 and the figure for lesser snow geese was 38,022. Projected estimates of total number of birds taken in the region by First Nations people were 56,536 and 55,076, respectively, for the two species (Berkes *et al.* 1994). Of all hunters reporting, 80%-90% participated in the waterfowl hunt in both seasons (Berkes *et al.* 1994, Prevett *et al.* 1983). The recent estimates of kill and participation are similar to those of a decade earlier (48,977 Canada geese and 50,146 snow geese, Thompson and Hutchison 1989). The estimates for Canada geese are higher than those from the mid 1970s (range 17,577-23,508 for 3 years; Prevett, Lumsden and Johnson 1983) and also higher for snow geese except in one year (range 31,284-50,334 over the same 3 years). Estimates of snow goose kill are also higher than reported for the 1950s (35,000-40,000; Hanson and Currie 1957). Increased harvests are primarily due to an increase in the aboriginal population of the Lowland. The harvest per hunter (often equated with household) has stayed very similar over the decades. The mean annual waterfowl kill per hunter was nearly 100; for snow geese it averaged 37 per hunter over the whole coast, with variations among communities (Prevett *et al*. 1983). The mean waterfowl kill per harvester was 93.7 in 1990 (Berkes *et al*. 1994); for snow geese it was 38.7 (Table 2.2).

It is interesting to note that the harvest of snow geese, while higher, has not risen proportionately with the increase in the mid-continent population from which the birds are taken. This may indicate that increasing aboriginal harvest for management of high populations (Johnson 1997) might be difficult to achieve. Hunters from the James Bay communities have stated that the fall snow goose hunt is poorer than it used to be; they complain of fewer birds being present in James Bay (in contrast to the known growth of the meta-population) and also that flocks are more difficult to decoy. Disproportionate changes in populations around the Hudson Bay region (i.e., higher in the west) or changes in migration routes could explain an observation of fewer geese in James Bay. The extreme south end of James Bay historically provided major staging habitat for reproductively successful snow geese (i.e., families with young) (Prevett *et al*. 1982). A partial explanation for the elders' observations of more difficult hunting may be that flocks now generally have a smaller proportion of young (because of high pre-fledging and immediate post-fledging gosling mortality); thus they would react differently to decoys. Elders from Peawanuck and Moose Factory have also related to us that geese are thinner and taste different (worse) than in the past. This thinning may be a result of habitat degradation which influences accumulation of nutrients and the taste difference may be related to depletion of primary forage species and use by geese of other plants.

Estimated Food Value of the Native Harvest in the Hudson Bay Lowland of Ontario

In the region as a whole, the estimated edible weight of Canada geese killed was 120,000 kg/yr and for lesser snow geese the value was 88,000 kg/yr (Berkes *et al*. 1994). The protein equivalent is approximately 24 g protein 100 g^{-1} meat. The protein available from all bush foods was estimated to be 97 g per adult per day in the region (Berkes *et al*. 1994). The replacement value of waterfowl in 1990 was between $8.14 and $11.40 per kg of edible meat in stores (poultry) in settlements.

The tradition of wildlife harvesting appears to be very strong in the region and represents a major contribution to the overall regional economy and cultural sustainability of the Hudson Bay Lowland Cree. A similar economy exists in James Bay and Ungava, Québec and although magnitude of aboriginal waterfowl harvest is much less elsewhere, it is no less important culturally and in terms of food value.

Harvest in Canada and the United States

Trends in harvest and hunter numbers are shown in Fig. 2.9a for areas in the central United States and Canada where mid-continent lesser snow geese are hunted. As noted, the number of geese harvested and the harvest rate have declined in both countries as the population of geese has increased. Many factors are cited for the declines, including large flocks, flocking behavior that makes decoying difficult, a preponderance of experienced adults and a wealth of choices of feeding areas. Harvest per hunter has increased, particularly in the Central Flyway and this has compensated somewhat for the decline in hunter numbers, but not sufficiently to keep harvest rate from declining.

SUMMARY OF ISSUES

Are There Too Many White Geese?

The answer differs for each white goose population and on whether a social/economic or biological perspective is required. Most populations of LSGO, ROGO and GSGO continue to grow, and at the landscape level (i.e., the continental scale) the system has the capacity to support further population growth. However, sufficient capacity at one time in the annual cycle (non-breeding) and in one region of their range (migration and winter) does not mean that all places on all occasions have sufficient capacity for sustained growth of populations. While the wintering areas appear to have the human-induced biological capacity to support the current high populations, the breeding grounds do not. The growth and decline of the McConnell River and other colonies of West Hudson Bay is a prime example. Staging, nesting and brood-rearing habitats in the eastern and central Canadian Arctic and some temperate staging and wintering areas show measurable short-term deterioration and cumulative degradation. The resource deficit caused by this degradation will not be easy to correct as recovery of these habitats likely will take decades.

A combination of direct and indirect human-generated factors are at the root of the twentieth century increase of Arctic geese. These major factors, such as agricultural practices and climate change, are not the responsibility of wildlife management agencies. Some conservation programs of these agencies (e.g., refuges, hunting regulations) have had an important synergistic effect on the increase in population size, (e.g., by expanding areas of suitable habitat for the birds and by dispersing geese over wide areas). Nevertheless, these agencies are left with the primary responsibility of changing the direction of population growth, if the damage caused by geese is deemed publicly unacceptable. Although agricultural economics is beyond direct wildlife agency control, it would be prudent to engage in discussions with the agricultural community about alternative agricultural practices less beneficial to geese because they play a pivotal role in the phenomenal success of geese. As long as cultivation of rice, corn and other cereal grains used by geese is economically profitable and agricultural practices remain unchanged, the output of these agro-ecosystems will allow continued population growth of geese.

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Part III DYNAMICS OF THE MID-CONTINENT POPULATION OF LESSER SNOW GEESE - PROJECTED IMPACTS OF REDUCTIONS IN SURVIVAL AND FERTILITY ON POPULATION GROWTH RATES

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INTRODUCTION

Our primary task was to generate a set of scenarios involving decreases in survival and reproductive success that reduce the annual growth rate of the mid-continent population of lesser snow geese. By implementing management actions corresponding to those scenarios, the numbers of lesser snow geese in the midcontinent population should decline. Once the population reaches a size that prevents further damage and allows recovery of damaged areas, management actions can be changed to use scenarios that hold the population size near that new level.

One of the problems modeling or monitoring the system is knowing how many geese there really are. Our best current estimates are from the mid-winter surveys. These serve as indices since the sample counts may miss some individuals (and groups) and may include some more than once. If we assume that the surveys are performed consistently (even if biased) and assume that annual changes in the indices are representative of changes in the entire mid-continent population, then annual growth rates based on the indices (indexed growth rates) can be taken as an unbiased estimate of the annual growth rate ($\lambda = N_{t+1} / N_t$) of the mid-continent population. The current indexed growth rate is $\lambda = 1.049$ (Figure 1) and is used both as an initial point of reference for our modeling and for monitoring purposes.

In this report, we develop scenarios that lead to growth rates over the range $\lambda = 1.05, ..., 0.5$. To provide some feel for the impact of instituting management plans corresponding to those growth rates, we modeled the dynamics of hypothetical populations of lesser snow geese that began at either 3,000,000 or 5,000,000 individuals (Figure 2a,b). The underlying model ($N_t = N_0 \times \lambda^t$) assumes no density dependence. This assumption is legitimate in the case of a population that has increased its numbers due to an increase in carrying capacity of the environment. We have indicated the Central and Mississippi Flyway Councils Regulatory Threshold value of 1,500,000 as a point of reference. **Please note that there is no a *priori* reason to suppose that this is the population size that prevents further damage and allows recovery of damaged areas of the arctic ecosystem.**

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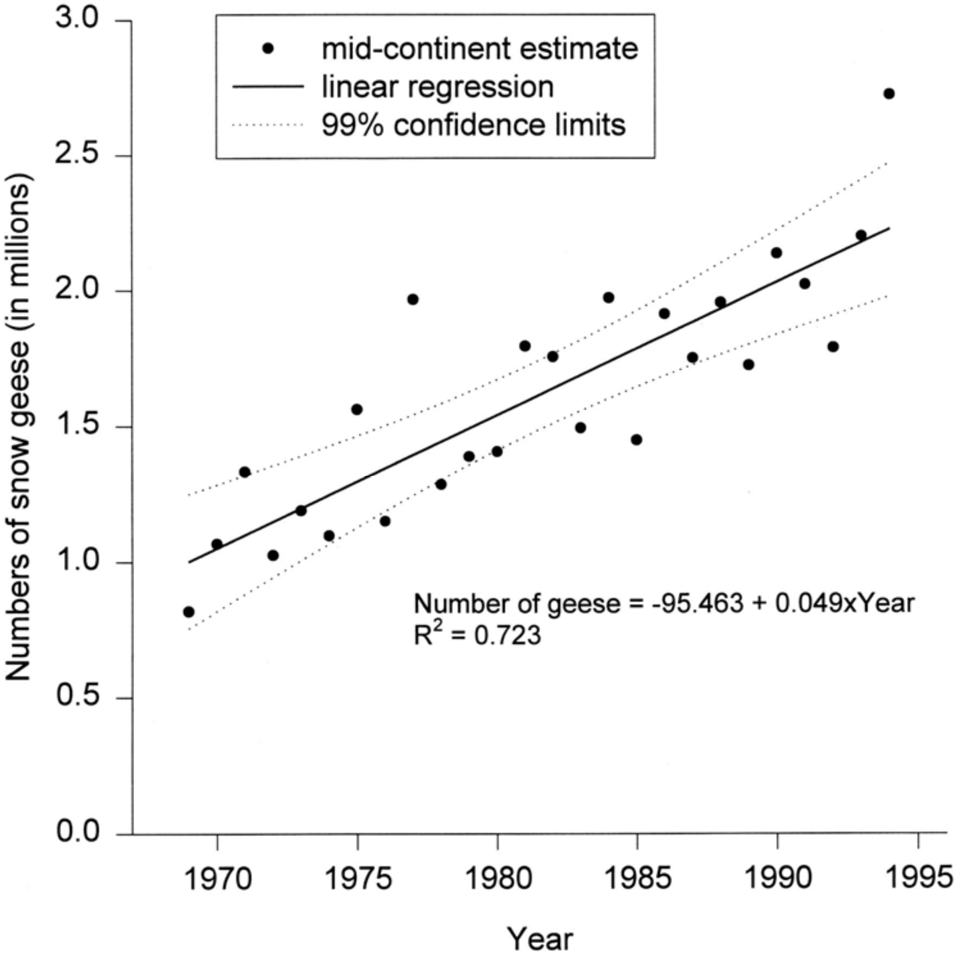


Figure 1. Mid-winter survey estimates and indexed growth rate for the Mid-continent population of lesser snow geese. Data from D.E. Sharp, Central Flyway Harvest and Population Survey Book (1995, page 82).

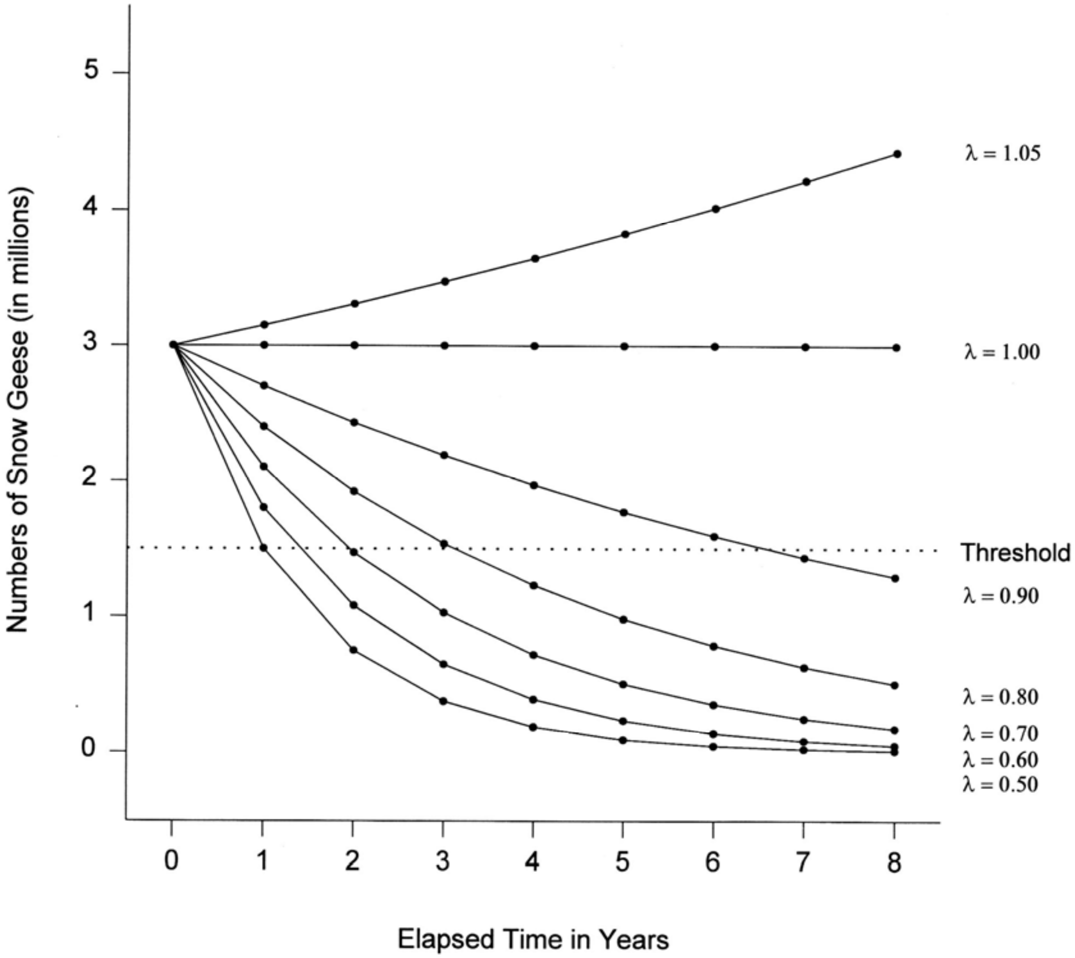


Figure 2a. Projected Dynamics of a Population of 3,000,000 Lesser Snow Geese for Various Growth Rates

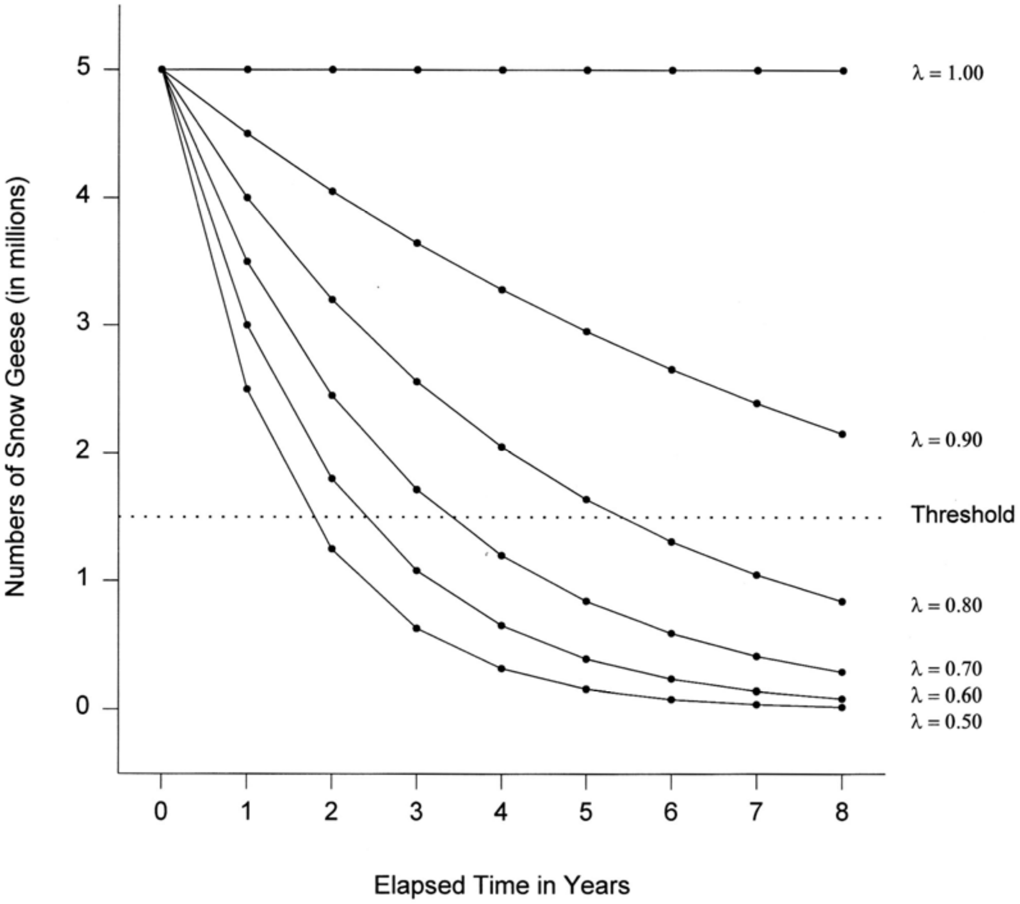


Figure 2b. Projected dynamics of a population of 5,000,000 lesser snow geese for various growth rates.

Obviously, the lower the growth rate is below 1.0, the faster the population declines. It must be kept in mind, however, that habitat monitoring is a key component to this program and implementation may take 3 to 5 years. As such, it might be judicious to avoid extremely quick reductions (such as those achieved with values as low as λ = 0.5 or 0.6) since we might not have monitoring in place before the population was reduced substantially. Growth rates within the range of λ = 0.7 to 0.9 would seem more appropriate, at least for a population of 3,000,000.

In a more general fashion, it is possible to calculate the time it would take to reduce a population of unknown size by a specified proportion. We generated a set of such times for a range of reductions over a series of different growth rates (λ<1) and summarized them in Table 1. Again, allowing for time to get habitat monitoring in place, growth rates in the range of λ=0.7 to 0.9 may be the most reasonable.

MODEL

The annual cycle of lesser snow geese is illustrated in Figure 3. We evaluated annual population growth dynamics and developed our scenarios with a birth-pulse matrix projection model that coincides with the synchronous breeding pattern of the birds. Given what we know about age-specific differences in reproductive success, we used a 5 stage model of age classes i = 1, 2, 3, 4, 5+ that correspond to ages 0-1, 1-2, 2-3, 3-4, >4. We assumed a post-breeding census that begins accruing annual mortality immediately after each individual advances 1 age class and reproduces. We equated fledging with "birth" and used it as a point of reference for reproductive output. Finally, we collapsed seasonal mortalities into a single annual product.

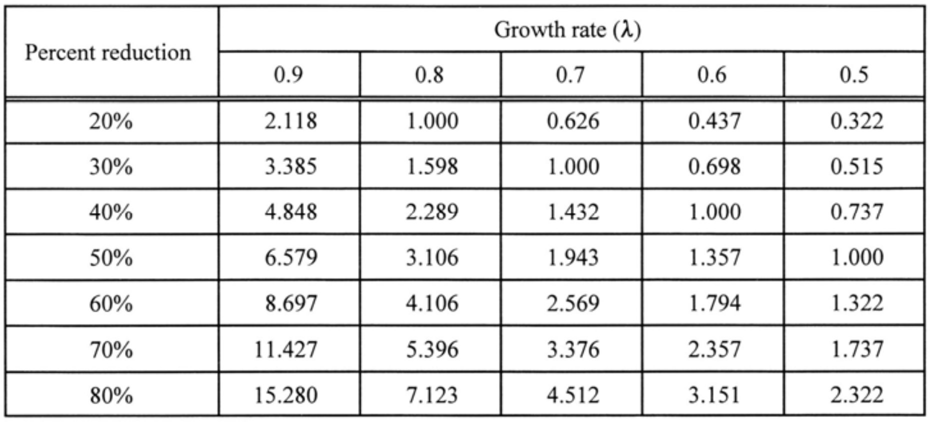
The annual cycle can be reduced to the simple life cycle graph depicted in Figure 4. The 9 transition paths are estimated as:

$$F = BP_i \times (TCL_i / 2) \times (1\text{-}TNF_i) \times P1_i \times P2_i \times (1\text{-}TBF_i) \times P3_i \times s_a \text{ for } i = 1,2,\ldots,5 \quad (1)$$

$$P_1 = s_0 \quad (2)$$

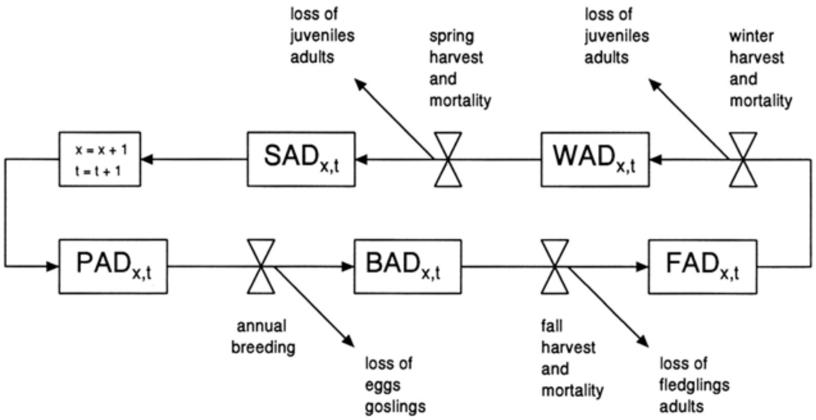
$$P_i = s_a \text{ for } i > 1 \quad (3)$$

where for age class i: BP is breeding propensity, TCL is clutch size, TNF is total nest failure, P1 is egg survival, P2 is hatching success, TBF is total brood failure, P3 is gosling survival and s_0 and s_a are the annual survival probabilities for juveniles (age = 0-1) and adults (age > 1) respectively. Additional technical details regarding these variables are found in Table 2. We reduced clutch size by ½ to focus on females only.



Percent reduction	Growth rate (λ)				
	0.9	0.8	0.7	0.6	0.5
20%	2.118	1.000	0.626	0.437	0.322
30%	3.385	1.598	1.000	0.698	0.515
40%	4.848	2.289	1.432	1.000	0.737
50%	6.579	3.106	1.943	1.357	1.000
60%	8.697	4.106	2.569	1.794	1.322
70%	11.427	5.396	3.376	2.357	1.737
80%	15.280	7.123	4.512	3.151	2.322

Table 1. The number of years required to reduce a population to a specified percentage of its initial size under various growth rates.



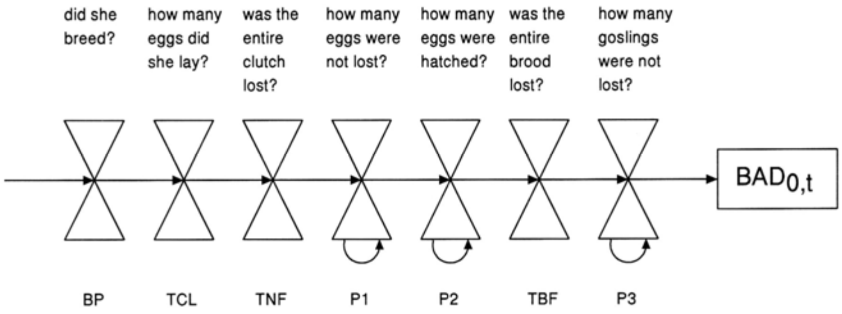
PAD is the pre-breeding age distribution

BAD is the post breeding age distribution

FAD is the fall age distribution

WAD is the winter age distribution

Figure 3a. The lesser snow goose annual cycle.



The outloops indicate that those transition probabilities are evaluated independently for each egg and gosling, respectively. The others are evaluated once for each female or nest.

Figure 3b. The reproductive protion of the lesser snow goose annual cycle.

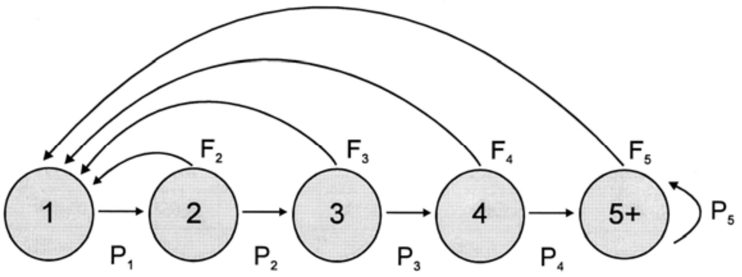
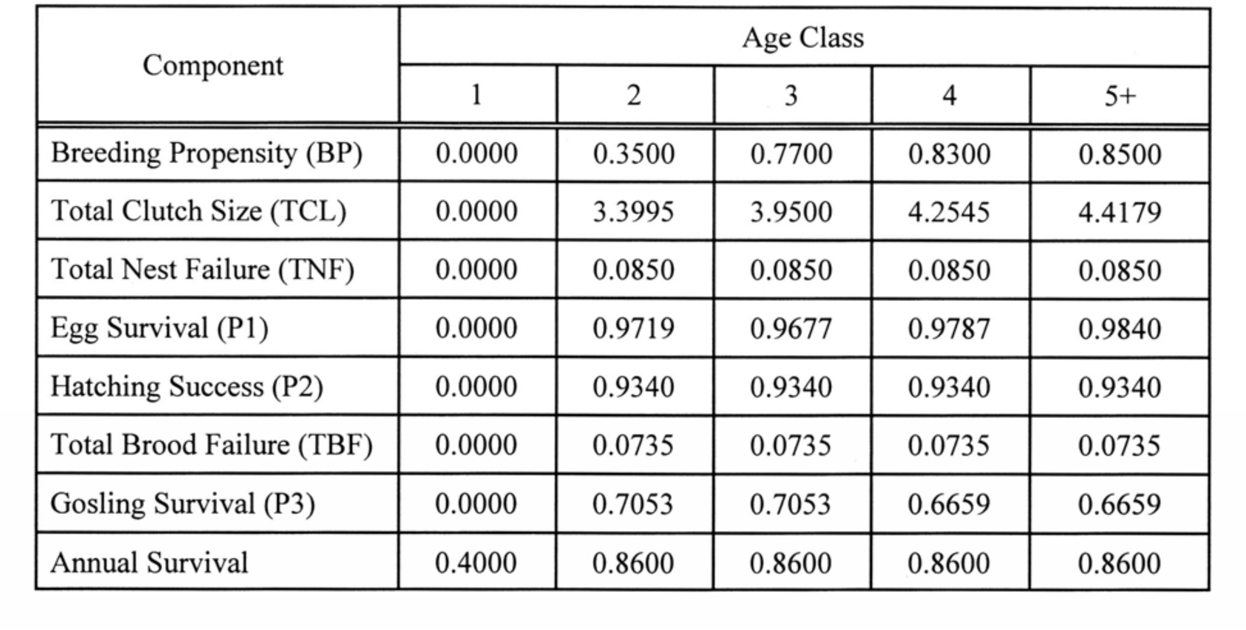


Figure 4. Life cycle graph for the lesser snow goose. Numbered circles correspond to age classes. P values are age-specific survivals. F values are age-specific fertilities.



Component	Age Class				
	1	2	3	4	5+
Breeding Propensity (BP)	0.0000	0.3500	0.7700	0.8300	0.8500
Total Clutch Size (TCL)	0.0000	3.3995	3.9500	4.2545	4.4179
Total Nest Failure (TNF)	0.0000	0.0850	0.0850	0.0850	0.0850
Egg Survival (P1)	0.0000	0.9719	0.9677	0.9787	0.9840
Hatching Success (P2)	0.0000	0.9340	0.9340	0.9340	0.9340
Total Brood Failure (TBF)	0.0000	0.0735	0.0735	0.0735	0.0735
Gosling Survival (P3)	0.0000	0.7053	0.7053	0.6659	0.6659
Annual Survival	0.4000	0.8600	0.8600	0.8600	0.8600

Table 2. Estimates of reproductive and survival parameters for the La Pérouse Bay colony.

Definitions:

Breeding Propensity is the probability that a female who is alive at time t actual breeds.

Total Clutch Laid is the total number of eggs laid by a female.

Total Nest Failure is the probability that a female losses her entire clutch of eggs during incubation.

Egg Survival is the conditional probability that a single egg in a clutch survives through the incubation periods *given* that the clutch did not fail totally.

Hatching Success is the probability that an egg that survives during incubation hatches and that the gosling leaves the nest.

Total Breed Failure is the probability that a female losses her entire brood of goslings during the period from hatching to fledging.

Gosling Survival is the conditional probability that a single gosling in a brood survives the period between hatching and fledging *given* that the brood is not totally lost.

Annual Survival is the probability that an individual survives the period from when it is age x = i-1 to age x = i. For age class i = 1 this means surviving from fledging (x = i-1 = 0) to the first anniversary of fledging (x = i = 1).

Note that we dichotomize losses during both the incubation (TNF and P1) and the brood rearing (TBF and P3) periods to account for bimodality in the distributions of those losses.

The life cycle graph was cast as the Leslie style matrix A for evaluation of annual growth rate of the population. The population was represented as the vector n where the elements correspond to the number of individuals in each age class. The form of A and n are:

$$A = \begin{matrix} 0 & F_2 & F_3 & F_4 & F_5 \\ P_1 & 0 & 0 & 0 & 0 \\ 0 & P_2 & 0 & 0 & 0 \\ 0 & 0 & P_3 & 0 & 0 \\ 0 & 0 & 0 & P_4 & P_5 \end{matrix} \qquad n = \begin{matrix} n_1 \\ n_2 \\ n_3 \\ n_4 \\ n_5 \end{matrix}$$

The population was modeled or "projected" through time as: $n_t = A \times n_{t-1}$. The growth rate λ was estimated from A using standard techniques of linear algebra.

CHOICE OF MODEL PARAMETERS

In selecting estimates for each of the parameters, we are limited by the fact that our best estimates come from the long-term study at La Pérouse Bay and may not be applicable to the entire mid-continent population. Adult survival for La Pérouse Bay birds has increased over the past 25 years but the pattern and extent do not appear to differ from less precise estimates for adults from either the Cape Henrietta Maria or West Hudson Bay colonies. Indeed, the increased survival of adults has likely been a major cause of the mid-continent population growth. The La Pérouse Bay estimate for this parameter seems generally applicable.

Reproductive success and first-year survival are more difficult issues. Reproductive success has declined substantially for those birds that continue to nest and rear their broods within the historical confines of the La Pérouse Bay colony. This reduction is no doubt related to habitat degradation in that region and the current estimates of reproductive success from La Pérouse Bay seem somewhat inappropriate for modeling the entire mid-continent population. For that reason, we have used estimates taken from the 1973 to 1984 period when the vegetation at La Pérouse Bay was above the threshold for adequate foraging and gosling growth.

A second problem using reproductive success estimates from La Pérouse Bay for modeling the midcontinent population is that La Pérouse Bay is one of the more southern colonies. As such, females may arrive with proportionately more food reserves and may be subject to fewer weather-related delays that could result in clutch size reduction through follicular resorption. The La Pérouse Bay females are also less prone to the irregular total failures associated with exceptionally late melt in the higher arctic. All else being equal, then, overall reproductive success at La Pérouse Bay might be higher than at more northern colonies.

Mortality during the first year ($1-s_0$) reflects both hunting and non-hunting losses. Although non-hunting mortality accrues over the entire year, it is thought to be especially high during the immediate post-fledging period and during the early, staging portion of fall migration. Mortality related both to hunting and to the condition of staging habitat, where birds from several colonies mix, should have the same impact on most juveniles, regardless of their colony of origin. In contrast, local habitat conditions may have a major impact on immediate postfledging losses and this component of first-year mortality may be colony specific. Recent estimates of first year survival from La Pérouse Bay may be too low for modeling the mid-continent population since local habitat is severely degraded. However, values from the mid to late 1980's may provide a reasonable estimate since they predate severe degradation at La Pérouse Bay but include the more global impacts of hunting and the general 1 to 2 decade decline in the condition of common staging habitat in lower Hudson and James Bays.

The reproductive and survival parameter estimates from La Pérouse Bay for the period before habitat degradation began severely impacting local success are summarized in Table 2. The values of the associated Leslie matrix are illustrated in the life cycle graph given in Figure 5. The population growth rate based on these estimates is $\lambda = 1.107$ which is higher than the indexed estimate of $\lambda = 1.049$ (with 1.037-1.061 as the 95% confidence interval).

As explained above, it is possible that components of reproductive success estimated before severe habitat degradation at La Pérouse Bay could be higher than those for more northern colonies (which make up most of the mid-continent population). If that is the case and if we assume the indexed rate is correct, it seems reasonable to modify the estimates in Table 1 to generate a set of data more appropriate to modeling the entire mid-continent population. We changed adult survival to 0.88, the most recent (1987) value available from the analyses of the La Pérouse Bay band recovery data. We changed juvenile survival to 0.30, the corresponding value for that same year. The population growth rate incorporating only those two changes is $\lambda = 1.081$ which is still above the indexed estimate.

If we retain those more recent survival estimates and reduce our estimate of overall reproductive success by 18.6% - a value consistent with 1 complete failure every 9 years or a reduction in each reproductive component of 3%, we arrive at values for the Leslie matrix illustrated in the life cycle graph given in Figure 6. The growth rate for this set of estimates is $\lambda = 1.052$.

Since the true values for the fecundity components of the entire mid-continent population are not known, we proceeded using the two sets of estimates illustrated in Figures 5 and 6. We will refer to them as the **La Pérouse Bay** and **mid-continent** data sets, respectively. As will become clear in the following section on elasticity analyses, conclusions regarding management options and scenarios for reducing growth rate of the midcontinent population are largely independent of which of these sets is finally chosen.

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 those elements with higher elasticity will alter the growth rate more than changing those with lower elasticities.

The elasticities of the 9 elements are depicted in Figure 7a along with the parameter estimates of those elements. Not surprisingly, the composite age elements (P_5 ; F_5) each have higher elasticities than their single age element counterparts (P_1 P_2 P_3 P_4 ; F_2 F_3 F_4). The elements P_2 , P_3 , P_4 and P_5 depend exclusively on the same demographic variable s_a (equation (3). The sum of their elasticities are 0.747 and 0.679 for the mid-continent and La Pérouse Bay data sets, respectively, indicating that these 4 elements account for 74.7% and 67.9% of the projected growth of the population.

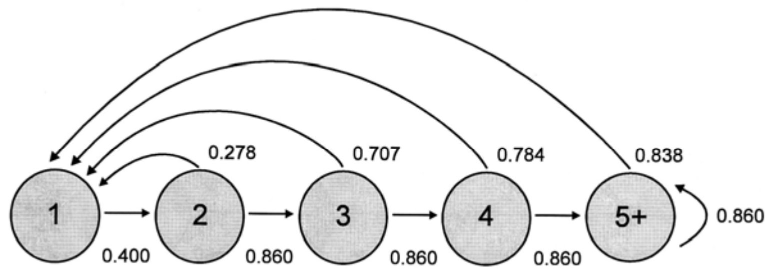


Figure 5. Life cycle graph for the lesser snow goose. La Perouse Bay data set.

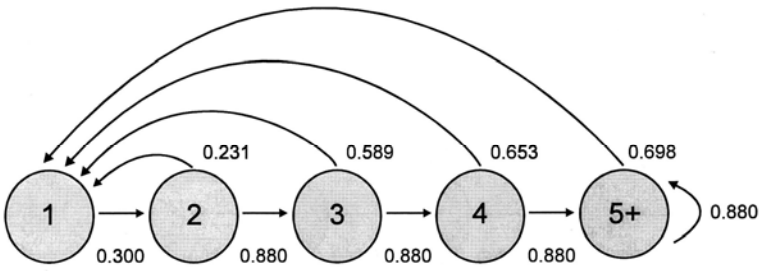


Figure 6. Life cycle graph for the lesser snow goose. Mid-continent data set.

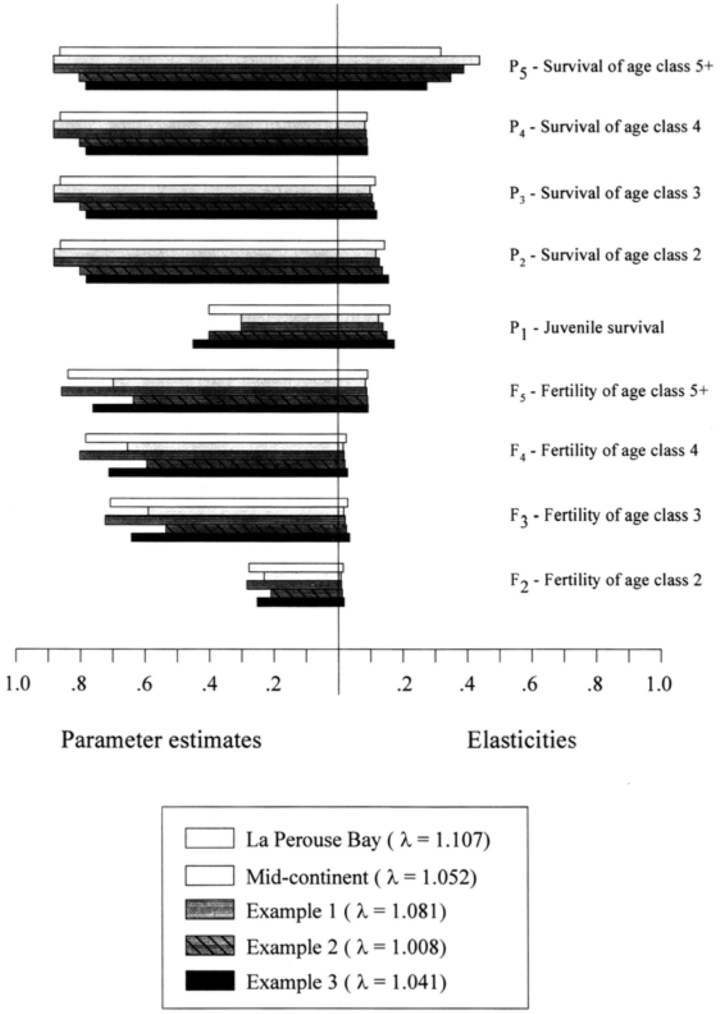


Figure 7a. Estimates and elasticities of the model parameters for 5 data sets.

To examine the generality of the latter result, we estimated elasticities for three example sets of estimates that cover a range of survivals, fertilities and growth rates (Figure 7a). In all cases, these 4 adult survival components account for more than 65% of the elasticity and are thus the primary determinant of population growth. As such, it is apparent that minor adjustments to the estimates of reproductive success, such as those to account for inter-colony differences, will have little impact on the overall dynamics or growth rate of the midcontinent population.

Adult survival (s_a) actually contributes more to the control of λ than pooling the elasticities of the elements P_2 , P_3 , P_4 and P_5 indicates. Since we used a post-breeding census model, s_a also contributes to the elements F_2 , F_3 , F_4 and F_5 (equation 1) and a portion of the elasticities of those matrix elements "belongs" to s_a . Similarly, life cycle parameters such as clutch size, nesting success, etc. contribute to more than one element in the matrix (i.e., F_2 , F_3 , F_4 and F_5 - equation 1). We estimated the contributions of each of the life cycle parameters (Table 2) to the elasticity of λ by partial differentiation. Those contributions, depicted in Figure 7b for the mid-continent and La Pérouse Bay data sets, are termed "lower level elasticities". While they do not sum to 1 (as do the higher level elasticities), they do provide a relative measure of the impact of a proportionate change in each parameter on λ.

Adult survival clearly makes the highest relative contribution to the growth rate of the mid-continent population. It is also the variable that offers the greatest numerical potential for altering that growth rate. For example, a 10% reduction in adult survival would result in more than a 5-fold greater reduction in λ than would a 10% reduction in any contributor to reproductive success. It must be kept in mind, however, that the management utility of such high elasticity variables also depends on whether they can be altered to the levels required to effect desired changes in growth rate. In some cases, it may be politically or economically more feasible to institute management actions that combine changes in both high and low elasticity variables.

SCENARIOS

Increasing Adult Mortality

We examined the effect of increasing adult mortality on population growth rate by decreasing adult survival from its initial estimate $s_a = 0.88$ (mid-continent) and $s_a = 0.86$ (La Pérouse Bay) to 50% of that initial estimate in 5% increments. (The series was s_a , $.95 \times s_a$, $.90 \times s_a$,…, $.50 \times s_a$.) This resulted in reducing λ from 1.052 to 0.583 for the mid-continent data set (Figure 8a - adults only) and from $\lambda = 1.107$ to 0.629 for the La Pérouse Bay data set (Figure 8b - adults only).

Joint Harvest of Adults and Juveniles

Although one might attempt to selectively increase only adult mortality through harvest, it is likely that hunters would increase their direct harvest of juveniles at the same time. We investigated this for both data sets by decreasing both adult and juvenile survival at the same time. It is widely believed that part of the difference in adult and juvenile survival reflects an increased relative vulnerability of juveniles to hunting mortality. Unfortunately, it is not known whether that increased relative vulnerability itself depends on the level of adult mortality or harvest pressure.

To gain some insight into both effects, we performed two sets of simulations. In the first, we assumed that increased juvenile relative vulnerability was independent of the level of adult mortality. That is, we assumed the ratio of juvenile survival to adult survival (s_0 / s_a) did not change as adult mortality increased (Figure 9 - constant vulnerability). The decreasing survival series used in the simulations was: s_a, $.95 \times s_a$, $.90 \times s_a$, …, $.50 \times s_a$ for adults and s_0, $.95 \times s_0$, $.90 \times s_0$, …, $.50 \times s_0$ for juveniles. The joint effects of these reductions are indicated by the “adult and juvenile - increased juvenile mortality constant vulnerability” plots on Figures 8a and b. The impact of increasing the mortality of both adults and juveniles (through harvest) is to lower λ at a faster rate.

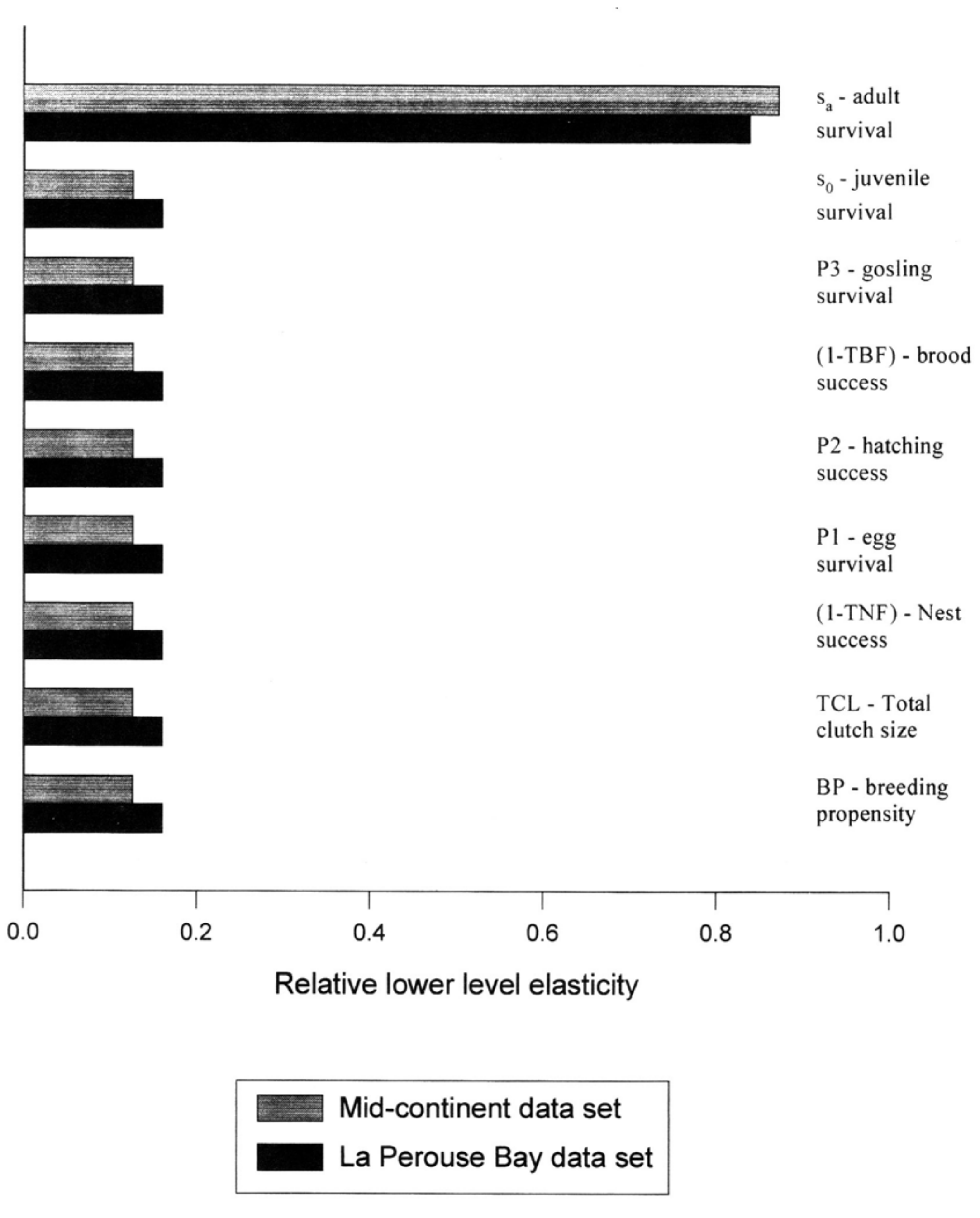


Figure 7b. Relative lower level elasticities of the 9 parameters of the life cycle of lesser snow geese. (See Table 2 for definitions.)

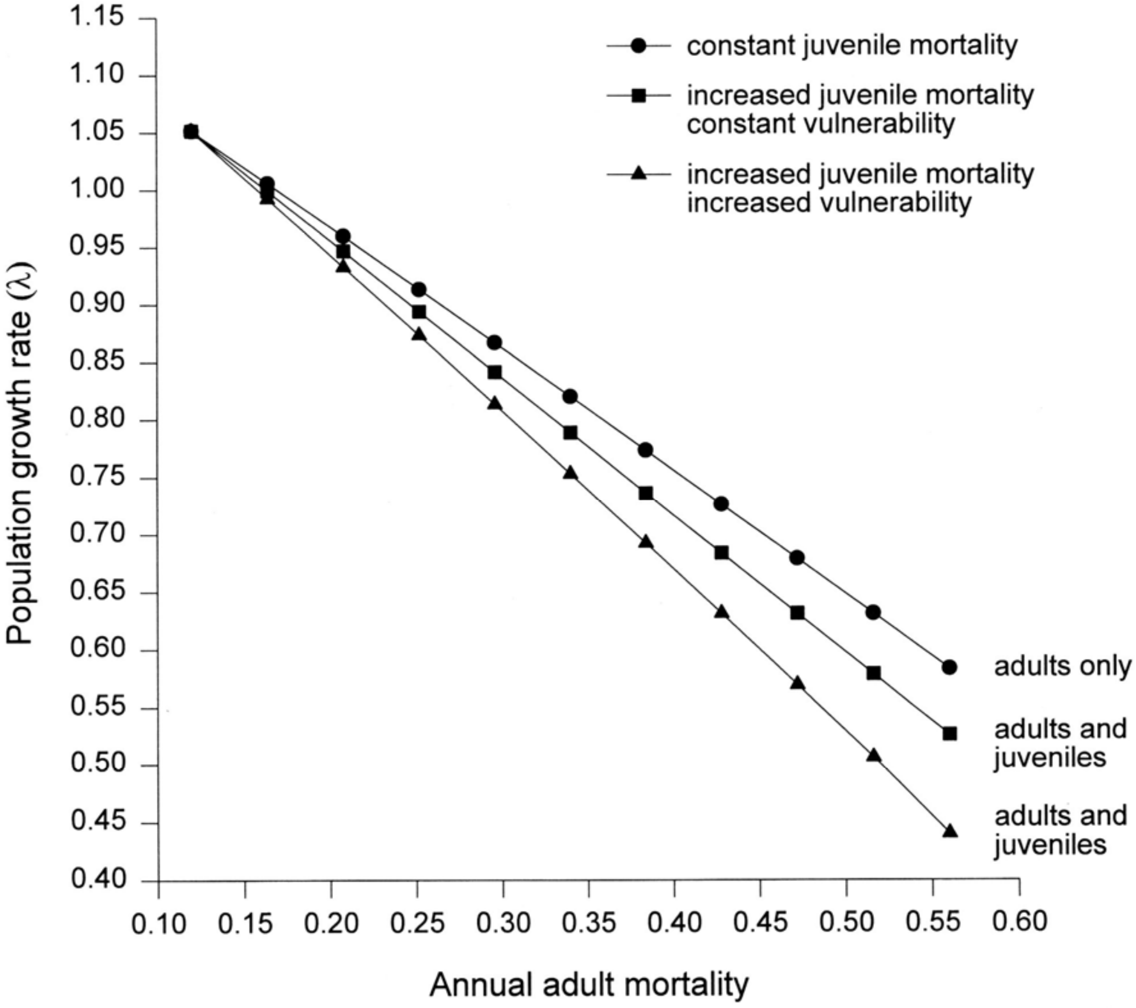


Figure 8a. The effects of increasing annual adult mortality on the population growth rate for the Mid-continent data set. Three models of associated juvenile mortality are considered.

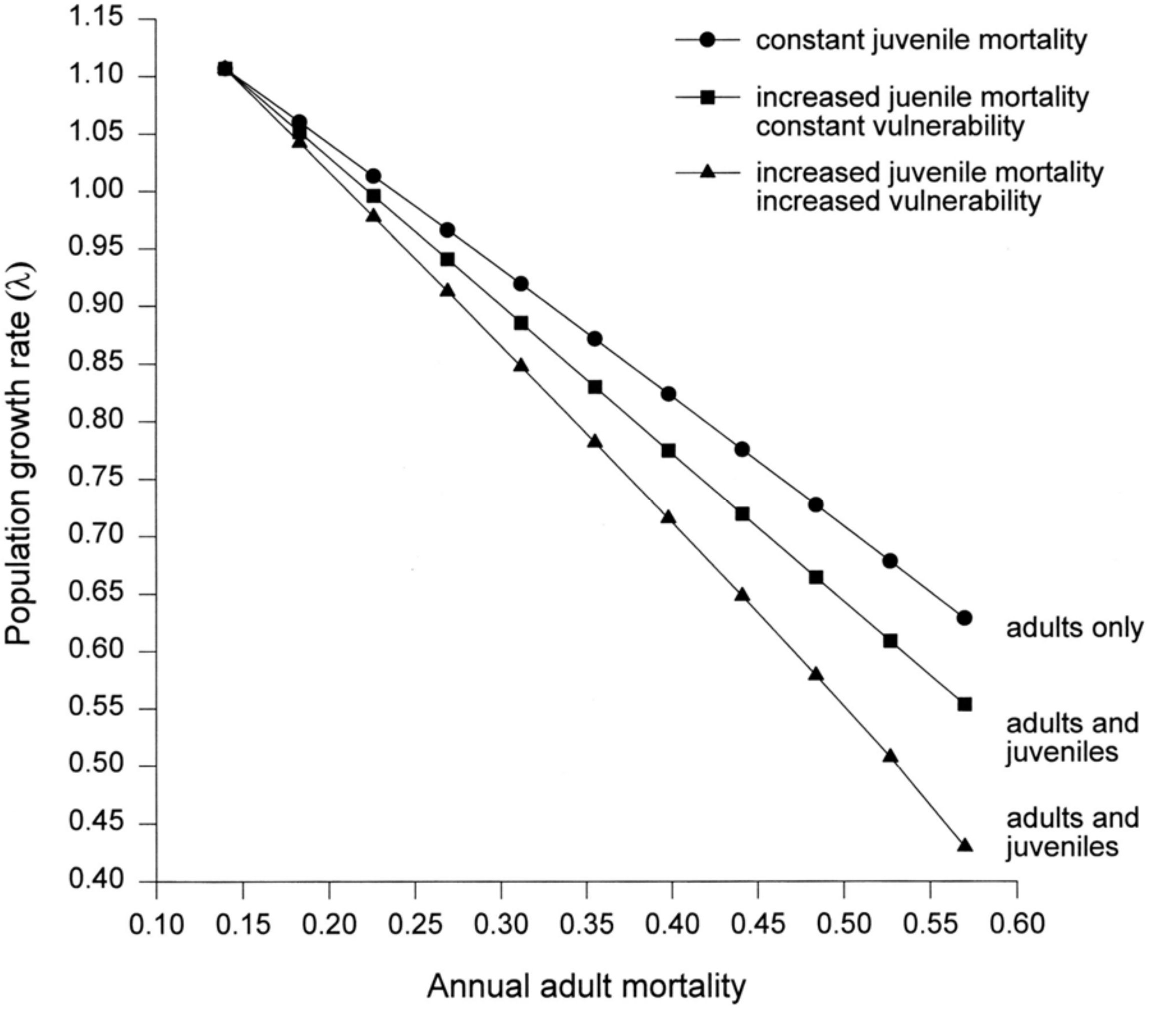


Figure 8b. The effect of increasing annual adult mortality on the population growth rate for the La Perouse Bay data set. Three models of associated juvenile mortality are considered.

In the second simulation, we increased the relative vulnerability of juveniles as adult mortality increased such that the ratio of juvenile survival to adult survival (s_0 / s_a) declined to 0 over the range of increased adult mortalities examined (Figure 9 - increasing vulnerability). We used this extreme rate of increase in vulnerability (juvenile survival reaches 0% of its initial value when adult survival reaches 50% of its initial value) in hopes of defining the extreme limit of such an effect. The decreasing series used was: s_a, $.95 \times s_a$, $.90 \times s_a$,…, $.50 \times s_a$ for adults and s_0, $.90 \times s_0$, $.80 \times s_0$, …, $.00 \times s_0$ for juveniles. The joint effects are indicated by the "adult and juvenile - increased juvenile mortality increased vulnerability" plots on Figures 8a and b. The impact of increasing adult mortality and both the mortality and relative vulnerability of juveniles at the same time is higher than the other scenarios. Since we used an extreme pattern of relative vulnerability, it is likely that reality lies between the two “adults and juveniles” curves on Figures 8a and b.

It is possible that increases in adult harvest could reduce juvenile survival independently of increases in juvenile harvest. If one or both parents are required to successfully shepard their young through their first migration south, their first winter and/or their return north the following spring, then increased adult harvest could increase non-hunting mortality of juveniles. If this were the only source of increased juvenile survival, then the relation of λ to increased adult mortality would be identical to the joint harvest situation with constant vulnerability in Figures 8a and b. If the increase in adult harvest results in this “parental care” effect as well as an increase in juvenile harvest, then again, reality likely lies between the two “adults and juveniles” curves on Figures 8a and b.

Egg Harvest

Harvesting eggs from the nests of laying and incubating females reduces the reproductive success of those individuals. From the perspective of our model, such egging can be viewed as a reduction in clutch size (TCL), an increase in nest failure (TNF) or a reduction in egg survival (P1). Since our projections of population growth rate use the product of these (and other) variables as a composite fertility (F_i in Figure 4 and equation (1)), we examined the potential impact of egging on population growth rate simply by decrementing overall fertility. The decreasing fertility series used was: F_i, $.95\times F_i$, $.90\times F_i$, …, $.50\times F_i$ with the reductions applied equally over the age classes. The effects of decreasing fertility on the population growth rate λ is depicted in Figures 10a and 10b for the mid-continent and La Pérouse Bay data sets, respectively. For reference, we included the effect on λ of reducing adult survival by the same proportionate amounts (s_a, $.95\times s_a$, $.90\times s_a$, …, $.50\times s_a$).

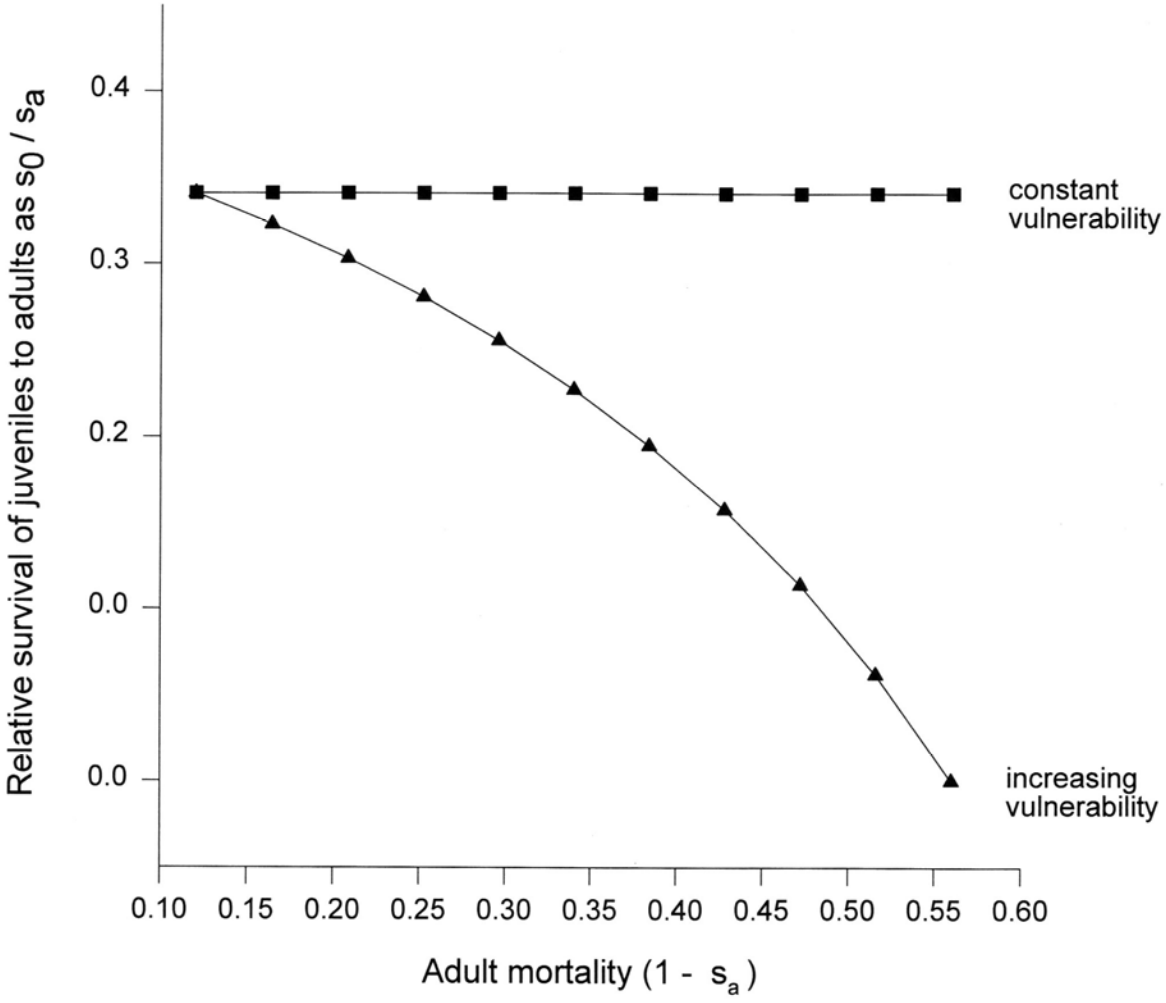


Figure 9. The effect of increasing adult mortality on the relative survival of juveniles to adults under two models of vulnerability. Mid-continent data set.

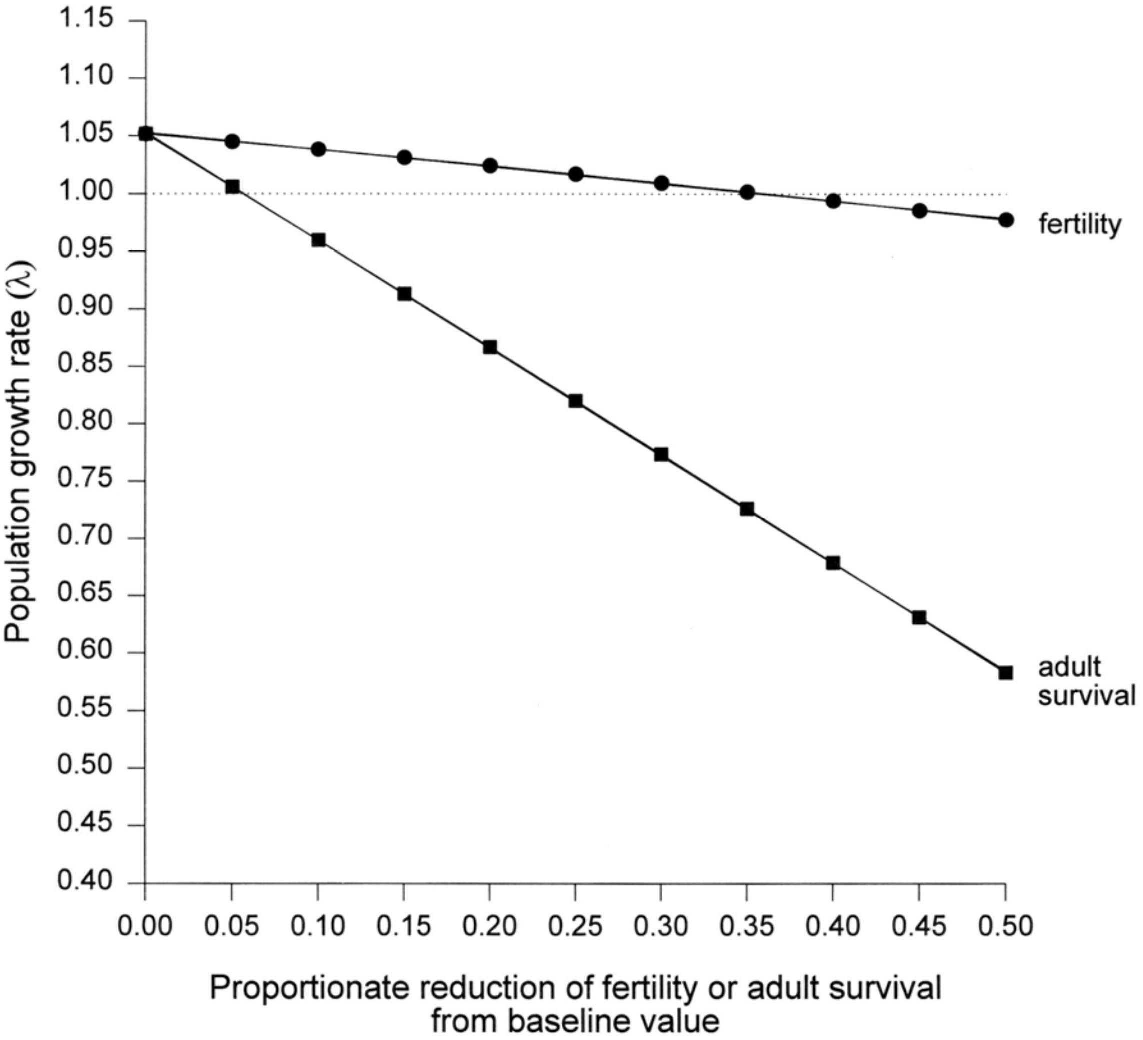


Figure 10a. The effect of reducing fertility or adult survival on population growth rate. Mid-continent data set.

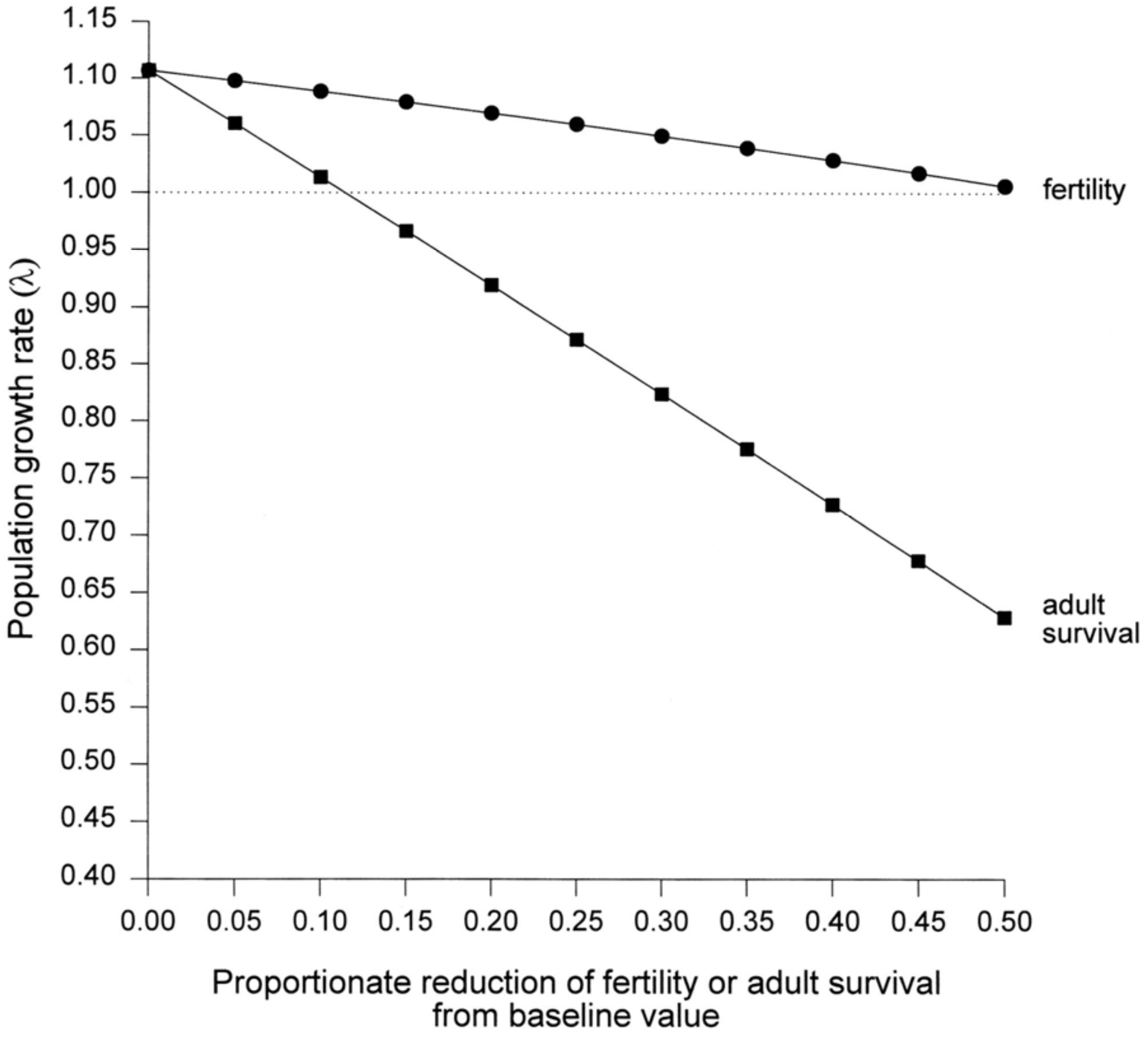


Figure 10b. The effect of reducing fertility or adult survival on population growth rate. La Perouse Bay data set.

Consistent with the elasticity analyses, reductions in fertility do not have nearly as great an impact on λ as do equally proportionate reductions in adult survival. For the mid-continent data set, for example, it takes a 5.7% reduction in current adult survival (to $.943 \times s_a$) to make the population decline ($\lambda = 0.9999$). By contrast, it requires a 35.8% reduction in fertility (to $.642 \times F_i$) to achieve the same thing. To appreciate the magnitude of the latter action, assume that there are 2,500,000 nesting females in the mid-continent population and that the entire fertility reduction is to be accomplished by egging which we will view as a decrease in nesting success. Our current estimate for nesting success in the mid-continent data set is (1-TNF) = 0.7448, obtained by applying the entire 18.6% reduction in the La Pérouse Bay data set to nesting success (see above.) Reducing the current level of nesting success by 35.8% to 0.4782 (.642×.7448), we find that 1,304,500 (=2,500,000 × (1 - 0.4782)) nests would have to fail totally to force λ just below 1.0. This is an increase of 666,500 nests over the 638,000 nests currently expected to fail totally (=2,500,000 × (1 - 0.7448)). Assuming a modal clutch size of 4 eggs (averaged over the age classes), it would require the collection of 2,666,000 eggs from the additionally harvested nests to force the mid-continent population's growth to a level just below $\lambda < 1.0$.

As a last bench mark, reducing fertility by 5.7% (to $.943 \times F_i$) reduces λ from 1.052 to 1.044 rather than to $\lambda < 1$ as was the case when adult survival was reduced by this proportion (above). If that fertility reduction were again achieved solely through egging, it would require the collection of 142,000 eggs.

APPLICATIONS

The overall strategy of the Habitat Working Group is to: 1) **decrease** the growth rate of the midcontinent population to some **$\lambda<1$** using a management program of reduced survival and reproductive success and monitor the population to see that the appropriate decrease and reductions are achieved; 2) monitor the arctic coastal ecosystem and when the population size is at a level that is causing no further damage, **change** the management program to one that allows the population to stabilize with a growth rate of **$\lambda\approx1.0$**. The size of that stabilized population should become the new Regulatory Threshold.

We presented a set of scenarios that relate λ to decreasing adult mortality, decreasing adult and juvenile mortality and decreasing fertility. Before choosing one or more of them, an appropriate initial value for the reduced λ must be selected after several factors are considered. These include both the size of the current midcontinent population and the time frame over which it should be reduced. The latter, of course, depends on the new regulatory threshold size - **a value we cannot really know in advance**.

The simulations depicted in Figures 2a and 2b and the values in Table 1 provide some guidance. If we accept that it will take 3 to 5 years to get an ecosystem and goose monitoring program in place and begin collecting relevant data and if we use the current regulatory threshold of 1,500,000 as a first approximation of a new stabilized target, then $\lambda< 0.8$ seems too severe, even for a current population of 5,000,000. If the current population is closer to 3,000,000, then a growth rate closer to $\lambda=0.9$ would seem more appropriate. In the following example, we assume the current population is between these estimates and we set the initial reduced growth rate at $\lambda=0.85$.

Given the elasticities of the parameters, it is tempting next to appeal solely to adult survival and make it the focus of our management efforts. As mentioned above, this is not always best and our view is that an approach combining reductions in survival with reductions in fertility through increased harvest of eggs is a reasonable overall course of action to lower λ. It is also our view, however, that the elasticity of fertility is such that even a substantial increase in egg harvest will be insufficient to appreciably alter reduction scenarios based on adult mortality. As such, we will focus the rest of this section on increasing adult and juvenile mortality and calculating associated harvest estimates.

We center on the 3 models that consider joint harvest of adults and juveniles and only on the midcontinent data set. To that end, we have recast Figure 8a as Figure 11, adding a horizontal that corresponds to λ=0.85 and dropping perpendiculars from the intersections of the horizontal with the 3 models. Those perpendiculars intersect the x-axis at points that give the adult mortality needed to achieve λ=0.85 under each of the models.

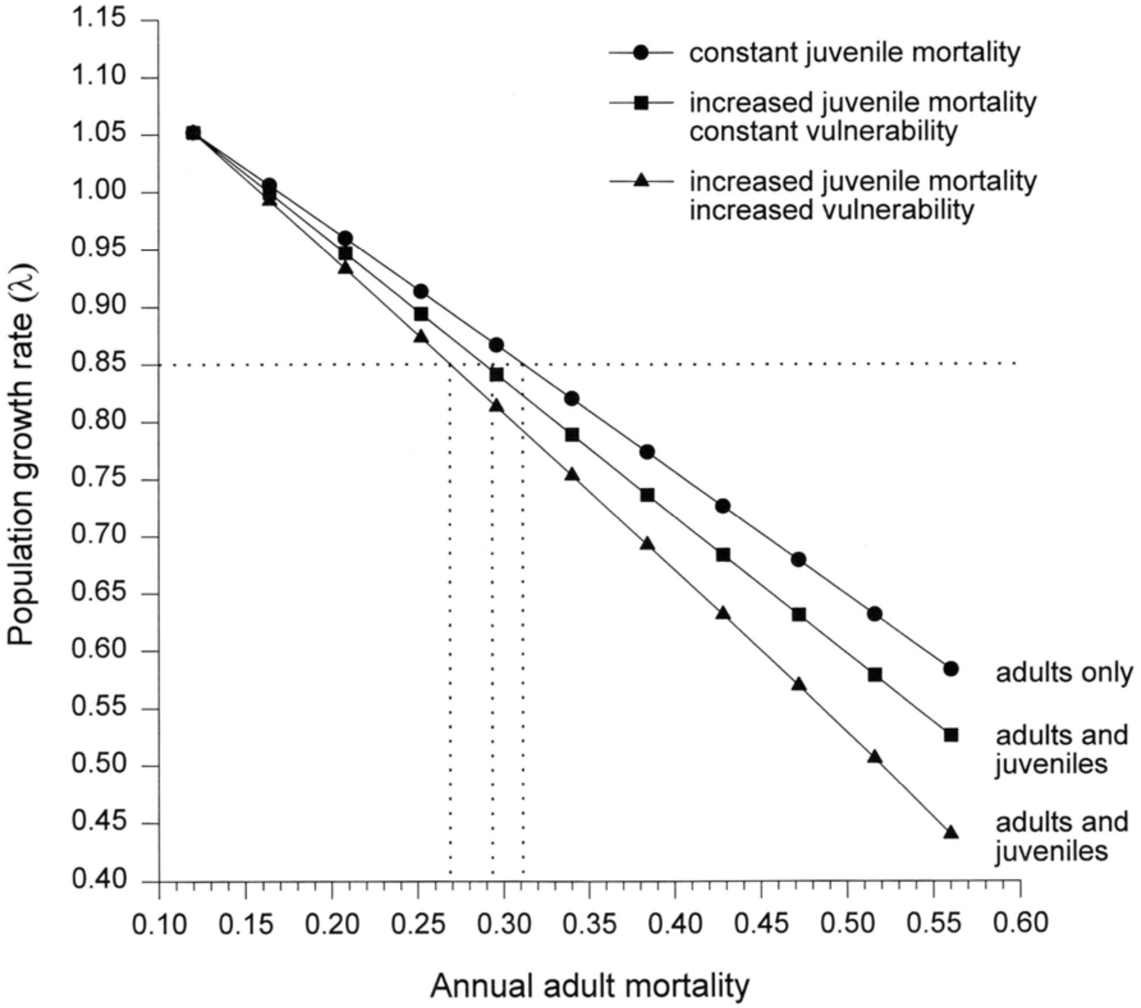


Figure 11. The effect of increasing annual adult mortality on the population growth rate for the Mid-continent data set. Three models of associated juvenile mortality are considered.

For the "adult only" model, an annual adult mortality of 0.312 is required to achieve λ=0.85. This model assumes that there is no increase in the harvest of juveniles in the face of increased adult harvest and does not seem too realistic. It was included primarily as a point of reference.

It is more reasonable to assume that there will be an increase in the harvest (or at least mortality) of juveniles associated with any increase in adult harvest. What is not clear is whether that increase will be proportional to the increased harvest of adults (Figure 8 - constant vulnerability) or whether juvenile mortality will increase disproportionately with increased adult harvest. The latter could result from increased vulnerability (Figure 8a) and/or decreased parental care. Reality likely lies between these two models, indicated on Figure 11 by the 2 adults and juveniles lines. This gives us a range of adult mortalities from 0.27 to 0.29 that would lead to λ=0.85. It should be recalled that associated increases in juvenile mortality are built into the models and do not need to be expressly calculated.

We assume that increasing adult mortality from its current level of 0.12 ($1-s_a$) to a new level between 0.27 and 0.29 will be achieved with hunting mortality. As such, the final translation of increased adult mortalities into a management plan must consider the relative contributions of hunting and non-hunting sources to adult mortality. The approach we have taken is based on recoveries of banded individuals and the data we have used comes from the banding program at La Pérouse Bay.

By way of review, let:

f = recovery rate (probability that a banded bird is shot, retrieved, and has the band reported)

H = harvest rate (probability that a bird is shot and retrieved)

ø = reporting rate (probability that the band is reported from a banded, harvested bird)

K = hunting mortality rate (probability that a bird is lethally shot)

c = retrieval rate (probability that a lethally shot bird is retrieved)

K is the value we seek and it can be found from the relationships: $H = f / ø$ and $K = H / c$ so that $K = f / ø / c$.

Although recoveries of birds banded at La Pérouse Bay declined over the 20 year period from 1968 to 1988, there was little decline after 1980. We used the unweighted mean of the 1980-1988 estimates as an estimate of direct recovery rate $f = 0.0254$. Using traditional estimates from mallard duck banding studies of $ø = 0.38$ and a retrieval rate of $c = 0.80$, we find that $K = 0.0836$. If we define E as non-hunting mortality rate and assume additive mortality of the instantaneous rates, we find that annual adult survival rate $s_a = (1-K) \times (1-E)$. Given our estimates of $s_a = 0.88$ and $K = 0.0836$, we find $E = 0.0398$.

We then find the K's associated with our new mortality rates of $m_{low} = 0.27$ and $m_{high} = 0.29$ as:

$K_{low} = 1 - (.73/.9602) = 0.2397$

$K_{high} = 1 - (.71/.9602) = 0.2605$

To achieve $\lambda = 0.85$, then, we will have to increase the current hunting mortality rate $K=0.0836$ by a factor between 2.87 and 3.11.

The most recent average estimate of actual harvest, based on hunter surveys and the parts inventory, is approximately 305,000. If we assume that this estimate, like the mid-winter inventory, is a representative index of true harvest rather than the actual total harvest and if we assume that the retrieval rate remains the same, then to achieve a reduction in growth rate to $\lambda=0.85$, this harvest index will have to increase approximately 3-fold to 915,000 birds.

Once the population size begins going down, the actual total harvest required to sustain an adult mortality between 0.27 and 0.29 will necessarily decrease. The latter stems from the relationship of hunting mortality rate to total harvest number and population size. If we let G be the total number of geese harvested and G/.8 be the total number killed by hunters, then the hunting mortality rate at time t can be estimated as $K_t = (G/.8) / N_t$ where N_t is the population size at time t. If G/.8 remains the same each year and N_t declines, then K_t must increase and so must the adult mortality rate. As the adult mortality rate increases, the population growth rate declines below $\lambda=0.85$ and the population will decline at an ever-increasing rate. While overshooting the annual mortality rate for a few years may not stress this population, the practice should not be continued indefinitely.

To avoid the situation, total number of geese harvested should be reduced as the population declines to hold adult mortality constant. If we view the actual harvest estimate as an index, then regulations must be adjusted annually so that it remains at approximately 3 times the current estimate. If we view it as the actual total harvest, then regulations must be adjusted annually so that it decreases at a rate that maintains adult mortality between .27 and .29.

As an alternative, comparative example, assume that we seek an initial reduction in the population growth rate that is less severe so that our initial $\lambda = 0.95$. From Figure 11, we can find $m_{low} = 0.20$ and $m_{high} = 0.21$. Following procedures outlined above, we then calculate $K_{low} = .1668$ and $K_{high} = 0.1773$. Referring to the current hunting mortality rate $K = 0.0836$, we find that to attain $\lambda = 0.95$ we will have to increase current hunting mortality rate by a factor of 1.99 to 2.12.

CONCLUSIONS

Our modeling is based on a strategy that seeks to reduce population growth rate to some sustained level with $\lambda < 1.0$ until a target population size can be achieved and stabilized by altering that strategy so that $\lambda \approx 1.0$. The estimates for mortality and harvest reached in the above examples are based on our assumptions regarding current population size, time span for reduction and a rough, first approximation of the stabilized target population that is approximately 50% of the current population size. Different assumptions will lead to somewhat different values under this type of strategy but will likely require that a harvest index be increased to a level 2 to 3 times the current values for several years. Such an increase in harvest will lead to a growth rate of between $\lambda = 0.85$ and $\lambda = 0.95$ and require 3 to 7 years to reduce the mid-continent population to 50% of its current level (Table 1). It is not known whether the coastal tundra can support a population of that reduced size without suffering further damage.

ACKNOWLEDGMENTS

We appreciate the advice of Jim Nichols and John Young on a variety of issues covered in this report. Alex Dzubin, Art Brazda and Dave Sharp continue to provide us with limitless data and insights.

Part IV MANAGEMENT STRATEGIES TO ADDRESS THE MIDCONTINENT LESSER SNOW GOOSE OVERPOPULATION PROBLEM

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INTRODUCTION

Waterfowl management programs have a long and successful history of providing hunting opportunity consistent with the long-term conservation of populations. Landscape level changes in habitats, due primarily to agriculture but also to refuge provision, have increased the productivity and survival of midcontinent snow geese resulting in the overabundance of these birds. Traditional management programs have not been able to restrain the growth of the Mid-continent snow goose population. Waterfowl managers have, for many years, increased bag limits and lengthened seasons in the Mississippi and Central Flyways in the dual effort of reducing population size and allowing additional recreational hunting opportunity. Despite this, populations have continued to grow and have become a serious problem as documented in Part II of this report.

Managers have engaged in extensive discussions regarding what extraordinary actions could be taken to reduce the numbers of snow geese. As a result of their collective and extensive experience, they have serious doubts that further liberalization of traditional hunting frameworks and techniques can be effective. Nevertheless, managers believe that hunters can, and must be, a major element of the ultimate solution. The collective wisdom of waterfowl managers was drawn upon in the assembly of this section of the report.

Effective population reduction will require reducing adult survival. The most effective time to do this is during the migration and wintering periods when the birds are in areas where hunters are most abundant. Hunters provide a motivated and experienced work force that do not have to be compensated for their involvement if it involves techniques, regulations and situations to which they can easily adapt. The hunting public has a strong vested interest in the long-term integrity of waterfowl populations and will almost certainly be willing and active participants.

Efforts to reduce the population will have to deal with both reducing the numbers of birds in the population and with halting further population growth. Both survival and recruitment rates will likely be addressed. Along with immediate actions to reduce the population size, it is important that managers address the associated habitat issues and the required long-term solutions for maintaining the population size at an appropriate level. A broad range of techniques, covering the entire geographical and temporal distribution of snow geese, will likely be needed.

Below is a list of management strategies recommended to control the overpopulation of snow geese. These have been reconciled through discussions with the Arctic Goose Habitat Working Group, with managers in the Mississippi and Central Flyways and with several other colleagues involved in waterfowl management. In developing this list, a wide range of alternatives was considered. Those which were considered to be ineffective were rejected. Also rejected were strategies which were not consistent with the guiding principle that recognizes the birds as a valuable natural resource for viewing, hunting and food (see Introduction page 4).

Management strategies have been grouped into two categories:

I) Population control by hunters.

II) Population control by wildlife agencies.

These treatments are not listed in order of priority.

I. POPULATION CONTROL BY HUNTERS

Hunters provide the principal financial and political support for waterfowl management. Hunting in the United States and Canada is the major source of mortality for adult snow geese, accounting for 68 percent of adult mortality (K/(K+E) on p. 98). In addition, residents of northern Canada are major users of the snow goose resource. Because of this, hunters throughout the range of snow geese must play an important role in helping to manage snow goose numbers.

While interest in hunting snow geese is high in many areas, many waterfowl hunters have little interest in snow geese. These hunters cite a number of reasons for avoiding snow geese, including: poor table quality, difficulty in processing, difficulty in hunting and equipment expense. Some of these reasons are real, others are viewed to be perceptions or misconceptions which have been perpetuated over time. Regardless, increasing the take of snow geese by hunters to the full potential will require that managers address these issues through communication, education and specific management activities.

A. Spring Harvest by Shooting

Managing overpopulations of migratory birds may require removal of constraints with international migratory bird treaties. The Migratory Bird Treaty with Canada, designed 80 years ago, and the companion treaties with Mexico, Russia and Japan are primarily responsible for the successful conservation of migratory bird populations across North America. Today however, effective management by harvest of mid-continent snow geese, and several other goose populations, is hindered by closed seasons called for in the Treaty. The federal governments of the United States and Canada could negotiate a revision to the Migratory Bird Treaty which would allow appropriate hunting of migratory birds between March 10 and September 1. It is recognized that the recent Treaty amendment negotiations took many years to accomplish. However, it is believed that the two countries should be able to more quickly reach closure on an amendment which would allow managed hunting to preserve the arctic habitats which are vital to a large portion of North America’s migratory birds.

Additionally, it may be possible to take birds for "management purposes" outside the normal hunting framework dates under the newly revised Migratory Bird Treaty. This cannot occur until the U.S.

Senate has provided its "advice and consent" and the President has ratified the Treaty. International consultation and regulations could follow. Harvest could be permitted under special rules and regulations using normal hunting techniques after March 10. Hunting after March 10 currently occurs only in the northern regions of Canada where people with aboriginal status are allowed to take birds in the spring. One way a management type of hunt could be accomplished is by issuing special collecting permits to hunters. This would be done by the U.S. Fish and Wildlife Service (FWS), Canadian Wildlife Service (CWS) or through state or provincial agencies. It is important to make a distinction between the normal hunting seasons and a management season designed to harvest excess birds from the population.

Snow geese are known to be in excellent condition and a far superior table bird during the spring. In addition, spring hunting would likely draw considerable interest from waterfowl hunters because other migratory bird seasons would not be open.

B. Late Season Hunting

Hunting could be permitted during the late season, prior to March 10. In 1996, hunting of snow geese was permitted in “southern states” (including portions of Iowa and Nebraska and states south) until March 10. The same opportunity could be provided to northern states which may have snow geese present prior to March 10. Opponents to this late season hunting argue that geese should not be hunted during the spring migration period when nutrient reserves are being accumulated and reproductive activities are starting. Additional arguments center around disturbance to other species during the spring migration period. Late season hunting may provide the best opportunity for hunting mortality to be additive and thus have maximum snow goose population control benefits. Currently, the 107-day season length restriction (required by the Migratory Bird Treaty) limits hunting opportunity for snow geese in southern areas north to and including Ontario. Late seasons also provide excellent opportunity to attract additional snow goose hunters because other migratory bird seasons are not open. Note: Snow goose hunting is permitted until March 10 for the 1996-1997 hunting season throughout the Mississippi and Central Flyways, except for the Rainwater Basin portion of Nebraska.

C. Hunting Methods

Restrictions on hunting methods (manner of taking) could be eased to allow increased opportunities to harvest snow geese. Many state, provincial and federal regulations on hunting methods were implemented to help protect waterfowl populations, to regulate hunter ethics and to make hunting more “fair”. Historically, such regulations include, but are not limited to, prohibitions on the use of electronic calls, baiting, live decoys, methods of concealment, sneaking, hazing, shooting from vehicles, the types of firearms that can be used, and the number of shells allowed in a gun magazine. Currently, many of the US federal regulations are being considered in a rewriting of 50CFR. States and provinces also have laws and regulations which may unnecessarily restrict hunters attempting to take snow geese. Many of these regulations are not appropriate for a waterfowl population that needs to be controlled. Because of concern for impacts to other species, regulations could be relaxed first in areas with “snow goose only” seasons. If regulation changes are demonstrated to be successful in increasing the harvest of snow geese in these areas, then regulation changes for snow geese could be pursued where and when other species are also hunted. In many cases both federal and state or provincial regulations would need to be changed.

Many hunters and commercial hunting guides are convinced that permitting the use of electronic calls would greatly enhance the harvest of snow geese. Snow goose harvest is low because of the many “experienced” adults in the population and because of their gregarious behavior of traveling in large flocks during the fall and winter. During the past 30 years, snow geese have learned to avoid decoy spreads and thus have become very difficult to hunt. Electronic calls were apparently used legally for a few years in the early 1960's and showed great promise in attracting geese to decoys. Electronic calls could bring birds into closer range over decoys allowing hunters to harvest more birds. An additional benefit would be the reduced loss of birds to crippling. Law enforcement would likely have concerns about the potential use of electronic calls when harvesting other species. Electronic calls could first be allowed in “snow goose only” hunt areas. It is not known if snow geese would learn to avoid electronic calls after several years of use. Research to measure changes in snow goose response to electronic calls should be conducted.

D. Subsistence Harvest in the Far North

Subsistence harvest in the far north could be increased. Increasing the harvest by native people in the Arctic could increase the overall harvest of snow geese, and could be managed so as to be colony-specific to a large extent. Subsidies have recently (1994) been implemented in the Northwest Territories to provide people with transportation equipment for trapping; this coincidentally serves to improve the potential for access to geese in spring. Communities associated with goose colonies are not currently restricted in their harvest. However, with encouragement, people would respond by harvesting more geese to be shipped to neighboring communities which do not have access to birds. The proposed Amendment to the Migratory Bird Treaty between the United States and Canada provides the opportunity for commercial sale and trade of migratory birds within and between aboriginal communities in Canada for peoples whose land claim settlements call for this provision. Some communities have already indicated an interest in pursuing this, specifically to help with the problem of overabundance, and in ways consistent with long term conservation (e.g., they would prefer colony specific quotas). This interest and awareness should be supported, with assistance in developing a long-term program directed at maintaining a reduced population. It would be important to develop monitoring activities to measure the harvest and impacts on goose numbers in individual colonies.

E. Egging

The taking of eggs on the breeding grounds for subsistence purposes could be increased. Migratory bird eggs are a traditional source of food for northern residents. Egging has declined over most of the Arctic for a variety of reasons. It may to be possible to reinstate the egging tradition in groups of native people. The potential to use egging to help control snow geese suggests the need to investigate sustainable egging techniques best suited for waterfowl populations that are increasing, decreasing or stable. Such a study has been proposed by Bob Bromley, Northwest Territories waterfowl biologist. The proposed experimental population would be lesser snow geese on the west Hudson Bay coast. Recommendations for egg quotas could be developed.

F. Provide Additional Hunting on State, Provincial and Federal Refuges

Additional snow goose hunting opportunity could be provided on state, provincial and federal refuges. Allowing hunting in refuges used by snow geese could increase the total harvest and indirectly provide benefits similar to hazing. In some cases, hunting opportunities could be increased with little effort. In other situations, extensive redirection of refuge management activities would be required. There are concerns about the impacts of increased snow goose hunting on refuges to other species which are also hunted on refuges. Refuges could first be opened during “snow goose only” seasons such as currently occur during the late season in southern states. If increased snow goose hunting seasons on refuges were successful, managers could develop strategies to address concerns about hunting snow geese and other species on refuges at the same time. In some cases, principally fall staging areas, refuges or rest areas serve to hold birds during the hunting season and thus contribute to increased harvest. Elimination of these types of areas could decrease harvest in these areas. Also, increased hunting on refuges could increase depredation problems on surrounding croplands. Disturbance and impacts to other migratory birds could be a major concern. Use of this strategy in conjunction with strategy II-C could increase the efficiency of both strategies in reducing and controlling snow goose numbers.

G. Award Programs

Awards or incentives could be offered to increase the harvest. Reward leg bands applied to geese could be used to increase hunter interest in taking snow geese. A high value or “million dollar” leg band or multiple bands of lesser value could generate considerable interest in snow goose hunting. Similar programs have been used in fishing contests for many years. If a reward band were applied to an adult goose, the probability of harvest would be low. The cost of the prize could be covered by an insurance policy. Contest participation forms could be sold, with proceeds being dedicated to additional snow goose management efforts. Another option would be a “lottery” based on a randomly selected band number from leg bands turned in by hunters. Programs such as these could generate considerable interest in snow goose hunting, but could also lead to some waste or problems, either perceived or real, with hunter behavior or hunter ethics. Any activity dealing with bands could also be detrimental to other waterfowl banding programs by changing reporting rates. There may be other avenues to pay or somehow reward hunters who assist with snow goose population control. In some regions it may be most efficient and economical to hire people to harvest snow geese using normal hunting techniques.

H. Reciprocal, International or Inter-state/Provincial Snow Goose Hunting Licenses

Wildlife agencies could cooperate to allow hunters legally licensed to hunt waterfowl in their own home state or province to hunt snow geese in another state or province. This would not preclude the need to purchase Canadian or US federal migratory bird hunting stamps. States/Provinces could require reciprocal legislation or could allow “free” snow goose hunting without reciprocity. As an example, if appropriate legislation was passed by states and provinces, a hunter legally licensed to hunt waterfowl in North Dakota, could also hunt snow geese (only) in Saskatchewan (if he/she had a Canadian Migratory Bird Hunting Permit), and any other cooperating state or province from Minnesota and South Dakota to Texas and Louisiana if he/she had a federal Duck Stamp. Hunters wishing to hunt species other than snow geese would need to purchase appropriate licenses. This strategy would serve to increase snow goose hunting activity, increase snow goose harvest, increase the number of hunters, recruit new hunters, help to build hunting traditions, increase sales of arms and ammunition (and thus Pittman-Robertson funding), and increase waterfowl hunting expenditures into local, regional and national economies. A problem could be the logistics of passing similar legislation in all participating states and provinces. Some may argue that this program could reduce income from license sales. However, it seems unlikely that many hunters would hunt only snow geese year after year. Many of these hunters would be recruited to hunt other species and thus benefit wildlife agencies through license purchases. This strategy would have very low administrative costs and could be especially useful for states and provinces where snow geese regularly move across political boundaries. Currently, several states (North Dakota, Minnesota, and Colorado) have reciprocal reduced license fee agreements for youth waterfowl hunters.

I. Improved Access for Hunting on Private Land

Agencies could work to improve access to snow goose hunting on private lands. A major problem faced by many hunters is gaining access to private land for hunting. In most areas, private land is posted to prohibit hunting or leased to specific hunters or guiding services. Increasing the proportion of the landscape available to hunters would increase hunting opportunity and the harvest. Agencies could seek to increase access through information and education programs, individual contacts, purchasing or leasing hunting rights, tax incentives or other options. This strategy would increase the harvest of snow geese as well as provide benefits similar to hazing.

J. Subsidize Hunting

Agencies could work to reduce the cost of snow goose hunting or provide financial incentives for hunters and guides. Some hunters may not take up hunting because of the expense and difficulty in purchasing, maintaining and transporting equipment, especially decoys. Agencies, tourism promotion groups, chambers of commerce, wildlife clubs or private enterprise could supply or arrange for decoys, trailers and other equipment (such as coveralls, blinds, guns and calls) through loan or rental. There are several examples of similar incentive programs. Currently, North Dakota Game and Fish Department has a fishing equipment loan program through libraries for youth wanting to fish. The North Dakota Park Service has a camping equipment program for those wishing to try camping. Such a program would be especially useful to novice or first-time hunters, students, apartment and urban dwellers and nonresidents who fly or travel long distances to hunt but don't wish to hire guides. A long-term benefit of such a program may be the recruitment of new hunters. An additional approach may be to help develop guide operations. Agencies could help individuals acquire small business loans or grants or provide other subsidies to assist in the development of snow goose guiding operations.

K. Bag Limits and Possession Limits

Bag and possession limits could be liberalized. Bag limits for snow geese have been liberalized over the past 15 years. While it was recognized that increases in bag limits would have little impact on the total harvest, limits were liberalized to provide as much hunting opportunity as possible. Bag limit and season length changes have also increased the sportsmen's awareness of the snow goose population problem. Snow goose hunting is often a 'boom or bust' situation. Many times hunters have opportunities to take only a few birds. Less frequently, hunters have opportunities to take large numbers of birds. In these cases, more liberal bag limits, or even no bag limit, could serve to increase harvest. Guides are generally opposed to large bag limits because it increases the time and cost of providing hunts.

Possession limits can restrict the harvest for nonresidents and residents who travel and hunt more than two days. Thus, increases in possession limits could serve to increase harvest. There may be a need to consider the secondary effects of bag and possession limit liberalizations on other species. There is also concern that additional increases in bag and possession limits could degrade the image of snow geese as a desirable migratory game bird. Some are concerned that excessive bag limits will "devalue" snow geese in the minds of hunters and the public. Note: Snow goose possession limits were increased to 30 in the Mississippi Flyway and 40 in the Central Flyway and four times the daily bag in Manitoba for the 1996-97 season.

An alternative approach would be to issue tags that would allow hunters to take a set number of birds (say 100) during each season. Hunters could take all the birds in a single day or spread the take out throughout the season. Once the tags were used, then hunters could still be allowed to hunt under daily bag and possession limits. A similar approach would be to issue bonus tags which could be used by hunters to take birds in excess of the daily bag limit. Only birds in excess of the daily bag limit would need to be tagged. Such tags could be called "Arctic Habitat Conservation Tags" to help educate hunters about the need to harvest additional snow geese.

L. Shooting Hours

Shooting hours could be adjusted to increase hunting opportunity and harvest. Shooting hours for waterfowl end at sunset in the United States and one-half hour after sunset in Canada. Extending shooting hours in the U.S. to one-half hour after sunset could increase snow goose harvest.

Half-day hunting is currently used in ND, MB and SK and many private hunting areas in southern states to increase the harvest of snow geese. Restricting hunting to the first half of the day allows geese to rest and feed and encourages them to remain in an area for an extended time period. Although harvest in a local area may be increased by half-day hunting, geese which remain on northern migration areas in the fall may experience higher survival rates than those that are forced to migrate earlier. Elimination of half-day hunting could reduce the total take of geese in northern areas but increase the take in other areas. Survival rates could decrease if hunting pressure forced geese to migrate rather than remain in an area to build nutrient reserves. To be effective, half-day hunting may need to be eliminated simultaneously in adjoining jurisdictions.

Snow geese can quickly adapt to half-day shooting hours by feeding only in the afternoon. Some type of variable or changing shooting hours in half-day hunt areas could increase the harvest. Shooting hours could be periodically adjusted so that snow geese could not adapt to regular shooting hour schedules, while still allowing adequate feeding time so that birds would not be driven from the area. Research or evaluation of periodic shooting hour changes should be conducted to determine their effectiveness in increasing harvest.

M. Nonresident Hunter Quotas, Day and Zone Restrictions

Agencies could work to increase the number of nonresident snow goose hunters. Some states and provinces have restrictions on the number of nonresident waterfowl licenses sold, restrictions on the number of days nonresidents can hunt and restrictions on zones open to hunting by nonresidents. These restrictions could be eliminated or changed to encourage nonresidents to hunt snow geese. Virtually all states and provinces charge higher fees for nonresident waterfowl hunters. These fees could be reduced to encourage snow goose hunting.

N. Information and Education Program

Snow geese can be more difficult to hunt than other geese and snow goose hunters tend to have lower rates of success. There are likely several reasons for this. Snow geese usually occur in large flocks which makes decoying and other hunting techniques difficult. Additionally, a high percentage of the population is composed of older, experienced adults which are more difficult to hunt successfully. Snow geese experience boom or bust production. In years with high production, an abundance of young (inexperienced) birds in the flocks increases hunter success. Hunters have low success during production busts when few young birds are present. Snow goose hunting can be quite expensive and time consuming compared to other geese. Many of the more successful hunters use one thousand or more decoys. Snow geese receive mixed reviews as to table quality. While many people enjoy eating snow geese, other find other goose species more appealing. Snow geese generally do not pluck well as the skin frequently tears during plucking.

Communication efforts could be undertaken to increase hunting and the harvest of snow geese. Snow goose hunting could be encouraged by improving the image of the activity, improving perceptions of the desirability of snow goose hunting and helping hunters learn techniques and find places to hunt. Efforts could be directed at recruiting new hunters and recovering hunters who have quit. Seminars, workshops, videos, booklets, popular magazine articles and similar delivery methods would be used. Local organizations, chambers of commerce, guide services and others can work to attract more hunters. Recipes could be developed and promoted in books and magazines to increase the interest in using snow geese as food.

II. POPULATION CONTROL BY WILDLIFE AGENCIES

If improvements in hunting opportunity cannot achieve a higher harvest of birds, and a reduction in the size of the snow goose population to a level commensurate with habitat protection, recovery and maintenance, then direct population reduction will be necessary. Strategies IIA and IIB are aimed at “direct population control”, i.e., purposeful removal of birds from the population using techniques other than hunting. Strategy IIC is directed at reducing the population growth rate and size by reducing both survival and recruitment.

A. Commercial Harvest

Commercial harvest opportunities could be permitted and developed to allow private enterprise to take, process and market snow geese for food. Hunters could also be permitted to sell snow geese to specialized poultry markets. It is understood that the current Migratory Bird Treaty amendment, if approved, will allow the sale of migratory birds only between aboriginal communities in Canada. A basic need may be to reduce regulation restrictions which would make implementation of a commercial harvest difficult. Encouraging a commercial harvest could be a very cost effective way for agencies to increase snow goose harvest. Both hunters and the general public may find commercial harvest distasteful. Birds harvested commercially could be sold for food in the United States and Canada or shipped to native communities in the north for use as food. Birds could also be shipped to Europe where there is a thriving market for wild game, including waterfowl. A concern is that commercial operators may become dependent on snow geese as a source of income and that the snow goose population may not be able to support a commercial harvest in every year. If the population were reduced, demands for commercial harvest would compete with demands for hunting opportunity. Commercialization of a snow goose harvest would have to be initiated with a full understanding that commercial harvest would be reduced or eliminated when populations were at objective levels.

B. Trapping and Culling Birds on Migration and Wintering Areas

Wildlife agencies or their designees could capture geese using a variety of techniques such as rocket netting. Captured geese would be killed and used for human consumption. Donation to food shelters or other needy organizations is possible. Feathers and down could perhaps be sold to recover some program expenses if special permits were allowed.

C. Refuge Management

Management practices on state, provincial and federal refuges could be changed to reduce the availability of food subsidies, roosting areas and areas safe from hunting. The concept is to decrease survival of adult and young birds and to reduce their reproductive potential. Efforts such as eliminating or reducing agricultural crops which provide food, managing water, restricting roost sites and permitting activities which help to move birds off refuge situations would all help to reduce population growth. Conflicts may exist with management practices which benefit other migratory birds and wildlife.

PRIORITY RECOMMENDATIONS

The alternative of doing nothing and letting nature take its course with snow geese and arctic habitats is rejected. The snow goose problem is a man-caused problem. Doing nothing to correct this situation would lead to a significant environmental disaster. Therefore, it is recommended that appropriate management actions be implemented as quickly as possible.

It is believed that no single management strategy can correct the snow goose overpopulation problem. Rather, population control will only be achieved through application of a variety of techniques each applied wherever and whenever possible. Virtually all strategies considered and proposed are controversial at some level. Most, especially those with the most promise for successfully achieving population control, are highly controversial. Resolution of controversial aspects of the most potentially effective strategies should be a priority focus of all agencies involved.

A comprehensive communication plan aimed at informing all potentially affected interests across North America about the snow goose problem and the need for resolution needs to be developed and implemented immediately. In addition to informing people about the problem, this plan should also contain specific strategies for dealing with the controversies implicit in implementing population control measures. It must be geared at obtaining the consent or “permission to proceed” from those most likely to stand in the way of successfully dealing with the snow goose problem. To ignore these interests and their concerns will guarantee failure. Because the primary authority and responsibility for management of these populations lies with the U.S. Fish and Wildlife Service and the Canadian Wildlife Service, these two agencies need to take the lead in accomplishing this task. State and provincial agencies and other partners who have a large stake in the welfare of snow geese and arctic habitats must stand prepared to provide as much assistance as possible.

Increasing hunting opportunity needs to be the focus of initial snow goose population control efforts. All reasonable avenues for increasing the kill of snow geese by hunting need to be implemented across the United States, Canada and Mexico prior to consideration of more direct and rigorous techniques (II-A and II - B). If the mid-continent snow goose population is not reduced by 50 percent by 2005 (or significant progress is not being made), then efforts should be initiated to implement strategies aimed at direct population control as detailed under Section II.

The Mississippi and Central Flyway Councils were asked to review an earlier draft of proposed management strategies and to recommend those which should receive high priority for implementation. Two recommendations which received a “priority” recommendation from both the Central and Mississippi Flyways were implemented for the 1996-1997 waterfowl season: 1) extending snow goose hunting frameworks to March 10 throughout both flyways and 2) increasing possession limits.

In addition, both flyways recommended three other strategies for immediate implementation.

1. Relax restrictions on the use of electronic calls. This should be first done at times and in areas with “snow goose only” seasons. Research should be conducted to determine the

effectiveness of this technique and to provide baseline data to determine if snow geese learn to avoid electronic calls.

2. Provide additional hunting on state, provincial and federal refuges. Management practices should be adjusted to reduce refuge benefits to snow geese and to increase the harvest both on and around refuges. Changes should include, but not be limited to, opening additional areas on these refuges to hunting, and reducing food resources, roosting areas and areas safe from hunting. Care will be needed to avoid significant impacts to other species using refuges. However, managers must balance the concern for other species on refuges with concern for the snow geese and the variety of other species which depend on healthy arctic habitats. Concern for other species on refuges must not preclude addressing the serious snow goose/arctic habitat problem. Refuge managers should be the target of communication efforts to inform them about the snow goose problem and the role they can play in helping to resolve it. Managers should be charged with the task of reducing refuge benefits to snow geese while maintaining benefits to other species whenever possible.

3. Both Flyways recognized the need to hunt snow geese beyond March 10 and the difficulty in modifying Migratory Bird Treaties to allow this. However, in the long run, Treaty modification to allow spring hunting may be one of the most effective and efficient population control techniques available. The U.S. and Canadian governments should jointly pursue Treaty modifications which will allow management of over-populations of migratory birds. Work on a new Treaty amendment should begin immediately.

The Mississippi Flyway suggested that elimination of state and provincial restrictions on nonresident waterfowl hunting licenses and day and zone restrictions should receive high priority. The Central Flyway agreed that this strategy would be useful, but believed this to be an extremely controversial issue in some states which would require considerable effort to implement legislative changes. The Flyways and state agencies should pursue these issues.

Relaxation of restrictions on shell limits, baiting, hazing, live decoys and shooting hours were all recommended as useful strategies to pursue. Of these, changes in baiting regulations have the most potential for increasing harvest. It was suggested that baiting regulations for snow geese could be identical to that for dove hunting. Shooting hours could be relaxed to allow hunting until one-half hour after sunset as is the current practice in Canada. Again relaxation of these hunting method restrictions could be implemented first in “snow goose only” hunt areas. Both federal governments and state and provincial agencies should cooperate to implement appropriate changes in hunting restrictions which could increase the harvest of snow geese.

Both Flyways recognized the need to increase the harvest by northern residents but also recognized the difficulty of significantly increasing the take by these hunters. Government agencies in Canada should implement strategies to increase the take of snow geese by northern residents.

Both Flyways recognized the potential need for agencies to implement direct population control (II-A and II-B). The high cost of this work and the difficulty and expense of using the birds for human consumption were seen as significant obstacles. At some point, if direct population control becomes necessary, the principle of ethical use of the birds may have to be set aside in favor of more rigorous efforts to control the population and save arctic habitats. While it is hoped that this never occurs, managers need to be aware of and begin preparing for this possibility.

ACKNOWLEDGEMENTS

The original list of management strategies was developed with the assistance of the Central Flyway Waterfowl Technical Committee. The first draft of this report was conceived in Memphis at a meeting of the management strategy subcommittee which included Bruce Batt, Ray Alisauskas, Dave Ankney, Bruce Barbour, Brad Bales and myself. I thank both the Mississippi Flyway Technical Section and the Central Flyway Waterfowl Technical Committee for providing a critical review and comments and suggestions on an earlier draft of this report. Much encouragement and numerous comments, suggestions and improvements were provided through discussions and correspondence with Bruce Batt, Dave Ankney, Bob Bromley, Ken Abraham, Rocky Rockwell, Bruce Barbour, Dave Case and many others. My thanks to all who contributed.

Part V: EVALUATION OF THE ARCTIC GOOSE MANAGEMENT INITIATIVE

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INTRODUCTION

The aim of the monitoring program for the Arctic geese and habitats is to provide the means for evaluating progress toward habitat protection and goose population goals. Our current model of goosehabitat interaction supposes that low harvest rates of geese lead to high adult survival which leads to population growth which in turn causes habitat degradation. We propose to monitor each of these four important components of the interaction model; i.e., harvests, adult survival, goose populations, and status of the tundra habitats. The present proposal deals primarily with white geese but monitoring of other goose species is also required. Populations of large geese breeding in the States and southern parts of the provinces are growing even faster than white geese, provide more hunting opportunity and have the potential to cause ever greater conflicts. The mix of Giant Canadas with other wintering populations requires intensive harvest management (Rusch *et al* 1996). Annual banding and populations estimates are crucial parts of the derivation process used to estimate harvests of the large Canadas.

HARVEST

Harvests of geese are monitored in Canada and the United States by questionaires to hunters and analysis of tail fan collections. Reasonable estimates of white goose harvests can be obtained from these surveys, but colony-specific estimates are not feasible at this time.

Colony-specific harvest estimates could be obtained by derivation analysis (weighted band recovery methods). These require that all breeding colonies are banded and their numbers are estimated. These conditions are not currently being met on any breeding colonies.

The parameter that influences goose survival is harvest rate (HR). Harvest rate can be estimated from the direct band recovery rate (DBRR) and the presumed reporting rate (HR1=DBRR/RR-seeH-f/ϕ, pp 94-96) or from the quotient of harvest and fall flight estimates (HR2=Harvest/Fall Flight). An increase in goose harvest rates is the primary and most important management strategy. We recommend that both HR1 and HR2 be estimated: 1) for snow geese at the metapopulation level (i.e., Western, Central and Eastern Arctic).

SURVIVAL

We believe that adult survival of snow geese is primarily a function of harvest rate, and that increase HRs will lead to reduced adult survival. Alternatively, increased harvest rates may be compensatory rather than additive. Adaptive management requires knowledge of the harvest rate-survival relationship.

Banding

From the standpoint of demographic analysis of goose populations, sufficient geese should be banded or marked to provide precise survival estimates for young and adult geese of each colony or population. Ideally banding would be conducted annually to generate year-specific recovery and survival rates and information on distribution and derivation or harvest. Because of costs and the long-term nature of the initiative, we therefore propose that Arctic banding should be conducted and coordinated with population surveys, and that monitoring efforts should rotate among sites over a period of three years. In the eastern Arctic, for example, snow geese would be estimated and banded at McConnell River, Southhampton Island and Baffin Island on a three-year rotation. We recommend annual banding and surveys of white geese at Cape Hennrietta Maria and La Perouse Bay. Banding goals would be 5,000 adults per year.

Large sample sizes would allow estimation of annual survival rates for adults at the metapopulation level (i.e., Eastern Arctic, etc.) Direct recovery rates and survival rates of young would be also estimated at the metapopulation level.

Enhanced Reporting

We believe a program to enhance the reporting rate of harvested bands is an important part of any Arctic banding program. At present, the cost of banding at a colony in the Arctic ranges between $50,000 and $100,000 depending on the remoteness of the location. If 1000 geese were banded at a remote colony, costs could be as high as $100 per goose. If the average direct band recovery rate is 3%, about 15% of the bands are eventually recovered; thus each recovery would cost about $750. Rewards of up to $200 per band or other similar expenditures to enhance reporting are cost effective for Arctic geese.

POPULATION INDICES AND ESTIMATES

Midwinter Index

The midwinter index is the primary historic and current method of monitoring numbers of snow geese. These indices should continue because they provide valuable long-term trend data at the continental level. Midwinter indices suffer because 1) counts are imprecise due to difficulty counting large numbers and in achieving complete coverage of all areas; and 2) geese counted in winter are aggregations of birds from many colonies, populations and flyways.

Spring and Summer Surveys

We believe that numbers of geese should be estimated on the breeding areas wherever possible. We propose that numbers of snow geese in each colony be estimated once every 3 years from aerial photography or from helicopters flown on stratified transects. Due to lack of consistent funding, only a few helicopter surveys have been flown and aerial photography has been sporadic. Some eastern

Arctic colonies have not been surveyed since 1978. Surveys conducted with banding are an option to consider for remote colonies. August helicopter transects can provide estimates of breeding geese, nonbreeding geese, proportion with young and young per successful adult. Stratified transects flown from helicopters also provide opportunities for banding random samples. Coordination of August surveys and banding would eliminate one or two additional expeditions to remote Arctic colonies.

COASTAL TUNDRA HABITAT

Protection of coastal tundra habitats is the ultimate goal of the proposed goose management strategy, and some habitat monitoring is essential. We propose that the permanent plots established around James and Hudson Bays be expanded throughout the Arctic in coastal tundra habitats. These plots should be monitored on an annual schedule to detect vegetation trends, to elucidate goose vegetation-weather-climate relationships and to provide ground-truth data to permit development and maintenance of habitat signatures for interpretation of satellite imagery.

Satellite imagery of about 20% of all coastal tundra should be obtained and analyzed every year; thus each area would be "revisited" every five years.

EVALUATION

Progress toward program goals should be evaluated annually. The annual evaluation report should describe objectives, strategies and activities and provide preliminary description of progress toward goals. A comprehensive analysis of harvest rates, survival rates, population trends and habitat condition should be conducted every five years.

The five year evaluation should provide detailed quantitative analyses of harvest, survival, population and habitats; and the interactions among these estimates and other environmental variables.

LITERATURE CITED

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Part VI: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE ACTION

Arctic Goose Habitat Working Group

CONCLUSIONS

The Arctic Goose Habitat Working Group concludes:

1. Over-abundance of several populations of Arctic-nesting geese in North America is causing major damage to Arctic habitats used by geese and other wildlife. In some cases this goes beyond a simple "habitat problem" and more on the scale of an "ecosystem in peril".

2. A "trophic cascade" of events, resulting from over-grazing and grubbing by some Arctic geese, creates soil salinity and moisture conditions that lead to desertification of the affected Arctic landscapes. These habitats will not likely regain their original plant communities for many decades into the next millennium. The most degraded of these habitats will likely never recover.

3. This habitat damage is increasing in extent and will not be corrected or reversed by any known natural phenomena. We cannot forecast how long it will be before most of the finite supply of habitat that is available for nesting by tundra- and coastal-breeding birds will be permanently degraded or destroyed. However, the destruction is progressing at a rapid rate with several major breeding colonies of mid-continent lesser snow geese showing extensive signs of permanent habitat degradation.

4. Habitats used by mid-continent white geese are in particular jeopardy. The degradation is such that recruitment rates at several large nesting colonies have declined. In the short term, however, such declines will not likely bring those colonies or the entire mid-continent population under control through density dependent regulation. As nesting and especially brood rearing habitat declines, families simply disperse to adjacent areas that are not yet degraded. Recruitment for those families increases and the geographically larger colony grows in number and continues to spread further. It is not known for how long or over what geographic range this expanding cycle of local growth, degradation and dispersal can or will continue.

5. There appears to be only two ultimate outcomes if management agencies chose a "do-nothing" approach to dealing with these problems: for one, the population will decline dramatically (crash) after recruitment rates fall to the level where they could not maintain numbers in the face of mortality from all hunting and non-hunting causes, especially those related to senescence of surviving adults. If this were to occur, we believe the decline would happen during the early part of the next century and the recovery of populations would be protracted beyond the next century because the habitat to support the rebuilding of populations would be extremely limited.

   Alternatively, the population could remain at relatively high levels, likely continuing to grow for several years, with geese in ever-worsening physiological condition followed by the ultimate destruction of a major component of the Arctic ecosystem that is important, not only to white geese, but also to other geese and a wide variety of migrant and resident vertebrates. Problems with white geese and agriculture in southern areas would continue to grow. Besides the ecosystem consequences, some specialists believe this would lead to high populations of poorly-conditioned birds living, effectively, in "slum" conditions, and this is why the problem will not be self-correcting.

6. Natural resource managers, charged with the long-term welfare of these populations and their habitats, have the responsibility of implementing management programs to prevent the future ecological disaster that we believe is inevitable. A time-frame for the occurrence of widespread ecosystem breakdown isn't readily apparent, since there has been no directly related "real world" experience for managers and scientists by which to make such projections. However, we know the process has already started, we know it is expanding and we think that damage to the most severely degraded habitat is essentially permanent.

7. The most effective population reduction efforts will focus on reducing adult survival as this is the prime factor sustaining growth of these populations.

8. No single technique will solve these problems. Multifaceted and multiagency approaches are required. Most of these will require actions beyond normal waterfowl harvest management frameworks.

RECOMMENDATIONS

The Arctic Goose Habitat Working Group recommends that:

1. The U.S. Fish & Wildlife Service and the Canadian Wildlife Service should assign full time staff coordinators to developing and advancing effective strategies to reduce mid-continent white geese to the desired population levels. This should be established and promoted under an international program named something like the Arctic Goose Management Initiative of the Arctic Goose Joint Venture. The Working Group should be retained in an expert advisory capacity, but believes strongly that full-time staff attention to this problem is needed.

2. A comprehensive communications strategy should be developed and implemented by the CWS and USFWS to inform the general public, sportsmen, private conservation groups, animal welfare organizations, government officials and native American and Canadian aboriginal peoples of the problem caused by over-abundance of certain Arctic and sub-Arctic goose populations. This should be initially focused on mid-continent white geese as they are causing the most severe Arctic ecosystem damage. A fully informed public is critical to the successful implementation of any future management actions.

3. The responsible public agencies in Canada and the U.S. should implement proactive population reduction measures to reduce mid-continent white goose populations to a level of about 50% of current numbers by the year 2005. This requires that the population growth rate be reduced to an annual level of between 0.85 and 0.95 (5% - 15% reduction in total numbers per year) from the current growth rate of about 1.05 (5% growth per year). Because the main driving force in

population growth rate is adult survival and because most of the specific population reduction recommendations relate to increasing the kill by hunters, the harvest rate should be increased to about 3 times the current level.

4. All the management strategies included in Part IV of this report should be considered as viable alternatives for increasing harvest of mid-continent white geese. These have been reviewed and scrutinized by a broad range of professional waterfowl managers from the U.S. and Canada and represent actions that respect the integrity of the birds as important resources for the public at large, as game birds for hunters and as food for all these groups.

5. We applaud the fact that two of the Working Group's recommendations have already been implemented in the Central and Mississippi Flyways for 1996, namely: 1) extending snow goose hunting frameworks to March 10th, and; 2) increasing possession limits to 3 and 4 times the daily bag. We also applaud the Arviat Hunters and Trappers initiative to explore the feasibility of increasing harvest of adults near the McConnell River. The following additional steps should be implemented by the fall of 1997: 1) legalize the use of electronic calling devices for snow goose hunting; 2) legalize baiting for snow geese in special snow goose population reduction seasons, and; 3) provide additional hunting on and around state, provincial and federal refuges by opening additional areas to hunting and reducing food resources to disperse birds to surrounding farm land.

6. Increased harvest by northern residents will also reduce adult survival and thus the growth rate of mid-continent white geese. Discussions should proceed with native Canadians to further develop their participation in this international waterfowl conservation/ecosystem management initiative. For example, we believe native Canadians should be encouraged to increase their harvest of adult white geese to whatever can be effectively used to subsidize their annual nutritional requirements.

   Restrictions on egging of snow goose eggs should be removed. The Natives should be encouraged to shift hunting pressure that they currently apply to other goose populations, especially those in poor population status such as the Southern James Bay Canada geese, to white geese. Consultation with the aboriginal peoples should be pursued to search for other methods that they may be able to employ in this cause.

7. Through Treaty amendment or through special waterfowl management provisions under the current Treaty, extend the hunting period for midcontinent white geese beyond both the current 107 day limit and the March 10th closing date. We urge that this be done within one year of the delivery of this report. This will directly raise additive mortality on breeding-age birds. White geese are in the best condition of the whole annual cycle at this time of year, and therefore are also at their best, in terms of food quality for humans.

8. We emphasize that the evaluation strategy outlined in Part V of this report should be further developed and implemented as part of an overall white goose population management initiative. This should be phased in over the next few years as technical considerations are resolved and as

funds become available. The Working Group does not believe that management actions to reduce populations should be held back until all technical and financial considerations for an evaluation effort are resolved. There is virtually no risk that implementation of the management tools described in this report will have an overwhelming or irreversible impacts on population size in the near term. There is considerable urgency to reduce population growth rates of white geese and to begin to learn about the many other factors impacted by new regulations, such as public acceptance and enforceability. Further, there will undoubtedly be a time lag during which hunters will equip themselves, learn new hunting methods and become more comfortable with the major changes such as late winter and spring hunting. Implementation of the Arctic Goose Management Initiative should provide excellent opportunities for integration of monitoring and management activities in an effective adaptive management application wherein on-going feedback from monitoring is used directly to modify, or affirm, future management actions.