THE STATUS OF ROSS'S GEESE

REPORT OF THE ARCTIC GOOSE JOINT VENTURE ROSS'S GOOSE SUBCOMMITTEE

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

Edited by: Timothy J. Moser

ARCTIC GOOSE JOINT VENTURE ROSS'S GOOSE SUBCOMMITTEE

Ray T. Alisauskas	Canadian Wildlife Service
Andrew B. Didiuk	Canadian Wildlife Service
David C. Duncan	Canadian Wildlife Service
James R. Kelley	U.S. Fish and Wildlife Service
Timothy J. Moser[a]	U.S. Fish and Wildlife Service
Robert F. Rockwell	American Museum of Natural History
Daniel R. Yparraguirre	California Department of Fish and Game

[a] Subcommittee chair
Cover photo by D. K. Kellett Warner, Canadian Wildlife Service

The Status of Ross's Geese

Table of Contents

EXECUTIVE SUMMARY

During the second half of the 20th century, North American light geese (i.e., lesser snow geese {*Chen caerulescens caerulescens*}, greater snow geese {*Chen caerulescens atlantica*}, and Ross's geese {*Chen rossii*}) have exhibited geometric population growth and reached historically unprecedented population levels. The large and rapidly expanding numbers of light geese have resulted in serious ecological and economic damage. Lesser and greater snow geese have been the subject of previous Arctic Goose Joint Venture reports and much media attention, but relatively little information has been compiled regarding the less conspicuous Ross's goose. This report of the Arctic Goose Joint Venture compiles current information on Ross's geese in North America regarding population status, population dynamics, harvest, disease, Ross's goose impact on tundra ecosystems, and projected impacts of current harvest strategies on Ross's goose population growth.

Estimates of Ross's goose population size have increased from 5,000-6,000 wintering geese in 1931 to more than 800,000 in spring of 1998. Although more than 90% of Ross's geese still breed in their traditional Queen Maud Gulf nesting areas, increasing numbers now nest along west Hudson Bay, Southampton Island, the Hudson Bay Lowlands, and Baffin Island. Photo-inventory surveys of the Ross's goose breeding population in 1998 were 6 times higher than population goals of the North American Waterfowl Management Plan and the Pacific Flyway Council.

The wintering distribution of Ross's geese has also greatly expanded eastward from their traditional haunts in California. Once rare outside the Pacific Flyway, Ross's geese comprise a small to substantial proportion of light geese observed during species composition surveys in the Central and Mississippi Flyways. Although harvest and the abundance of Ross's geese continues to increase in the Pacific Flyway, nearly 40% of banded Ross's geese are now recovered in the more easterly Central and Mississippi Flyways.

Ross's geese can degrade the ecosystems in which they reside. Ross's geese have degraded lowland vegetation at Queen Maud Gulf Migratory Bird Sanctuary and west Hudson Bay, predominantly through grubbing in nesting colonies. Because of their ability to closely crop above-ground vegetation, Ross's geese may delay or prevent the recovery of tundra vegetation at sites already impacted by snow geese. Ross's and lesser snow geese are suspected carriers of avian cholera and are among the species that are thought to be reservoirs for the disease. Therefore, the increased abundance and density of Ross's and snow geese likely pose an increased risk in the spread, transmission, and frequency of avian cholera outbreaks in North America.

The continental harvest of Ross's geese has increased substantially since 1962; however, Ross's goose populations have increased rapidly over the last 40 years under harvest rates well above recent and current levels. Harvest rates of adult Ross's geese during 1995-99 were about 3%, the lowest harvest rates since 1961. Juvenile harvest rates during 1995-99 have increased from 5% to 7%, but are lower than estimated harvest rates during 1961-85 and are similar to those during 1986-94.

The observed and modeled growth rates of North American Ross's geese are 8-10% annually. Population models indicate that the North American Ross's goose population will remain above North American Waterfowl Management Plan population goals if current (1999-2000) harvest management strategies are continued, even for a total of 10 years. The rate of population growth or decline depends largely on the population level and the actual realized harvest. Current harvest management strategies for light geese in the Central and Mississippi Flyways appear to pose little threat to maintaining abundant Ross's geese in these regions of recent population expansion and in their traditional Pacific Flyway and Canadian range. Programs to monitor Ross's and other North American light goose resources should be continued and enhanced.

Chapter 1:

INTRODUCTION

Timothy J. Moser, U.S. Fish and Wildlife Service
Ray T. Alisauskas, Canadian Wildlife Service

During the second half of the 20th century, North American light geese (i.e., lesser snow geese {*Chen caerulescens caerulescens*}, greater snow geese {*Chen caerulescens atlantica*}, and Ross's geese {*Chen rossii*}) exhibited geometric population growth and have reached historically unprecedented population levels. The rapidly expanding numbers of light geese have been implicated in serious ecological and economic damage, particularly in Canada's Arctic and subarctic (Ankney 1996, Abraham and Jeffries 1997). An earlier report of the Arctic Goose Joint Venture, *Arctic Ecosystems in Peril* (Batt 1997) provided a comprehensive overview of continental light goose issues and problems, with a focus on midcontinent lesser snow geese. A subsequent report, *The Greater Snow Goose* (Batt 1998), specifically addressed issues and dynamics of that eastern North American subspecies. This report, *The Status of Ross's Geese,* compiles current information on the Ross's goose, the third and least conspicuous taxon of North American light goose.

Ross's geese resemble diminutive versions of lesser snow geese, although other morphological differences are apparent on close inspection. Ross's geese are frequently overlooked due to their small size and their sympatric distribution with the more abundant lesser snow goose throughout their annual life cycles. Due to the formerly low numbers of Ross's geese, their restricted breeding and wintering ranges which are shared with snow geese, and the similar appearances of Ross's and snow geese, knowledge regarding Ross's goose population status is more limited than for other light geese. The breeding grounds of the Ross's goose were discovered only in 1938 (Gavin 1940). The species was thought to have been near extinction in the early 1900s and to number only 5,000-6,000 in 1931 (Ryder and Alisauskas 1995). Since then, Ross's geese have exhibited rapid growth in numbers and distribution, and by 1998 the North American spring population of Ross's geese was estimated to number at least 800,000 birds (F. D. Caswell, Canadian Wildlife Service, unpublished data; R. T. Alisauskas et al. 1998, Canadian Wildlife Service, unpublished report).

Recent research and monitoring have documented the rapid population increase of Ross's geese, the expansion of their breeding range eastward across Canada's Arctic and subarctic, and the winter range expansion from California eastward to the midcontinent of the United States and to Mexico. Nevertheless, the extent to which Ross's geese contribute to the environmental and economic concerns associated with other North American light geese has not been explicitly addressed.

In October of 2000, the Arctic Goose Joint Venture (AGJV) formed the Ross's Goose Subcommittee to compile and summarize existing information specific to Ross's geese. This report, *The Status of Ross's Geese*, subsequently was endorsed by the AGJV Management Board in March of 2001 and complements information presented in *Arctic Ecosystems in Peril* (Batt

1997). *The Status of Ross's Geese* addresses topics of Ross's goose biology, population status, disease, harvest, habitat interactions, and population dynamics. To the extent available information allows, this report examines: (1) the impact that Ross's geese have on northern habitats; and (2) the potential effect on Ross's goose populations resulting from harvest regulations that have been implemented to reduce populations of midcontinent lesser snow geese. The authors hope that this information will facilitate science-based management of North America's important light goose resources.

ACKNOWLEDGMENTS

LITERATURE CITED

Abraham, K. F., and R. L. Jeffries. 1997. High goose populations: causes, impacts and implications. Pages 7-72 *in* B. D. J. Batt, editor. 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.

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, D. Stern, and K. D. Warner. 1998. Spatial and temporal dynamics of Ross's and snow goose colonies in Queen Maud Gulf Bird Sanctuary, 1966-1998. Progress report on numbers of geese and colonies, September 1998. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Ankney, C. D. 1996. An embarrassment of riches: too many gaggles of geese. Journal of Wildlife Management 60:217-223.

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.

Batt, B. D. J., editor. 1998. The greater snow goose: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication. U.S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario.

Gavin, A. 1940. Where the Ross' Geese nest, part II. The discovery. Beaver (Dec):8-9.

Ryder, J. P., and R. T. Alisauskas. 1995. Ross' Goose (*Chen rossii*). Number 162 *in* A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Chapter 2:

SPECIES DESCRIPTION AND BIOLOGY

Ray T. Alisauskas, Canadian Wildlife Service

Ross's geese (*Chen rossii*) share the genus with lesser snow geese (*Chen caerulsecens caerulescens*), and greater snow geese (*Chen caerulescens atlantica*). They are closely related to snow geese (Avise et al. 1992), and occasionally hybridize with them (Trauger et al. 1971, Alisauskas et al. 1998a). In this report, they are collectively referred to as light geese. Before recent expansion in range and numbers of all 3 groups (see below), winter populations of Ross's geese were found largely in the western United States and, during breeding, Ross's geese were largely confined to Canada's central Arctic (Bellrose 1976). Ross's geese were and still are associated with lesser snow geese during their annual cycle. Members of this genus are highly gregarious, but Ross's geese frequently occur with lesser snow geese in large flocks of up to several hundred thousand birds. Co-occurrence of Ross's geese and greater snow geese in eastern North America is rare.

Ross's geese are the smallest bodied of the three groups of light geese, with white plumage and black tips on primary wing feathers, a trait shared with snow geese. Lesser snow geese show variation in plumage color giving rise to white phase and blue phase individuals; there is an east-west cline in plumage color ratios of lesser snow geese with blue phase most common in the east and white phase most common in the west. "Blue" plumage exists within both Ross's and greater snow geese, but is very rare (McLandress 1983). Downy Ross's goose goslings show a polymorphism (white vs. yellow) not evident after 3-4 weeks, and the genetic basis for this is unknown (Cooke and Ryder 1971). Relative to snow geese, Ross's geese are not only smaller, but are also different in body proportions. The neck is shorter in relation to its body, and the bill is shorter relative to head size. Ross's geese lack the "grin patch" and large lamellae (i.e., tooth-like serrations) along edges of upper and lower mandibles (i.e., jaws) that are characteristic of snow geese. Ross's geese can have various-sized caruncles, or wart-like structures, along the base of the bill (McLandress and McLandress 1979), a feature absent in both lesser and greater snow geese. Juvenile plumage tends to be slate gray in Ross's geese, but intensity and extent on the body is less than in snow geese and not as obvious in the field nor in the hand. Ross's geese have different vocalizations (Ryder and Alisauskas 1995) and a more rapid wing beat than lesser snow geese, however discriminating between the two species, particularly when they are flying, is still difficult without experience.

Weights of Ross's geese (Ryder and Alisauskas 1995) and lesser snow geese (Ankney 1982) are highly variable during the annual cycle because both can store large amounts of fat (Ankney and MacInnes 1978, Bon 1996). Nevertheless, adult Ross's goose females (1,826 ± 160 g, *n* = 75) weigh less than adult snow goose females (2,706 ± 270 g, *n* = 99) upon arrival at the Karrak Lake breeding colony (R. T. Alisauskas,

Canadian Wildlife Service, unpublished data). Age of first reproduction and breeding probability by adult Ross's geese are the subject of current research, and may differ from respective rates observed in snow geese. Despite differences in egg and body size, the incubation period in both Ross's geese and snow geese ranges from about 21 to 23 days. Craig (2000) suggested that Ross's goose embryos attain a higher level of functional maturity in the egg than do snow geese, thereby hatching in a more developed state (Slattery and Alisauskas 1995). Ross's geese tend to disperse farther from nesting areas than do snow geese during brood rearing (Slattery 1994). Ross's geese appear to possess greater adaptations for dispersal to brood-rearing areas, e.g., greater functional maturity of hatchlings, compared to lesser snow geese (Slattery and Alisauskas 1995). Differences in dispersal distances may be related to differences in food preference between species, and may be consistent with interspecific differences in bill morphology. Alisauskas (1998) suggested there were differences in the habitats occupied on the midcontinent wintering grounds by Ross's and lesser snow geese, due in part to differences in bill morphology and possible diet preferences. Ross's geese appear to avoid coastal marshes (Harpole et al. 1994), but currently are increasing in numbers on inland agricultural habitats in the midcontinent (Alisauskas 1998).

Clutch size at Karrak Lake for Ross's geese (3.31 ± 0.01, $n = 5,182$) was lower than for snow geese (3.55 ± 0.02, $n = 4,770$) from 1991 to 2000. Over the same period, nest success was similar, 84.5% and 81.3%, respectively. In some years, snow geese at Karrak Lake show a substantial decline in nest success not exhibited by Ross's geese. Ross's goose eggs are smaller than those of lesser snow geese, and it is possible to discriminate between nests of the two species by egg size (Alisauskas et al. 1998a).

Most Ross's geese in the Queen Maud Gulf Bird Sanctuary share nesting colonies with snow geese. Despite this, there seem to be few extra-pair fertilizations (Dunn et al. 1999). Previously, Ross's geese tended to select islands in shallow lakes for nesting colonies, but more recently they are found nesting in greater numbers on mainland areas (Alisauskas and Boyd 1994), possibly a consequence of increasing numbers of snow geese whose presence may improve chances of successful nesting by Ross's geese. For example, Bantle (1998) showed that attack rates by Ross's geese on foraging arctic foxes increased in relation to increasing density of snow geese.

Peak spring migration by snow geese in western Saskatchewan occurs before 1 May, whereas it is after 1 May by Ross's geese, which may be found in high numbers there as late as 15 or 20 May. At Karrak Lake, Ross's geese also have a somewhat different migration chronology, arriving and nesting 3 or more days later than snow geese (Alisauskas 2001). Dzubin (1965) reported that Ross's geese begin to arrive in southern Saskatchewan by the first week of September, with the greatest influx in late September; departures were largely completed by mid-October. Ross's geese now may remain until the end of October, mixing and departing with large numbers of snow geese. Changes in fall migration chronology remain to be quantified.

Whereas midcontinent lesser snow geese breed in high numbers over large areas of Canada's eastern and central Arctic (Cooke et al. 2000), most Ross's geese apparently

are still largely confined to Canada's central Arctic in and near the Queen Maud Gulf Bird Sanctuary. Most light geese there nest in 5 or 6 colonies, the largest of which is at Karrak Lake (Kerbes 1994, Alisauskas et al. 1998b). However, the number of new colonies is growing (Alisauskas and Boyd 1994) and it is unlikely that all existing colonies with Ross's geese are known. The 2000 population estimate at Karrak Lake was $395,000 \pm 106,000$ (95%CL) Ross's geese, and $264,000 \pm 42,000$ snow geese (Alisauskas 2001). Ongoing research at Karrak Lake leading to estimation of various vital rates (survival, fecundity, age of first reproduction, breeding propensity, immigration, and emigration) will improve population modeling of Ross's geese.

Little is known about habitat use and requirements of Ross's geese during spring migration through boreal regions from Prairie Canada to Arctic nesting areas, and from brood-rearing areas to Prairie Canada in late summer and autumn. Greater detail about Ross's goose biology is provided by Ryder and Alisauskas (1995).

LITERATURE CITED

Alisauskas, R. T. 1998. Winter range expansion and relationships between landscape and morphometrics of midcontinent Lesser Snow Geese. Auk 115:851-862.

Alisauskas, R. T. 2001. Nutritional ecology and population biology of Ross's Geese. Progress report, January, 2001. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Alisauskas, R. T., and H. Boyd. 1994. Previously unrecorded colonies of Ross' and Snow geese in the Queen Maud Gulf Bird Sanctuary. Arctic 47:69-73.

Alisauskas, R. T., S. M. Slattery, J. P. Ryder, M. L Gloutney, A. D. Afton, R. H. Kerbes, and M. R McLandress. 1998a. Discrimination of Ross' and Lesser Snow Goose eggs. Journal of Field Ornithology 69:647-653

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, D. Stern, and K. Warner. 1998b. Spatial and temporal dynamics of Ross's and snow goose colonies in Queen Maud Gulf Bird Sanctuary, 1966-1998: Progress report on numbers of geese and colonies, September 1998, Canadian Wildlife Service, Saskatoon, Saskatchewan.

Ankney, C. D. 1982. Annual cycle of body weight in lesser snow geese. Wildlife Society Bulletin 10:60-64.

Ankney, C. D., and C. D. MacInnes. 1978. Nutrient reserves and the reproductive performance of female Lesser Snow Geese. Auk 95:459-471.

Avise, J. C., R. T. Alisauskas, W. S. Nelson, and C. D. Ankney. 1992. Matriarchal population genetics structure in an avian species with female natal philopatry. Evolution:1084-1096.

Bantle, J. L. 1998. Arctic fox predation on Ross's and Lesser Snow Geese. Thesis, Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania.

Bon, R. L. 1998. Spring nutritional ecology of migrating and breeding Ross' Geese. Thesis, Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.

Cooke, F., and J. P Ryder. 1971. The genetics of polymorphism in the Ross' goose (Anser rossii). Evolution 25:483-490.

Cooke, F., C. M. Francis, E. G. Cooch, and R. T. Alisauskas. 2000. Impact of hunting on population growth of mid-continent Lesser Snow Geese *in* H. Boyd, editor. Population modelling and management of Snow Geese. Canadian Wildlife Service Occasional Paper No. 102.

Craig, L. M. 2000. Comparative incubation ecology of Ross's and Lesser Snow Geese at Karrak Lake, Nunavut. Thesis, Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan.

Dunn, P. O., A. D. Afton, M. L. Gloutney, and R. T. Alisauskas. 1999. Forced copulation results in few extrapair fertilizations in Ross's and lesser snow geese. Animal Behaviour 57:1071-1081.

Dzubin, A. 1965. A study of migrating Ross' Geese in western Saskatchewan. Condor 67:511-534.

Harpole, D. N., D. E. Gawlick, and R. D. Slack. 1994. Differential winter distribution of Ross' Geese and Snow Geese in Texas. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 48:14-21.

Kerbes, R. H. 1994. Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Canadian Wildlife Service Occasional Paper No. 81.

McLandress, M. R. 1983. Winning with warts? A threat posture suggests a function for caruncles in Ross' geese. Wildfowl 34:5-9.

McLandress, M. R., and I. McLandress. 1979. Blue-phase Ross' geese and other blue-phase geese in western North America. Auk 96:544-550.

Ryder, J. P., and R. T. Alisauskas. 1995. Ross' Goose (*Chen rossii*). Number 162 *in* A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural

Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Slattery, S. M. 1994. Neonate reserves, growth and survival of Ross' and Lesser Snow Goose goslings. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Slattery, S. M., and R. T. Alisauskas. 1995. Egg characteristics and body reserves of neonate Ross' and Lesser Snow Geese. Condor 97:970-984.

Trauger, D. L., A. Dzubin, and J. P. Ryder. 1971. White geese intermediate between Ross' Geese and Lesser Snow Geese. Auk 88:856-875.

Chapter 3:

DISTRIBUTION AND ABUNDANCE

James R. Kelley, U.S. Fish and Wildlife Service
David C. Duncan, Canadian Wildlife Service
Daniel R. Yparraguirre, California Department of Fish and Game

DISTRIBUTION

Approximately 90-95% of all Ross's geese breed in the Queen Maud Gulf region of the central Canadian Arctic (Kerbes 1994). Small numbers of Ross's geese also breed on Banks Island in the western Arctic, along western and southern Hudson Bay, and Southampton and Baffin Islands in the eastern Arctic. Prior to the 1960s, Ross's geese nested primarily in the central Arctic region and most birds migrated to wintering areas in California. This species has dramatically expanded its range eastward in recent decades (Ryder and Alisauskas 1995; Fig. 1). Examination of the distribution of Ross's goose harvest among Flyways illustrates the range expansion. Ross's geese did not occur in the Central Flyway harvest survey until 1974, and did not occur in the Mississippi Flyway harvest survey until 1982. The first occurrence of Ross's geese in the Atlantic Flyway harvest was in 1996 (Sharp and Moser 2000). A large proportion of Ross's geese winter
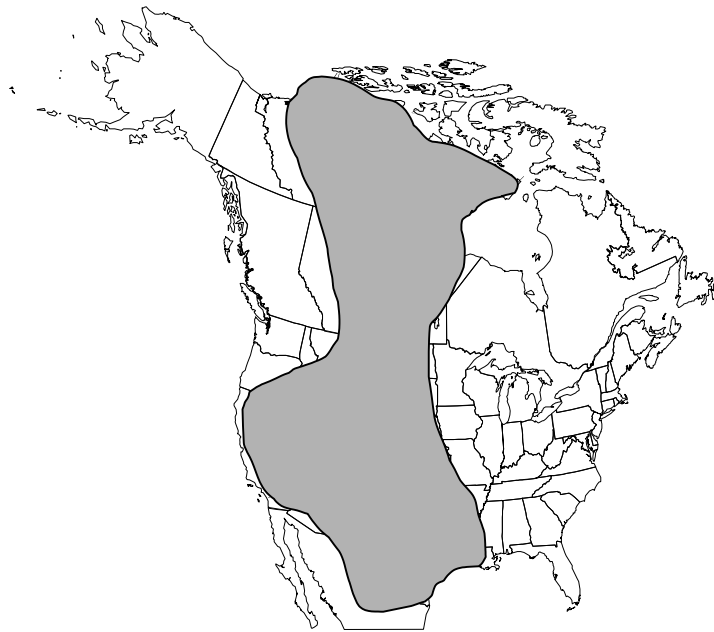

Fig. 1. Primary geographic range of the Ross's goose.

in the Central Valley of California (Ryder and Alisauskas 1995). Smaller numbers of Ross's geese winter in New Mexico, Texas, Mexico, Louisiana, and Arkansas. Changes in the distribution of harvest and recoveries of banded birds further illustrates the range expansion from the 1950s to the 1990s (Moser and Duncan, this report).

Ross's geese in the Mid-continent Population (MCP) of light geese. These Ross's geese migrate primarily through North Dakota, South Dakota, Nebraska, Kansas, Iowa, and Missouri, and winter in Arkansas, Louisiana, Mississippi, and eastern, central, and southern Texas. Field studies conducted in Texas during winter indicate that Ross's geese comprise approximately 5.7% of light geese (lesser snow and Ross's geese combined) found in the MCP range (Texas Parks and Wildlife Department, unpublished data). Ground-based observations of light goose flocks wintering in Louisiana during 2001 indicated that Ross's geese comprised 2.3% of all light geese in sampled areas, and up to 19% of individual flocks (Helm 2001).

Ross's geese in the Western Central Flyway Population (WCFP) of light geese. These Ross's geese winter in southern Colorado, northwestern Texas, New Mexico, and the Northern Highlands of Mexico (Hines et al. 1999). Intensive surveys of WCFP light geese are conducted at major migration and wintering areas in Colorado, New Mexico, Texas, and Chihuahua, Mexico each year during the months of November, December, and January. Light goose population estimates of major roost sites within the survey area are obtained from aerial and ground surveys. Information collected from light goose flocks include estimates of flock size, species composition, color phase ratio, immature:adult age ratio, and family size. Proportions of snow and Ross's geese are calculated from adult geese only. During 2000/01, Ross's geese comprised approximately 24% of WCFP light geese (Thorpe 2001; Fig. 2).

Ross's geese in the Pacific Flyway. Ross's geese in the Pacific Flyway migrate primarily to the Central Valley of California. Grinnell and Miller (1944) reported Ross's geese in both the Sacramento Valley and the northern portion of the San Joaquin Valley. Bellrose (1976) indicated that the majority of Ross's geese wintered in the lower San Joaquin Valley of California. More recently, McLandress (1979) documented that a larger segment of the Ross's goose population wintered in the Sacramento Valley than in the San Joaquin Valley. The percentage of Ross's geese banded in the central Arctic that are recovered by hunters in the Pacific Flyway has declined from nearly 100% in the 1950s and 1960s, to 60% during 1990-98, although the number of Ross's geese harvested in the Pacific Flyway is still increasing.

ABUNDANCE

In the early 20th century, Ross's geese were considered to be the rarest goose species that visited the U.S. (Bent 1925). Although the location of the species' breeding colonies were unknown, the principal wintering grounds were limited to the central valleys of California. No population estimates were made in the early 20th century,
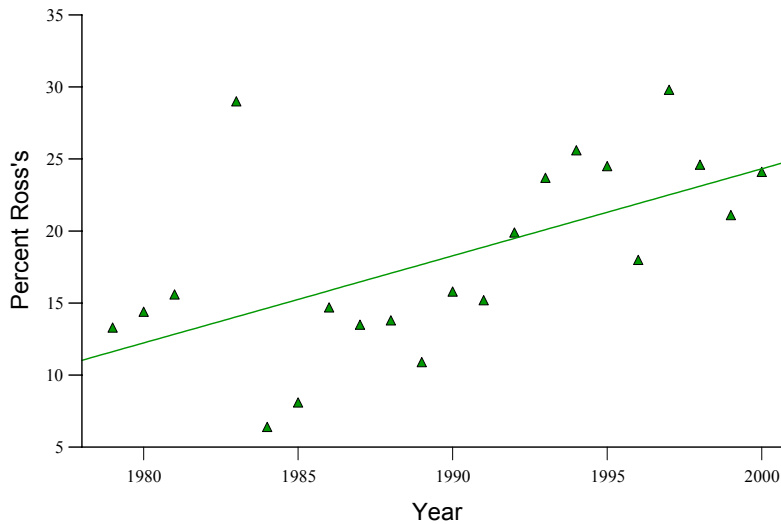
Fig. 2. Proportion of Ross's geese in the Western Central Flyway Population of light geese during winter, 1979-2001 (Thorpe 2001). Data for 1982 were not available.

although Bent (1925) cited a report of a flock of "several thousand individuals" on the Missouri River in Montana in April 1885. Photographic surveys of Ross's geese on breeding colonies began in 1966. Although not complete counts, annual winter indices of light geese in the midcontinent region are available beginning in 1970.

Breeding Ground Population Estimates

Long-term estimates of the spring population of Ross's geese are obtained from periodic photographic inventories of breeding colonies conducted since 1966 (Kerbes 1994). The number of Ross's geese in the central Arctic, as determined from photo surveys, has increased from 34,000 birds in 1966, to 567,000 birds in 1998 (Table 2). An additional 52,000 Ross's geese were estimated in the eastern Arctic (Table 2). Including an additional 30% to account for non-breeders (Kerbes et al. 1999), the total spring population on known colony sites in the central and eastern Arctic likely was near 805,000 birds in 1998. Assuming an annual growth rate of 9.0% (U.S. Fish and Wildlife Service 2001, Alisauskas and Rockwell, this report), the total spring population will be 1.04 million in 2001, and nearly 2.3 million by 2010.

Aerial and ground sampling in the central Arctic in 1998 at the Queen Maud Gulf Bird Sanctuary (Alisauskas et al. 1998) and other locations (Caswell et al. 1997, CWS unpublished data) suggests the number of Ross's geese in the Canadian Arctic in 1998 may have exceeded 1,000,000 breeding and non-breeding geese at various colonies, higher than estimated from the most recent photo-inventory.

Table 2. Photo-inventory estimates of breeding Ross's geese in the central and eastern Arctic, 1966-98 (Kerbes 1994, Canadian Wildlife Service unpublished data, Caswell et al. 1997).

Year	Central Arctic	Eastern Arctic	Total
1966	34,000		34,000
1976	77,300		77,300
1982	90,800		90,800
1988	188,000		
1990		2,000	190,000[a]
1998	567,000	52,000	619,100

[a] 1988 and 1990 pooled.

Annual Winter Indices

Winter waterfowl surveys are conducted each year throughout all lower 48 States in the U.S. These surveys began in some areas as early as 1935 but consistent annual coverage began in 1955. Biologists did not begin separate inventories of MCP and WCFP geese until the winter of 1969/70. By maintaining similar survey methods from year to year, the winter index is useful for monitoring trends of various populations. Because winter indices are available every year for most light goose populations (versus periodically for Arctic breeding colony estimates), the winter index is utilized to annually monitor population trends and aid in making management decisions.

Because not all areas in each State are surveyed, the winter surveys do not provide complete population estimates for light geese. Instead, the survey provides an index to the winter population of geese, which should not be confused with the size of the breeding population. Furthermore, population growth rates derived from breeding and wintering areas are not directly comparable because birds from a particular breeding area may winter in several geographic regions. Past photographic inventories of eastern Arctic lesser snow goose nesting colonies suggested that winter indices averaged about half of the actual spring population estimate (Kerbes 1975). Boyd et al. (1982) used a correction factor of 1.6 to apply to winter indices to estimate the approximate breeding population size of lesser snow geese in spring. It is likely that similar correction factors are valid for Ross's geese.

Ross's geese in the Mid-continent Population (MCP) of light geese. The winter index of MCP light geese (lesser snow and Ross's geese combined) increased from approximately 777,000 birds in 1970, to approximately 2.6 million birds in 2000. Assuming that Ross's geese comprise 4% of the MCP winter index (mean of Texas and Louisiana field studies cited earlier), the winter index included approximately 106,000 Ross's geese. During 1970-2000, the MCP light goose winter index increased 3.3% per year. The rate of increase has risen to 4.2% per year in the past 10 years.

Ross's geese in the Western Central Flyway Population (WCFP) of light geese. WCFP light geese that occur in the U.S. are surveyed every winter in Central Flyway States. A more comprehensive winter survey of WCFP light geese is obtained every 3 years when light geese are also surveyed in Mexico. The winter index of WCFP light geese has increased from approximately 42,000 birds in 1970 to approximately 256,000 birds in 2000. During 1970-2000, the WCFP winter index increased 6.2% per year. Assuming Ross's geese comprise 24% of the WCFP winter index (Thorpe 2001), the index would include approximately 61,400 Ross's geese.

Ross's geese in the Pacific Flyway. Long-term annual winter indices are not available for Ross's geese in the Pacific Flyway. Annual winter surveys from 1956 to 1978, when Ross's geese were thought to winter exclusively in the San Joaquin Valley, indicated an increase in Ross's geese in California from 13,100 to 31,200. In 1977, McLandress (1979) estimated the post-hunting-season population in the Central Valley to be 106,000. Species composition surveys conducted in the Central Valley during the winters of 1988/89 and 1989/90 resulted in Ross's goose estimates of 214,700 and 168,400, respectively (Silveira 1989, 1990). The survey was repeated in 1992, resulting in an index of 221,300 birds (Mensik and Silveira 1993). Efforts to repeat the survey in California since then have been hampered by a wider distribution of roosting geese due to winter flooding of rice fields and observer access difficulties due to wet winters. The survey was completed in December of 2000 and resulted in an estimate of 256,000 Ross's geese (Feldheim, in preparation).

The continental population goal for Ross's geese in the North American Waterfowl Management Plan (NAWMP)(U.S. Department of the Interior 1998) is 100,000 breeding birds. The Pacific Flyway Council (1992) adopted a continental Ross's goose population goal of 100,000 breeding or 150,000 wintering birds. Therefore, the 1998 photo-survey estimate of 619,000 breeding Ross's geese in the central and eastern Arctic (combined) is more than 600% higher than the NAWMP and Pacific Flyway Council goals.

LITERATURE CITED

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, D. Stern, and K. D. Warner. 1998. Spatial and temporal dynamics of Ross's and snow goose colonies in Queen Maud Gulf Bird Sanctuary, 1966-98. Progress Report on numbers of geese and colonies, September 1998. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania.

Bent, A. C. 1925. Life histories of North American wild fowl. Part II. Dover Publications. New York.

Boyd, H., G. E. J. Smith, and F. G. Cooch. 1982. The lesser snow geese of the eastern Canadian Arctic: their status during 1964-1979 and their management from 1982-1990. Canadian Wildlife Service Occasional Paper Number 46, Ottawa, Ontario.

Caswell, F. D., A. B. Didiuk, R. Bazin, and J. S. Wendt. 1997. A multi-species, multi-purpose program to monitor trends of eastern Arctic geese of the Northwest Territories. The 9th North American Arctic Goose Conference and Workshop. Victoria, British Columbia.

Feldheim, C. F. In preparation. Distribution of lesser snow and Ross's geese in California, winter 2000-2001. Unpublished report. California Department of Fish and Game, Sacramento, California.

Grinnell, J., and A. H. Miller. 1944. The distribution of the birds of California. Cooper Ornithological Club, Berkeley, California.

Helm, R. 2000. Results of the January 2001 Ross's goose survey. Louisiana Department of Wildlife and Fisheries, Baton Rouge, Louisiana.

Kerbes, R. H. 1975. The nesting population of lesser snow geese in the eastern Canadian arctic. Canadian Wildlife Service Report Series Number 35, Ottawa, Ontario.

Kerbes, R. H. 1994. Colonies and numbers of Ross' geese and lesser snow geese in the Queen Maud Gulf Migratory Bird Sanctuary. Canadian Wildlife Service Occasional Paper Number 81, Ottawa, Ontario.

Kerbes, R. H., V. V. Baranyuk, and J. E. Hines. 1999. Estimated size of the Western Canadian Arctic and Wrangel Island lesser snow goose populations on their breeding and wintering grounds. Pages 25-38 *in* R. H. Kerbes, K. M. Meeres, and J. E. Hines, editors. Distribution, survival, and numbers of lesser snow geese of the Western Canadian Arctic and Wrangel Island, Russia. Canadian Wildlife Service Occasional Paper Number 98, Ottawa, Ontario.

McLandress, M. R. 1979. Status of Ross's geese in California. Pages 255-265 *in* R.L. Jarvis and J.C. Bartonek, editors. Management and biology of Pacific Flyway geese. Oregon State University Bookstores. Corvallis, Oregon.

Mensik, G., and J. G. Silveira. 1993. Status of Ross' and lesser snow geese wintering in California, 1992. USFWS unpublished report.

Pacific Flyway Council. 1992. Pacific Flyway management plan for Ross' geese. Pacific Flyway Study Committee. C/o U.S. Fish and Wildlife Service. Portland, Oregon.

Ryder, J. P., and R. T. Alisauskas. 1995. Ross' goose (Chen rossii). Number 162 *in* A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Sharp, D. E., and T. J. Moser, compilers. 2000. Central Flyway harvest and population survey data book. U.S. Fish and Wildlife Service. Denver, Colorado.

Silveira, J. G. 1989. Distribution of lesser snow and Ross's geese in California, winter 1988-1989. Unpublished Report, California Department of Fish and Game, Sacramento, California.

Silveira, J. G. 1990. Distribution of lesser snow and Ross's geese in California, winter 1989-1990. Unpublished Report, California Department of Fish and Game, Sacramento, California.

Thorpe, P. P. 2001. Western Central Flyway Light Goose Productivity Report - 2000. Pages 19-35 *in* J. K. Bidwell, compiler. 2001. Productivity surveys of geese, swans, and brant wintering in North America - 2000. U.S. Fish Wildlife Service, Division of Migratory Bird Management, Old Town, Maine.

U.S. Department of the Interior. 1998. Expanding the vision – 1998 update North American waterfowl management plan. U.S. Fish and Wildlife Service. Washington, D.C.

U.S. Fish and Wildlife Service. 2001. Draft environmental impact statement: Light goose management. Washington, D.C.

Chapter 4:

INTERACTION WITH ARCTIC AND SUBARCTIC HABITATS

Andrew B. Didiuk, Canadian Wildlife Service
Ray T. Alisauskas, Canadian Wildlife Service
Robert F. Rockwell, American Museum of Natural History

Considerable study and evaluation has been conducted on the effects of lesser snow geese upon coastal wetland habitats in the La Perouse Bay region of northern Manitoba, along the coastline of Hudson Bay to Cape Henrietta Maria, along the shores of James Bay, Ontario, and Akimiski Island, Northwest Territories (Abraham and Jeffries 1997). Habitat damage by lesser snow geese in these areas is considered to be primarily caused by foraging activities during early spring and the nesting period. Damage is caused by both locally nesting snow geese and by large numbers of transient snow geese which can concentrate in and near nesting colonies for variable periods of time in the spring. Grubbing activity by snow geese (i.e., foraging by uprooting plant roots and rhizomes) can be particularly destructive to vegetative swards. Increasing numbers of lesser snow geese have been associated with intensified reduction in extent and biomass of graminoid vegetation in these areas. The impacts of Ross's geese on vegetation has received considerably less attention than has that of snow geese. In this chapter, we review what currently is known about the effects of Ross's geese on Arctic and subarctic habitats.

The long bill of the lesser snow goose has been considered an adaptation for excavating below-ground portions of plants (Alisauskas 1998). The shorter bill of the Ross's goose may be less effective for grubbing, however Ross's geese do grub during nest building (Fig. 1) and during spring when a large portion of their diet is sedge and grass roots (Ryder and Alisauskas 1995). The bills of Ross's geese may also enable them to graze on shorter or already closely cropped vegetation which can prevent or retard vegetation recovery in degraded areas. Thus, Ross's geese may contribute to impacts on northern wetland habitats.

Most Ross's geese nest in the Queen Maud Gulf Migratory Bird Sanctuary (QMGBS) in the central Arctic and along the west coast of Hudson Bay in Nunavut. Some also nest along the southern coast of Southampton Island, the western coast of southwest Baffin Island, and at La Perouse Bay near Churchill, Manitoba (Barry and Eisenhart 1958, Ryder and Cooke 1973, Caswell et al. 1997). Since both lesser snow geese and Ross's geese nest and raise broods in close proximity, attributing impacts on vegetation to one or the other species is difficult. Habitats, habitat use, goose numbers, and goose distribution vary among nesting areas. Activities of geese, and the types and degree of impacts upon habitat also vary among different portions of the reproductive period. Assessment of the relative impacts of lesser snow and Ross's geese on habitats at

these areas must include consideration of the proportion and abundance of species using each site and their distributions during the portions of the breeding season.

QUEEN MAUD GULF MIGRATORY BIRD SANCTUARY, NUNAVUT

Photographic inventories indicate populations of breeding Ross's geese at colonies within the QMGBS have increased from 77,000 to 475,000 from 1976 to 1998 (R. H. Kerbes, Canadian Wildlife Service, unpublished data). Snow goose populations in these areas are similar in number to those of Ross's geese and have shown similar increases over time. As of 1998, Ross's geese comprised 42% of the total light goose population of the QMGBS (Alisauskas et al. 1998).

Pre-nesting Period

At nesting colonies, there is about a 3-day lag between peak arrival of breeding geese and the peak of nesting. Nonbreeders may settle temporarily in colonies and mix with breeding geese, or form large flocks of nonbreeders outside or on the periphery of colonies. Upon arrival, both lesser snow geese and Ross's geese grub for roots and rhizomes of wetland vegetation.

Knowledge of Ross's and lesser snow geese foraging area distribution during the pre-nesting period is limited so it is not known if possible impacts on vegetation are restricted to nesting areas. There is very little impact by transient geese since there are very few light geese traveling north to more northerly nesting areas (e.g., Jenny Lind Island).

Nesting Period

Most of the information regarding Ross's goose populations and their effects upon habitat has been collected at the Karrak Lake colony. At this colony, recent studies indicate that the Ross's goose spring population has increased to 395,000 in 2000 and comprises about 50% of the total population of nesting light geese (Alisauskas and Rockwell, this report).

Ross's and snow geese strip and grub vegetation to build and maintain their nests (Fig. 1). Where geese nest in lowland habitats, with grasses, sedges and various herbs on shallow peats, almost all of the vegetation is stripped or grubbed, biomass is extremely low, and underlying peat is exposed. In upland habitats (e.g., gravel ridges) biomass is also removed but this impact is less evident because peat is at most a thin veneer and vegetative biomass is low. In rock and boulder outcrops, where vegetative biomass is naturally limited, impact by nesting geese is also less evident although most of the edible plant biomass is also removed.

Land-cover mapping from satellite images in 1989 showed the extent of exposed peats in lowland habitats at Karrak Lake (Didiuk and Ferguson in press). The extent of

exposed peats corresponded well with the limits of the nesting colony at that time. Loss of vegetative biomass in upland habitats (gravel ridges and rock/boulder outcrops) cannot be adequately assessed from satellite imagery, but it is reasonable to assume most of the edible vegetative biomass in these habitats within the nesting colony has been removed by nesting and foraging geese. Mapping of land cover from satellite images in 1996 indicated an increased area of nesting geese, and a corresponding increased area of exposed peats with very little vegetative biomass (A. Didiuk, Canadian Wildlife Service, unpublished data).

At Karrak Lake, detailed comparative studies of Ross's and snow goose diets and foraging behavior during spring 1993 showed that Ross's geese foraged for 9.2 h/day compared to 7.1 h/day by snow geese before incubation (Gloutney et al. 2001). Despite these high rates of foraging, little food is ingested during egg-laying (Ross's geese: 12.4 g/day, snow geese: 9.6 g/day on a dry mass basis) or during incubation recesses (Ross's geese: 2.9 g/day, snow geese: 6.5 g/day). Much of the diet is composed of mosses and other foods of poor quality such as woody roots, bearberry leaves, and cranberry leaves. Before incubation, dry mass of more nutritious foods such as fine shoots of chickweed (*Stellaria* spp.) and sedges (*Carex* spp.) constituted 38% (dry mass) of Ross's goose diets and 33% of snow goose diets. Gloutney et al. (2001) suggested that the similarity between species in low quantity and quality of diets was the result of the cumulative removal of vegetation by high populations of geese over the previous 3 decades.

The relative impacts of lesser snow geese and Ross's geese presumably can be gauged by their relative proportions within the nesting colonies. At Karrak Lake, Ross's geese comprise about 50% of the total population of nesting geese. However, Ross's geese mainly nest in lowland habitats, and lesser snow geese mainly nest in upland habitat. Much of the removal of vegetation of lowland habitats is the result of not only foraging by Ross's geese, but also of their nest building activities (Fig. 1).

Charlwood and Alisauskas (unpublished ms) showed that the oldest areas of the goose colony had the lowest estimate of vegetation diversity compared to areas where geese had not yet nested. Similarly, species richness was highest in areas devoid of nesting geese and contained an average of 7 (150%) more species than the oldest areas of the colony. Also, the proportion of damaged habitat (i.e., the sum of exposed substrate, exposed peat, and *Senecio congestus*) was greatest (0.386) in the oldest parts of the colony (Fig. 2) and declined at locations away from the colony (0.085) in areas with no nesting geese. Most differences in damage occurred between areas which had nesting geese for <10 years versus ≥11 years. The foregoing analysis did not consider the composition of goose species. However, the number of Ross's goose nests/sample plot was correlated positively with the proportion of exposed peat/sample plot and the number of lesser snow goose nests/sample plot was not. This appeared to be related to the fact that Ross's geese nest in low-lying areas, zones with an accumulation of peat formerly covered by a layer of live vegetation; whereas snow geese arrive earlier and nest earlier in the higher, rockier areas which become snow-free first. Thus combined foraging and nest-building activities by Ross's geese have altered wet low-lying areas that formerly supported live sphagnum moss/sedge communities to areas of exposed peat. This segregation of fine-scale nesting

habitat by Ross's and snow geese at Karrak Lake allows assessment of the separate effects of foraging and nest-building by each species.

Therefore, during recent years when Ross's geese have increased greatly, they may have caused much of the loss of vegetation biomass in lowland areas of the Karrak Lake colony, and at other nesting colonies in the QMGBS.

Brood-rearing Period

After hatch, both lesser snow geese and Ross's geese disperse from nesting colonies and are often found in mixed-species flocks of adults and young. Many geese of both species travel all the way to the coastline of Queen Maud Gulf, a distance of about 70 km. During these movements, geese forage in lowland habitat, particularly along the various drainages leading to the coastline. Mean dispersal distances toward the coast from Karrak Lake by Ross's geese were about 45 km, whereas snow geese moved an average of about 15 km to brood-rearing areas, although there was considerable overlap between species (Slattery 1994). This mixing during brood rearing makes it difficult to separate species-specific impacts of foraging.

Slattery (2000) used goose exclosures to deduce that the combined effects of vegetation removal by Ross's and snow geese were large (Fig. 3). Moreover, standing crop and protein density of plants increased with increasing distance toward the coast from the colony at Karrak Lake. Above-ground biomass in exclosures increased linearly with distance from the coast, whereas that in control plots showed no increase until about 60 km from Karrak Lake. By taking the difference in biomass, Slattery (2000) was able to calculate the grazing intensity along this continuum from the colony to the coast. The combined effect of both species showed that about 50% of the above-ground biomass had been removed over an area of about 5,000 km^2. Because Ross's geese constituted about 50% of the light geese in this area, they could have removed as much as 25% of the total above-ground biomass within this large study area. Slattery (2000) suggested that reduced biomass within preferred habitats close to the colony was suggestive of a biodeterioration zone from cumulative annual grazing pressure nearer the colony where density of geese was greatest. These observations were consistent with density-dependent effects on goslings; structural size and body condition of captured goslings increased with distance from the colony.

Land-cover mapping from satellite imagery in 1989, and field surveys in 1991-93 did not reveal any significant exposure of peats due to foraging by geese away from nesting colonies. Mapping from satellite imagery in 1996 revealed some areas of exposed peats which may have been related to reduced water levels in lowland wetlands or foraging by geese (A. B. Didiuk, Canadian Wildlife Service, unpublished data). Vegetation sampling has confirmed exposed peat areas are present outside of, but very near, the nesting colony (Charlwood and Alisauskas, unpublished ms). Further work is required to explain and quantify these changes.

Grazing of shoots and fruiting bodies of grasses and sedges are the primary feeding activities of adult light geese and their goslings during brood rearing (Fig. 3). Grubbing also occurs in brood-rearing areas by nonbreeding flocks, particularly in wet sedge meadows.

Post-fledging Period

Fledged goslings and adults stage on brood-rearing areas of QMGBS after the brood-rearing period. Although little work has been done at this time of year, there is likely a shift in diet from green vegetation (high in protein for tissue growth) to below-ground portions of plants (which are high in carbohydrates) to increase fat reserves for migration. At this time, sedges and grasses relocate nutrients to below-ground storage organs. Hence grubbing activity may increase again during this period. Few migrant geese from more northerly regions join locally breeding and molting geese during this period. The effects of late summer/early fall grubbing by lesser snow geese or Ross's geese upon wetland vegetation is unknown.

MCCONNELL RIVER MIGRATORY BIRD SANCTUARY AND WEST HUDSON BAY, NUNAVUT

Ross's geese occasionally have been reported within this sanctuary since the 1960s. By 1994, a large number of Ross's geese established a nesting colony within the existing lesser snow goose colony at McConnell River, and in 1997, 24,000 nesting Ross's geese were counted in this area. Ross's geese comprised about 16% of all light geese nesting along the west coast of Hudson Bay, Nunavut in 1997. Thus, large numbers of Ross's geese in this region are a relatively recent occurrence and probably contributed little to previous large-scale habitat deterioration here. The recently increased numbers of Ross's geese may contribute to habitat degradation additive to that of snow geese, retardation or prevention of habitat recovery if snow goose use decreases, limited localized effects, or have little impact.

Nesting density differs between lesser snow geese and Ross's geese here. In 1997, at the McConnell River nesting colony, the 24,000 Ross's geese nested within a 3.4 km^2 area, and 22,000 lesser snow geese nested within a 250 km^2 area. The area occupied by nesting Ross's geese in 1997 represented 1.4% of the area occupied by nesting light geese at the McConnell River nesting area.

There may be additional Ross's geese nesting in small numbers elsewhere west of Hudson Bay, but the known area of nesting Ross's geese at McConnell River was only 0.4% of the total area occupied by nesting light geese within this region (783 km^2).

Pre-nesting Period

After spring arrival to nesting areas, lesser snow geese and Ross's geese may have to wait for several days for snow to disappear from nesting sites. Transient geese,

en route to more northern nesting sites may also concentrate in some areas of coastal wetlands within and near nesting colonies. Wetland habitat degradation through grubbing can occur at this time (reduction in turf size of coastal sedges and reduced shoot frequency of inland fresh-water sedges and grasses).

The lower marsh zone along the coastline is currently limited in extent, with only small patches widely distributed along the coastline. The role that resident and transient light geese have played in this is not clear but is under investigation (Kerbes et al. 1990, A. B. Didiuk, Canadian Wildlife Service, unpublished data).

The upper marsh zone along the coastline varies from 50 to 200 m in width, and is heavily grazed. Measures of plant biomass are similar to the heavily grazed turfs at La Perouse Bay, Manitoba. Dicotyledons are greatly reduced, also indicative of heavy grazing. There is no evidence of significant replacement of graminoids by mosses in this habitat, and goose exclosure studies demonstrate rapid regrowth and seed set of grass species. Although heavily grazed, there is no evidence that the extent of upper marsh zone has been significantly reduced by the foraging activities of geese. This habitat may not be available for foraging and nest establishment in the early spring due to potentially later snow melt. Aerial photography of nesting colonies of light geese show that there are fewer nests in this zone immediately adjacent to the coastline. The upper marsh is heavily grazed. However, it is a continuous strip for most of the 200 km from the Manitoba/Nunavut border to Maguse River. Flocks of geese likely move up and down this very extensive strip of habitat.

Inland from the upper marsh is a broad zone which previously was low-shrub tundra. Low-shrub tundra typically is a mosaic of sedge and grass fens interspersed with hummocks covered by shrubs. Hummocks in these areas provide early nesting sites for lesser snow geese. Land-cover mapping with satellite imagery in 1987, and annual aerial and ground surveys since that time indicate this low-shrub tundra has been replaced by extensive areas of exposed peats. It is reasonable to assume that some of this habitat change is due to spring grubbing by lesser snow geese. Whether grubbing by nesting and migrant lesser snow geese and Ross's geese was the only or the major cause of these exposed peats is currently unknown.

If migrant Ross's and lesser snow geese occasionally are delayed in the southern portion of this coastal region due to extensive snow cover farther north, then both lesser snow geese and Ross's geese may grub in these habitats and contribute to degradation. The frequency of such delays and the concentrations of migrant and resident lesser snow geese and of Ross's geese in these areas is unknown. Large numbers of Ross's geese were not observed nesting in this region until 1994; however, the abundance of transient Ross's geese prior to that is unknown.

Nesting Period

Ross's geese at McConnell River are distinctly colonial with very high nest densities in specific portions of the overall nesting area of light geese. Most geese appear

to be concentrated in areas with relatively well-defined borders (i.e., abrupt transition from high-density Ross's geese to lower-density lesser snow geese). Ross's geese at the colony north of McConnell River are concentrated in a lowland depression with limited micro-relief and large areas of exposed peat. They are surrounded by lesser snow geese which nest in lower densities, most often on hummocks with low shrubs. Ross's geese arrive later, and nest in lower areas where snow cover disappearance is delayed; similar to the high proportion of Ross's geese that nest in lowland areas at QMGBS (Charlwood and Alisauskas ms). Some Ross's geese are concentrated on islands, peninsulas, and portions of the shorelines of a lake complex.

Brood-rearing Period

Banding and aerial surveys indicated most light geese disperse inland with their broods after hatch in early July (McLaren and McLaren 1982). Some broods disperse 1-8 km inland in a region of former low-shrub tundra where exposed peat is characteristic, and where grass and sedge growth is extremely limited. A smaller number of broods disperse farther inland, from 5 to 25 km or more, to forage in patches of intact sedge and grass fens beyond the coastal plain. Other broods remain within 1 km of the coastline where they concentrate their foraging on the upper marsh zone within 200 m of the coastline.

Prior to 1994 most of the light goose broods probably were lesser snow geese. Since the establishment of the large Ross's goose nesting colonies at McConnell River, large numbers of Ross's goose broods forage during the summer along the immediate coastline (usually less than 1 km from the coastline). Banding and survey data indicate Ross's geese are usually restricted to this immediate coastal area, except possibly in the McConnell River region where Ross's goose broods may travel several km inland along the north and south channels of the river. Banding and survey data also suggest Ross's goose broods are abundant as far south as the Thaane River, and it is assumed that most of these broods originate from the McConnell River nesting colonies. However, some broods may be associated with low densities of nesting Ross's geese among lesser snow geese south of McConnell River. Banding and survey data suggest Ross's goose broods may now comprise the majority of light goose broods from Wolf Creek to the Thaane River, within 1 km of the coastline, whereas only lesser snow geese are found farther inland (A. B. Didiuk, Canadian Wildlife Service, unpublished data).

During the summer brood-rearing period, both lesser snow geese and Ross's geese primarily graze on above-ground vegetation, although grubbing increases as the habitat quality deteriorates. In the upper marsh, turfs of sedges and grasses are maintained at a very low height by "picking" of short growing stems of these plants. The very long strip of upper marsh, from the Manitoba/Nunavut border to the Maguse River, tends to distribute foraging by light geese over a fairly large expanse of habitat. Flocks of broods can move long distances north and south through this habitat. Summer grazing effects by Ross's geese are primarily restricted to the upper marsh zone from Wolf Creek to the Thaane River, except in the McConnell River region where Ross's goose broods

travel up the north and south channels of the river. The precise role of lesser snow and Ross's geese on habitat degradation in this region is not clear.

In more inland areas, lesser snow geese primarily graze the upper portions of sedges and grasses, and their fruiting bodies. Some grubbing for rhizomes does occur but it appears to be very limited.

Post-fledging Period

After fledging in late August, locally breeding light geese and migrant geese from more northerly nesting areas forage in the coastal wetlands. There is no information available to determine the extent, timing, or impacts of fall foraging by light geese during this period. Grubbing for rhizomes likely begins again in the fall when grasses and sedges transfer nutrients to below-ground storage organs. Ross's geese grub for roots in the spring and probably continue to grub during the post-breeding period as well.

LA PEROUSE BAY, MANITOBA

Ross's geese historically have been observed at the La Perouse Bay colony, both as pairs and mated to lesser snow geese (usually male Ross's mated to female lesser snow geese) but their numbers have been exceptionally small. As such, their contribution to documented damage on the marsh has been proportionally minor. During the past 3 years, increasing numbers of Ross's goose families (now > 50) have been observed feeding on the long-term study marsh at the mouth of the Mast River during the brood-rearing period. Over the same time period, use of this formerly intact feeding sward by lesser snow geese has declined.

Intensive behavioral observations indicate that the light goose families feed throughout the daylight hours and often into the twilight periods (B. Pezzanite, American Museum of Natural History, unpublished data). Historically, the snow geese fed in a more crepuscular fashion with peaks near dawn and dusk. The grasses and sedges in this region have been reduced drastically both in terms of overall above-ground biomass and stem density. It appears, however, that the few Ross's geese currently using this degraded salt marsh are able to survive quite well as brood size does not decline during the season and condition of juveniles is good.

Biologists at La Perouse Bay are currently examining the impact of Ross's goose foraging on the marsh. We are particularly concerned over the impact on the revegetation potential of the degraded marsh. The numbers of snow geese raising their broods and feeding in the traditional brood-rearing areas have declined, partly due to a general shift of broods southward along the coast to other foraging areas. This decline may also be due to the stem density and sizes of remnant vegetation at La Perouse Bay being below that which will sustain them, or which is "attractive" to them. Before the Ross's geese showed up, the marsh was actually showing some increase in vegetative cover. Now that the Ross's geese are also using the area, that recovery has been

reversed. It is not clear whether the Ross's geese have different behaviors that allow them to use the reduced forage, whether they have different thresholds for foraging (from an optimal foraging view), or whether this is a coincidence.

SOUTHAMPTON ISLAND AND BAFFIN ISLAND, NUNAVUT

Although Ross's geese have been reported from both Southampton and Baffin Islands, banding and survey data suggest their numbers are small and they are relatively uncommon compared to the large numbers of lesser snow geese breeding in both these areas (Caswell et al. 1997). Similarly, there is little information available on habitat conditions and potential habitat degradation by light geese at these two islands. Given the relatively small numbers of Ross's geese on both islands, it is unlikely that Ross's geese contribute significantly to light goose foraging impacts.

SUMMARY

The large numbers of Ross's geese at QMGBS, particularly at large colonies such as Karrak Lake, result in significant impacts upon wetland vegetation. Impacts are concentrated in the actual nesting areas, which are a small proportion of the entire QMGBS. At West Hudson Bay, increasing numbers of Ross's geese at two nesting colonies result in significant impacts upon wetland vegetation. This is restricted to nesting areas in a portion of the coastal plain of West Hudson Bay, Nunavut. Low to very low numbers of Ross's geese at Southampton Island, west Baffin Island, and La Perouse Bay result in minor overall impacts on wetland vegetation by Ross's geese, particularly in comparison to the much larger numbers of lesser snow geese in those areas. There is potential, however, for Ross's geese to have a disproportionate per capita impact on already degraded habitat.

Fig. 1. Ross's goose nest at Karrak Lake (mid-June, 1997) in former sphagnum-birch habitat. Note (1) use of peat substrate for nest construction, (2) extensive barrens of exposed peat surrounding nest, and (3) absence of grasses or sedges. Photo by R. T. Alisauskas.

Fig. 2. Habitat in the center of Ross's/lesser snow goose colony at Karrak Lake after goose hatch (late July, 1999). Note (1) invasion of ragwort (*Senecio congestus*), a pioneer species associated with disturbed or damaged habitats, (2) moss carpets between ground birch (*Betula glandulosa*) typically found in low wet areas, cranberry (*Vaccinium vitis-idaea*), and Labrador tea (*Ledum decumbens*), and (3) absence of grasses and sedges. Photo by D. K. Kellett Warner.

Fig. 3. Vegetation enclosure 60 km north of Karrak Lake near the coast of Queen Maud Gulf showing cumulative impact of grazing during summer by gosling and adult Ross's and lesser snow geese on a stand of *Carex aquatilis* (mid-August, 1998). Area is used by geese originating from Karrak Lake. Photo by R. T. Alisauskas.

LITERATURE CITED

Abraham, K. F., and R. L. Jeffries. 1997. High goose populations: causes, impacts and implications. Pages 7-72 *in* B. D. J. Batt, editor. 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.

Alisauskas, R. T. 1998. Winter range expansion and relationships between landscape and morphometrics of midcontinent Lesser Snow Geese. Auk 115:851-862.

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, D. Stern, and K. D. Warner. 1998. Spatial and temporal dynamics of Ross's and snow goose colonies in Queen Maud Gulf Bird Sanctuary, 1966-98. Progress report on numbers of geese and colonies, September 1998. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Barry, T. W., and J. N. Eisenhart. 1958. Ross' geese nesting at Southampton Island, Northwest Territories. Auk 75:89-90.

Caswell, F. D., A. B. Didiuk, R. Bazin, and S. Wendt. 1997. A multi-species, multi-purpose program to monitor trends in eastern Arctic geese of the Northwest Territories. Abstract. The 9th North American Arctic Goose Conference, Victoria British Columbia.

Charlwood, J., and R. T. Alisauskas. Vegetation correlates of nesting history and density by Ross's and Lesser Snow Geese at Karrak Lake, Nunavut. Unpublished report. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Didiuk, A. B., and R. Ferguson. In press. Land cover mapping of Queen Maud Gulf Migratory Bird Sanctuary, Nunavut. Canadian Wildlife Service Occasional Paper.

Gloutney, M. L., R. T. Alisauskas, A. D. Afton, and S. M. Slattery. 2001. Foraging time and dietary intake by breeding Ross's and Lesser Snow Geese. Oecologia: in press.

Kerbes, R.H., Kotanen, P.M. and Jefferies, R.L. 1990. Destruction of wetland habitats by lesser snow geese: a keystone species on the west coast of Hudson Bay. Journal Applied Ecology 27:242-258.

McLaren, P. L. and M. A. McLaren. 1982. Migration and summer distribution of lesser snow geese in interior Keewatin. Wilson Bulletin 94:494-504.

Ryder, J. P. and R. T. Alisauskas. 1995. Ross' goose. Number 162 *in* A. Poole and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, and the American Ornithologists Union, Washington, D.C.

Ryder, J. P., and F. Cooke. 1973. Ross' geese nesting in Manitoba. Auk 90:691-692.

Slattery, S. M. 1994. Neonate reserves, growth and survival of Ross's and Lesser Snow Goose goslings. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.

Slattery, S. M. 2000. Factors affecting first-year survival in Ross's Geese. Dissertation, University of Saskatchewan, Saskatoon, Saskatchewan.

Chapter 5:

DISEASE MORTALITY EVENTS INVOLVING ROSS'S GEESE

Michael D. Samuel, U.S. Geological Survey, National Wildlife Health Center
Kathryn A. Converse, U.S. Geological Survey, National Wildlife Health Center
Kimberli J. Miller, U.S. Geological Survey, National Wildlife Health Center

Based on disease outbreaks reported to the U.S. Geological Survey (USGS) National Wildlife Health Center since 1968, the principal disease affecting Ross's geese is avian cholera (Tables 1 and 2). Other causes of mortality include losses during severe storms, botulism Type C, necrotic enteritis, soybean impaction, and two pesticide poisoning events. A number of avian cholera mortality events have coincided with lead poisoning mortality. Mortality events involving light geese (Ross's and snow geese) in the Central Flyway showed a gradual increase in the frequency and total severity of losses occurring since the 1960s (Table 1). All of the mortality events in the Central Flyway that involved Ross's geese also included snow geese. Ross's geese were typically a small proportion of the light geese that died during these mortality events. In the Pacific Flyway, the frequency of mortality events involving Ross's geese was similar during the 1980s and 1990s, but the severity of losses increased 2-3 times during the later period (Table 2). Most of these events included both Ross's and snow geese; however, a few events involved Ross's geese without snow geese. Many additional mortality events that occurred in the Central and Pacific Flyways involved snow geese, but Ross's geese were not reported during these events (Table 3 and 4). Causes of the mortality events that involved snow, but not Ross's geese were similar to those reported for both species. Avian cholera was the primary cause of mortality, followed by botulism, lead poisoning, drowning, and several toxic events. Avian cholera outbreaks have also been reported during spring migration from western Canada, especially in the late 1970s and early 1980s (Wobeser et al. 1979, 1982) and these outbreaks seemed to be confined almost entirely to snow and Ross's geese (Wobeser 1992). In summary, it appears that most of the general disease and mortality factors that affect snow geese also affect Ross's geese. In general, it is not known whether the frequency of events or magnitude of losses reflects the relative abundance of Ross's and snow geese and/or changes in light goose abundance over time. However, an increase in snow goose populations since the 1980s has corresponded with an increase in the magnitude of avian cholera mortality occurring in Nebraska's Rainwater Basin (M. D. Samuel, USGS, and G. Mack, U.S. Fish and Wildlife Service, unpublished data).

Previous studies have provided limited information about the potential impacts and role of Ross's geese in avian cholera outbreaks. Rosen (1972) compared the winter abundance of several waterfowl species in California during 1970/71 to losses from avian cholera. Although more snow geese died than Ross's geese the percentage of mortality was 7.3% of the wintering Ross's goose population and 1.5% of the snow goose population. Rosen (1972) concluded that avian cholera mortality in the winter of 1970/71

may have impacted Ross's geese in California. McLandress (1983) indicated that >90% of the disease mortality in Ross's and snow geese during 1975-77 in California was caused by avian cholera. The conclusion that avian cholera is the primary cause of disease mortality in light geese is also supported by the data from mortality events throughout the Central and Pacific Flyways. Although the patterns of vulnerability may vary by age and sex classes or degree of disease severity, McLandress (1983) concluded that snow and Ross's geese had similar susceptibility to avian cholera.

Although avian cholera kills thousands of waterfowl annually in North American wetlands, the reservoir for *Pasteurella multocida*, the bacterium that causes this highly infectious disease, has been uncertain (Botzler 1991). Two potential reservoirs have been suggested as a source of this bacterium for waterfowl populations: carrier birds and wetland sites. Recent studies have been conducted by the USGS National Wildlife Health Center to evaluate the wetland reservoir hypothesis. One study was conducted during and following avian cholera outbreaks to determine how long *P. multocida* survived in wetlands and a second study was conducted during the subsequent fall to determine whether *P. multocida* persisted in wetlands until migratory birds arrived. Results from these studies indicated that *P. multocida* did not survive in wetlands for extended periods once outbreaks had ceased. In addition, the bacterium was not present during the fall in years following outbreaks (M. D. Samuel et al., USGS, unpublished data). These results are contrary to the hypothesis that wetlands are the primary reservoir for this disease.

In contrast to the wetland hypothesis, some investigators have suspected that avian cholera was primarily perpetuated by carrier birds (Wobeser 1992) and that light geese may be the primary source of disease because outbreaks have been associated with their fall and spring migration (Brand 1984; Wobeser et al. 1979, 1982), they suffer outbreaks and chronic mortality every year (Mensik and Samuel 1995), outbreaks that may perpetuate the disease cycle occur on snow goose breeding areas (Samuel et al. 1999a), and the magnitude of mortality in other species has been associated with snow goose mortality (M. D. Samuel, USGS, and G. Mack, U.S. Fish and Wildlife Service, unpublished data). Recent studies on snow geese in the western Arctic found that some snow geese may be carriers of *P. multocida* (Samuel et al. 1997), and about half of the snow geese infected with avian cholera during outbreaks on the breeding grounds survived infection (Samuel et al. 1999b). Samuel et al. (1999b) suspected that these survivors could be carriers of the bacteria and play an important role in transmitting the organism to susceptible birds. Because snow geese are frequently involved in avian cholera outbreaks, associate in dense winter aggregations, and nest in colonies which seem to facilitate continuation of the disease cycle, Samuel et al. (1999b) believed that snow geese may be particularly important in the epizootiology of avian cholera. Unfortunately, there is little corresponding information on the potential role of Ross's geese in the epizootiology of avian cholera and whether these geese may also be important in the disease cycle. Because these two species of light geese have similar behavior patterns, extensively intermingle on migration and wintering areas, and occur in dense aggregations, it seems plausible that they may play similar roles in the epizootiology of avian cholera. However, it would be difficult to separate the potential

role of Ross's geese in this disease without specific research studies to determine if they are carriers of *P. multocida*. Early results from research examining the occurrence and frequency of avian cholera carriers in the Playa Lakes region suggest both snow and Ross's geese can be carriers of P. multocida (M. D. Samuel, USGS, unpublished data). Similar research studies on snow and Ross's geese have been recommended for the Central Valley of California.

In addition to its potential impact on light geese, avian cholera is of particular concern because most species of waterfowl, raptors, and other birds using wetland ecosystems are susceptible (Botzler 1991, Friend 1999). Although the factors that trigger an outbreak are poorly understood, it is commonly believed that weather, stress, and high densities of susceptible birds are important contributors (Botzler 1991, Windingstad et al. 1998). Increased densities of waterbirds, especially gregarious light goose species, probably increase the risk of disease transmission and outbreak events (Wobeser 1992). Once an outbreak starts, wetland contamination from diseased birds is the primary source of infection to susceptible birds of all species, although other routes of transmission such as bird-to-bird contact are likely (Wobeser 1992). Some species of waterfowl, especially light geese, may carry the organism and be more disposed to avian cholera outbreaks, which concurrently or subsequently affect other less susceptible species. In addition, the increased abundance of light geese and the large-scale mixing of these populations may enhance the exchange and spread of avian cholera and other disease agents (Wobeser 1992). Loss of habitat, increased abundance of light geese and other waterfowl, and increased densities of waterbirds are all factors that likely contribute to increasing the risk of avian cholera outbreaks, increasing the risk of infecting other waterbirds using the same wetlands, and increasing the continental distribution of this infectious disease.

Table 1. Summary of mortality events involving Ross's geese in the Central Flyway, 1968-2000.

Dates	Mortality events			Minimum estimated dead[a]			Summary by location and diagnosis		
	Total	Ross's only	Ross's and snow	Total	Ross's	Snow	States/Provinces[b]	n	Diagnosis
1968-79	2	0	2	300	unk.	unk.	NE	1	Storm trauma
				2,724	unk.	unk.	NE	1	Avian cholera and lead poisoning
1980-89	8	0	8	12,691	69	6,750	NM (3), NE (2), Alberta, CAN	6	Avian cholera (In one event birds were also diagnosed with lead poisoning and storm trauma)
				300	30	175	NM	1	Botulism type C and avian cholera
				13	unk.	unk.	NM	1	Diazinon toxicosis
1990-2000	28	0	28	75,590	2281	55,452	NE (14), TX (3), SD (2), CO, KS, Saskatchewan CAN, Chihuahua MEX (2)	24	Avian cholera or suspect avian cholera (In some events birds were also diagnosed with lead poisoning, gout, or suspect aflatoxicosis).
				743	2	89	ND	2	Necrotic enteritis
				10,000	unk.	1,021	NE	1	Storm trauma
				137	unk.	unk.	OK	1	Soybean impaction

[a] Totals include either direct number of carcasses collected or estimated mortality.
[b] Parentheses indicted the number of events in each state.
Unk. Individual estimates of mortality not available for all species.

Table 2. Summary of mortality events involving Ross's geese in the Pacific Flyway, 1970-2000.

| Dates | Mortality events | | | Minimum estimated dead[a] | | | Summary by location and diagnosis | | |
	Total Events	Ross's only	Ross's and snow	Total	Ross's	Snow	States/Provinces[b]	n	Diagnosis
1970-79	3	1	2	2,624	218	1,250	CA (3)	3	Avian cholera
1980-89	58	3	55	26,625	1,257	4,320	CA (29)	29	Avian cholera
				20,124	1,472	6,146	CA (24), OR	25	Avian cholera (In all events, some birds were also diagnosed with lead poisoning, botulism type C or trauma).
				17,356	37	154	CA (3)	3	Botulism type C (In some events birds were also diagnosed with avian cholera, and/or lead poisoning).
				6	1	5	CA	1	Dimethoate toxicosis
1990-2000	50	2	48	79,551	2,663	4,431	CA (33), MT, NV	35	Avian cholera or suspect avian cholera
				33,679	1,986	4,274	CA (11)	11	Avian cholera (In all events, some birds were also diagnosed with lead poisoning, botulism type C, trauma, aspergillosis and/or tracheal obstruction).
				5,304	5	20	CA (2)	2	Botulism type C
				1,500	82	205	CA	1	Storm trauma
				20	3	unk.	CA	1	Open

[a] Totals include either direct number of carcasses collected or estimated mortality.
[b] Parentheses indicted the number of events in each state.
Unk. Individual estimates of mortality not available for all species.

Table 3. Summary of mortality events involving snow geese, but not Ross's geese in the Central Flyway, 1970-2000.

Dates	Total mortality events	Minimum estimated dead[a]		Summary by location and diagnosis		
		Total	Snow	State/Province[b]	n	Diagnosis
1970-79	11	47,828	2,847	NE (5), TX (3), MT, SD	10	Avian cholera (In some events birds were also diagnosed with lead poisoning or suspect aflatoxicosis).
		7,500	unk.	TX	1	Aflatoxicosis
1980-89	68	176,819	2,962	NE (19), TX (7), SD (3), CO (2), NM (2), KS, WY	35	Avian cholera or suspect avian cholera (In all events, some birds were also diagnosed with lead poisoning, and/or aspergillosis, gunshot trauma).
		860	432	TX (3), NE (3), SD	7	Lead poisoning (In some events birds were also diagnosed with avian cholera or gunshot trauma).
		575	18	ND (2), OK (2), TX, NE	6	Toxicosis pesticide suspect (In one event birds were also diagnosed with visceral gout).
		4,097	3,095	ND (2), SD (2), Manitoba CAN	5	Necrotic enteritis or suspect necrotic enteritis (In one event birds were also diagnosed with sodium toxicosis and aspergillosis).
		9,050	72	TX (4)	4	Mycotoxicosis or aflatoxicosis. (In some events birds were also diagnosed with lead poisoning, avian cholera, and/or gunshot trauma).
		29	6	IA, ND, TX	3	Open

		180	30	ND (2)	2	Sodium toxicosis or suspect sodium toxicosis
		500	unk.	CO	1	Botulism type C
		1,600	unk.	TX	1	Parathion toxicosis
		97	unk.	OK	1	Fluorine toxicosis
		400	unk.	SD	1	Nitrate toxicosis
		100	unk.	TX	1	Storm trauma and gunshot
		52	2	NM	1	Salmonellosis suspect
1990-2000	51	34,053	21,848	TX (11), NE (6), NM (4), SD (3), CAN (2), ND, CO	28	Avian cholera or suspect avian cholera (In one event birds were also diagnosed with lead poisoning, necrotic enteritis, gunshot trauma).
		384	32	TX (4), KS, NM	6	Open
		1,925	1,756	ND (4), SD	5	Necrotic enteritis or enteritis
		287	267	TX (2)	2	Lead poisoning
		1,952	unk.	TX (2)	2	Aflatoxicosis (In one event birds were also diagnosed with avian cholera).
		144	81	KS, NE	2	Aspergillosis (In one event birds were also diagnosed with trauma).
		45	16	TX	1	Septicemia and open
		2,500	unk.	SD	1	Sodium toxicosis
		45	7	OK	1	Soybean impaction
		134	14	NE	1	Storm trauma
		34	34	TX	1	Hepatitis
		3,061	9	ND	1	Botulism type C

[a] Totals include either direct number of carcasses collected or estimated mortality.
[b] Parentheses indicted the number of events in each state.
Unk. Individual estimates of mortality not available for all species.

Table 3. Continued.

Table 4. Summary of mortality events involving snow geese, but not Ross's geese in Pacific Flyway, 1970-2000.

Dates	Total mortality events	Minimum estimated dead[a]		Summary by location and diagnosis		
		Total	Snow	State/Province[b]	n	Diagnosis
1970-79	9	14,310	10,330	CA (6), CAN (2)	8	Avian cholera (In some events birds were also diagnosed with aspergillosis, lead poisoning and/ or gunshot trauma).
		1,244	58	CA	1	Botulism, avian cholera and lead poisoning
1980-89	37	40,538	35,380	CA (19), OR (2), ID	22	Avian cholera (In all events, some birds were also diagnosed with lead poisoning, botulism type C or trauma).
		7,080	14	CA (6)	6	Botulism type C (In some events birds were also diagnosed with lead poisoning).
		713	102	CA (5)	5	Lead poisoning
		40	unk.	CA	1	Zinc phosphide toxicosis
		57	unk.	CA (2)	2	Carbofuran toxicosis
		369	10	CA	1	Open
1990-2000	19	37,411	10,585	CA (13), Saskatchewan CAN (2), ID	16	Avian cholera (In one event birds were also diagnosed with lead poisoning).
		10	10	CA	1	Trauma
		60	unk.	CA	1	Lead poisoning
		200	unk.	AK	1	Drowning suspect

[a] Totals include either direct number of carcasses collected or estimated mortality.
[b] Parentheses indicted the number of events in each state.
Unk. Individual estimates of mortality not available for all species.

LITERATURE CITED

Botzler, R. G. 1991. Epizootiology of avian cholera in wildfowl. Journal of Wildlife Diseases 27:367-395.

Brand, C. J. 1984. Avian cholera in the central and Mississippi Flyways during 1979-80. Journal of Wildlife Management 48:399-406.

Friend, M. 1999. Avian cholera. Pages 74-92 *in* M. Friend and J. C. Franson, editors. Field manual of wildlife diseases, general field procedures and disease of birds. U.S. Geological Survey Information and Technology Report 1999-001.

McLandress, M. R. 1983. Sex, age, and species differences in disease mortality of Ross' and lesser snow geese in California: implications for avian cholera research. California Fish and Game 69:196-206.

Mensik, G., and M. D. Samuel. 1995. Studying snow geese and avian cholera. California Waterfowl, October-November 1995.

Rosen, M. N. 1972. The 1970-71 avian cholera epornitic's impact on certain species. Journal of Wildlife Diseases 8:75-78.

Samuel, M. D., D. R. Goldberg, D. J. Shadduck, J. I Price, and E. G. Cooch. 1997. *Pasteurella multocida* serotype 1 isolated from a lesser snow goose: Evidence of a carrier state. Journal of Wildlife Diseases 33:332-335.

Samuel, M. D., J. Y. Takekawa, G. Samelius, and D. R. Goldberg. 1999a. Avian cholera mortality in lesser snow geese nesting on Banks Island, Northwest Territories. Wildlife Society Bulletin 27:780-787.

Samuel, M. D., D. J. Shadduck, D. R. Goldberg, V. Baranyuk, L. Sileo, and J. I. Price. 1999b. Antibodies against Pasteurella multocida in snow geese in the western Arctic. Journal of Wildlife Diseases 35:440-449.

Windingstad, R. M., M. D. Samuel, D. D. Thornburg, and L. C. Glaser. 1998. Pages 283-290 *in* D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, editors. Biology and management of Canada geese. Proceedings of the international Canada goose symposium, Milwaukee, Wisconsin.

Wobeser, G., D. B. Hunter, B. Wright, D. J. Nieman, and R. Isbister. 1979. Avian cholera in waterfowl in Saskatchewan, spring 1977. Journal of Wildlife Diseases 15:19-24.

Wobeser, G., F. A. Leighton, A. D. Osborne, D. J. Nieman, and J. R. Smith. 1982. Avian cholera in waterfowl in western Canada, 1978-1981. Canadian Field-Naturalist 96:317-322.

Wobeser, G. 1992. Avian cholera and waterfowl biology. Journal of Wildlife Diseases 28:674-682.

Chapter 6:

HARVEST OF ROSS'S GEESE

Timothy J. Moser, U.S. Fish and Wildlife Service
David C. Duncan, Canadian Wildlife Service

Hunting Regulations

The hunting of Ross's geese was unregulated until 1918 when the Migratory Bird Treaty Act (MBTA) in the United States and the Migratory-Birds Convention Act (MBCA) in Canada were enacted. Prior to 1918, the total annual harvest of Ross's geese likely was small due to their low population level and restricted range. However, Ross's geese commonly were shot in portions of California during market-hunting days around 1900 and some considered shooting a risk to the species at that time (Grinnel et al. 1918).

From 1918 to 1931, goose hunting seasons in the U.S. and Canada generally were greater than 90 days in length and included aggregate goose bag limits (the number of individuals of a single species or any combination of species that could be taken per day), generally 8 per day in the U.S. Concern over low staging and wintering numbers led to the closure of Ross's goose hunting seasons in the U.S. from 1931 through 1962, in Alberta from 1941 to 1962, in the Northwest Territories from 1944 to 1962, and in the Yukon from 1953 to 1962.

In response to increasing population indices of Ross's geese during the winters of 1955-62 limited hunting seasons for Ross's geese were reestablished in the U.S. and Canada in 1963 (Table 1, Dzubin 1965). Daily bag and possession limits for Ross's geese in the Pacific and Central Flyways were restricted to 1 goose from 1963 to 1978. After 1978, harvest of Ross's geese in the U.S. was regulated under light goose aggregate bag limits (snow and Ross's geese combined). Subsequent regulations in the Pacific Flyway have been relatively stable while those in the Central and Mississippi Flyways have been liberalized incrementally in response to increasing populations (Table 1). By 1994, season lengths in all 4 U.S. flyways were at or near the maximum of 107 days allowed under the MBTA.

After reestablishing Ross's goose seasons in 1963, Canada did not establish specific regulations for Ross's geese, but opening dates for light goose seasons in Alberta and Saskatchewan were often delayed until after the first week of October to reduce Ross's goose harvest. During the 1970s in prairie Canada (AB, SK, MB), the total goose aggregate bag limit was 5/day. In response to increasing goose populations, separate aggregate bag limits were established for light and dark geese in the 1990s. The bag limit for light geese was increased further to 8-10/day in 1997-98, and to 10-20/day in 2000 in response to degradation of northern habitats and continued increases in light goose abundance. By 1994, hunting season lengths in Canada were at or near the maximum of

Table 1. Summarized[a] hunting frameworks for Ross's and snow geese in the Pacific, Central, and Mississippi Flyways, 1962-2000.

	PACIFIC FLYWAY				CENTRAL FLYWAY								MISSISSIPPI FLYWAY		
					WEST TIER - MT, WY, CO, NM, W. TX				EAST TIER - ND, SD, NE, KS, OK, E. TX						
	SEASON		BAG/POSS[b]		SEASON		BAG/POSS[b]		SEASON		BAG/POSS[b]		SEASON		BAG/POSS[b]
YEAR	CLOSE	DAYS	SNOW	ROSS'S	CLOSE	DAYS	SNOW	ROSS'S	CLOSE	DAYS	SNOW	ROSS'S	CLOSE	DAYS	SNOW ROSS'S
1962	Jan 6	75	6/6	Closed[c]	Jan 06	75	5/5 TGA	Closed[c]	Jan 13	75	5/5 TGA	Closed[c]	Jan 13	60	5/5 LGA
1963	Jan 5	90	6/6	1/1	Jan 05	90	5/5 TGA	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	70	5/5 LGA
1964	Jan 10	90	6/6	1/1	Jan 10	90	5/5 TGA	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	70	5/5 LGA
1965	Jan 9	90	6/6	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	70	5/5 LGA
1966	Jan 8	90	6/6	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	75	5/5 TGA	1/1	Jan 15	70	5/5 LGA
1967	Jan 14	90	6/6	1/1	Jan 14	75	5/5 TGA	1/1	Jan 14	75	5/5 TGA	1/1	Jan 14	70	5/5 LGA
1968	Jan 12	93	6/6	1/1	Jan 15	75	2/2 TGA	1/1	Jan 15	75	5/5 TGA	1/1	Jan 12	70	5/5 LGA
1969	Jan 11	93	6/6	1/1	Jan 15	86	2/4 TGA	1/1	Jan 15	86	5/5 TGA	1/1	Jan 11	70	5/5 LGA
1970	Jan 17	93	6/6	1/1	Jan 17	90	2/4 TGA	1/1	Jan 17	75	5/5 TGA	1/1	Jan 24	70	5/5 LGA
1971	Jan 16	93	6/6	1/1	Jan 16	90	2/4 TGA	1/1	Jan 16	75	5/5 TGA	1/1	Jan 23	70	5/5 LGA
1972	Jan 20	93	6/6	1/1	Jan 24	93	2/4 TGA	1/1	Jan 24	72	4/4 TGA	1/1	Jan 20	70	5/5 LGA
1973	Jan 20	93	6/6	1/1	Jan 20	93	2/4 TGA	1/1	Jan 20	72	5/5 TGA	1/1	Jan 20	70	5/5 LGA
1974	Jan 19	93	6/6	1/1	Jan 19	93	2/4 TGA	1/1	Jan 19	72	5/5 TGA	1/1	Jan 20	70	5/5 LGA
1975	Jan 18	93	3/6	1/1	Jan 18	93	2/4 TGA	1/1	Jan 18	72	5/5 TGA	1/1	Jan 20	70	5/5 LGA
1976	Jan 23	93	3/6	1/1	Jan 23	93	2/4 TGA	1/1	Jan 23	72	5/5 LGA	1/1	Jan 20	70	5/5 LGA
1977	Jan 22	93	3/6	1/1	Jan 22	93	2/4 TGA	1/1	Jan 22	86	5/5 LGA	1/1	Jan 20	70	5/5 LGA
1978	Jan 21	93	3/6	1/1	Jan 21	93	2/4 TGA	1/1	Jan 21	86	5/5 LGA	1/1	Jan 20	70	5/5 LGA
1979	Jan 20	93	3/6 LGA		Jan 20	93	2/4 TGA		Jan 20	86	5/5 LGA		Jan 20	70	5/5 LGA
1980	Jan 18	93	3/6 LGA		Jan 18	93	2/4 TGA		Jan 18	86	5/10 LGA		Jan 20	70	5/10 LGA
1981	Jan 17	93	3/6 LGA		Jan 17	93	2/4 TGA		Jan 17	86	5/10 LGA		Jan 20	70	5/10 LGA
1982	Jan 23	93	3/6 LGA		Jan 23	93	2/4 TGA		Jan 23	86	5/10 LGA		Jan 20	70	5/10 LGA
1983	Jan 22	93	3/6 LGA		Jan 22	93	2/4 TGA		Jan 22	86	5/10 LGA		Jan 20	70	5/10 LGA
1984	Jan 20	93	3/6 LGA		Feb 12	93	2/4 TGA		Feb 12	86	5/10 LGA		Jan 20	70	5/10 LGA
1985	Jan 19	93	3/6 LGA		Feb 16	93	5/10 LGA		Feb 16	86	5/10 LGA		Jan 20	70	5/10 LGA
1986	Jan 18	93	3/6 LGA		Feb 15	93	5/10 LGA		Feb 15	86	5/10 LGA		Jan 20	70	5/10 LGA
1987	Jan 17	93	3/6 LGA		Feb 14	93	5/10 LGA		Feb 14	86	5/10 LGA		Jan 17	70	5/10 LGA
1988	Jan 22	93	3/6 LGA		Feb 14	95	5/10 LGA		Feb 14	86	5/10 LGA		Jan 22	70	5/10 LGA
1989	Jan 21	93	3/6 LGA		Feb 18	95	5/10 LGA		Feb 18	100	5/10 LGA		Jan 21	80	7/14 LGA
1990	Jan 20	93	3/6 LGA		Feb 17	100	5/10 LGA		Feb 17	86;100	5/10;7/14 LGA		Jan 20	80	7/14 LGA
1991	Jan 19	93	3/6 LGA		Feb 16	107	5/10 LGA		Feb 16	86;100	5/10;7/14 LGA		Jan 31	80	7/14 LGA
1992	Jan 17	93	3/6 LGA		Feb 14	107	5/10 LGA		Feb 14	107	10/20 LGA		Jan 31	80	7/14 LGA
1993	Jan 23	100	3/6 LGA		Feb 13	107	5/10 LGA		Feb 13	107	10/20 LGA		Feb 14	80	7/14 LGA
1994	Jan 20	100	3/6 LGA		Feb 28	107	5/10 LGA		Feb 28	107	10/20 LGA		Feb 14	107	7/14 LGA
1995	Jan 21	100	3/6 LGA		Mar 10	107	5/10 LGA		Mar 10	107	10/20 LGA		Feb 14	107	10/20 LGA
1996	Jan 19	100	3/6 LGA		Mar 10	107	10/40 LGA		Mar 10	107	10/40 LGA		Mar 10	107	10/30 LGA
1997	Jan 18	100	3/6 LGA		Mar 10	107	10/40 LGA		Mar 10	107	10/40 LGA		Mar 10	107	10/30 LGA
1998[d]	Jan 17	100	3/6 LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA
1999[d]	Jan 23	100	3/6 LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA
2000[d]	Jan 21	100	3/6 LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA		Mar 10	107	20/none LGA

[a] Some spatial and temporal deviations from Flyway-wide regulations occurred.

[b] Daily bag and possession limits: LGA = Light goose aggregate; any combination of light goose species up to these limits may be taken unless additional restrictions apply (see Ross's goose column). TGA = Total goose aggregate; any combination of goose species may be taken up to these limits unless additional restrictions apply (see Ross's goose column).

[c] Ross's goose seasons were closed from 1931 through 1962.

[d] Special regulations were implemented in the Central and Mississippi Flyways that allowed new techniques and the take of light geese between Mar. 10 and Sep. 1.

107 days allowed under the MBCA and extended from early September to late November/early December.

Traditionally, Mexico has regulated goose harvest under total goose aggregate bag limits (generally 3-5/day during the 1990s). In 2000 however, several Mexican States liberalized goose regulations by implementing separate aggregate bag limits of 5 dark and 10-15 light geese per day (E. Carrera, Ducks Unlimited de Mexico, personal communication).

In February 1999, the U.S. Fish and Wildlife Service (USFWS) promulgated rules that allowed special provisions for light goose hunting (i.e., electronic calls, unplugged shotguns) when other waterfowl and crane seasons were closed, and implemented a conservation order in States of the Mississippi and Central Flyways (Federal Register; 64 FR 7507-7517). The conservation order allowed the take of light geese at any time of year given certain restrictions, allowed the special provisions above, extended shooting hours, and removed bag limits. The Canadian Wildlife Service (CWS) implemented special regulations that allowed for harvest of lesser and greater snow geese only (Ross's geese excluded) between 10 March and 1 September in areas of Manitoba and Quebec beginning in 1999, and in Saskatchewan and Nunavut beginning in 2001.

Currently, most Ross's geese are taken in North America under 3 types of regulations. Regular-season harvest occurs during annually promulgated hunting seasons for licensed or permitted hunters and is estimated by annual operational harvest surveys. Subsistence harvest and the take during conservation order periods in the U.S. are regulated and assessed by other methods.

Distribution of Ross's Goose Harvest

In the first half of the 20th century, anecdotal reports suggested that most Ross's geese were harvested in California and Alberta, although some Ross's geese were observed or shot in the Mississippi Flyway as early as 1910 (Dzubin 1965). Dzubin (1965) noted an eastward shift in the fall migration of Ross's geese during 1960-64. An easterly shift in the harvest distribution of Ross's geese was also apparent after banding and extensive harvest monitoring programs began in the 1960s. Maps of the band recoveries (i.e., a banded bird that is shot or found dead and reported to banding authorities) of all Ross's geese banded in North America (Fig. 1), the distribution of recoveries of Ross's geese banded only in the central Arctic (Table 2), and the estimated distribution of Ross's goose harvest in the U.S. (Table 3) all show a progressive eastward shift from the 1960s through the 1990s.

When biologists began estimating the harvest of Ross's geese in the 1960s by examining goose tails provided by randomly selected hunters, harvest of Ross's geese was recorded only in the Pacific Flyway, primarily California. The harvest of Ross's geese was first detected in harvest surveys in the Central Flyway in 1974, in the Mississippi Flyway in 1982, and in the Atlantic Flyway in 1996. The proportion of U.S.

regular-season harvest that occurred in the Pacific Flyway declined from 100% in the 1960s to 29% in the 1990s, while the proportions in the Central Flyway and the Mississippi Flyways increased from 0% to 56%, and from 0% to 15%, respectively (Table 3). The increased harvest that occurred in the east was in addition to, not in lieu of, increased harvest of Ross's geese in the Pacific Flyway (Table 4).

During the 1990s, 53% of the U.S. regular-season harvest has occurred in the 4 States of Arkansas, California, Louisiana, and Texas. The pattern of harvest of Ross's geese across the Canadian prairie Provinces during 1975-99 shows that the majority of birds are now harvested in Saskatchewan, with variable proportions harvested in Alberta and Manitoba (Table 3). The proportion of the Canadian and U.S. Ross's goose harvest that occurs in Canada has decreased from 52% during the 1970s to 36% and 32% during the 1980s and 1990s, respectively (Fig. 2).
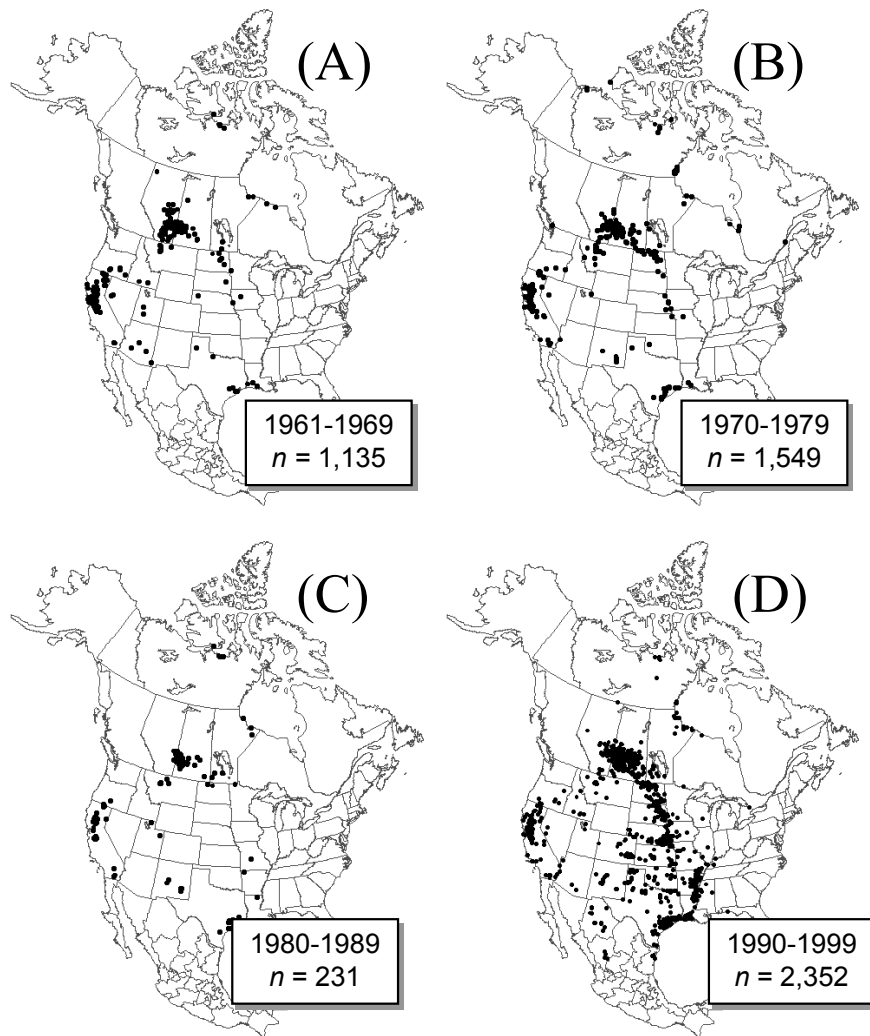

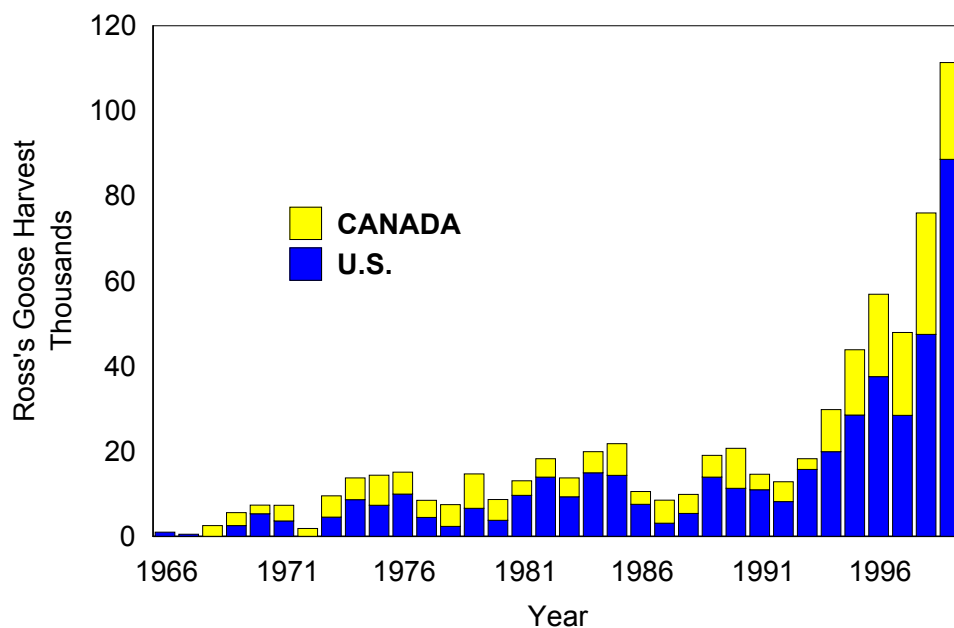Fig. 1. Distribution of Ross's goose band recoveries in North America, 1961-99 (from Alisauskas 2001).

Fig. 2. Estimated regular-season harvest of Ross's geese in the United States and Canada, 1966-99.

Table 2. Flyway distribution (%) of United States recoveries (1960-98) of Ross's geese banded in the central Canadian Arctic[a].

Flyway	Period			
	1960-69 ($n = 279$)	1970-79 ($n = 274$)	1980-89 ($n = 45$)	1990-98 ($n = 479$)
Pacific	96	94	87	60
Central	3	5	13	32
Mississippi	<1	<1	0	8
Atlantic	0	0	0	0

[a] Ross's geese banded between 95 and 115 degrees west longitude.

Table 3. Distribution (%) of regular-season Ross's goose harvest in the United States among Flyways, and in Canada among prairie Provinces, 1966-99[a].

	Period			
	1966-69	1970-79	1980-89	1990-99
United States				
Pacific Flyway	100	92	60	29
Central Flyway	0	8	33	56
Mississippi Flyway	0	0	6	15
Canada				
Alberta		28	21	16
Saskatchewan		61	61	72
Manitoba		8	18	10

[a] Data includes harvest estimates from 1966 to 1999 for the U.S. and from 1974 to 1999 for Canada.

Table 4. Mean annual regular-season Ross's goose harvest in the United States and Canada by period during 1966-99 (Federal harvest estimates from Sharp and Moser 2000).

Period	Mississippi Flyway	Central Flyway	Pacific Flyway	U.S. total	Canada total	Total U.S. and Canada
1966-69[a]	0	0	512	512	2,808	4,078
1970-79	0	402	4,893	5,295	4,705	10,000
1980-89	611	3,190	5,803	9,605	4,745	14,350
1990-99	4,536	16,594	8,536	29,674	13,565	43,239

[a] Harvest estimates for Ross's geese were first derived in the U.S. in 1966 and in Canada in 1968.

Magnitude of Ross's Goose Harvest

Subsistence harvest of Ross's geese is negligible in their traditional Queen Maud Gulf nesting areas (Ryder and Alisauskas 1995) and very low numbers, if any, are taken during limited subsistence hunting of snow geese in the Northwest Territories, Nunavut, Manitoba, and Saskatchewan (Dickson 1996).

Dzubin et al. (1966) estimated that the 1965/66 harvest of Ross's geese in prairie Canada was 1,800-2,300 birds and harvest in California was about 3,600-4,500 birds. Standardized waterfowl harvest estimates for Ross's geese have been conducted in the

U.S. since 1966 and in Canada since 1968. The estimated harvest of Ross's geese in the U.S. and Canada increased slowly from the 1960s to the 1980s and then increased more rapidly through the 1990s (Table 4, Fig. 2). Harvest estimates fit an exponential growth curve during 1968-99 (r^2 = 0.77, P <0.0001) with an annual growth rate of about 12% (Fig. 2). The rapid increase in harvest during 1992-99 appears linear (r^2 = 0.88, P = 0.0006) and represents an annual increase in harvest of 12,450 Ross's geese. Harvest has increased rapidly in the Central and Mississippi Flyways over time while the average harvest in the Pacific Flyway increased more gradually (Table 4). The estimated regular-season harvest in the U.S. and Canada reached a maximum level of 111,360 during the 1999/2000 season (Fig. 2).

Surveys to estimate waterfowl harvest in Mexico are not routinely conducted, but information from Kramer et al. (1995) suggests Ross's goose harvest there is negligible. They estimated that 1,391 light geese were harvested annually during 1987-93, a small but unquantified proportion of which were Ross's geese (G. W. Kramer, personal communication).

Federal harvest estimates in the U.S. do not include take of Ross's geese during conservation order periods, but the take of light geese during these periods is estimated by participating States. We estimated the take of Ross's goose during conservation order periods by multiplying the pooled State estimates of light goose harvest within the Central and Mississippi Flyways by the proportion of Ross's geese taken during regular hunting seasons in those Flyways. These calculations estimated that 17,508 and 43,055 additional Ross's geese were taken during 1998/99 and 1999/2000, respectively. The estimated continental take for Ross's geese during the 1999/2000 hunting season and conservation order periods was about 154,400.

Assessment of Recovery and Harvest Rates on Ross's Geese

We examined banding data to assess if recent increases in Ross's goose harvest corresponded to increases in the harvest rate of Ross's geese (i.e., harvest as a proportion of population size). Recovery rate (the probability a banded bird is shot or found dead and reported to banding authorities) is a relative index of the harvest pressure on a population. Alisauskas analyzed recoveries of banded Ross's geese in North America during 1961-99 (using Program MARK and BROWNIE time-specific models, R. T. Alisauskas, CWS, unpublished data). These estimates include reports of banded birds harvested during conservation order periods as well as during regular hunting seasons. Recovery rates (which are impacted by changes in reporting rates, see paragraphs below) peaked in the late 1960s and early 1970s, then declined to the late 1980s. Recovery rates generally increased from 1993 to 1999 for adults and from 1990 to 1999 for juveniles. However, average adult recovery rates for the 1990s are lower than all decades since the 1960s, and average juvenile recovery rates of the 1990s were lower than the 1960s and 1970s. Even the highest recent estimates (1999/2000) for adult and juvenile recovery rates (which are biased high due to recent increases in reporting rates) were surpassed in many years during the 1960s and 1970s.

Recovery rates may be misleading because they are influenced by band-reporting rates (i.e., the proportion of harvested banded birds that are reported to banding authorities). Dividing recovery rates by band-reporting rates yields an index to the harvest rate of the population. Estimates of band-reporting rates are obtained through periodic reward-band studies of mallards and have remained quite consistent from 1972 to 1991 (Henny and Burnham 1976, Nichols et al. 1991, Nichols et al. 1995). Although no reward-band studies have been conducted on geese, there is no information to indicate that band-reporting rates for geese differ substantially from mallards. Furthermore, if band-reporting rates for geese are consistent over time, the index to harvest rate remains valid regardless of the relationship to mallard reporting rates.

In an effort to increase band-reporting rates, North American waterfowl banders in 1995 began to use bands inscribed with a toll-free telephone number rather than the previously used abbreviated mail address. Band-reporting rates have increased drastically since 1995 due to this new band inscription and the associated public information campaigns. Estimated direct reporting rates for mallards have increased from 38% during 1988-91 (Nichols et al. 1995) to 91% in 1999 (J. A. Dubovsky, USFWS, personal communication). Of the band recoveries reported from the 1999/2000 waterfowl season, 92% of Ross's and lesser snow goose direct recoveries were reported via the 1-800 phone number, similar to the 93% of mallard bands that were reported via phone. The proportion of bands reported by phone in 1996/97 were 54% for Ross's and lesser snows and 68% for mallards (the mallard reporting rate estimate was 0.62, J. Dubovsky, USFWS, personal communication). These data suggest that increases in reporting rates for geese initially lagged behind mallards but increased to the same relative degree as mallards by 1998/99 (85% of light geese and 89% of mallards reported by phone).

We corrected estimated Ross's goose recovery rates (R. T. Alisauskas, CWS, unpublished data) with band-reporting rates referenced above (0.32 for 1961-87, 0.38 for 1988-94, Nichols et al. 1995), and for the years 1995-99 with both the "old estimate" (0.38, ignoring recent increases in reporting rates), and with "new estimates" of mallard direct reporting rates (0.62 in 1995 to 0.91 in 1999) to estimate harvest rates of Ross's geese (Fig. 3). We believe the actual harvest rate is best approximated using new reporting rates after the 1996/97 winter because the proportion of goose bands reported by phone quickly increased to levels similar to mallards. For 1995/96 and 1996/97, the best estimate of harvest rate likely lies between the rates derived with old and new estimates.

Estimates of harvest rates (Fig. 3) indicate the highest rates for adult and juvenile Ross's geese occurred around 1969 with subsequent declines in harvest rate at least through 1990. Figure 3 indicates that harvest rates of adults (using new reporting rate estimates) have been low and stable at about 3% since 1995. Similarly, harvest rates for juvenile geese are near historical lows, but have been increasing slowly since 1995 to a 1999 level of about 7%. Because Ross's goose populations have increased rapidly over
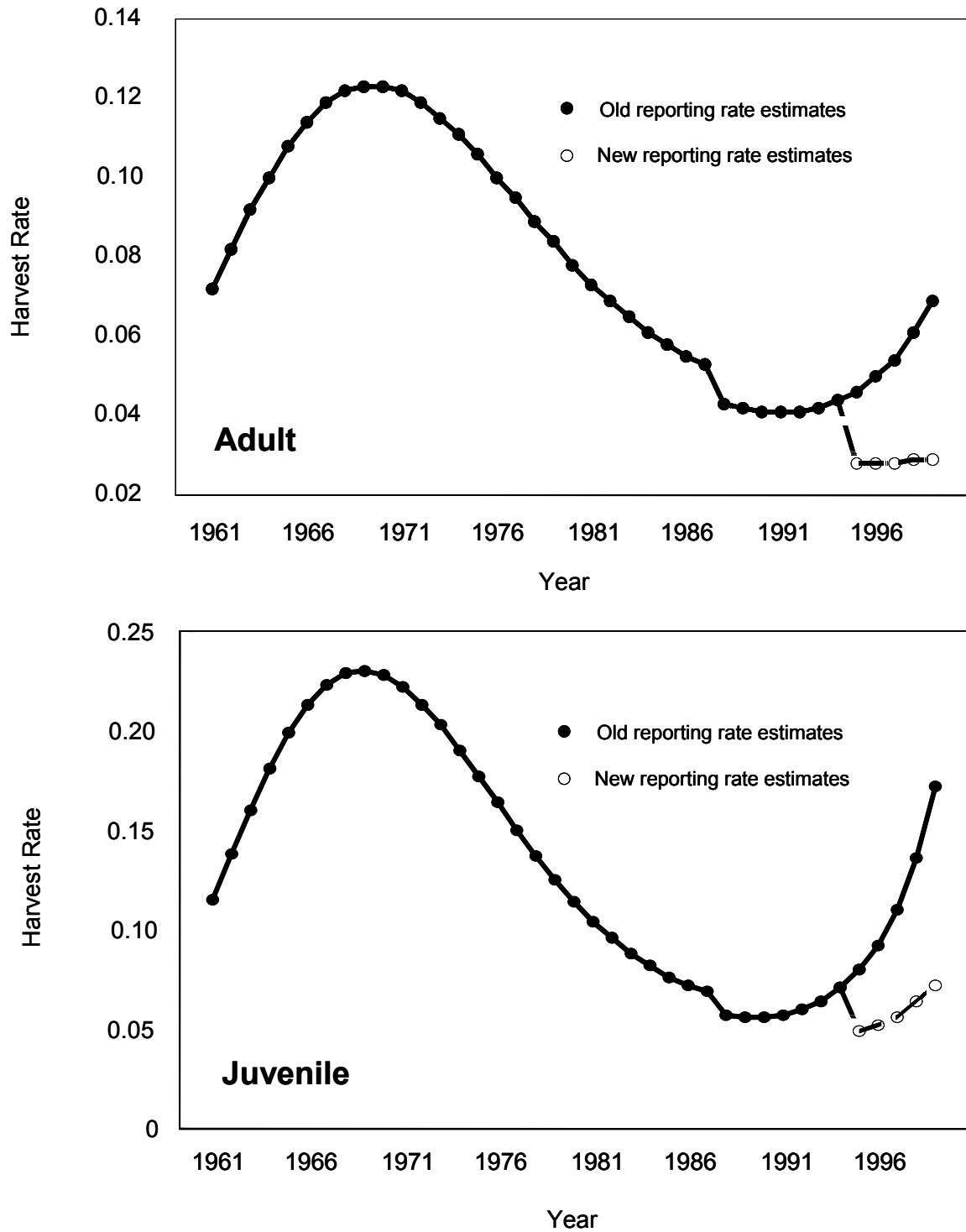
Fig. 3. Estimated harvest rates (recovery rate divided by reporting rate) for adult and juvenile Ross's geese banded in North America, 1961-99. Open circles indicate use of estimated reporting rates derived from reward band studies of banded mallards since 1995, when toll-free phone numbers were included on band inscriptions; closed circles

indicate use of estimated reporting rates from bands inscripted with traditional messages. See text for more information.
the last 40 years under harvest rates well above current levels, it is unlikely that current harvest strategies will curtail future population growth.

Proportion of Ross's Geese in the Harvest of Light Geese

Ross's geese have comprised an increasing proportion of the regular-season light goose harvest in the U.S. and Canada since the 1970s, when they constituted about 2% of the harvest. During 1990-99 Ross's geese represented a mean of about 5% of the light goose harvest.

The increased proportion of Ross's geese in the harvest could be explained by their higher population growth rate relative to midcontinent lesser snow geese (Alisauskas and Rockwell, this report), increased vulnerability to the gun (or hunter selection) of Ross's geese compared to snow geese, or increased numbers of snow geese being classified as Ross's geese in harvest surveys of tail fans due to reductions in snow goose body size (Cooch et al. 1991).

Dzubin (1965) included the opinion of J. D. Soper that Ross's geese are more vulnerable to the gun than are snow geese. Although anecdotal information from some hunters would support this contention, a comparison of banding data from of Ross's and snow geese banded in similar locations, time periods, and with similar marker types did not. We compared direct recovery rates of Ross's geese and lesser snow geese banded in the Queen Maud Gulf Bird Sanctuary during 1989-98. Analysis of variance indicated no significant differences in direct recovery rates between species (or interactions including species) in models including species, marker type, and year of banding for juveniles ($P > 0.90$) or adults ($P > 0.87$). This analysis took advantage of relatively simultaneous banding of both species in this sympatric breeding area and use of the same array of marker types (neck collars, colored legbands, and standard legbands only) but could not account for the more westerly wintering distribution of Ross's geese. However, band-reporting rates for mallards were higher in the Pacific Flyway than the Central Flyway (Nichols et al. 1995) which would have the effect of increasing the relative Ross's goose recovery rate and making Ross's geese appear more vulnerable to the gun in the analysis. The potential influence of declining snow goose body size on overestimation of Ross's goose harvest is under examination.

Production Estimation from Harvest Data

Harvest surveys, through the analysis of goose tails provided by hunters, also provide indices to the annual production of young geese. Because immature geese are more vulnerable to hunters than are adults (see recovery rates), age-ratio estimates are only relative indicators of gosling production among years. We compared age ratios of Ross's geese and snow geese to examine relative indices of gosling production and

changes in production over time. Although sample sizes for some years are small, these indices suggest that Ross's geese, on average, fledge more goslings per adult than do snow geese. Immature-to-adult ratios in the harvest were often twice as high for Ross's geese as those for snow geese in the U.S. harvest. This suggests that Ross's geese have been, and continue to be more productive than snow geese, although we note that if the vulnerability of young to adults varies between Ross's and snow geese, comparisons between species are less valid. Snow goose age ratios appear to be declining while Ross's goose age ratios appear to be increasing. Apparently, factors that may be reducing the productivity of snow geese are not impacting Ross's geese to the same extent.

LITERATURE CITED

Alisauskas, R. T. 2001. Nutritional ecology and population biology of Ross's geese, January, 2001. Unpublished report. Canadian Wildlife Service. Saskatoon, Saskatchewan.

Cooch, E. G., D. B. Lank, R. F. Rockwell, and F. Cooke. 1991. Long-term decline in body size in a snow goose population: evidence of environmental degradation? Journal of Animal Ecology 60:483-496.

Dickson, K. 1996. Wildlife harvests by aboriginal communities in Canada. Unpublished report. Canadian Wildlife Service. Hull, Quebec.

Dzubin, A. 1965. A study of migrating Ross geese in western Saskatchewan. Condor 67:511-534.

Dzubin, A., H. Miller, and G. Schildman. 1966. Distribution of recoveries of Ross' geese banded in the Kindersley district, Saskatchewan, 1961 to 1964. Unpublished report. Saskatoon, Saskatchewan.

Grinnel, J., H. C. Bryant, and T. I. Storer. 1918. The game birds of California. University of California Press. Berkeley, California.

Henny, C. J., and K. P. Burnham. 1976. A reward band study of mallards to estimate band reporting rates. Journal of Wildlife Management 40:1-14.

Kramer, G. W., E. Carrera, and D. Zaveleta. 1995. Waterfowl harvest and hunter activity in Mexico. Transactions of the 60th North American Wildlife and Natural Resource Conference. 60:243-250.

Nichols, J. D., R. J. Blohm, R. E. Reynolds, R. E. Trost, J. E. Hines, and J. P. Bladen. 1991. Band reporting rates for mallards with reward bands of different dollar values. Journal of Wildlife Management 55:119-126.

_____, R. E. Reynolds, R. J. Blohm, R. E. Trost, J. E. Hines, and J. P. Bladen. 1995. Geographic variation in band reporting rates for mallards based on reward banding. Journal of Wildlife Management 59:697-708.

Ryder, J. P., and R. T. Alisauskas. 1995. Ross' Goose (*Chen rossii*). Number 162 *in* The Birds of North America. A. Poole and F. Gill, editors. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Sharp, D. E., and T. J. Moser, compilers. 2000. Central Flyway harvest and population survey data book. U.S. Fish and Wildlife Service. Denver, Colorado.

Chapter 7:

POPULATION DYNAMICS OF ROSS'S GEESE

Ray T. Alisauskas, Canadian Wildlife Service
Robert F. Rockwell, American Museum of Natural History

In this chapter, we estimate annual rates of change for Ross's goose populations, and evaluate population response to increases in harvest. This exercise requires estimates of fecundity and survival and is based largely on unpublished data and analyses in progress (Alisauskas et al. ms[a], Alisauskas et al. ms[b]), or unpublished progress reports (Alisauskas et al. 1998b) based on ongoing research. Some estimates of vital rates (e.g., breeding propensity) for Ross's geese were not available and are the object of current research. It must be stressed that this modeling exercise is an approximation and makes a number of assumptions that are detailed below. In some cases, these reflect our attempt to simplify a complex system while in others it reflects uncertainty in the population parameter estimates. Current uncertainty regarding some parameters required that assumptions be made about specific probabilities, based on information on other Arctic goose populations or our best estimates. In cases where data were absent for Ross's geese, we relied on data from other species. In cases where we were uncertain about appropriate parameter values, we used values in population projection matrices that would result in an underestimation of the Ross's goose growth rate. Thus, our conclusions are subject to future revision as new information becomes available, and should be considered as preliminary.

Background

Under density-independence, population size in any year, N_{t+1}, is a function of size in the previous year, N_t, times the finite rate of population change or annual rate of population growth, λ, simply

$$N_{t+1} = \lambda N_t$$

So, for declining populations, $\lambda < 1$; if the population is stable, $\lambda = 1$; and if the population is increasing, $\lambda > 1$. Further, λ can be estimated from age-specific survival and fecundity rates using Leslie projection matrices (see below), but in its simplest form,

$$\lambda = F + S$$

where F = some measure of recruitment per female and S = annual survival rate of adult females (see below). The annual rate of population growth can also be estimated by log-linear regression of N over t (e.g., Eberhardt and Simmons 1992) as

$$\log N_t = \log N_0 + t \log \lambda$$

where $\log \lambda = e^r$ for continuously breeding populations or, alternatively and more appropriately for Arctic goose populations, $\lambda = (1 + r)$, and r is the intrinsic rate of increase (i.e., the population growth rate per individual).

Realized Growth in Population of Breeders at Karrak Lake

According to current estimates, more than 90% of Ross's geese still spend much of the summer in their traditional nesting areas in the Queen Maud Gulf Bird Sanctuary (QMGBS), despite some expansion of breeding range to the west and east (Ryder and Alisauskas 1995). Alisauskas et al. (1998) visited 87 of 92 light goose colonies documented by Kerbes (1994) and Alisauskas and Boyd (1994); 74 of these were active colonies. The 5 largest colonies contained over 92% of nesting geese in or near QMGBS. These 5 colonies (including Karrak Lake) also accounted for 91% of Ross's geese in the region. The Karrak Lake colony alone contained 40% of Ross's geese in the region. Kerbes (1994) estimated that Karrak Lake contained 38% of known Ross's geese near Queen Maud Gulf (QMG) in 1988. The number of Ross's geese nesting at Karrak Lake, together with its central location in the QMG, suggests that this colony well represents the continental population of breeding Ross's geese. Kerbes (1994) estimated from photographic counts of geese at known colonies that the average finite rate of increase in Ross's geese at QMG during 1965-88 was 1.077.

Since Kerbes' (1994) report, a photo-survey conducted in 1998 estimated 437,837 light geese nesting at Karrak Lake (R. H. Kerbes, personal communication). If all population estimates of Ross's geese from aerial photography (1976-98) and Ryder's estimate from 1965 are used in log-linear regression over time (1965-98), the finite rate of increase is 1.080.

Numbers of breeding Ross's geese have been estimated annually at Karrak Lake, 1993-2000, using stratified sampling of nests on 30-m radius plots. Sample plots were stratified based on nest density and sampling intensity and were systematically spaced at 0.5 km intervals in areas of high nesting density in the center of the colony, or increments of 1 km in areas of lower nest density. Nests were not obstructed by vegetation, and we have assumed complete detection of nests because of high visibility and multiple visits to sample plots. All nests on each plot are mapped and all eggs are measured and counted. Nests of Ross's and lesser snow geese were discriminated using egg measurements following Alisauskas et al. (1998a). Plots are revisited at least once to estimate nest success. Survival rate of individual eggs was estimated by visiting a subsample of nest plots up to 5 times. Standard procedures were followed using estimators in Thompson (1992:103). Breeding population estimates ($^\wedge N$) and 95% confidence limits (CL) were:

> 1993: $225,000 \pm 86,000$;
> 1994: $198,000 \pm 62,000$;
> 1995: $224,000 \pm 79,000$;
> 1996: $359,000 \pm 136,000$;
> 1997: $218,000 \pm 79,000$;
> 1998: $329,000 \pm 99,000$;
> 1999: $404,000 \pm 85,000$;
> 2000: $395,000 \pm 106,000$.

Regression of $\text{Log}(^\wedge N_t)$ on t, where $t_0 = 1993$, yields $95\%\text{CL}(r) = 0.0972 \pm 0.0729$. Following Eberhardt and Simmons (1992), we calculate $\lambda = (1 + r) = 1.0972$, because using $\lambda = e^r = 1.1021$, which implies continuous population growth, is not realistic for "birth pulse" populations such as Arctic-nesting geese. Thus, estimates of realized λ for breeding geese were derived independently from the estimates of λ using population projection (see below).

This point estimate of λ is higher than the one variously estimated for midcontinent lesser snow geese (λ ≈ 1.05) (Rockwell et al. 1997). Interestingly, Ross's geese at Karrak Lake show annual rates of population increase almost twice that of midcontinent lesser snow geese, and this has important implications on the relative potential response of each species to increased harvest rates.

Estimation of Survival Rates

We estimated annual survival probabilities, *S*, for Ross's geese banded and recovered during 1961-99 using band-recovery models (Brownie et al. 1985) as implemented by Program MARK (White and Burnham 1999). We included all adults banded in North America (*n* = 13,083) regardless of location of banding, as most were banded north of 56°N latitude; juvenile geese were stratified by whether they were banded north of 56°N latitude (summer *n* = 12,915) or south (rest of the annual cycle *n* = 2,337). For this exercise, we used the mean survival rate of adults and young calculated from year-specific survival rates. We estimated process variation in age-specific survival rates using these data following White et al. (in press). Results of survival estimation used in this report are preliminary, but are based on current analyses and preparation of Alisauskas et al. (ms[b])

Modeling Details

We examined population dynamics of Ross's geese with a projection model approach. In brief, we computed the mean 10-year stochastic growth rate from the best available estimates of demographic variables and their variances using brute-force, Monte Carlo modeling. We then used the results to project the continental population of this species for 10 years at the mean growth rate and at the upper and lower 95% confidence limits of that rate. We repeated the exercise using values of some of the variables depreciated by 1% to ascertain the relative impact of such changes on the population's dynamics. Finally, we examined the impact of additional annual removal of adults from additional harvest on population dynamics.

We used a 3-stage model (ages = 1, 2, 3+) to allow for the potential of reduced reproductive success of birds in age class 2. We parameterized it as a pre-breeding census, birth-pulse model where the first row fertilities are:
$$F_i = BP_i \times 0.5 \times CS \times NS \times HS \times GS \times s0$$
where BP is breeding probability, CS is clutch size, NS is nesting success, HS is hatching success, GS is gosling survival from hatching to fledging and *s*0 is juvenile survival from fledging to the next pre-breeding census. We assume that $BP_1 = 0$ and that $BP_2 \leq BP_{3+}$. We assume that these variables function independently from one another, and from adult survival.

The survival cells ($a_{2,1}$, $a_{3,2}$ and $a_{3,3}$) were all set to s_a. Because variance in these parameters is a biological reality, we used a stochastic approach rather than a deterministic one based solely on means. For stochasticity, we selected estimates for the variables for a single year by drawing them from an appropriate random distribution (below), combined them according to the formulation of a pre-breeding census matrix, projected the population for 1 year, reselected

estimates, projected for the next year, and so on for 10 years. In all cases, we assume stochastic effects are independent of each other. We then calculate the stochastic growth rate for the population λ_s using the Heyde-Cohen (1985) equation:

$$\ln \lambda_s = \frac{\ln N(T) - \ln N(1)}{T - 1}$$

To obtain an estimate of the mean and 95% confidence limits of the stochastic growth rate, we repeated this 1000 times and report the arithmetic mean and the lower and upper 2.5 percentiles (i.e., upper and lower 95% CL) of the 1000 estimates.

Owing to the log-normal nature of the distribution of population size, the average of these stochastic growth rates is less than or equal to that obtained by extracting the dominant eigenvalue of the mean matrix (λ_0). This is seen in the relation:

$$\ln \lambda_s = \ln \lambda_0 - \frac{\sigma^2}{2}$$

To place the stochastic growth rates on the usually recognized scale, we exponentiated the mean and the confidence limits. Note that the exponentiated confidence limits are not symmetrical about the exponentiated mean.

For illustrative purposes, the mean and 95% CL's were used to project populations of fixed initial size for the 10-year period and presented as graphs. To examine the relative impact of some potential management options, we re-ran these simulations decrementing either the age-specific survival probabilities or the age-specific fertility estimates by 1%. Because the elements contributing to fertility are multiplicative and independent, decrementing the fertility rates by 1% could represent a 1% decrement in any single element or a composite decrement totaling 1%. We present projections using these decremented stochastic growth rates as graphs for illustrative purposes. We also calculated the relative effect of these perturbations as:

$$re_i = \left(\frac{\lambda_{base} - \lambda_i}{\lambda_{base}} \right) \times \left(\frac{1}{p} \right)$$

where λ_{base} is the unperturbed stochastic growth rate, λ_i is the decremented stochastic growth rate and $p = 0.01$. These values are analogous to elasticities extracted from the mean deterministic matrix but do not necessarily equal them numerically. Like elasticities, however, they provide a guide to the relative impact an equal proportionate change in a demographic variable would have on stochastic growth rate of the population.

Parameter Estimates

Unless otherwise noted, age-specific fertility or survival rates come from papers, reports, or unpublished data of R. T. Alisauskas (cited above). In the following, we detail how point estimates and associated distributions were determined, and how they were incorporated into the stochastic model.

Breeding Propensity: $BP_2 = 0.35$; $BP_{3+} = 0.82$ - no values are available for Ross's geese (ROGO) so we initially used those for lesser snow geese from La Pérouse Bay. Estimates are from Rockwell et al. (1997) with BP_{3+} being an average over the La Pérouse Bay estimates for i

= 3, 4, 5+. This is an area where more information is required for Ross's geese, and which is currently being investigated at Karrak Lake.

Clutch Size: We used data from 1966 to 1999 from Karrak Lake. Mean estimate is 3.49 and the variance is 0.047. The latter reflects both process and sampling variance. Assuming the two are independent, the value represents an upper limit on process variance. Using it will underestimate the stochastic growth rate. We sampled this variable from a random normal distribution using 3.49 and 0.22 as μ and σ (see Tuljapurkar 1997).

Nesting Success: We used data from 1966 to 1999 from Karrak Lake. Mean nesting success was 0.83 with a range of 0.68 to 0.92. We sampled this variable from a random uniform distribution with those lower and upper limits.

Hatching Success: We used data from 1995 to 1998 from Karrak Lake. With only 4 year's data, we used a constant mean value of 0.82.

Gosling Survival: Although there are some data on the immature-to-adult ratios at hatching and near fledging from Karrak Lake, those data do not include an estimate of pairs that suffered total failure because such birds may move out of the sampling area. Thus, the initial trials of the model made use of lesser snow goose data from La Pérouse Bay. Using those data from Rockwell et al. (1997), this variable was estimated as a composite of total brood survival (1-TBF) and gosling survival (P3). We used the means over age classes of 0.93 and 0.69 for a composite of 0.64. This is an area where we require more data.

Juvenile Survival: We used data with a mean of 0.54 and variance of 0.0398 (see above). As for clutch size, the variance is a composite of process and sampling variance. We assumed this variable follows a beta distribution and estimated the shaping variables A and B by simulation in MATLAB release 12. They are A = 2.834 and B = 2.41. We sampled this variable using those estimates and BETARND from the statistics tool box of MATLAB release 12.

Adult Survival: We used data with a mean of 0.866 and (square root of) process variance of 0.0128 (see above). This estimate predates the special regulations and conservation order associated with the management of lesser snow geese of the Mid-continent Population, and should reflect survival of Ross's geese associated with "normal" harvest. Again, we assumed a beta distribution with shaping variables estimated by simulation of A = 608.3929 and B = 94.156. Again, we sampled this variable using BETARND.

Results

For reference to population dynamics of Ross's geese before increased harvest of midcontinent lesser snow geese associated with the conservation order, we calculated a deterministic, average matrix based on the means of the fecundity and survival parameters. The deterministic growth rate found as the dominant eigenvalue of the matrix is $\lambda_0 = 1.0926$. The stochastic growth rate of this population is estimated from our modeling as $\lambda_s = 1.0904$ with lower and upper 95% confidence limits of 1.0438 and 1.1343 respectively. As expected, the

stochastic growth rate is less than the deterministic one, but both are very similar to the estimate from log-linear analysis of trend data in estimated population size of Ross's geese breeding at Karrak Lake, 1993-2000. Projections for a population initialized with 400,000 females are depicted in Fig. 1. This represents projected growth of this population in the absence of any additional harvest associated with special regulations or conservation order periods stemming from the lesser snow goose management program. Fig. 2 represents population size from an initial population of 500,000 females for comparison with Fig. 1.

The growth rate of the population with a 1% reduction in adult survival (maintaining a fixed coefficient of variation) is $\lambda_s = 1.0811$ (1.0355 to 1.1225). This represents a relative reduction in stochastic growth rate of 0.85. For a 1% reduction in fertility, the stochastic growth rate is $\lambda_s = 1.0885$ (1.0425 to 1.1296) corresponding to a relative reduction of 0.17. These relative effects on stochastic growth (0.85 and 0.17) agree reasonably well with the asymptotic elasticities of adult survival and fertility estimated from the deterministic matrix as 0.84 and 0.16, respectively. The relative effects of these reductions are depicted in Fig. 3.
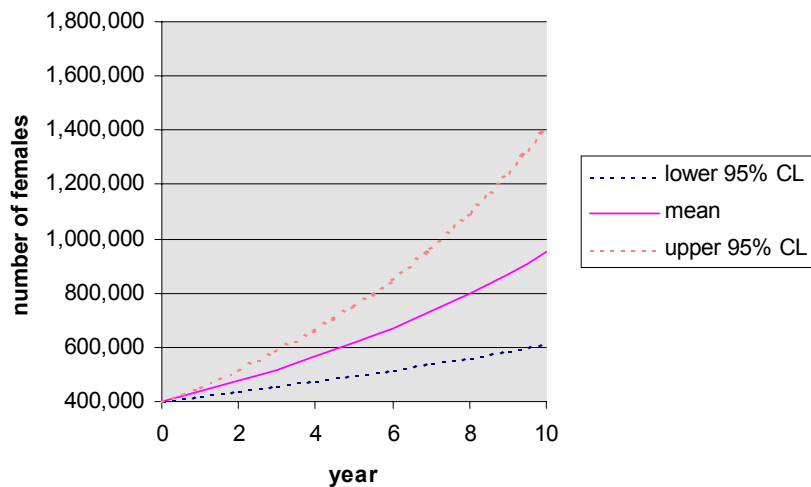

Fig. 1. Stochastic population projection of Ross's geese over 10 years assuming an initial population size of 400,000 females.
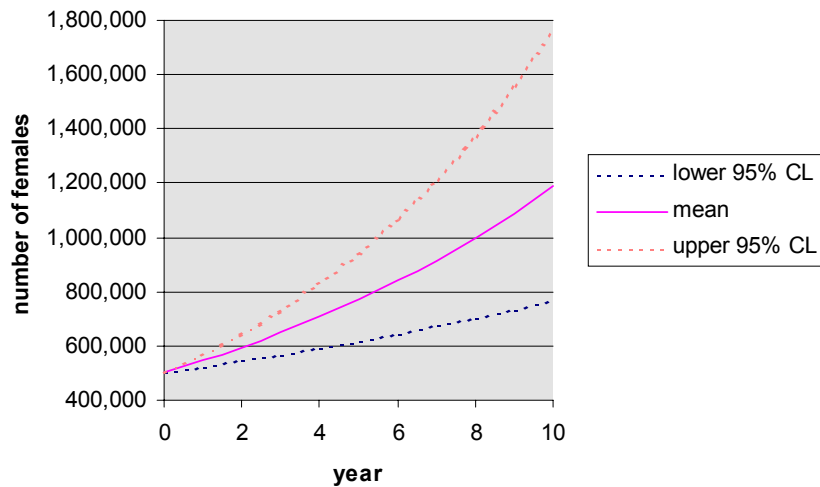
Fig. 2. Stochastic population projection of Ross's geese over 10 years assuming an initial population size of 500,000 females.
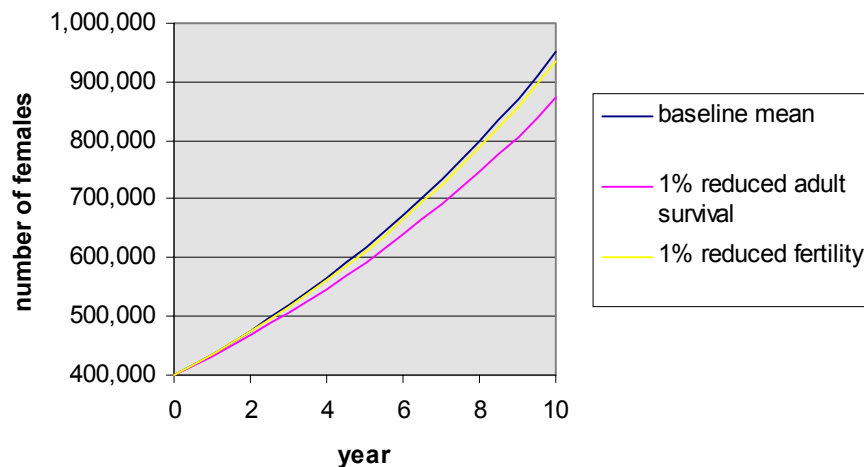

Fig. 3. Relative effects of 1% reduction in adult survival and recruitment on base population growth of Ross's geese. Initial population size of 400,000 females is assumed.

We estimated the potential impact of additional harvest of Ross's geese resulting from the expanded lesser snow goose harvest regulations implemented in 1998-99 (refer to harvest chapter) modeling the removal of a fixed number of Ross's geese each year. This is similar to "by-catch" models used in fisheries projections. We estimated the number of Ross's geese removed in the following way. For the regular season, we calculated the average total harvest of

Ross's geese in the Central and Mississippi Flyways (U.S.) and Canada for 1995 to 1997, the 3 years before any special regulations were implemented. This total is 40,432. We subtracted that mean from the total for 1999 of 86,665 and considered the difference of 46,233 to be the total Ross's "by-catch" during the regular season.

We estimated Ross's goose harvest during conservation order periods (1998-99 and 1999-2000) from 1999-2000 data, the higher harvest of the 2 years available. During conservation order periods we only have harvest estimates for snow and Ross's geese combined. We assumed that the proportion of Ross's geese in the conservation order harvest was the same as within the Mississippi and Central Flyways during the 1999 regular-season harvest, 0.037 and 0.124, respectively. The 1999-2000 conservation order harvests in those 2 flyways were 362,872 and 238,948, respectively and scaling by the appropriate harvest proportions yields a conservation order Ross's goose harvest of 43,056. The total Ross's goose by-catch is thus 89,289 (i.e., 46,233 + 43,056) and since our model considers only females, we estimated the fixed number of Ross's goose females to be removed as 44,645 (assuming an equal sex ratio in the harvest).

The impact of additional harvest of Ross's geese under the assumption of additive mortality is depicted in Fig. 4 for an initial population of 400,000 females and in Fig. 5 for an initial population of 500,000 females. We examined 2 scenarios. In the first, a constant block of 44,645 was removed each year for all 10 years of the projection. Assuming the true stochastic growth rate of the population is near the estimated mean or below, this scenario leads to a reduction if the initial population size of Ross's geese <496,000. This is an extreme scenario, however, since the size of the by-catch is likely to go down as the population declines. Moreover, the removal is not likely to extend for 10 years. Current management scenarios for the midcontinent population of lesser snow geese target a 5-year program. Furthermore, it is important to note that the projection is sensitive to the initial population size, and that populations comprised of >496,000 female Ross's geese will not decline at the rate illustrated in Fig. 4, and in fact, continue to increase (Fig. 5).

We examined a second scenario where the increased harvest of Ross's geese was suspended after 5 years. Although the same decline is seen when the actual stochastic growth rate is near the estimated mean or below, the population quickly rebounds when additional harvest was terminated (Fig. 6) on an initial population of 400,000. Again, for initial populations >496,000 females, the additional block harvest would not induce population declines (Fig. 7). This may be one of the most important points of this exercise. Given the conservative nature of our estimates of the population growth potential for this species and the nature of this by-catch pressure, it is clear that the species is capable of rebounding in a quick and positive fashion.

It is important to stress that the patterns depicted in both of our scenarios depend heavily on the starting population size estimate of 400,000 females. Given that value and our estimated stochastic growth rate of $\lambda = 1.09$, then an additional block harvest >36,000 females will lead to declines as depicted. Viewed in the opposite way, if the size of the "by-catch" is 44,645 and the source population for this extra harvest is really ≥496,056 (rather than 400,000) the mean growth rate, depicted as declining in Fig. 4, would actually increase (Fig. 5). This shows not only how
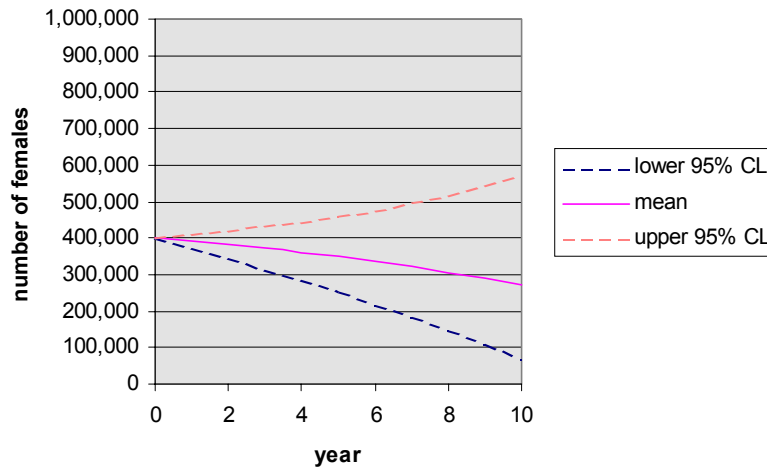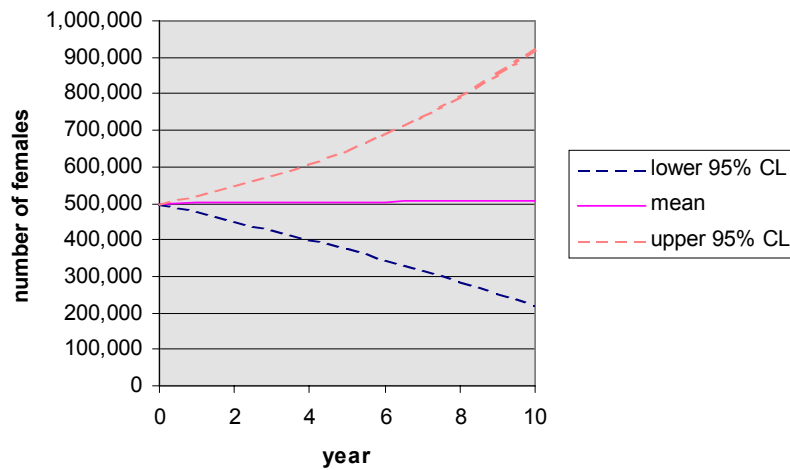
Fig. 4. Effect of additional harvest of 44,645 females on Ross's goose population growth, assuming an initial population of 400,000 females. Initial populations ≥~496,000 result in continued population increases at this level of additional harvest.

Fig. 5. Effect of additional harvest of 44,645 females on Ross's goose population growth, assuming an initial population of 500,000 females. Initial populations ≥~496,000 result in continued population increases at this level of additional harvest.
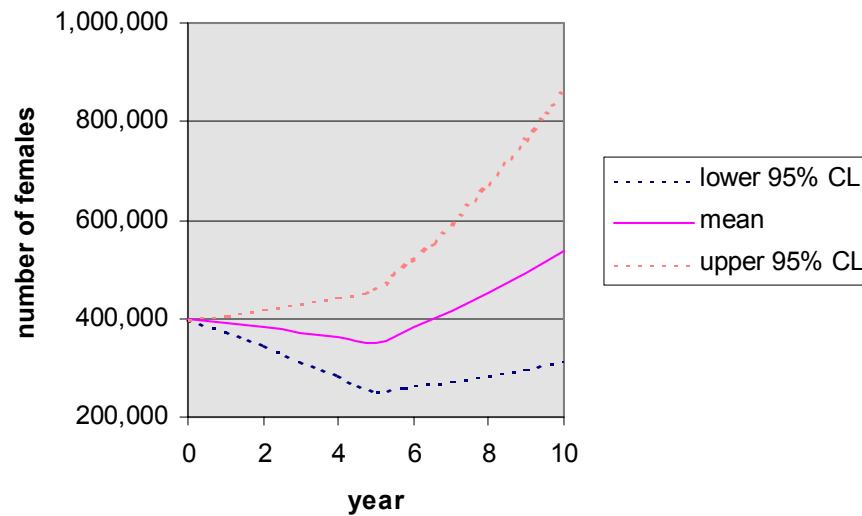
Fig. 6. Effect of additional harvest of 44,645 females for 5 consecutive years on Ross's goose population growth, assuming an initial population of 400,000 females.
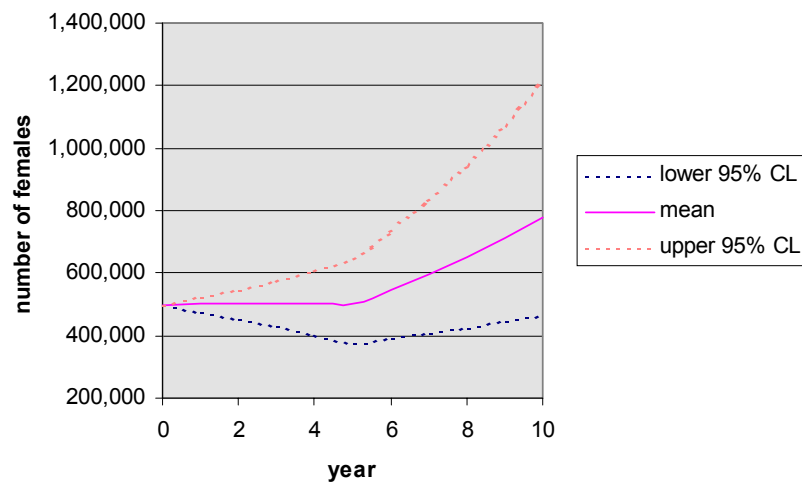

Fig. 7. Effect of additional harvest of 44,645 females for 5 consecutive years on Ross's goose population growth, assuming an initial population of 500,000 females.

sensitive the projections are to initial conditions but emphasizes the need for continued estimation of survival and fertility rates through continued banding and nesting studies.

Other Considerations

Our simulations assume a homogenous population of Ross's geese exposed equally to a base and extra-season harvest rate across their range. However, it is wise to consider historical changes in the numbers and distribution of Ross's geese across North America. Before their eastward expansion in migration and winter range, Ross's geese were largely confined to the Queen Maud Gulf region in Canada's central Arctic during summer, eastern Alberta and western Saskatchewan on the Canadian Prairies during migration, and the Central and Imperial Valleys of California in the Pacific Flyway during winter. Current Ross's goose population levels are at peak historical levels in the Pacific Flyway as well as the newly pioneered areas of the midcontinent (Kelley et al., this report). Thus, conclusions from our modeling exercise about expected reduction in Ross's goose population growth as a result of new regulations for midcontinent snow geese should be thought of as overestimating the effects. Conversely, it could be viewed that the "by-catch" would constitute a larger proportion of the Ross's geese that winter in the midcontinent region. Again, however, such developments might wisely be considered from the historical context of Ross's goose distribution. Even if it were possible to seriously reduce Ross's geese from their range in the recently pioneered midcontinent region, it is expected that Ross's geese in the Pacific Flyway would continue to grow under current conditions. Compared to rarity of Ross's geese in the 1950's (Ryder and Alisauskas 1995), a reduced number in the midcontinent region concurrent with the presence of hundreds of thousands in California probably should not prompt biological concern. Finally, under all of these scenarios of variable population size and bulk additional harvest, the North American population of Ross's geese is predicted to remain above the North American Waterfowl Management Plan population goal of 100,000 breeding geese (or 50,000 breeding females).

Final Caveat

We stress that the results presented are preliminary and based on a lot of assumptions. We strongly urge that estimation of survival and fecundity rates for Ross's geese continue.

LITERATURE CITED

Alisauskas, R. T., and H. Boyd. 1994. Previously unrecorded colonies of Ross' and Lesser Snow Geese in the Queen Maud Gulf Bird Sanctuary. Arctic 47:69-73.

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, H. Boyd, and D. Stern. Ms[a]. Productivity and population growth of Ross's geese and snow geese in Queen Maud Gulf Bird Sanctuary, 1966-1998. In preparation for Journal of Wildlife Management.

Alisauskas, R. T., K. L. Drake, S. M. Slattery, F. D. Caswell, A. B. Didiuk, and R. Bazin. Ms[b]. Distribution, survival and recoveries of Ross's geese in North America, 1961-1999. In preparation for Journal of Wildlife Management.

Alisauskas, R. T., S. M. Slattery, J. P. Ryder, M. L. Gloutney, A. D. Afton, R. H. Kerbes, and M. R. McLandress. 1998a. Discrimination of Ross's and Lesser Snow Goose eggs. Journal of Field Ornithology 69:647-653.

Alisauskas, R. T., S. M. Slattery, D. K. Kellett, D. Stern, and K. D. Warner. 1998b. Spatial and temporal dynamics of Ross's and snow goose colonies in Queen Maud Gulf Bird Sanctuary, 1966-1998. Unpublished progress report on numbers of geese and colonies. September 1998. Canadian Wildlife Service, Saskatoon, Saskatchewan.

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985. Statistical inference from band recovery data – a handbook. United States Department of Interior, Fish and Wildlife Service Resource Publication Number 156. Washington, D. C.

Eberhardt, L. L., and M. A. Simmons. 1992. Assessing rates of increase from trend data. Journal of Wildlife Management 56:603-610.

Heyde, C. C., and J. E. Cohen. 1985. Confidence intervals for demographic projections based on products of random matrices. Theoretical Population Biology 27:120-153.

Kerbes, R. H. 1994. Colonies and numbers of Ross' Geese and Lesser Snow Geese in the Queen Maud Gulf Migratory Bird Sanctuary. Canadian Wildlife Service Occasional Paper Number 81.

Rockwell, R. F., E. G. Cooch, and S. Brault. 1997. Dynamics of the mid-continent population of Lesser Snow Geese - projected impacts of reductions in survival and fertility on population growth rates. Pages 73-100 in B. D. J. Batt, editor. 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.

Ryder, J. P., and R. T. Alisauskas. 1995. Ross' Goose (*Chen rossii*). Number 162 in A. Poole, and F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Thompson, S. K. 1992. Sampling. John Wiley and Sons. New York, New York.

Tuljapurkar, S. 1997. Stochastic matrix models. Pages 59-88 *in* S. Tuljapurkar, and H. Caswell, editors. Structured Population Models in Marine, Terrestrial and Freshwater Systems. Chapman and Hall, New York.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:120-139.

White, G. C., K. P. Burnham, and D. R. Anderson. In press. Advanced features of Program MARK.

Chapter 8:

SUMMARY

This chapter contains the major points within *The Status of Ross's Geese* that address management issues regarding North American Ross's geese. The items are grouped by the chapter in which more information can be found.

Distribution and Abundance

More than 90% of Ross's geese nest in the Queen Maud Gulf region of the central Arctic.

Prior to the 1960s, most Ross's geese wintered in California. In recent decades, there has been a significant eastward expansion of the wintering range of Ross's geese.

The number of breeding Ross's geese estimated from photographic surveys at known breeding colonies has increased from 34,000 birds in 1966 to 619,000 in 1998.

The 1998 photographic survey estimate of 619,000 breeding Ross's geese was more than 600% of the continental goals of the NAWMP and Pacific Flyway Council.

Estimated spring populations of breeding and non-breeding Ross's geese at known colonies exceeded 800,000 birds in 1998. At the recent growth rate of 9.0% annually, the indicated total spring population for 2001 is 1.04 million Ross's geese.

Increasing trends in annual winter indices of Ross's geese corroborate rapid population growth and range expansion documented in Arctic nesting areas.

Interaction with Habitats

Ross's geese have degraded lowland habitats in the Queen Maud Gulf Migratory Bird Sanctuary predominantly due to grubbing in nesting areas. There is also evidence of Ross's goose impact on wetland habitats during the brood-rearing period at QMGBS.

Ross's geese have degraded lowland vegetation on west Hudson Bay, but the area of impact is small at this time.

Because of their ability to closely crop above-ground vegetation, Ross's geese may delay or prevent the recovery of tundra vegetation at sites already impacted by snow geese.

Disease Mortality

Avian cholera is the primary disease affecting Ross's geese in North America. Waterfowl appear to be the likely reservoir for avian cholera, and Ross's and lesser snow geese are indicated carriers of the disease.

An increased abundance and density of light geese likely pose an increased risk in the spread, transmission, and frequency of avian cholera outbreaks that occur in North America. Increases in avian cholera outbreaks are also more likely to affect the other species of birds using wetland ecosystems.

Harvest

Indices of harvest indicate a progressive eastward expansion in U.S. wintering range of Ross's geese from the 1960s through the 1990s.

Regular-season harvest of Ross's geese in the U.S. and Canada increased exponentially during 1968-99. Recent harvest appears to be increasing linearly at approximately 12,000 Ross's geese per year during 1993-99.

Harvest of Ross's geese in Mexico appears negligible.

Subsistence harvest of Ross's geese in North America appears negligible.

Estimated take of Ross's geese during the 1998/99 and 1999/00 Conservation Order periods in the Mississippi and Central Flyways were approximately 17,500 and 43,000, respectively.

Estimated harvest rates (recovery rate/reporting rate) of juvenile and adult Ross's geese during 1987-95 are lower than estimates for 1961-86. Analysis indicates adult harvest rates since 1995 have been about 3%, the lowest rate since 1961. Juvenile harvest rates from 1995 to 1999 have increased from 5% to 7%, are lower than harvest rates during 1961-85, and are similar to those during 1986-94.

Population Dynamics

Several observed and modeled estimates of Ross's goose population growth rate indicate Ross's geese are increasing 8-10% per year.

The impact on Ross's goose populations of harvest strategies directed at midcontinent lesser snow geese depends on initial Ross's goose population size.

A Ross's goose population comprised of <496,000 females is predicted to decline under harvest pressure associated with liberalized regular seasons and new special

harvest provisions directed at midcontinent lesser snow geese. A Ross's goose population comprised of >496,000 females is predicted to continue to increase under this harvest pressure.

Ross's geese have a high capacity to recover from any population declines associated with increased harvest.

Effects of increased harvest associated with new harvest provisions are anticipated to be higher in the recently pioneered midcontinent range of Ross's geese where liberalization of regulations and special harvest provisions have been implemented.

Modeling indicated that the continental population of Ross's geese will remain above North American Waterfowl Management Plan and the Pacific Flyway Council population goals even under sustained (10-year) implementation of new harvest provisions.

Continued estimation of survival and recruitment of Ross's geese is strongly urged to evaluate effects of increased harvest.