

SURVEYS OF NESTING LESSER SNOW GEESE AND ROSS'S GEESE IN ARCTIC CANADA, 2002 - 2009

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*A Special Publication of the Arctic Goose Joint Venture of the
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Cover photo: Snow and Ross's Geese at nests on the Karrak Lake Colony, Nunavut, 2008.
Photo credit: Richard Kerbes

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ABSTRACT

Aerial photographic and visual surveys of colonies of lesser snow geese, *Chen caerulescens* *caerulescens*, (hereafter, snow geese) and Ross's geese, *Chen rossii*, were done in the Eastern Arctic in 2003-2008, the Central Arctic in 2006, and the Western Arctic in 2002-2009. Estimated numbers of nesting snow geese in known colonies of the Eastern Arctic were 3,075,000 in 1997 and 3,282,800 (a 7% increase) in 2005-2008. Estimates in the known colonies of the Central Arctic were 740,600 in 1998 and 1,463,800 (a 98% increase) in 2006. Eastern plus Central Arctic thus totalled 4,746,600 nesting "midcontinent" snow geese in 2005-2008, a 24% increase from the 1997-1998 surveys. The estimate of nesting Ross's geese (in colonies shared with snow geese) in the Central Arctic was 519,300 in 1998; in 2006 it was 1,326,300, a 155% increase. Small but increasing numbers of nesting Ross's geese were detected in Eastern Arctic snow goose colonies, especially at McConnell River, which had at least 23,500 nesting Ross's in 1997 and 42,700 in 2008, a 74% increase. In the Western Arctic the total estimate of nesting snow geese in 2002 (579,300) was 19% higher than the previous estimate in 1995; in 2007 (303,800) it was low due to a very late spring on Banks Island; and in 2009 (427,500) it was 12% less than in 1995. Colonies surveyed were Egg River on Banks Island, which held most (97.2 - 99.9%) of the nesting geese, and two small colonies on the Canadian mainland. The Western Arctic population also includes several small colonies in Alaska, estimated to total 18,000 nesting birds in 2011. A new and improved method using aerial digital imagery was introduced in 2009 for the Western Arctic surveys, replacing traditional aerial film photography.

INTRODUCTION

Management action initiated in 1999 was aimed at reducing the numbers of “midcontinent” snow geese (defined as those nesting in the Eastern and Central Arctic) and Ross’s geese by increasing the harvest of those birds (Batt 1997). Evaluation of the effectiveness of that action included updated breeding ground surveys to determine if numbers of nesting adults would actually be reduced (Alisauskas et al. 2011, Leafloor et al. 2012). Surveys to estimate nesting numbers of each species, snow geese and Ross’s geese (together = “light geese”), using aerial photography, aerial visual surveys, and ground surveys, were conducted in the Eastern Arctic in 1997 and the Central Arctic in 1998 (Kerbes et al. 2006). Subsequent surveys in those regions, and the Western Arctic, were carried out as follows:

2002 - Western Arctic

2003 - West Hudson Bay

2004 - Southampton Island

2005 - Baffin Island

2006 - Central Arctic

2007 - Western Arctic

2008 - West Hudson Bay and Southampton Island

2009 - Western Arctic

Objectives of the 2002 - 2009 surveys were to estimate the number and distribution of nesting snow geese in the known colonies of the Eastern, Central and Western Arctic (Figs. 1 and 2), and of nesting Ross’s geese in the Central Arctic and at McConnell River in the Eastern Arctic. These surveys were focused on adults at their nests at the time of each June survey, and did not estimate numbers of non-breeders or failed breeders.

Note: The South Hudson Bay (Fig.1) region of the Eastern Arctic was not included in the post-1998 photo surveys. Instead, estimates of nesting snow geese were obtained using visual helicopter surveys in 2005 and 2006 by K. Abraham and K. Ross (pers. comm., see discussion below), and their results are included in this report.

METHODS

Aerial photography of the nesting colonies (Kerbes 1975, Kerbes et al. 1999, 2006) was done in June 2002-2008 (Table 1), using a Partenavia aircraft equipped with a large format (23 x 23 cm) LMK1000 or LMK2000 camera, 153 mm lens, and black and white film. Kodak Plus-X film was used to photograph the colonies from an altitude of 762 m above ground level, thereby providing a photo scale of 1:5,000, covering a strip of ground 1.15 km wide. Kodak Panatomic-X film was used at an altitude of 1,524 m, providing 1:10,000 scale, covering a strip 2.3 km wide. The scale 1:5,000 and 1:10,000 photos provided total or systematic sample coverage of the nesting colonies from which counts of white morph light geese were taken. Additional “low level” photography, using Plus-X from 305 m provided photo scale 1:2,000, for sample counts to estimate the percent blue morph among total light geese.

Digital imagery of nesting Western Arctic snow geese in 2009 (Table 1) was obtained from a Partenavia aircraft equipped with an Applanix DSS 439 digital imaging system, including GPS data. Different flying altitudes were tested but most of the imagery was acquired from about 1200 m above ground level, producing a pixel image representing about 21 cm x 21 cm on the ground. Each digital frame thus was visually analogous to a 23X23 cm photograph at a scale of 1:6500.

Analyses of air photos were done by the Canadian Wildlife Service (CWS) in Saskatoon, Saskatchewan per Kerbes et al. (2006). Sample counts of nesting geese throughout a given colony were obtained from a systematic subsample of photos. White morph birds (or both white and blue morph birds from low level photos) were counted by examining the original film negatives in roll form on a light table with a binocular microscope. Counts of geese were made using a transparent grid of 0.5, 1.0 or 2.0 cm squares, depending on the density of geese and scale of film being analyzed, placed beneath the film. Birds were recorded as nesting birds, and therefore included in the estimates, if they were in pairs, singles or groups of up to 4 on the ground. They were considered non-breeders, and not included, if they were “flyers” = all geese in flight, or “flocks” = groupings of 5 or more birds on the ground showing no evidence of standing or sitting in pairs.

The percentage of blue morph birds among light geese was estimated from sample counts of nesting birds from low level photos and/or of flying birds from both low and high level photos. In the Western Arctic, blue morph snow geese were known to be present, but their rarity made it unnecessary to use low level air photos for sample counts. Therefore the percentages of blues, and of Ross’s geese, were estimated from banding data. Colony boundaries were determined from the air photos by scanning and/or analyses to verify extent of area occupied by the nesting birds, supplemented in some cases by observations taken from the photo aircraft. Larger colonies were divided into strata based on nesting bird densities.

The estimate of nesting geese on each colony was obtained by expanding the estimated total number of white snows plus Ross's geese by the estimated percentage blue morph of total geese. For colonies that were stratified according to density ranges, the number of white morph nesting birds was estimated for each stratum, and then for the whole colony. That total was then expanded by the percentage blue morph to estimate the total nesting birds, with 95% confidence limits, for the entire colony.



Photo credit: Richard Kerbes

Estimating numbers of Ross's and snow geese in the Central Arctic: Due to substantial numbers of both Ross's and snow geese in the colonies, and since white morph snow geese could not be separated from Ross's geese on aerial photos, separate ground surveys were needed to estimate the proportion of Ross's geese among total light geese (Kerbes 1994, Kerbes et al. 2006). Those surveys were done by a helicopter-supported crew working from a camp at Karrak Lake (Colony 3) in 2005 and 2006. At colonies 3, 9, 10, 58, 81, 88 and 106, species and colour morph composition were determined by observers with binoculars counting numbers of Ross's geese, white morph snow geese, and blue morph snow geese at points chosen to representatively sample each colony. To sample mainland areas of colonies representatively, we used the following protocol. From where the helicopter landed, two to four observers walked at least 250 paces along paths (as constrained by any permanent water bodies) judged to maximize angles of travel between observers. After the initial sample nearest the helicopter, each observer continued to walk for about 500 paces away from the helicopter (again, as constrained by permanent water bodies) and another similar sample was taken. On islands with the longest axis $< \sim 300$ metres, only one sample of species/colour composition was taken; on islands ~ 300 to ~ 500 metres, > 1 sample was taken. On larger islands, the protocol for mainland sampling was used except that the minimum distance between sample points was 250 paces.

Search for potential “new” (previously unreported) colonies was done visually by the crews of the helicopter and the air photo aircraft as they moved to and from their target colonies. Special attention was given to checking shallow lakes with islands, which were considered preferred colony sites for Ross’s geese (Ryder 1969, Kerbes 1978). The ground crew also made visual aerial estimates of numbers of nesting light geese from the helicopter at small colonies as a supplement to the air photo coverage obtained from the photo plane. In cases where geese were nesting on islands, numbers were estimated using a hand counter, counting groups of 10 or 100. These counts included unknown numbers of non-breeders.

Data from the analyses of air photos, visual aerial surveys, and ground surveys were used to estimate the size and species composition of the colonies. All previously known major colony sites and almost all of the previously known smaller colony sites were surveyed by aerial photography and/or visual estimation from the helicopter. Four colonies, numbers 3, 9, 10 and 46, plus certain other colonies, constituted key colonies, at which both air photo and ground surveys were conducted. Air photos and ground work provided four types of data:

- a) Counts of white morph light geese, from scale 1:5,000 or 1:10,000 air photos at the large colonies and some of the small colonies;
- b) Counts of light geese visually estimated from the helicopter;
- c) Counts of blue and white morph nesting birds (from scale 1:2,000 air photos) and/or flying non-breeding birds (from scale 1:5,000 or 1:10,000 scale photos), for an estimate of the proportion of blue morph snows among light geese;
- d) Ground sampling of nesting birds for the proportions of Ross's, white snows, and blue snows among light geese present.

Data a, c, and d were obtained for all major and some of the other colonies. For these “key” colonies, the numbers, species and colour composition, with standard errors, were calculated after Kerbes (1994). In some colonies, photo samples were available to calculate the percentage blue snow geese among total light geese, but no ground data were available on snow: Ross’s goose ratios. Assuming that those colonies had the same percentage blue among snow geese as the mean for the nearest key colonies, we calculated the number of white snow geese, and subtracted that number from the total white snows plus Ross’s geese to get the number of Ross’s geese. In colonies with no samples for estimating colour morph or species ratios, we assumed that the percentage Ross’s geese among light geese, and the percentage blue snow among light geese, were the same as the mean values for the other colonies. Standard errors could not be calculated for the estimates of each species at colonies where independent ground surveys were not conducted.

In the Eastern Arctic, the Ross’s goose colony at McConnell River required a special combination of air photo and ground data, as noted below. At other Eastern Arctic colonies, ground surveys to detect Ross’s geese were not attempted, but small numbers of Ross’s were caught in banding drives for snow geese. Limited visual counts from a helicopter were obtained for Ross’s goose numbers on Baffin Island.

Digital imagery processing and analyses, Western Arctic, 2009: As explained by M. Mitchell of the United States Fish and Wildlife Service (USFWS) “The DSS is a complete medium format digital aerial imaging solution that includes the fusion of a 39 megapixel aerial camera, a flight management system, and a GPS-Aided INS Direct Georeferencing system. The data were processed using Applanix PosPac MMS 5.4 calculating a navigation solution using Omnistar satellite positioning system. The imagery was processed from raw data format to TIF using PosPac MMS Image View, correcting for lens falloff. INPHO Orthomaster was used to create orthophotos using the GPS data collected with the imagery and using the 25 meter ASTER GDEM2 as an auxiliary correction for the vertical data. Lens distortion was corrected during the orthophoto creation process. Orthovista was used to create the orthophoto mosaics. Color balancing was applied to images at this time to create a seamless mosaic. ERDAS 2010 was used to create pyramid layers and compute statistics.”

With both forward and lateral overlap accounted for, the resulting data files appeared as if they were a single “photograph” of the entire colony. CWS analysed those data using ESRI ArcGIS software and applying grid overlays. Counts within sample areas were done on-screen and tabulated by the software. The analyst visually recorded individual geese, identifying nesting birds and non-breeders as in photo analyses above. The location of each bird was plotted on the computer screen. Systematic sample counts throughout the colony were obtained for Egg River, and stratification and statistical procedures were carried out as noted above. Nearly complete counts were obtained for the small colonies at Anderson River and Kendall Island.

RESULTS

In the Eastern Arctic, over the period 2003–2008, 22 colonies were surveyed (Table 2, Fig. 1), some in more than one year. During 2005–2008, the estimated total of nesting snow geese was 3,282,800. Most (49%) were on Baffin Island, 29% on Southampton Island, 8% on West Hudson Bay, and 15% on South Hudson Bay. McConnell River on West Hudson Bay held an estimated 60,200 nesting Ross’s geese in 2003 and 42,700 in 2008.

In the Central Arctic in 2006, we estimated 2,790,100 nesting light geese (1,463,800 snow geese and 1,326,300 Ross’s geese; Table 3, Fig. 2) in 75 occupied colonies. Most colonies were in or near (within 12 km of) the Queen Maud Gulf Migratory Bird Sanctuary (QMGMBS), with 66 occupied colonies containing 971,000 Snows and 1,280,900 Ross’s. The remainder were east and north of the QMGMBS, where we recorded 492,800 Snow and 45,500 Ross’s geese nesting in 9 colonies. We surveyed 100 (93%) of the 108 previously known light goose colony sites in the Central Arctic. Of the 100 sites visited, 63 in the QMGMBS were occupied. We also surveyed 12 previously un-surveyed colonies: 8 in the QMGMBS and 4 to the north and east of the QMGMBS.

In the Western Arctic, the Egg River colony on Banks Island had an estimated 570,500 nesting birds in 2002; 295,100 in 2007; and 427,000 in 2009. The Anderson River colony had 1,900, 4,100, and 200 birds respectively; and Kendall Island 6,900, 4,600, and 300 respectively. Therefore the total numbers of snow geese estimated from the surveys of the Western Canadian Arctic in 2002, 2007, and 2009 were 579,300; 303,800; and 427,500, respectively. Using banding data from 2003-2007, the estimated percentage blue phase among total snow geese was 0.55% (n=8,233). Ross's geese were rare - only seven (0.1%) were captured in that sample.

DISCUSSION

“Midcontinent” nesting snow geese (Eastern plus Central Arctic) increased from a minimum of 1.1 million nesting birds in 1973-76 to 4.7 million in 2003-2006. The historical pattern of that growth, by regional components and with extrapolations between survey years, is shown in Figure 3. The estimate of nesting lesser snow geese at *all* known colonies in 2003 – 2009 can be considered as: 3,282,800 Eastern Arctic + 1,463,800 Central Arctic + 445,500 Western Arctic (includes Alaska) + 105,000 Wrangel Island (2004 estimate by Baranyuk, cited in Pacific Flyway Council 2006) = 5,297,100 in total. Although these four nesting regions are distinct and separate geographically, geese from each region overlap in varying degrees with those of other regions on migration and wintering areas. Connections and exchange among regions have been shown through studies of marked birds (Kerbes et al. 1999, Drake and Alisauskas 2004, Wood et al. 2011, Alisauskas et al. 2012b, Leafloor et al. 2012,) and genetics (Shorey et al. 2011).

Eastern Arctic 2003-2008

Baffin Island

Estimated numbers of nesting snow geese on Baffin Island changed little from 1973 to 1979, but increased almost 4-fold from 454,800 birds in 1979 to 1,733,500 in 1997 (Kerbes et al. 2006). In 2005, we estimated 1,618,600 nesting birds (Table 2, Figs. 4 and 5), which was 7% less than in 1997, indicating that growth there may have levelled off. Similarly, helicopter transect surveys in August, conducted annually on Baffin from 1996-2009 by F.D. Caswell and S. Wendt, estimated an average of ~1.6 million adult-plumaged birds, with no significant trend over that time (Alisauskas et al. 2012b).

Occupied nesting areas were smaller at all colonies in 2005 than in 1997, except for **Cory Bay**, where area more than doubled from 1997 to 2005 (Table 2, Figs. 6 – 10). In 2005 the absence of nests on **Air Force and Prince Charles islands** in Foxe Basin, and the declines at **Taverner Bay, Koukdjuak River** and **Cape Dominion**, were probably due to reduced nesting caused by a later snow melt in

these more northern colonies. **Bowman Bay** in 2005 was similar to 1997, while **Cory Bay** to the southwest showed a major increase, about 5-fold, from 1997 (42,500) to 2005 (240,000), probably due to shifting of nesting from the northern colonies to Cory Bay where snow may have cleared earlier than it did to the north. **Garnet Bay** (Figure 4) only 20 km south west of Cory Bay, had 2,200 nesting birds in 1997 but was not occupied in 2005.

Weighted mean colour ratio of the contiguous colonies of **Koukdjuak River**, **Cape Dominion**, and **Bowman Bay** on the Great Plain of the Koukdjuak, was 72.0 % blue in 2005, little changed from 72.8% blue in 1997. It had been 64% in 1979 and 61% in 1973 (Kerbes et al. 2006). Samples of snow geese banded in 2002-2005 provided the colour ratios used to extrapolate total snow geese from our photo counts of the white morph nesting geese. They were grouped (Table 2) for **Taverner Bay** and **Koukdjuak River** (62% blue) and for the southern colonies (80% blue).

Ross's geese on Baffin Island

In August 1992, F.D. Caswell (pers. comm.) captured 3 Ross's geese during banding, providing the first evidence of the species on Baffin Island, and in 1994 he captured another 20 adult Ross's geese with 33 goslings, confirming that they were nesting there. From an August 1995 survey, F.D. Caswell (pers. comm.) estimated 950 breeding adult and 1,750 young Ross's geese in the area from Cape Dominion to north of the Koukdjuak River. The area from Cape Dominion south to Bowman Bay was not surveyed, so the total number of Ross's geese probably was higher. Estimates of adult Ross's geese from F.D. Caswell's August helicopter transect surveys from 1996 to 2009 had wide overlapping confidence intervals, but they suggested a trend to increasing numbers, from approximately 5,000 adult-plumaged birds in 2002 to 25,000 in 2008 (Alisauskas et al. 2012b). A visual aerial survey of nesting geese on western Baffin Island in late June 2011 found fairly large concentrations of Ross's geese nesting immediately north and south of the Koukdjuak River near the coast, but no other obvious concentrations were noted (J. Leafloor and F. Roetker, pers. comm.).

Southampton Island

Southampton Island had an estimated 652,500 nesting snow geese in 2004 (Table 2, Figs. 11 and 12), 10% less than in 1997. However, in 2008 there were 939,700 nesting birds, 30% more than in 1997.

Boas River, including **Ell Bay**, (Fig. 13) with 472,400 nesting birds in 2004 and 644,000 in 2008, remained the largest Southampton colony, containing about 70-72% of the island's snow geese, having held 75% in 1979 and 73% in 1997. Among the three small colonies (Fig.14), **Bear Cove**, at about 13,000 nesting birds, changed little among years, while **Sutton River** saw a large increase from 1997 (900) to 2004 (3,100) but then in 2008 a decrease to 600. **Maurice Point**, which had been visited but had no nesting birds in 1997 or previous surveys, had 400 nesting birds in 2004. It increased dramatically to 10,500 in 2008. The **Coral Harbour** and **East Bay** colonies (Figure 15) together held similar numbers in 1997 (156,700) and 2004 (151,200), but were 43% larger in 2008



Photo credit: Richard Kerbes

(223,400), by which time their borders had merged. **Coats Island** (Fig. 11), about 80 km south of Southampton, was known to have migrant snow geese, but no nesting was reported in 1995 or previously (Gaston and Ouellet 1997). In June 2011, J. Leafloor and F. Roetker, (pers. comm.) did an aerial reconnaissance of the island and observed a snow goose colony “too large to count”.

Colour ratios (Table 2) of the snow geese in 2004, from air photos (Bear Cove area), banding (East Bay) and 35 mm photos of non-breeders (Boas River and Ell Bay) showed an increase at Boas River from 24.8% blue phase in 1997 to 31.3% in 2004, but little change at East Bay, from 45.2% in 1997 to 43% in 2004. Colour ratios in 2008 at both Boas River and East Bay were similar to those of 2004.

Ross's geese of Southampton Island

Ross's geese were recorded nesting at East Bay and Boas River as early as the 1950s (Barry and Eisenhart 1958). CWS Banding Office records show that in the 1950s and 1960s there were only 9 (0.02%) Ross's in a total of 39,032 light geese banded on Southampton Island. Further banding there in 1979 recorded an increase, with 10 (0.40%) Ross's in a total of 2,509 light geese banded (Abraham and Ankney 1986). In recent banding, from 2001 to 2010 a total of 2,954 Ross's were selectively captured, indicating that their numbers are probably increasing on Southampton Island.

West Hudson Bay

Nesting snow geese at west Hudson Bay (Table 2, Figs. 16 and 17) declined from 1973 to 1980, reached a high of 420,000 in 1985, declined to 211,600 in 1997, increased to 261,100 in 2003, and declined slightly to 246,300 in 2008.

McConnell River (Fig. 18), formerly the major colony of West Hudson Bay, grew from 14,000 nesting birds in 1941 to 326,000 in 1973 (MacInnes and Kerbes 1987), but has declined since then, to 51,200 in 2003 and 69,500 in 2008. Negative impacts to breeding ground habitats by grubbing and over-grazing by increasing numbers of snow geese were first reported in the late 1960s and early 1970s on the McConnell River delta (Lieff 1973). Further impacts were documented there and in the northern part of the McConnell colony in the mid-1980s by Kerbes et al. (1990). It seems likely that habitat deterioration on the McConnell River colony has caused a shift of nesting snow geese, especially to Maguse River, but also to colonies south of McConnell River. In spite of, or perhaps related to, the decline of snow geese at McConnell, a large Ross's goose colony (see below) became established there in 1994 (Kerbes et al. 2006).

Maguse River (Fig. 19), first recorded in 1973 with 1,000 nesting birds, became the largest colony on West Hudson Bay in 1997, with 80,900 nesting birds (Kerbes et al. 2006). Since then it increased by 47% to 118,700 birds in 2003 and subsequently declined slightly to 111,500 in 2008.

Wolf Creek (Fig. 20) declined by 55% between 1997 and 2003, and recovered to 2,600 in 2008 for a net decline of 41% since 1997.

South McConnell (Fig. 21) doubled from 1997 (26,800) to 2003 (55,400), but in 2008 declined to 30,600.

The colony at **Tha-anne River**, located on three small islands in the river delta, is of special historical interest, being the first (1912) known location of nesting snow geese on West Hudson Bay (local elder T. Siatala, pers. comm. to R. Kerbes in 1980). It supported 6,400 nesting birds in 1973 (Kerbes, 1975) but only 34 by 1997, and none in 2003 and 2008.

The **Geillini River** colony (Fig. 22) was first recorded in 1997 with 34,000 birds and showed similar numbers in 2003 and 2008.

McConnell River Ross's goose colony

The Ross's colony, established at McConnell River in 1994, was surveyed on the ground in 1994, 1995 and 1997 (Kerbes et al. 2006). It has consisted of a dense concentration of nesting Ross's geese surrounded by less dense nesting snow geese. In 1997, the entire area of the Ross's goose colony was photographed, plus the surrounding area occupied by snow geese, thus allowing a total count of Ross's geese and white snow geese within that area. High density counts from the film (20 or more nesting birds per 100m X 100m grid square) were assumed to be entirely Ross's geese. The location and total count of those high density samples defined the boundary and our estimate of 23,500 nesting Ross's geese in the colony.

Subsequent ground surveys by Caswell (2009) were used to estimate Ross's goose numbers in the colony, increasing from 53,600 nesting birds in 2003, to 57,500 in 2004, to 69,000 in 2005, then

levelling off at about 81,900 in 2006 and 81,400 in 2007. In 2003 and 2005 we used a method similar to that of 1997, with air photo analysis (of samples rather than total cover, and a high density stratum rather than high density cells) combined with ground information about the limits and distribution of Ross's nests from J. Caswell (pers. comm.) to estimate the size of the colony using the air photo counts. Numbers of nesting Ross's geese from photo surveys were estimated to be 60,200 in 2003 and 61,000 in 2005 (Figs. 23 and 24), similar to Caswell's (2009) estimates for those years. The nesting areas occupied in 2003 and 2005 were larger, but in the same general area as the nesting area defined in 1997, with the exception of the islands on the lake at the northeast corner of the McConnell snow goose colony (Fig. 18). Those islands were occupied by Ross's geese and a few gulls (*Larus spp.*) in 1997 (Kerbes et al. 2006, A. Didiuk pers. comm.), but by gulls only from 2003 – 2007 (J. Caswell, pers. comm.). In 2008 another air photo survey, using methods as in 2003 and 2005, estimated that 42,700 Ross's geese were present.



Photo credit: Dana Kellett

South Hudson Bay

The snow goose colonies of south Hudson Bay (Fig. 25) were surveyed by aerial photography from 1973 to 1997 (Kerbes et al. 2006). Since then, K. Abraham and K. Ross (pers. comm.) surveyed them with visual helicopter transects (Ross et al. 2004), and they provided the following results. They estimated that South Hudson Bay held 478,200 nesting snow geese in 2003-2006, a 17% increase from 1997 (Table 2, Fig. 26), which contrasted with a 3.4 fold increase from 1979 to 1997 (Kerbes et al. 2006). Colony results were as follows:

La Pérouse Bay colony had 58,700 nesting snow geese in 1997 and 83,600 in 2006, a 42% increase. The Knife River colony, which had 4,700 birds in 1997, has not been surveyed since then.

Cape Henrietta Maria, the major colony of South Hudson Bay, increased by 13%, from 320,000 estimated nesting birds in 1997 to 362,000 in 2005 (Hudson Bay Project, 2012). West Pen Island colony held steady at 16,500 nesting birds in 1997 and 2005. Shell Brook colony, which had 5,300 birds in 1997, was not occupied in subsequent survey years.

Akimiski Island, which had at least 3,450 nesting snow geese in 1997 (Abraham et al. 1999), had an estimated 2,000 birds in 2005.

Thompson Point, a new small colony established in the late 1990s or early 2000s, was surveyed in 2006 and estimated to hold just over 14,000 nesting snow geese.

Ross's geese: Abraham (2002) estimated 5,000 nesting birds at Cape Henrietta Maria in 2002 and R. Rockwell (pers. comm.) surmised that there were 3,000 at La Pérouse Bay in 2004.

Central Arctic 2006

The 2.8 million light geese estimated to be nesting at known colonies in the Central Arctic in 2006 was more than twice the 1.3 million estimated to be there in 1998 (Tables 3 and 4, Figs. 2 and 27). In 2006, 81% of known nesters were in or near the QMGMBs, as compared to 91% in 1998 (Kerbes et al. 2006). Several large colonies have been identified outside the QMGMBs, to the east on Rasmussen Basin, to the northeast on Adelaide Peninsula and King William Island, and to the northwest on Victoria Island (Fig. 2). The first colonies documented in the Central Arctic were in the QMGMBs, and they contained almost exclusively Ross's geese (Gavin 1947, Hanson et al. 1956). Significant numbers of snow geese were nesting among the Ross's geese by 1965 (Ryder 1969, 1971). Since then, the numbers of both species have increased rapidly (Tables 4 and 5, Fig. 27). As noted below, the colonies of the QMGMBs tend to contain a much higher proportion of Ross's geese than do the colonies outside the QMGMBs. The percentage of blue morph among snow geese in the Central Arctic was estimated at 23% in 2006 and 19% in 1998.

Queen Maud Gulf Migratory Bird Sanctuary

The estimated percentage of Ross's geese among light geese in the QMGMBs colonies declined from a high of 77% in 1965 to 58% in 1976, to 46% in 1982, and to a low of 40% in 1988; then rose to 43% in 1998 and 57% in 2005-2006. Over the 23-year period from 1965 to 1988 the number of snow geese increased at a faster rate than the Ross's geese, with annual average rate of change of 15.4% for snow geese and 7.7% for Ross's geese (Kerbes 1994). However, over the 10-year period 1988 to 1998 the increase rate for Ross's (10.7%) was higher than for snows (8.8%) (Kerbes et al. 2006), and the rate of increase for Ross's geese from 1998 to 2006 was 12.6 % per year, vs. 5.1% for snow geese (Fig. 27).

A total of 110 colonies have been recorded from 1965 to 2006 in and near the QMGMBs. Most of the known colony sites have been covered by photo and/or visual survey each survey year. Exceptions are two colonies on the western fringe. **Colony 108**, located at the Tingmeak River mouth in the extreme northwest corner of the QMGMBs (Fig. 2), was identified as a snow goose colony by Bromley and Stenhouse (1994) during post-hatch aerial surveys of waterfowl in 1989 and 1991. They estimated about 2,000 light geese were present in that area in each of those years. It was not covered by our surveys until 2005, when it had an estimated 500 nesting birds. **Colony 20**, in the southwest corner of the QMGMBs (Fig. 2), varied from 50 to 500 nesting birds from 1965 to 1988, but was not visited in 1998 or 2005. It is located on an unusual site, a high rocky island in the middle of the rapids of a swiftly flowing river.

Most nesting light geese of the QMGMBs have been in only a few large colonies, especially colonies 3 and 10. The percentage of total birds in those two colonies increased steadily from 52% in 1965-1967 to 89% in 2006 (Table 5, Fig. 28). The number of occupied colonies increased from 37 in 1965-1967 to 73 in 1998, but then decreased to 66 in 2005. “New” (previously undocumented) colonies have been recorded in each survey year following the original 1965-1967 survey, with 5 new colonies in 1976, 7 in 1982, 17 in 1988, 26 in 1990-1991, 10 in 1998, and 8 in 2005. Many colonies, especially the smallest ones, were not occupied each year. Of the 66 colonies known to have been occupied in at least one survey year between 1965 and 1988, the number occupied by nesting geese in all years in which they were checked, from date of discovery was 36 (55%) up to 1998, and 33 (50%) up to 2006 (Table 6).

Major QMGMBs Colonies

Colony 3, Karrak Lake (Fig. 29 and 30), held the largest percentage of nesting light geese in the QMGMBs in the surveys of 1965-1967 (39%), 1976 (41%), 1982 (54%), and 1988 (46%). However, in 1998 its percentage fell to 38%, being surpassed by Colony 10 with 42%. In 2005-06, Colony 3, with 901,000 birds, had 40% of the total, while Colony 10, with 1.1 million birds, had 49% (Table 3 and 5, Fig. 28). Estimates in 1998 and 2006 of the number of nesting light geese at Colony 3 based on 30 m ground plots were about 25% higher than our estimates from photo surveys, and possible reasons for this discrepancy were discussed by Alisauskas et al. (2012b). The most obvious of those was that the ground survey estimated the total number of birds that attempted to nest over the whole season while the photo survey estimated only the number of birds nesting at mid-incubation, i.e. significant nest loss/abandonment could have occurred before the photo survey was done. Also, when Alisauskas et al (2012b, p. 169) referred to the photo survey excluding standing groups >4, in fact we excluded such groups only after determining that they did not consist of closely associated pairs (see Methods). Another possible reason for the discrepancy between ground and photo estimates for Colony 3 given by Alisauskas et al (2012b, p. 169) - detection of blue geese on air photos - does not apply because we used ground estimates, not photos, for species and colour ratios.

Colony 10 (Fig. 31 and 32) has had the fastest rate of increase since 1982 among the major colonies. The number of birds at Colony 10 increased over 3-fold from 1982 to 1988, over 4-fold from 1988 to 1998, and over 2-fold from 1998 to 2006 (Table 4, Fig. 28). In 2006, the percent blue of snow geese (Table 3) continued to be higher at Colony 10 (25%) than at Colony 3 (22%). Being the furthest east of the major QMGMBs colonies, Colony 10 may be the major recipient of immigrants from the Eastern Arctic where snow geese have higher blue ratios than in QMGMBs (Kerbes et al. 2006). Also, a substantial movement of neck banded Ross's geese moving from West Hudson Bay to the QMGMBs, especially Colony 10, has been documented by Drake (2006) and Caswell (2009).

Colony 46 (Fig. 33) expanded 27-fold between 1982 and 1998. A large part of that growth was due to its coalescing with Colonies 27 and 45 between 1988 and 1998. It grew by 45% from 69,500 nesting birds in 1998 to 100,500 in 2006.

Colony 9, at 107 km from the coast of Queen Maud Gulf, is the most inland of the major colonies. After expanding (Fig. 34) more than 12-fold from 1965 to 1988, its population size decreased (Fig. 35) by 52%, from 75,000 nesting birds in 1988 to 36,100 in 1998. It held only about 9,100 in 2006, 75% less than in 1998. Reasons why Colony 9 is the only major QMGMBs colony to be in decline are unclear. There is no evidence that environmental conditions, such as habitat, spring snow clearance, or weather are relatively worse there than at the other major colonies. Kerbes et al. (2006) speculated that predation by grizzly bears (*Ursus arctos horribilis*) may be a factor. Part of the mechanism of Colony 9's decline may be through emigration of breeding birds to other colonies, especially colonies 10 and 3. As has been shown with snow geese (Geramita and Cooke 1982), substantial numbers of both female and male Ross's geese move, and they tend to move from smaller to larger colonies, and from lower to higher density nesting areas of the large colonies (Drake 2006, Alisauskas et al. 2012a).



Photo credit: Richard Kerbes

Colonies Outside QMGMBs

The proportion of Central Arctic light geese known to be nesting in colonies outside the QMGMBs area (Fig. 2) was very small prior to 1998. In 1998 significant new “outside” colonies were recorded, amounting to 9.0% of the estimated 1.3 million birds in the Central Arctic (Kerbes et al. 2006). In 2005-2006 that proportion doubled, to 19.3% of 2.8 million birds (Tables 3 and 4), showing that the non-QMGMBs colonies are an important and growing segment of the Central Arctic. As noted below, available data suggest that the colonies outside the QMGMBs have lower proportions of Ross’s geese than the colonies in the QMGMBs.

Elliot Bay Colony (Fig. 36), although first reported in 1979, was not surveyed until 1998 (Kerbes et al. 2006). The largest of the Central Arctic colonies outside the QMGMBs, it almost tripled in size, from 45,900 nesting light geese in 1998 to 171,500 in 2006. As noted above for Colony 10, it may be getting substantial emigrants from west Hudson Bay or other Eastern Arctic colonies. Continued rapid expansion of this colony seems likely, since it is near to large areas of potential summer habitats on Chantry Inlet to the east (McLaren and McLaren 1982, Hines et al. 2003, Johnson et al. 2000).

Adelaide Peninsula Colony 1, first recorded in 1998 with 200 nesting birds, was not visited in 2005-2006. **Adelaide 2** (Fig. 37), also first recorded in 1998 with 12,700 nesting birds, grew almost 6-fold, to 73,200 in 2006. **Adelaide 3** (Fig. 38), first recorded in 2005, had 12,600 birds in the photo survey of 2006. Adelaide Peninsula also had dispersed nesting just north of Sherman Basin, but south of Adelaide Colonies 1, 2, and 3, and at 2 locations east of Barrow Inlet (Alisauskas 2006). We assumed that the Adelaide and Elliot Bay colonies had the same percentage of Ross’s geese as the eastern colonies of the QMGMBs, 50 km distant.

Inglis River Colony (Fig. 39), on the east shore of Rasmussen Basin, almost 200 km north east of the QMGMBs, was known since 1975, and tripled in size from 10,800 in 1995 to 30,700 nesting snow geese in 1998 (Kerbes et al. 2006). Its rapid expansion continued, to 126,400 in 2006. Two Ross’s geese were recorded in this area in 1995 (Kerbes et al. 2006), but the high percentage of blue morph (25%) among light geese at Inglis River suggested that it probably did not support a significant number of Ross’s geese.

Kuugarjuk Lake Colony, located about 40 km north of Inglis River, was first recorded in 1994 with 1,800 nesting snow geese, growing to 2,300 in 1995 and to 4,300 in 1998 (Kerbes et al. 2006), declining to 900 in 2006. As at Inglis River, 25% blue morph birds suggested that most light geese there were snow geese.

Erebus Bay Colony (Fig. 40), located on western King William Island, about 150 km north of the QMGMBs, had 93,800 nesting birds estimated from aerial photography in 2006. Snow geese were known to be nesting on King William Island earlier (Paul Iqalak, pers. comm., Bromley and Stenhouse 1994) but no colony sites had been reported until Alisauskas (2006) observed nesting birds at Erebus Bay in 2005 during waterfowl transect surveys by helicopter.

Jenny Lind Island Colony (Fig. 41) lies about 100 km north of the QMGMBs in Queen Maud Gulf. The island has had a very large light goose population relative to its very limited habitat, with obvious risk of starvation of moulting adult geese and their young in summer, unable to fly from the island to seek food resources elsewhere (Kerbes et al. 2008). Small numbers of nesting snow geese were first reported in 1962-1966, increasing to 54,100 adults (including non-breeders) estimated in July 1985. June photo surveys of nesting adults since then have estimated 39,200 in 1988, 19,300 in 1998, and 21,600 in 2006. The proportion of Ross's geese on Jenny Lind was estimated in 1988 at 2.7% of the nesting light geese. Population decline in the 1980s was consistent with anecdotal reports by others that die-offs of snow geese occurred in 1984, 1985 and 1989, and with August 1989 fieldwork which found evidence of habitat degradation and malnourishment of young geese. In spite of the evidence of limited food resources on Jenny Lind Island, the number of nesting birds in 2006 was similar to what it was in 1998 (Kerbes et al. 2008).

On Victoria Island, Bromley and Stenhouse (1994), from their post-hatch surveys of July 1989-1991, estimated there were almost 2,000 snow geese with about 50 broods in each of the Albert Edward Bay area and the south east area of the island. In 2006, the photo surveys confirmed that substantial colonies had developed in both of those areas. **Icebreaker Colony** (Fig. 42), located about 5 km inland from Icebreaker Channel, opposite Jenny Lind Island, had an estimated 16,600 nesting birds in 2006. **Anderson Bay Colony** (Fig. 43), on southeast Victoria Island, had 21,500 nesting birds in 2006. Groves and Mallek (2012) flew transect surveys for waterfowl and other birds in those areas in June 2011. Although their survey was not designed to detect or estimate the size of colonies, they found evidence of increased numbers of snow geese, recording about 130,000 on south eastern Victoria Island.

Western Arctic 2002-2009

The estimated total nesting snow geese in the three known Western Canadian Arctic colonies (Fig. 44) almost tripled from about 170,000 in 1976 to 486,000 in 1995. The estimate in 2002 was 19% more than in 1995, and the number in 2009 was 26% less than in 2002. Thus, there was a net decrease of 12% between 1995 and 2009 (Figure 45, Tables 7 and 8).

Egg River colony (Fig. 46) on Banks Island continued to have almost all of the nesting birds known to occur in the Western Arctic. It has consisted of a main area on Egg River, south of Big River, and a smaller, sometimes separate, sometimes connected, area about 5 – 10 km to the southwest on Rotten Creek (Kerbes 1986, Kerbes et al. 1999). In 2009 geese did not nest in the Rotten Creek area. The total colony area fluctuated from 305 km² in 2002, when spring was unusually early, to 93 km² in 2007 when spring was late (Table 7). In 2009, when the date of snow melt was average, the number was significantly higher than in 2007, but not up to the level of 1995 or 2002, which were early spring years at Egg River. Ground studies at Egg River from 1995 to 1998 by Samelius et al. (2008) found that the late snow melt in 1997 reduced the number of nesting geese to even less than it was

in 2007. The ground survey in 1995 by Samelius et al. (2008) of the Egg River colony excluded the Rotten Creek area and estimated a total of 404,000 nesting birds. That estimate was 6.2 % less, but not significantly different, than the 1995 photo estimate of the whole colony minus Rotten Creek, $479,300 - 48,700 = 430,600$ (Kerbes et al. 1999).

Anderson River and Kendall Island, the two small colonies (Figures 47 and 48), did not show a decrease in 2007 as at Egg River. However, the combined total estimate for the two, after fluctuating between 1,500 and 9,500 nesting birds between 1976 and 2007, dropped to only 500 in 2009. Nesting birds at both colonies consistently occupied the same deltaic islands from 1976 to 2009, with only minor variations in distribution (Kerbes 1986, Kerbes et al. 1999, Wiebe Robertson and Hines 2006, Obst et al. 2013). Their numbers and nesting success appear to be limited not only by late snow melt as in 2009 (Blake Bartzen, pers. comm.), but also by annually variable but often severe predation by barren-ground grizzly bears (Armstrong 1998). The timing of the arrival of bears has been observed to coincide with peak egg-laying, and Obst et al. (2013) found that in 2005 and 2006, grizzlies accounted for 82% of the nest failures. In 2007, at Anderson River, before hatch and after the aerial photography had been done, J. Hines (pers. comm.) observed that most of the nests had been destroyed by grizzly bears. Flooding in the deltas can also prevent and/or destroy nesting efforts (Barry 1967, Wiebe Robertson and Hines 2006, Obst et al. 2013).



Photo credit: Richard Kerbes

In addition to the above locations, nesting snow geese have also been reported from southern Banks Island and western Victoria Island, but numbers up to 1995 were relatively small, estimated at a few hundred birds in total (Kerbes et al. 1999). Groves and Mallek (2012) flew transect surveys for waterfowl and other birds in those areas in June 2011. They found evidence of increased numbers of snow geese, recording almost 5,000 on south western Victoria Island, but did not observe any nests.

In **Alaska**, about 1,000 nesting snow geese were recorded at Howe Island in the Sagavanirktok River delta in the mid-90s by Johnson (1996). He also reported, from banding and neck banding studies, that they were part of the Western Arctic snow goose population. Annual aerial waterfowl surveys on the Arctic Coastal Plain of Alaska (Burgess et al. 2012) recorded increasing numbers of snow geese, from 430 in 1995 to about 26,000 in 2011. Those surveys identified four nesting colonies (Fig. 44), the largest being at Ikpikpuk River delta. Known since 1992, that colony was estimated, using 35 mm aerial photography and ground sampling, to have 8,886 nests, or almost 18,000 nesting birds in 2011 (Burgess et al. 2012). Although numbers are still small compared to the big Canadian colonies, nesting snow geese have increased rapidly in Alaska over the past 20 years.

The Western Arctic population grew at an estimated 3.3% per annum from 1960 to 1981 (Kerbes 1986), at 6.3% from 1981 to 1995, and has remained nearly stable, with a decline of 0.9% per annum from 1995 to 2009. The long-term annual growth rate has been about 2.6 % from 1976 to 2009, based on our photo survey estimates.

Shift from film photography to digital imagery

Surveys of light goose colonies in the Canadian Arctic have used large format (23 X 23 cm) aerial cameras and photographic film since the surveys began in 1972 (Kerbes 1975, Kerbes et al. 2006). Obtaining air photos or digital imagery of the nesting colonies, weather permitting, is fast and efficient, but analyzing photographic film is a slow process, compared to that of digital imagery. By the early 2000s digital aerial cameras were becoming viable alternatives to conventional film cameras. In 2009 in the Western Arctic, high resolution digital imagery was used to survey snow goose colonies for the first time, with increased efficiency in the fieldwork and especially in the analysis, as compared to conventional photography. Digital imagery was used again on Baffin Island in 2011 and in the Western Arctic in 2013. Further efficiencies are expected as processing and analyses are fine-tuned.

The acquisition by the USFWS of the Applanix 439 digital imaging camera system in 2009 to replace the aging LMK2000 analog system represented a significant advance in aerial waterfowl surveying methods. The field advantages of a digital system include: replacement of large, expensive rolls of film by small, cheap electronic memory, prompt and on-site image quality feedback, and embedded image metadata. In monitoring colonies of light geese, the detailed spatial distribution of nesting birds is important. A significant advancement is achieved with the electronic geo-referencing of images. Previously, with photographic film and paper maps, a huge amount of time was spent manually mapping the photo coverage and verifying photo scale. With digital, geo-referenced imagery the colony information is simple to derive and portray, and the precise location of each goose image is recorded.

Digital photography provides increased efficiency for manual counting of goose images through better ergonomics, ease of zooming in and out, image enhancement capability, and computerized tabulation of numbers (paperless data entry). Automated counting of goose images holds potential for further increasing efficiency of analysis. While this appears to work very well for birds on open water (Milton et al. 2006, Groom et al. 2011), there are considerable challenges to the automated process when the birds are on land. There is greater variation in background, resulting in a wide variety of contrast scenarios between goose image and background, as well as competing images (gulls, rocks, ice or snow patches, and other “unidentified objects”). Nonetheless, some areas of light goose colonies do lend themselves to the process due to uniformity of habitat and relative lack of competing objects. Those areas can be selected for automation, reducing the analyst’s manual counting task load.

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TABLES AND FIGURES

Table 1. Photo surveys of nesting lesser snow geese and Ross's geese of the Canadian Arctic, showing dates, locations, personnel and equipment, 2002-2009.

Year and area	Team		Aircraft type	Camera	Photo dates
2002 Western Arctic	Al Cilurso ¹	Jim Bredy ¹	Partenavia	LMK1000	8-9 June
2003 West Hudson Bay	R. Foster ¹	B. Lubinski ¹	Partenavia	LMK2000	12-18 June
2004 Southampton Is.	B. Lubinski ¹	K. Warner ²	Partenavia	LMK2000	25-26 June
2005 Baffin Is.	B. Lubinski ¹	D. Caswell ²	Partenavia	LMK2000	18-29 June
2006 Central Arctic	B. Lubinski ¹	K. Warner ²	Partenavia	LMK2000	18-23 June
2007 Western Arctic	B. Lubinski ¹	K. Warner ²	Partenavia	LMK2000	15-22 June
2008 West Hudson Bay	B. Lubinski ¹	K. Warner ²	Partenavia	LMK2000	21-24 June
2008 Southampton Is.	B. Lubinski ¹	K. Warner ²	Partenavia	LMK2000	25-26 June
2009 Western Arctic	B. Lubinski ¹	K. Warner ²	Partenavia	Applanix ³ DSS 439	19-24 June

¹*US Fish & Wildlife Service;* ²*Canadian Wildlife Service;* ³*Digital*

Table 2. Results of surveys of nesting lesser snow geese in colonies of the Eastern Arctic in 1997, compared to West Hudson Bay 2003 and 2008, Southampton Island 2004 and 2008, Baffin Island 2005, and South Hudson Bay 2005 and 2006, with \pm 2 SE where feasible.

Colony and year	2005 - 2008					2003 - 2004					1997 ^a				
	NESTING BIRDS No. ±2 SE	CHANGE SINCE PREVIOUS SURVEY	PERCENT BLUE	NESTING AREA (KM ²) WITH % ANALYSED	DENSITY (NESTING ADS/KM ²)	NESTING BIRDS No. ±2 SE	CHANGE SINCE PREVIOUS SURVEY	PERCENT BLUE	NESTING AREA (KM ²) WITH % ANALYSED	DENSITY (NESTING ADS/KM ²)	NESTING BIRDS No. ±2 SE	PERCENT BLUE	NESTING AREA (KM ²) WITH % ANALYSED	DENSITY (NESTING ADS/KM ²)	
Baffin Island															
Prince Charles Island ^b	-	-	-	-	-	-	-	-	-	-	1,700	66%	9 552	3%	<1
Air Force Island ^b	-	-	-	-	-	-	-	-	-	-	17,300	23%	1 652	6%	10
Taverner Bay	417,700	17%	-11%	62%	657	636					469,300	30%	66.7%	364	10%
Koukdjuak River	428,800	37%	-5%	62%	909	1%	472				450,100	31%	66.7%	2 110	5%
Cape Dominion	84,800	25%	-72%	80%	518	3%	164				298,200	44%	80.3%	1 472	7%
Bowman Bay	447,300	22%	-1%	80%	425	3%	1052				452,200	36%	80.3%	619	12%
Cory Bay	240,000	23%	465%	80%	158	6%	1523				42,500	51%	80.3%	66	24%
Garnet Bay	-	-	-	-	-	-	-	-	-	-	2,200	34%	80.3%	4	100%
Subtotal Baffin Island	1,618,600	13%	-7%	2666	607						1,733,500	17%	15 639	5%	109
Southampton Is.															
Boas River	644,000	26%	36%	31%	1610	4%	400				529,100	25%	24.8%	1735	6%
Ell Bay	47,900	26%	328%	31%	174	10%	275				22,600	83%	24.8%	140	9%
Bear Cove	13,300	28%	-6%	41%	97	7%	137				14,200	26%	21%	114	6%
Sutton River	600	8%	-81%	41%	4	56%	150				3,100	60%	237%	10	39%
Maurice Point	10,500	34%	2525%	41%	27	14%	389				400	11%	-	44%	3
Coral Harbour	58,600	28%	61%	41%	183	4%	320				36,400	28%	206%	43%	12%
East Bay	164,800	20%	44%	41%	697	3%	236				114,800	18%	-21%	43%	45%
Subtotal Southampton Is.	939,700	18%	44%	2792	337						652,500	16%	-10%	2956	6%
West Hudson Bay															
Maguise River	111,500	26%	-6%	25%	118	4%	945				118,700	27%	47%	25%	177
Wolf Creek	2,600	32%	30%	25%	18	17%	144				2,000	34%	-55%	25%	30
McConnell River ^c	69,500	28%	36%	25%	165	8%	421				51,200	33%	-22%	25%	153
South McConnell	30,600	31%	-45%	25%	107	6%	286				55,400	31%	107%	25%	139
Tha-anne River	0	-	-	-	-	-	-				0	-	-	-	-
Gaillini River	32,100	25%	-5%	25%	160	8%	201				33,800	24%	-0%	25%	140
Subtotal W. Hudson Bay	246,300	15%	-6%	568	434						261,100	16%	23%	656	398
South Hudson Bay^d															
Knife River ^e	-	-	-	-	-	-	-				4,700	9%	35.6%	22	78%
La Pérouse Bay (2006)	83,600		30%								58,700	20%	35.6%	110	33%
Thompson Point (2006)	14,100		-								16,500	22%	64.6%	7	5%
West Pen Island (2005)	16,500		0%								5,300	35%	64.6%	7	31%
Shell Brook (2006)	0										320,000	15%	64.6%	277	4%
Cape Henrietta Maria (2005)	362,000		13%								3,400	-	74.6%	-	-
Akimiski Island (2005)	2,000		-41%								408,700				
Subtotal S. Hudson Bay	478,200		17%												
Arctic total	3,282,800		7% ^f								3,075,000				

^a From Kerbes *et al.* 2006

^b 2005 Air Force Island aerial visual survey found insignificant nesting geese; Prince Charles Island not visited

^c Plus nesting Ross geese at McConnell R.: 42,700 in 2008; 60,200 in 2003; and 23,500 in 1997 (see text)

^d Cape Henrietta Maria (2005) kriging estimate (Hudson Bay Project 2012). Other 2005-2006 South Hudson Bay, data K. Abrahams and K. Ross, unpublished data.

^e Not visited since 1997

^f Change since 1997

Table 3. Estimated number of lesser snow geese (with percent blue morph) and Ross's geese nesting in the Central Canadian Arctic, June 2006, with ± 2 SE where feasible, with percent change since 1998.

<i>Queen Maud Gulf Migratory Bird Sanctuary area</i>											
COLONY ^a	TOTAL			SNOW				ROSS'S			
	NO. NESTING BIRDS	± 2 SE	%CHANGE SINCE 1998	NO. NESTING BIRDS	± 2 SE	%CHANGE SINCE 1998	%BLUE AMONG SNOW ^b	NO. NESTING BIRDS	± 2 SE	%CHANGE SINCE 1998	%ROSS'S AMONG S&R ^b
3 ^c	900,783	11%	106%	477,681	16%	86%	22%	423,102	17%	136%	47%
9	9,113	21%	-75%	7,024	29%	-74%	29%	2,089	71%	-78%	23%
10	1,111,634	21%	132%	329,523	24%	44%	25%	782,112	21%	212%	70%
46	100,458	23%	45%	66,288	27%	45%	20%	34,170	36%	45%	34%
58	35,424	24%	5267%	21,323	35%	5467%	18%	14,100	46%	4990%	40%
68	32,552	38%	-38%	30,217	40%	-38%	14%	2,335	135%	-36%	7%
88	32,239	19%	160%	24,248	22%	143%	24%	7,991	40%	234%	25%
106	6,615	10%	-	4,782	51%	-	17%	1,833	130%	-	28%
Photo estimates	2,228,818	11%	105%	961,086	12%	56%	23%	1,267,732	14%	170%	57%
Remaining 56 colonies with visual estimates	23,072			9,921			23%	13,151			57%
QMG Total	2,251,890		96%	971,007			23%	1,280,883			57%
<i>Central Arctic colonies outside Queen Maud Gulf MBS area (photo estimates)</i>											
Adelaide Pen. 2	73,242	30%	478%	62,256	-	722%	25%	10,986	-	115%	15%
Adelaide Pen. 3	12,622	33%	-	10,729	-	-	25%	1,893	-	-	15%
Elliot Bay	171,489	29%	274%	138,906	-	407%	25%	32,583	-	76%	19%
Jenny Lind Is. ^d	21,572	18%	12%	21,572	-	-	21%	-	-	-	^d
Inglis River ^e	126,438	11%	311%	126,438	-	-	25%	-	-	-	^e
Kuuguarjuk Lake ^{ef}	946	0%	-78%	946	-	-	25%	-	-	-	^e
Anderson Bay ^e	21,452	29%	-	21,452	-	-	21%	-	-	-	^e
Icebreaker ^e	16,642	37%	-	16,642	-	-	21%	-	-	-	^e
Erebus ^e	93,840	24%	-	93,840	-	-	24%	-	-	-	^e
Outside QMG Total	538,243	11%		492,781			24%	45,462			8%
Total Central Arctic	2,790,133			1,463,788			23%	1,326,345			48%

^a Includes small colonies which have coalesced with the larger colony (see Table 4)

^b Colour and species ratios from ground truth, low level photos, and/or flyers on photos, from 2006 where possible, otherwise from 2005 or 1998

^c Karrak Lake

^d Ross's abundance unknown, estimated to have had 3% Ross's in 1988

^e Ross's abundance unknown, totals assume insignificant number of Ross's

^f Total count

Table 4a. Estimated combined number of nesting lesser snow and Ross's geese (with percent Ross's) in June, Central Canadian Arctic, 1965-1967 (from Ryder 1969, 1971), 1976, 1982, 1988 (from Kerbes 1994), 1998 (from Kerbes et al 2006) and 2005-06. See Fig. 2 for colony locations.

Colony	1965-67		1976		1982		1988		1998		2005-06	
	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)
1	12	(100)	569	(58)	203	(50)	897	(75)	730	(42)	325	^a
2	2,000	(75)	5,667	(78)	4,938	(51)	5,591	(44)	3,610	(53)	1,630	^a
3	17,060	(70)	54,537	(60)	105,583	(52)	212,820	(33)	436,837	(41)	900,783	^b (47)
4	180	(17)	0		92	(0)	407	(48)	280	(42)	6	^a
5	100	(60)	0		0		2	(0)	0		0	^a
6	230	(87)	0		388	(64)	706	(41)	720	(42)	4	^a
7	54	(93)	0		0		0		13	(42)	0	^a
8	3,800	(68)	4,172	(39)	835	(62)	2,692	(42)	1,876	(42)	318	^a
9	6,200	(97)	15,082	(24)	36,393	(30)	75,209	(29)	36,065	(26)	9,113	^b (23)
10	5,600	(89)	27,115	(77)	34,381	(47)	111,807	(65)	479,534	(52)	1,111,634	^b (70)
11	40	(100)	0		35	(63)	0		38	(42)	0	^a
12	85	(71)	38	(58)	0		23	(41)	265	(40)	322	^a
13	360	(83)	428	(58)	464	(36)	59	(41)	1,251	(40)	82	^a
14	60	(100)	418	(58)	19	(100)	67	(41)	57	(40)	40	^a
15	1,500	(80)	1,497	(47)	681	(14)	6,580	(41)	14,683	(40)	362	^a
16	40	(100)	0		37	(5)	123	(41)	92	(42)	2	^a
17	30	(67)	626	(58)	34	(0)	212	(41)	700	(42)	10	^a
18	200	(100)	1,256	(58)	2,810	(9)	6,637	(8)	2,549	(4)	2	^a
19	450	(83)	427	(58)	9	(100)	902	(41)	1,291	(40)	14	^a
20	50	(100)	534	(58)	80	(43)	172	(48)	-		-	^c
21	190	(74)	28	(58)	554	(0)	16	(50)	324	(42)	2	^a
22	125	(80)	0		0		0		540	(42)	2	^a
23	^d		826	(58)	594	(53)	2,115	(48)	750	(42)	534	^a
24	^d		164	(58)	258	(43)	432	(48)	260	(42)	186	^a
25	^d		213	(58)	126	(0)	366	(48)	376	(42)	26	^a
26	^d		0		12	(42)	0		68	(42)	34	^a
27	^d		4,760	(38)	828	(64)	1,521	(41)	in Col. 46		in Col. 46	
28	^d		0		0		178	(41)	-		in Col. 10	
29	^d		7,324	(64)	1,284	(51)	1,085	(41)	1,881	(40)	140	^a
30	^d		593	(58)	254	(0)	383	(41)	48	(41)	24	^a
31	^d		0		88	(64)	127	(41)	48	(42)	30	^a
32	^d		0		16	(63)	0		300	(42)	0	^a
33	^d		0		0		0		0		0	^a
34	^d		107	(58)	58	(64)	2	(0)	220	(42)	0	^a
35	^d		427	(58)	0		0		500	(42)	0	^a
36	150	(38)	4,241	(47)	1,334	(55)	5,224	(63)	in Col. 9		in Col. 9	
37	80	(40)	142	(58)	247	(0)	2	(0)	60	(42)	16	^a
38	^e		427	(58)	196	(48)	0		0		0	^a
39	^e		51	(58)	127	(27)	95	(48)	232	(42)	0	^a
40	^e		1,519	(0)	98	(0)	765	(48)	100	(42)	0	^a

Table 4b.

Colony	1965-67	1976		1982		1988		1998		2005-06	
	NO. NESTING BIRDS (%Ross's)	NO. NESTING BIRDS (%Ross's)		NO. NESTING BIRDS (%Ross's)		NO. NESTING BIRDS (%Ross's)		NO. NESTING BIRDS (%Ross's)		NO. NESTING BIRDS (%Ross's)	
41	e	295	(58)	0		0		37	(40)	0	^a
42	e	213	(58)	40	(0)	67	(41)	50	(41)	20	^a
43	e	e		102	(64)	28	(41)	500	(42)	8	^a
44	e	e		37	(43)	491	(48)	80	(42)	98	^a
45	e	e		306	(64)	523	(41)	in Col. 46		in Col. 46	
46	e	e		2,553	(64)	22,736	(18)	69,506	(34)	100,458	^b (34)
47	e	e		123	(63)	17	(41)	0		0	^a
48	e	e		133	(63)	429	(41)	620	(42)	2	^a
49	e	e		120	(64)	37	(41)	0		0	^a
50	e	e		e		1,003	(41)	35	(42)	0	^a
51	e	e		e		683	(41)	in Col. 3		in Col. 3	
52	e	e		e		68	(41)	0		0	^a
53	e	e		e		32	(41)	0		10	^a
54	e	e		e		261	(41)	0		80	^a
55	e	e		e		492	(41)	240	(42)	52	^a
56	e	e		e		235	(41)	0		0	^a
57	e	e		e		541	(41)	890	(42)	420	^a
58	e	e		e		141	(41)	360	(42)	35,424	^b (40)
59	e	e		e		54	(41)	4	(42)	0	^a
60	e	e		e		301	(41)	0		70	^a
61	e	e		e		441	(41)	0		0	^a
62	e	e		e		416	(41)	400	(42)	450	^a
63	e	e		e		257	(41)	615	(42)	0	^a
64	e	e		e		14	(41)	0		0	^a
65	e	e		e		148	(41)	in Col. 3		in Col. 3	
66	e	e		e		342	(41)	0		-	^c
67 ^g	e	e		e		e		0		0	^a
68 ^g	e	e		e		e		52,263	(7)	32,552	^b (7)
69 ^g	e	e		e		e		0		0	^a
70 ^g	e	e		e		e		0		0	^a
71 ^g	e	e		e		e		130	(42)	80	^a
72 ^g	e	e		e		e		0		0	^a
73 ^g	e	e		e		e		140	(42)	370	^a
74 ^g	e	e		e		e		-		-	^c
75 ^g	e	e		e		e		-		0	^a
76 ^g	e	e		e		e		in Col. 68		in Col. 68	
77 ^g	e	e		e		e		-		-	^c
78 ^g	e	e		e		e		0		0	^a
79 ^g	e	e		e		e		2	(42)	20	^a
80 ^g	e	e		e		e		460	(42)	120	^a
81 ^g	e	e		e		e		3,654	(74)	-	^c
82 ^g	e	e		e		e		0		0	^a
83 ^g	e	e		e		e		0		0	^f
84 ^g	e	e		e		e		170	(42)	10	^a
85 ^g	e	e		e		e		20	(42)	10,000	^a

Table 4c

Colony	1965-67		1976		1982		1988		1998		2005-06	
	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)	NO. NESTING BIRDS	(%Ross's)
86 ^g	e		e		e		e		13,975	(42)	0 ^a	
87 ^g	e		e		e		e		0		0 ^a	
88 ^g	e		e		e		e		12,376	(19)	32,239 ^b	(25)
89 ^g	e		e		e		e		-		0 ^a	
90 ^g	e		e		e		e		0		0 ^a	
91 ^g	e		e		e		e		570	(42)	- ^c	
92 ^g	e		e		e		e		0		27 ^a	
93	e		e		e		e		220	(42)	0 ^a	
94	e		e		e		e		10	(42)	4 ^a	
95	e		e		e		e		10	(42)	0 ^a	
96	e		e		e		e		660	(42)	0 ^a	
97	e		e		e		e		460	(42)	0 ^a	
98	e		e		e		e		300	(42)	0 ^a	
99	e		e		e		e		300	(42)	200 ^a	
100	e		e		e		e		220	(42)	- ^c	
101	e		e		e		e		1,000	(42)	500 ^a	
102	e		e		e		e		260	(42)	in Col. 10	
103 ^h	e		e		e		e		e		320 ^a	
104	e		e		e		e		e		4,000 ^a	
105	e		e		e		e		e		1,000 ^a	
106	e		e		e		e		e		6,615 ^b	(28)
107	e		e		e		e		e		600 ^a	
108	e		e		e		e		e		500 ^a	
109	e		e		e		e		e		- ⁱ	
110	e		e		e		e		e		- ⁱ	
Subtotal QMG MBS	44 300^j	(77)	133,696	(58)	196,470	(46)	466,975	(40)	1,146,833	(43)	2,251,890	(57)
Jenny Lind Is.	i		i		i		39,200	(3)	19,253	(3)	21,572 ^b	(3)
Adelaide Pen. 1	e		e		e		e		200	(40)	- ^c	
Adelaide Pen. 2	e		e		e		e		12,680	(40)	73,242 ^b	(15)
Adelaide Pen. 3	e		e		e		e		e		12,622 ^b	(15)
Elliot Bay	e		e		i		i		45,861	(40)	171,489 ^b	(19)
Inglis River	e		i		i		i		30,735		126,438 ^b	^k
Kuuguarjuk Lake	e		e		e		e		4,308		946 ^b	^k
Anderson Bay	e		e		e		e		e		21,452 ^b	^k
Icebreaker	e		e		e		e		e		16,642 ^b	^k
Erebus	e		e		e		e		e		93,840 ^b	^k
Subtotal N & E of QMG MBS							39,200	(3)	113,037	(21)	538,243	(8)
Total	44 300^j	(77)	133,696	(58)	196,470	(46)	506,174	(37)	1,259,870	(41)	2,790,133	(48)

^a Visual estimate

^b Estimated from aerial photographs

^c Not counted in 2005-06

^d Geese known to be present (Ryder 1969)

^e Status unknown, likely unoccupied

^f Lake had drained from natural causes

^g Nesting geese known to be present in 1990 and/or 1991 (Alisauskas and Boyd 1994)

^h Nesting geese known to be present in 2000 (Alisauskas pers. comm.)

ⁱ Nesting geese known to be present (see text)

^j Total as extrapolated in Kerbes et al (1983)

^k Ross's geese numbers assumed to be negligible

Table 5. Summary of survey estimates of lesser snow and Ross's geese nesting in and adjacent to the Queen Maud Gulf Migratory Bird Sanctuary, 1965-2006.

	1965-67	1976	1982	1988	1998	2005-06
No. of occupied colonies ¹	37	30	41	57	73	66
Total no. of nesting birds (Ross's plus snows)	44,300	133,700	196,500	467,000	1,146,800	2,251,900
Total no. of nesting Ross's geese (Percentage of total geese)	34,000 (77%)	77,300 (58%)	90,800 (46%)	188,000 (40%)	495,100 (43%)	1,280,900 (57%)
Total no. of nesting snow geese	10,300	56,400	105,700	279,000	651,700	971,000
Percentage of blue-morph among snow geese	5.0%	14.9%	8.0%	19.6%	18.6%	23.0%
Top 4 colonies per survey year, percentage of total nesting geese per colony						
Colony 2		4%	3%			
Colony 3 ²	39%	41%	54%	46%	38%	40%
Colony 8	9%					
Colony 9 ³	14%	11%	19%	16%		
Colony 10 ⁴	13%	20%	17%	24%	42%	49%
Colony 46 ⁵				5%	6%	4%
Colony 58						2%
Colony 68					5%	
All other colonies	26%	23%	8%	10%	9%	5%
	100	100	100	100	100	100

¹ Includes colonies which have merged with others

² Includes Colonies 51 and 65

³ Includes Colony 36

⁴ Includes Colony 28

⁵ Includes Colonies 27 and 45

Table 6. Persistence of lesser snow and Ross's goose colonies, 1965 to 2006 in and adjacent to Queen Maud Gulf Migratory Bird Sanctuary, starting with survey year colony first reported (see Fig. 2 for locations).

Colony presence by year ¹							
Colony	1965-67 ²	1976 ³	1982 ³	1988 ³	1990-91 ⁴	1998 ⁵	2005-06 ⁶
1	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+
3	+	+	+	+	+	+	+
4	+	0	+	+	0	+	+
5	+	0	0	+	0	0	0
6	+	0	+	+	0	+	+
7	+	0	0	0	0	+	0
8	+	+	+	+	-	+	+
9	+	+	+	+	-	+	+
10	+	+	+	+	+	+	+
11	+	0	+	0	-	+	0
12	+	+	0	+	-	+	+
13	+	+	+	+	-	+	+
14	+	+	+	+	-	+	+
15	+	+	+	+	-	+	+
16	+	0	+	+	-	+	+
17	+	+	+	+	-	+	+
18	+	+	+	+	-	+	+
19	+	+	+	+	-	+	+
20	+	+	+	+	-	-	-
21	+	+	+	+	-	+	+
22	+	0	0	0	-	+	+
23	+	+	+	+	-	+	+
24	+	+	+	+	-	+	+
25	+	+	+	+	+	+	+
26	+	0	+	0	-	+	+
27	+	+	+	+	+	+	+
28	+	0	0	+	0	-	+
29	+	+	+	+	-	+	+
30	+	+	+	+	0	+	+
31	+	0	+	+	-	+	+
32	+	0	+	0	-	+	0
33	+	0	0	0	-	0	0
34	+	+	+	+	-	+	0
35	+	+	0	0	-	+	0
36	+	+	+	+	-	+	+
37	+	+	+	+	-	+	+
38		+	+	0	-	0	0
39		+	+	+	-	+	0
40		+	+	+	-	+	0
41		+	0	0	-	+	0
42		+	+	+	-	+	+
43			+	+	-	+	+
44			+	+	+	+	+
45			+	+	-	+	+
46			+	+	-	+	+
47			+	+	-	0	0
48			+	+	-	+	+
49			+	+	+	0	0
50				+	-	+	0
51				+	-	+	+
52				+	-	0	0
53				+	-	0	+
54				+	-	0	+
55				+	-	+	+

Colony presence by year ¹							
Colony	1965-67 ²	1976 ³	1982 ³	1988 ³	1990-91 ⁴	1998 ⁵	2005-06 ⁶
56				+	0	0	0
57				+	-	+	+
58				+	-	+	+
59				+	-	+	0
60				+	+	0	+
61				+	-	0	0
62				+	+	+	+
63				+	-	+	0
64				+	-	0	0
65				+	-	+	+
66				+	+	0	-
67					+	0	0
68					+	+	+
69					+	0	0
70					+	0	0
71					+	+	+
72					+	0	0
73					+	+	+
74					+	-	-
75					+	-	0
76					+	+	+
77					+	-	-
78					+	0	0
79					+	+	+
80					+	+	+
81					+	+	-
82					+	0	0
83					+	0	0
84					+	+	+
85					+	+	+
86					+	+	0
87					+	0	0
88					+	+	+
89					+	-	0
90					+	0	0
91					+	+	-
92					+	0	+
93						+	0
94						+	+
95						+	0
96						+	0
97						+	0
98						+	0
99						+	+
100						+	-
101						+	+
102						+	+
103							+
104							+
105							+
106							+
107							+
108							+
109							+
110							+

¹ + = Colony site occupied; 0 = Colony site not occupied; - = Colony site not visited

² Ryder 1969

³ Kerbes 1994

⁴ Alisauskas and Boyd 1994

⁵ Kerbes et al 2006

⁶ See Table 4

Table 7. Photographic surveys of lesser snow goose colonies in the Western Arctic June 8-9, 2002; June 15 and 22, 2007; and June 22-24, 2009.

YEAR	COLONY	NO. NESTING BIRDS	(\pm S.E.)	TOTAL NESTING AREA KM ²	%ANALYSED ON PHOTOS	MEAN DENSITY BIRDS/HA
2002	Egg River ^a	570,517	(\pm 60,915)	304.5	14%	18.7
	Anderson R.	1,857	-	19.3	100%	1.0
	Kendall Is.	6,948	(\pm 2,396)	7.7	73%	9.0
	Total	579,322		331.5		17.5
2007	Egg River ^a	295,126	(\pm 39,838)	93.1	17%	31.7
	Anderson R.	4,062	(\pm 75)	25.2	100%	1.6
	Kendall Is.	4,567	(\pm 553)	9.1	96%	5.0
	Total	303,755	(\pm 39,842)	127.4		
2009	Egg River ^b	427,019	(\pm 63,773)	203.5	15%	21.0
	Anderson R.	222		21	82%	0.1
	Kendall Is.	287		7.7	100%	0.4
	Total	427,528		232.2		

^a Includes Rotten Creek area

^b Rotten Creek area not occupied

Table 8. Estimated numbers of lesser snow geese in the Western Arctic colonies, 1976-2009, by photo surveys unless noted otherwise.

YEAR	EGG RIVER	ANDERSON RIVER	KENDALL ISLAND	TOTAL	REFERENCE
1976	165,000	3,800	800	169,600	Kerbes 1983
1981	198,100	8,400	1,000	207,500	Kerbes 1986
1987	196,500	7,200	1,400	205,100	Kerbes et al 1999
1995	479,400	3,600	3,000	486,000	Kerbes et al 1999
1996	436,000 ^a	2,788 ^b	210 ^b	438,998	Samelius et al 2008, Wiebe Robertson and Hines 2006
1997	264,000 ^a	806 ^b	2,506 ^b	267,312	Samelius et al 2008, Wiebe Robertson and Hines 2006
1998	452,000 ^a	596 ^b	736 ^b	453,332	Samelius et al 2008, Wiebe Robertson and Hines 2006
1999		246 ^b	1,608 ^b		Wiebe Robertson and Hines 2006
2000		1,142 ^b	472 ^b		Wiebe Robertson and Hines 2006
2001		1,327 ^b	1,199 ^b		Wiebe Robertson and Hines 2006
2002	570,500	1,900	6,900	579,300	this study
2003		502 ^b	58 ^b		Canadian Wildlife Service (unpub. data)
2004		26 ^b	1,914 ^b		Canadian Wildlife Service (unpub. data)
2005		1,472 ^a	2,236 ^b		Obst et al 2013, Canadian Wildlife Service (unpub. data)
2006		2,334 ^a	2,242 ^b		Obst et al 2013, Canadian Wildlife Service (unpub. data)
2007	295,100	4,100	4,600	303,800	this study
2008		1,504 ^b	1,724 ^b		Canadian Wildlife Service (unpub. data)
2009 ^c	427,000	200	300	427,500	this study

^a Ground survey

^b Helicopter survey

^c Digital imagery survey



Figure 1. Nesting regions of lesser snow and Ross's geese in the Eastern Arctic (Baffin Island, Southampton Island, West Hudson Bay and South Hudson Bay), Central Arctic (see Fig. 2), and Western Arctic.

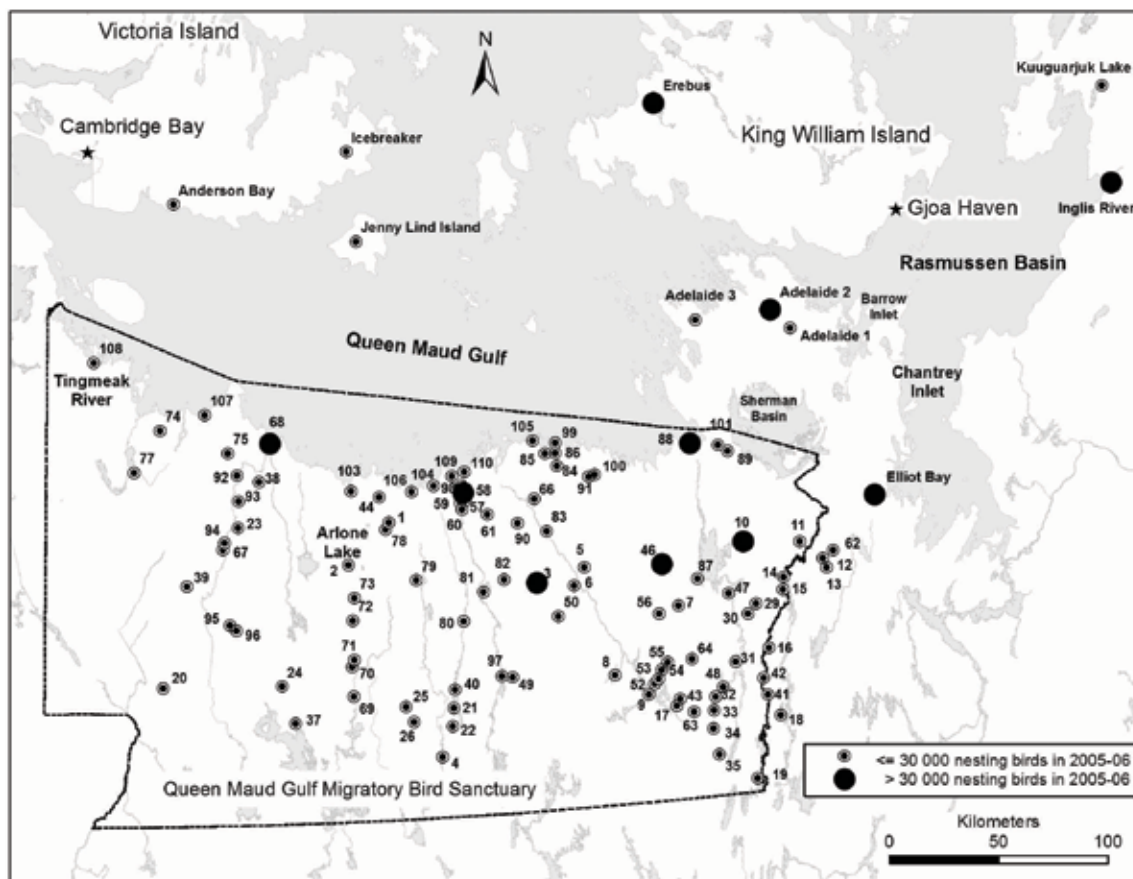


Figure 2. Lesser snow and Ross's goose colony sites in the Central Arctic, Nunavut, 1965-2006, see Fig. 1 and Tables 3-6. Colony 3 includes 51 and 65, Colony 9 includes 36, Colony 10 includes 28 and 102, Colony 46 includes 27 and 45, and Colony 68 includes 76.

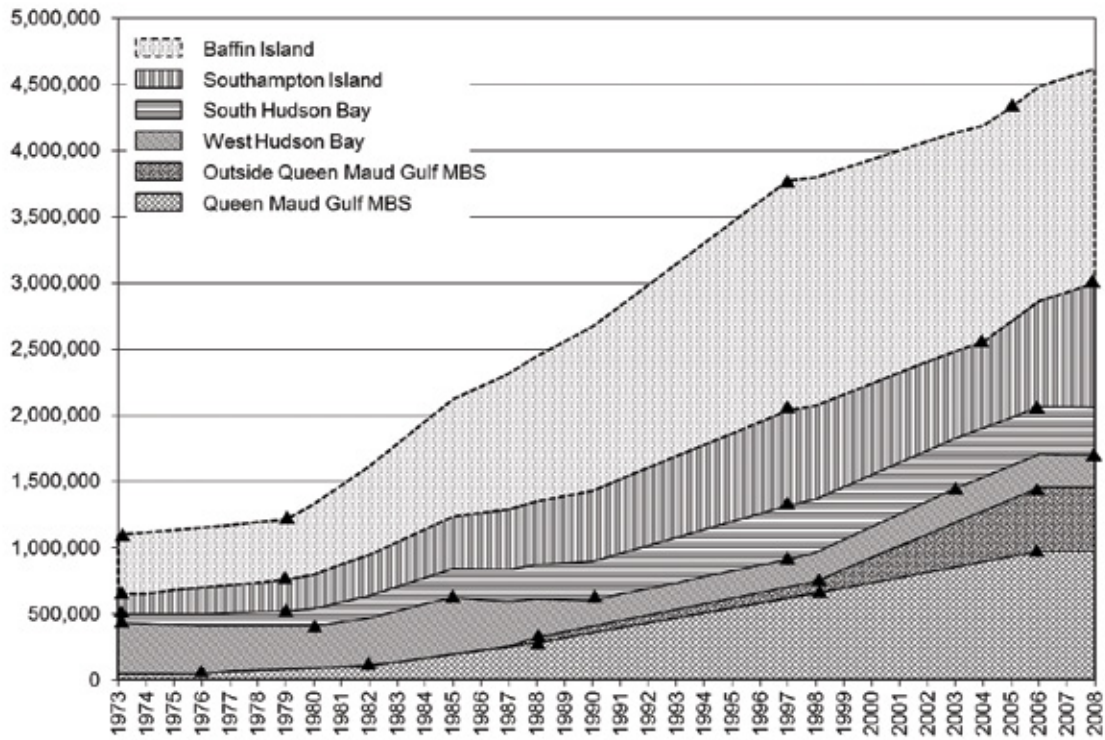


Figure 3. Midcontinent lesser snow goose population, number of nesting birds per region, Eastern and Central Arctic; growth extrapolated between photo survey estimates (triangles); see Tables 2, 3 and 5.

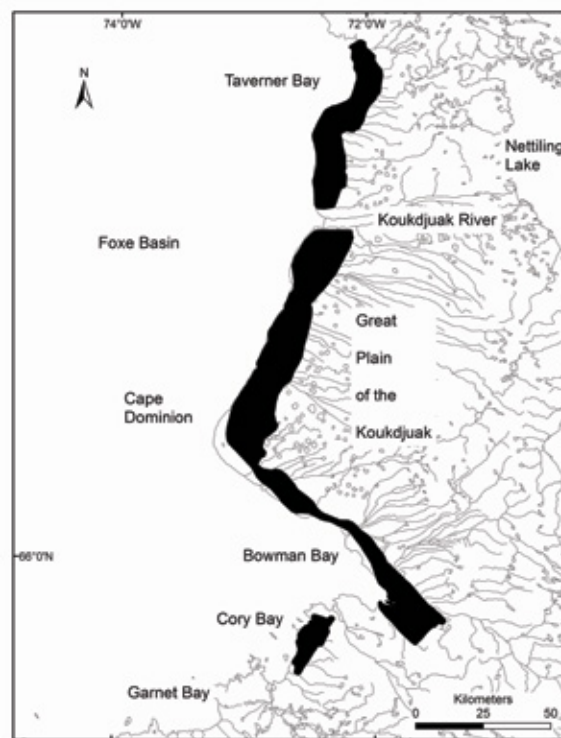


Figure 4. Baffin Island lesser snow goose colonies showing area occupied by nests in 2005.

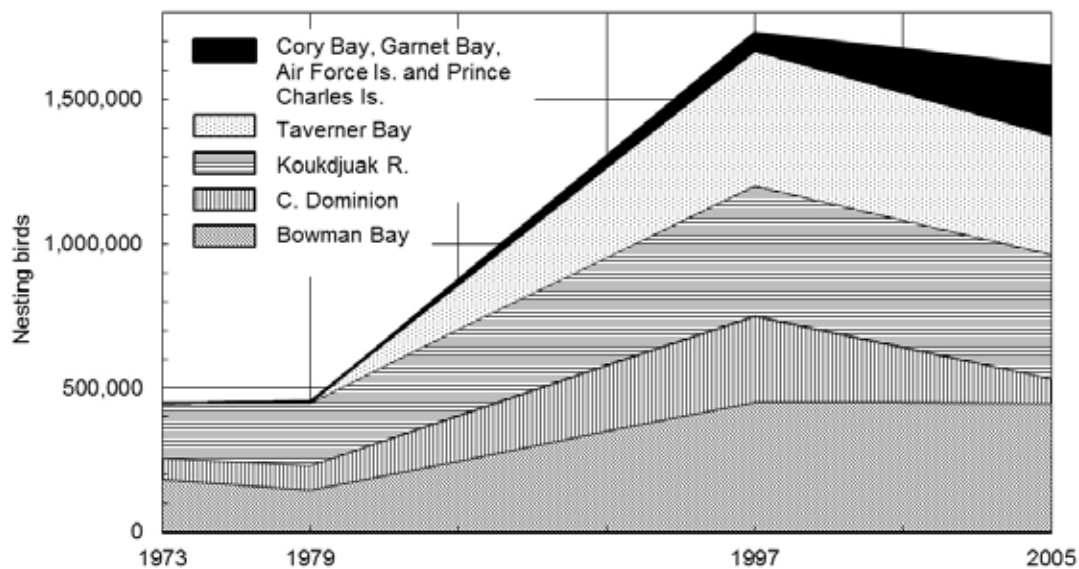


Figure 5. Growth in numbers of nesting birds by colony of lesser snow geese, Baffin Island, 1973-2005.

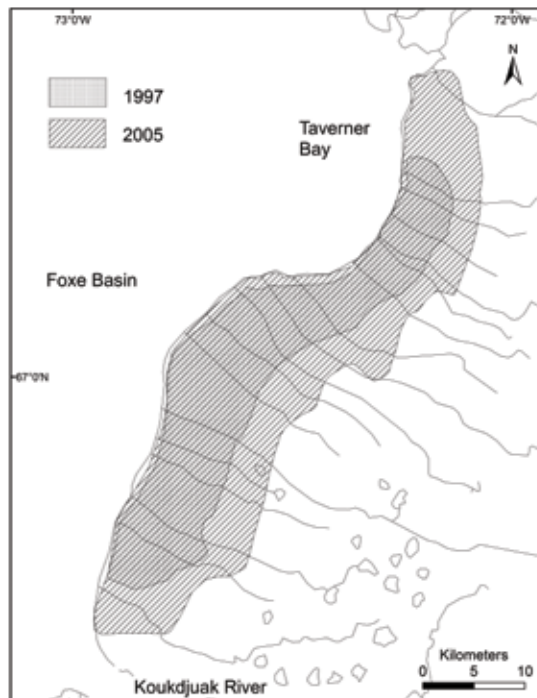


Figure 6. Lesser snow goose colony at Taverner Bay, Nunavut, showing the area occupied by nests, June, 1997 and 2005.

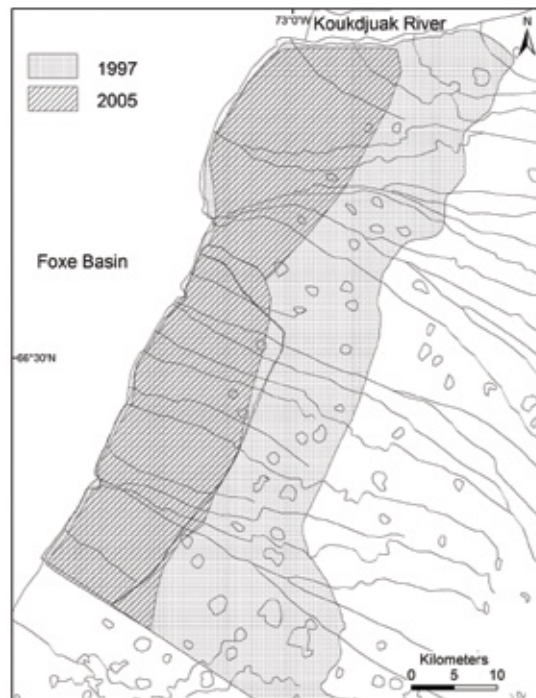


Figure 7. Lesser snow goose colony at Koukdjuak River, Nunavut, showing the area occupied by nests, June, 1997 and 2005.

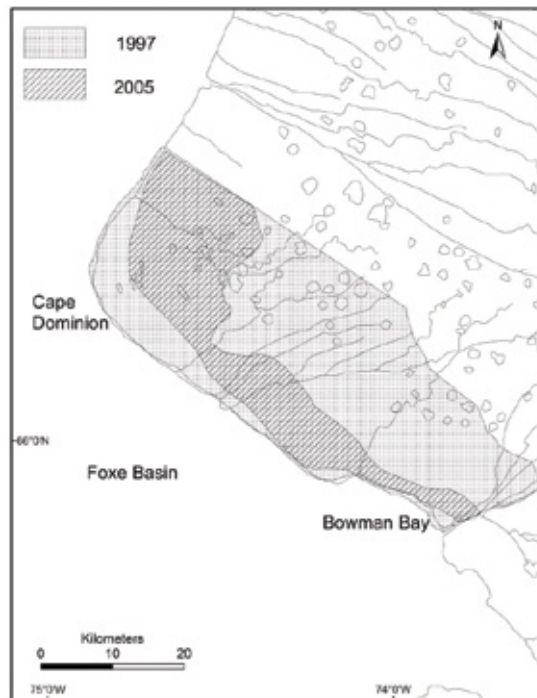


Figure 8. Lesser snow goose colony at Cape Dominion, Nunavut, showing the area occupied by nests, June, 1997 and 2005.

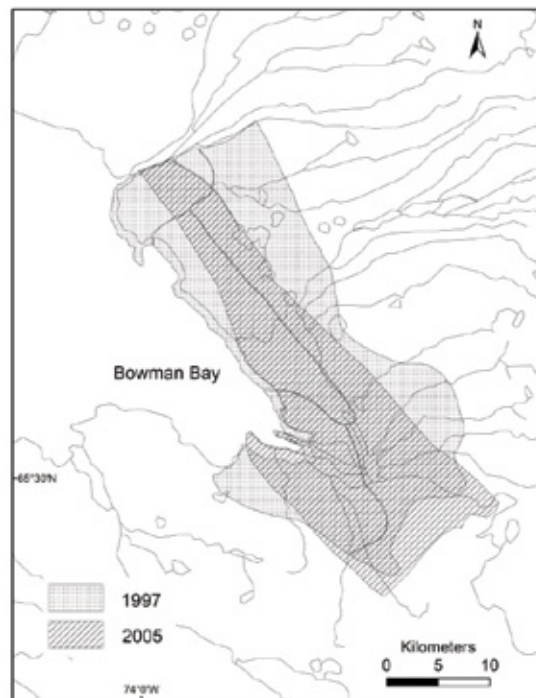


Figure 9. Lesser snow goose colony at Bowman Bay, Nunavut, showing the area occupied by nests, June, 1997 and 2005.

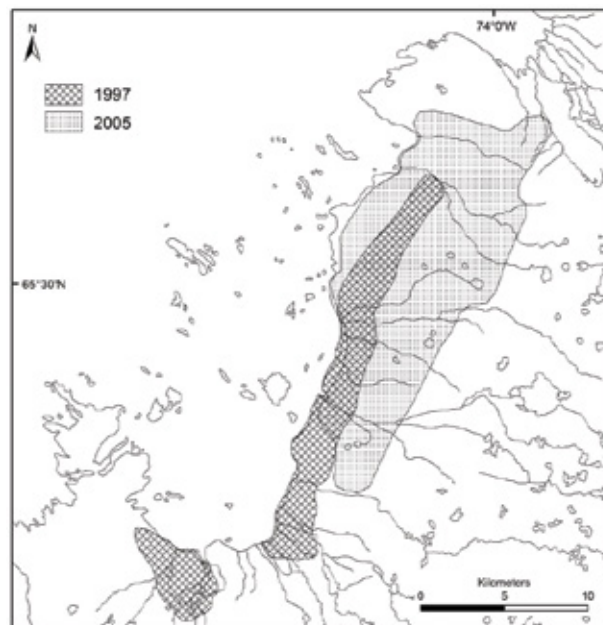


Figure 10. Lesser snow goose colony at Cory Bay, Nunavut, showing the area occupied by nests, June, 1997 and 2005.

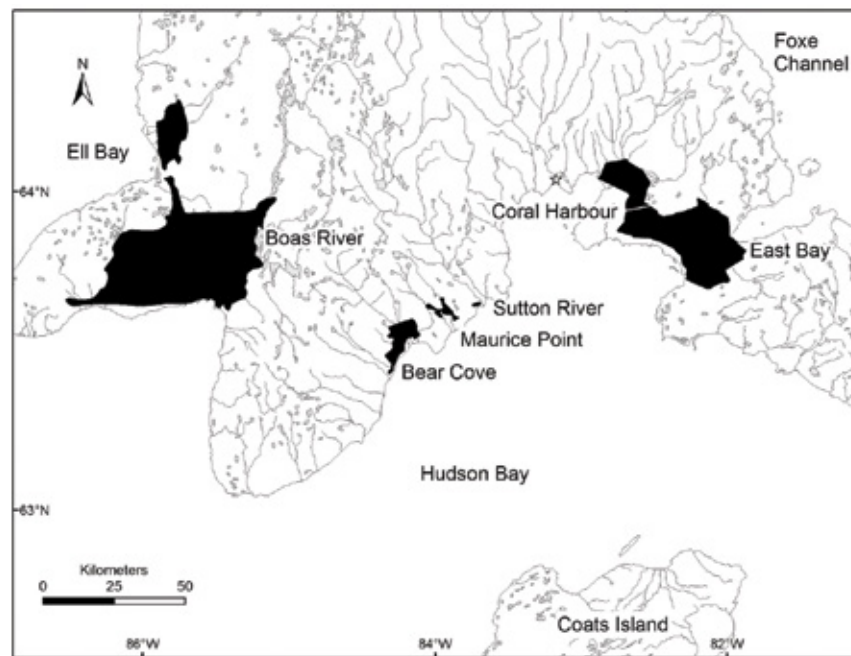


Figure 11. Southampton Island lesser snow goose colonies, showing the area occupied by nests in 2008

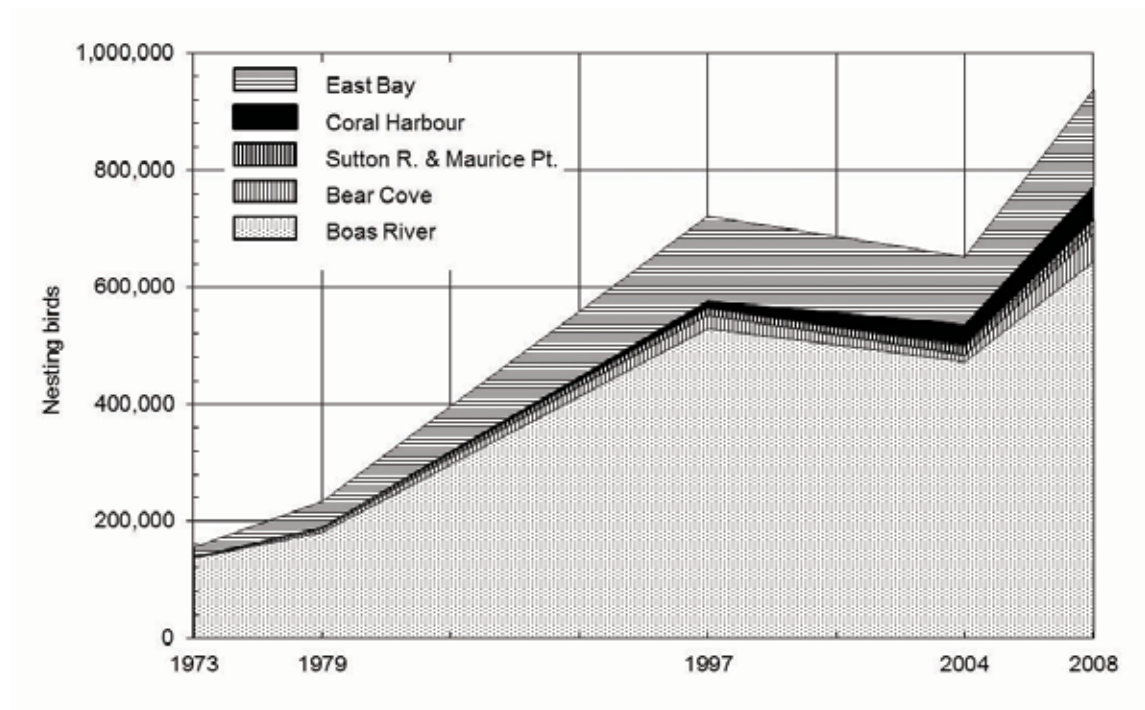


Figure 12. Growth in numbers of nesting birds by colony of lesser snow geese, Southampton Island, 1973-2008.

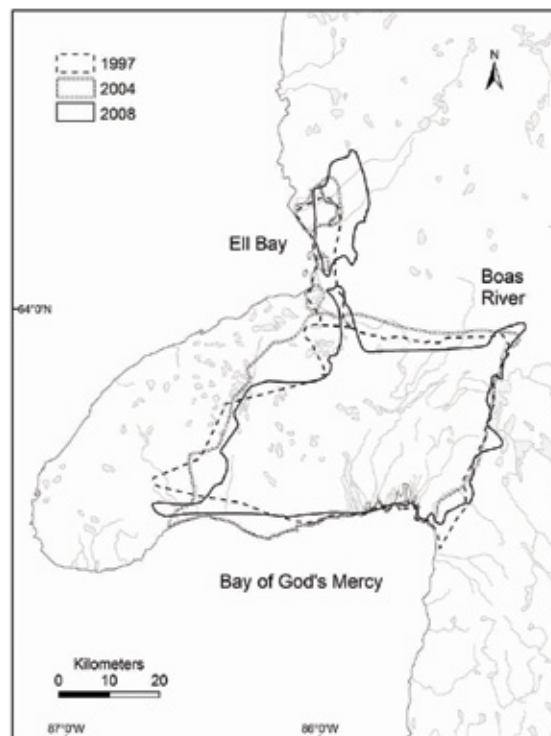


Figure 13. Lesser snow goose colonies at Ell Bay and Boas River, Nunavut, showing the area occupied by nests, June, 1997, 2004 and 2008.

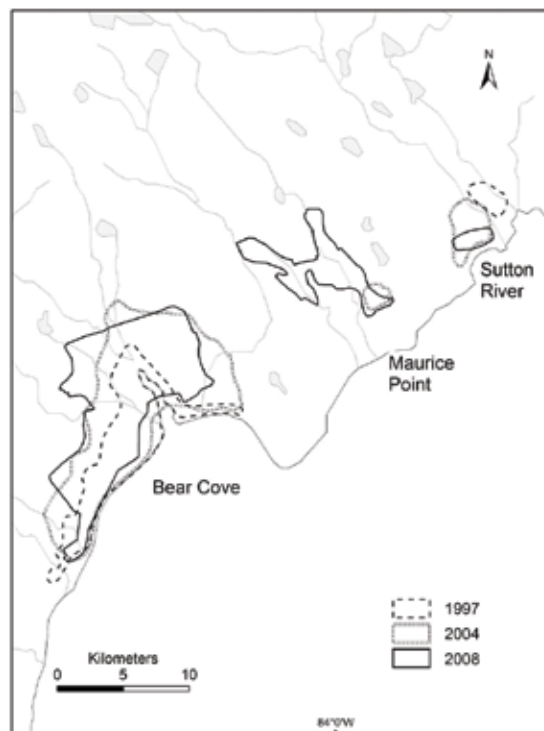


Figure 14. Lesser snow goose colonies at Bear Cove, Maurice Point and Sutton River, Nunavut, showing the area occupied by nests, June, 1997, 2004 and 2008.

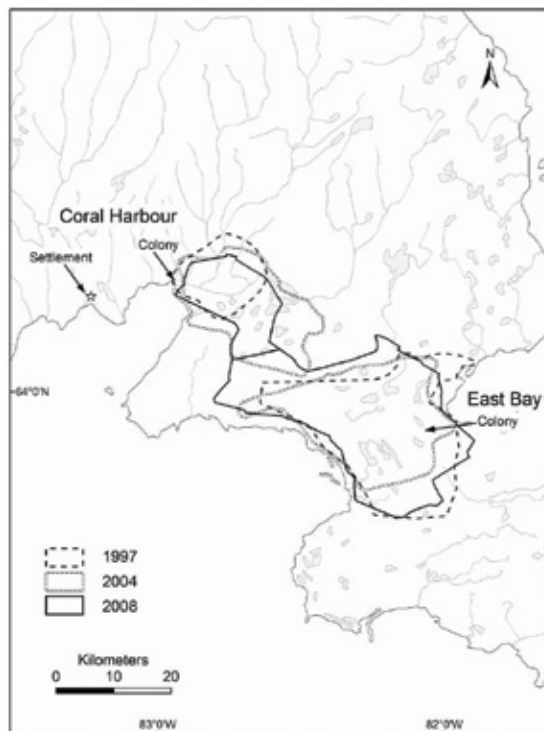


Figure 15. Lesser snow goose colonies at Coral Harbour and East Bay, Nunavut, showing the area occupied by nests, June, 1997, 2004 and 2008.

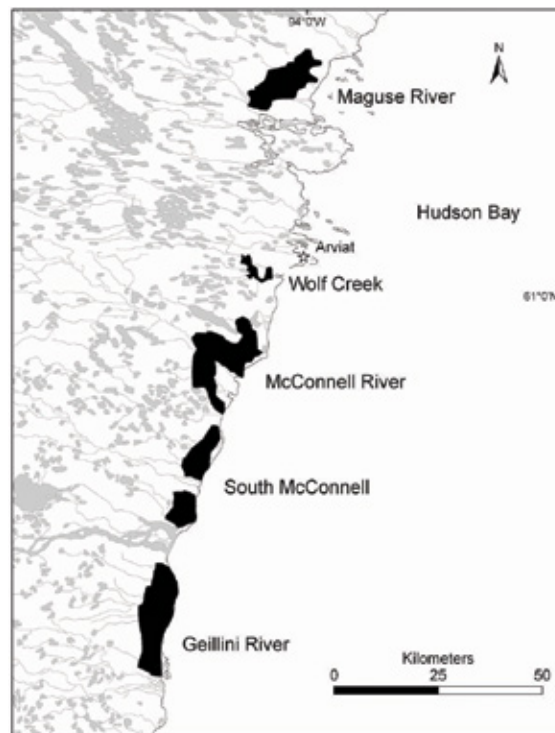


Figure 16. West Hudson Bay lesser snow goose colonies, showing the area occupied by nests, June, 2008.

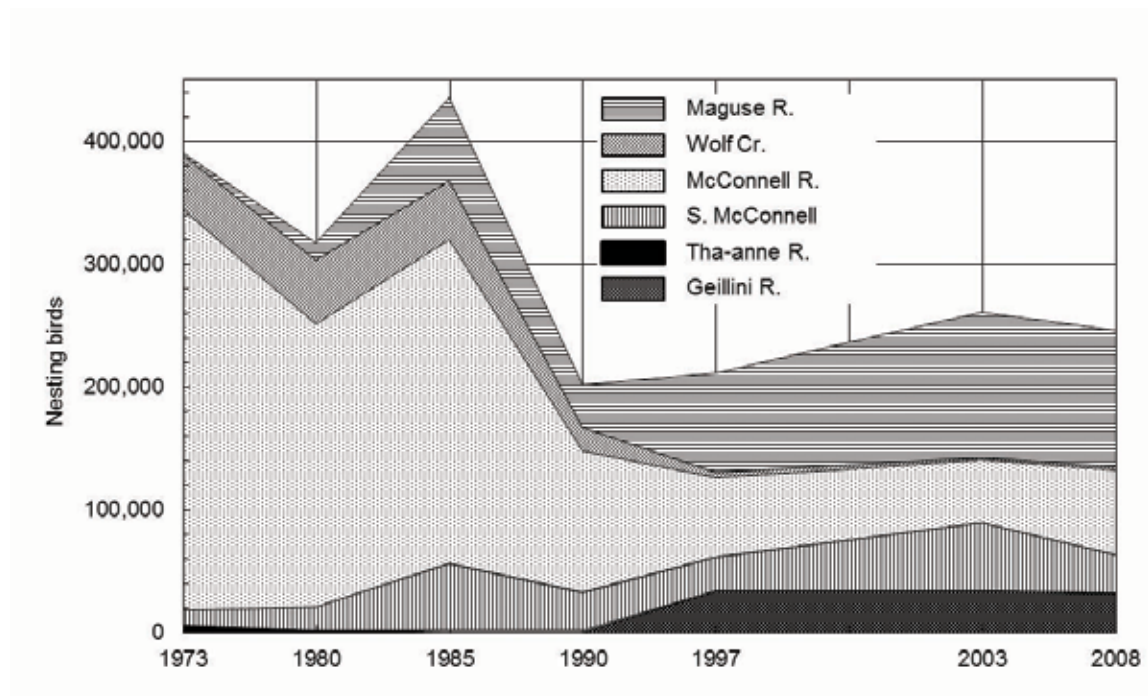


Figure 17. Growth in numbers of nesting birds by colony of lesser snow geese, West Hudson Bay, 1973-2008.

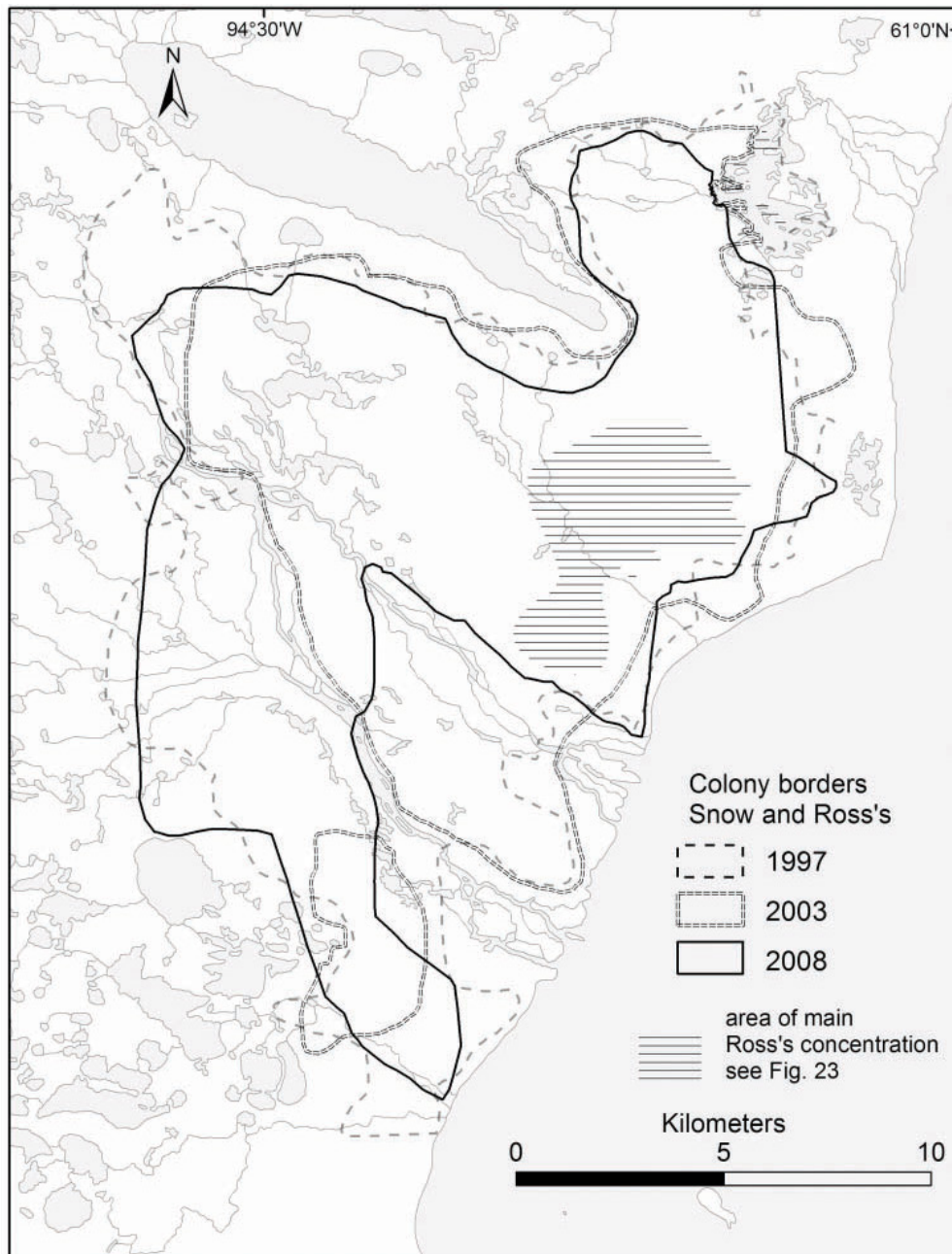


Figure 18. Lesser snow and Ross's goose (see Fig. 23) colonies at McConnell River, Nunavut, showing the area occupied by nests, June 1997, 2003 and 2008.

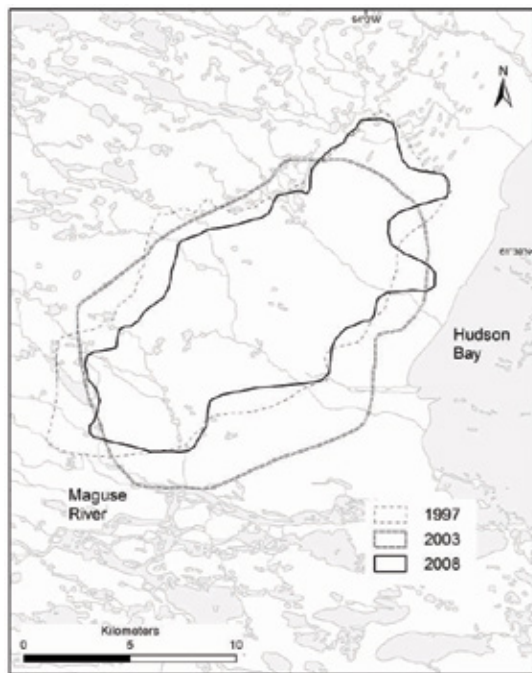


Figure 19. Lesser snow goose colony at Maguse River, Nunavut, showing the area occupied by nests, June, 1997, 2003 and 2008.

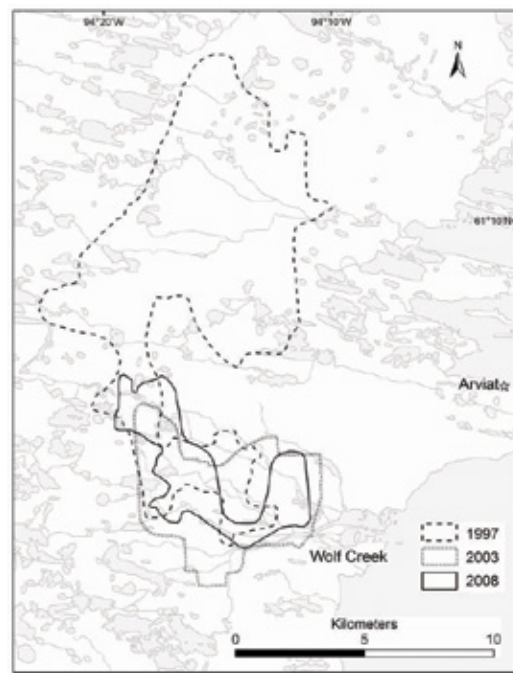


Figure 20. Lesser snow goose colony at Wolf Creek, Nunavut, showing the area occupied by nests, June, 1997, 2003 and 2008.

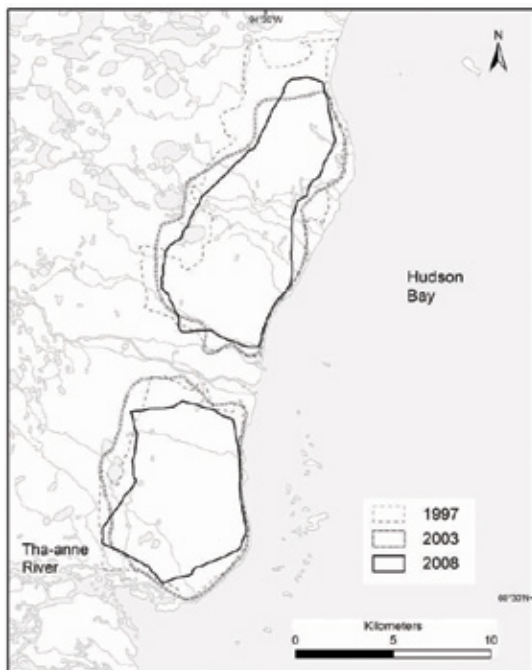


Figure 21. Lesser snow goose colony at South McConnell River, Nunavut, showing the area occupied by nests, June, 1997, 2003 and 2008.

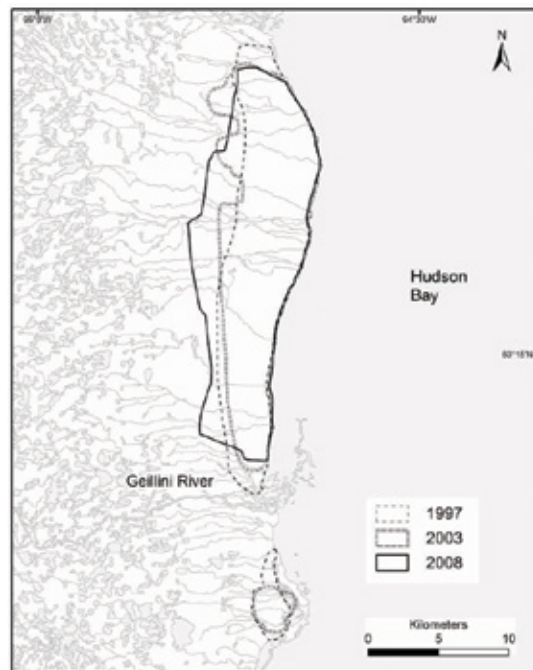


Figure 22. Lesser snow goose colony at Geillini River, Nunavut, showing the area occupied by nests, June, 1997, 2003 and 2008.

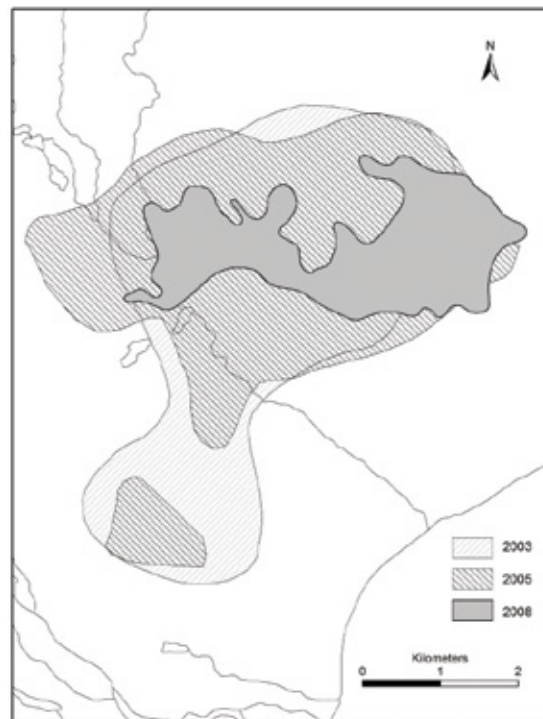


Figure 23. Ross's goose colony at McConnell River, Nunavut, showing the area occupied by mainly Ross's geese as determined by photo surveys, June, 2003, 2005 and 2008 (see Fig. 18)

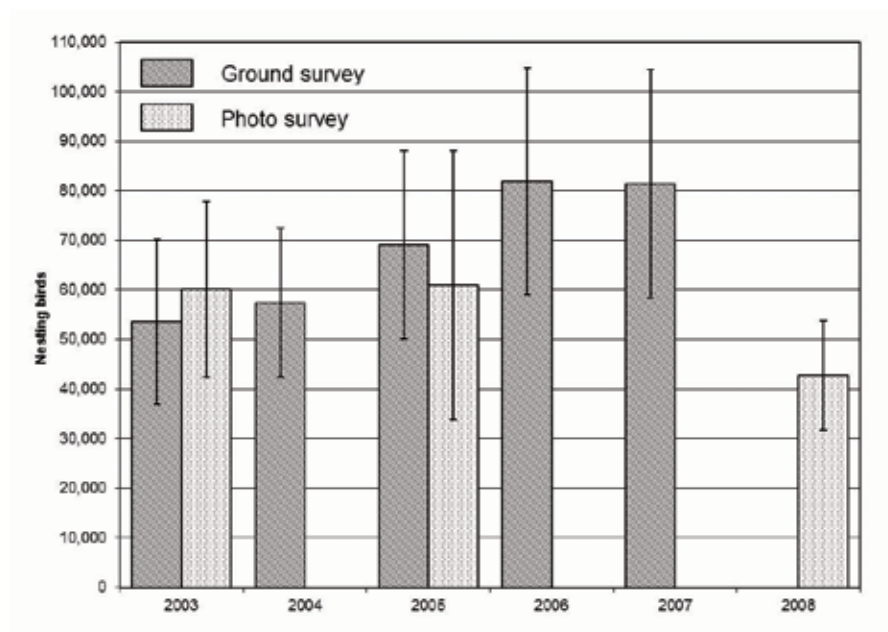


Figure 24. Size of Ross's goose colony at McConnell River, Nunavut, June 2003-2008, as determined by ground surveys 2003-2007 (J. Caswell, pers. comm.) and photo surveys in 2003, 2005 and 2008.

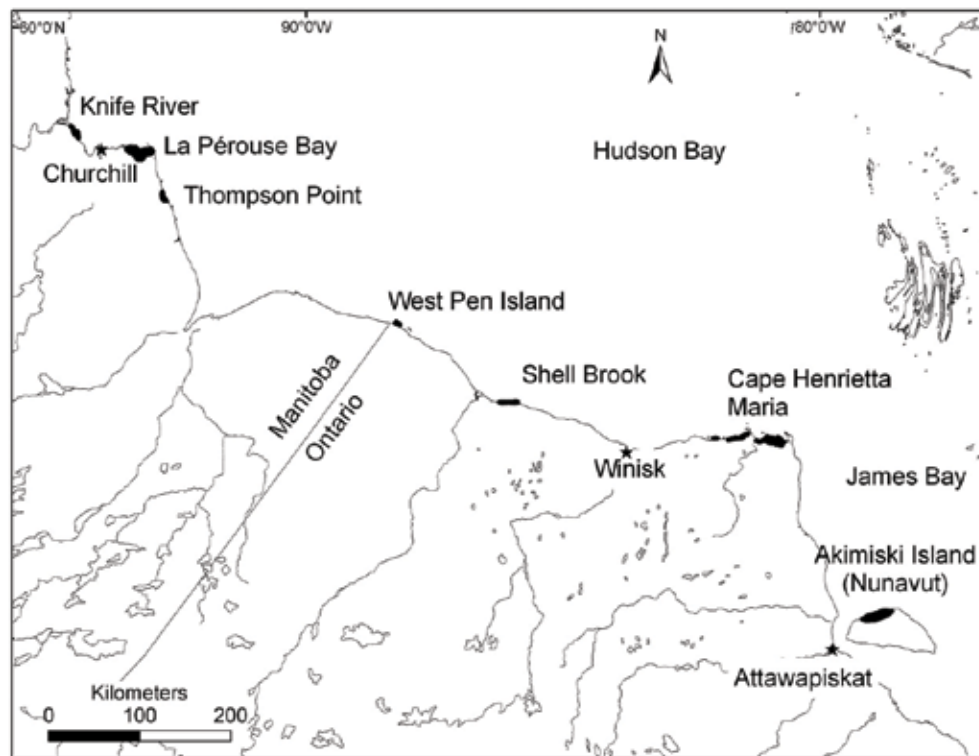


Figure 25. South Hudson Bay lesser snow goose colonies, June 2006.

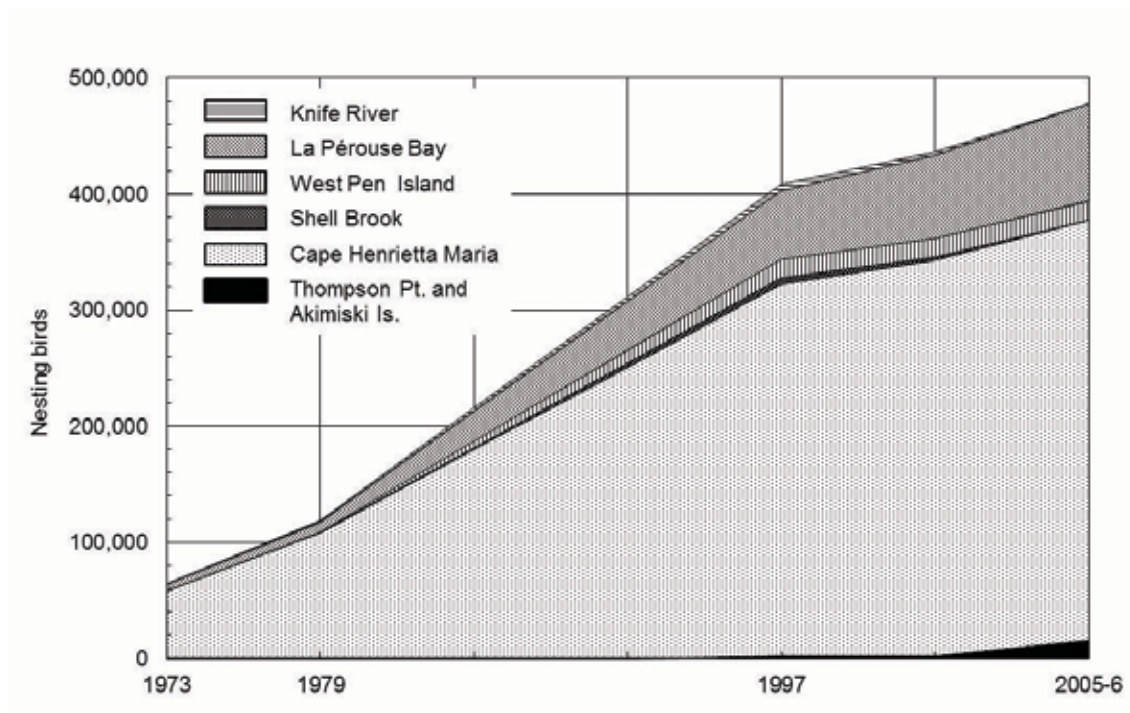


Figure 26. Growth in numbers of nesting birds by colony of lesser snow geese, South Hudson Bay, 1973-2006.

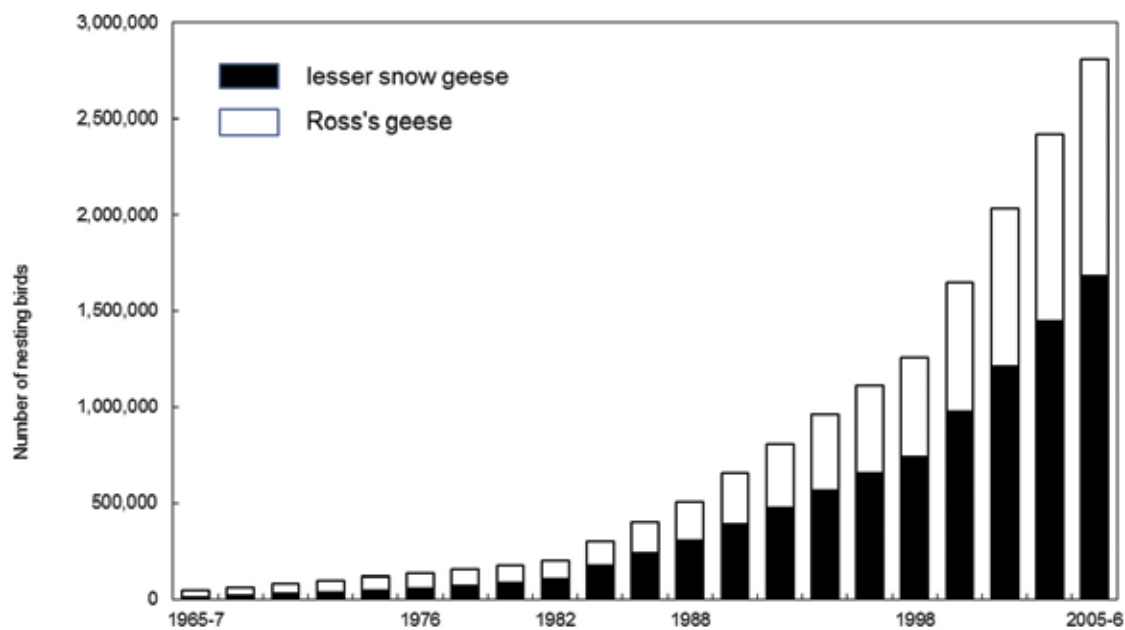


Figure 27. Numbers of nesting Ross's geese and lesser snow geese, Queen Maud Gulf Migratory Bird Sanctuary area 1965-2006; growth extrapolated at 2 year intervals between photo surveys.

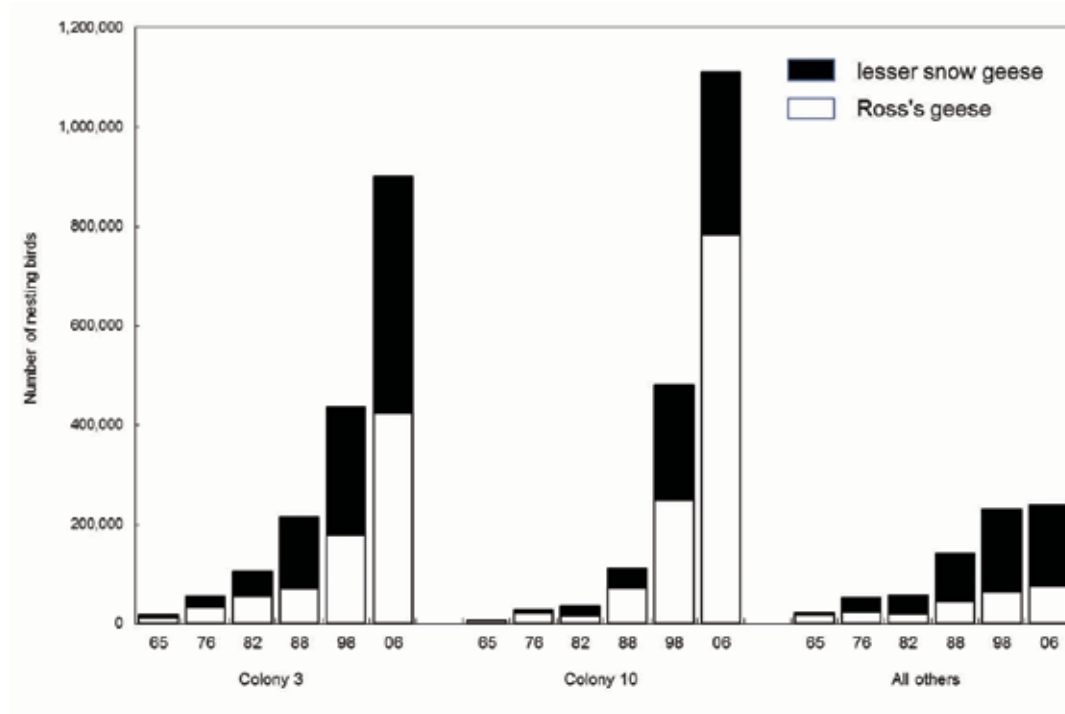


Figure 28. Numbers of Ross's geese and lesser snow geese nesting in Colonies 3 and 10, compared with all other colonies combined in the Queen Maud Gulf Migratory Bird Sanctuary area, 1965-2006.

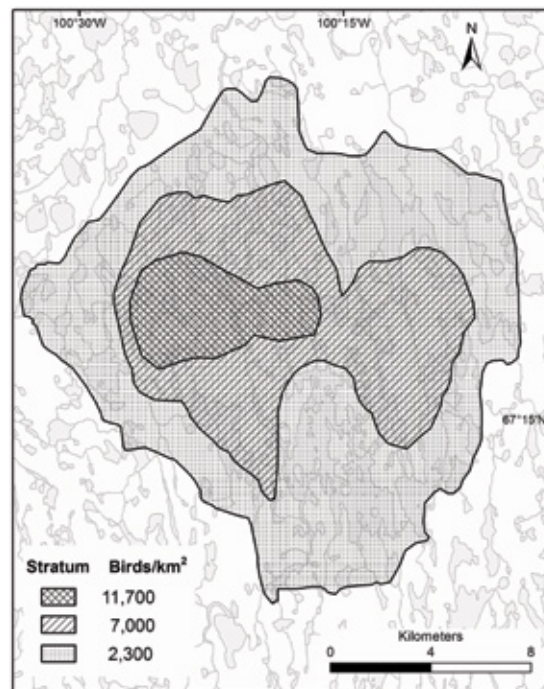


Figure 29. Colony 3 (Karrak Lake) including Colonies 51 and 65, showing the area occupied by nesting lesser snow and Ross's geese, June, 2006 and density in nesting birds / km².

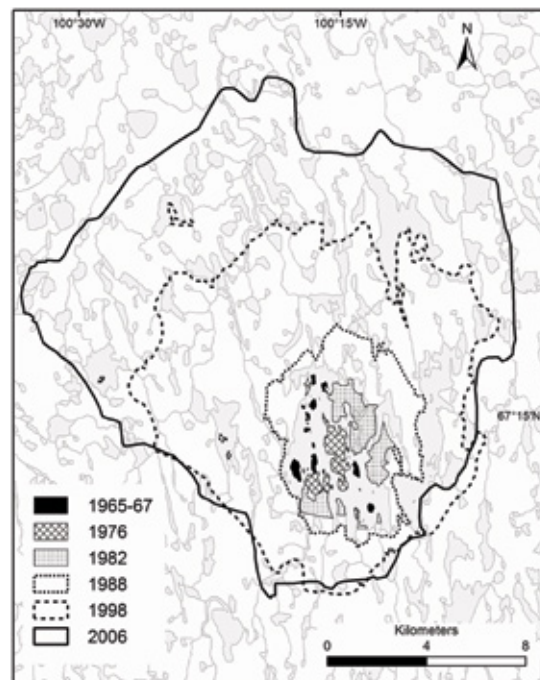


Figure 30. Colony 3 (Karrak Lake) including Colonies 51 and 65, showing the area occupied by nesting lesser snow and Ross's geese, 1965-1967, with expansion recorded in 1976,1982,1988,1998 and 2006.

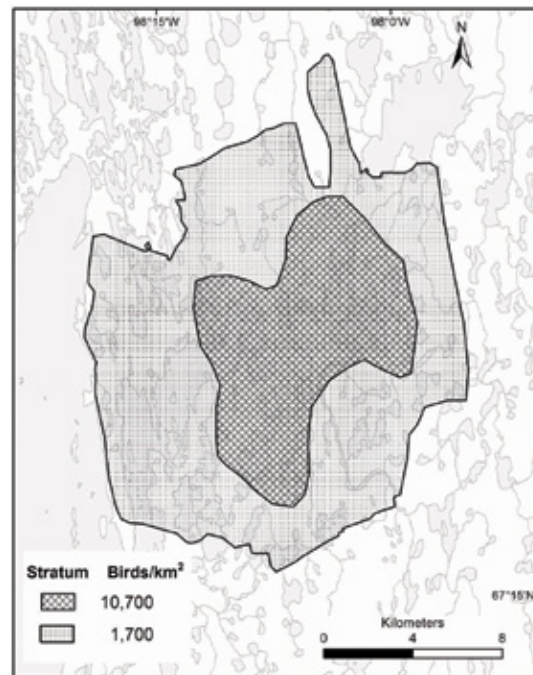


Figure 31. Colony 10, including Colonies 28 and 102, showing the area occupied by nesting lesser snow and Ross's geese, June, 2006 and density in nesting birds / km².

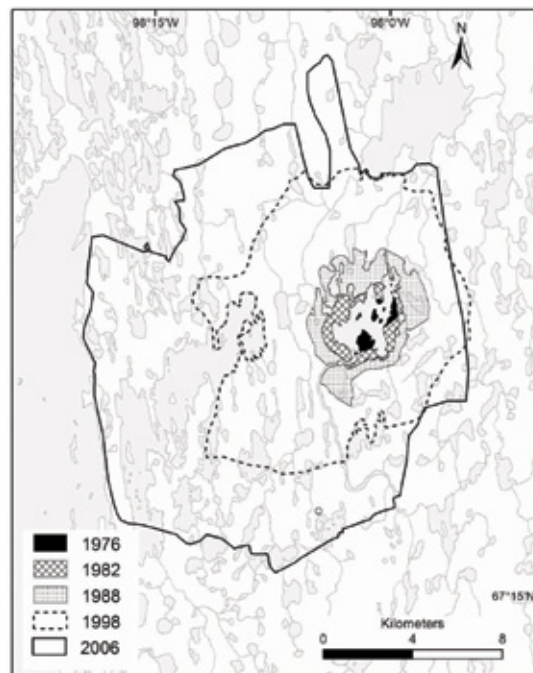


Figure 32. Colony 10, including Colonies 28 and 102, showing the area occupied by nesting lesser snow and Ross's geese in 1976, with expansion recorded in 1982, 1988, 1998 and 2006.

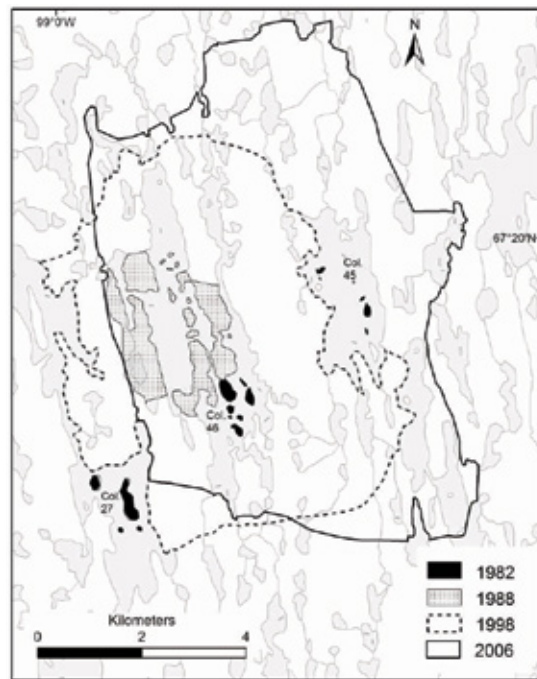


Figure 33. Colonies 46, 27 and 45, showing the area occupied by nesting lesser snow and Ross's geese in 1982, with expansion recorded in 1988, 1998 and 2006.

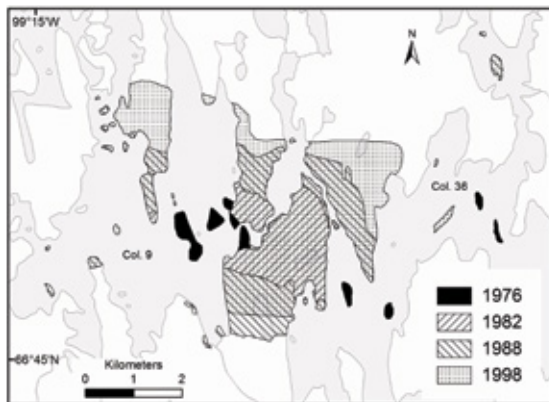


Figure 34. Colonies 9 and 36, showing the area occupied by nesting lesser snow and Ross's geese showing expansion from 1976 to 1982, 1988 and 1998.



Figure 35. Colonies 9 and 36, showing the area occupied by nesting lesser snow and Ross's geese showing reduction from 1998 to 2006.

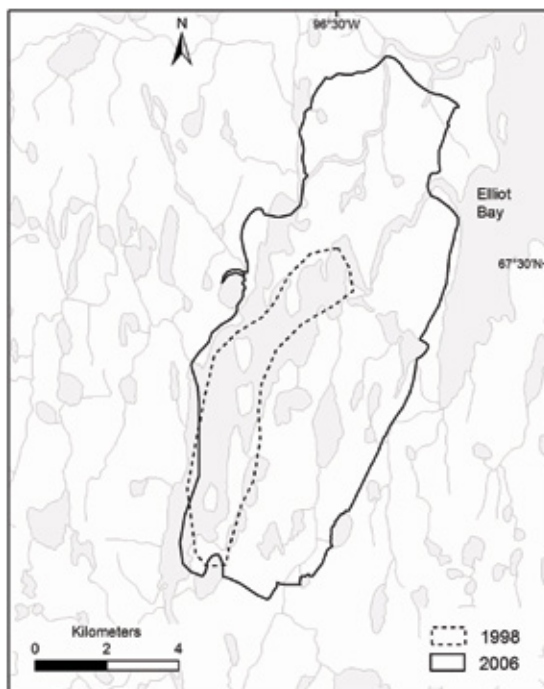


Figure 36. Elliot Bay colony, showing the area occupied by nesting lesser snow and Ross's geese in 1998, with expansion recorded in 2006.



Figure 37. Adelaide Peninsula 2 colony, showing area occupied by nesting lesser snow and Ross's geese in June, 1998 and 2006.

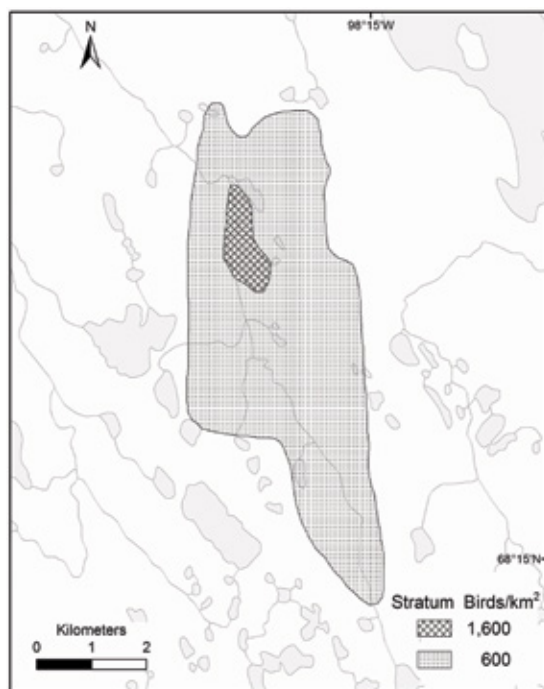


Figure 38. Adelaide Peninsula 3 lesser snow Goose colony, Nunavut, showing the area occupied by nests, June, 2006 and density in nesting birds / km².

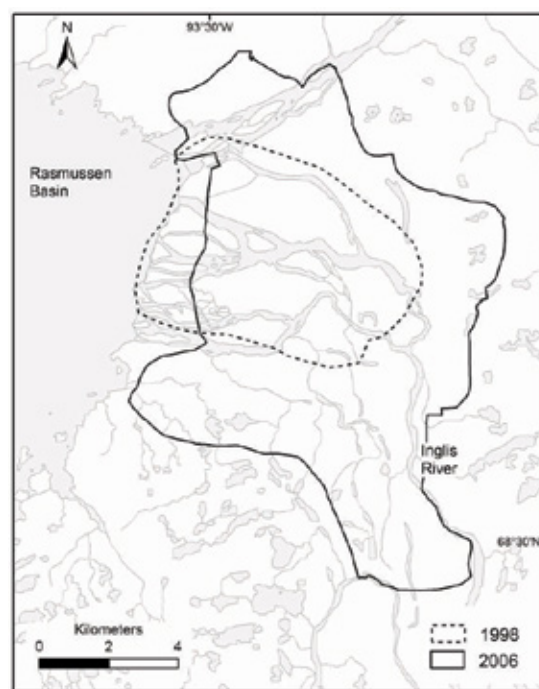


Figure 39. Colony at Inglis River, showing area occupied by nesting lesser snow and Ross's geese in June, 1998 and 2006.

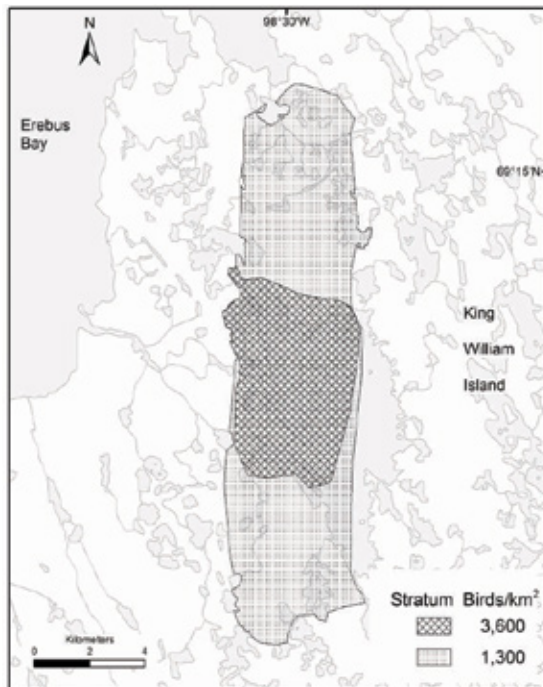


Figure 40. Lesser snow goose colony at Erebus Bay, Nunavut, showing the area occupied by nests, June, 2006 and density in nesting birds / km².

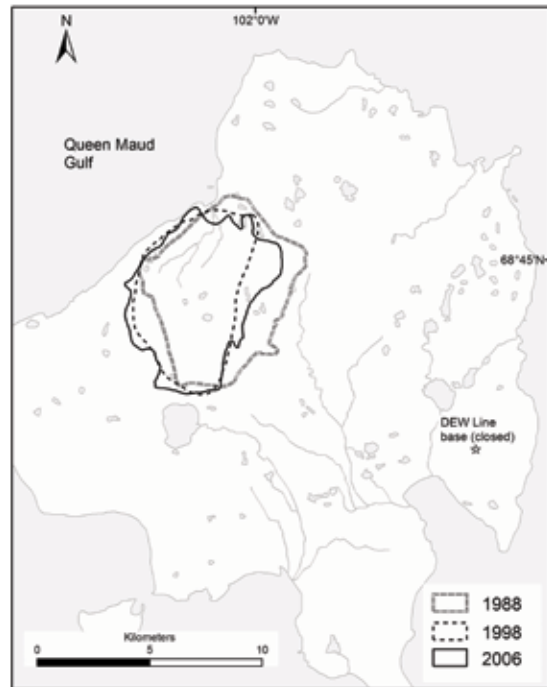


Figure 41. Colony at Jenny Lind Island, showing area occupied by nesting lesser snow and Ross's geese in June, 1988, 1998 and 2006.



Figure 42. Lesser snow goose colony at Icebreaker Channel, Nunavut, showing the area occupied by nests, June, 2006 and density in nesting birds / km².

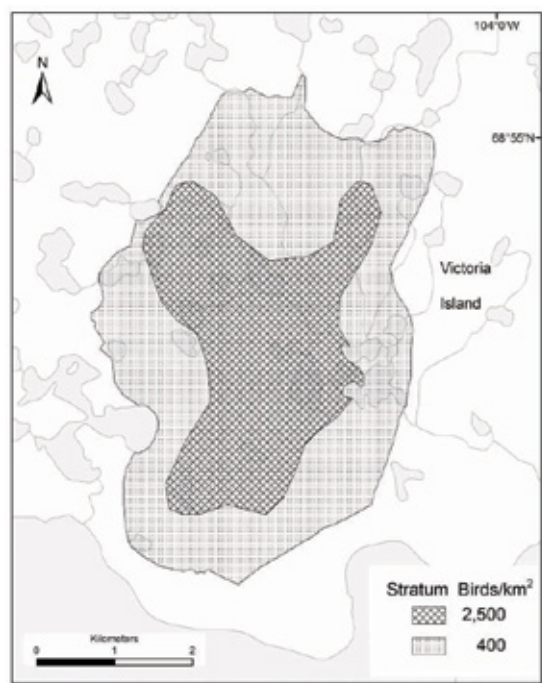


Figure 43. Lesser snow goose colony at Anderson Bay, Nunavut, showing the area occupied by nests, June, 2006 and density in nesting birds / km².

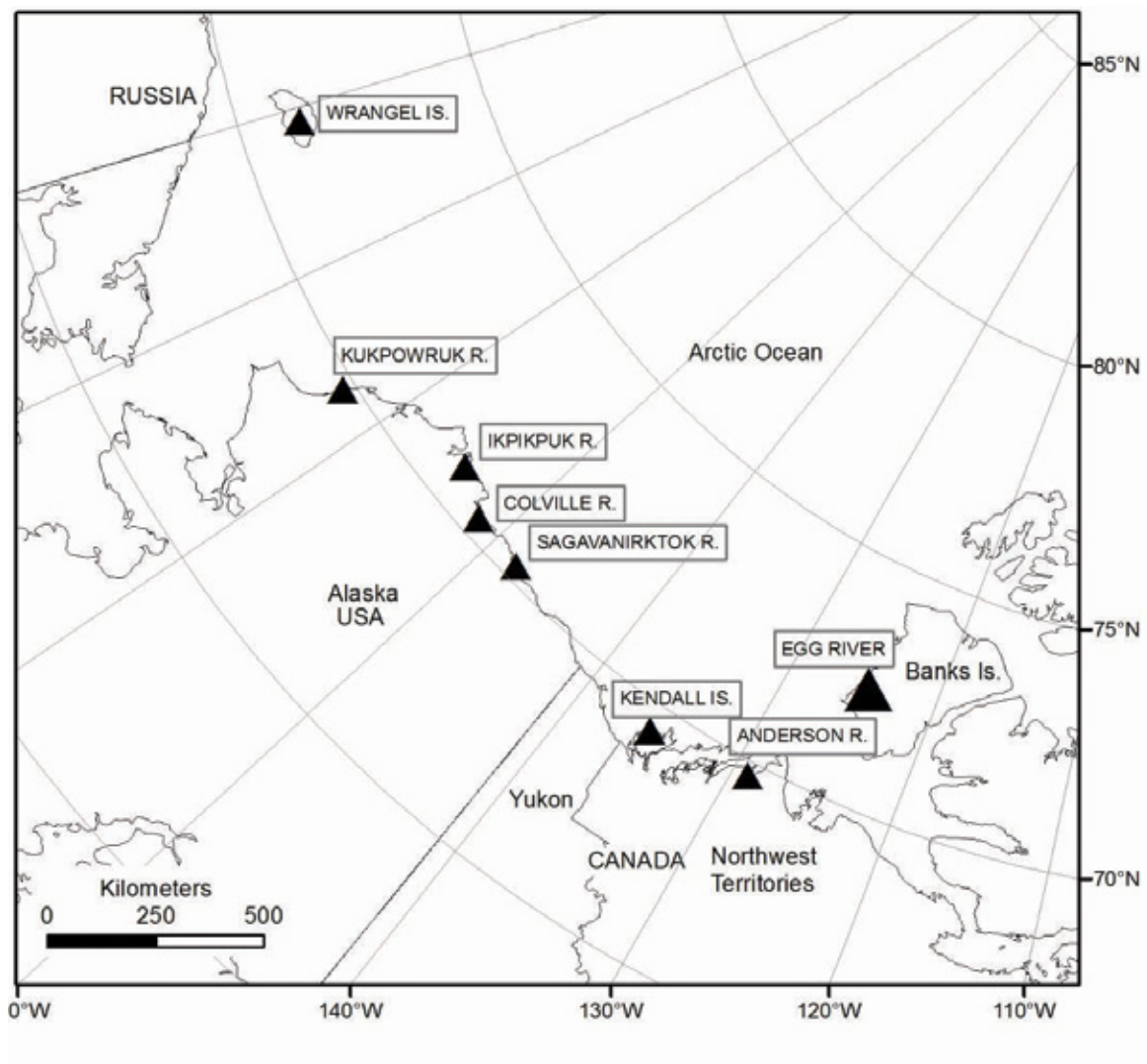


Figure 44. Nesting colonies of lesser snow geese (triangles) in the western Canadian arctic, Alaska (Burgess et al 2012) and Wrangel Island.

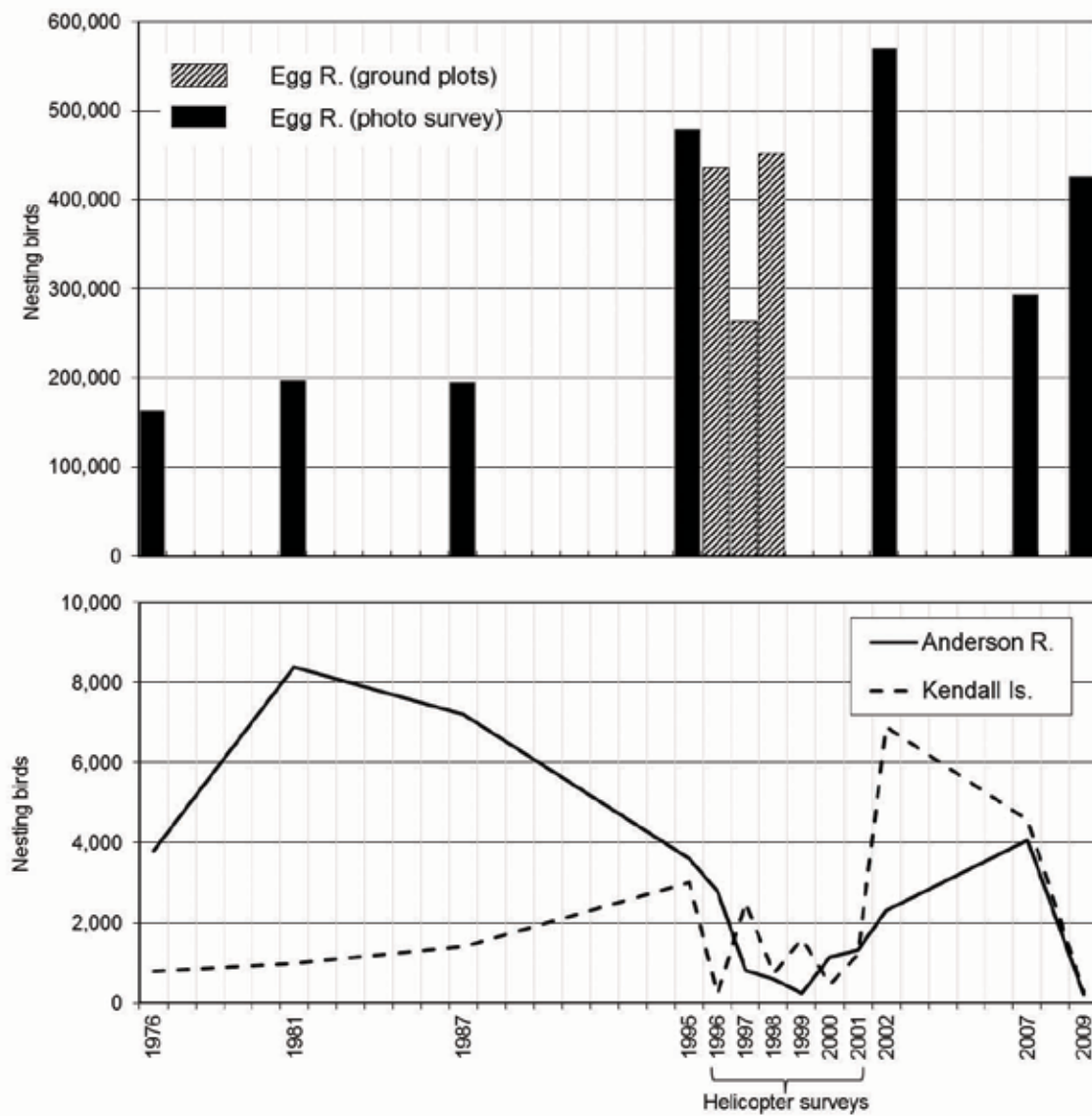


Figure 45. Numbers of lesser snow geese at Egg River, Anderson River and Kendall Island, 1976 to 2009 as determined by photo survey except: Egg River 1996-1998 by ground plots (Samelius et al 2008) and Anderson R. and Kendall Is. 1996-2001 by helicopter survey (Wiebe Robertson and Hines 2006).

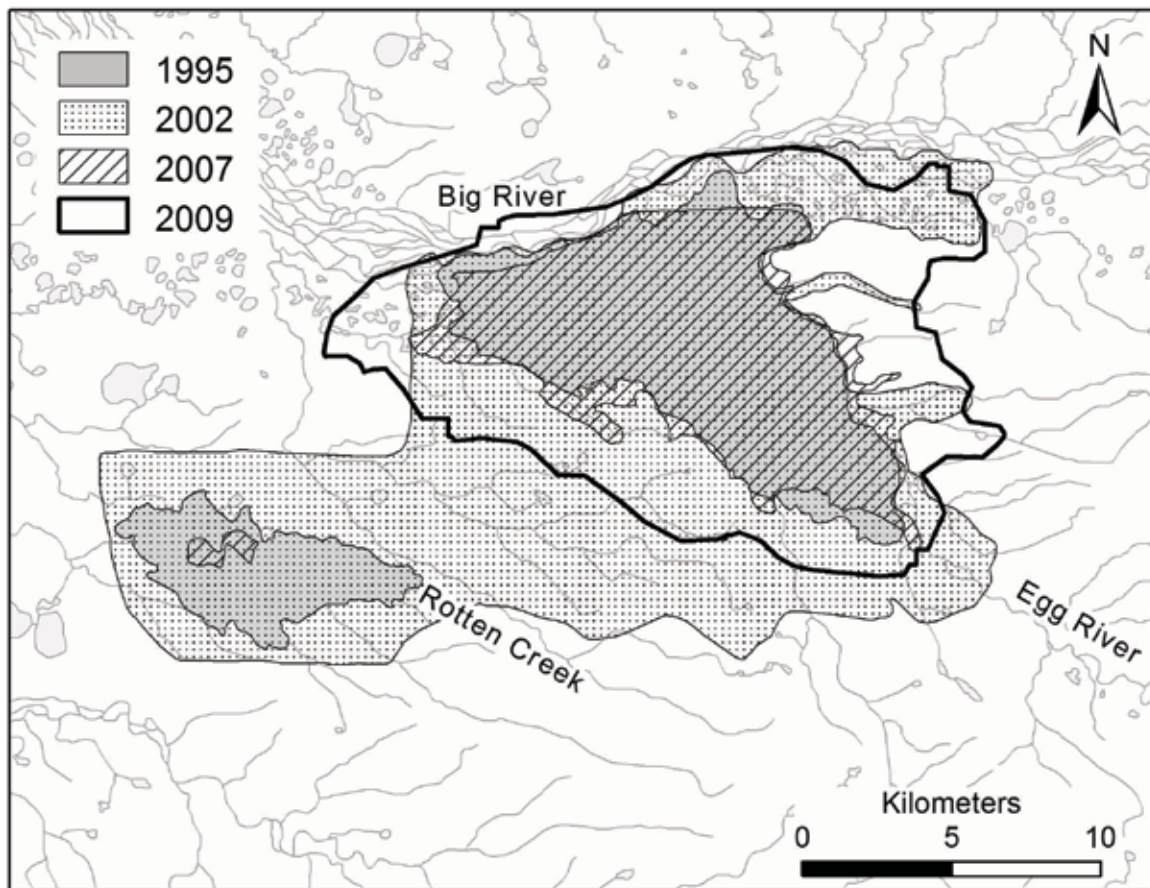


Figure 46. Lesser snow goose colony at Egg River, Banks Island, NWT, showing the area occupied by nests, June, 1995, 2002, 2007 and 2009.

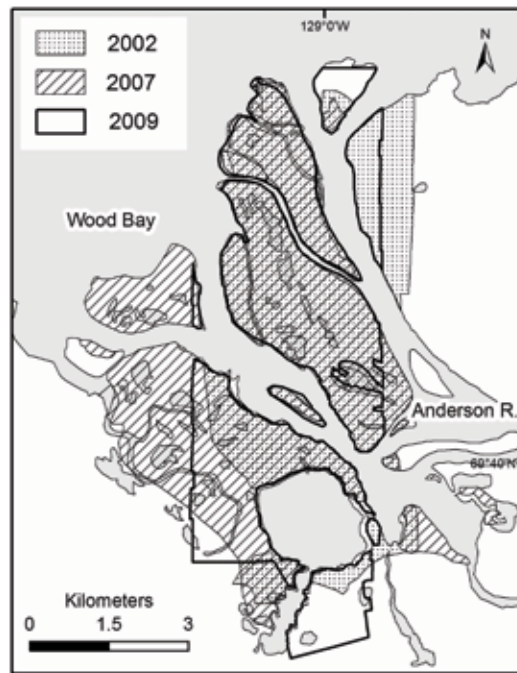


Figure 47. Lesser snow goose colony at Anderson River, NWT, showing the area occupied by nests, June, 2002, 2007 and 2009.

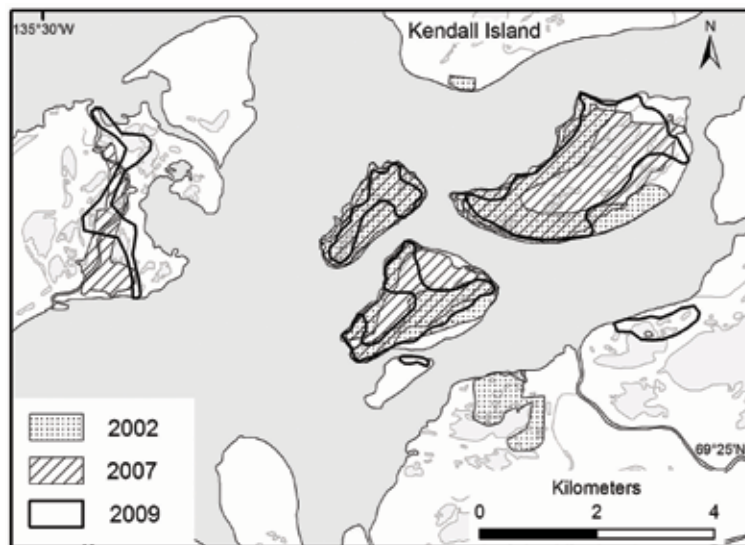


Figure 48. Lesser snow goose colony at Kendall Island, NWT, showing the area occupied by nests, June, 2002, 2007 and 2009.

