4.3 Fall migration

4.3.1 King Eiders

Young King Eiders are among the earliest fall migrants in the Holman area, arriving in the Safety Channel area from eastern Prince Albert Sound and stopping around protected island breaks and bays. King Eiders pass through the Holman area in fairly large numbers from early to late September. Fall migration routes are less well defined than spring routes, and fewer birds move through Masoyuk than in the spring (presumably due to the more widespread presence of open water elsewhere). Safety Channel (and environs) is a consistently used fall staging area, and groups of 20–30 individuals are commonly seen there.

Although Holman residents make little concerted effort to hunt waterfowl in fall, some eiders are taken incidentally to seal hunting and fishing. Fall migrant eiders (especially King Eiders) are reported to be in good shape and have abundant fat.

4.3.2 Canada Geese and Black Brant

Canada Geese and Black Brant do not fly through the Holman area in fall. They are thought to move south from their major moulting/brood-rearing areas at the head of Prince Albert Sound to the mainland coast. Some local movements of these species are seen in the Safety Channel area.

4.3.3 Pacific Common Eiders

Pacific Common Eiders are the latest fall migrants present in the Holman area. Typical freeze-up for marine coastal areas is mid-October; in some years, young-of-the-year are present in the last available open water (around the Safety Channel islands) and occasionally are frozen in the ice there. Although some local movements occur, this species leaves the Holman area with little notice and may follow a migration route that is different from that followed by King Eiders, moving south towards the mainland.

4.4 General ecology

4.4.1 Predation

Glaucous Gulls and, to a lesser extent, jaegers (including Long-tailed Jaegers *Stercorarius longicaudus*, Pomarine Jaegers *S. pomarinus*, and Parasitic Jaegers *S. parasiticus*) were the most commonly mentioned predators of eider eggs and young.

Arctic foxes *Alopex lagopus* take adults, young, and eggs and are thought to be the reason that waterfowl nest on islands. Peregrine Falcons *Falco peregrinus*, Snowy Owls *Bubo scandiacus*, and Gyrfalcons *Falco rusticolus* are also known to prey on adults and young.

4.4.2 Population dynamics

Holman hunters were familiar with the periodic die-offs of eiders that have occurred both near Banks Island (see below) and on the mainland during very late springs when open leads in the sea ice are not available to the migrating eiders (Barry 1968; Palmer 1976; Fournier and Hines 1994). Local residents have not observed similar occurrences near Holman. People believe that this phenomenon does not occur near Holman, because starving eiders will not be able to fly that far if the shore leads close near the mainland or Banks Island.

Most hunters suggest that Canada Geese are now more abundant in the Holman area than they were in the past. They were first seen near Holman in the mid-1970s and have apparently increased steadily since then. However, Canada Geese have been present in the lowlands of the Kagloryuak River Valley for as long as local people can remember. In contrast to the situation with Canada Geese, eider numbers are thought to have remained fairly stable, and elderly hunters report no change in abundance over the years. Black Brant, although never numerous, are thought to have declined over the long term.

Weather is thought to be the main cause of changes in local waterfowl numbers, and many people feel that the general climate in the Holman area has become warmer over the years. Earlier springs and higher temperatures in summer have been noticed especially. Some areas that were formerly bare ground are now covered by vegetation. Some hunters believe that this has attracted Canada Geese to such areas at the expense of Black Brant.

5. Results: Sachs Harbour region

5.1 Spring migration

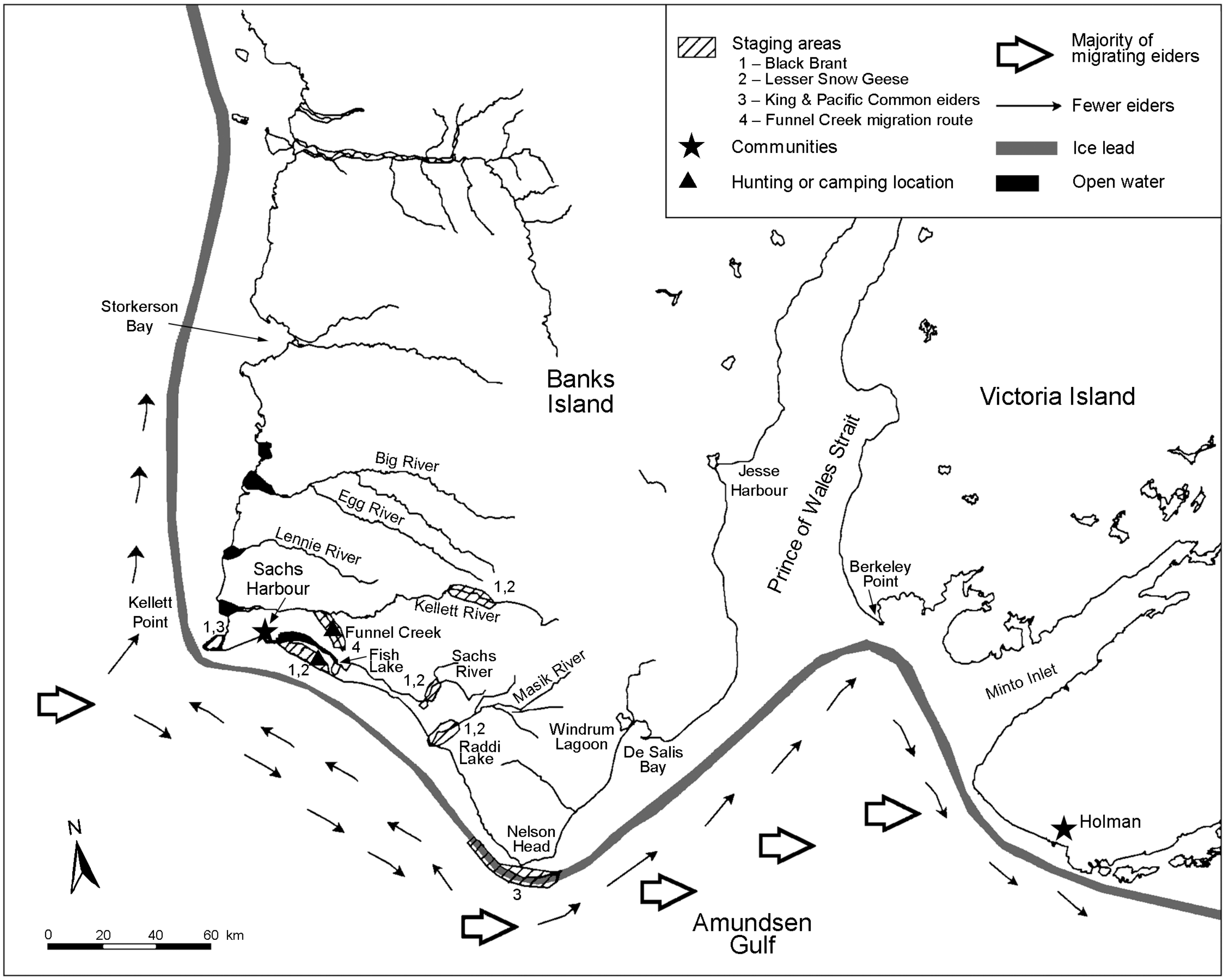
5.1.1 Sandhill Cranes

Sandhill Cranes are among the first birds to arrive at Sachs Harbour. In early May, pairs and small groups are seen arriving from the southeast, travelling inland along the valley of the Sachs River to nesting areas. Groups of cranes are frequently seen in spring at the community landfill site, where they apparently scavenge carrion and feed on insect larvae.

5.1.2 King and Pacific eiders

A large ice lead, which runs along the west coast of Banks Island south to Kellett Point and then southeast towards Nelson Head, opens at the end of April (Fig. 7). King Eiders are the first birds to use this open water, arriving in early May, presumably from the west (Barry 1986). Pacific Common Eiders arrive slightly later (early to mid-May) and are thought to move in mainly from the southeast. Both species of eider occur in mixed groups along the ice edge, particularly off Nelson Head, with peak numbers occurring in early to mid-June. A continual flux of eiders is observed around Sachs Harbour; eiders move from their main staging area off Nelson Head west along the ice edge to the Cape

Figure 7
Important hunting areas and open water staging areas for waterfowl in the Sachs Harbour region



Kellett area. Sex ratios of these staging eiders are reported to be about equal.

People who had lived in the De Salis Bay area reported large numbers of King Eiders travelling east along the ice edge towards Berkeley Point in early June (Fig. 7). These people had knowledge of the Holman area and stated that "many more" eiders came through Masoyuk than along the coast off De Salis Bay. This observation supports the contention that the main migration into the Holman area follows a more direct route from Nelson Head to Cape Ptarmigan, rather than following shore leads from Berkeley Point.

5.1.3 Lesser Snow Geese and Tundra Swans

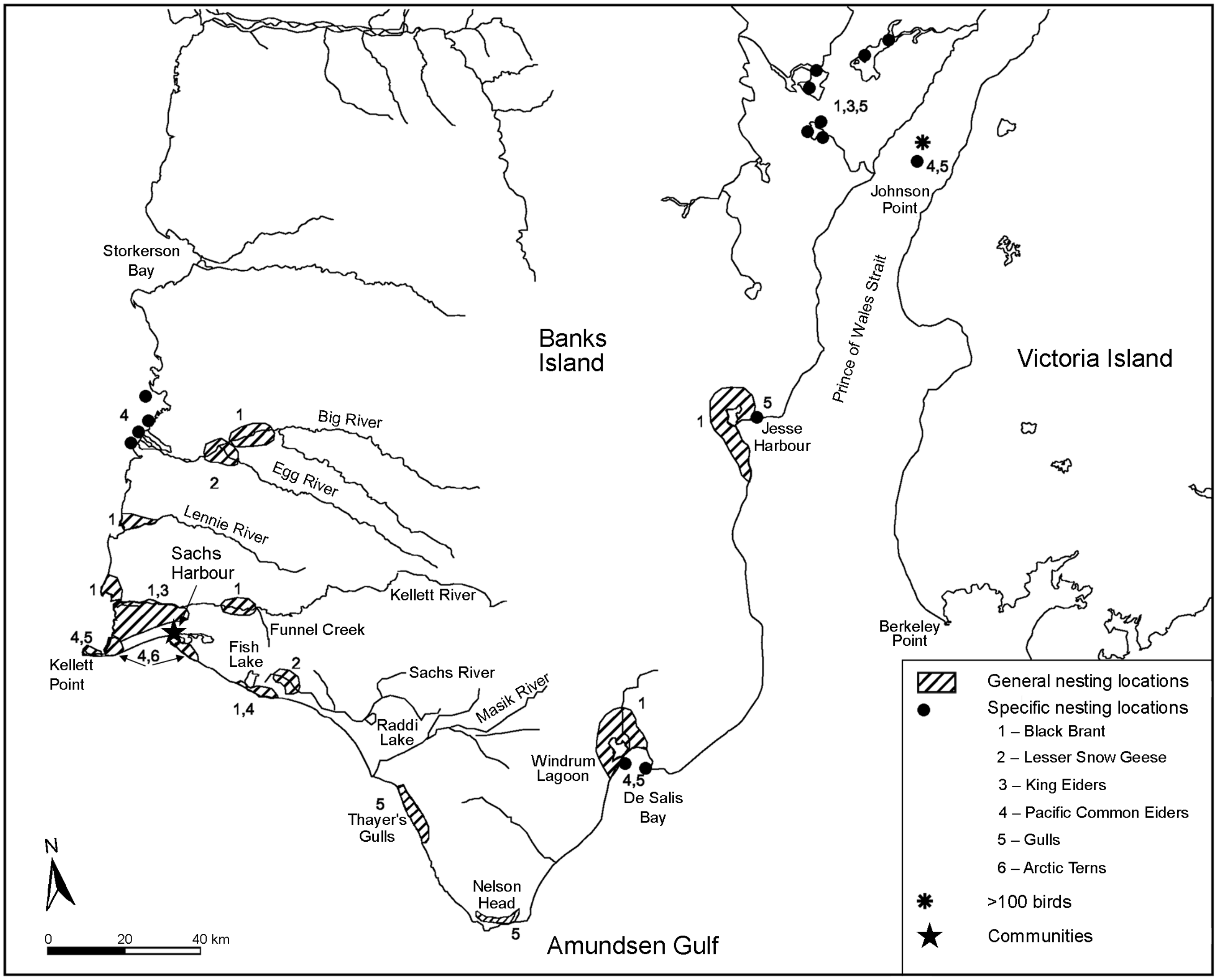
Lesser Snow Geese and Tundra Swans first arrive in the Sachs Harbour area in mid- to late May. One hunter believed that the cliffs demarcating the Masik River Valley are used as a landmark by migrating Lesser Snow Geese (Fig. 7). These large, south-facing promontories are the first landforms to become snow-free in spring, and their black surface can be easily seen in an otherwise white landscape. The cliffs are used as a reference point by hunters travelling offshore on the sea ice.

The Masik River Valley is a major spring stopping place for both Lesser Snow Geese and Tundra Swans. These birds are thought to migrate directly to the valley from the mainland. Other important staging areas are the wetlands above Raddi Lake, the upper Kellett River region (including Shoran, Survey, and Robert lakes), and the wetland-rich coastal strip extending from Fish Lake to the Sachs River (Fig. 7).

The length of the staging period for Lesser Snow Geese on Banks Island is generally brief and depends on how fast the snow melts on the main breeding colony near the Egg River (Fig. 8). Flocks will remain at staging areas until warm weather prevails and the breeding grounds are snow-free. In the event of continuing cool weather, some females "dump" eggs, and large numbers of abandoned eggs can be seen in places with bare ground.

Small numbers of blue-phase individuals are observed among the flocks of Snow Geese. As well, small numbers of Canada Geese are occasionally seen with the Snow Geese flocks.

Figure 8
Important nesting locations for waterfowl in the Sachs Harbour region



5.1.4 Black Brant

Black Brant are relatively late arrivals at Sachs Harbour, first appearing in early June. They arrive from the south and use the same staging sites as Lesser Snow Geese. Black Brant also concentrate in the barrier bay created by the Cape Kellett sand spit before heading inland to nesting areas (Fig. 7).

5.1.5 Spring migration routes

Large river mouths along the west coast, such as those of the Kellett, Lennie, and Big rivers, offer open freshwater habitat in late May (Fig. 7). At this time, King Eiders leave the ice edge and stage in these deltas before travelling to inland nesting areas. Lesser Snow Geese and Black Brant also stage at these river mouths.

Funnel Creek, a tributary of the Kellett River, is a major migration route for Lesser Snow Geese and Black Brant. Particularly large numbers of Snow Geese, en route to the nesting area at the confluence of the Egg and Big rivers, are "funnelled" through this area by the local topography (Fig. 8).

The Sachs River is also a well-known migration route for all waterfowl species. Flights of Black Brant, Lesser Snow Geese, and eiders travel along this waterway from staging areas near Raddi Lake to the coastal lowlands between Fish Lake and Sachs Harbour. The Sachs River and associated wetlands to the south of the river are the most important hunting area used by Sachs Harbour residents (Fig. 7).

5.2 Nesting

5.2.1 Sandhill Cranes and Tundra Swans

Sandhill Cranes are among the earliest birds to nest on Banks Island. They are reported to nest at low densities throughout the Sachs Harbour area and usually begin laying in mid- to late May on snow-free areas with south-facing exposures. Two eggs are laid, and both parents tend the nest. The typical hatching date is mid-June, and occasional family groups are seen in lowland areas near Sachs Harbour.

Tundra Swans are sparsely distributed throughout the lower part of Banks Island and have not been observed north of the Big River by local hunters. Tundra Swans usually lay four eggs in early June, and incubation continues into July. Swans depart from the Sachs Harbour area in early to mid-September.

5.2.2 *Lesser Snow Geese*

Lesser Snow Geese usually begin nesting at the Egg River colony in the first week of June (Fig. 8). In years with late springs, eggs are sometimes dumped on the snowpack at the colony. During spring breakup in such years, numerous eggs have been observed washing downstream in the runoff created from melting snow. At least in some years, nesting occurs near the Sachs River north of Fish Lake and near the Kellett and Lennie rivers (Fig. 8). Peak hatching occurs in early July.

Post-hatching movements to brood-rearing areas are fairly direct, and there is a mass exodus of adults and young from the Egg River colony during the first week of July. Family groups are commonly seen throughout the southwestern part of the island, but no specific brood-rearing areas were identified. The typical fledging date is mid-August.

Non-breeding adult Lesser Snow Geese moult on large lakes in the interior of the island and at river deltas on the west coast. No specific moulting areas were mentioned, as flocks of moulting adults appear to be widely distributed throughout the western part of the island.

Mass southerly migrations of both non-breeders and family groups occur in late August or early September.

5.2.3 *King Eiders*

King Eiders appear to nest slightly before Pacific Common Eiders on Banks Island. King Eider pairs can be seen flying inland from coastal areas, seeking out nesting grounds around freshwater ponds by the second week of June. King Eiders are reported to nest at “low densities” throughout Banks Island, with slightly higher densities being observed near the lower Kellett River. King Eiders were reported to nest frequently on islands in large freshwater lakes, and the lakes located northwest of Johnson Point were specifically identified as having a number of nests (Fig. 8). By the third week in June, small flocks of grouped males were observed flying along the Sachs River or sitting in tidal areas off the west coast of Banks Island.

Hatching takes place from mid- to late July. Brood rearing takes place on freshwater ponds and lakes throughout Banks Island, and families sometimes join into small crèches. No key habitats for brood rearing were reported. This possibly indicates a fairly even distribution of broods throughout the island.

5.2.4 *Pacific Common Eiders*

Pacific Common Eiders nest at low density along the barrier beaches, sand spits, and coastal uplands of the western coast of Banks Island. Nesting colonies have been found on the islands off the mouth of the Big River (Moose, Sik-Sik, Rabbit, and Terror islands), at Kellett Point, at De Salis Bay, and at Princess Royal Island (off Johnson Point on the eastern coast of Banks Island) (Fig. 8). The latter colony is reported to support hundreds of nesting Pacific Common Eiders as well as a large number of gulls (likely Glaucous Gulls). Other colonies are reported to consist of 20 or more nesting females.

Groups of male Pacific Common Eiders can be seen near the nesting colonies after incubation commences in mid- to late May. Eggs hatch in late July to early August, and groups of broods and attendant females are observed along coastal lagoons and near nesting islands. Concentrations of Pacific Common Eider ducklings have been noted at Kellett Point, De Salis Bay, and Jesse Harbour (Fig. 9).

5.2.5 *Black Brant*

Black Brant are reported to nest at low densities throughout the interior and coastal lowlands of Banks Island. The De Salis Bay and Jesse Harbour areas were reported to have good numbers of nests. The valley of the Big River, upstream from the confluence of the Egg River, and the deltas of the Kellett and Lennie rivers were reported to support small colonies of Brant (Fig. 8). Black Brant usually begin nesting by mid-June.

Hatching usually occurs in mid- to late July, and most broods have been seen in the various river deltas along the west coast (Fig. 9). A number of broods and moulting adults have also been seen at the Nelson River lowlands (east of Nelson Head), Jesse Harbour, and De Salis Bay. The greatest reported concentration of moulting Black Brant was in the De Salis Bay area, specifically the wetlands and large lakes along the north side of Windrum Lagoon (Fig. 9).

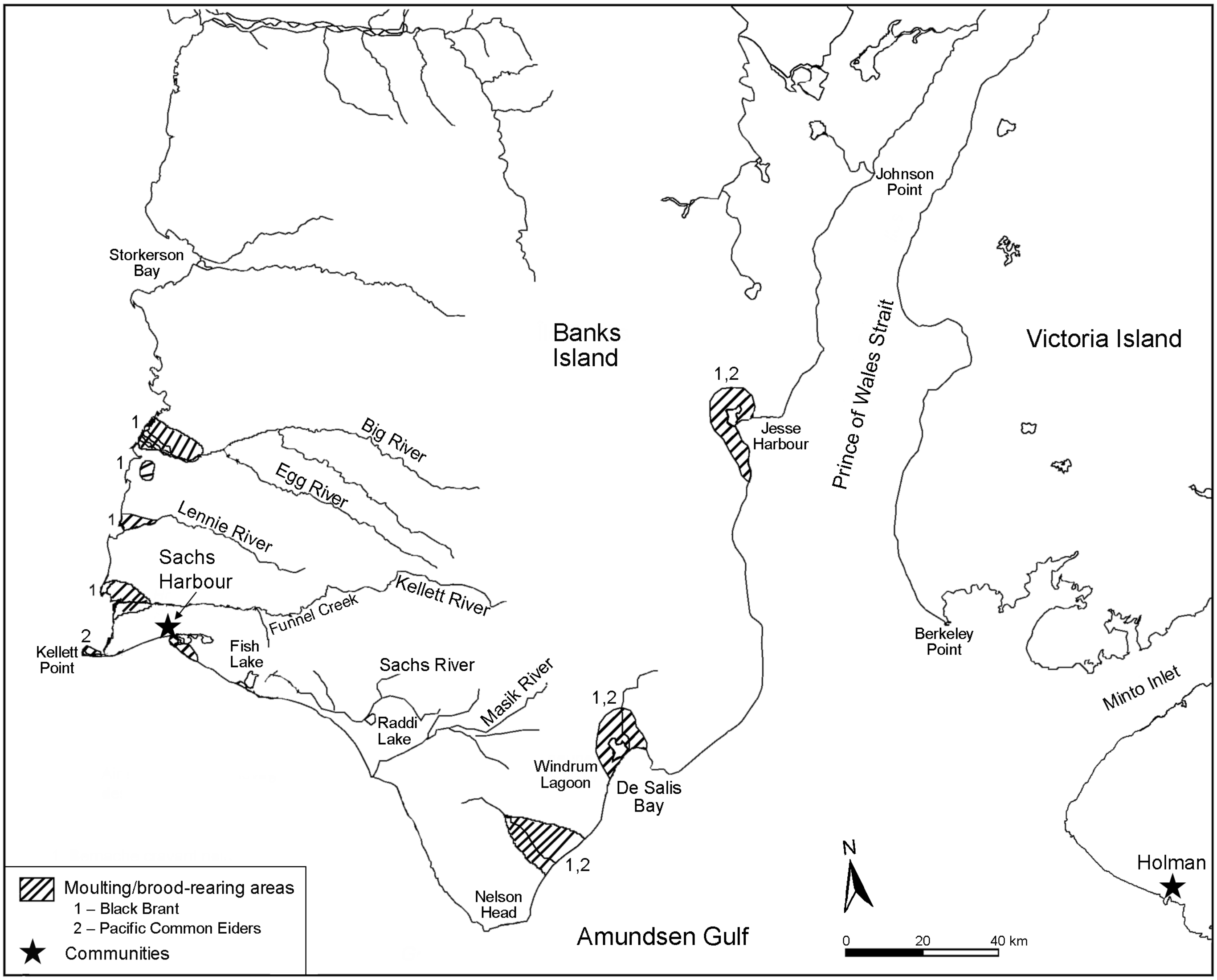
Associations between nesting Snowy Owls and other birds, especially Black Brant, were reported by several hunters. Black Brant, King Eiders, and shorebirds have all been observed nesting near owls. Snowy Owls are found mainly in the interior of Banks Island, and their nesting locations change from year to year, presumably in relation to fluctuations in lemming (*Dicrostonyx groenlandicus* and *Lemus sibiricus*) abundance. Brant and other species apparently nest near owl nest sites as a predator defence strategy (Cotter and Hines 2001); however, several hunters reported seeing remains of goslings around owl nests in such situations, indicating that owls occasionally prey on young Snow Geese or Brant.

5.3 Fall migration

5.3.1 *King Eiders and Black Brant*

Local hunters occasionally shoot migrating waterfowl in the fall while fishing or seal hunting. The Sachs River and the area near Kellett Point are places where fall migrants,

Figure 9
Important brood-rearing and moulting areas for waterfowl in the Sachs Harbour region



primarily Black Brant and eiders, are hunted. The migration period is short for both King Eiders and Brant. These species typically travel in flocks of 10–30 birds, moving west along the Sachs River past Sachs Harbour. Some birds stage briefly at Kellett Point and typically depart for the mainland by mid-September.

5.3.2 Lesser Snow Geese

In fall, migrating Lesser Snow Geese quickly pass over the community of Sachs Harbour at great heights, thus providing little opportunity for hunting. In most years, Snow Geese have left Banks Island by early September.

5.3.3 Pacific Common Eiders

Pacific Common Eiders can be seen in the open waters off Sachs Harbour until freeze-up in early October. They are frequently seen travelling offshore in small flocks of 10–15 birds, but no obvious migration pattern is discernible from these movements.

5.4 General ecology

5.4.1 Predation

Interviewees said that Glaucous Gulls, the three species of jaegers, and Arctic foxes took both eggs and young of many species of birds. The sizeable fox population on Banks Island is thought to reflect the abundance of birds nesting on the island. Polar bears *Ursus maritimus* are also thought to occasionally prey upon waterfowl nests, as these large carnivores have been seen moving up the Big River Valley from the coast towards the main Lesser Snow Goose nesting grounds.

5.4.2 Population dynamics

Mass die-offs of King Eiders have occurred in several late springs in the Sachs Harbour area when heavy ice cover and prevailing winds limited the size of shore leads and forced eiders away from coastal feeding areas. King Eiders, which arrive at Banks Island before Pacific Common Eiders, were most heavily affected. The most substantial die-off in memory took place in late May of 1990. Thousands of starving or dead eiders were found on the sea ice and beaches near Sachs Harbour. Many of the surviving ducks were so weak that they could be easily captured by hand. Die-offs also occurred in the mid-1950s, 1964 (Barry 1968), and the late 1970s. With the exception of the 1990 incident, the exact years in which these mortality events occurred could not be determined from the interviews.

Despite the periodic die-offs, no obvious trend in the numbers of either King Eiders or Pacific Common Eiders was noted over the years. In contrast, both Canada Geese and Lesser Snow Geese appear to be more abundant than previously. Most people reported a distinct decline in the population of Black Brant over the years and remember when larger flocks of Brant migrated to Banks Island in spring. Climate change was implicated in changes in the numbers of certain waterfowl, with warmer springs and summers contributing to more vegetation on certain parts of the island.

6. Discussion

Much of the information provided by hunters from both Holman and Sachs Harbour was geographic in nature and therefore best summarized and depicted on maps. Areas used by waterfowl within the area in which people hunted and travelled appeared to be well known, and the results of interviews with different individuals were highly corroboratory. Prior to this work, many of the areas used by waterfowl near Holman and Sachs Harbour were not well documented or summarized in written form. Thus, the identification, based on Inuvialuit local knowledge, of important and potentially sensitive areas for waterfowl during migration and breeding should prove to be especially useful to organizations and agencies responsible for conservation and resource management.

Some of the most interesting "new" findings from the interviews include the documentation of migration and nesting areas for King and Common eiders in the Holman region and identification of important nesting areas for Black Brant and the migration paths of Lesser Snow Geese on Banks Island.

7. Acknowledgements

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Aerial surveys of Lesser Snow Goose colonies at Anderson River and Kendall Island, Northwest Territories, 1996–2001

Myra O. Wiebe Robertson and James E. Hines

Canadian Wildlife Service, Environmental Stewardship Branch, Environment Canada, Suite 301, 5204–50th Avenue, Yellowknife, NT X1A 1E2

Abstract

Most Lesser Snow Geese *Anser caerulescens caerulescens* in the Inuvialuit Settlement Region of the Western Canadian Arctic nest on Banks Island, with smaller colonies on the mainland, at the Anderson River and Kendall Island bird sanctuaries. Because of their small size and uncertain status, the mainland colonies were surveyed by helicopter from relatively high elevations (230 m above ground) in 1996–2001 to estimate the numbers of Lesser Snow Geese present. Numbers of nesting geese at Anderson River declined from a peak of 8360 birds in 1981 to approximately 1200 birds in 2000–2001. Numbers at Kendall Island have varied from 210 to 2510 nesting Lesser Snow Geese in recent years and show no obvious long-term trend. We observed large numbers of non-nesting geese (19–87% of the birds present, $\bar{x}$ = 55%) at both colonies during the helicopter surveys. We suspect that many of the non-nesting birds were failed breeders. At Anderson River, nesting failure has been severe in recent years, apparently due to destruction of clutches by barren-ground grizzly bears *Ursus arctos horribilis*. Although helicopter surveys are not as accurate as air photo surveys for counting nesting pairs, the helicopter counts at Anderson River and Kendall Island also record non-breeders or failed breeders, which are more likely to be missed in the air photo surveys. For the smaller colonies in the Western Arctic, and likely for other similar areas elsewhere in northern Canada, helicopter surveys should be a cost-effective method for annual monitoring of the breeding colonies, especially when carried out in association with other fieldwork. We recommend that these surveys be continued annually at the Anderson River and Kendall Island colonies to supplement the periodic air photo surveys carried out at five-year intervals.

1. Introduction

More than 95% of the Lesser Snow Geese *Anser caerulescens caerulescens* in the Inuvialuit Settlement Region nest on Banks Island, with the remaining geese nesting at colonies in the Anderson River Delta Migratory Bird Sanctuary and the Kendall Island Migratory Bird Sanctuary (Kerbes et al. 1999). Numbers of Lesser Snow Geese on Banks Island have increased substantially since the 1960s, and it has been recommended that this stock be stabilized at its current level to prevent overgrazing problems such as have occurred in the Central and Eastern Arctic (Abraham and Jefferies 1997; Hines et al. 1999). Suggested methods to reduce the Banks Island stock include increased harvest during migration and on the wintering grounds and increased subsistence harvest in spring near the breeding grounds. However, one concern about increasing the harvest is that it could negatively affect the smaller colonies in the Inuvialuit Settlement Region.

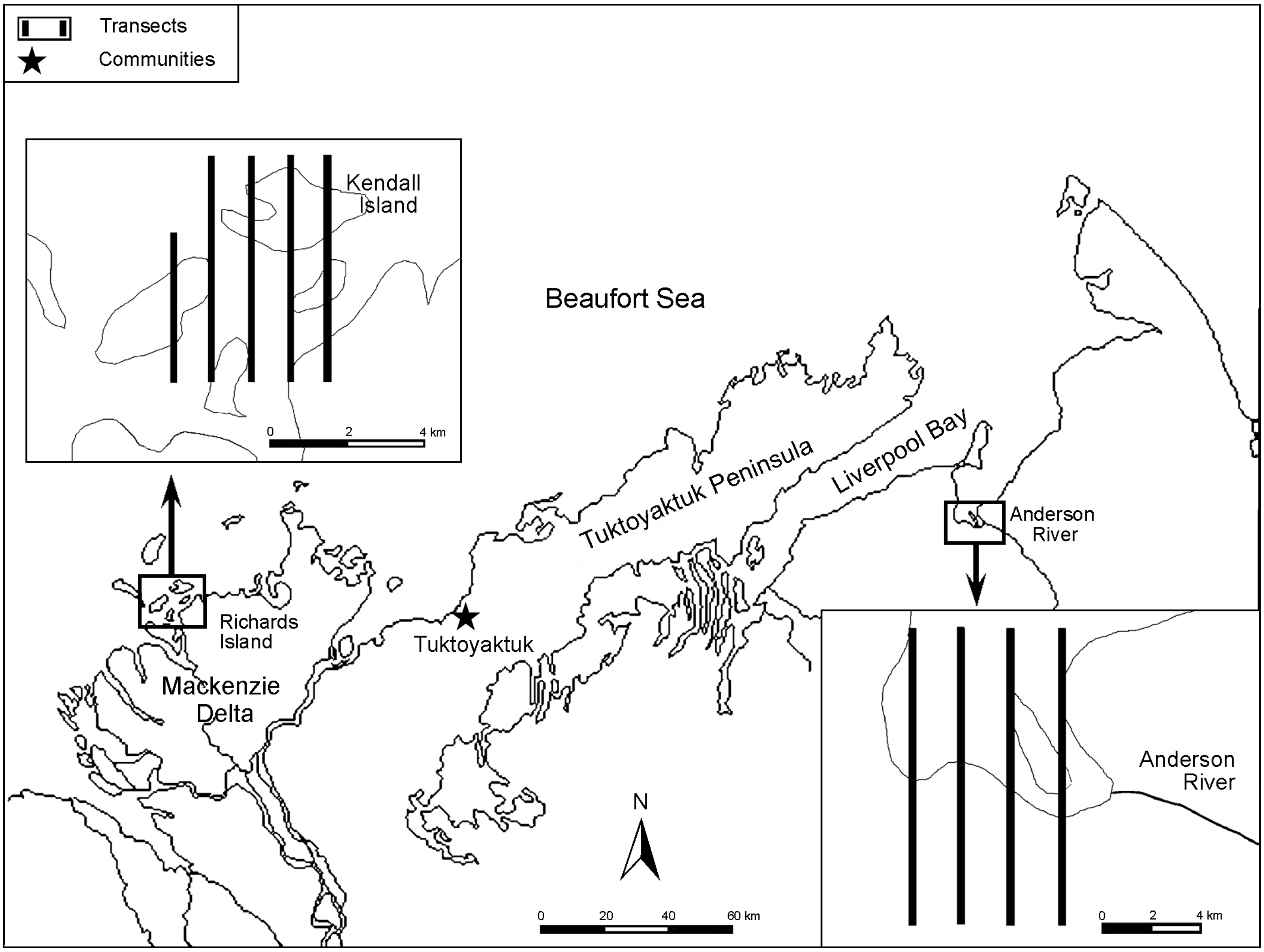
We surveyed the Anderson River and Kendall Island colonies by helicopter in June 1996–2001, to estimate the numbers of nesting and non-nesting Lesser Snow Geese present. Our results supplement the results of air photo surveys of the colonies, which have been made every 5–8 years since 1976 (Kerbes 1983, 1986; Kerbes et al. 1999).

2. Methods

Helicopter surveys to estimate numbers of Lesser Snow Geese were flown at the Anderson River colony (69°42′N, 129°00′W) on 19 June 1996, 18 June 1997, 13 June 1998, 18 June 1999, 17 June 2000, and 17 June 2001 (Fig. 1). Surveys were flown at the Kendall Island colony (69°28′N, 135°18′W) on 20 June 1996, 16 June 1997, 15 June 1998, 18 June 1999, 18 June 2000, and 16 June 2001. Surveys were carried out in a Bell 206L helicopter with two observers, one in the left front seat and the other in the right rear seat, which had a bubble window for better viewing. The pilot was in the right front seat and was responsible for navigating the aircraft along the transect line, but did not record observations.

Transects were flown in straight lines approximately 230 m above the ground. To make sure that the transects were standardized to width, we carried out a “calibration flight” at survey height over known landmarks and marked a reference line on the helicopter window indicating the edge of the transect. The helicopter was flown as slowly as needed to carry out complete counts, with the ground speed varying from 30 to 80 km/h, depending on wind conditions and number of geese present. All transects were oriented north and south. Four 12-km-long transects, covering a total of 96 km^2, were flown at Anderson River (Fig. 1).

Figure 1
Transects flown over Lesser Snow Goose colonies at Kendall Island and Anderson River in June of 1996–2001



Five transects, ranging in length from 8 to 12 km and covering an area of 122 km^2, were flown at Kendall Island. Transects were spaced 2 km apart, and observers recorded all Lesser Snow Geese sighted within 1 km of each side of the transect. Thus, the entire colonies were surveyed, and the number of Lesser Snow Geese in the colony was simply the total number counted during the survey. We were able to determine from the air if individuals were nesting. Nesting pairs tended to be regularly spaced and typically did not fly as the helicopter passed over. Non-nesting geese were in scattered, small to medium-sized flocks (usually 3–100 birds) and typically flushed well ahead of the helicopter. To avoid duplicate counts, we recorded if non-nesting flocks flew from one side to the other side of the transect and took this into account when tabulating the data.

3. Results

Total numbers of Lesser Snow Geese at the Anderson River colony remained stable at approximately 3000–3500 geese from 1996 to 1998 but declined dramatically to 1100 in 1999 and remained relatively low in 2000 and 2001 (Table 1). Similarly, we observed a more than 50% decline in the numbers of nesting geese over the six years, from 2800 in 1996 to 1300 in 2001. On average, only 44% of the geese observed at Anderson River were nesting, although this proportion varied greatly from year to year. Over 80% of the geese were nesting in 1996, but only 20% and 23% were nesting in 1997 and 1999, respectively, and 50% and 57% were nesting in 2000 and 2001, respectively.

Numbers of Lesser Snow Geese at the Kendall Island colony varied greatly from year to year, ranging from 1645 to 4255 geese (Table 1). Relatively few of the geese (<740) present at Kendall Island were nesting when we surveyed the colony in 1996, 1998, and 2000, but 1200–2510 geese were nesting there in the other three years. The proportion of total geese that were nesting ranged from 13 to 59%.

4. Discussion

Our helicopter surveys followed methods used previously at Lesser Snow Goose colonies in the Rasmussen Lowlands in the Central Canadian Arctic (Hines and Kay, unpubl. data). There, counts were repeated to verify the accuracy of the method; results from the repeat counts were similar to the first counts, with the average count being within 14% of the original counts. Thus, helicopter surveys seem to be a reliable method of monitoring colony numbers.

As well, the relatively high elevation, compared with most other aerial waterfowl surveys, allows wide transects and less disturbance to nesting birds. Helicopter surveys, at least those at Anderson River and Kendall Island, allowed us to count non-nesting birds, which are more likely to be missed in air photo surveys (Kerbes et al. 1999).

Our survey results and the aerial photographs suggest that numbers of nesting geese at Anderson River have declined from >8000 geese in the early 1980s to about 15% of that total in 2000 and 2001 (Table 1). Numbers of nesting Lesser Snow Geese at Kendall Island fluctuated between 210 and 3050 birds between 1976 and 2001, with no apparent long-term trend in population size. During our surveys, we observed many non-nesting geese at both colonies. Because the non-nesters were still closely associated with the colonies, we suspect that many of these birds were failed nesters rather than non-breeders, which are less frequently found near the colonies at the time our surveys were carried out (Barry 1967; Kerbes 1986). Egg predation by barren-ground grizzly bears *Ursus arctos horribilis* has been a significant cause of nest failure at Anderson River in some years (Barry 1967; Armstrong 1998), and local Inuvialuit hunters reported an increase in sightings of grizzly bears in or near the colony in recent years (F. Pokiak, pers. commun.). We observed a grizzly bear and two yearling cubs on a transect during the Anderson River surveys in 1999, and their presence may have been one reason for the very low nesting numbers that year. Grizzly bears have also been sighted at the Kendall Island colony in some years (Hines, unpubl. data). In addition, low nesting numbers at the Kendall Island colony may have resulted from occasional spring flooding of the Mackenzie Delta (Barry 1967), as in 1993, when flooding prevented any geese from nesting at the Kendall Island colony (Hines, unpubl. data).

Unlike the Banks Island colony, Lesser Snow Goose numbers at the Anderson River and Kendall Island colonies are not increasing, and the recent productivity of the colonies, particularly at Anderson River, seems very low. Proposed increases in harvest of the Western Arctic Population of Lesser Snow Geese could potentially lead to further declines at the Anderson River colony and to declines at the unstable Kendall Island colony. Thus, we recommend that monitoring of these colonies continues while strategies to increase the harvest of the Banks Island geese are being applied. Although helicopter surveys are not as accurate as air photo surveys for estimating numbers of nesting pairs, the helicopter surveys do cover a broader area, making it possible to count non-breeders or failed breeders. Thus, this method is cost-effective for annual monitoring of the breeding colonies, especially when carried out in conjunction with other fieldwork. We recommend that annual helicopter surveys be continued at the Anderson River and Kendall

Table 1
Numbers of Lesser Snow Geese at Anderson River and Kendall Island colonies, 1960–2001

Year	Non-nesting geese	Nesting geese	% nesting	Total adults	Method (source)
Anderson River					
1960	–	–	–	8000	Reconnaissance (Barry 1967)
1976	1017[a]	3826	79	4843	Air photo surveys (Kerbes 1986)
1981	878[a]	8360	90	9238	Air photo surveys (Kerbes 1986)
1987	507[a]	7186	93	7693	Air photo surveys (Kerbes et al. 1999; Kerbes, unpubl.)
1995	2359[a]	3607	60	5966	Air photo surveys (Kerbes et al. 1999; Kerbes, unpubl.)
1996	660	2788	81	3448	Helicopter surveys (this study)
1997	2682	806	23	3488	Helicopter surveys (this study)
1998	2409	596	20	3005	Helicopter surveys (this study)
1999	860	246	22	1106	Helicopter surveys (this study)
2000	1158	1142	50	2300	Helicopter surveys (this study)
2001	988	1327	57	2315	Helicopter surveys (this study)
Average ± SE, 1996–2001	1460 ± 352	1151 ± 36	44	2610 ± 369	
Kendall Island					
1960	–	–	–	7500	Reconnaissance (Barry 1967)
1976	745[a]	832	53	1577	Air photo surveys (Kerbes 1986)
1981	111[a]	1042	90	1153	Air photo surveys (Kerbes 1986)
1987	360[a]	1380	79	1740	Air photo surveys (Kerbes et al. 1999; Kerbes, unpubl.)
1995	1025[a]	3050	75	4075	Air photo surveys (Kerbes et al. 1999; Kerbes, unpubl.)
1996	1435	210	13	1645	Helicopter surveys (this study)
1997	1749	2506	59	4255	Helicopter surveys (this study)
1998	1431	736	34	2167	Helicopter surveys (this study)
1999	1288[b]	1608[b]	56	2896[b]	Helicopter surveys (this study)
2000	1249	472	27	1721	Helicopter surveys (this study)
2001	924	1199	56	2123	Helicopter surveys (this study)
Average ± SE, 1996–2001	1346 ± 111	1122 ± 345	45	2468 ± 401	

[a] For the air photo surveys, the number of non-nesters is known for the colony area only; hence, these estimates should be interpreted as the minimum number present (Kerbes et al. 1999).
[b] Low clouds at Kendall Island during the 1999 survey resulted in some parts of the survey being flown at slightly less than 230 m. Although we attempted to adjust our field of view to take this into account, it is possible that numbers of geese were somewhat higher than reported here.

Island colonies in association with the periodic air photo surveys, which should continue to be carried out at five-year intervals (Kerbes et al. 1999).

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Concluding discussion: Status of geese and swans in the Inuvialuit Settlement Region

James E. Hines

Canadian Wildlife Service, Environmental Stewardship Branch, Environment Canada, Suite 301, 5204–50th Avenue, Yellowknife, NT X1A 1E2

The previous papers summarize recent surveys of the distribution and abundance of Arctic geese and swans in one of their most important breeding grounds in North America. The surveys, carried out in the Inuvialuit Settlement Region between 1989 and 2001, provide a useful baseline against which future management of waterfowl from the Western Canadian Arctic can be evaluated. Below, the results from our studies are interpreted in conjunction with what we know about the status, harvest, and variety of environmental pressures acting on these populations — both within the Inuvialuit Settlement Region and elsewhere in North America. A number of information needs pertaining to these particular stocks of geese and swans and recommendations to enhance the management of the populations are described.

1. Greater White-fronted Goose

The Greater White-fronted Geese *Anser albifrons* nesting in the Inuvialuit Settlement Region are managed as part of the Mid-continent Population (Sullivan 1998), a mixture of geese from a wide breeding range from Alaska to central Nunavut that share broadly overlapping ranges during fall and winter. Our surveys indicated that more than 55 000 adult Greater White-fronted Geese were present in the Inuvialuit Settlement Region during 1989–1993. In years of average reproductive success, the total number of adult plus young geese departing from the region in fall would have approached 75 000 birds and made up 11% of the Mid-continent Population.

Greater White-fronted Geese are the most intensively harvested waterfowl species in the Inuvialuit Settlement Region, with local people taking 3% of the spring population as part of their subsistence harvest (Table 1). At a continental level, recent sport harvests in Canada and the United States seem very high, averaging 207 000 birds in the 1990s (Kruse and Sharp 2002), or 25% of the average fall survey numbers. Regulations regarding the sport harvest of Mid-continent Greater White-fronted Geese were liberalized in the late 1990s, and some recent harvests have greatly exceeded 300 000 geese. The actual level of harvest that Mid-continent Greater White-fronted Geese can safely sustain is poorly understood, but it is worthwhile noting that harvest rates in the 25% range have been implicated in the declines of highly productive populations of Arctic or sub-Arctic nesting geese (Timm and Dau 1979; Hestbeck 1994), and much lower harvest rates (about 15%) are expected to bring about a substantial reduction in the number of Lesser Snow Geese *Anser caerulescens caerulescens* from the Central and Eastern Canadian Arctic (Boyd 2000). In addition to concerns about the large harvest taken from the Mid-continent Population of Greater White-fronted Geese as a whole, there is good evidence that survival rates of birds from the Western Canadian Arctic and interior Alaska are low relative to those for the Central Arctic component of the population (Hines, unpubl. data).[1] Since the mid-1980s, Greater White-fronted Geese have declined in interior Alaska (Hodges et al. 1996; Spindler and Webb 2002), possibly from this high harvest/low survival regime (Spindler et al. 2002), and there is accumulating evidence that the entire Mid-continent Population has decreased in recent years (Canadian Wildlife Service Waterfowl Committee 2002). Population trend data are not available for the Inuvialuit Settlement Region, but, given the low survival rates of Greater White-fronted Geese from the region and the declining population trends in interior Alaska and possibly for the Mid-continent Population as a whole, there is very good reason to be concerned about the effects of harvest on the population in the Inuvialuit Settlement Region. The current status of Greater White-fronted Geese in the Western Canadian Arctic and the impact of the recently liberalized harvest regulations in southern Canada and the United States on this stock of geese need to be carefully assessed through additional surveys and banding.

2. Lesser Snow Goose

The Western Arctic Population of Lesser Snow Geese nests at small colonies at Kendall Island, the Anderson River delta, and the Sagavanirtok River delta (Alaska), as well as at the large Egg River colony and smaller associated colonies on Banks Island. Our recent surveys focused on the two mainland colonies in the Inuvialuit Settlement Region and documented the low rate of reproductive success and the variable (Kendall Island) or declining (Anderson River) trend in goose numbers at the two colonies.

[1] Average survival rates for Greater White-fronted Geese from 1990 to 1995 based on band recoveries or observations of neck-collared geese: interior Alaska (0.63–0.71), Western Canadian Arctic (0.67–0.72), Central Canadian Arctic (0.77–0.78).

The status, distribution, numbers, survival estimates, and harvest rates of the Western Arctic Population were recently summarized by Kerbes et al. (1999). The overall population has grown at a rate of about 3% per year since the 1960s, but at a higher rate (6%) since 1976. This growth was almost entirely due to increased numbers of geese on Banks Island, where nesting birds numbered 479 000 at the time of the most recent air photo survey (1995). This estimate did not include non-breeding birds, which make up more than 20% of the spring population in most years. Thus, as suggested by more recent (1996–1998) aerial counts of flightless geese, the current population level would have exceeded 500 000 adults in spring, and the fall population (adults plus young) has probably averaged about 750 000 geese in the late 1990s (Samelius et al. in press).

Harvest rates for the overall population have averaged 1% within the Inuvialuit Settlement Region (Table 1) and raise no concern if birds returning to Banks Island are targeted. Annual harvests of only a few hundred birds returning to one of the mainland colonies could have a great impact on local populations, however, so it is important that harvest on the mainland is focused on migrating birds heading for Banks Island, and not on locally breeding birds. At a continental level, harvest from the Western Arctic Population averaged <10% in the late 1980s, and it was recommended that harvest rates be returned to 1970s levels (15–20%) to help stabilize the population (Kerbes et al. 1999).

Neck-collaring and banding programs (supported in part by Inuvialuit funding) have provided detailed information about the fall and winter distribution of Western Arctic Lesser Snow Geese once they reach southern Canada and the United States (Kerbes et al. 1999). A key result of those programs has been the documentation of an eastward (and apparently ongoing) shift in the fall and winter distributions of Western Arctic Lesser Snow Geese over the past 30 years (Hines et al. 1999). The proportion of the population wintering in California decreased from 90% during the 1960s and 1970s to 75% during the late 1980s and early 1990s. Many more Western Arctic geese now winter in an area termed the Western Central Flyway (northern Mexico, New Mexico, southeastern Colorado, northwestern Texas). For management purposes, it is useful to consider the Pacific Flyway (California) and Western Central Flyway segments of the population separately, as virtually all the recent population growth seems to have occurred in the Western Central Flyway.

Elsewhere on their breeding range, Lesser Snow Geese are causing severe damage to the lowland habitat on which geese and many other species of wildlife depend (Kerbes et al. 1990; Abraham and Jefferies 1997). In recent years, the Banks Island colonies seem to have grown as rapidly as the problematic Mid-continent Population of the Eastern and Central Arctic. The lowland habitat on Banks Island will be threatened by overgrazing if this population growth continues. As a population management strategy, it would probably be good to limit the growth of the Western Arctic Population by returning harvest rates to 1970s levels (15–20%) to help stabilize the population (Kerbes et al. 1999). Any increased harvest should definitely focus on the increasing Banks Island and Western Central Flyway components of the population but avoid overharvesting the small or decreasing segments of the population nesting at Anderson River and Kendall Island.

Somewhat limited evidence (Armstrong et al. 1999) suggests that some Western Central Flyway geese share a common northward migration route through the central United States and prairie Canada with the masses of geese that comprise the Mid-continent Population of Lesser Snow Geese. This raises two possible and somewhat contradictory management concerns: (1) there is a possibility that large numbers of Mid-continent Lesser Snow Geese will move northward to Banks Island with the Western Arctic Population; and (2) there is a risk that highly liberalized spring hunting seasons put in place to limit the growth of the Mid-continent Population will have an impact, inadvertently, on the Western Arctic Population. Both possible scenarios require that the harvest and the shifting distributions of these populations are adequately monitored.

The overall trend of a growing population of Lesser Snow Geese in the Inuvialuit Settlement Region is driven by the dynamics of the numerically dominant and increasing colonies of geese on Banks Island. In contrast, the situation with the two smaller mainland colonies is entirely different: the numbers of geese at Anderson River have declined greatly since the 1980s, the numbers at Kendall Island have varied greatly, and the reproductive success at both colonies (but especially Anderson River) has been low. Both the

Table 1
Estimated regional and continental populations and harvests of geese and swans from the Inuvialuit Settlement Region (ISR)

			Recent annual harvest rate	
Species/population	ISR adult population[a]	ISR harvest[b]	Within ISR (%)[c]	Both within and outside ISR (%)[d]
Greater White-fronted Goose (Mid-continent Population)	55 600	1 410	3	20–25
Lesser Snow Goose (Western Arctic Population)	529 000	5 407	1	<10
Canada Goose (Short-grass Prairie Population)	84 000	586	1	11–13
Brant (Banks Island and mainland)	16 400	401	2	6
Tundra Swan (mainland)	28 700	113	<1	3–4

[a] Sources: Kerbes et al. (1999); Hines et al. (2000); Samelius et al. (in press); this report.
[b] Source: unpublished data from the Inuvialuit Harvest Study.
[c] ISR harvest divided by ISR population.
[d] Sources: Hines et al. (1999, 2000); Kruse and Sharp (2002); this report.

influence of barren-ground grizzly bear *Ursus arctos horribilis* predation on massive reproductive failures at these colonies and the apparent deterioration of the habitat in the outer part of the Anderson River delta (Armstrong 1998) require detailed study.

3. Canada Goose

Canada Geese *Branta canadensis* from the Inuvialuit Settlement Region belong to the Short-grass Prairie Population. The status of these geese was recently summarized by Hines et al. (2000), who reported that the population had increased in size and had expanded its range northward on Victoria Island and onto Banks Island as well. The local knowledge interviews carried out at Holman and Sachs Harbour and presented elsewhere in this report agree with this finding. An analysis of data from aerial surveys, neck collar observations, and band returns indicated the existence of at least two different stocks of Canada Geese in the Northwest Territories: (1) a sub-Arctic/boreal stock made up of Lesser Canada Geese *B. c. parvipes* that nest below the tree line; and (2) an Arctic stock consisting of the smaller Richardson's Canada Goose *B. c. hutchinsii*. Geese from the former stock are apparently present in the Inuvialuit Settlement Region mainly as non-breeders that undertake a northward "moult migration," whereas the latter group makes up most of the breeding birds present. On the mainland of the Inuvialuit Settlement Region, breeding geese were especially abundant on the Parry Peninsula, and moulting geese congregated at a few extensive lowland sites, such as Harrowby Bay and the delta of the Smoke and the Moose rivers (Alexander et al. 1988; Hines et al. 2000). The Arctic-nesting segment of the population seems to have increased in size from the 1950s to the mid-1990s, whereas the sub-Arctic/boreal segment showed no obvious long-term trend. However, more recent counts on the wintering grounds have decreased by about two-thirds since the mid-1990s (Kruse and Sharp 2002), suggesting that the Short-grass Prairie Population has undergone a drastic decline, at a rate of 12% per annum (Canadian Wildlife Service Waterfowl Committee 2002).

Each year, Inuvialuit hunters take only a very small proportion (1%) of the Canada Geese that migrate to the Western Canadian Arctic (Table 1). At a continental scale, the harvest rate for Canada Geese from the Inuvialuit Settlement Region was 11–13% during the early 1990s and had not increased from the 1970s (Hines et al. 2000). Although Canada Geese are harvested only in modest numbers in the Inuvialuit Settlement Region and are normally, therefore, of less management concern to the Inuvialuit than certain other species, the rapid downward trend in the overall Short-grass Prairie Population is troubling. It would be useful, and cost-effective, to monitor numbers and the apparent shifting distribution of this population advantageously as part of other "multispecies" surveys. Banding of Canada Geese could be carried out in an efficient manner in association with similar work on Greater White-fronted Geese.

4. Brant

Two populations of Brant *Branta bernicla* breed in the Inuvialuit Settlement Region. The more numerous Pacific or Black Brant *B. b. nigricans* nests in small scattered colonies and as dispersed pairs in coastal lowlands on Banks Island, Victoria Island, and the mainland. Surveys reported in previous papers documented the numbers and distribution of Black Brant on both Banks Island and the mainland of the Inuvialuit Settlement Region. The far less abundant Grey-bellied or Western High-Arctic Brant, although not officially recognized as a subspecies, appears to be possibly taxonomically distinct. It breeds on Prince Patrick, Eglinton, and Melville islands. The two types of Brant have similar migration routes and staging areas (Reed et al. 1998), but most Grey-bellied Brant winter farther north on the Pacific coast than do Black Brant. Our fieldwork suggests that some Grey-bellied Brant may occur on Banks Island as flightless moulters.

More than 6000 adult Brant were present on the mainland in 1995–1998. Historically, the most important nesting area for Brant in the Western Canadian Arctic has been the Anderson River Delta Migratory Bird Sanctuary, but the number of Brant nesting there has declined by more than 50% since the 1970s (Hines, unpubl. data). Apparently, in recent years, Brant nests at Anderson River have been heavily attacked by predators, especially barren-ground grizzly bears. There is also some evidence that habitat quality or quantity has been reduced at Anderson River as well, possibly as a result of saltwater inundation of the outer delta during a storm surge (Armstrong 1998). Banding studies have revealed that some Brant that formerly nested at Anderson River have emigrated to the Campbell Island and Smoke–Moose Delta area of western Liverpool Bay.

About 10 000 adult Brant are present on Banks Island each summer. Numerous small nesting colonies, usually located on islands in lakes, and mostly consisting of fewer than 10 nests, are scattered throughout the western lowlands that comprise Banks Island Migratory Bird Sanctuary No. 1. In general, numbers of nesting birds are low in other parts of Banks Island. In July, more than 2000 moulting (flightless) adults are present on lakes in the western lowlands. Recaptures of previously marked individuals in these moulting areas indicate that a significant number of the moulting Brant come from other nesting areas in the Western Arctic, Alaska, and Wrangel Island (Russian Federation). Significant numbers of individuals, similar in appearance to Grey-bellied Brant, occurred among these moulting flocks. A major issue concerning Brant and other species of migratory birds that utilize lowland areas on Banks Island is the increasing population of Lesser Snow Geese there. A similar concern exists for Grey-bellied Brant of Prince Patrick, Eglinton, and Melville islands, as small and possibly increasing numbers of breeding and moulting Lesser Snow Geese have been observed in the very limited lowland habitat in the western High Arctic (M. Fournier and S. Boyd, pers. commun.).

Annual harvest of Brant in the Inuvialuit Settlement Region is >400 birds (Table 1), but about 8000 Brant are harvested elsewhere in the Pacific Flyway each year from a population that has averaged about 140 000 birds (Subcommittee on Pacific Brant 1992; Sedinger et al. 1994; Reed et al. 1998). This 6% harvest rate is well below that witnessed in the 1960s and 1970s (12%), when the Pacific Flyway Population was declining (Sedinger et al. 1994). Given the recent low productivity of Brant observed in the Western Canadian Arctic (Armstrong 1998; Cotter and Hines 2001; this study), maintaining harvest rates at currently low levels should be a highly desirable management strategy.

5. Tundra Swans

The Mackenzie Delta, Tuktoyaktuk Peninsula, and neighbouring parts of the mainland of the Inuvialuit Settlement Region comprise one of the most important breeding areas for Tundra Swans *Cygnus columbianus* in North America. We estimated that about one-third of the Eastern Population of Tundra Swans emanates from the mainland of the Inuvialuit Settlement Region each year. The Eastern Population of Tundra Swans has numbered about 100 000 in recent years (Canadian Wildlife Service Waterfowl Committee 2002) and is rather small relative to many other populations of waterfowl. Tundra Swans from the Inuvialuit Settlement Region migrate eastward across the continent and winter primarily in coastal areas of Maryland, Virginia, and North Carolina. Winter distributions within this general area have shifted substantially in the past few decades, possibly due to habitat changes. Therefore, major long-term threats to this species on migration routes and wintering grounds are loss and degradation of the freshwater and coastal marshes on which swans are highly dependent (Limpert and Earnst 1994; Anonymous 1998).

The annual harvest of Tundra Swans in the Inuvialuit Settlement Region was reported at 113 birds from 1988 to 1995 (Table 1). This estimate is probably low, as hunters may be hesitant to report all swans they have killed. Sport hunting seasons for Eastern Population Tundra Swans occur in a few states in the United States, and the mean annual harvest was 4051 from a population that averaged 90 770 during the 1990s. Although the continent-wide harvest rate (<5%) is low relative to rates for geese, Tundra Swans have low reproductive output and probably cannot withstand a heavy harvest. Given the importance of the Mackenzie Delta and neighbouring parts of the mainland to swans, the sensitivity of swans to disturbance (see review by Ritchie and King 2000), and the plans for large-scale gas and oil development in the Inuvialuit Settlement Region, increased industrial activity will likely be the biggest environmental stressor facing swans and other migratory birds on the mainland in the future.

6. Management issues and information needs

Table 2, based on the preceding discussion, summarizes important management issues and identifies priority information needs pertaining to populations of geese and swans in the Western Canadian Arctic. In addition to the specific information needs identified for each species, the key “take home” message from this review is the unsure status of several stocks of waterfowl. Most species are being harvested near the maximum allowable level, and Greater White-fronted Geese, Canada Geese, and the colonies of Lesser Snow Geese and Black Brant at Anderson River are possibly declining or already exist in low numbers.

In addition to pressures already acting on goose and swan populations on migration routes and wintering grounds, the traditional security of safe and undisturbed breeding grounds little affected by humans is no longer a given. In the Western Canadian Arctic, all populations are potentially threatened by the extensive plans for gas and oil development, which could influence numbers and productivity in a variety of known and unanticipated ways (Truett and Johnson 2000). Over a longer term, global climate warming is predicted to exert its greatest effect in the western Northwest Territories (Cohen 1997) and could severely affect populations of geese (Maarouf and Boyd 1997) and other migratory birds (Gratto-Trevor 1997) through reduction in the quantity or quality of lowland tundra on which these animals depend. Enhanced information will be required to identify, manage, and mitigate the cumulative effects of industrial development, changing climate, and other stressors on migratory birds and their habitats. It is hoped that this review will provide direction for future research and monitoring efforts and thereby help guarantee the long-term conservation of waterfowl populations from the Inuvialuit Settlement Region.

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Table 2
Populations of geese and swans occurring in the Inuvialuit Settlement Region (ISR) and management issues and concerns pertaining to each of the populations. Priority research, which should be carried out to address the specific conservation issues, is indicated.

Population	Issue/concern	Research priorities
Greater White-fronted Geese	• Survival rates of Greater White-fronted Geese from the ISR are low relative to those for some other areas. • As a whole, Mid-continent Population of Greater White-fronted Geese has incurred very high (unsustainable?) harvests in recent years. • Apparent population decline in western Northwest Territories, Yukon, and Alaska, and possibly for the population as a whole? • No population trend data are available for the ISR.	• Repeat a subset of aerial transects to determine population trend in the ISR (multispecies surveys). • Band geese to determine survival and harvest rates and geographic distribution of harvest.
Lesser Snow Geese	• Numbers of Lesser Snow Geese have increased substantially on Banks Island and could cause habitat destruction. • Small colonies at Anderson River and Kendall Island are decreasing or less secure. • Increased harvest of Lesser Snow Geese is being encouraged.	• Habitat studies to determine impact of Lesser Snow Geese on the lowland habitat of Banks Island and to develop a long-term numeric goal for the population. • Band geese to (1) evaluate impacts of increased spring harvest on the different colonies; (2) delineate areas where Banks Island geese can be selectively harvested without affecting the small colonies; and (3) monitor continuing eastward shift of migrating and wintering geese. • Carry out surveys at five-year intervals to document population trends at the three Western Arctic colonies.
Brant	• Inuvialuit hunters from Tuktoyaktuk would harvest more Brant if they were available. • The decline of the overall Pacific Flyway Population from historic levels and the more recent decreases in the Grey-bellied or Western High-Arctic subpopulation (a possibly endangered subspecies) and the nesting colony at Anderson River are management concerns.	• Evaluate the impact of grizzly bear predation and other factors on the colonies of Black Brant and Lesser Snow Geese at Anderson River. • Monitor Brant populations opportunistically as part of other studies. • Determine taxonomy and population status of Grey-bellied or Western High-Arctic Brant.
Canada Geese	• No long-term population trend for ISR. • Wintering ground counts of Short-grass Prairie Population of Canada Geese have declined drastically since mid-1990s.	• Monitor Canada Goose distribution and abundance as part of “multispecies” surveys. • Band Canada Geese to determine harvest and survival rates.
Tundra Swans	• The Mackenzie Delta region is one of the most important breeding areas for Tundra Swans in North America. • Tundra Swans are sensitive to disturbance and are one of the easiest species of waterfowl to monitor throughout their spring and summer cycle. • Planned gas and oil developments in the Mackenzie Delta could threaten swans and other waterfowl.	• Monitor swan distribution and abundance as part of “multispecies” surveys. • Evaluate impacts of gas and oil exploration and development on Tundra Swans.

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Appendix 1. Minimum visibility correction factors for some species of waterfowl encountered in helicopter surveys in Arctic Canada

James E. Hines[1] and Maureen F. Kay[1,2]

[1] *Canadian Wildlife Service, Environmental Stewardship Branch, Environment Canada, Suite 301, 5204–50th Avenue, Yellowknife, NT X1A 1E2*
[2] *Present address: 68 Fair Oaks Drive, St. Albert, AB T8N 1R1*

Aerial surveys of waterfowl and other wildlife are subject to a number of potential biases that influence the visibility of animals. For the species of waterfowl most frequently encountered in our helicopter surveys in Arctic tundra habitat, we developed visibility correction factors by using a "double-counting" or "mark–recapture" approach (Caughley and Grice 1982; Pollock and Kendall 1987; Anthony et al. 1992).

Fieldwork for developing visibility correction factors was undertaken in two locations in the Northwest Territories and Nunavut: (1) the Inuvialuit Settlement Region from 1992 to 1993 and (2) the Rasmussen Lowlands of the Central Arctic from 1994 to 1995. Studies in both areas followed the same procedure. Both observers were seated on the left side of the aircraft (a float-equipped Bell 206B or Bell 206L helicopter), which was flown at the same elevation (about 45 m) and ground speed (80–100 km/h) as during the regular surveys. Each observer recorded the number of each species of waterfowl that he/she observed within 200 m of the left side of the aircraft and the time of each observation (to the nearest second). Sightings made by both observers of the same species and number of birds made within the same 10-second interval were treated as duplicate sightings. Sightings that did not meet the above criteria were treated as non-duplicate sightings. The number of birds present in the area of observation was then calculated using the Lincoln-Petersen method for mark–recapture data (Krebs 1989; Pollock et al. 1990):

$$\hat{N} = \frac{n_{front}\, n_{back}}{m}$$

where:

$\hat{N}$ = estimated number of birds of a given species present on the visibility transect
n_{front} = number of birds seen by front-seat observer
n_{back} = number of birds seen by back-seat observer
m = number of duplicate individuals (i.e., birds seen by both front-seat and back-seat observers).

and

$$SE_{\hat{N}} = \sqrt{\frac{(n_{front}+1)(n_{back}+1)(n_{front}-m)(n_{back}-m)}{(m+1)^2(m+2)}}$$

where:

$SE_{\hat{N}}$ = standard error of estimated number of birds present.

For each species, the visibility correction factor (VCF) and its standard error (SE_{VCF}) were calculated using the following formulas:

$$VCF = \frac{\hat{N}}{n_{front}}$$

$$SE_{VCF} = \frac{SE_{\hat{N}}}{n_{front}}$$

Visibility correction factors for different species

Adequate samples (>50 individuals sighted in total) to allow for calculation of visibility correction factors were collected for four species (Greater White-fronted Geese *Anser albifrons*, Canada Geese *Branta canadensis*, King Eiders *Somateria spectabilis*, and Long-tailed Ducks *Clangula hyemalis*) (Table 1). We also calculated visibility correction factors for "dark geese" as a group using a pooled sample of Greater White-fronted Geese, Canada Geese, and individuals that could not be identified to species. Visibility correction factors ranged from 1.4 for Greater White-fronted Geese to 2.7 for Long-tailed Ducks. The precision of the visibility correction factor estimates, as estimated by the standard errors, was high for Greater White-fronted Geese and "dark geese," moderate for King Eiders, and lowest for Canada Geese and Long-tailed Ducks.

For two reasons, we believe that the visibility correction factors developed using the double-counting or mark–recapture approach would tend to be biased low and therefore produce conservative estimates of population size. First, an important assumption of the Lincoln-Petersen estimator is that all the individuals in the population are equally "catchable" (Krebs 1989). This is clearly not true for either Canada Geese or Greater White-fronted Geese, as nesting pairs of both species are much more difficult to spot from the air than are non-nesting pairs (Bromley et al. 1995). Conditions of unequal catchability would lead to an underestimate of $\hat{N}$ (and, in our particular circumstance, a low visibility correction factor), as the "catchable population" is smaller than the actual population. Second, an individual, pair, or group of geese was deemed to be "recaptured" when identical numbers of birds were independently sighted by both observers at about the same time. Because single birds or pairs made up a high proportion of the sightings in our surveys, there was a good chance, especially in areas of higher population density, that some of the birds deemed as "recaptures" were not actually duplicate observations.

Table 1
Visibility correction factors (VCFs) developed for helicopter transect surveys of Arctic waterfowl, 1992–1995

Species	Number seen by front-seat observer	Number seen by rear-seat observer	Number seen by both observers	Estimated number present ± SE	% of total estimated number present sighted by front-seat observer	VCF ± SE
Greater White-fronted Goose	1237	1280	911	1738.0 ± 15.8	71.2	1.405 ± 0.013
Canada Goose	44	63	26	106.6 ± 9.7	41.3	2.423 ± 0.220
All "dark" geese[a]	1459	1520	1064	2084.3 ± 18.2	70.0	1.429 ± 0.012
King Eider	210	244	137	374.0 ± 12.4	56.1	1.781 ± 0.059
Long-tailed Duck	58	90	33	158.2 ± 13.8	36.7	2.727 ± 0.237

[a] Dark geese include Greater White-fronted Geese, Canada Geese, and geese not identified to species.

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