James E. Hines
Myra O. Wiebe Robertson
(Editors)

Surveys of geese and swans in the Inuvialuit Settlement Region, Western Canadian Arctic, 1989–2001

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Abstract

The Inuvialuit Settlement Region of the Western Canadian Arctic is one of the most important breeding areas for geese and swans in North America. As well as being of international conservation significance, the waterfowl from the Inuvialuit Settlement Region make up an important part of the subsistence diet of the local Aboriginal people, and the spring waterfowl hunt is a cultural tradition of the Inuvialuit. To establish appropriate baseline population estimates for future comparisons and long-term management of sustainable harvests, a number of goose and swan surveys were conducted in the region between 1989 and 2001. The studies reported in this Occasional Paper include (1) aerial surveys on the mainland Inuvialuit Settlement Region to determine the distribution and abundance of Black Brant *Branta bernicla nigricans*, 1995–1998, (2) aerial surveys of breeding and moulting Brant on Banks Island, 1992–1994, (3) aerial counts of Greater White-fronted Geese *Anser albifrons*, Canada Geese *Branta canadensis*, and Tundra Swans *Cygnus columbianus* on the mainland Inuvialuit Settlement Region, 1989–1993, (4) Inuvialuit local knowledge about populations and important areas for waterfowl near the communities of Sachs Harbour on Banks Island and Holman on western Victoria Island, (5) monitoring numbers of Lesser Snow Geese *Anser caerulescens caerulescens* at the small and vulnerable mainland colonies at Kendall Island and Anderson River Migratory Bird Sanctuaries, 1996–2001, and (6) an investigation of visibility correction factors for helicopter transect counts of waterfowl.

The surveys greatly enhance our knowledge of the distribution, abundance, and productivity of geese and swans in the Western Canadian Arctic. The results 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. At a continental level, most species are currently harvested near the maximum allowable level, and this, along with other stressors acting during the fall–winter period, may negatively impact several local populations that are declining or already exist in low numbers. On the breeding grounds, proposed oil and gas development and global climate warming are relatively new threats that could cause additional conservation problems. A number of information needs and recommendations to enhance the management of the waterfowl populations of the region are presented.

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Introduction

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The Inuvialuit Settlement Region of the Western Canadian Arctic (Fig. 1) is one of the most important breeding grounds for waterfowl and other migratory birds in North America (Bellrose 1980). Large numbers of Greater White-fronted Geese *Anser albifrons*, Black Brant *Branta bernicla nigricans*, Canada Geese *B. canadensis*,[1] Lesser Snow Geese *Anser caerulescens caerulescens*, Tundra Swans *Cygnus columbianus*, King Eiders *Somateria spectabilis*, Common Eiders *S. mollissima*, shorebirds, and other species breed within this region (Bellrose 1980; Alexander et al. 1988; Johnson and Herter 1989). Many species of waterfowl are harvested by local residents for subsistence purposes (Bromley 1996; Fabijan et al. 1997), and so the Inuvialuit are concerned about the management of regional populations of these waterfowl. General national and continental concerns about the status of many species further emphasize the need for careful management.

The Inuvialuit Final Agreement entitles the Inuvialuit to special involvement in managing wildlife in the Western Arctic (Committee for Original Peoples Entitlement 1984).[2] The settlement of the Western Arctic Claim has facilitated increased research on and improved monitoring of migratory birds and has led to many population studies of waterfowl and other bird species in the region since the late 1980s (Fig. 1). Although most studies were driven by the uncertain status of or particular concerns about certain species, a multispecies approach has been used to acquire population information on a number of other species as well. Results from some of these investigations have been reported elsewhere (Dickson 1997; Kerbes et al. 1999; Hines et al. 2000; Samelius et al. in press).

This report documents the results of monitoring and inventory studies of Black Brant, Greater White-fronted Geese, Tundra Swans, Lesser Snow Geese, Canada Geese, and related species during various periods from 1989 to 2001. This information is essential for current management of bird populations at both regional and continental levels. Most studies establish important baselines for monitoring the long-term well-being of these populations.

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[1] The traditional classification of Canada Geese as a single species (Bellrose 1980) has been retained throughout this paper. Thus, we treat Canada Geese as including both *Branta canadensis* and *B. hutchinsii*, as described in the most recent revision to the American Ornithologists' Union checklist (Banks et al. 2004).

[2] The Inuvialuit Final Agreement affects a 1.18 million square kilometre area (the Inuvialuit Settlement Region) in the northern Northwest Territories and Yukon. As a requirement of the Inuvialuit Final Agreement, a cooperative wildlife management system (involving Inuvialuit and territorial and federal government representatives) has been established for the region. A primary function of the comanagement system is to provide guidance to government wildlife conservation and resource management programs.

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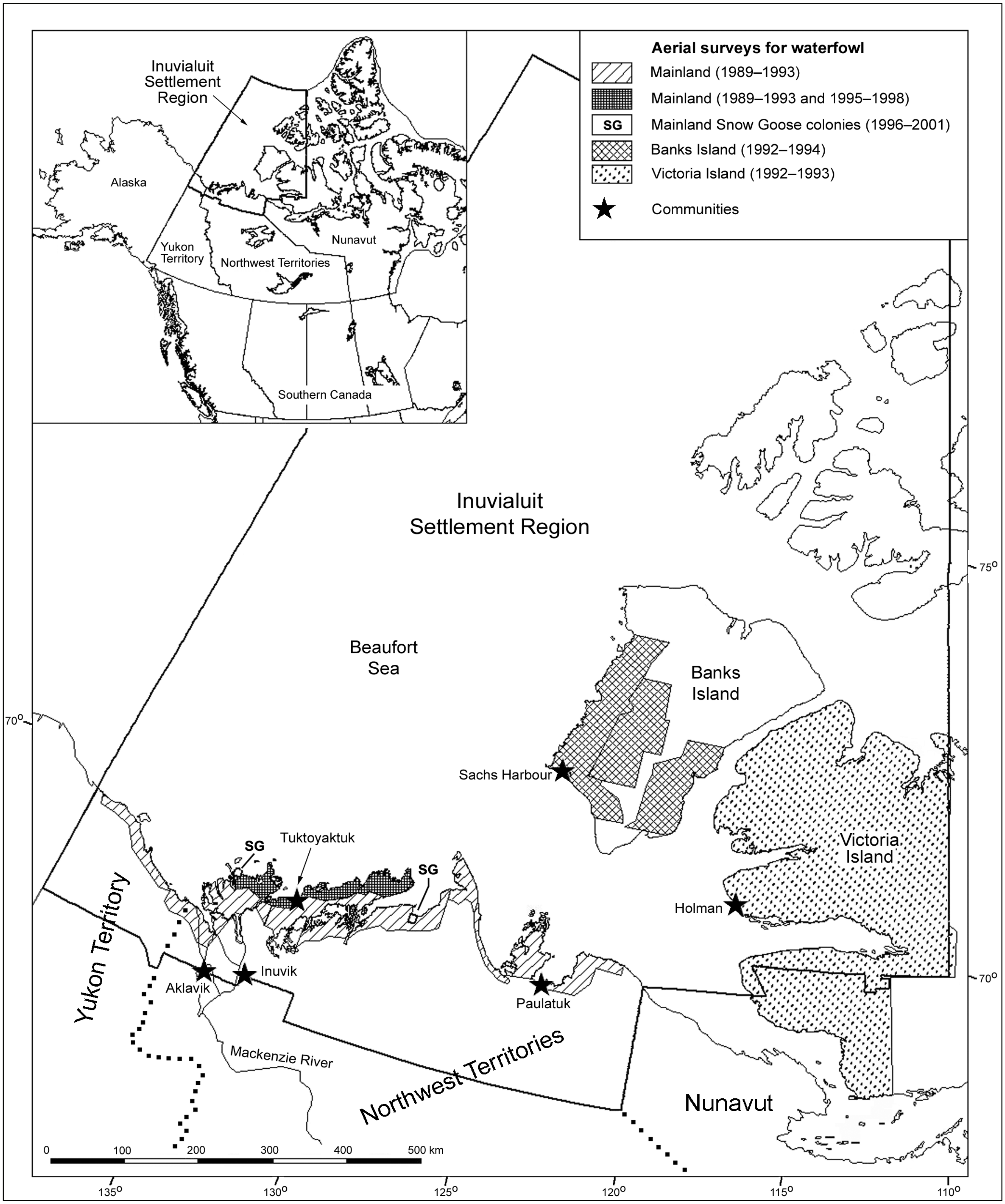
Figure 1
Areas in which aerial surveys for waterfowl and other birds were conducted in the Inuvialuit Settlement Region, 1989–2001. Results from the surveys are presented in this report, except for those from Victoria Island, which were presented in reports by Dickson (1997) and Hines et al. (2000).



Status, distribution, and abundance of Black Brant on the mainland of the Inuvialuit Settlement Region, Northwest Territories, 1995–1998

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Abstract

To determine the distribution and abundance of Black Brant *Branta bernicla nigricans* on the mainland of the Inuvialuit Settlement Region, aerial surveys were flown over a 5014-km^2 area of the Tuktoyaktuk Peninsula, Mackenzie Delta, and western Liverpool Bay in June of 1995–1998. The estimated number of Brant, corrected for birds not seen by observers, was 2756 ± 413 (standard error) (0.56 ± 0.08 birds/km^2 on 4930 km^2) at the Tuktoyaktuk Peninsula – Mackenzie Delta and 3176 ± 588 (37.81 ± 7.00 birds/km^2 on 84 km^2) at Campbell Island – Smoke–Moose Delta in Liverpool Bay. Another 76–225 Brant were found on small islands in western Liverpool Bay just outside the survey strata. Thus, the total population estimate for the Tuktoyaktuk Peninsula, Mackenzie Delta, and western Liverpool Bay was 6100 birds. Numbers of Brant at western Liverpool Bay have apparently increased since the 1970s or 1980s. Several hundred Black Brant also nest at the Anderson River delta (just east of our survey area), where numbers appear to have declined substantially since the 1970s or earlier. Recaptures of banded Brant suggest that some breeding individuals may have shifted from Anderson River to western Liverpool Bay (approximately 70 km west). Significant numbers of previously marked Black Brant were recaptured during banding drives in 1990–1998, and this information provided a Jolly-Seber estimate, which included both survey strata and Anderson River, of 6211 ± 868 Brant. The proportion of young birds among flocks captured during banding drives varied greatly from year to year (from 8% to 54% young), indicating that annual reproductive success was quite variable and sometimes low. Our results provide a baseline against which future population estimates can be compared.

1. Introduction

Winter surveys of the Pacific Flyway Population of Black Brant *Branta bernicla nigricans* suggest that the population has declined since the 1960s (Reed et al. 1998). Declines in breeding populations on the Yukon–Kuskokwim Delta, Alaska, and Wrangel Island, Russian Federation, have been observed (Sedinger et al. 1993; Ward et al. 1993), and local hunters are concerned that Black Brant numbers on the mainland of the Inuvialuit Settlement Region, Northwest Territories, are declining also. The small size of the Black Brant population (about 120 000 birds in the early 1990s; Reed et al. 1998) puts this species at significant risk of catastrophic mortality or reproductive failure caused by pollution, disease, adverse weather, or disturbance. The maritime and colonial nature of Black Brant and the potentially limited abundance of suitable habitat compound the risk.

On average, about 500 Brant are harvested annually near breeding areas on the mainland of the Inuvialuit Settlement Region, and this harvest is high relative to expected local population levels. The abundance, critical habitat, and productivity of Black Brant from this area are not well understood. Without a better understanding of the status of Black Brant in the Inuvialuit Settlement Region, safe harvest levels cannot be determined, and the conservation of the waterfowl resource cannot be guaranteed.

The objectives of this study were to determine the distribution and abundance of Black Brant at the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay in order to help determine how large a harvest the Black Brant population can sustain and to find out what measures can be taken to guarantee the long-term conservation of regional Black Brant stocks.

2. Methods

2.1 Study area

Previous investigations indicated that Brant on the mainland of the Inuvialuit Settlement Region are mostly limited to the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay (Alexander et al. 1988; Hines, unpubl. data). Those areas lie within the Arctic Coastal Plains Physiographic Region (Bostock 1970) and are characterized by a variety of landscapes (Mackay 1963). Drainage is greatly impeded by the presence of permafrost throughout the area and the low relief along the coast. Wetlands (high- and low-centre polygons, fens, marshes, and shallow water) cover 25–50% of the area (National Wetlands Working Group 1988). Plant communities on the study area are typical of the Low Arctic; dwarf shrubs and lichens prevail in upland areas, thickets of willow (*Salix*) and dwarf birch (*Betula*) exist on slopes and along the edges of rivers and streams, and sedge (*Carex*) and cottongrass (*Eriophorum*) tundra are most frequent in the lowlands. Turf vegetation dominated by salt-tolerant sedges and grasses is found in some areas flooded by high tides, mainly in or near sheltered bays, lagoons, estuaries, and islands. Such places constitute much of the preferred habitat of Black Brant on the study area.

2.2 Aerial surveys

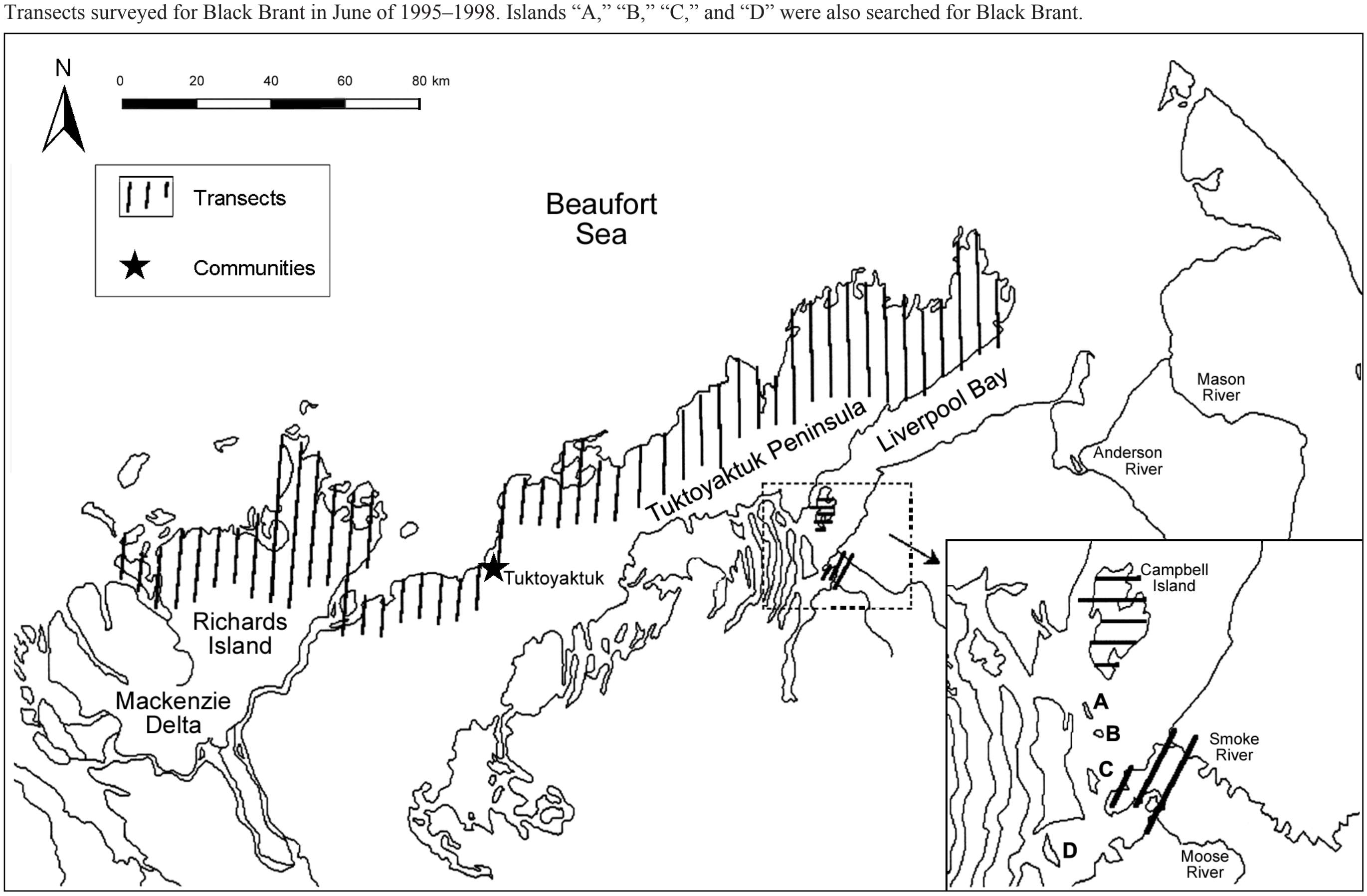
Aerial surveys of adult Black Brant were flown at the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay from 11 to 22 June each year from 1995 to 1998 (Fig. 1). Transects were flown in straight lines using a Bell 206L helicopter travelling at 80–100 km/h approximately 45 m above the ground. Based on more extensive waterfowl surveys on the mainland (Hines et al., this volume), higher densities of Black Brant were expected in Liverpool Bay (Campbell Island and the Smoke–Moose Delta) than in the remainder of the study area (Tuktoyaktuk Peninsula and Mackenzie Delta); thus, these two areas were considered to be separate strata. Most transects at the Tuktoyaktuk Peninsula – Mackenzie Delta were 5 km apart and oriented north and south, perpendicular to the coast. Transects at Campbell Island – Smoke–Moose Delta were 2 km apart and oriented to optimize coverage of this area (Fig. 1). Transects were divided into 2-km segments for recording data.

The 48 transects at the Tuktoyaktuk Peninsula and Mackenzie Delta ranged from 10 to 44 km and averaged 20.5 km in length. Overall, there were 986 km of transect in this area, and 8% of the 4930-km^2 stratum was surveyed. The eight transects at Campbell Island – Smoke–Moose Delta ranged from 2 to 10 km and averaged 5.3 km in length. Overall, 42 km of transect were located at Campbell Island and the Smoke–Moose Delta, and 20% of the 84-km^2 stratum was surveyed.

Surveys were carried out by two observers, one in the left front seat and the other in the right rear seat, which had a bubble window for easier viewing. The pilot did not record observations but was responsible for navigating the aircraft and indicating to the observers the starting and end points of each transect segment. Transect width was calibrated by flying the helicopter past landscape features that were a known distance from the line of flight so that a line designating the outer edge of the transect could be marked on the aircraft window for reference. Observations of Black Brant within 200 m of each side of the transect line were recorded on audio tapes that were later transcribed. Observations made outside the transects provided additional information on the distribution of non-breeding groups and the location of colonies.

The population density (± standard error [SE]) and an estimate of the population size (± SE) were determined for each stratum according to the ratio method (Jolly 1969) and then combined to determine total population size (refer to Hines et al. [2000] for details on specific calculations). Significant numbers of waterfowl are missed during aerial surveys (Pollock and Kendall 1987; U.S. Department of the Interior and Environment Canada 1987; Bromley et al. 1995).

Figure 1
Transects surveyed for Black Brant in June of 1995–1998. Islands “A,” “B,” “C,” and “D” were also searched for Black Brant.



Female "dark" geese such as Brant are infrequently seen from the air if they are on nests, so each observation of one or two Brant was treated as a breeding pair (i.e., two birds) (U.S. Department of the Interior and Environment Canada 1987). Calculations for the total population size used the adjusted number of breeding birds and the number of birds in groups of three or more. Additionally, both members of a pair may be missed, and all or some members of a group may be missed. Thus, we adjusted our estimates by a minimum visibility correction factor of 1.5, as recommended for estimating numbers of "dark" geese in the Inuvialuit Settlement Region by Hines et al. (2000) (see also Appendix 1 of this volume).

We also flew over the small islands in Liverpool Bay that are located just northwest of the Smoke–Moose Delta (islands "A," "B," "C," and "D" in Fig. 1). We either circled or flew down the middle of each island at approximately 45 m above ground and recorded the numbers of Black Brant and Glaucous Gulls *Larus hyperboreus* on each island.

2.3 Banding of Black Brant

Brant were banded on the mainland of the Inuvialuit Settlement Region in 1990–1998. Adult Brant are flightless for 3–4 weeks each summer as they moult their "flight" feathers and grow new ones, and young birds do not attain flight until mid-August. Brant were captured by helicopter drives (Timm and Bromley 1976; Maltby 1977) late in the flightless period when the young birds were large enough to withstand the stress of being captured. Each captured Brant was equipped with a numbered metal band on one leg and a blue plastic band with a unique three-digit alphanumeric code on the other leg. From the sample of birds caught during the banding drives, a mark–recapture estimate of adult population size (independent of the aerial surveys mentioned above) was calculated using the Jolly-Seber method with the program JOLLY (Pollock et al. 1990). Productivity was estimated from the proportion of young birds among all Brant captured during banding drives.

3. Results

3.1 Aerial surveys

The distribution of Black Brant was similar in all four survey years (Fig. 2). Large numbers of Brant were seen in the Smoke–Moose Delta. Campbell Island also had high numbers of Brant in all years except 1998 (Fig. 2). Scattered pairs of Brant and flocks of non-breeders were seen on the northeastern part of the Tuktoyaktuk Peninsula. Few Black Brant were seen on Richards Island and the outer Mackenzie Delta, and none was seen in the southwestern part of the Tuktoyaktuk Peninsula. Both pairs and flocks (i.e., groups of three birds or more) had a high degree of overlap in their areas of use, with the major exception being that flocks were less likely to use inland areas on the Tuktoyaktuk Peninsula (Fig. 3).

We observed 436, 453, 846, and 448 Black Brant on transects in 1995, 1996, 1997, and 1998, respectively. The mean estimated population size, adjusted with a visibility correction factor of 1.5, was 5900 adults (Table 1). Annual estimates of total numbers were similar in all years except 1997, when the population estimate was 77% higher than the mean of the other three years. On average, almost 900 pairs were estimated to be present on the survey area, with the most pairs recorded in 1996 and the fewest pairs recorded in 1998. Black Brant and Glaucous Gulls were frequently seen nesting together.

Black Brant were also observed outside the survey strata at the small islands in Liverpool Bay, used by approximately 76–225 Brant each year (Table 2). Most of the Black Brant present on the islands in 1995, 1996, and 1998 were nesting. Many Glaucous Gulls were also present on the islands in those years, with Black Brant nesting among or near the nesting gulls. Fewer nesting or total Brant were present on these islands in 1997, although Glaucous Gulls were still nesting there.

3.2 Banding program

From 1990 to 1998, 4825 adult and young Black Brant were captured on the mainland of the Inuvialuit Settlement Region. Included in the total were 605 previously banded adult Brant, 3020 newly banded adults, and 1200 newly banded young (Table 3). Black Brant were banded at Anderson River in 1990–1993 and 1998 and at Campbell Island, the Smoke–Moose Delta, and the Tuktoyaktuk Peninsula in 1991–1997. The proportion of young birds captured during banding drives has varied greatly from year to year (Table 3).

In the samples of Brant caught during 1994–1998, an average of >20% of the adults had been previously marked (Table 3). Relatively high recapture rates such as this allowed us to use mark–recapture analyses to derive a second estimate of population size that was independent of the aerial surveys. We did not use birds captured in 1990 in these analyses, because very few birds were captured in that year. Analyses of the recapture data using the mark–recapture method indicated an estimated population size of 6211 ± 868 adult Black Brant.[1] This estimate also includes Brant from Anderson River, an area not included in the aerial surveys.

4. Discussion

4.1 Important nesting, brood-rearing, and moulting areas

High densities of Black Brant nested at Campbell Island, the Smoke–Moose Delta, and nearby islands in Liverpool Bay in most years of our study. We estimated that, on average, approximately 350 pairs breed in this relatively small area each year. Use of this nesting area may have increased recently; reconnaissance surveys suggested that

[1] Program JOLLY attempts to fit the data to various models that differ in whether survival probabilities and capture probabilities are constant or variable among years. Although none of the models fit the data well (goodness-of-fit tests: $P \leq 0.01$ for all models), we believe that this method has merit in determining an approximate population size. We report the results from the most general model, which assumed that survival probabilities and capture probabilities varied among years.

Figure 2
Locations where Black Brant were seen during aerial surveys at the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay in June of 1995–1998. Black Brant were observed also at the Anderson River delta (indicated by question mark), but exact numbers there are uncertain.

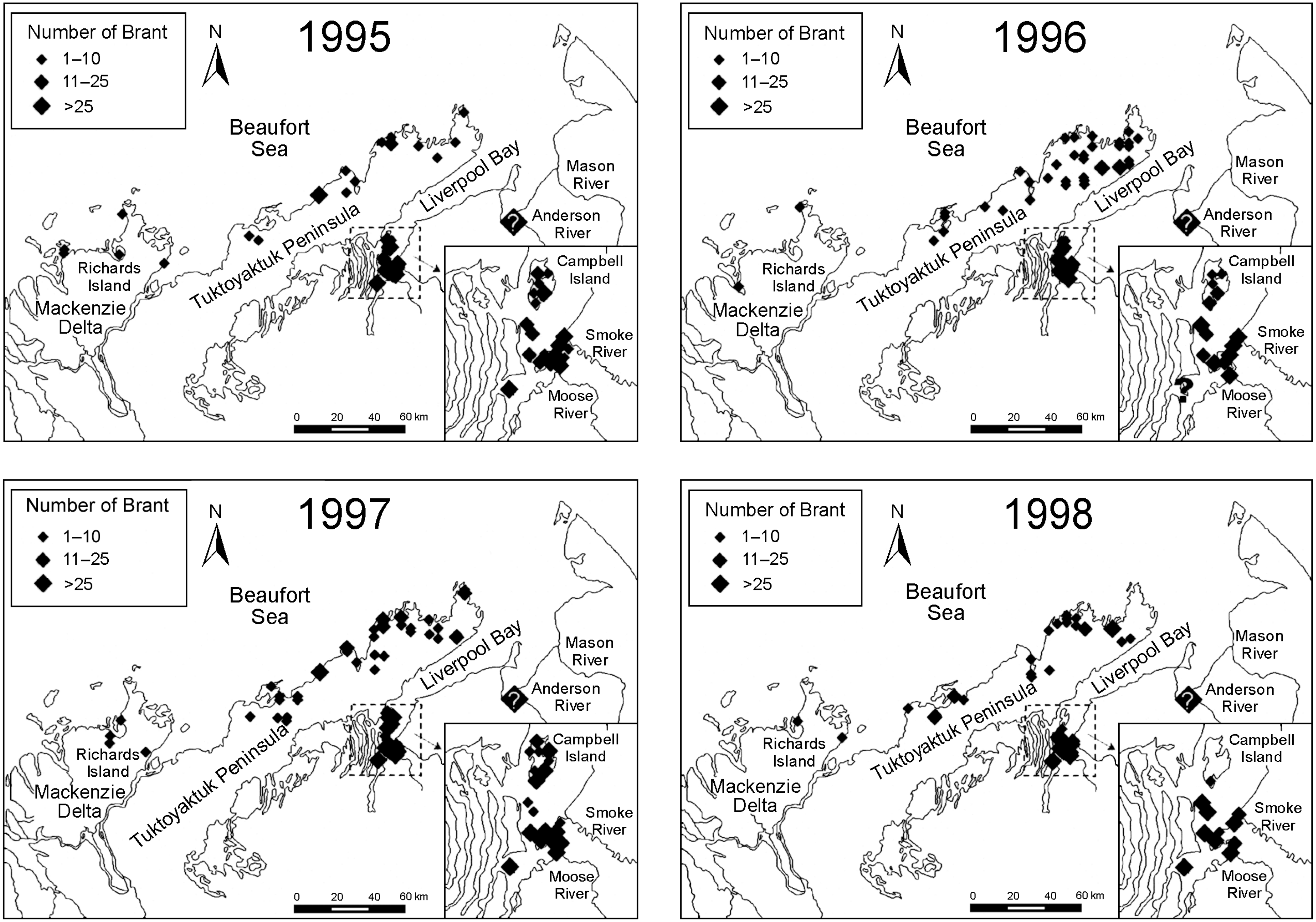
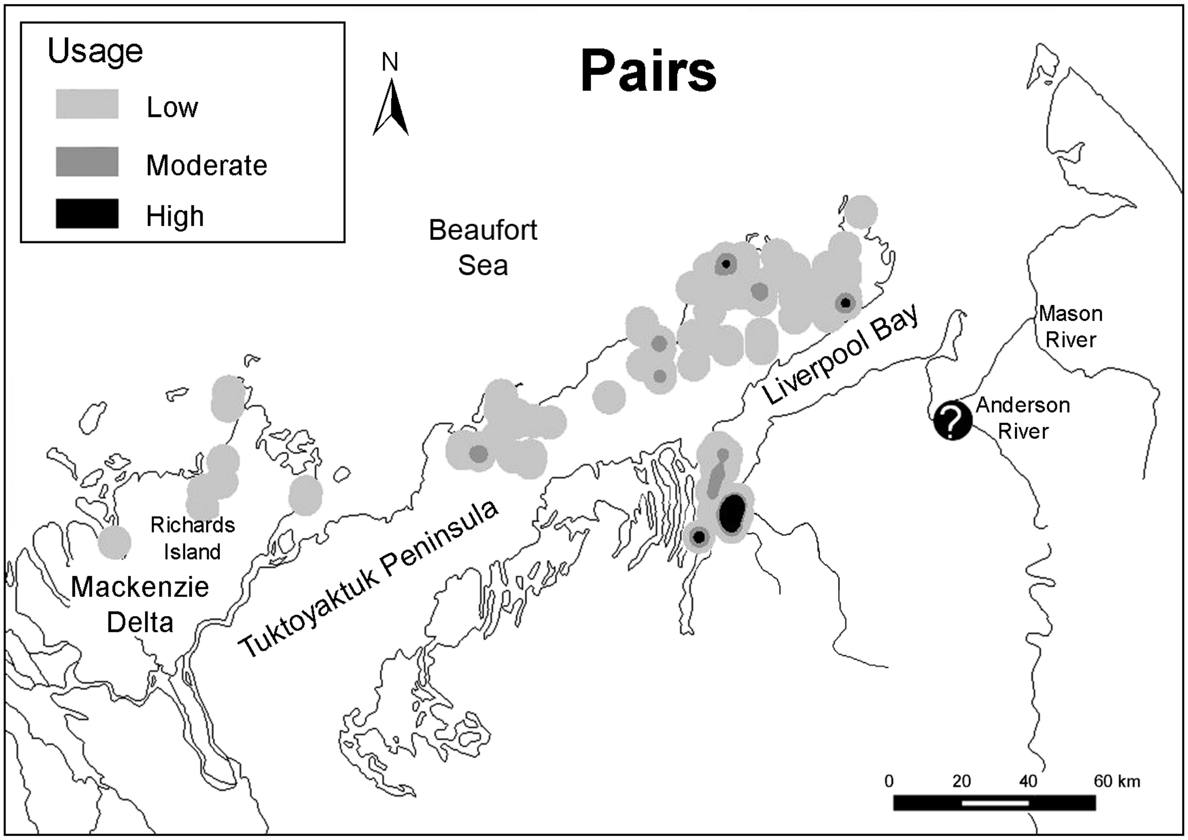


Figure 3
Use of the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay by Black Brant pairs and flocks (i.e., groups of three or more birds) in June of 1995–1998. Black Brant were observed also at Anderson River delta (indicated by a question mark), but exact numbers there are unknown.



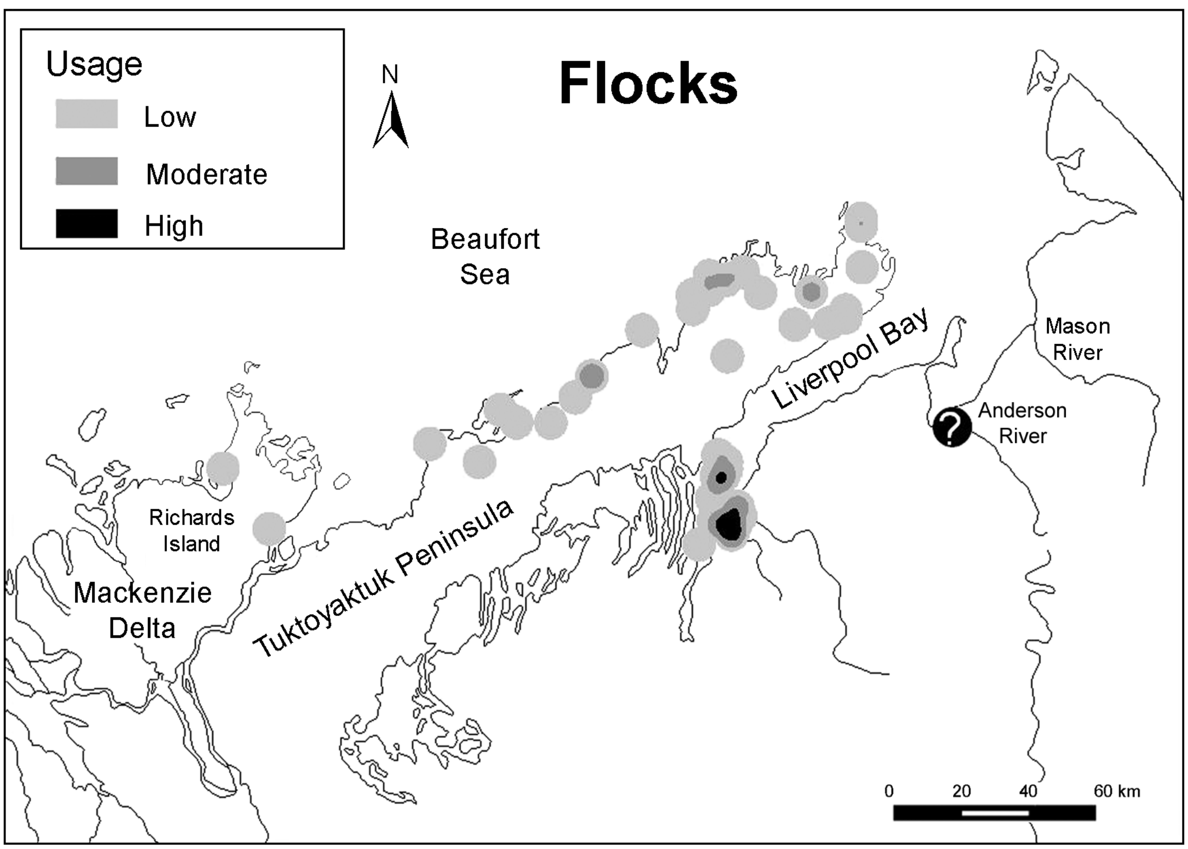


Table 1
Estimated numbers and densities of a) Black Brant and b) Black Brant pairs at the Tuktoyaktuk Peninsula – Mackenzie Delta and Campbell Island – Smoke–Moose Delta, as determined from aerial surveys in June of 1995–1998

a) Black Brant

Area	Year	Number of birds ± SE	Density (birds/km^2) ± SE
Tuktoyaktuk Peninsula – Mackenzie Delta	1995	1313 ± 610	0.27 ± 0.12
	1996	1788 ± 427	0.36 ± 0.09
	1997	2525 ± 616	0.51 ± 0.13
	1998	1725 ± 525	0.35 ± 0.11
	Average (no VCF[a])	1838 ± 275	0.37 ± 0.06
	Average (adjusted by VCF)	2756 ± 413	0.56 ± 0.08
Campbell Island – Smoke–Moose Delta	1995	1835 ± 581	21.85 ± 6.92
	1996	1715 ± 816	20.42 ± 9.72
	1997	3340 ± 934	39.76 ± 11.12
	1998	1580 ± 764	18.81 ± 9.10
	Average (no VCF[a])	2118 ± 392	25.21 ± 4.67
	Average (adjusted by VCF)	3176 ± 588	37.81 ± 7.00
Entire survey area[b]	1995	3148 ± 843	0.63 ± 0.17
	1996	3503 ± 921	0.70 ± 0.18
	1997	5865 ± 1119	1.17 ± 0.22
	1998	3305 ± 927	0.66 ± 0.18
	Average (no VCF[a])	3955 ± 479	0.79 ± 0.10
	Average (adjusted by VCF)	5933 ± 719	1.18 ± 0.14

b) Black Brant pairs

Area	Year	Number of pairs ± SE	Density (pairs/km^2) ± SE
Tuktoyaktuk Peninsula – Mackenzie Delta	1995	225 ± 63	0.05 ± 0.01
	1996	513 ± 128	0.10 ± 0.03
	1997	525 ± 122	0.11 ± 0.02
	1998	300 ± 111	0.06 ± 0.02
	Average (no VCF[a])	391 ± 54	0.08 ± 0.01
	Average (adjusted by VCF)	586 ± 82	0.12 ± 0.02
Campbell Island – Smoke–Moose Delta	1995	315 ± 180	3.75 ± 2.14
	1996	385 ± 161	4.58 ± 1.92
	1997	100 ± 45	1.19 ± 0.53
	1998	15 ± 10	0.18 ± 0.12
	Average (no VCF[a])	204 ± 61	2.43 ± 0.73
	Average (adjusted by VCF)	306 ± 92	3.64 ± 1.10
Entire survey area[b]	1995	540 ± 190	0.11 ± 0.04
	1996	898 ± 206	0.18 ± 0.04
	1997	625 ± 130	0.12 ± 0.03
	1998	315 ± 111	0.06 ± 0.02
	Average (no VCF[a])	594 ± 82	0.12 ± 0.02
	Average (adjusted by VCF)	892 ± 123	0.18 ± 0.02

[a] Visibility correction factor.
[b] This does not include Black Brant at the small islands west of the Smoke–Moose Delta (Table 2) or the Anderson River delta.

during the 1980s and earlier, there were, on average, fewer than 150 pairs nesting in the general area (Alexander et al. 1988). We saw many flocked birds at Campbell Island and the Smoke–Moose Delta, suggesting that this area is also important habitat for non-breeders and failed breeders.

While banding Brant during late July and early August, we encountered many flocks of flightless adults with young at Campbell Island and the Smoke–Moose Delta. However, no flocks of flightless Brant were found at nearby islands A–D in Liverpool Bay at that time. We suspect that Brant nesting on the four smaller islands move their young to the lowlands of Campbell Island and the Smoke–Moose Delta (≥4 km distant). Thus, Campbell Island and the Smoke–Moose Delta appear to be critical brood-rearing areas for Black Brant throughout western Liverpool Bay. In addition, moulting flocks consisting of only adults were found at Campbell Island and the Smoke–Moose Delta, indicating that non-breeders and failed breeders use this area for most of the summer. Approximately 100–250 Black Brant used the Smoke–Moose Delta for moulting and brood rearing during the 1980s and earlier, but use of Campbell Island by Black Brant during that period was not documented (Alexander et al. 1988).

Low densities of Brant were observed nesting on the northeastern part of the Tuktoyaktuk Peninsula, and a few pairs were seen on Richards Island and the outer Mackenzie Delta. We estimated that almost 590 pairs breed on the Tuktoyaktuk Peninsula – Mackenzie Delta (Table 1), about 30% more than the total number of pairs breeding in the more densely populated areas of western Liverpool Bay (400; Table 4). In addition, flocks of non-breeders and failed breeders were observed on the Tuktoyaktuk Peninsula in June, particularly near the northern coast. Scattered flocks of flightless adults with young sighted during late July – early August near the northern coast of the Tuktoyaktuk Peninsula suggest that Brant that successfully nest on the Tuktoyaktuk

Table 2
The number of Black Brant seen in June at four small islands located in western Liverpool Bay, 1995–1998

Location	Number of birds 1995	1996	1997	1998
Island A	75 (total for islands A, B, and C; most Black Brant nesting)	27 (3–5 nests)	2 (1 nest)	32 (1 nest)
Island B		25 (10–12 nests)	8 (no nests)	69 (30 nests)
Island C		24 (6 nests)	29 (no nests)	46 (4 nests)
Island D	67 (60 nests)	Not surveyed	69 (17 nests)	78 (24 nests)
Total	142 (>60 nests)	≥76 (19–23 nests)	108 (18 nests)	225 (59 nests)

Table 3
The number of Black Brant captured during banding on the mainland of the Inuvialuit Settlement Region, 1990–1998

Year	Adults	Young	Total	% young in sample	Number (%) of adults recaptured[a]
1990	75	0	75	?[b]	4 (5.3)
1991	343	39	382	10.2	5 (1.5)
1992	542	66	608	10.9	83 (15.3)
1993	352	321	674[c]	47.6	53 (15.1)
1994	466	126	592	21.3	101 (21.7)
1995	479	181	660	27.4	120 (25.1)
1996	164	190	354	53.7	42 (25.6)
1997	720	62	782	7.9	98 (13.6)
1998	483	215	698	30.8	99 (20.5)
Total	3624	1200	4825[c]	24.9	605 (16.7)

[a] Number and percentage of adults captured in a given year that had been banded in previous years. Most recaptured Black Brant were previously banded on the mainland of the Inuvialuit Settlement Region, but a few recaptured Black Brant were from other areas, such as Alaska.
[b] Young not banded in 1990, but production was apparently high. Approximately 60 additional adults and >150 young were caught and released without banding at Anderson River. Large groups of adults and young were also observed at the Smoke–Moose Delta.
[c] Includes one individual of unknown age.

Table 4
Approximate numbers of breeding Black Brant pairs at known nesting areas on the mainland of the Inuvialuit Settlement Region (ISR)

Area	Pairs	Source
Yukon North Slope	100	Hines, unpubl. data
Islands north of Richards Island (outer Mackenzie Delta)	100	Alexander et al. 1988
Tuktoyaktuk Peninsula – Mackenzie Delta	600	This study
Western Liverpool Bay	400	This study
Anderson River delta	≤500	Sedinger et al. 1993; Reed et al. 1998; Hines and Wiebe Robertson, unpubl. data[a]
Mason River	100	Alexander et al. 1988
Paulatuk region	200	Hines, unpubl. data
Total breeding pairs on the mainland of the ISR	≤2000	

[a] Current numbers at Anderson River are uncertain, but most evidence suggests that the number of breeding pairs at Anderson River has declined from approximately 1200 pairs during the 1960s (Barry 1967; Barry 1982) to less than half that number in recent years.

Peninsula move their young to nearby coastal lowlands, where they join with other families. Dispersed groups of nesting and moulting Brant had also been observed on the Tuktoyaktuk Peninsula during the 1980s and earlier (Alexander et al. 1988).

Black Brant also nest in other areas of the mainland of the Inuvialuit Settlement Region not included in our survey (Table 4). In particular, the Anderson River delta is an important nesting and brood-rearing area for Brant (Alexander et al. 1988). Approximately 1200 pairs nested at Anderson River during the 1960s (Barry 1967; Barry 1982), although less than half that number seem to have nested there during the early 1990s (Sedinger et al. 1993; Reed et al. 1998; but see Armstrong 1998). Although we did not survey this area rigorously for Black Brant, our observations also support the idea that the number of Brant nesting at Anderson River has declined. Only a few hundred Black Brant were seen at Anderson River in June of 1996–1998 during survey flights at 230 m over the Lesser Snow Goose *Anser caerulescens caerulescens* and Brant colony (Wiebe Robertson and Hines, Lesser Snow Goose paper, this volume). Although we undoubtedly missed many Brant because of the difficulty of detecting dark geese from that height, we believe that we would have seen more than a few hundred Brant if ≥2000 adults had been present. Approximately 3000 adults, plus their young, typically used the Anderson River delta in July and August for moulting and brood rearing during the 1980s and earlier (Alexander et al. 1988), but we have observed at most a few hundred moulting adults and their young there in recent years, despite relatively intensive aerial searches of the available habitat during our banding program.

Significant fluctuations in numbers have been documented at other Black Brant colonies (Ward et al. 1993; Sedinger et al. 1994; Stickney and Ritchie 1996). These changes have been partially attributed to changes in nest predation or habitat quality (Sedinger et al. 1994). High rates of egg predation by barren-ground grizzly bears *Ursus* *arctos horribilis* occurred at the Anderson River delta in the 1990s (Armstrong 1998; F. Pokiak, pers. commun.), and this may be one reason for the decline in nesting Black Brant there. In addition, some areas of the delta that were apparently covered with grass and sedge in the 1960s are now just mudflats (Barry 1967; Armstrong 1998), suggesting that habitat deterioration might also be a reason for the decline (Sedinger et al. 1994). In contrast to the situation at Anderson River, numbers of Black Brant nesting in western Liverpool Bay may have increased in recent years. Data from moulting individuals that were captured in multiple years during banding operations in 1990–1994 indicate that Black Brant have a high probability of moving from Anderson River to western Liverpool Bay in a subsequent year, but a low probability of the reverse move (Wiebe Robertson and Hines, unpubl. data). Thus, it is possible that some Brant have shifted from Anderson River to western Liverpool Bay.

4.2 Annual reproductive success

High variability in the annual reproductive success of Brant has been documented at many sites (Reed et al. 1998), and our results also exhibited substantial annual variability. Black Brant appeared to have good reproductive success on the study area in 1996, when numbers of breeding pairs were high at Campbell Island and the Smoke–Moose Delta and a high proportion of young were caught during banding drives. In contrast, in 1997, reproductive success was very poor in some areas, including western Liverpool Bay (where relatively few Brant nested and we observed many groups of failed breeders or non-breeders). Few groups of adults with young were seen in that area when we were banding in July 1997. Brant nesting on the Tuktoyaktuk Peninsula in 1997 may have had better success than those at western Liverpool Bay. Estimated numbers of Black Brant pairs on the Tuktoyaktuk Peninsula were high in 1997 compared with other years, and the number of flightless adults with young seen during banding operations was typical of other years, or even slightly higher. Interestingly, in 1996 and 1997, the average daily temperatures in May and June were similar (Table 5), suggesting that spring temperature was not a predominant influence on reproductive success in those two years (cf. Barry 1962).

Reproductive success of Black Brant was moderate in 1995 and 1998. Slightly fewer pairs of Brant were seen on the Tuktoyaktuk Peninsula in 1995, but overall numbers were similar to other years. In 1998, slightly lower numbers of breeding pairs were seen on the survey area, but more Brant nested on the small islands in Liverpool Bay. The proportion of young in the sample of Black Brant caught during banding drives in both years was slightly above the average.

4.3 Reliability of estimates

Results from the aerial transect surveys (Table 1) plus birds counted on nearby islands in Liverpool Bay (Table 2) suggested that the Black Brant population on the study area was 6100 adults. If Brant from Anderson River are included, the total estimate would be approximately 6100–7100 adults (Table 4). The mark–recapture method, which includes Anderson River birds, produced a similar population estimate of 6200 adults, suggesting that the accuracy of our survey results is reasonable.

The population estimates for three of four years were similar, but the estimated population size from the 1997 surveys was high compared with other years. Nesting geese typically are less visible during aerial surveys than non-nesting geese (Bromley et al. 1995), so our large population estimate in 1997 was probably the result of the large numbers of failed breeders and non-breeders present (particularly at the Smoke–Moose Delta) rather than reflecting an actual increase in population size. Nonetheless, because our study spanned four years, we believe that potential biases from samples acquired during years with very high or very low nesting effort were minimized in our average population estimates.

4.4 Management implications

The Black Brant population on the mainland of the Inuvialuit Settlement Region appears to have increased in some areas, such as western Liverpool Bay, but declined substantially at Anderson River, which was once considered to be one of the most important breeding areas for Black Brant outside the Yukon–Kuskokwim Delta, Alaska (Sedinger et al. 1993). We also found significant numbers of Brant breeding on the Tuktoyaktuk Peninsula, where exact historical numbers are uncertain (Alexander et al. 1988).

Our findings suggest a number of research gaps and monitoring needs for Black Brant on the mainland of the Inuvialuit Settlement Region. More research on the influence of grizzly bear predation and habitat quality on the apparent decrease of Black Brant at Anderson River would be useful. Although grazing habitat at Campbell Island and the Smoke–Moose Delta appears to be in good shape, we do not know if this area can support many birds over the long term. A better understanding of the potential for Black Brant to shift nesting areas successfully would be valuable. Nonetheless,

Table 5
Mean daily temperatures at Tuktoyaktuk on the mainland of the Inuvialuit Settlement Region in spring, 1995–1998[a]

	Mean daily temperature (°C)				
Date	1995	1996	1997	1998	P
1–15 May	1.89[a]	−8.42[b]	−8.29[b]	−1.69[a]	0.0001
16–31 May	−0.08[a]	−0.38[a]	−1.60[a]	5.02[b]	0.0003
1–15 June	8.81[a]	5.50[a]	7.82[a]	7.01[a]	0.255
16–30 June	7.46[a]	9.07[ab]	9.00[ab]	12.05[b]	0.017

[a] P-values are from ANOVA comparisons among years, and means with the same letter were not significantly different.

preliminary analyses of survival rates of banded individuals suggest that adult survival rates are >85% (Hines and Wiebe Robertson, unpubl. data), similar to or higher than rates reported from other studies of Brant (Barry 1982; Kirby et al. 1986; Ward et al. 1997). This means that the ≥500 Brant that are harvested some years on the mainland of the Inuvialuit Settlement Region may include geese migrating through the area as well as local breeders. Given the high survival rate, it seems unlikely that current harvest levels in the Inuvialuit Settlement Region are negatively affecting the local population, although more detailed investigations are needed on survival rates and the specific proportions of local breeders in the harvest. We also recommend that this population continue to be monitored through periodic aerial surveys, by banding, using the mark–recapture approach, and, if possible, with ground counts at the larger colonies. The results reported herein should serve as a good baseline for future comparisons.

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Distribution and abundance of breeding and moulting Brant on Banks Island, Northwest Territories, 1992–1994

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Abstract

Aerial surveys were conducted over most (28 414 km^2) of southern Banks Island, Northwest Territories, to determine the distribution and abundance of breeding and non-breeding Brant *Branta bernicla*. In 1992–1993, we estimated that there was an average population of 8745 ± 1115 (standard error) adult Brant on the study area. Taking into account the low densities of Brant that existed in unsurveyed parts of the island, we estimated that at least 10 000 adults were present. Brant were found nesting throughout the study area, including the interior of the island, where earlier observers had not recorded them. The greatest numbers (6455 ± 1007) and densities (0.52/km^2) of Brant were found on the western lowlands. Both numbers and densities were considerably lower in the interior and eastern parts of the island. We estimated that there were 116 nesting colonies present on the study region and possibly as many as 130 colonies on all of Banks Island during 1993 (a good nesting year). The total population in the two areas (the western lowlands and the interior/eastern parts of the island) surveyed in both 1992 and 1993 remained stable. However, the proportion of Brant observed in nesting colonies increased from 6% to 32% between 1992 and 1993, the proportion occurring as dispersed pairs declined from 40% to 22%, and the proportion occurring in flocks of non-breeders decreased from 54% to 47%. These changes can probably be attributed to the much earlier spring in 1993. In 1992 and 1993, brood surveys were conducted in a 252-km^2 area in the western lowlands. The number of broods observed was small; although brood and gosling densities appeared to be higher in 1993 (0.20 broods/km^2, 0.34 goslings/km^2) than in 1992 (0.07 broods/km^2, 0.20 goslings/km^2), the differences were not statistically significant ($P > 0.05$). Approximately 2300 Brant moulted within the study area in 1992, 1993, and 1994, primarily on lakes located within 20 km of the west coast. During July of each year, between 1100 and 1500 Brant were captured and banded. Many of the same lakes were used by moulting flocks each year. Brant appeared to show high fidelity to the area where they had previously moulted, and most (88%) birds captured two or more times were <5 km distant from their previous capture site. Nonetheless, we captured 196 Brant (i.e., 5% of the total number handled) that had not been banded originally on Banks Island. Origins of these birds included the mainland of the Northwest Territories 300 km southwest of Banks Island, the Yukon–Kuskokwim Delta and North Slope in Alaska, and Wrangel Island in the Russian Federation. Most Brant moulting on the western lowlands of Banks Island were Black Brant *B. b. nigricans*, although 11% of the birds could have been classified as Grey-bellied Brant (or Western High-Arctic Brant), which, although they have no official taxonomic status, are thought to be an endangered and unique subspecies by many biologists.

1. Introduction

The Pacific Flyway Population of Brant *Branta bernicla* is small compared with most other populations of Arctic-nesting geese (U.S. Department of the Interior and Environment Canada 1986). Concerns about long-term declines of this population, composed mostly of the subspecies Black Brant *B. b. nigricans* (Reed et al. 1998), on both breeding and wintering areas have been expressed (Subcommittee on Pacific Brant 1992; Sedinger et al. 1993). Because of their small population size, highly social nature, and widely varying reproductive success and the limited availability of suitable habitat in some locations, Brant are potentially susceptible to catastrophic mortality or reproductive failure caused by pollution, disease, adverse weather, disturbance, and habitat loss.

Brant and other species of waterfowl make up an important part of the subsistence diet of the Inuvialuit (Bromley 1996; Fabijan et al. 1997), who, by means of their final land claim agreement, are guaranteed a preferential right to the allowable harvest of migratory birds in the Western Canadian Arctic. In order to manage waterfowl populations carefully so that significant allowable harvests can be sustained, sound information on a number of population parameters, including distribution, numbers, survival rates, and productivity, is required. This is particularly important with regard to Brant populations, which are small relative to most other goose populations, have relatively low and variable reproductive success, and require high survivorship to maintain themselves (Kirby et al. 1985).

The current numbers and population status of Brant in the Western Canadian Arctic are poorly known, and the information available is very out of date. From 1992 to 1994, we carried out an investigation of Brant on Banks Island, a potentially important breeding area for this species in the

Western Canadian Arctic (Manning et al. 1956; Barry 1960; Subcommittee on Pacific Brant 1992). Our specific objective was to determine the distribution and abundance of nesting and moulting Brant on the island.

2. Study area

Banks Island (60 165 km^2) is situated in the Northwest Territories in the southwestern corner of the Canadian Arctic Archipelago (Fig. 1). The climate of the island is dry and cold. For example, at the community of Sachs Harbour, annual precipitation for the years 1971–2000 averaged 149 mm, and the mean daily temperatures for January and July in those years were −29.3ºC and 6.8ºC, respectively (Environment Canada 2003).

Banks Island comprises three topographic regions: Northern Uplands, Southern Uplands, and Central Lowlands (Vincent 1982). Western and central Banks Island, where we carried out much of our fieldwork, lie primarily within the Central Lowlands, a low plain occurring largely within 150 m of sea level and characterized by rolling hills, shallow valleys, and alluvial flats (Fyles 1962). The Central Lowlands can be divided into coastal and interior regions, the former encompassing the drainages of many small rivers as well as the lower reaches of four major river systems: the Kellett, Big, Storkerson, and Bernard (Fig. 1). These rivers occupy broad shallow valleys and become highly braided as they near the Beaufort Sea. The wet lowlands adjacent to the rivers are characterized by large tundra polygons and rounded shallow ponds (Fyles 1962). Some common plants of the valley bottoms include mountain avens *Dryas integrifolia*, bistort *Polygonum viviparum*, buttercup *Ranunculus hyperboreus*, horsetail *Equisetum variegatum*, cottongrass *Eriophorum scheuchzeri*, rush *Juncus biglumis*, and several species of louseworts (*Pedicularis* spp.), saxifrages (*Saxifraga* spp.), sedges (*Carex* spp.), and willows (*Salix* spp.) (Porsild 1955). The interior of the Central Lowlands rises 250 m above sea level, and the topography is dominated by a plateau of dry, well-drained, rolling hills and is dissected by a dendritic network of broad, shallow river valleys and gullies (Fyles 1962). Four plant species are ubiquitous on these rolling hills: the sedge-like *Kobresia myosuroides*, mountain avens, cinquefoil *Potentilla rubricaulis*, and Arctic oxytrope *Oxytropis arctica* (Porsild 1955).

Eastern Banks Island lies within the Southern Uplands (Vincent 1982). The area extending from the east coast to approximately 50 km inland is dominated by a plateau of rolling hills, many of which extend to Prince of Wales Strait, where they drop off sharply to the sea. The headwaters of many of the major westward-flowing rivers occur in this region (Fyles 1962). The hills are well drained and dry, and the vegetation is similar to that found in the interior of the Central Lowlands (Porsild 1955).

Based on topography (Fyles 1962; Vincent 1982), the expected distribution of Brant (Manning et al. 1956; Barry 1960), and the potential amount of lowland habitat in the region, we divided the study area into three strata. The East Coast stratum (7000 km^2) was located within the Southern Uplands, and the West Coast stratum (12 436 km^2) and Inland stratum (8978 km^2) were both located in the Central Lowlands. Parts of the Central Lowlands (approximately 6900 km^2) (in particular the northwestern corner of Banks Island), the Northern Uplands (20 500 km^2), and the extreme southern part of Banks Island (4300 km^2) were not included in our study area (Fig. 1). There was little lowland habitat there (Fyles 1962; Vincent 1982), and these areas were expected to support very low densities of Brant.

3. Methods

3.1 Aerial survey of Brant

A helicopter transect survey of nesting and non-breeding Brant was conducted in the West Coast stratum from 16 to 22 June in 1992 and from 11 to 24 June in 1993. The Inland stratum was surveyed from 26 to 28 June in 1992 and from 25 to 27 June in 1993. Surveys were carried out in the East Coast stratum only in 1993 (from 29 June to 1 July). Transects in the West Coast stratum (n = 50) were aligned east–west and were spaced every 5 km, whereas transects in the Inland stratum (n = 16) ran north–south and were 10 km apart. Transects in the East Coast stratum (n = 14) were also spaced at 10-km intervals, but were aligned east–west. All transects were 50 km in length and were divided into 2-km segments. A global positioning system was used to navigate along the transects and to determine the starting point of each segment. Observations were made from a float-equipped Bell 206B helicopter flying at a height of 45 m above ground and at a ground speed of approximately 80 km/h. Observations of Brant within 200 m of the transect centre line were recorded on audio tape and later transcribed onto data forms. For each sighting, the transect and segment numbers were recorded, as were group sizes and whether pairs were solitary or associated with colonies.

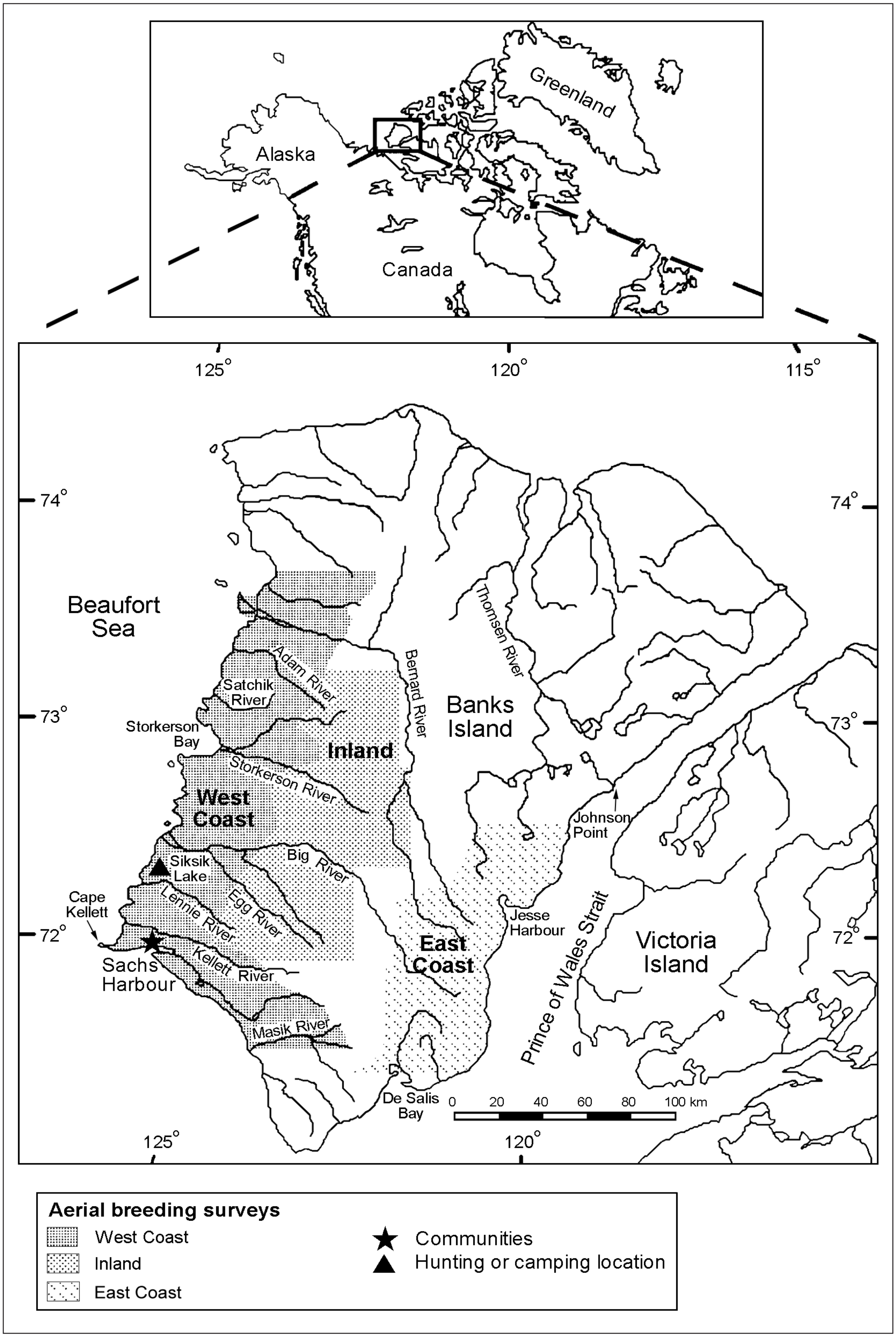
Female Brant are difficult to spot from the air if they are on nests, so any observation of a lone Brant was interpreted as a pair in calculating population estimates (Dzubin 1969; U.S. Department of the Interior and Environment Canada 1987). Three or more Brant observed together were classified as a group (i.e., probable non-breeders). To calculate the minimum number of birds present in a stratum, we multiplied the number of pairs by two and added that number to the number of grouped birds.

Minimum population estimates, later adjusted for visibility, and densities (± standard errors) were calculated for each stratum using the method recommended by Jolly (1969) for equal-sized sample units. Population estimates and densities for both years were averaged to calculate the mean number of Brant in each stratum. The standard error (SE) of the mean population estimate for each stratum was calculated as follows:

$$SE = \frac{\sqrt{VAR_{1992} + VAR_{1993}}}{2}$$

where VAR_{1992} and VAR_{1993} are the variances for the population size in 1992 and 1993, respectively. The minimum population size for the entire study region was the sum of estimates for the individual strata. The standard error (SE) of the minimum population estimate was calculated as follows:

Figure 1
Location of strata for aerial breeding survey of Brant on Banks Island, Northwest Territories, 1992–1993



$$SE = \sqrt{VAR_{WC} + VAR_{IL} + VAR_{EC}}$$

where VAR_{WC}, VAR_{IL}, and VAR_{EC} are the variances for the minimum population size of the West Coast, Inland, and East Coast strata, respectively.

In order to compensate for Brant missed during the surveys, a visibility correction factor was applied to the breeding pair and population estimates. Hines et al. (2000) recommended a minimum visibility correction factor of 1.5 for dark geese from the Western Canadian Arctic. From the air, Brant are similar in appearance to other dark geese and difficult to spot. We believe that a visibility correction factor of 1.5 should produce conservative population estimates under most conditions.

Potential between-year differences in the proportion of the Brant population made up of dispersed pairs, colonial pairs, and flocked birds were evaluated using 2 × 2 contingency tables, and annual changes in Brant numbers in a given stratum were assessed by a Wilcoxon two-sample test (Sokal and Rohlf 1981). The significance level was set at $\alpha = 0.05$ for all statistical tests.

3.2 Aerial survey of Brant broods

Aerial surveys of Brant broods were conducted from 3 to 5 August in 1992 and on 28 July in 1993, following methods similar to those used for the breeding pair surveys. Due to budgetary and logistic constraints, brood surveys were conducted only in the part of the Big River Valley where breeding pair densities were relatively high. Ten transects, each 14 km in length and divided into 2-km segments, were surveyed in a 252-km^2 area that extended 40 km inland from the coast (Fig. 2). We recorded the number of adults, broods, and goslings observed on each transect segment. As broods of Brant tend to amalgamate as they get older (Reed et al. 1998), the number of individual broods in such groups was calculated by dividing the number of adults present by two. Population estimates (± standard errors) for the 252-km^2 survey area were calculated for adults, broods, and young following the method recommended by Jolly (1969) for equal-sized sampling units. Annual changes in Brant brood densities were assessed by a Wilcoxon two-sample test (Sokal and Rohlf 1981).

3.3 Moulting Brant

As part of a banding and marking program, we searched by helicopter for moulting adult Brant on most lakes and large ponds in the West Coast stratum between the Kellett River and the Satchik River (Fig. 1). The region searched extended up to 40 km in from the coast and made up about 30% of the West Coast stratum. Counts of the flightless non-breeders or failed breeders were carried out from 24 to 31 July in 1992, from 13 to 26 July in 1993, and from 12 to 18 July in 1994. The flightless Brant had moulted their remiges and could be readily captured by helicopter drives (Timm and Bromley 1976; Maltby 1977). Each captured Brant was fitted with a standard numbered metal band on one leg and a uniquely coded plastic band on the other leg. The age, sex, and belly colour of each Brant were recorded. Belly colour, which is useful in identifying Brant from different populations, was classified using a Munsell soil colour chart (sheet 10YR; see Boyd and Maltby 1979).

4. Results

4.1 Breeding survey

Although Brant were observed throughout the study area, the overall population densities of pairs, non-breeding Brant, and total Brant were considerably higher in the West Coast stratum than in either the Inland stratum or the East Coast stratum (Table 1). In the West Coast stratum, Brant were recorded on 75% and 72% of the transects in 1992 and 1993, respectively, whereas in the Inland stratum, they were observed on 50% of the transects in 1992 and 63% of the transects in 1993. In the East Coast stratum, surveyed only in 1993, Brant were recorded on only 21% of the transects. The two highest concentrations of sightings were found within the West Coast stratum, between Sachs Harbour and the Big River (51% and 23% of all sightings in 1992 and 1993, respectively) and between Liot Point (20 km north of Storkerson Bay) and the Adam River (20% and 34% in 1992 and 1993, respectively). Overall, 74% of the Brant on the study area were found in the West Coast stratum, 21% in the Inland stratum, and only 4% in the East Coast stratum.

During the aerial surveys or during general reconnaissance flights, 45 Brant nesting colonies were found in 1992–1993 (Fig. 2). In the strata surveyed in both years, 10 colonies were found in 1992 and 38 were found in 1993. Although colonies were found throughout the area surveyed, most (76%, 34/45) were situated in the West Coast stratum, particularly in the Big River Valley (Fig. 2). Based on the number of colonies found on our transects, we estimated that there were 15 and 116 colonies on the study area in 1992 and 1993, respectively (1993 estimate includes 20 colonies for the East Coast stratum that were not surveyed in 1992).

The mean densities of Brant for the entire study area were 0.31 birds/km^2, 0.08 breeding pairs/km^2, and 0.15 non-breeders/km^2. The estimated total population for the study area was 8745 Brant, including 2273 pairs (52% of the total birds) and 4199 flocked (non-breeding) birds (48% of the total) (Table 1).

There were no significant annual changes in the total numbers of Brant or total numbers of pairs of Brant seen in either the West Coast stratum or the Inland stratum ($P > 0.05$ for all comparisons). Although nearly identical numbers of Brant were counted in 1992 and 1993 in the overall area surveyed in both years (Table 1), the composition of the population in terms of social groupings changed substantially between years (Fig. 3). In 1992, only 6% of the observed Brant occurred in nesting colonies, compared with 32% in 1993 ($P < 0.01$). The increased proportion of Brant that occurred in colonies in 1993 was accompanied by a large decrease (from 40% to 22%) in the proportion of dispersed pairs ($P < 0.01$) and a smaller (but still statistically significant) decrease in the proportion of Brant that occurred in flocks of non-breeders ($P < 0.01$). Lone Brant (as opposed to sightings of two birds) made up a much greater proportion of the “indicated pairs” in 1993 (55%, n = 40) than in 1992

Figure 2
Location of Brant nesting colonies, banding locations of moulting Brant, and transects for aerial brood survey of Brant on Banks Island, Northwest Territories, 1992–1994

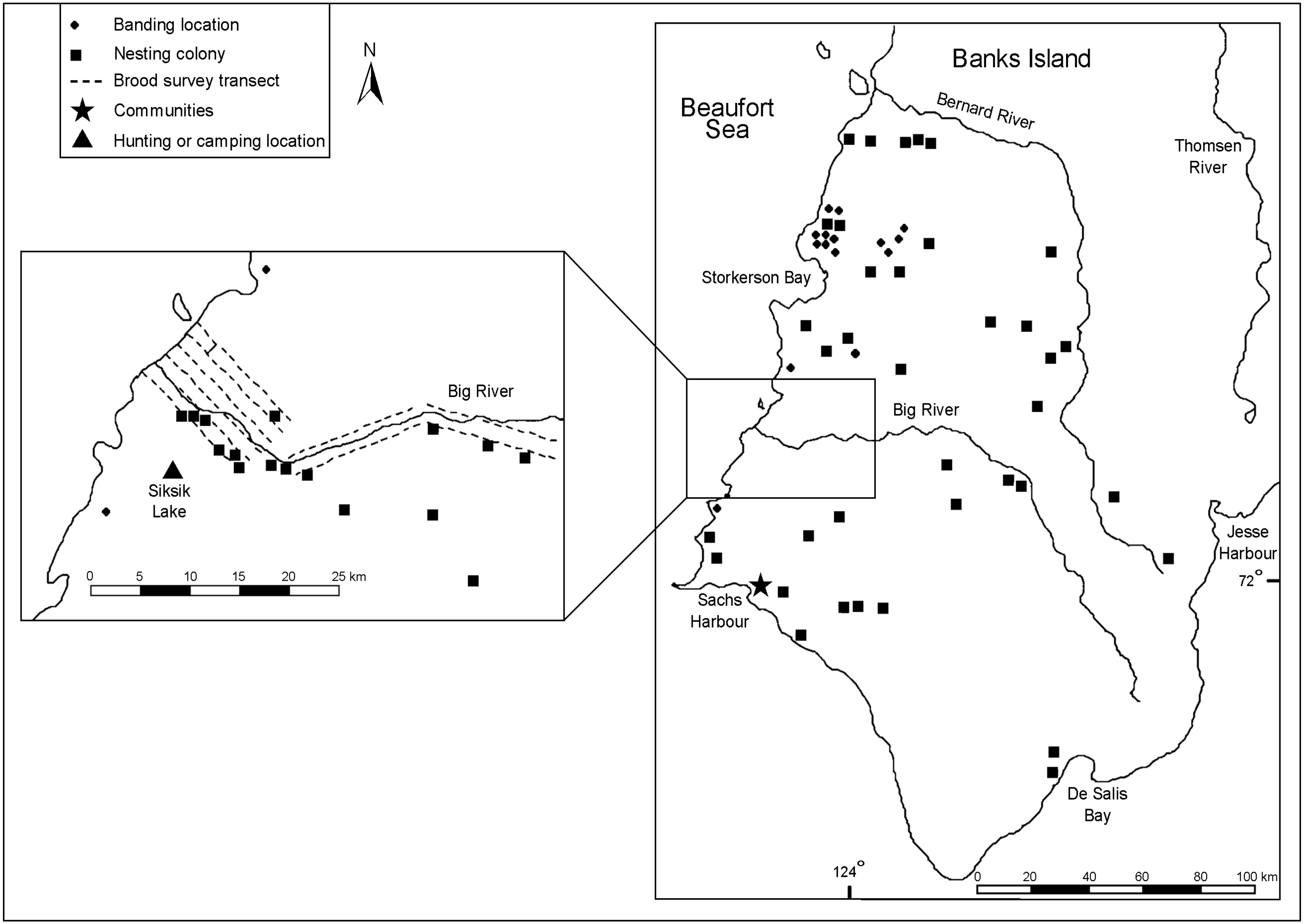


Table 1
Population estimate and density of indicated breeding pairs, flocks of non-breeders, and total indicated Brant in the three survey strata on Banks Island, 1992–1993

Stratum	Year	Number of dispersed pairs	Number of colonial pairs	Total number of pairs	Pair density (numbers/km²)	Number of non-breeders in flocks	Total number of birds	Total density of birds (numbers/km²)
West Coast	1992	1007 (± 162)	174 (± 118)	1181 (± 227)	0.095	2263 (± 656)	4625 (± 918)	0.372
	1993	348 (± 75)	746 (± 342)	1094 (± 349)	0.088	1791 (± 489)	3979 (± 978)	0.320
	Average (no VCF[a])	678 (± 89)	460 (± 181)	1138 (± 208)	0.092	2027 (± 409)	4303 (± 671)	0.347
	Average (adjusted by VCF)	1017 (± 134)	690 (± 272)	1707 (± 312)	0.138	3041 (± 614)	6455 (± 1007)	0.521
Inland	1992	112 (± 64)	0	112 (± 64)	0.012	729 (± 303)	953 (± 295)	0.105
	1993	253 (± 90)	140 (± 138)	393 (± 150)	0.044	814 (± 351)	1600 (± 498)	0.179
	Average (no VCF)	183 (± 55)	70 (± 69)	253 (± 81)	0.028	772 (± 232)	1278 (± 289)	0.142
	Average (adjusted by VCF)	275 (± 83)	105 (± 104)	380 (± 122)	0.042	1158 (± 348)	1918 (± 434)	0.213
West Coast	1992	1119 (± 174)	174 (± 118)	1293 (± 236)	0.060	2992 (± 723)	5578 (± 965)	0.260
and Inland	1993	601 (± 117)	886 (± 368)	1487 (± 380)	0.069	2605 (± 602)	5579 (± 1097)	0.260
combined	Average (no VCF)	860 (± 105)	530 (± 194)	1390 (± 223)	0.065	2799 (± 460)	5579 (± 731)	0.261
	Average (adjusted by VCF)	1290 (± 158)	795 (± 291)	2085 (± 335)	0.098	4199 (± 705)	8369 (± 1097)	0.393
East Coast	1993	75 (± 53)	50 (± 49)	125 (± 68)	0.018	0	250 (± 137)	0.036
	Average (adjusted by VCF)	113 (± 80)	75 (± 74)	188 (± 102)	0.027	0	376 (± 206)	0.054
Entire study area	(adjusted by VCF)	1403 (± 176)	870 (± 300)	2273 (± 350)	0.080	4199 (± 705)	8745 (± 1115)	0.308

[a] Visibility correction factor.

(26%, n = 85) (P < 0.01), suggesting that proportionately more of the dispersed pairs were nesting in 1993 than in 1992.

4.2 Brood survey

Only a small number of Brant were observed during the brood surveys (Table 2), which took place about 18–20 days after the peak of hatch in 1992 and 21 days after the peak of hatch in 1993. We saw almost three times as many broods and 1.7 times as many goslings in the survey area in 1993 than in 1992; however, the differences between years were not statistically significant (P > 0.05), probably due to the small samples.

4.3 Moulting Brant

On western Banks Island, we saw approximately 2500 flightless adult Brant on 18 lakes in 1992, 2000 on 22 lakes in 1993, and 2300 on 16 lakes in 1994. The mean size of these "moulting" flocks was 140, 85, and 145 in 1992, 1993, and 1994, respectively. We captured and banded 1105 (44%) of the moulting Brant in 1992, 1400 (70%) in 1993, and 1547 (67%) in 1994. Over the three years, Brant were captured on 17 different lakes (Fig. 2). On average, 60% of the Brant captured each year (range: 55–68%) were on eight lakes located 15–30 km north of the mouth of the Storkerson River (near the Satchik River) and 5–15 km inland from the coast, 11% were on four lakes located at the same latitude as the previous location but 25 km farther inland, 20% were on three lakes located about halfway between the Big and Storkerson rivers, and 9% were on two lakes situated near the Lennie River. Brant used many of the same lakes for moulting each year: at the seven sites where Brant were captured in 1992, Brant were captured at five and four of the sites in 1993 and 1994, respectively.

In 1992 and 1993, 2423 different Brant were captured. In total, 248 individuals (10% of the Brant marked) were recaptured in 1993 or 1994. Most recaptures (88%) occurred within 5 km of their previous site of capture on the island.

A significant proportion (5%) of the 4052 Brant that we captured were originally banded in locations other than Banks Island. Banding locations of these 196 Brant included the Yukon–Kuskokwim Delta (23%) and North Slope (48%) in Alaska, Wrangel Island in the Russian Federation (2%), and the Anderson River/Liverpool Bay area on the mainland of the Western Canadian Arctic (26%).

Males made up 53%, 54%, and 51% of all Brant captured in 1992, 1993, and 1994, respectively. Belly colour was recorded for most birds captured and ranged from 2 (black) to 7 (light). The mean belly colour was 3.41 (standard deviation [SD] = 1.05, mode 3, n = 990) in 1992, 3.40 (SD = 0.95, mode 3, n = 1399) in 1993, and 3.16 (SD = 0.90, mode 3, n = 1541) in 1994. Most birds appeared to be typical Black Brant, but at least 11% of the Brant had lighter belly scores (>4 on the Munsell soil chart) and, by this criterion, could have been classified as Grey-bellied (or Western High-Arctic) Brant. Grey-bellied Brant, although not officially recognized as a subspecies, appear to be taxonomically distinct and are of special management concern because of their small population size (Reed et al. 1998).

5. Discussion

5.1 Numbers and distribution of adult Brant

Our surveys, which covered 47% of Banks Island, provided an average population estimate of 8745 Brant. Aerial reconnaissance of parts of the island (Cotter, unpubl. data) and ground-based surveys conducted in Aulavik National Park of Canada on northern Banks Island (Henry and Mico 1997) indicate that very low densities of Brant

Figure 3
Composition of the Brant population in the West Coast stratum and Inland stratum on Banks Island, Northwest Territories, 1992 and 1993

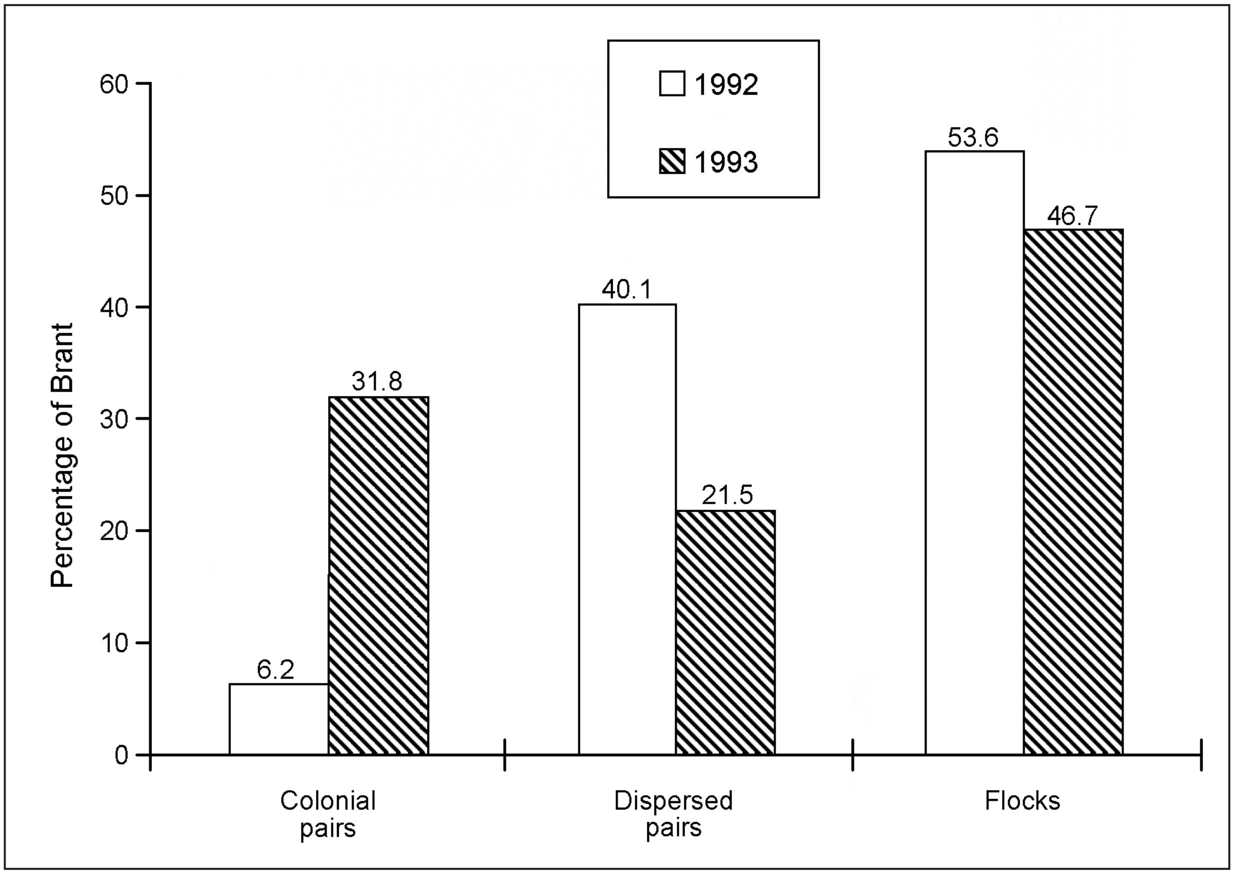


Table 2
Number of individuals sighted, density, and population estimate (± standard error) of adult and young Brant in a 252-km² area on western Banks Island, Northwest Territories, during late summer, 1992–1993

	Number observed			Density (number/km²)			Estimated numbers present		
Year	Adults	Broods	Goslings	Adults	Broods	Goslings	Adults	Broods	Goslings
1992	45	4	11	0.80 ± 0.34	0.07 ± 0.05	0.20 ± 0.12	203 ± 85	18 ± 12	50 ± 30
1993	31	11	19	0.55 ± 0.23	0.20 ± 0.11	0.34 ± 0.18	140 ± 59	50 ± 27	86 ± 44
Average	38	8	15	0.68 ± 0.21	0.13 ± 0.06	0.27 ± 0.11	172 ± 52	34 ± 15	68 ± 27

occur in the unsurveyed part of the island as well. The 31 751-km² part of the island that was not surveyed, primarily the Northern and Southern Uplands, was similar in topography and vegetation to the East Coast stratum (Porsild 1955; Fyles 1962; Vincent 1982). If it is assumed that densities of Brant in the unsurveyed area were very low and similar to those in the East Coast stratum (0.05 Brant/km²), the overall population estimate for the island would increase by approximately 1500 Brant to a total of 10 300 individuals. Assuming an average colony size of 12.8 nests (Cotter and Hines 2001) and 32% of population nesting colonially (Fig. 3), we estimate that there would be approximately 130 colonies present on Banks Island in a "good" nesting year, such as 1993. Observations of pairs during the aerial breeding surveys, as well as the location of nesting colonies, demonstrated that Brant nested throughout the study area, including the interior of Banks Island, where their status had been uncertain: some range maps showed Brant as absent from the interior (Johnsgard 1975; Boyd et al. 1988), whereas others showed Brant to nest throughout the island (Palmer 1976; Godfrey 1986). Nevertheless, Brant were not distributed evenly throughout the study area. The proportion of transects on which Brant were observed and the density of Brant pairs and groups of non-breeders were highest in the West Coast stratum, intermediate in the Inland stratum, and lowest in the East Coast stratum. The most important region on the island is the West Coast stratum, which supported about 6455 Brant, over 60% of the total estimate for all of Banks Island. The higher numbers in the West Coast stratum reflect the greater availability of lowland habitat (particularly the coastal plain, with its numerous lakes and ponds and the presence of nesting islands on many of those lakes and ponds) for breeding, brood rearing, and foraging in this stratum compared with the other two strata.

In the two years of our transect surveys (1992 and 1993), the Pacific Flyway Population numbered about 125 000 individuals in January (from Figure 6 in Reed et al. 1998). Our estimate for Banks Island of 10 300 Brant therefore represented 8% of the Pacific Flyway Population, with the West Coast stratum alone accounting for 5% of the population.

5.2 Annual differences in breeding effort and success

We carried out aerial surveys of Brant on Banks Island during two breeding seasons with highly different spring weather and phenology. Snowmelt during our first year of study, 1992, appeared to be very late on Banks Island (Cotter and Hines 2001) and throughout the circumpolar Arctic in general (Ganter and Boyd 2000). In contrast, Brant nesting dates and snowmelt occurred 8–14 days earlier in 1993 than in 1992 (Cotter and Hines 2001). We estimated that nesting productivity was nearly four times higher in 1993 than in 1992, due primarily to the greater number of Brant nesting in 1993 and secondarily to larger average clutch size and greater nesting success that year (Cotter and Hines 2001). The data from our breeding pair surveys also demonstrated clear differences in reproductive effort between years. The number of colonies, number of nesting birds, and proportion of dispersed pairs that were nesting increased from 1992 to 1993, and the proportion of the population that occurred in flocks of non-breeders declined. Our late-summer brood surveys were restricted to a relatively small part of the study area. We observed nearly 2.8 times as many broods in 1993 as in 1992 and 1.7 times more goslings in 1993 than in 1992. The results from our surveys (reported here) and nesting studies (Cotter and Hines 2001) are consistent with other studies, which show that spring weather is one of the most important factors influencing reproductive success of Brant and other Arctic geese (Barry 1962; Newton 1977; O'Briain et al. 1998; Ganter and Boyd 2000).

5.3 Moulting Brant and their origins

Over 2000 Brant moulted annually on lakes within 20 km of the west coast of Banks Island during 1992–1994. In any given year, over half of these birds moulted on lakes located in a 20-km-diameter area north of Storkerson Bay.

A significant proportion of Brant recaptures in 1993 and 1994 were birds that were originally captured and banded at the Yukon–Kuskokwim Delta in Alaska, on the North Slope of Alaska, or on the mainland of the Inuvialuit Settlement Region to the southwest of Banks Island. A few had been banded on Wrangel Island in the Russian Federation.

It is evident that western Banks Island is an important moulting area for Brant. Other important moulting sites may exist elsewhere on the island. We were able to check two potential locations. Approximately 470 moulting Brant were observed during a reconnaissance flight at Castel Bay on the northern coast of Banks Island on 8 July 1992 (Cotter, unpubl. data). In contrast, no Brant were observed on 27 July 1993 during a reconnaissance flight over Windrum Lagoon, located on De Salis Bay on the southern end of Banks Island (Hines, unpubl. data), which had been identified as a potentially important area for Brant by Kay et al. (this volume).

As noted in Section 4.3, most Brant moulting near the west coast of Banks Island were Black Brant, although a number of the captured birds were similar in belly colour to Grey-bellied (or Western High-Arctic) Brant (see Reed et al. 1998: 4), which nest on the Queen Elizabeth Islands (Boyd and Maltby 1979). The mean belly colour of 3.4 from our study was close to that obtained previously for Black Brant from Banks Island and Alaska (from Figures 2 and 3 in Boyd and Maltby 1979). Each year, however, >10% of the Brant we captured could have been classified as Grey-bellied Brant. The observation that moulting Grey-bellied Brant might occur on Banks Island is of special interest because of the recent numerical decline of this stock of geese from about 20 000 in 1995 to only about 10 000 in 1996–2002 (Canadian Wildlife Service Waterfowl Committee 2003).

6. Conclusions and management implications

With the exception of parts of the mainland of the Inuvialuit Settlement Region (Wiebe Robertson and Hines, Brant paper, this volume) and now Banks Island, recent and accurate population estimates are not available for Brant from the Western Canadian Arctic. We estimated that over 10 000 Brant (approximately 8% of the Pacific Flyway Population) used Banks Island during the breeding seasons of 1992 and 1993. Approximately equal numbers were breeding pairs and non-breeders. The most important area for Brant was the lowland extending from the western coast approximately 50 km inland (lying within Banks Island Migratory Bird Sanctuary No. 1). Over 60% of the Brant were found in the stratum encompassing these lowlands. In addition, an average of 2300 Brant, a significant proportion with origins outside of Banks Island, moulted during July of each year on the western lowlands. Due to the vulnerability of Brant to a variety of factors, as is evidenced by declines in wintering counts in the early 1960s to the late 1970s, careful monitoring of the Brant population is necessary. For Banks Island, better information is needed on the distribution and abundance of breeding and moulting Black Brant (and moulting Grey-bellied Brant) in regions we could not survey. In addition, better information on the breeding effort and success of dispersed (non-colonial) pairs and an inventory of important brood-rearing sites would be useful. Brant share the lowland habitats on Banks Island with an increasing population of Lesser Snow Geese *Anser caerulescens caerulescens* (Kerbes et al. 1999). The impact that this increasing population of Lesser Snow Geese is having on lowland habitats, on which Brant and a number of other species of migratory birds depend, needs to be determined.

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Aerial surveys of Greater White-fronted Geese, Canada Geese, and Tundra Swans on the mainland of the Inuvialuit Settlement Region, Western Canadian Arctic, 1989–1993

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Abstract

From 1989 to 1993, we carried out helicopter transect surveys to determine the numbers, distribution, and productivity of Greater White-fronted Geese *Anser albifrons*, Canada Geese *Branta canadensis*, and Tundra Swans *Cygnus columbianus* on the mainland of the Inuvialuit Settlement Region of the Western Canadian Arctic. The estimated size of the adult populations in the 26 605-km^2 survey area in June was 47 500 for Greater White-fronted Geese, 18 000 for Canada Geese, and 16 900 for Tundra Swans. In addition, we estimated that there were 2900 Greater White-fronted Geese, 4800 Canada Geese, and 1600 Tundra Swans in seven areas (totalling 513 km^2) where moulting adults congregated each year. Low densities of geese and swans are known to occur outside the survey area but still on the mainland of the Inuvialuit Settlement Region. Taking this into account would increase the overall population estimates for the mainland to approximately 55 600 Greater White-fronted Geese, 30 300 Canada Geese, and 28 700 Tundra Swans. In years of average reproductive success, birds from the Inuvialuit Settlement Region would have comprised 11% of the Mid-continent Population of Greater White-fronted Geese, 9% of the Short-grass Prairie Population of Canada Geese, and 35% of the Eastern Population of Tundra Swans. Counts were repeated in a 12 743-km^2 area each year from 1990 to 1993 and were averaged for potential comparisons with future surveys. The overall averages for total population size and number of breeding pairs on this area would allow us to detect an 18% change in the numbers of Greater White-fronted Geese, a 20% change in the numbers of Tundra Swans, and a 35% change in the numbers of Canada Geese. For 1990–1993, a subset of the transects was resurveyed in mid-July to determine an annual index of reproductive success. Productivity was 0.26, 0.29, and 0.21 broods/pair and average brood sizes were 3.0, 3.2, and 2.5 young for Greater White-fronted Geese, Canada Geese, and Tundra Swans, respectively. Productivity was highest in the year of the earliest spring, 1991, and lowest during 1992, when snowmelt was very late. Given the local importance of geese and swans to the Inuvialuit, the continental significance of waterfowl populations from the Inuvialuit Settlement Region, the apparent decline in some populations, and the variety of stressors acting on these populations, we recommend that our surveys be repeated at not more than 10-year intervals to help guarantee the conservation and management of these waterfowl.

1. Introduction

The Inuvialuit Settlement Region of the Western Canadian Arctic is an important breeding and moulting area for Greater White-fronted Geese *Anser albifrons*, Canada Geese *Branta canadensis*, Lesser Snow Geese *Anser caerulescens caerulescens*, Tundra Swans *Cygnus columbianus*, and several other species of waterfowl (Barry 1967; Alexander et al. 1988; Johnson and Herter 1989; Dickson 1997; Kerbes et al. 1999; Hines et al. 2000). The Aboriginal people of the region, the Inuvialuit, rely on waterfowl for subsistence harvest and, by their land claim agreement, are assured of preferential rights to the allowable harvest of the migratory birds in the region (Committee for Original Peoples Entitlement 1984). Information on bird numbers, distribution, habitat requirements, survival, and productivity is needed to determine if current local and international harvest levels are sustainable and to ensure that populations are conserved for the long-term use of the Inuvialuit and other people residing or hunting within the migratory range of these species.

The Greater White-fronted Geese breeding in the Inuvialuit Settlement Region are part of the Mid-continent Population. Geese from this population nest in parts of Alaska, the Yukon, and the Western and Central Canadian Arctic. They stage in the Prairie provinces during migration and winter in Texas, Louisiana, Arkansas, and Mexico. Current information on the status of the population is somewhat uncertain, and there is concern that annual international harvests of Mid-continent Greater White-fronted Geese might exceed sustainable levels. As a result, wildlife conservation agencies have placed a high priority on studies that would help us better manage Greater White-fronted Geese (Anonymous 2002).

From 1989 to 1993, we carried out aerial surveys of waterfowl on the mainland of the Inuvialuit Settlement Region to determine the numbers, distribution, and productivity of Greater White-fronted Geese, Canada Geese, and Tundra Swans in the region. The data so gathered provide an important baseline against which the future status of the populations can be assessed.

2. Study area and methods

The 27 118-km^2 study area lies within the Arctic Coastal Plains Physiographic Region and is characterized by rolling lowland plains and abundant wetlands (especially near the Mackenzie Delta and on the Tuktoyaktuk Peninsula) (Bostock 1970; Wiken 1986). Dominant plant communities include grasses and sedges (*Carex* spp.) in lowland and coastal areas, tall shrubs near some lakes and streams, and widespread tundra composed of shorter shrubs, cottongrass *Eriophorum*, and scattered herbs (Bliss et al. 1973; Corns 1974; Wiken 1986). Open forest–tundra occurs in the southern part of the Inuvialuit Settlement Region, and white spruce *Picea glauca* reaches its northern limit in this area. Daily temperatures average <10°C during spring and summer (Environment Canada 2003). Precipitation is low, averaging 139 mm per year, but snowfall is possible in any season.

Aerial surveys were conducted between 11 and 21 June of 1989–1993, during the period when most species of waterfowl were widely dispersed as breeding pairs. The main survey area was divided into seven main strata (totalling 26 605 km^2) based on geographic, physiographic, and habitat differences (Fig. 1; top). In addition, seven smaller areas (totalling 513 km^2) of known importance to moulting geese and swans (Barry 1967; Alexander et al. 1988) were surveyed more intensively (Fig. 1; bottom). Together, the latter areas were treated as a separate "moulting area" stratum. Due to budgetary and time constraints, not all strata were surveyed annually, although we were able to survey a 12 743-km^2 core area corresponding to the Tuktoyaktuk Peninsula and Mackenzie Delta strata each year from 1990 to 1993. Therefore, annual indices of population size were available for nearly half of the overall study area for a four-year period.

The survey procedure involved flying straight transects in a Bell 206B or 206L helicopter at an elevation of 45 m and ground speed of 80–100 km/h. Most transects were oriented in a north–south direction (approximately perpendicular to the coastline) and were spaced at 10-km intervals, except in a few areas of prime waterfowl habitat, where transects were 5 km apart. Transects in the moulting areas were spaced at 2-km intervals. Regular transects averaged 25 km in length (range: 6–82 km). In the moulting areas, most transects were less than 10 km in length, and the average length was 6 km. All transects were divided into 2-km segments, which served as the basic unit for recording data.

Surveys were conducted with two observers, one seated in the left front seat and the other in the right rear seat (equipped with a bubble window for better viewing). All observations of geese and swans within an estimated 200 m of the flight path were recorded on audio tape and later transcribed.

Population estimates and densities (± standard errors) for the different strata were calculated using the ratio method (Jolly 1969). Population densities for all years were averaged to calculate the average number of geese and swans in the stratum. The standard error (SE) of the mean population estimate for each stratum was determined as follows:

$$SE = \frac{\sqrt{\Sigma S_i^2}}{n}$$

where S_i^2 is the variance of the stratum population estimate in year i and n is the number of years the stratum was surveyed. The sizes of some strata were increased somewhat as the study evolved and we expanded surveys into previously unsurveyed areas. When the size of the stratum varied among years, the largest area surveyed in any year was used in calculating the average population estimate for the stratum. The total population estimate for the Inuvialuit Settlement Region was the sum of the individual stratum population estimates, and the variance for the total population estimate was the sum of all stratum variances.

Female Greater White-fronted and Canada geese are seen infrequently from the air if they are on nests, so each observation of one or two geese was treated as an indicated breeding pair (i.e., as two birds) in calculating numbers of breeding geese (U.S. Department of the Interior and Environment Canada 1987). The total population size was estimated as the number of indicated breeding pairs multiplied by two plus the number of birds in groups of three or more.

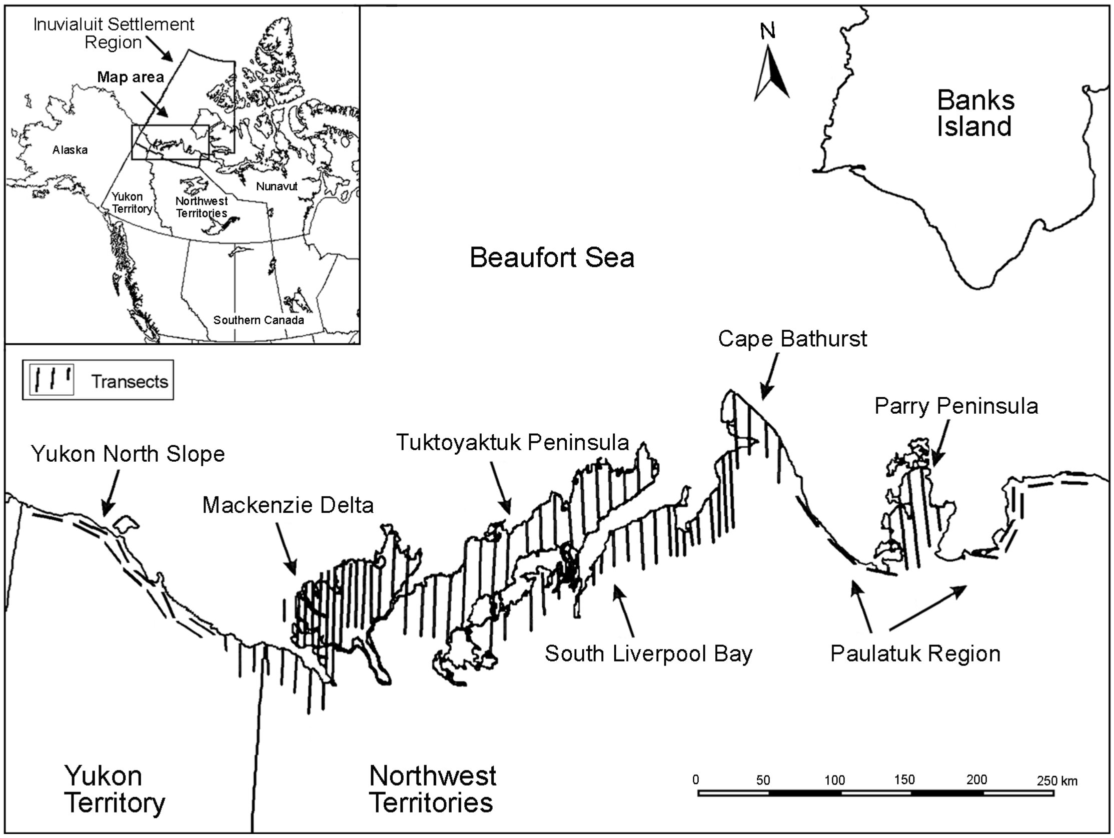
Adjusting observations to account for missed females may still underestimate the actual population size, because there may be groups, pairs, or lone geese that were not sighted from the air. Visibility correction factors to adjust for dark geese missed during helicopter surveys in tundra habitats range between 1.4 and 2.1 (Bromley et al. 1995; Hines et al. 2000; see also Appendix 1). Based on those studies, we believe that using a visibility correction factor of 1.5 provides a conservative estimate of the number of "dark" geese in a given area. We applied this visibility correction factor to both breeding pair and total population estimates (and their standard errors) for all strata except the moulting areas (where geese were typically bunched in large flocks on water and were readily seen from the air).

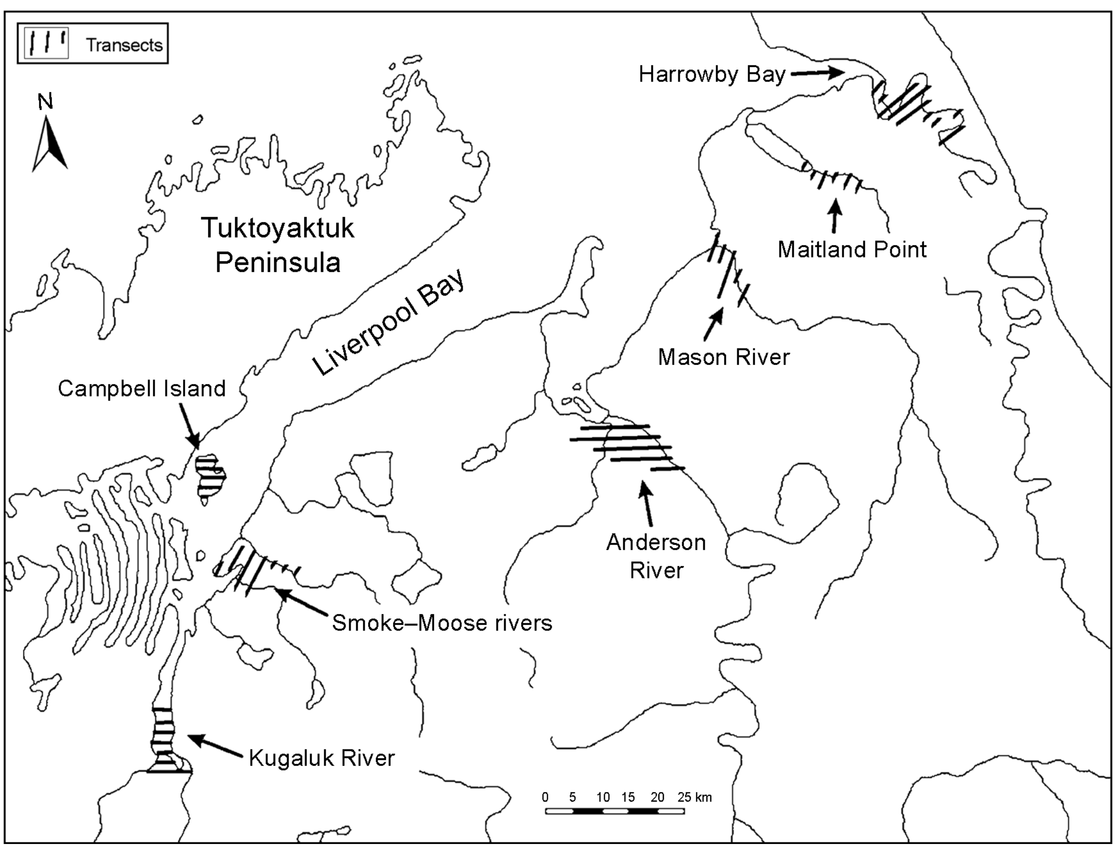
Tundra Swans are highly visible and not likely to be missed during the surveys. Thus, the total population size was calculated using the number of swans actually observed. Indicated breeding pairs were calculated by summing all sightings of one or two swans and then dividing by two (Wilk 1988). Neither the total population estimate nor the breeding pair estimates for Tundra Swans were adjusted by a visibility correction factor.

A 12 743-km^2 "core area" was surveyed each year to determine the year-to-year variability in population sizes of geese and swans, evaluate the relative precision of surveys, and find out what change in population size could be detected by repeating the surveys in the future. As a measure of survey precision, we calculated coefficients of variation for the annual and average population estimates for each species. The percentage change in population size that could be detected in future surveys was then determined following the methods outlined in Krebs (1989: 179). We assumed a significance level of $\alpha = 0.05$ in this evaluation.

Repeat surveys of 22–31% of the study area (6091–8372 km^2) were also carried out in July of 1990–1993 in the Mackenzie Delta, Tuktoyaktuk Peninsula, and South Liverpool Bay strata to calculate an index of the annual productivity of geese and swans. The procedure for these surveys was identical to that for the June breeding surveys, except that particular emphasis was placed on recording sightings of broods and the number of young in each brood.

Figure 1
Transects surveyed for waterfowl in the Inuvialuit Settlement Region, 1989–1993





An index of the number of broods per breeding pair was calculated using information on the number of pairs from the June breeding surveys and on the number of broods from the July surveys for the same transects. The proportion of young in the population was calculated using the number of young seen on the July surveys divided by the total number of birds estimated to be present. In the latter calculation, the estimated number of birds present was the number of young seen (July surveys) plus the number of adults seen on the same transects during the June surveys. Counts from neither the June nor July surveys were adjusted by visibility correction factors when estimating productivity (i.e., we assumed that adult birds were equally visible in both surveys).

3. Results

3.1 Numbers and distribution

3.1.1 Greater White-fronted Geese

The estimated population size of Greater White-fronted Geese was 47 452 ± 2528 geese in the 26 605-km^2 survey area, plus an additional 2870 ± 393 geese in the moulting stratum (Tables 1 and 2; Fig. 2). Among the main survey strata, the highest numbers of geese occurred in the Tuktoyaktuk Peninsula and South Liverpool Bay strata, where densities averaged 2.37 ± 0.18 and 3.43 ± 0.33 geese/km^2, respectively. Fewer geese were present in the other main survey strata, where densities ranged from 0.04 to 1.54 geese/km^2. We estimated that there were 8219 ± 399 pairs in the 26 605-km^2 survey area (Table 3) and an additional 247 ± 33 pairs in the moulting stratum (Table 4).

Estimated numbers of Greater White-fronted Geese in the 12 743-km^2 "core" area surveyed each year from 1990 to 1993 are presented in Figure 3 and Table 5. The overall coefficient of variation for both the mean population estimate and the estimated number of indicated pairs was 7%, indicating that the average estimate of population size for the four-year period was precise and would provide a good baseline for detecting long-term population trends. We determined that if the surveys were repeated in the future and similarly precise estimates were obtained, we would be able to detect an 18% change in population size.

3.1.2 Canada Geese

The estimated population size for Canada Geese was 17 974 ± 3566 in the 26 605-km^2 survey area and an additional 4775 ± 2304 geese in the moulting stratum (Tables 6 and 7; Fig. 4). Aside from the moulting area stratum, which, by the manner in which it was defined, contained very high densities of geese (an average of 9.31 ± 4.49 geese/km^2), the highest numbers of geese occurred on the Parry Peninsula and Cape Bathurst, where densities averaged 3.79 ± 1.18 and 1.23 ± 0.57 geese/km^2, respectively. Fewer geese were present in the other strata, and densities were lower (0.10–0.88 geese/km^2). We estimated that there were 3335 ± 491 pairs in the 26 605-km^2 survey area (Table 8) and only 40 ± 9 pairs in the moulting stratum (Table 9).

Because of the smaller numbers of Canada Geese sighted during the surveys, the precision of both the total population estimates and breeding pair estimates in the core 12 743-km^2 area was much lower than for Greater White-fronted Geese or Tundra Swans (Table 5; Fig. 3). The level of precision of the estimates would allow us to detect a 35% change in overall population or numbers of breeding pairs if similar surveys were carried out in the future.

3.1.3 Tundra Swans

We estimated that there were 16 913 ± 925 Tundra Swans in the 26 605-km^2 survey area and 1634 ± 370 swans in the moulting stratum (Tables 10 and 11; Fig. 5). As expected, the average population density within the moulting area stratum (3.19 ± 0.72 swans/km^2) was higher than within the other strata. The Mackenzie Delta, Tuktoyaktuk Peninsula, and South Liverpool Bay all supported relatively high population densities (0.83 ± 0.10, 0.89 ± 0.07, and 0.75 ± 0.08 swans/km^2, respectively), but fewer swans were present in the other strata, where densities were only 0.08–0.26 swans/km^2. The estimated number of pairs in the 26 605-km^2 survey area was 7190 ± 259 (Table 12), and an additional 189 ± 20 pairs were present in the moulting stratum (Table 13).

Overall population estimates and breeding pair estimates for Tundra Swans were relatively precise (Table 5; Fig. 3). A repeat survey of the 12 743-km^2 core area would allow us to detect a 20% change in overall numbers and an 11% change in the number of breeding pairs present.

3.2 Productivity

Productivity indices were calculated from the subset of transects surveyed during both the nesting and brood-rearing periods. We estimated that Greater White-fronted Geese produced an average of 0.26 broods/pair and had an average brood size of 3.0 young (Table 14). Canada Geese had similar reproductive success (0.29 broods/pair, 3.2 young/brood). Tundra Swans produced an average of 0.21 broods/pair, and the average brood size was 2.5 young. The number of broods per pair and the average brood size varied substantially among years for all species. Reproductive success was especially high after the earliest spring (1991) and very low after the late spring of 1992 (Table 15).

4. Discussion

Although the importance of the mainland of the Inuvialuit Settlement Region to waterfowl and other migratory birds has long been known (Barry 1967; Alexander et al. 1988; Johnson and Herter 1989), the helicopter transect surveys conducted from 1989 to 1993 represent the most complete effort to census the population of Greater White-fronted Geese, Canada Geese, and Tundra Swans in the region. Our surveys covered a large part of the mainland of

Table 1
Estimated densities and numbers of Greater White-fronted Geese in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Geese observed	Number of transects	Area (km^2)	Density ± SE ($geese/km^2$)	Number of geese ± SE
Mackenzie Delta	1989	365	9	3 668	2.35 ± 0.43	8 626 ± 1 581
	1990	247	23	6 091	0.70 ± 0.12	4 236 ± 750
	1991	309	24	6 091	0.81 ± 0.19	4 922 ± 1 143
	1992	261	24	6 091	0.68 ± 0.16	4 157 ± 992
	1993	232	24	6 091	0.61 ± 0.12	3 695 ± 728
				Average (no VCF[a])	1.03 ± 0.11	6 267 ± 641
				Average (adjusted by VCF)	1.54 ± 0.16	9 400 ± 962
Tuktoyaktuk Peninsula	1989	509	17	6 652	1.89 ± 0.29	12 596 ± 1 961
	1990	310	17	6 652	1.15 ± 0.26	7 672 ± 1 728
	1991	528	17	6 652	1.96 ± 0.35	13 066 ± 2 303
	1992	422	17	6 652	1.57 ± 0.24	10 443 ± 1 605
	1993	357	17	6 652	1.33 ± 0.21	8 835 ± 1 380
				Average (no VCF)	1.58 ± 0.12	10 522 ± 815
				Average (adjusted by VCF)	2.37 ± 0.18	15 784 ± 1 223
South Liverpool Bay	1989	765	15	3 280	4.31 ± 0.72	14 128 ± 2 369
	1990	492	15	3 500	2.80 ± 0.69	9 784 ± 2 416
	1991	319	21	4 721	1.49 ± 0.28	7 051 ± 1 300
	1992	337	21	4 721	1.58 ± 0.29	7 448 ± 1 380
	1993	340	21	5 796	1.25 ± 0.21	7 245 ± 1 194
				Average (no VCF)	2.28 ± 0.22	13 243 ± 1 271
				Average (adjusted by VCF)	3.43 ± 0.33	19 864 ± 1 906
Cape Bathurst	1991	53	7	1 737	0.68 ± 0.29	1 186 ± 506
	1992	26	4	1 279	0.50 ± 0.22	640 ± 283
	1993	19	4	1 279	0.37 ± 0.24	467 ± 305
				Average (no VCF)	0.52 ± 0.15	897 ± 253
				Average (adjusted by VCF)	0.77 ± 0.22	1 345 ± 379
Yukon North Slope	1990	11	11	1 821	0.13 ± 0.09	228 ± 156
				(adjusted by VCF)	0.19 ± 0.13	341 ± 233
Parry Peninsula	1991	16	6	2 784	0.16 ± 0.09	435 ± 242
				(adjusted by VCF)	0.23 ± 0.13	653 ± 363
Paulatuk Region	1991	2	10	1 724	0.03 ± 0.02	43 ± 42
				(adjusted by VCF)	0.04 ± 0.04	65 ± 63
All non-moulting strata (adjusted by VCF)				26 605	1.78 ± 0.10	47 452 ± 2 528

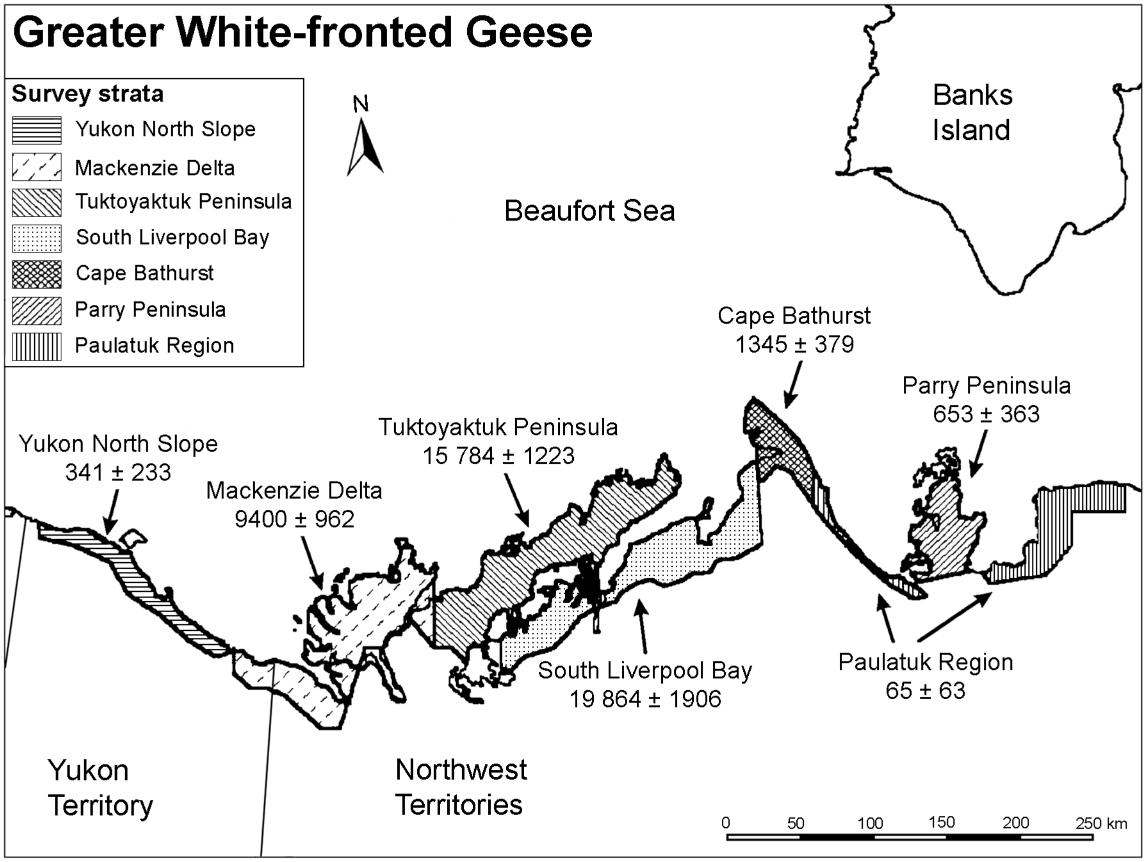
[a] Visibility correction factor.

Table 2
Estimated densities and numbers of Greater White-fronted Geese in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Geese observed	Number of transects	Area (km^2)	Density ± SE ($geese/km^2$)	Number of geese ± SE
Kugaluk River	1991	180	7	64	14.06 ± 6.13	903 ± 394
	1992	54	7	64	4.22 ± 1.96	271 ± 126
	1993	148	7	64	11.56 ± 7.94	742 ± 509
				Average (no VCF[a])	9.95 ± 3.41	638 ± 219
Campbell Island	1991	20	5	41	2.50 ± 0.94	102 ± 38
	1992	14	5	41	1.75 ± 0.85	71 ± 35
	1993	10	5	41	1.25 ± 0.77	51 ± 31
				Average (no VCF)	1.83 ± 0.49	74 ± 20
Smoke–Moose rivers	1991	104	7	82	6.19 ± 3.40	510 ± 280
	1992	116	7	82	6.90 ± 2.35	569 ± 194
	1993	44	7	82	2.62 ± 1.04	216 ± 86
				Average (no VCF)	5.24 ± 1.42	432 ± 117
Anderson River	1991	192	4	104	9.23 ± 4.54	962 ± 473
	1992	200	4	104	9.62 ± 3.43	1003 ± 357
	1993	353	4	104	16.97 ± 5.60	1769 ± 583
				Average (no VCF)	11.94 ± 2.66	1245 ± 277
Mason River	1991	116	5	68	8.53 ± 4.97	582 ± 339
	1992	86	5	68	6.32 ± 1.82	431 ± 124
	1993	29	5	68	2.13 ± 1.13	145 ± 77
				Average (no VCF)	5.66 ± 1.80	386 ± 123
Maitland Point	1991	12	6	40	1.50 ± 1.04	61 ± 42
	1992	11	6	40	1.38 ± 0.57	56 ± 23
	1993	15	6	40	1.88 ± 0.72	76 ± 29
				Average (no VCF)	1.58 ± 0.46	64 ± 19
Harrowby Bay	1991	11	7	101	0.55 ± 0.52	56 ± 53
	1992	4	9	113	0.17 ± 0.10	19 ± 11
	1993	2	9	113	0.08 ± 0.08	9 ± 9
				Average (no VCF)	0.27 ± 0.18	30 ± 20
Entire moulting stratum (no VCF)				513	5.60 ± 0.77	2870 ± 393

[a] Visibility correction factor.

Figure 2
Mean annual number (± standard error) of Greater White-fronted Geese present in the different survey strata in the Inuvialuit Settlement Region in June of 1989–1993



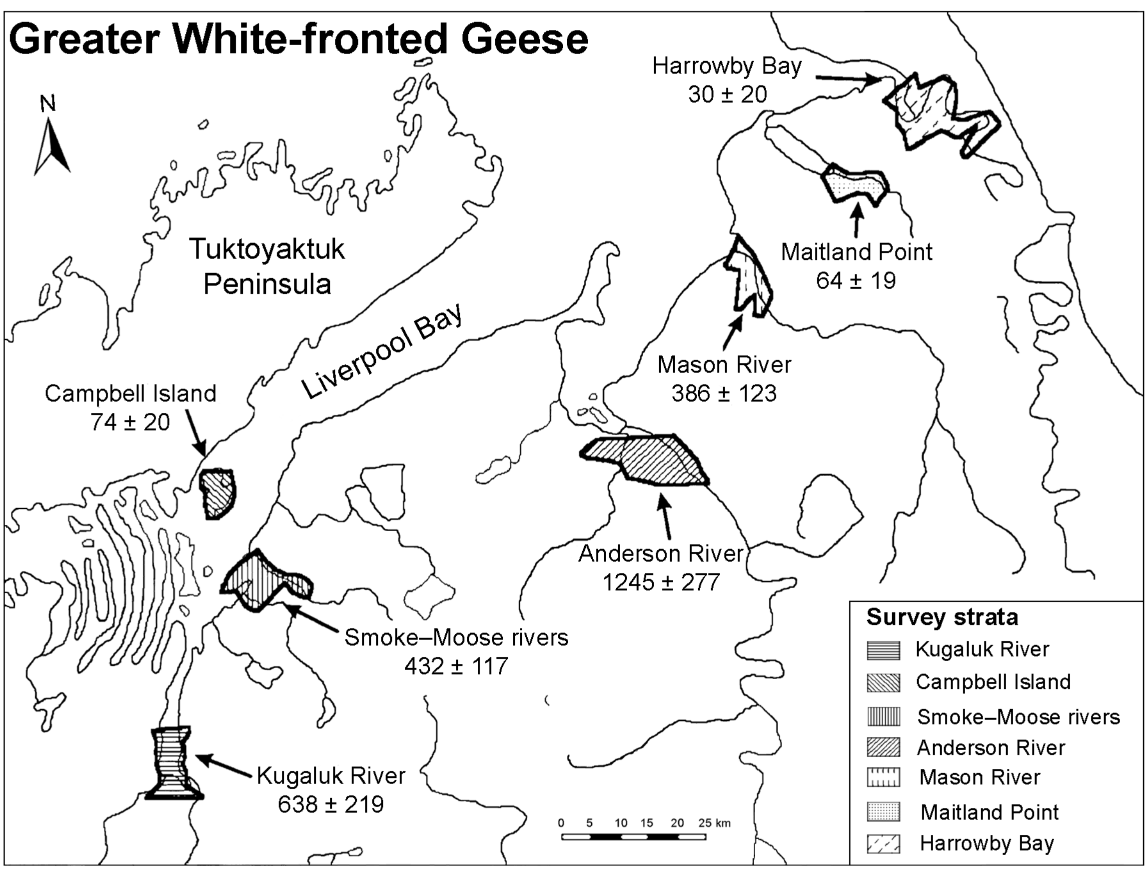


Table 3
Estimated densities and numbers of Greater White-fronted Goose pairs in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km^2)	Density ± SE (pairs/km^2)	Number of pairs ± SE
Mackenzie Delta	1989	53	9	3 668	0.34 ± 0.08	1 253 ± 306
	1990	51	23	6 091	0.14 ± 0.03	875 ± 171
	1991	51	24	6 091	0.13 ± 0.03	812 ± 196
	1992	63	24	6 091	0.17 ± 0.04	1 003 ± 237
	1993	59	24	6 091	0.15 ± 0.03	940 ± 193
				Average (no VCF[a])	0.19 ± 0.02	1 141 ± 129
				Average (adjusted by VCF)	0.28 ± 0.03	1 712 ± 194
Tuktoyaktuk Peninsula	1989	99	17	6 652	0.37 ± 0.06	2 450 ± 371
	1990	64	17	6 652	0.24 ± 0.05	1 584 ± 360
	1991	101	17	6 652	0.38 ± 0.06	2 499 ± 389
	1992	84	17	6 652	0.31 ± 0.05	2 079 ± 350
	1993	94	17	6 652	0.35 ± 0.06	2 326 ± 380
				Average (no VCF)	0.33 ± 0.02	2 189 ± 166
				Average (adjusted by VCF)	0.49 ± 0.04	3 283 ± 249
South Liverpool Bay	1989	102	15	3 280	0.57 ± 0.09	1 884 ± 300
	1990	39	15	3 500	0.22 ± 0.04	795 ± 127
	1991	47	21	4 721	0.22 ± 0.05	1 039 ± 247
	1992	47	21	4 721	0.22 ± 0.04	1 039 ± 204
	1993	98	21	5 796	0.36 ± 0.04	2 088 ± 227
				Average (no VCF)	0.32 ± 0.03	1 851 ± 145
				Average (adjusted by VCF)	0.48 ± 0.04	2 776 ± 217
Cape Bathurst	1991	7	7	1 737	0.09 ± 0.05	157 ± 80
	1992	4	4	1 279	0.08 ± 0.02	98 ± 26
	1993	4	4	1 279	0.08 ± 0.04	98 ± 53
				Average (no VCF)	0.08 ± 0.02	141 ± 38
				Average (adjusted by VCF)	0.12 ± 0.03	212 ± 57
Yukon North Slope	1990	0	11	1 821	0.00 ± 0.00	0 ± 0
				(adjusted by VCF)	0.00 ± 0.00	0 ± 0
Parry Peninsula	1991	5	6	2 784	0.05 ± 0.02	136 ± 59
				(adjusted by VCF)	0.07 ± 0.03	204 ± 89
Paulatuk Region	1991	1	10	1 724	0.01 ± 0.01	22 ± 21
				(adjusted by VCF)	0.02 ± 0.02	32 ± 32
All non-moulting strata (adjusted by VCF)				26 605	0.31 ± 0.01	8 219 ± 399

[a] Visibility correction factor.

Table 4
Estimated densities and numbers of Greater White-fronted Goose pairs in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km^2)	Density ± SE (pairs/km^2)	Number of pairs ± SE
Kugaluk River	1991	4	7	64	0.31 ± 0.16	20 ± 10
	1992	7	7	64	0.55 ± 0.21	35 ± 13
	1993	0	7	64	0.00 ± 0.00	0 ± 0
				Average (no VCF[a])	0.29 ± 0.09	18 ± 6
Campbell Island	1991	3	5	41	0.38 ± 0.18	15 ± 7
	1992	7	5	41	0.88 ± 0.43	36 ± 17
	1993	3	5	41	0.38 ± 0.21	15 ± 8
				Average (no VCF)	0.54 ± 0.17	22 ± 7
Smoke–Moose rivers	1991	5	7	82	0.30 ± 0.24	25 ± 20
	1992	11	7	82	0.65 ± 0.26	54 ± 22
	1993	7	7	82	0.42 ± 0.15	34 ± 12
				Average (no VCF)	0.46 ± 0.13	38 ± 11
Anderson River	1991	20	4	104	0.96 ± 0.24	100 ± 25
	1992	14	4	104	0.67 ± 0.37	70 ± 39
	1993	41	4	104	1.97 ± 0.72	206 ± 75
				Average (no VCF)	1.20 ± 0.28	125 ± 29
Mason River	1991	3	5	68	0.22 ± 0.16	15 ± 11
	1992	8	5	68	0.59 ± 0.09	40 ± 6
	1993	3	5	68	0.22 ± 0.08	15 ± 5
				Average (no VCF)	0.34 ± 0.07	23 ± 4
Maitland Point	1991	2	6	40	0.25 ± 0.13	10 ± 5
	1992	3	6	40	0.38 ± 0.12	15 ± 5
	1993	3	6	40	0.38 ± 0.12	15 ± 5
				Average (no VCF)	0.33 ± 0.07	13 ± 3
Harrowby Bay	1991	1	7	101	0.05 ± 0.05	5 ± 5
	1992	2	9	113	0.08 ± 0.05	9 ± 6
	1993	1	9	113	0.04 ± 0.04	5 ± 4
				Average (no VCF)	0.06 ± 0.03	7 ± 3
Entire moulting stratum (no VCF)				513	0.48 ± 0.06	247 ± 33

[a] Visibility correction factor.

Figure 3
Estimated numbers (± standard errors) of Greater White-fronted Geese, Canada Geese, and Tundra Swans present in the 12 743-km^2 "core" area on the mainland of the Inuvialuit Settlement Region surveyed each year, 1990–1993

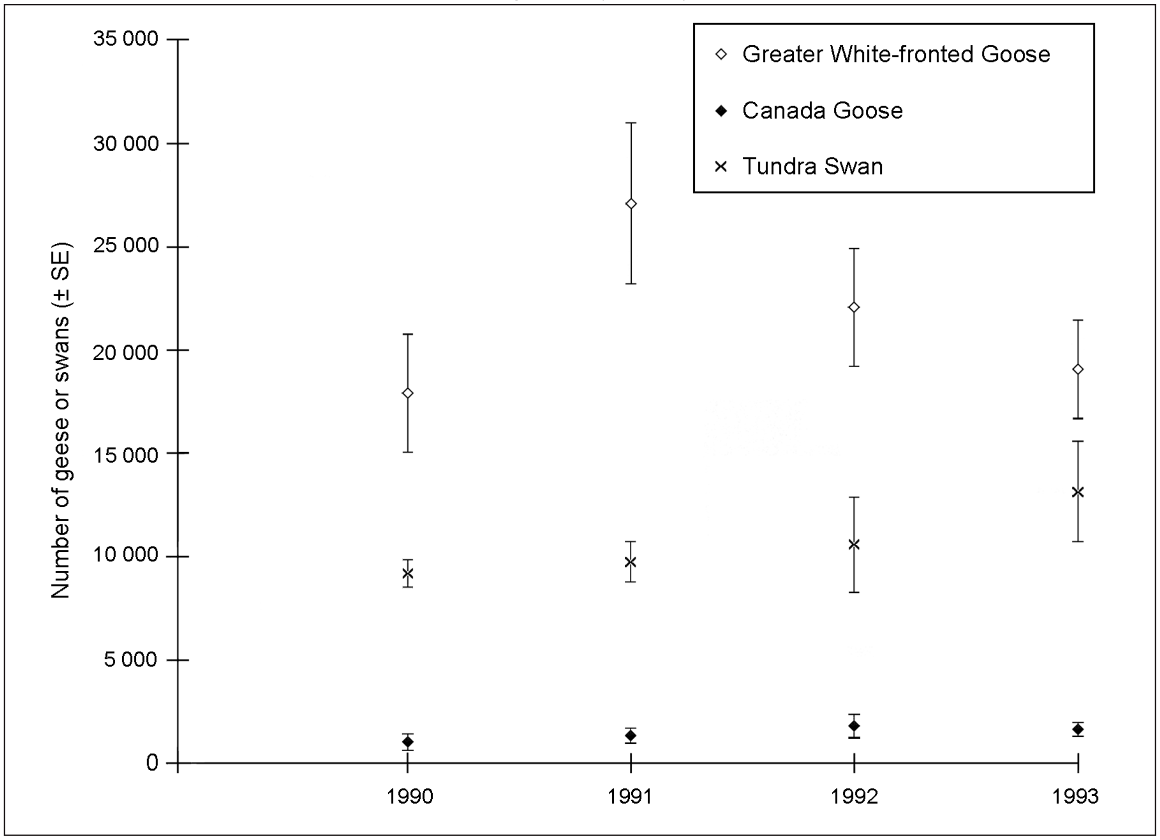


Table 5
The estimated number of Greater White-fronted Geese, Canada Geese, and Tundra Swans present in the 12 743-km^2 "core" area on the mainland of the Inuvialuit Settlement Region surveyed each year, 1990–1993

Year	Total population size	Standard error	Coefficient of variation	Number of indicated pairs	Standard error	Coefficient of variation
Greater White-fronted Goose						
1990	11 907	1 883	0.158	3 688	597	0.162
1991	17 988	2 571	0.143	4 968	654	0.132
1992	14 601	1 887	0.129	4 623	633	0.137
1993	12 530	1 560	0.124	4 899	639	0.131
Average 1990–1993	14 257	1 005	0.070	4 544	316	0.069
Canada Goose						
1990	934	413	0.443	243	86	0.353
1991	1 205	358	0.297	483	130	0.268
1992	1 632	536	0.329	470	170	0.362
1993	1 401	323	0.231	701	162	0.231
Average 1990–1993	1 293	208	0.161	474	70	0.148
Tundra Swan						
1990	9 116	638	0.070	4 134	337	0.081
1991	9 622	969	0.101	4 301	331	0.077
1992	10 409	2 272	0.218	3 924	426	0.108
1993	12 903	2 386	0.185	5 124	297	0.058
Average 1990–1993	10 512	873	0.083	4 371	176	0.040

Table 6
Estimated densities and numbers of Canada Geese in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Geese observed	Number of transects	Area (km^2)	Density ± SE ($geese/km^2$)	Number of geese ± SE
Mackenzie Delta	1989	18	9	3 668	0.12 ± 0.05	425 ± 186
	1990	19	23	6 091	0.05 ± 0.02	326 ± 107
	1991	38	24	6 091	0.10 ± 0.04	605 ± 220
	1992	59	24	6 091	0.15 ± 0.06	940 ± 350
	1993	40	24	6 091	0.10 ± 0.02	637 ± 141
				Average (no VCF[a])	0.11 ± 0.02	643 ± 109
				Average (adjusted by VCF)	0.16 ± 0.03	964 ± 164
Tuktoyaktuk Peninsula	1989	48	17	6 652	0.18 ± 0.09	1 188 ± 582
	1990	12	17	6 652	0.04 ± 0.04	297 ± 254
	1991	8	17	6 652	0.03 ± 0.01	198 ± 92
	1992	6	17	6 652	0.02 ± 0.01	148 ± 75
	1993	12	17	6 652	0.04 ± 0.02	297 ± 163
				Average (no VCF)	0.06 ± 0.02	426 ± 133
				Average (adjusted by VCF)	0.10 ± 0.03	638 ± 200
South Liverpool Bay	1989	87	15	3 280	0.49 ± 0.37	1 607 ± 1 212
	1990	25	15	3 500	0.14 ± 0.05	497 ± 166
	1991	48	21	4 721	0.22 ± 0.09	1 061 ± 417
	1992	29	21	4 721	0.14 ± 0.06	641 ± 286
	1993	29	21	5 796	0.11 ± 0.03	618 ± 171
				Average (no VCF)	0.22 ± 0.08	1 274 ± 451
				Average (adjusted by VCF)	0.33 ± 0.12	1 911 ± 676
Cape Bathurst	1991	153	7	1 737	1.97 ± 1.13	3 425 ± 1 968
	1992	19	4	1 279	0.37 ± 0.14	467 ± 175
	1993	6	4	1 279	0.12 ± 0.05	148 ± 58
				Average (no VCF)	0.82 ± 0.38	1 420 ± 661
				Average (adjusted by VCF)	1.23 ± 0.57	2 130 ± 992
Yukon North Slope	1990	8	11	1 821	0.09 ± 0.05	166 ± 90
				(adjusted by VCF)	0.14 ± 0.07	248 ± 135
Parry Peninsula	1991	259	6	2 784	2.53 ± 0.78	7 042 ± 2 183
				(adjusted by VCF)	3.79 ± 1.18	10 562 ± 3 275
Paulatuk Region	1991	47	10	1 724	0.59 ± 0.26	1 013 ± 457
				(adjusted by VCF)	0.88 ± 0.40	1 519 ± 685
All non-moulting strata (adjusted by VCF)				26 605	0.68 ± 0.13	17 974 ± 3 566

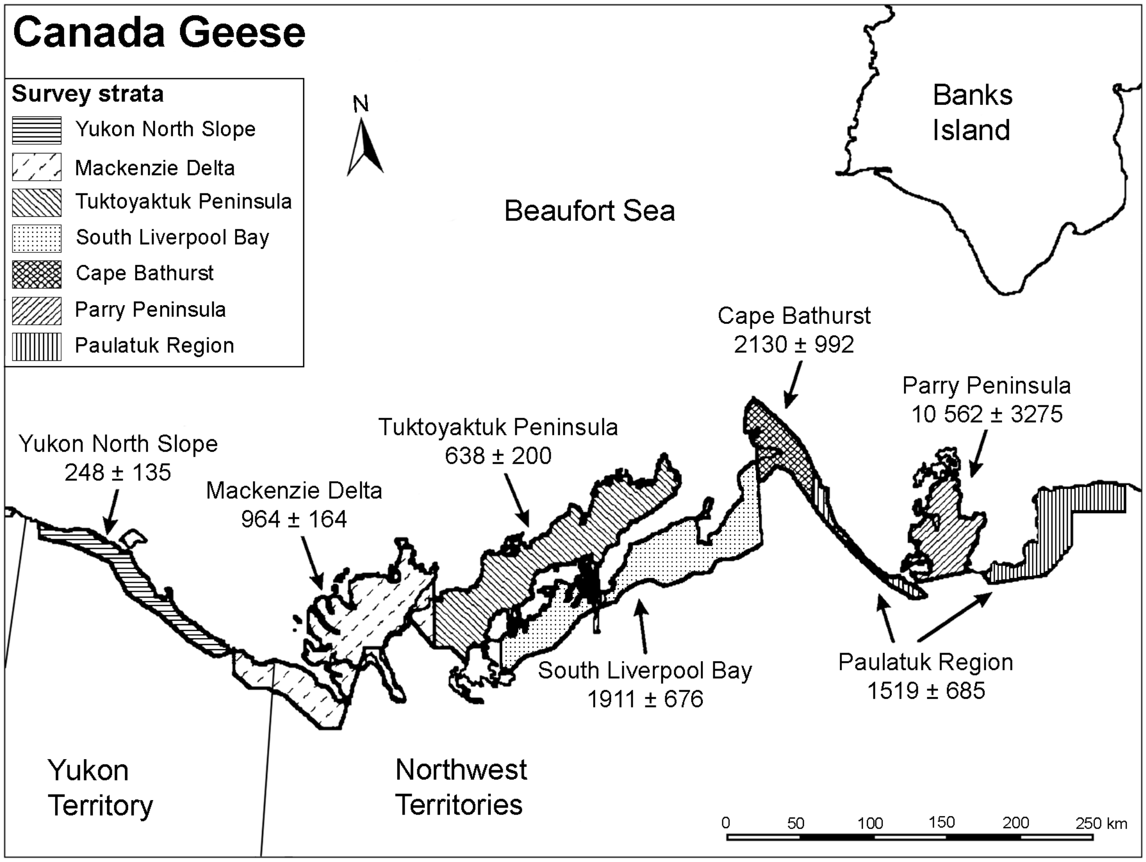
[a] Visibility correction factor.

Table 7
Estimated densities and numbers of Canada Geese in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Geese observed	Number of transects	Area (km^2)	Density ± SE ($geese/km^2$)	Number of geese ± SE
Kugaluk River	1991	13	7	64	1.02 ± 0.70	65 ± 45
	1992	23	7	64	1.80 ± 1.08	115 ± 69
	1993	2	7	64	0.16 ± 0.14	10 ± 9
				Average (no VCF[a])	0.99 ± 0.43	64 ± 28
Campbell Island	1991	36	5	41	4.50 ± 4.55	183 ± 185
	1992	0	5	41	0.00 ± 0.00	0 ± 0
	1993	0	5	41	0.00 ± 0.00	0 ± 0
				Average (no VCF)	1.50 ± 1.52	61 ± 62
Smoke–Moose rivers	1991	451	7	82	26.85 ± 14.75	2213 ± 1216
	1992	7	7	82	0.42 ± 0.25	34 ± 20
	1993	21	7	82	1.25 ± 0.60	103 ± 50
				Average (no VCF)	9.50 ± 4.92	784 ± 406
Anderson River	1991	11	4	104	0.53 ± 0.33	55 ± 34
	1992	24	4	104	1.15 ± 0.77	120 ± 81
	1993	2	4	104	0.10 ± 0.10	10 ± 10
				Average (no VCF)	0.59 ± 0.28	62 ± 29
Mason River	1991	14	5	68	1.03 ± 1.02	70 ± 70
	1992	0	5	68	0.00 ± 0.00	0 ± 0
	1993	51	5	68	3.75 ± 3.49	256 ± 238
				Average (no VCF)	1.59 ± 1.21	109 ± 83
Maitland Point	1991	161	6	40	20.13 ± 12.59	813 ± 509
	1992	0	6	40	0.00 ± 0.00	0 ± 0
	1993	11	6	40	1.38 ± 1.19	56 ± 48
				Average (no VCF)	7.17 ± 4.22	290 ± 170
Harrowby Bay	1991	1678	7	101	83.90 ± 60.05	8486 ± 6073
	1992	7	9	113	0.29 ± 0.29	33 ± 32
	1993	158	9	113	6.58 ± 3.95	741 ± 445
				Average (no VCF)	30.26 ± 20.06	3407 ± 2258
Entire moulting stratum (no VCF)				513	9.31 ± 4.49	4775 ± 2304

[a] Visibility correction factor.

Figure 4
Mean annual number (± standard error) of Canada Geese present in the different survey strata in the Inuvialuit Settlement Region, 1989–1993



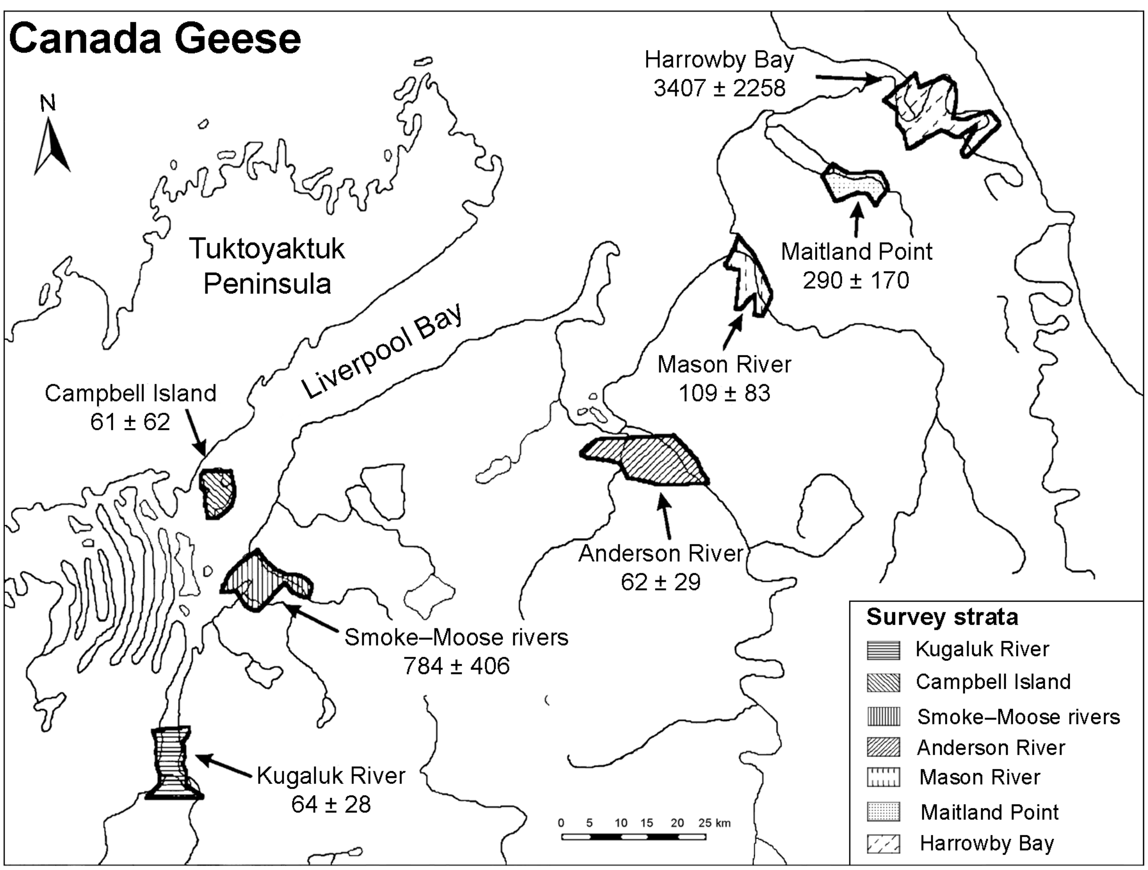


Table 8
Estimated densities and numbers of Canada Goose pairs in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	Number of pairs ± SE
Mackenzie Delta	1989	7	9	3 668	0.05 ± 0.03	165 ± 94
	1990	8	23	6 091	0.02 ± 0.01	137 ± 52
	1991	14	24	6 091	0.04 ± 0.01	223 ± 73
	1992	15	24	6 091	0.04 ± 0.02	239 ± 107
	1993	20	24	6 091	0.05 ± 0.01	319 ± 70
				Average (no VCF[a])	0.04 ± 0.01	239 ± 45
				Average (adjusted by VCF)	0.06 ± 0.01	358 ± 68
Tuktoyaktuk Peninsula	1989	8	17	6 652	0.03 ± 0.02	198 ± 100
	1990	1	17	6 652	0.00 ± 0.00	25 ± 24
	1991	4	17	6 652	0.02 ± 0.01	99 ± 46
	1992	3	17	6 652	0.01 ± 0.01	74 ± 37
	1993	6	17	6 652	0.02 ± 0.01	148 ± 82
				Average (no VCF)	0.02 ± 0.00	109 ± 29
				Average (adjusted by VCF)	0.02 ± 0.01	164 ± 43
South Liverpool Bay	1989	12	15	3 280	0.07 ± 0.02	222 ± 73
	1990	8	15	3 500	0.05 ± 0.02	163 ± 62
	1991	18	21	4 721	0.08 ± 0.03	398 ± 126
	1992	10	21	4 721	0.05 ± 0.02	221 ± 75
	1993	13	21	5 796	0.05 ± 0.01	277 ± 83
				Average (no VCF)	0.06 ± 0.01	338 ± 51
				Average (adjusted by VCF)	0.09 ± 0.01	508 ± 77
Cape Bathurst	1991	1	7	1 737	0.01 ± 0.01	22 ± 23
	1992	4	4	1 279	0.08 ± 0.04	98 ± 53
	1993	3	4	1 279	0.06 ± 0.02	74 ± 29
				Average (no VCF)	0.05 ± 0.02	85 ± 28
				Average (adjusted by VCF)	0.07 ± 0.02	128 ± 43
Yukon North Slope	1990	4	11	1 821	0.05 ± 0.03	83 ± 45
				(adjusted by VCF)	0.07 ± 0.04	124 ± 68
Parry Peninsula	1991	44	6	2 784	0.43 ± 0.11	1 196 ± 310
				(adjusted by VCF)	0.65 ± 0.17	1 794 ± 465
Paulatuk Region	1991	8	10	1 724	0.10 ± 0.03	172 ± 52
				(adjusted by VCF)	0.15 ± 0.05	259 ± 79
All non-moulting strata (adjusted by VCF)				26 605	0.13 ± 0.02	3 335 ± 491

[a] Visibility correction factor.

Table 9
Estimated densities and numbers of Canada Goose pairs in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km^2)	Density ± SE ($pairs/km^2$)	Number of pairs ± SE
Kugaluk River	1991	0	7	64	0.00 ± 0.00	0 ± 0
	1992	2	7	64	0.16 ± 0.09	10 ± 6
	1993	1	7	64	0.08 ± 0.07	5 ± 5
				Average (no VCF[a])	0.08 ± 0.04	5 ± 2
Campbell Island	1991	1	5	41	0.13 ± 0.13	5 ± 5
	1992	0	5	41	0.00 ± 0.00	0 ± 0
	1993	0	5	41	0.00 ± 0.00	0 ± 0
				Average (no VCF)	0.04 ± 0.04	2 ± 2
Smoke–Moose rivers	1991	4	7	82	0.24 ± 0.19	20 ± 16
	1992	2	7	82	0.12 ± 0.11	10 ± 9
	1993	4	7	82	0.24 ± 0.14	20 ± 11
				Average (no VCF)	0.20 ± 0.09	16 ± 7
Anderson River	1991	1	4	104	0.05 ± 0.05	5 ± 5
	1992	0	4	104	0.00 ± 0.00	0 ± 0
	1993	1	4	104	0.05 ± 0.05	5 ± 5
				Average (no VCF)	0.03 ± 0.02	3 ± 2
Mason River	1991	0	5	68	0.00 ± 0.00	0 ± 0
	1992	0	5	68	0.00 ± 0.00	0 ± 0
	1993	1	5	68	0.07 ± 0.07	5 ± 5
				Average (no VCF)	0.02 ± 0.02	2 ± 2
Maitland Point	1991	2	6	40	0.25 ± 0.15	10 ± 6
	1992	0	6	40	0.00 ± 0.00	0 ± 0
	1993	0	6	40	0.00 ± 0.00	0 ± 0
				Average (no VCF)	0.08 ± 0.05	3 ± 2
Harrowby Bay	1991	2	7	101	0.10 ± 0.06	10 ± 6
	1992	0	9	113	0.00 ± 0.00	0 ± 0
	1993	3	9	113	0.13 ± 0.07	14 ± 7
				Average (no VCF)	0.08 ± 0.03	8 ± 3
Entire moulting stratum (no VCF)				513	0.08 ± 0.02	40 ± 9

[a] Visibility correction factor.

Table 10
Estimated densities and numbers of Tundra Swans in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Swans observed	Number of transects	Area (km²)	Density ± SE (swans/km²)	Number of swans ± SE
Mackenzie Delta	1989	132	9	3 668	0.85 ± 0.15	3 120 ± 542
	1990	204	23	6 091	0.57 ± 0.06	3 498 ± 350
	1991	298	24	6 091	0.78 ± 0.12	4 747 ± 736
	1992	307	24	6 091	0.80 ± 0.24	4 890 ± 1 445
	1993	431	24	6 091	1.13 ± 0.38	6 865 ± 2 304
			Average (no VCF[a])		0.83 ± 0.10	5 036 ± 595
			Average (adjusted by VCF)		0.83 ± 0.10	5 036 ± 595
Tuktoyaktuk Peninsula	1989	303	17	6 652	1.13 ± 0.19	7 498 ± 1 232
	1990	227	17	6 652	0.84 ± 0.08	5 618 ± 534
	1991	197	17	6 652	0.73 ± 0.10	4 875 ± 631
	1992	223	17	6 652	0.83 ± 0.26	5 519 ± 1 754
	1993	244	17	6 652	0.91 ± 0.09	6 038 ± 620
			Average (no VCF)		0.89 ± 0.07	5 910 ± 476
			Average (adjusted by VCF)		0.89 ± 0.07	5 910 ± 476
South Liverpool Bay	1989	197	15	3 280	1.11 ± 0.21	3 638 ± 671
	1990	122	15	3 500	0.69 ± 0.23	2 486 ± 830
	1991	124	21	4 721	0.58 ± 0.11	2 741 ± 501
	1992	136	21	4 721	0.64 ± 0.11	3 006 ± 522
	1993	198	21	5 796	0.73 ± 0.20	4 219 ± 1 163
			Average (no VCF)		0.75 ± 0.08	4 344 ± 462
			Average (adjusted by VCF)		0.75 ± 0.08	4 344 ± 462
Cape Bathurst	1991	14	7	1 737	0.18 ± 0.09	313 ± 152
	1992	8	4	1 279	0.15 ± 0.04	197 ± 53
	1993	10	4	1 279	0.19 ± 0.05	246 ± 61
			Average (no VCF)		0.18 ± 0.04	305 ± 62
			Average (adjusted by VCF)		0.18 ± 0.04	305 ± 62
Yukon North Slope	1990	22	11	1 821	0.25 ± 0.08	455 ± 153
			(adjusted by VCF)		0.25 ± 0.08	455 ± 153
Parry Peninsula	1991	27	6	2 784	0.26 ± 0.06	734 ± 172
			(adjusted by VCF)		0.26 ± 0.06	734 ± 172
Paulatuk Region	1991	6	10	1 724	0.08 ± 0.04	129 ± 64
			(adjusted by VCF)		0.08 ± 0.04	129 ± 64
All non-moulting strata (adjusted by VCF)				26 605	0.64 ± 0.03	16 913 ± 925

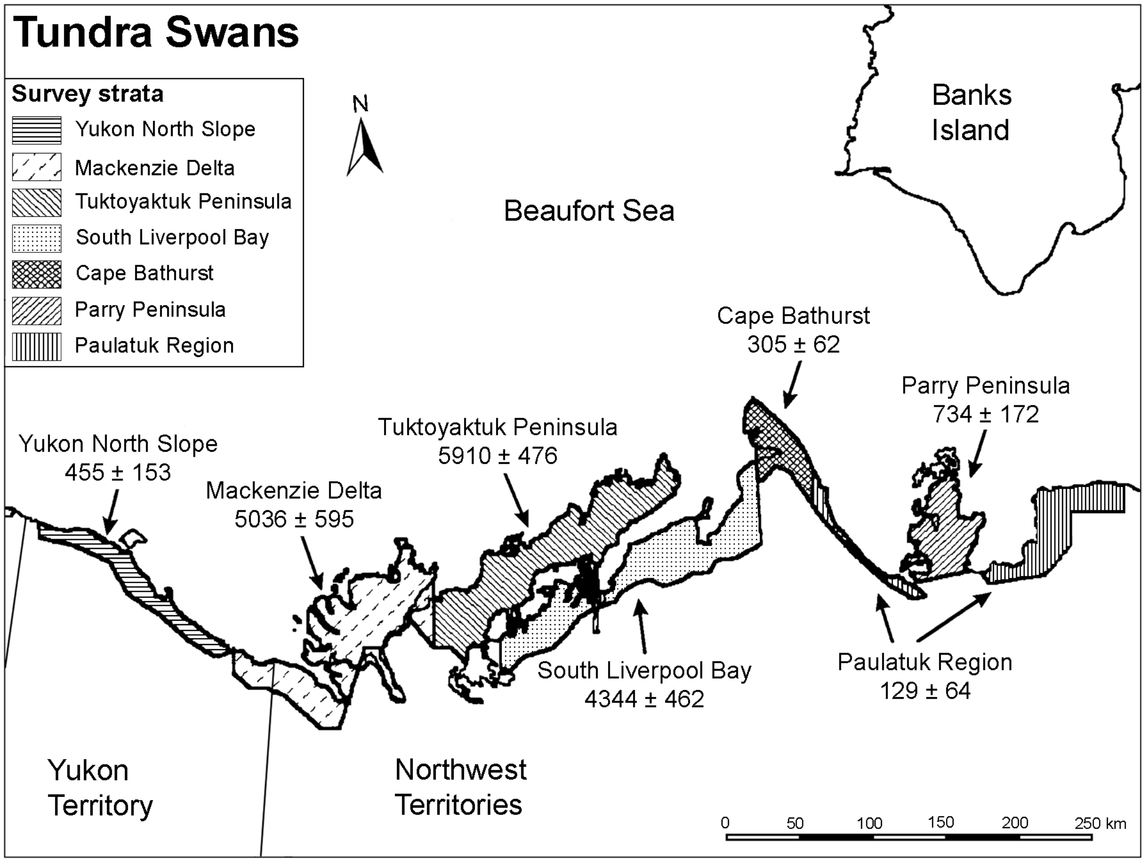
[a] Visibility correction factor.

Table 11
Estimated densities and numbers of Tundra Swans in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Swans observed	Number of transects	Area (km²)	Density ± SE (swans/km²)	Number of swans ± SE
Kugaluk River	1991	277	7	64	21.64 ± 9.52	1389 ± 611
	1992	301	7	64	23.52 ± 12.39	1509 ± 795
	1993	207	7	64	16.17 ± 7.10	1038 ± 456
			Average (no VCF[a])		20.44 ± 5.72	1312 ± 367
Campbell Island	1991	1	5	41	0.13 ± 0.10	5 ± 4
	1992	16	5	41	2.00 ± 1.31	81 ± 53
	1993	3	5	41	0.38 ± 0.23	15 ± 9
			Average (no VCF)		0.83 ± 0.44	34 ± 18
Smoke–Moose rivers	1991	32	7	82	1.90 ± 0.88	157 ± 73
	1992	18	7	82	1.07 ± 0.40	88 ± 33
	1993	3	7	82	0.18 ± 0.10	15 ± 8
			Average (no VCF)		1.05 ± 0.32	87 ± 27
Anderson River	1991	9	4	104	0.43 ± 0.16	45 ± 17
	1992	24	4	104	1.15 ± 0.05	120 ± 5
	1993	22	4	104	1.06 ± 0.38	110 ± 40
			Average (no VCF)		0.88 ± 0.14	92 ± 14
Mason River	1991	5	5	68	0.37 ± 0.20	25 ± 13
	1992	9	5	68	0.66 ± 0.53	45 ± 36
	1993	10	5	68	0.74 ± 0.35	50 ± 24
			Average (no VCF)		0.59 ± 0.22	40 ± 15
Maitland Point	1991	0	6	40	0.00 ± 0.00	0 ± 0
	1992	7	6	40	0.88 ± 0.76	35 ± 31
	1993	1	6	40	0.13 ± 0.11	5 ± 4
			Average (no VCF)		0.33 ± 0.26	13 ± 10
Harrowby Bay	1991	5	7	101	0.25 ± 0.13	25 ± 13
	1992	11	9	113	0.46 ± 0.23	52 ± 26
	1993	19	9	113	0.79 ± 0.24	89 ± 27
			Average (no VCF)		0.50 ± 0.12	56 ± 13
Entire moulting stratum (no VCF)				513	3.19 ± 0.72	1634 ± 370

[a] Visibility correction factor.

Figure 5
Mean annual number (± standard error) of Tundra Swans present in the different survey strata in the Inuvialuit Settlement Region, 1989–1993



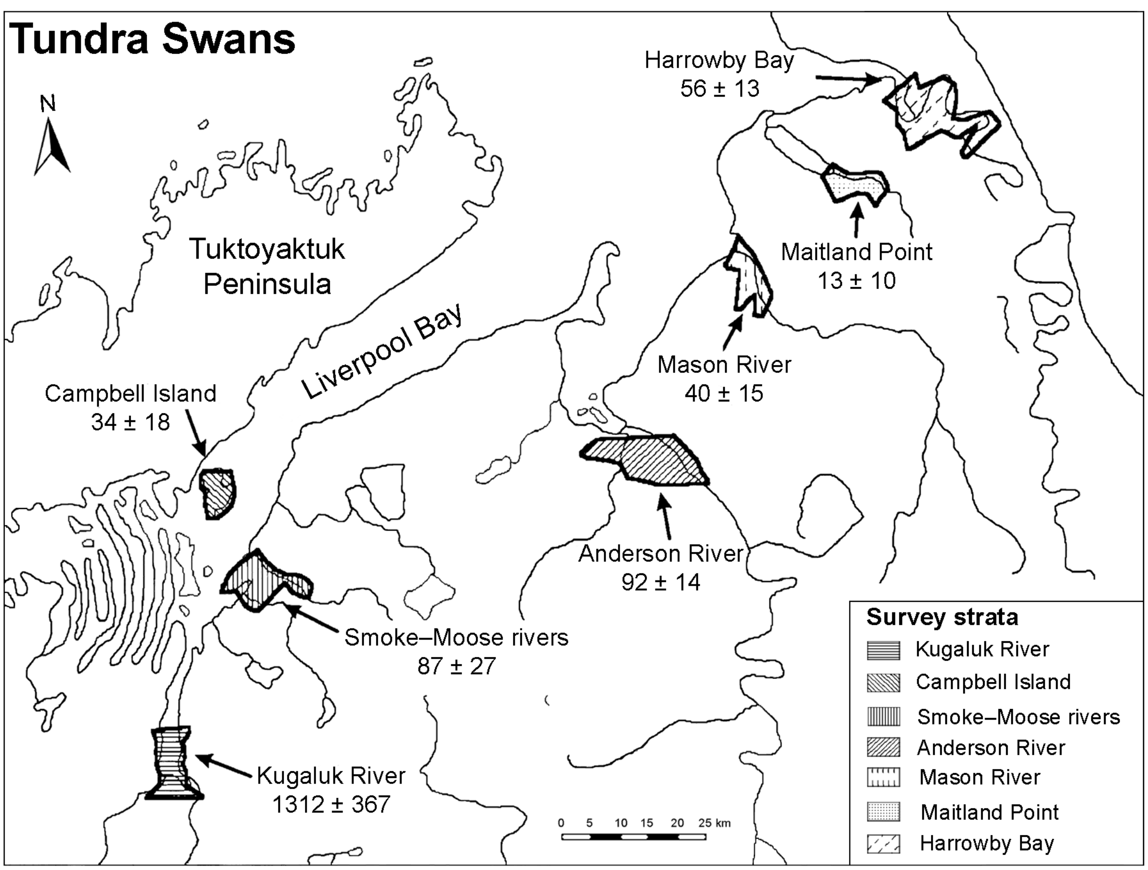


Table 12
Estimated densities and numbers of Tundra Swan pairs in survey strata on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km²)	Density ± SE (pairs/km²)	Number of pairs ± SE
Mackenzie Delta	1989	66	9	3 668	0.43 ± 0.07	1 560 ± 271
	1990	98	23	6 091	0.27 ± 0.03	1 672 ± 162
	1991	131	24	6 091	0.34 ± 0.03	2 087 ± 193
	1992	114	24	6 091	0.30 ± 0.03	1 808 ± 172
	1993	143	24	6 091	0.37 ± 0.03	2 278 ± 171
			Average (no VCF[a])		0.34 ± 0.02	2 087 ± 114
			Average (adjusted by VCF)		0.34 ± 0.02	2 087 ± 114
Tuktoyaktuk Peninsula	1989	141	17	6 652	0.53 ± 0.07	3 489 ± 467
	1990	100	17	6 652	0.37 ± 0.04	2 462 ± 295
	1991	90	17	6 652	0.33 ± 0.04	2 215 ± 270
	1992	86	17	6 652	0.32 ± 0.06	2 116 ± 389
	1993	115	17	6 652	0.43 ± 0.04	2 846 ± 243
			Average (no VCF)		0.39 ± 0.02	2 626 ± 153
			Average (adjusted by VCF)		0.39 ± 0.02	2 626 ± 153
South Liverpool Bay	1989	78	15	3 280	0.44 ± 0.07	1 441 ± 224
	1990	35	15	3 500	0.20 ± 0.04	713 ± 137
	1991	54	21	4 721	0.25 ± 0.04	1 182 ± 207
	1992	62	21	4 721	0.29 ± 0.04	1 359 ± 185
	1993	74	21	5 796	0.27 ± 0.05	1 566 ± 263
			Average (no VCF)		0.29 ± 0.02	1 677 ± 125
			Average (adjusted by VCF)		0.29 ± 0.02	1 677 ± 125
Cape Bathurst	1991	6	7	1 737	0.07 ± 0.03	123 ± 53
	1992	4	4	1 279	0.08 ± 0.02	98 ± 26
	1993	5	4	1 279	0.10 ± 0.02	123 ± 30
			Average (no VCF)		0.08 ± 0.01	141 ± 25
			Average (adjusted by VCF)		0.08 ± 0.01	141 ± 25
Yukon North Slope	1990	11	11	1 821	0.13 ± 0.04	228 ± 76
			(adjusted by VCF)		0.13 ± 0.04	228 ± 76
Parry Peninsula	1991	14	6	2 784	0.13 ± 0.03	367 ± 86
			(adjusted by VCF)		0.13 ± 0.03	367 ± 86
Paulatuk Region	1991	3	10	1 724	0.04 ± 0.02	65 ± 32
			(adjusted by VCF)		0.04 ± 0.02	65 ± 32
All non-moulting strata (adjusted by VCF)				26 605	0.27 ± 0.01	7 190 ± 259

[a] Visibility correction factor.

Table 13
Estimated densities and numbers of Tundra Swan pairs in moulting areas on the mainland of the Inuvialuit Settlement Region, June, 1989–1993

Stratum	Year	Pairs observed	Number of transects	Area (km²)	Density ± SE (pairs/km²)	Number of pairs ± SE
Kugaluk River	1991	11	7	64	0.82 ± 0.26	53 ± 16
	1992	20	7	64	1.52 ± 0.60	98 ± 39
	1993	17	7	64	1.29 ± 0.41	83 ± 26
			Average (no VCF[a])		1.21 ± 0.26	78 ± 17
Campbell Island	1991	1	5	41	0.06 ± 0.05	3 ± 2
	1992	2	5	41	0.25 ± 0.12	10 ± 5
	1993	2	5	41	0.19 ± 0.12	8 ± 5
			Average (no VCF)		0.17 ± 0.06	7 ± 2
Smoke–Moose rivers	1991	4	7	82	0.21 ± 0.07	17 ± 6
	1992	9	7	82	0.54 ± 0.20	44 ± 16
	1993	2	7	82	0.09 ± 0.05	7 ± 4
			Average (no VCF)		0.28 ± 0.07	23 ± 6
Anderson River	1991	5	4	104	0.22 ± 0.08	23 ± 8
	1992	12	4	104	0.58 ± 0.03	60 ± 3
	1993	11	4	104	0.53 ± 0.19	55 ± 20
			Average (no VCF)		0.44 ± 0.07	46 ± 7
Mason River	1991	3	5	68	0.18 ± 0.10	13 ± 7
	1992	3	5	68	0.18 ± 0.13	13 ± 9
	1993	2	5	68	0.15 ± 0.10	10 ± 7
			Average (no VCF)		0.17 ± 0.06	12 ± 4
Maitland Point	1991	0	6	40	0.00 ± 0.00	0 ± 0
	1992	0	6	40	0.00 ± 0.00	0 ± 0
	1993	1	6	40	0.06 ± 0.05	3 ± 2
			Average (no VCF)		0.02 ± 0.02	1 ± 1
Harrowby Bay	1991	3	7	101	0.13 ± 0.06	13 ± 7
	1992	2	9	113	0.08 ± 0.05	9 ± 5
	1993	10	9	113	0.40 ± 0.12	45 ± 14
			Average (no VCF)		0.20 ± 0.05	23 ± 5
Entire moulting stratum (no VCF)				513	0.37 ± 0.04	189 ± 20

[a] Visibility correction factor.

Table 14
Productivity of geese and swans on the mainland of the Inuvialuit Settlement Region as measured by transect counts of adults in June and broods in July, 1990–1993

Year	Area surveyed (km^2)	Pairs	Broods	Average brood size	Broods per pair	% young in population
Greater White-fronted Goose						
1990	6091	51	14	3.2	0.27	16.9
1991	6091	51	28	4.0	0.55	27.3
1992	8509	159	2	1.0	0.01	0.2
1993	8372	169	36	3.9	0.21	12.5
Average	7266	108	20	3.0	0.26	14.2
Canada Goose						
1990	6091	8	5	2.8	0.63	46.7
1991	6091	14	2	4.5	0.14	20.9
1992	8509	20	2	3.0	0.10	5.0
1993	8372	33	9	2.4	0.27	7.3
Average	7266	19	5	3.2	0.29	20.0
Tundra Swan						
1990	6091	98	25	2.5	0.26	23.3
1991	6091	131	30	2.3	0.23	17.0
1992	8509	195	23	2.6	0.12	6.3
1993	8372	227	54	2.7	0.24	11.8
Average	7266	163	33	2.5	0.21	14.6

Table 15
Mean daily temperatures at Tuktoyaktuk, Northwest Territories, in spring, 1990–1993[a]

	Mean daily temperature (°C)				
Date	1990	1991	1992	1993	P
1–15 May	-7.62^{ac}	1.12^{b}	-11.88^{c}	-6.49^{a}	0.0001
16–31 May	-1.09^{a}	1.51^{a}	-0.82^{a}	0.08^{a}	0.144
1–15 June	2.65^{ab}	1.34^{b}	1.65^{b}	5.53^{a}	0.007
16–30 June	10.87^{a}	8.67^{a}	10.87^{a}	8.83^{a}	0.357

[a] P-values are from ANOVA comparisons among years. Means with the same letter are not significantly different based on Duncan's Multiple Range test.

the Inuvialuit Settlement Region (>27 000 km^2) where geese and swans were most concentrated, but almost 80% of the mainland (101 000 km^2), where each of the three species occurred in low densities, could not be covered. Using data from the widespread but far less intensive waterfowl surveys conducted by the U.S. Fish and Wildlife Service each year in parts of the Northwest Territories, we estimated that the 101 000-km^2 area would have supported an additional 5250 Greater White-fronted Geese, 7253 more Canada Geese, and 10 109 more Tundra Swans.[1] If so, the total spring populations of the three species on the mainland of the Inuvialuit Settlement Region during 1989–1993 would have been about 55 600, 30 300, and 28 700, respectively. In years of average reproductive success, the total fall population size (adults plus young) emanating from the mainland of the Inuvialuit Settlement Region would have numbered about 74 000 Greater White-fronted Geese, 40 000 Canada Geese, and 33 000 Tundra Swans and represented about 11% of the Mid-continent Population of Greater White-fronted Geese, 9% of the Short-grass Prairie Population of Canada Geese, and 35% of the Eastern Population of Tundra Swans.[2] These data underscore the importance of the mainland of the Inuvialuit Settlement Region to continental waterfowl populations.

Estimated numbers of all three species in the 12 743-km^2 area surveyed annually varied from year to year. We believe that some of the variability in goose counts reflected the annual differences in the visibility of the birds, which is less in years when nesting effort is high (Bromley et al. 1995). Given that both our overall population estimates and visibility correction factors were derived over a number of years, annual variations in visibility of geese should not influence these average estimates to any great extent. The 1990–1993 averaged estimates for total numbers and breeding pairs of both Greater White-fronted Geese and Tundra Swans were relatively precise, and repeated surveys should allow us to detect population changes of 20% or less. The estimates for Canada Geese, although less precise, would still allow the detection of a 35% change in population size of that species.

[1] Data are for Stratum 14 of the Aerial Waterfowl Breeding Ground Population and Habitat Survey (Smith 1995). Stratum 14 stretches from the north side of Great Bear Lake to near the southern edge of our study area and encompasses an area of 202 796 km^2. Average densities of Greater White-fronted Geese, Canada Geese, and Tundra Swans in this area were 0.05, 0.07, and 0.10 birds/km^2, respectively, in 1989–1993. Goose population estimates presented by Smith (1995) have been corrected by a visibility correction factor of 2.5 for fixed-wing aircraft.

[2] Fall populations of Arctic geese contain, on average, about 25% young, and the Eastern Population of Tundra Swans contains, on average, about 15% young (see Bellrose 1980; Serie and Bartonek 1991; Ely and Dzubin 1994). Average fall or winter population estimates for geese and swans for 1989–1993 were 676 000 for the Mid-continent Population of Greater White-fronted Geese, 455 000 for the Short-grass Prairie Population of Canada Geese, and 93 000 for the Eastern Population of Tundra Swans (Sharp 1997).

Goose and swan populations from the Inuvialuit Settlement Region face a number of potential conservation problems, as evidenced by increasingly high rates of harvest, reduced rates of survival, and declining fall and winter counts of both Mid-continent Greater White-fronted Geese and Short-grass Prairie Canada Geese (Canadian Wildlife Service Waterfowl Committee 2002). Planned gas and oil development in the heart of the Tundra Swan range in the Mackenzie Delta and environs poses potential future problems for all species of waterfowl as well as swans. Therefore, we recommend that surveys of our core study area be carried out in the near future and repeated for three consecutive years out of every 10 years to monitor the well-being of regional waterfowl populations.

In the study area (6091–8372 km^2) surveyed in both June and July of 1990–1993, the productivity of both geese and swans varied in parallel and in accordance with spring weather. In general, reproductive success of all species was highest in the earliest springs and lowest during the coolest springs. Spring weather and timing of snowmelt have long been known to be critical factors limiting the reproductive success of Arctic waterfowl (e.g., Barry 1962; Newton 1977; Ganter and Boyd 2000). The fact that the reproductive success of the three species varied in parallel is of great interest. Tundra Swans, because of their appearance, size, and behaviour, are perhaps the ideal type of waterfowl to survey from the air and potentially can provide a useful index of the annual productivity for many species of waterfowl sharing the same general areas (King 1973; Lensink 1973). The Mackenzie Delta is one of the most important wetland ecosystems in the Arctic and is internationally recognized as one of the most important waterfowl habitats in North America (U.S. Department of the Interior and Environment Canada 1986). Monitoring of swan numbers and productivity in the Mackenzie Delta should provide a valuable indicator of the impact of industrial development and global climate change on the aquatic birds of this important habitat.

5. Acknowledgements

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Inuvialuit ecological knowledge of King Eiders, Pacific Common Eiders, Black Brant, and some other birds near Holman and Sachs Harbour, Northwest Territories

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Abstract

In 1992–1993, interviews of Inuvialuit hunters from Holman on Victoria Island and Sachs Harbour on Banks Island, Northwest Territories, were used to document local knowledge of King Eiders *Somateria spectabilis*, the Pacific race of Common Eider *Somateria mollissima v-nigra*, Black Brant *Branta bernicla nigricans*, Lesser Snow Geese *Anser caerulescens caerulescens*, and some other common species of birds. Interview topics included spring migration, nesting, moulting, brood rearing, fall migration, subsistence hunting, and general ecology. Much of the information provided by hunters was geographic in nature and is best represented on maps. From a waterfowl management perspective, information gathered on (1) the migration paths and nesting areas used by eiders near Holman and (2) the areas used by nesting Black Brant and migrating Lesser Snow Geese near Sachs Harbour is especially useful.

1. Introduction

Waterfowl are of great socioeconomic importance to the Inuvialuit of the Western Canadian Arctic. To guarantee the successful long-term management and conservation of waterfowl in the Inuvialuit Settlement Region, a better understanding of the basic biology of a number of species is required. In particular, better information on the habitat, distribution, and abundance of King Eiders *Somateria spectabilis*, the Pacific race of Common Eider *Somateria mollissima v-nigra* (referred to as Common Eiders or Pacific Common Eiders), and Black Brant *Branta bernicla nigricans* is necessary.

In northern Canada, an effective method of obtaining qualitative information on many species of wildlife is through discussions with Aboriginal hunters. Because of their need to harvest animals for food, the Inuvialuit and other native hunters can be expected to possess a good knowledge of the habitat, seasonal distribution, and abundance of many game animals. Migration routes, breeding areas, staging and moulting sites, behaviour, and body condition are all important considerations for subsistence hunters. The perceptions of native hunters concerning the abundance and distribution of harvested species can provide useful information that might not otherwise be available to wildlife managers.

In 1992 and 1993, the Canadian Wildlife Service interviewed Inuvialuit hunters residing at Holman on Victoria Island and at Sachs Harbour on Banks Island, Northwest Territories (Fig. 1). At that time, relatively few waterfowl surveys had been carried out on these mid-Arctic islands. The objectives of the interviews were to document local knowledge of the distribution, abundance, and ecology of King Eiders, Common Eiders, Black Brant, and other common species of waterfowl. We also recorded information on other species of migratory birds reported here, along with the findings on the focus species.

2. Study area

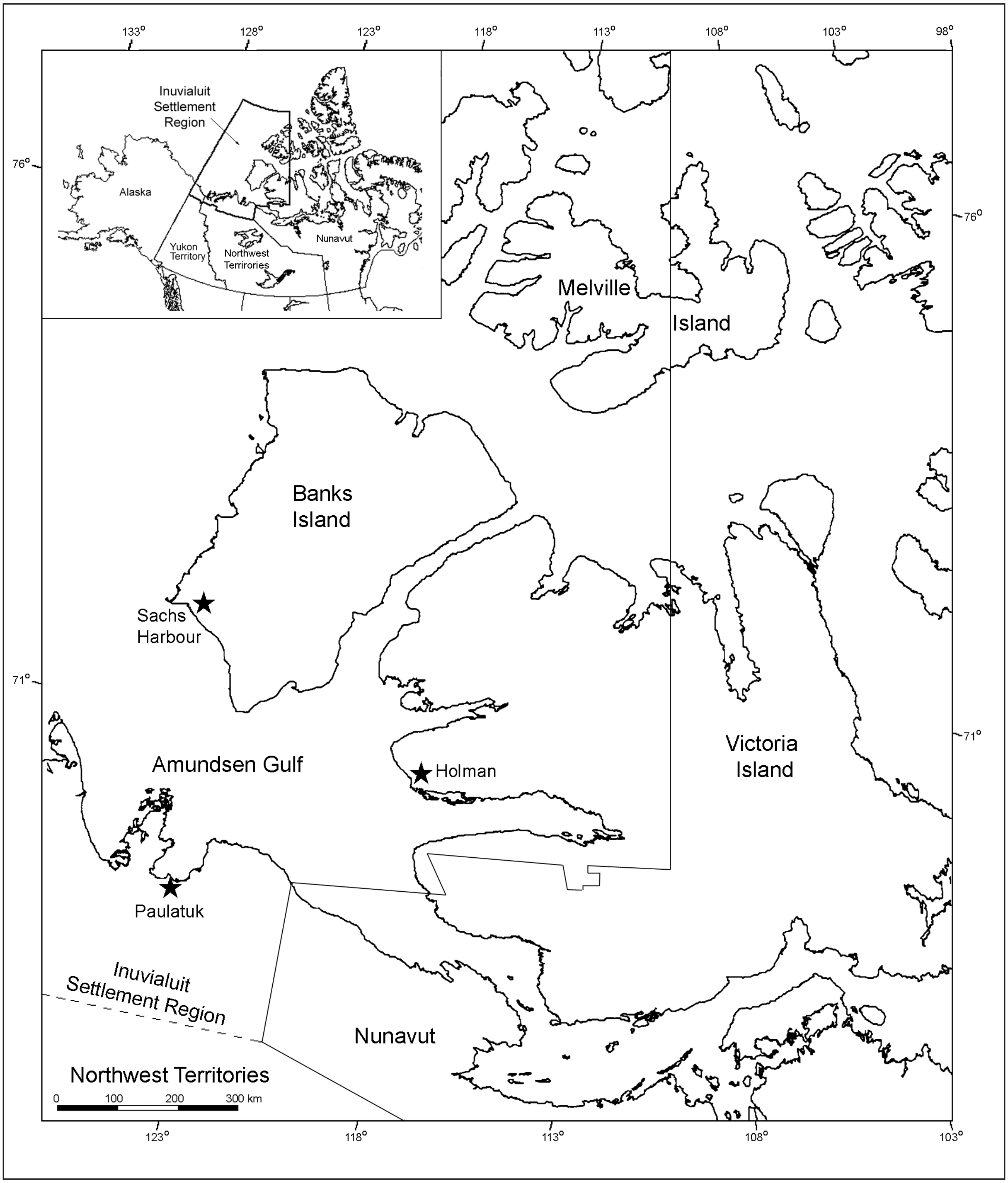
Interviews of Inuvialuit hunters were conducted at Holman (70°44′N, 117°45′W) (population 345) and Sachs Harbour (71º59′N, 125º10′W) (population 161), Northwest Territories, in 1992 and 1993 (Fig. 1). Residents of both settlements rely heavily on subsistence harvest of wildlife.

2.1 Sachs Harbour

Sachs Harbour is located on Banks Island, the most westerly island of the Canadian Arctic Archipelago (Fig. 1). Banks Island has a "polar desert" climate, with short, cool summers and long, dry winters (Steere and Scotter 1979). The annual mean daily air temperature at Sachs Harbour is −13.3°C. Mean daily temperatures during June, July, and August are 2.9, 6.8, and 3.5°C, respectively. Mean annual precipitation is 149.4 mm, and the mean annual snowfall is 105.4 cm (Environment Canada 2003). Leads (linear openings in the sea ice) typically form in late April, and watercourses begin to thaw by June. Freeze-up begins in mid-September, and streams are completely frozen by early November (Canadian Wildlife Service 1992).

Sachs Harbour is situated on a coastal lowland plain that covers central and western Banks Island (Steere and Scotter 1979). This plain is drained by a number of westward-flowing rivers, which originate in the uplands of eastern Banks Island. Broad, well-vegetated deltas have developed where these rivers enter the Beaufort Sea. A morainal belt along eastern Banks Island has created a gently rolling to rough topography east of Sachs Harbour. This moraine forms the principal drainage divide on Banks Island.

Figure 1
Location of Sachs Harbour and Holman in the Inuvialuit Settlement Region of the Northwest Territories



A high plateau (Nelson Head) is the dominant landform at the southern end of Banks Island (Steere and Scotter 1979).

Approximately 20% of Banks Island is covered by grassland and marsh, 50% is well vegetated, and 30% consists of barren or near-barren uplands and hillsides (Manning et al. 1956). Low-lying, level areas of the coastal plain support extensive grass and sedge cover. Plant cover diminishes upslope, and hilltops support mainly sparse clumps of dwarf shrubs, cushion plants, and lichens (Canadian Wildlife Service 1992). The high plateau southeast of Sachs Harbour and the southeastern part of the island from De Salis Bay to Jesse Harbour are sparsely vegetated. In the latter areas, sedge- and grass-dominated meadows occur mainly near streams and ponds (Steere and Scotter 1979).

2.2 Holman

Western Victoria Island is in the same climate region as Banks Island (Maxwell 1980). The mean annual temperature at Holman is −11.7°C, and only June, July, August, and September have mean daily temperatures above zero (4.2, 9.2, 6.6, and 0.5°C, respectively) (Environment Canada 2003). The total annual precipitation at Holman averages 162.4 mm, slightly over half of which occurs as snowfall (Environment Canada 2003).

The relief of western Victoria Island is gently rolling to hilly, and the landscape is dotted with numerous lakes (Allen 1982). Thick morainal deposits border the northwestern part of Prince Albert Sound and also occur on the southern portion of Diamond Jenness Peninsula. The rugged terrain of these areas consists of ridge-like and irregular-shaped hills. The Minto Inlet/Kuujjua River region has numerous cliffs and rock outcrops. The Shaler Mountains, a band of rugged ridges, high plateaux, steep escarpments, linear valleys, and summits rising to 500 m high, extend northeast from Holman, past the Kuujjua River to Hadley Bay (Thorsteinsson and Tozer 1962). The Kagloryuak River lowlands extend 100 km inland from the head of Prince Albert Sound.

Two dominant plant communities occur on western Victoria Island: dwarf shrub–sedge tundra on drier uplands and grass–sedge communities in lowland areas. Cover varies from continuous in some lowland areas to very sparse on drier uplands. Areas with more continuous vegetation include the Kagloryuak River lowlands, the area bordering the eastern half of Prince Albert Sound, and the small lowland at the head of Minto Inlet (Allen 1982).

3. Methods

Interviews were conducted following the "semi-directive" approach, with limited intervention by the interviewer. Nakashima and Murray (1988) considered this method to reduce interviewer bias, because it allowed hunters to discuss what they thought was important and of interest. All interviews were conducted by David Kay with the help of a local interpreter/assistant (David Kuptana in Holman and Geddes Wolkie, Sr. in Sachs Harbour). Interviews were recorded on audio tape, and the English dialogue between translator and interviewer was transcribed verbatim. Geographic information was recorded on acetate overlays of 1:250 000 topographic maps. A new sheet of acetate was used for each interview, so that the results of one interview did not affect the results of another. Data from all interviews were transferred onto a master 1:250 000 map.

Subsistence hunters (i.e., holders of Northwest Territories General Hunting Licences) at Sachs Harbour and Holman comprised a significant proportion of the population. Time constraints precluded the interviewing of all hunters, so a "short" list of potential interviewees was established using two main criteria: age and experience of the hunters. Older and more experienced hunters were chosen in order to obtain information on possible long-term changes in species population size and distribution. The list was further reduced after discussions with the two assistants to select interviewees who were most knowledgeable about wildlife in the region. In Holman, 43 individuals, ranging in age from 30 to 79 years, were interviewed. In Sachs Harbour, 14 people, ranging in age from 35 to 73 years, were interviewed.

Interview length ranged from less than one hour to more than three hours, depending on characteristics of the interviewees, such as knowledge, experience, and personality (e.g., how talkative they were). Information was acquired primarily on seven species/subspecies: Pacific Common Eiders, King Eiders, Black Brant, Canada Geese *Branta canadensis*, Lesser Snow Geese *Anser caerulescens caerulescens*, Tundra Swans *Cygnus columbianus*, and Sandhill Cranes *Grus canadensis*.

For each species, information was gathered on the following topics: (1) spring migration (chronology, routes, habitat use); (2) nesting (nest site selection, timing, duration, hatching, abundance); (3) moulting and brood rearing (location, habitat selection, chronology); (4) fall migration (chronology, patterns, habitat use); (5) subsistence hunting (location, timing); and (6) general ecology (species abundance, population changes, causes of mortality).

4. Results: Holman region

4.1 Spring migration

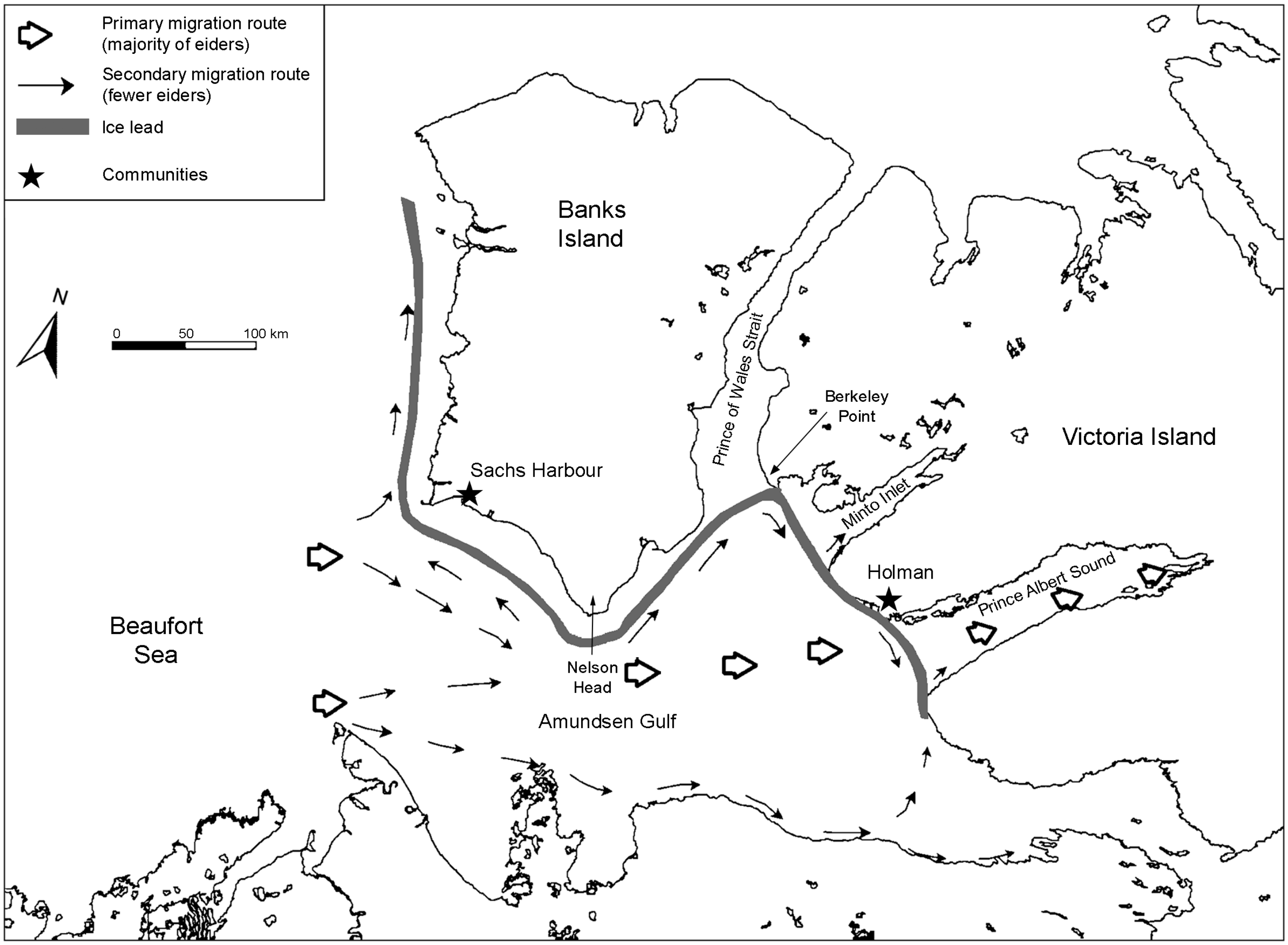
4.1.1 Sandhill Cranes, Canada Geese, and Tundra Swans

The first birds observed in the Holman region are Sandhill Cranes, Canada Geese, and Tundra Swans. These species arrive in early May when bare ground first appears. Their observed migration route is from the south. Local residents indicated that these species cross to Victoria Island from the mainland near Dolphin and Union Strait and fly past Holman en route to nesting areas.

4.1.2 Pacific Common Eiders

A large shore lead forms from Ramsay Island south along the coast to Holman Island and across the mouth of Prince Albert Sound by the end of May (Figs. 2 and 3). Other openings form where tidal currents occur near the islands in Safety Channel (Fig. 4). Pacific Common Eiders are the first waterfowl to use these staging/feeding areas, arriving in late

Figure 2
Open water leads and migration route of eiders in the Beaufort Sea/Amundsen Gulf region



May in small flocks composed of pairs. Courtship behaviour is exhibited by these early arrivals, and mating attempts are frequently observed. Pacific Common Eiders are reported to feed on molluscs and echinoderms at the main coastal shore lead. Shells and exoskeletons are sometimes seen along the ice adjacent to open water leads where eiders have been feeding.

4.1.3 King Eiders

The first King Eiders arrive in the Holman area in early June. Observations made by people who camp at Berkeley Point, Minto Inlet, and Cape Ptarmigan suggested that the main flight path originates from the direction of Nelson Head on Banks Island, with smaller numbers of eiders coming south from Prince of Wales Strait/Berkeley Point (Figs. 2 and 3).

Hunters described the spring migration as occurring in "three waves." The first wave consists of small groups of 5–10 pairs, which mix with Pacific Common Eiders already present in open water areas (Fig. 4). Feeding and courtship behaviours are exhibited by these early arrivals. A second wave arrives in mid-June in groups of 15–30 pairs. These migrants stage at open water leads and other areas that are kept free of ice by tidal currents. Pacific Common Eiders begin to nest at colonies in Prince Albert Sound, Minto Inlet, Berkeley Point, and Ramsay Island about this time (Fig. 5).

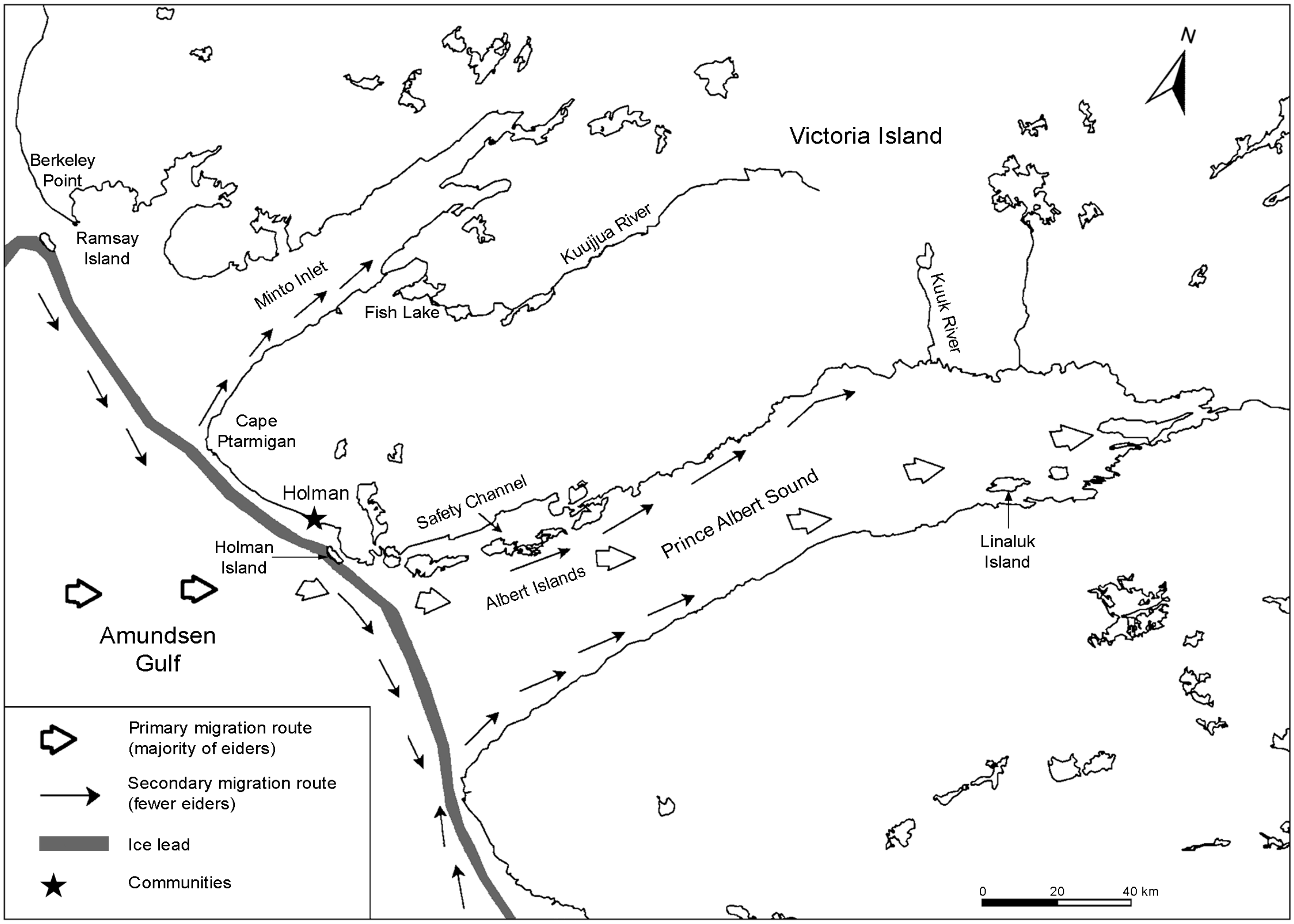
The third or "main bunch" of King Eiders arrives at Masoyuk, the traditional eider hunting "pass," around the third week in June (Figs. 3 and 4). These migrants do not stage in open water, and continuous flights of paired King Eiders are observed. Few Pacific Common Eiders are present in the final wave of migrating eiders.

The main shore lead near Holman funnels King Eiders south through Masoyuk. Most eiders then fly eastward past the islands in the Safety Channel, across Prince Albert Sound, and along the southern coast of the sound towards the mouth of the Kagloryuak River (Figs. 3 and 4). The migration period lasts about one week and is finished by the end of June.

People who have camped near Minto Inlet in spring report having seen very few migrating King Eiders and that Pacific Common Eiders, in relatively small numbers, are the main migrants. Some Holman residents formerly camped and hunted at the east end of Prince Albert Sound along the northern shore of Linaluk Island. Similar numbers of eiders are said to pass through this area as at Masoyuk (Fig. 3).

As the "third wave" of eider migration is finishing, small flocks of male King Eiders begin to arrive in the

Figure 3
Open water leads and migration route of eiders in the Holman region



Holman region from breeding areas farther east, suggesting that early nesting females are well into egg laying and that the pair bonds have broken (Lamothe 1973). These emigrant males follow the same route as immigrating flocks but pass through the Holman area without stopping to rest or feed. Their numbers increase into the first week of July, and the return migration past Holman is completed by mid-July. Most hunters believe that these migrants return to their distant moulting and wintering grounds, and no hunters reported seeing moulting King Eider males.

Based on the relative amounts of intra-abdominal and subcutaneous fat present in birds harvested at Masoyuk, female King Eiders are said to be in better body condition than males. Eggs with shells are frequently found in the reproductive tracts of harvested females, indicating the advanced breeding condition of these females. Less effort is made by hunters to hunt flocks of emigrant males, apparently because these birds are not very fat. Small numbers of emigrant male King Eiders are harvested (as are Pacific Common Eider males) for preparation as dry meat.

No subadult males are believed to be present at Holman during spring migration, and only drakes in full adult plumage are present. This observation concurs with that reported by T.W. Barry (in Palmer 1976), who suggested that very few subadult males enter the Beaufort Sea. Yearling females are thought to be present at Holman, however, and hunters believe that they can be distinguished from adults (which are said to have lighter plumage).

4.1.4 Black Brant

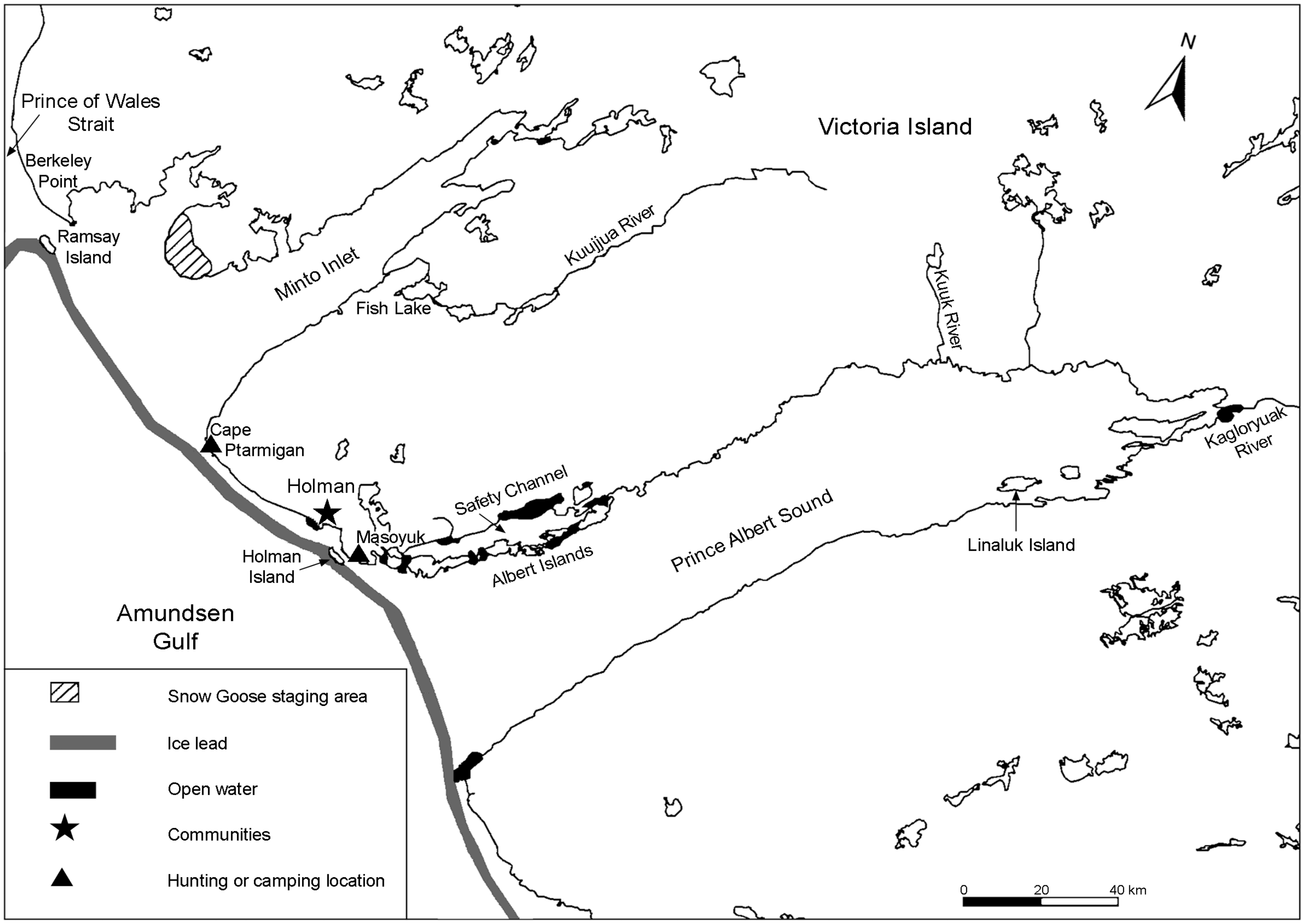
Black Brant arrive near Holman in mid- to late June, slightly before the main eider migration. Black Brant follow the same migration route as King Eiders and therefore are thought to originate from the same staging areas as well. Relatively few Brant come through the Holman area, and Brant are sparsely represented in local harvest surveys.

4.2 Nesting

4.2.1 Sandhill Cranes, Canada Geese, and Tundra Swans

Sandhill Cranes, Canada Geese, and Tundra Swans are the earliest species observed nesting in the Holman area, and all seem to have similar nesting chronologies. Egg laying is initiated shortly after arrival in early or mid-May. These species are described as being common throughout the area near Fish Lake Road (a travel route frequently used by Holman residents) and nest at low densities around inland lakes and ponds (Fig. 5). Some other areas were described as having higher densities of nesting Canada Geese. Several

Figure 4
Important hunting areas and open water staging areas for waterfowl in the Holman region



islands in Fish Lake (near the mouth of the Kuujjua River) were reported as having "lots" of nesting Canada Geese, although numbers could not be quantified (Fig. 5).

The coast and uplands to the northwest of Holman, as well as the northern coast of Prince Albert Sound (between Halahivik and the east end of Safety Channel), were stated by many people as being a "good" place for Canada Geese (Fig. 5). These people were familiar with the typical densities along the Fish Lake Road, and so this area should be considered as having relatively higher densities of nesting geese.

At the east end of Safety Channel are high cliffs that support a colony of both gulls (probably Thayer's Gulls *Larus thayeri*) and small Canada Geese (Fig. 5). It was not possible to quantify the number of goose nests present there from the interviews.

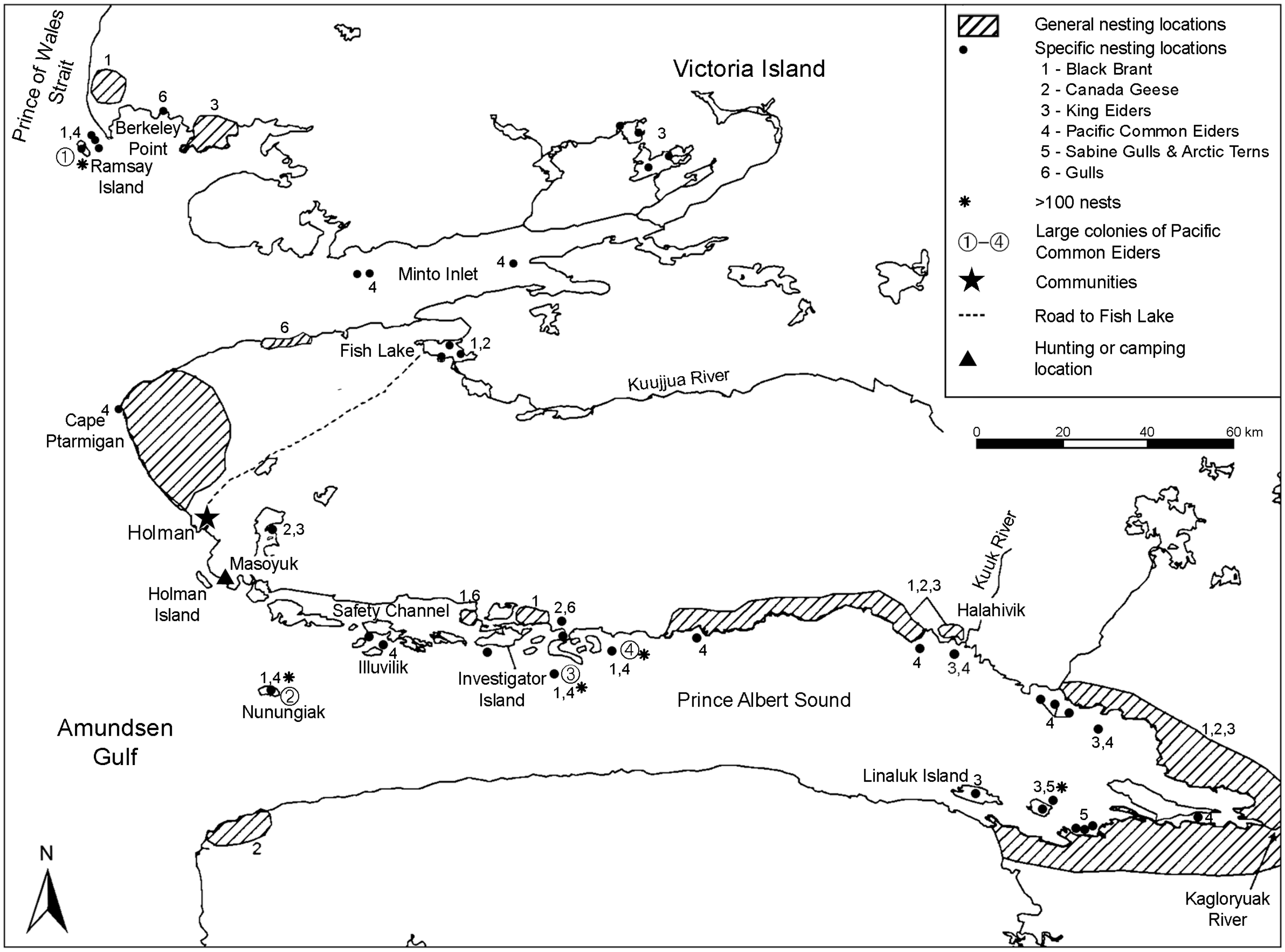
The most consistently noted area used by Canada Geese was the coast and lowlands at the head of Prince Albert Sound. An extensive area of several hundred square kilometres, stretching from the Kuuk River on the north coast down through the Kagloryuak River and along the south coast as far west as Linaluk Island, was identified as an important region for Canada Geese (Fig. 5), having the highest density of nesting Canada Geese of all areas mentioned.

4.2.2 Pacific Common Eiders

Pacific Common Eiders were observed to initiate nesting earlier than either King Eiders or Black Brant. Typical nesting dates for this species are from mid- to late June. Initiation may be delayed into July in late springs. Around the third week in June, groups of male Pacific Common Eiders are observed, suggesting that incubation has begun at nesting colonies (Abraham and Finney 1986). Twenty-two nesting colonies were identified by Holman hunters, all on offshore islands in Prince Albert Sound, in Minto Inlet, or near Ramsay Island (Fig. 5). The abundance of nesting eiders is fairly uniform from site to site, with most having 10–50 nests. Four sites were described as having "hundreds" of nests: colony 1 — Ramsay Island off Berkeley Point; colony 2 — Nunungiak (Horizon Islets) at the mouth of Prince Albert Sound and including two nearby unnamed islets in Prince Albert Sound; colony 3 — to the southeast of Investigator Island; and colony 4 — to the east of the Safety Channel archipelago (Fig. 5). All of the larger colonies had nesting Black Brant and Glaucous Gulls *Larus hyperboreus* as well as eiders. Colony 4 was described as having close to 100 Brant nests.

Pacific Common Eider pairs are observed throughout laying and into the first part of incubation. Pairs favour gravelly areas for nesting, the next most preferred areas

Figure 5
Important nesting areas for waterfowl in the Holman region



being those with plant cover. Pairs occasionally nest on solid rock and use mosses and sedges to line the nest. Old nest sites are reused, and some hunters believe that females return to the same nest they used in the previous year. Incubated clutches typically contain four eggs, although six- and seven-egg clutches were reported. Several people reported seeing both males and females incubating. This phenomenon was also reported by Inuit in Northern Quebec (Nakashima and Murray 1988).

Males tend to leave nesting females when the eggs are being incubated. Unlike King Eiders, male Pacific Common Eiders do not leave the breeding grounds immediately, and many males gather in protected bays and around islands to moult. Important moulting areas for male Pacific Common Eiders are the Safety Channel Islands in Prince Albert Sound and the coastal waters east of Berkeley Point (Fig. 6).

Small numbers of bird eggs are harvested by local people, but egging is not widespread. Gull eggs are preferred over those of eiders and other species. Apparently, the amount of egging is limited by ice conditions at peak nesting time, which restricts human access to nesting islands.

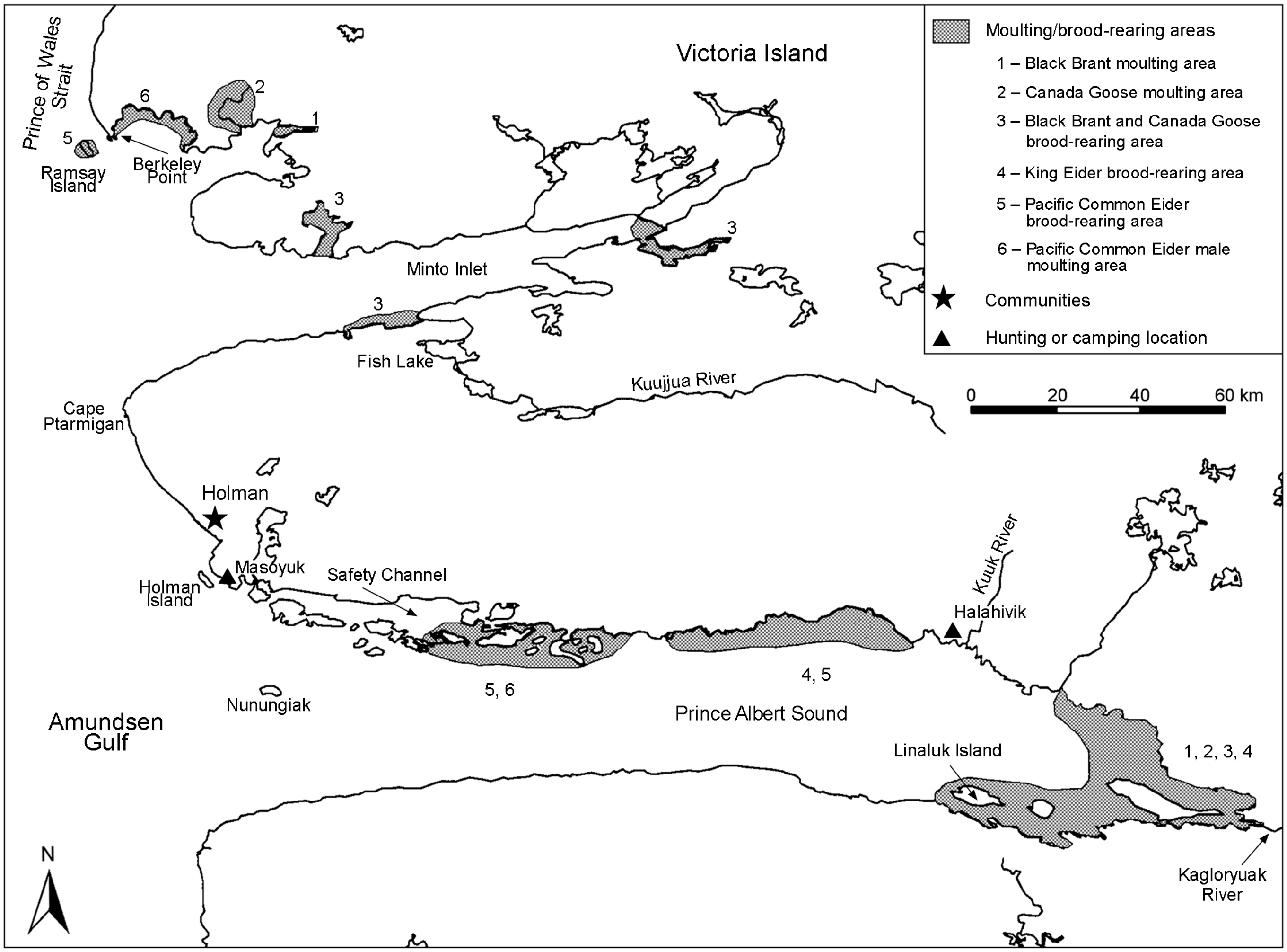
Hatching of Pacific Common Eider clutches peaks in mid- to late July, and large crèches of ducklings and females are seen around nesting islands about this time. Brood rearing occurs quite close to nesting islands (Fig. 6), and most people believe a main criterion influencing nest site selection is proximity to good feeding areas for ducklings. Crèche size in Prince Albert Sound is typically 3–10 females plus 20–50 ducklings. Crèches in the Ramsay Island area are generally larger, with hundreds of ducklings forming large rafts along the coasts. The fledging date for Pacific Common Eiders is usually early to mid-September.

4.2.3 King Eiders

King Eiders nest at low densities near ponds and lakes throughout the Holman area. Concentrations occur east of Berkeley Point, at a large lake complex north of Minto Inlet, and at Uyuoktok Lake (east of Holman). Other nesting areas occur along the coast of Prince Albert Sound from Safety Channel to Halahivik and from the Kuuk River through the Kagloryuak River valley and west to Linaluk Island (Fig. 5). One island colony, south of Investigator Island, is reported to have 20–50 females nesting beneath shelves of rock. At the east end of Prince Albert Sound, two islands were identified as having both King and Pacific Common eiders (Fig. 5).

The Linaluk Island area on the southeastern coast of Prince Albert Sound is reported to have two colonies of King Eiders (Fig. 5). One, on a small island northeast of Linaluk, is reported to contain large numbers of King Eiders as well

Figure 6
Important brood-rearing and moulting areas for waterfowl in the Holman region



as Sabine's Gulls *Xema sabini* and Arctic Terns *Sterna paradisaea*.

Nest initiation for King Eiders occurs at the end of June and continues into the first part of July. Males leave nesting females shortly after laying begins and congregate in large groups, which leave for unknown moulting areas west of Holman. Nests are situated on islands in inland lakes and around pond margins. Occasionally, nests have been found in upland areas some distance from water.

Hatching occurs in late July to early August, and females with young move to coastal areas for brood rearing. Broods hatching at inland areas near the east end of Prince Albert Sound move to rivers and then downstream to the coast. The east end of Prince Albert Sound is by far the most important brood-rearing area for King Eiders (Fig. 6). Crèches of 20–50 ducklings with attendant females can be seen at protected bays and islands there. Female King Eiders are thought to stay with broods until fledging, and no female moult migration is known to occur.

Flying young are first seen in mid- to late August. Flocks of young and female King Eiders start to move through the Holman area by early September.

4.2.4 Black Brant

Black Brant begin nesting in mid-June. Colonies of Brant occur at Berkeley Point, the islands in Fish Lake, the northeastern coast of Safety Channel, and some Pacific Common Eider colonies. Black Brant also nest in low densities along the coast northwest of Holman and along the northern and eastern coasts of Prince Albert Sound (Fig. 5). Most hunters agree that Brant are much more numerous at the head of Prince Albert Sound than near Holman and attribute this to the presence of Sabine's Gulls and Arctic Terns that nest there. Brant tend to nest in association with these and other avian species that aggressively defend the area around their nests against potential egg predators (Cotter and Hines 2001). Hatching occurs in early to mid-July, and large numbers of moulting Brant and young can be seen near the eastern end of Prince Albert Sound. Knowledge of fledging and fall movements is limited, as Black Brant are infrequently seen near Holman in the late summer and fall.

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

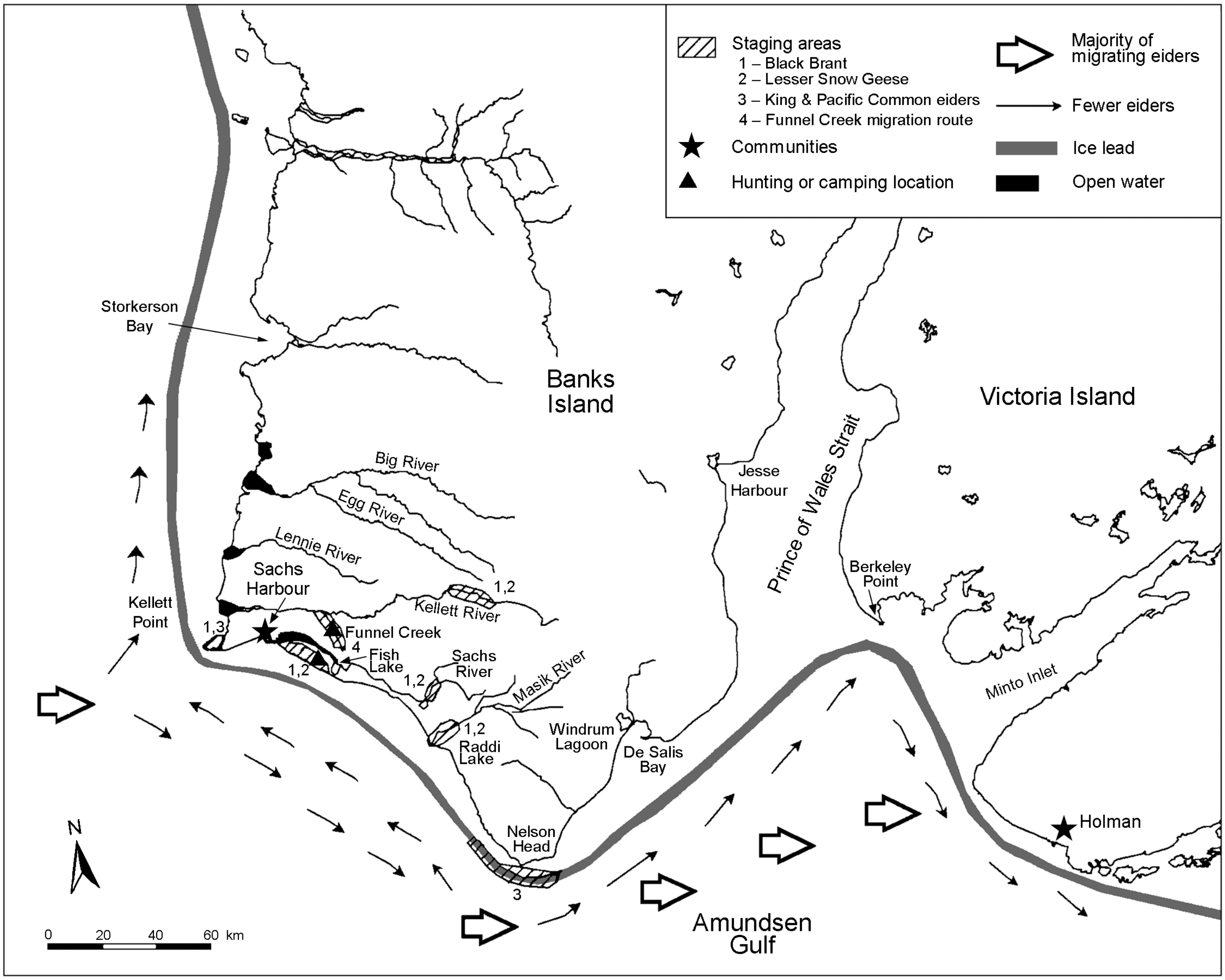
5.1.1 Sandhill Cranes

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

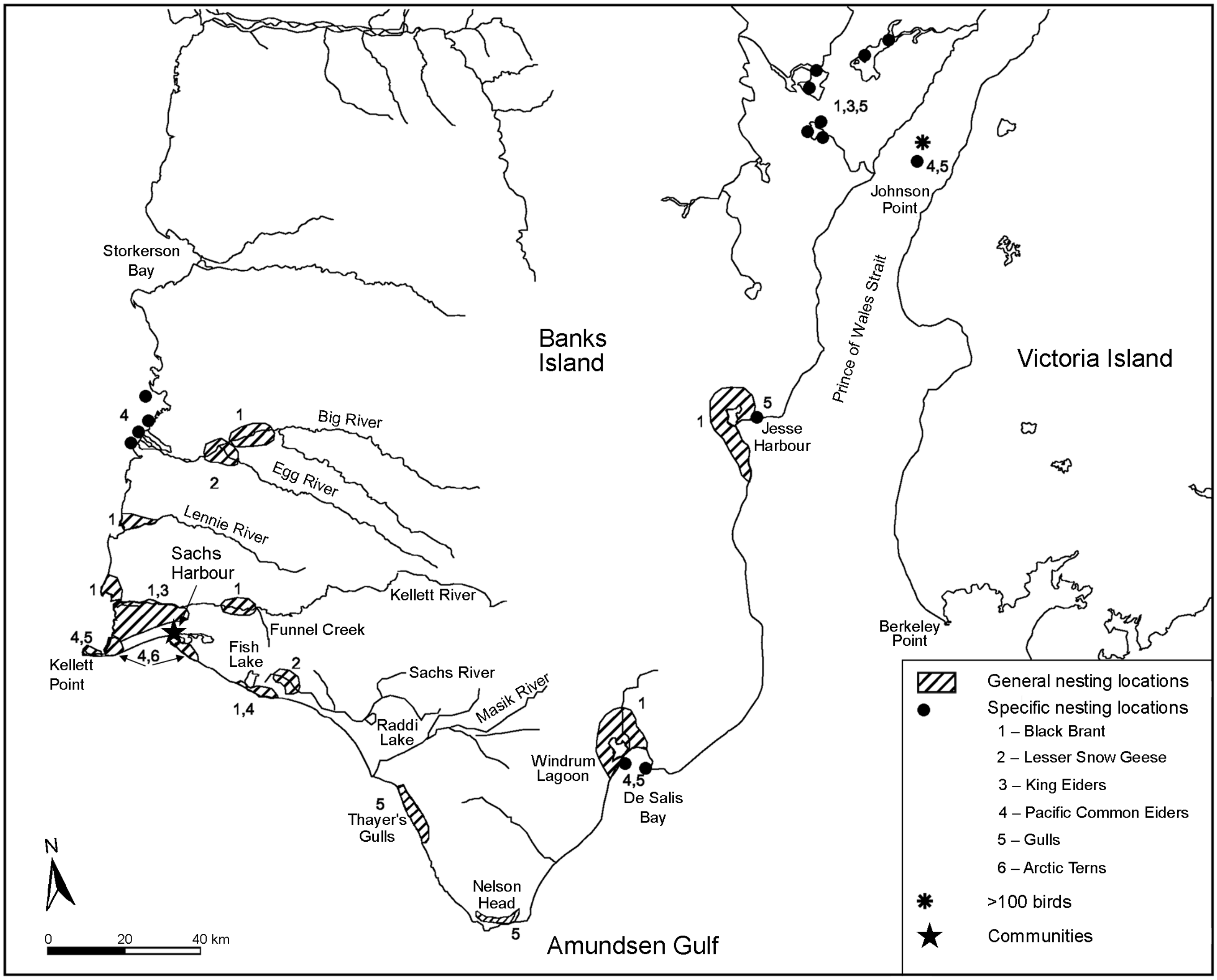
Lesser Snow Geese and Tundra Swans first arrive in the Sachs Harbour area in mid- to late May. One hunter believed that the cliffs demarcating the Masik River Valley are used as a landmark by migrating Lesser Snow Geese (Fig. 7). These large, south-facing promontories are the first landforms to become 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).

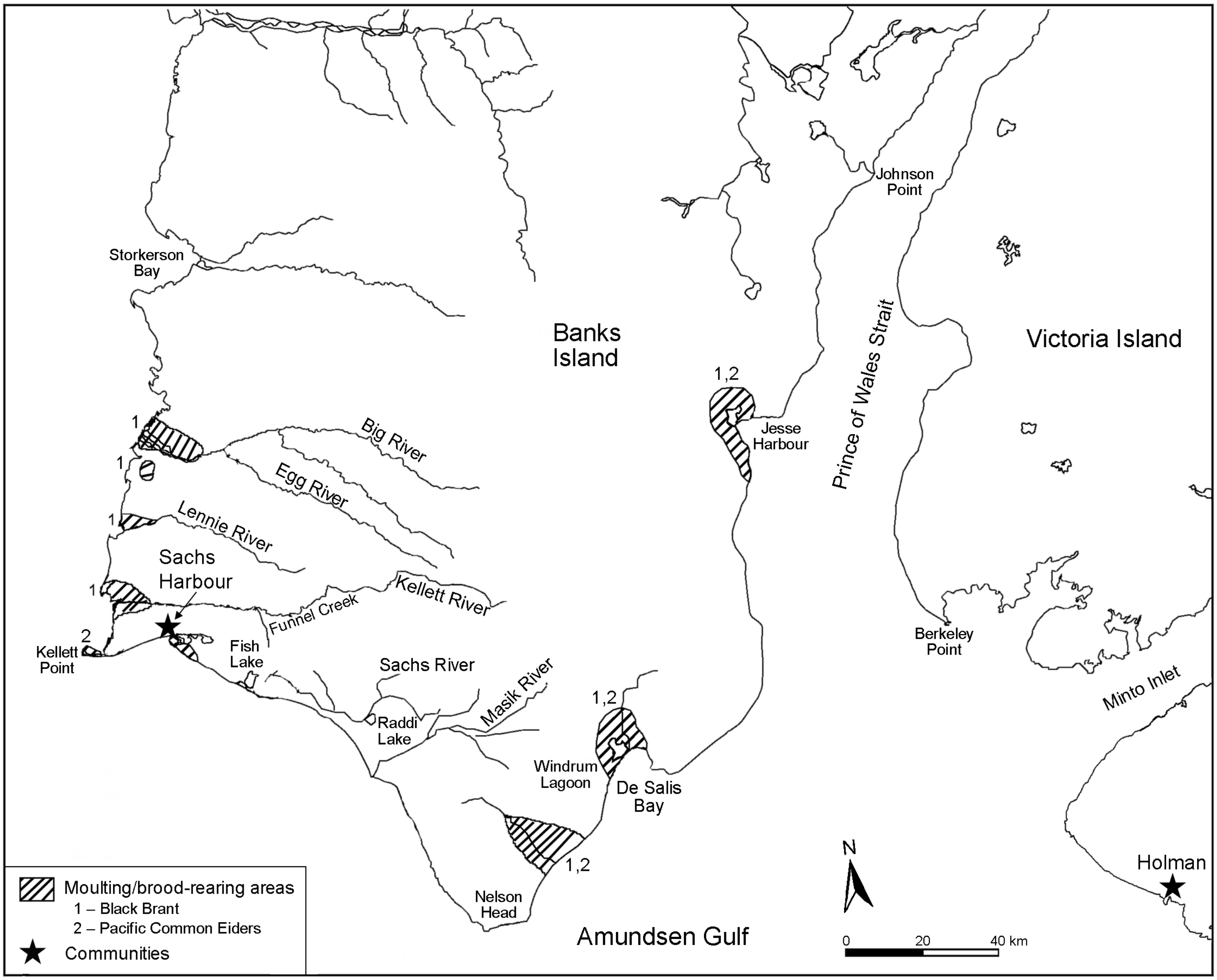
Associations between nesting Snowy Owls and other birds, especially Black Brant, were reported by several hunters. Black Brant, King Eiders, and shorebirds have all been observed nesting near owls. Snowy Owls are found mainly in the interior of Banks Island, and their nesting locations change from year 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

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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.

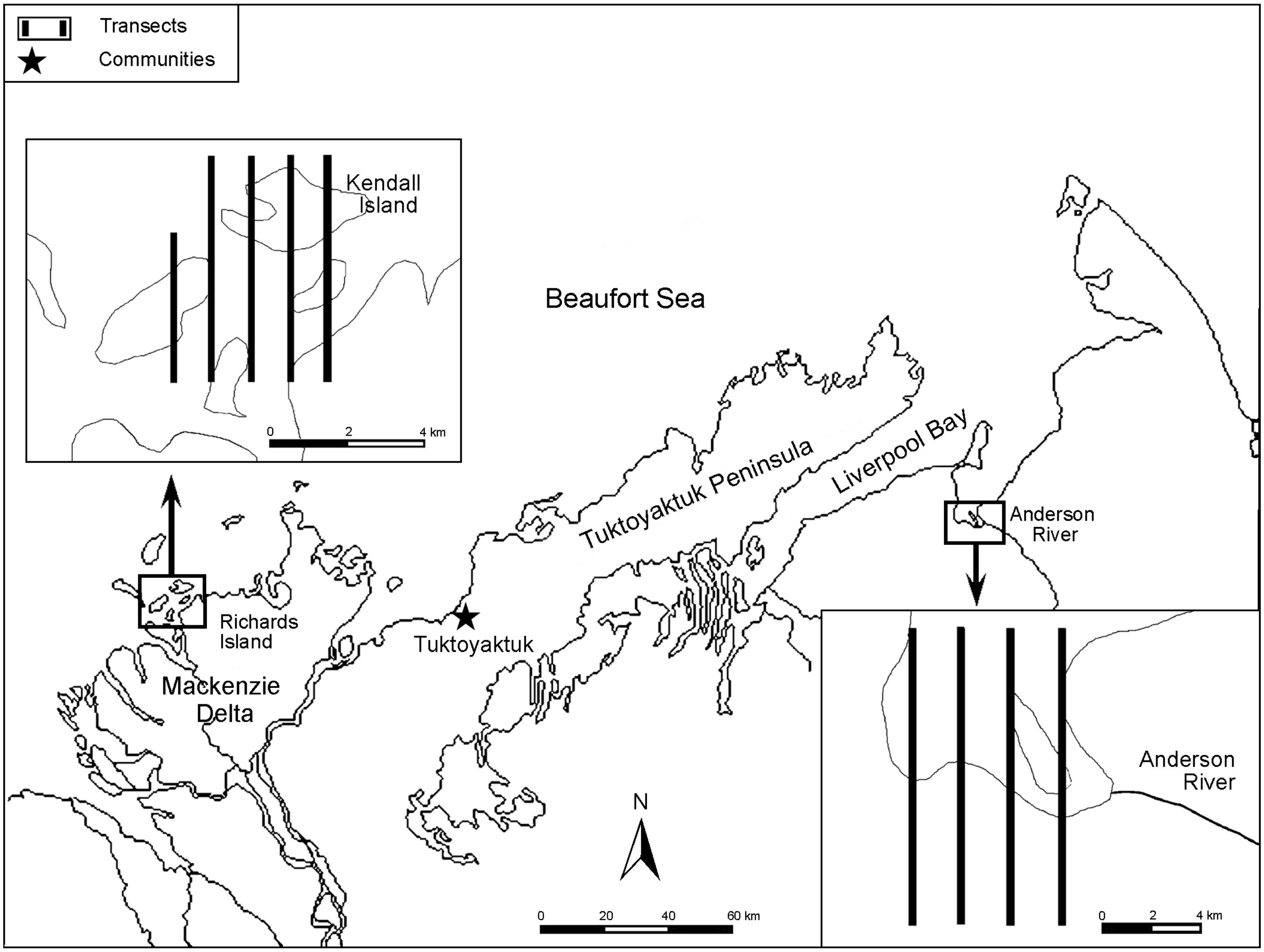
We surveyed the Anderson River and Kendall Island colonies by helicopter in June 1996–2001, to estimate the numbers of nesting and non-nesting Lesser Snow Geese present. Our results supplement the results of air photo surveys of the colonies, which have been made every 5–8 years since 1976 (Kerbes 1983,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

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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)

Species/population	ISR adult population[a]	ISR harvest[b]	Recent annual harvest rate: Within ISR (%)[c]	Recent annual harvest rate: 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

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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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