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

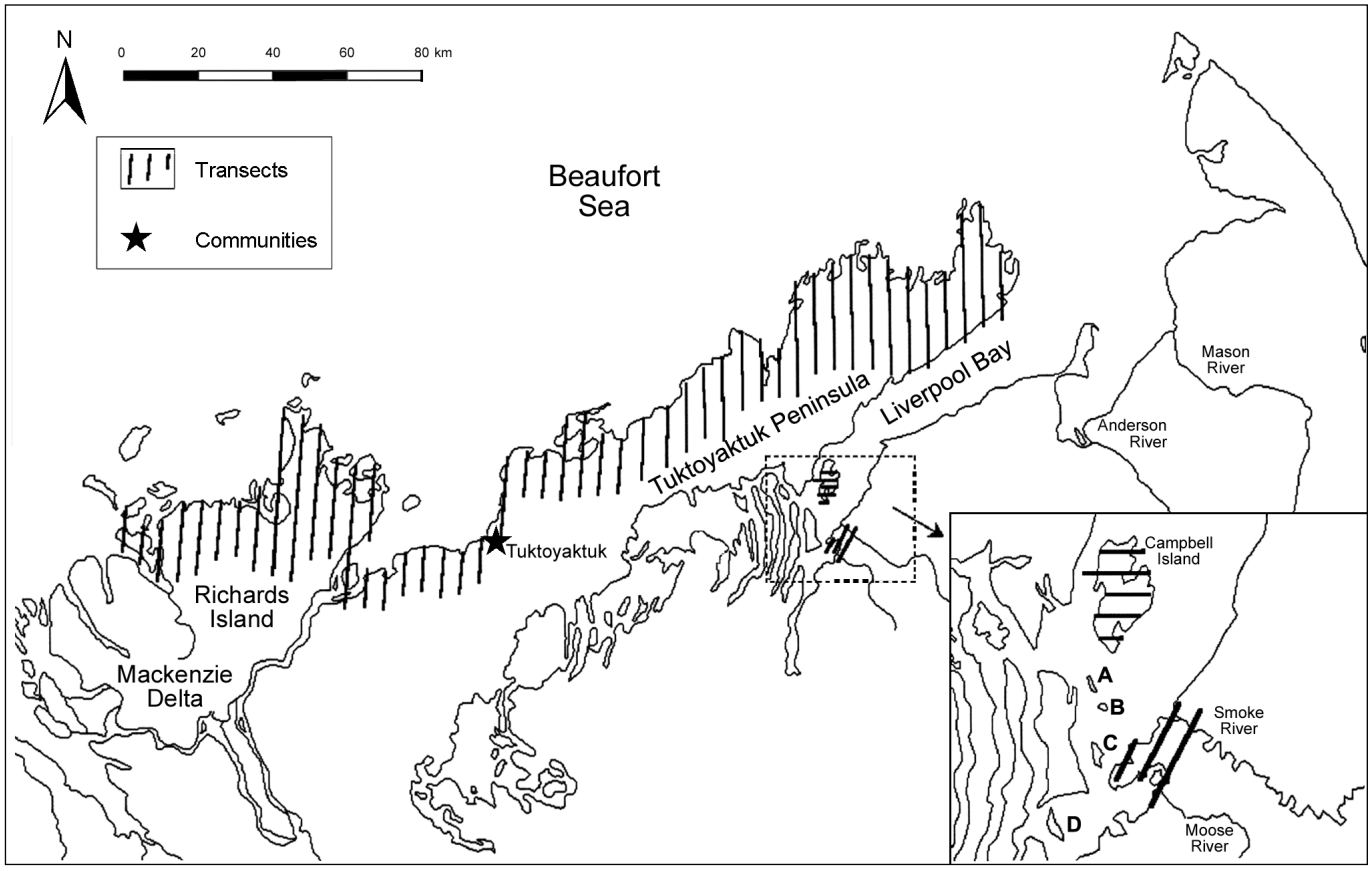
Aerial surveys of adult Black Brant were flown at the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay from 11 to 22 June each year from 1995 to 1998 (Fig. 1). Transects were flown in straight lines using a Bell 206L helicopter travelling at 80–100 km/h approximately 45 m above the ground. Based 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.

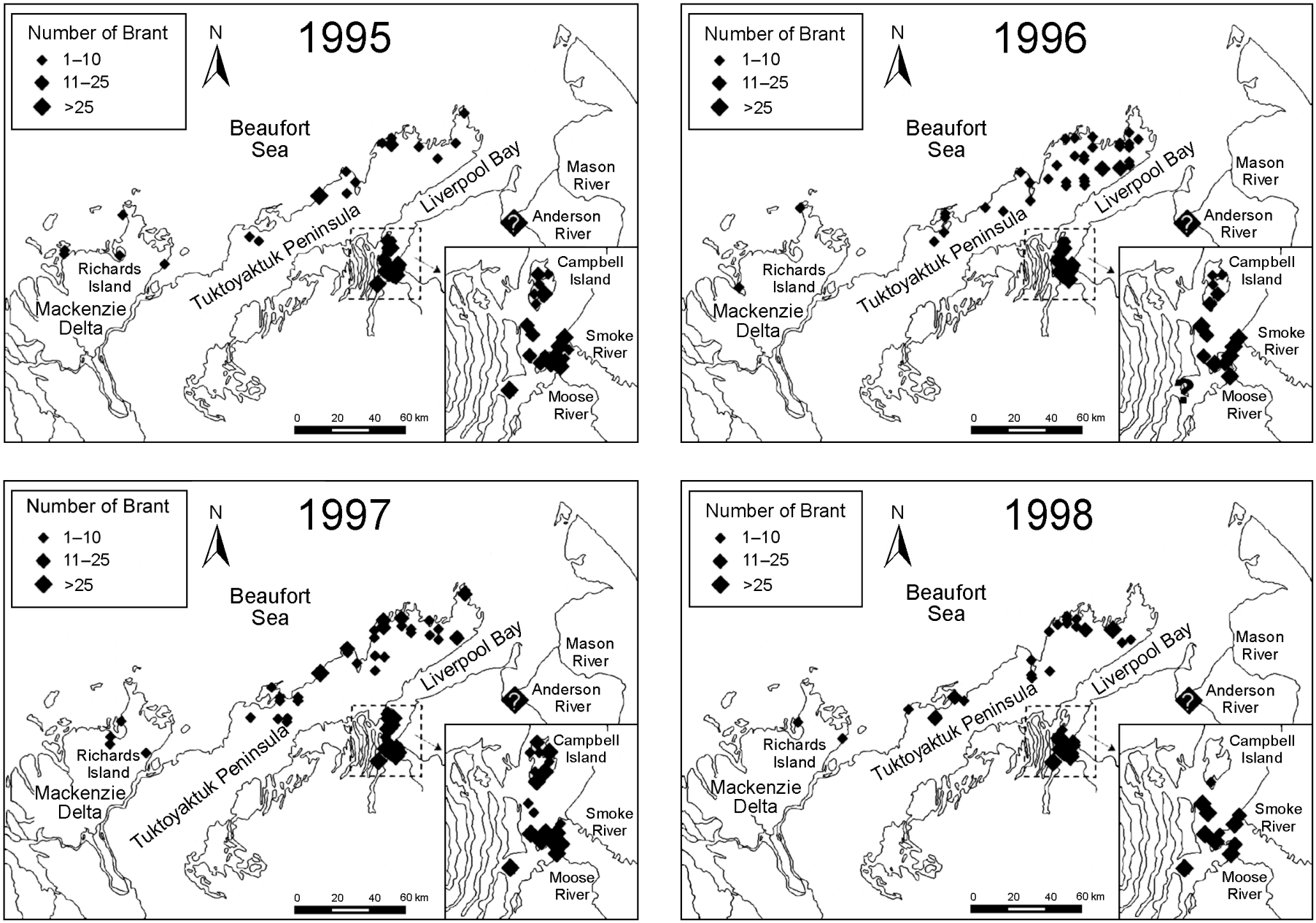
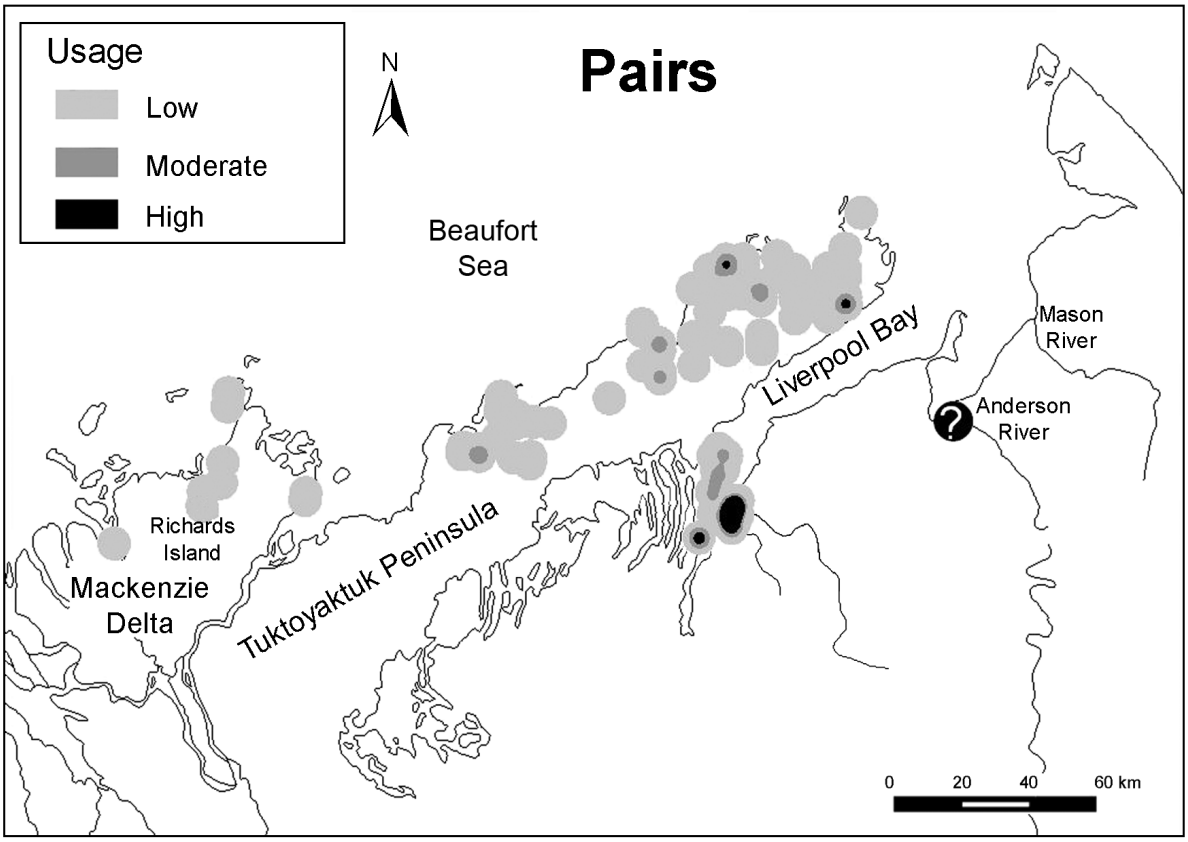


Figure 3
Use of the Tuktoyaktuk Peninsula, Mackenzie Delta, and Liverpool Bay by Black Brant pairs and flocks (i.e., groups of three or more birds) in June of 1995–1998. Black Brant were observed also at Anderson River delta (indicated by a question mark), but exact numbers there are unknown.



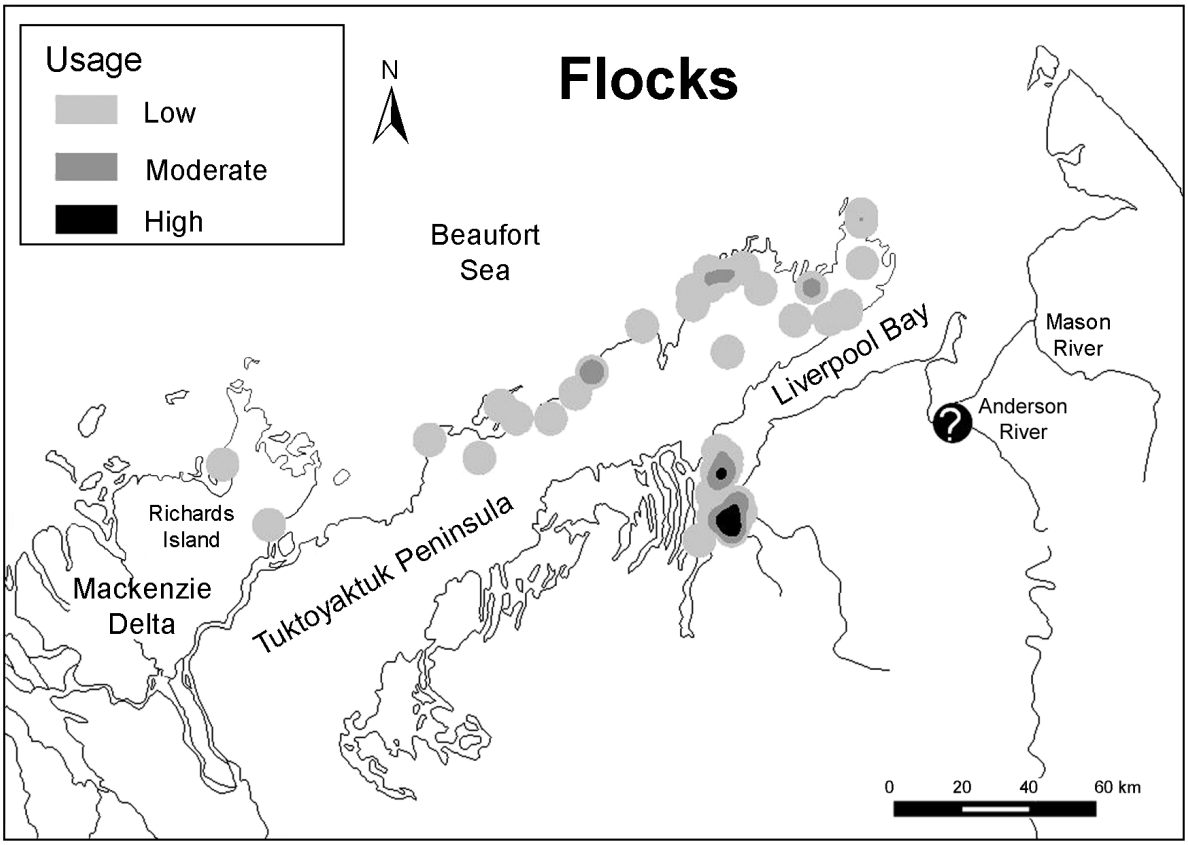


Table 1
Estimated numbers and densities of a) Black Brant and b) Black Brant pairs at the Tuktoyaktuk Peninsula – Mackenzie Delta and Campbell Island – Smoke–Moose Delta, as determined from aerial surveys in June of 1995–1998

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.

5. Acknowledgements

We thank the staff at the Polar Continental Shelf Project base in Tuktoyaktuk, Northwest Territories, and the Inuvik Research Centre for their expert logistical support, Rod Brook for assisting with the aerial counts, and Hugh Boyd, Autumn Downey, J.-F. Dufour, and Richard Kerbes for editorial assistance. Funding was provided by the Canadian Wildlife Service (Environment Canada), the Inuvialuit Final Agreement, and the Polar Continental Shelf Project (Natural Resources Canada).

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