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Habitat Conditions, Grizzly Bear Predation of Nests, and Spring Use of the Anderson River Delta by Lesser Snow Geese and Brant, 2005-2006

Joachim Obst, James E. Hines, Jean-François Dufour, Paul F. Woodard, and Robert G. Bromley

Prairie and Northern Region

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ABSTRACT

Numbers of Lesser Snow Goose (*Chen caerulescens caerulescens*) and Black Brant (*Branta bernicla nigricans*) nesting at the Anderson River Delta Migratory Bird Sanctuary (ARDMBS), Northwest Territories, have declined substantially over the past decade or longer. Hypothesized causes of the declines include loss of nesting habitat, nest predation by grizzly bears (*Ursus arctos horribilis*) or other predators, and human disturbance. The present investigation was carried out in the springs of 2005 and 2006 to examine possible causes of the population decline, evaluate current use of the sanctuary by geese, and describe current habitat conditions within a 44 km^2 study area at ARDMBS.

Spring phenology differed between the two years of study with snowmelt and river breakup occurring about a week earlier in 2006. Goose migration peaked about five days earlier in 2006 (May 18–19) than in 2005 (May 23–24). Approximately 20 000 Lesser Snow Geese in 2005 and 40 000 geese in 2006 migrated through a 1.7-km-wide count corridor en route to breeding grounds on Banks Island. Flock sizes ranged from 3 to ~200 and averaged 7.22 ± SE 0.23 geese (n = 1342 flocks).

Based on scan counts made from prominent observation sites as well as ground-based transects, we estimated that the Snow Goose colony at Anderson River delta numbered 736 breeding pairs and 1472 total adults in 2005 and 1167 breeding pairs and 2716 total adults in 2006, and was well below populations recorded in previous decades. The distribution of nesting pairs was concentrated on a few islands in the outer delta and was greatly influenced by flooding in the two years as well as the amount of vegetation present. The highest nest densities occurred in an area of low willows and abundant ground cover on Fox Den Island. Further north in the delta, where vegetation was sparse to non-existent and flooding was more severe, nesting was restricted to lines of driftwood on the more elevated levees.

Descriptions of annual flooding and its relationship to general habitat conditions in the study area are presented. The flood waters of the Anderson River peaked by mid-May in both years and receded by early June in 2005 and late May in 2006. Because of prolonged flooding, there was less dry land available to nesting geese at the time of clutch initiation in 2005.

Peak nest initiation occurred during the last week of May during both years of study. Clutch size ranged from 1–8 eggs and averaged 3.80 ± SE 0.07 (n = 312). The status of nests at the time of finding was used to evaluate the causes of nest loss. In 2005, only 59% of the nests (n = 284) were still active when first visited and the remaining nests (41%) had been depredated. In 2006, 64% of the nests (n = 224) were still active when first visited, whereas the remaining nests (36%) had been destroyed. Based on the nest survey and helicopter counts of broods later in summer, we estimated that nest success likely exceeded 70% in 2005 but was only 1–2% in 2006. The estimate for 2005 was somewhat higher than the maximum value of nest success that could be inferred from the nest predation data. Grizzly bears were the most frequently sighted mammalian predator and caused 82% of the known nest failures. Other important predators were red foxes (*Vulpes vulpes*), Common Ravens (*Corvus corax*), and Glaucous Gulls (*Larus hyperboreus*). Qualitative observations indicated that small mammals such as lemmings and voles (potential alternate or "buffer" prey for bears, foxes, or avian nest predators) were much more abundant during the year of high nest success.

Observations of grizzly bears were carried out from the time the bears arrived at the Anderson River delta (May 29 in 2005, May 30 in 2006) until our final days in the field (June 7, 2005, and June 8, 2006). Ten different grizzly bears were observed in the outer delta during the nesting season in 2005 and 7 bears in 2006. With the exception of one day at the start of the nesting period in 2005 when 9 bears were present, the average number of bears sighted per day was similar between years (1.7 bears per day over 9 days in 2005, 1.4 bears per day over 10 days in 2006). In 2005, most sightings (8 of 12) were of an apparently mated pair of bears seen on 8 of 10 days, whereas sightings were distributed more equally among bears in 2006. The movement patterns of the bears within the delta were mapped. During both years, grizzlies spent about 47% of their time actively searching for nests and destroyed 2.5 nests per hour of activity. The bears were able to reach most nesting islands and, in some areas of high nest density, nearly all nests were destroyed.

Large-scale vegetation loss and degradation has occurred in the outer delta during the last several decades (Borstad et al. 2008). During our study, we observed that most islands in the outer delta were sparsely vegetated or barren; only the more southern islands and the nearby mainland supported abundant vegetation. Standing stems of dead willows indicated areas where vegetation had died in previous years and salt-tolerant, turf-forming species of grasses and sedges made up much of the remaining plant cover in the outer delta. Soil and pond-water samples from the outer delta were highly saline, indicating limited capacity to support plant growth.

Based on our findings, earlier investigations at ARDMBS, and research carried out elsewhere along the Beaufort Sea coast, it is apparent that salt-water flooding is a primary cause of the vegetation loss. A number of factors may have caused the flooding, including historically rising sea levels, long-term reduction in ice cover on the Beaufort Sea, and increased exposure to storm surges due to erosion of a channel in the 1960s through Nicholson Peninsula, which formerly protected the Anderson River delta. Vegetation loss may have been further exacerbated by the feeding activities of large numbers of migrant Snow Geese. Whatever the causes, the disappearance of plant cover now limits the capacity of the outer delta to support nesting geese. In areas which formerly supported large numbers of geese, nests are now restricted to driftwood lines in otherwise sparsely vegetated areas. Spring flooding possibly further limits the use of these former nesting areas. As a result, Snow Goose nests are now concentrated in the remaining well-vegetated areas further inland where they are accessible to foraging grizzly bears.

The number of Brant nesting at ARDMBS appears to have declined even more steeply than the number of Snow Geese. The Brant population frequently exceeded 1200 nesting pairs in the 1960s through early 1980s, but our estimates (260 pairs in 2005 and 110 pairs in 2006) averaged only 15% of that number. Brant populations appear to face the same major constraints as Snow Geese: extensive loss of habitat and heavy rates of nest destruction by grizzly bears or other predators.

The management implications of our findings are discussed. Grizzly bears were the direct cause of most nest loss, but our observations suggest that grizzly bears could be effectively deterred from the goose colony by either passive (human presence) or more active (hazing) approaches. An average level of nest success of about 30% would be required to maintain a stable population assuming no additional habitat loss occurs (i.e., the carrying capacity of the outer delta for goose nesting remains the same). Although deterring bears might provide a short-term solution to the problem of declining goose numbers, the long-term prognosis for the populations is not good if habitat loss continues. Additional investigations into the complex inter-relationships among vegetation loss, soil salinity, salt-water flooding, goose grazing, and other environmental factors would be useful for management purposes.

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1. INTRODUCTION

Since 1960, goose nesting colonies have been monitored in the outer delta of the Anderson River Delta Migratory Bird Sanctuary (ARDMBS) in the Northwest Territories (Barry 1967; Armstrong 1995; Kerbes et al. 1999; Wiebe Robertson and Hines 2006). Over the past decade or more, declines in the Lesser Snow Goose (*Chen caerulescens caerulescens*) and Black Brant (*Branta bernicla nigricans*) nesting populations in the sanctuary have been reported by both biologists and Inuvialuit hunters (Armstrong 1995; Wiebe Robertson and Hines 2006). Potential causes of the declines include habitat loss, egg predation by grizzly bears (*Ursus arctos horribilis*) or other predators, and human disturbance. This report summarizes the results of our field study carried out in the springs of 2005 and 2006 to examine general use of the area by geese, habitat conditions, and possible causes of the population declines.

The study had several objectives:

(1) document the use of the outer delta of the ARDMBS by migrating flocks of Snow Geese passing through the area en route to breeding grounds on Banks Island;

(2) record numbers of nesting and non-nesting Snow Geese and Brant and their distribution within the outer delta;

(3) gather information on clutch size, nesting success, and causes of nest failure of the Snow Geese;

(4) document the occurrence of grizzly bears and other predators within the goose nesting areas and the impacts of the bears and other predators on goose nesting success;

(5) evaluate habitat conditions within the outer delta of the ARDMBS, and the current capacity of the habitat to support nesting Snow Geese and Brant;

(6) record observations of spring hunting of geese within and near the outer delta of the ARDMBS;

(7) determine the cause of declining numbers of nesting Snow Geese and Brant in ARDMBS; and

(8) describe the implications of the results and provide recommendations for the management of the sanctuary.

2. STUDY AREA

2.1 Anderson River delta

The 44-km^2 study area is located in the outer delta of the ARDMBS and encompasses 8–10 islands or island groups (each 0.1–6.4 km^2 in area, total area approximately 12.5 km^2), Grassy Point, and the Snow Goose Creek area (Figure 1). The islands and surrounding uplands amount to approximately 25 km^2 of land, and the remaining 19 km^2 of the study area is water. Primary observation points used in our study included the observation platform on the roof of the Canadian Wildlife Service (CWS) cabin (at 69° 42.5′ N, 128° 58.9′ W), high (>40 m ASL) bluffs located 2 km south of the cabin, and a small knoll about 1.5 km north of the cabin (Figure 1).

2.2 Physiography, ecoregion, habitat, and fauna

The study area is adjacent to the Arctic Ocean and located 40–50 km north of the tree line. It lies within the Arctic Coastal Plain physiographic region and the Low Arctic Ecoregion (Zoltai et al. 1979). The area is characterized by low arctic tundra and continuous permafrost with an active layer of 60–130 cm. Local soils have developed on a variety of sediments (till, fluvium, glaciofluvium, alluvium, colluvium, organic, marine, and other). The elevation generally ranges from 3–15 m above sea level with bluffs bordering the Anderson River reaching 50–60 m above sea level. The entire area was ice-free during the Late Wisconsin glaciation and was a refugium for flora and fauna (Zoltai et al. 1979). The diverse flora is influenced by the northern Mackenzie River valley and the central mainland arctic. Dominant land-cover types include dwarf shrubs, grasses, sedges, wetlands, small lakes, and bare ground. The outer Anderson River delta is very low (mostly <1 m above sea level) and characterized by sparsely or partially vegetated islands and mud flats.

The local diversity of vertebrate fauna must rank among the highest in the Canadian Arctic. Thirty-one species of terrestrial mammals including barren-ground caribou (*Rangifer tarandus*), grizzly bear, 6 species of marine mammals, and 147 species of birds have been observed within the delta and nearby parts of Wood Bay (Zoltai et al. 1979). The Anderson River delta has been recognized as a critical habitat for tens of thousands of migrating, moulting, and breeding waterfowl as well as being of importance to other species of wildlife (Latour et al. 2008). This importance prompted the federal government to establish the Anderson River Delta Migratory Bird Sanctuary in 1961 (T.W. Barry *in* Zoltai et al. 1979).

2.3 Climate and flooding

The climate is characterized by long, cold, and dark winters, and short, cool summers with continuous daylight. Weather data collected during 1971–2000 at Tuktoyaktuk (located 160 km west of the study area) indicate a mean January temperature of –25.9ºC, mean July temperature of 10.9ºC; and average annual precipitation of 139.3 mm (70.2 mm as rain, and 69.2 cm as snow). Occasionally, high winds and storms (with average wind speeds of 58–74 km/hr) come from the west, northwest and northeast. Storms occur most frequently from fall to mid-winter (Environment Canada weather website www.weatheroffice.gc.ca).

Mean monthly winds during 1971–2000 ranged from 17.6–21.7 km/hr at Cape Parry (170 km east of the study area). Predominant wind directions were from the west, north, and east. On average, high winds (52–63 km/hr) occurred about three days each month at Cape Parry and storms (65–105 km/hr) occurred occasionally, mainly during fall to mid-winter (Environment Canada weather website www.weatheroffice.gc.ca). Northerly winds sometimes cause storm surges on the Beaufort Sea and flooding of the outer Anderson River delta in fall and early winter (Billy Jacobson, pers. comm.). Islands in the outer delta are also exposed to tidal action and to spring flooding from the Anderson River.

3. METHODS

3.1 Personnel and logistics

In 2005, a team of four (Billy and Eileen Jacobson of Tuktoyaktuk, Northwest Territories, and Joachim Obst and Robert (Bob) Bromley of Yellowknife, Northwest Territories) arrived at the CWS cabin near the Anderson River delta on May 22 and carried out field work until June 8. A helicopter was used to transport the field crew and equipment between the Nicholson Point airstrip and the cabin. This was the only feasible air access at this time of year. A brief stop near Snow Goose Creek (an area of special interest) was made upon completion of fieldwork on June 8. In 2006, a team of five (Billy and Eileen Jacobson, Joachim Obst, Jean-François Dufour (Yellowknife), and Andrew Spaulding (Yellowknife)) conducted field work from May 16 to June 9 using similar logistics and modes of transportation as in 2005.

In 2005 and 2006, before river ice breakup, surveys and observations were conducted from the platform on the roof of the cabin, from the bluffs and a high site near the coast, and from hiking routes on the east side of the river between the bluffs and Grassy Point. The lookout points provided a good view with binoculars or spotting scope of most islands. Areas that were less visible because of distance or topography included western Fox Den Island, western Canoe Island, Triangle Island, and the Snow Goose Creek area (Figure 1). After river ice had broken up, an inflatable boat with an outboard motor was used to reach the goose nesting islands to conduct ground surveys. In 2005, access to islands by boat was hampered by low water levels, the presence of "ground" ice that had floated to the surface of the river, strong winds, and waves. Due to these conditions, the team was unable to access islands until June 4 despite following previously known boat routes (Billy Jacobson, pers. comm., Figure 2); the boat was grounded frequently on the muddy bottom of the shallow channels. In 2006, higher prevailing water levels made for easier boating, enabling us to reach islands from June 2 onwards by travelling the same routes as in 2005.

3.2 Weather

In both years, weather conditions were recorded several times daily as well as during all observations and surveys. Variables recorded included visibility, fog, haze, cloud cover, rain, sleet, snowfall, temperature, estimated snow and ice cover, wind direction, and wind velocity. The latter variable was estimated in 2005 and measured with an anemometer in 2006.

3.3 Spring migration of Lesser Snow Geese

3.3.1 Counts of migrating geese

Counts of migrating geese, modified after Hawkings (1982), were carried out from the observation platform on the CWS cabin from May 22–29, 2005, and from May 17–26, 2006. Flying geese were counted in the main migration route in view, a 1.7-km-wide corridor stretching between the cabin and the bluffs (located south of the cabin on the east side of the river) (Figure 2). The bluffs and the crest of a hill blocked any view further south, thus permitting consistency in recording methods. Counts were conducted by two observers (one using binoculars to count geese and the other recording data). Counts lasted about 0.5 hrs and were spaced at approximately 3-hr intervals during three time periods (0600–1200 hours, 1200–1800 hours, and 1800–2400 hours), for a total of six counts per day. The count data were used to calculate the number of migrating geese per minute and to estimate the total passage of geese between 0600 and 2400 hrs each day. The numbers of migrating pairs and flocked geese flying towards the east or northeast, and the numbers of geese flying west towards the nesting islands were recorded separately. Numbers of geese returning westward were subtracted from the eastward passage of geese to estimate the net number of migrants.

3.3.2 Reports of local hunters

In 2005 and 2006, reports on the regional goose migration were obtained by listening daily to the Spillsbury SBX 11A "bush radio" for communications among Inuvialuit goose hunters. Insights on habitat changes in the Anderson River delta, predator activities, and traditional use of wildlife in the delta were gathered through discussions with team member Billy Jacobson, a local Inuvialuit hunter with 40+ years of experience in travelling, hunting, and assisting in wildlife research in the region. Anecdotal information on spring goose hunting and bear sightings in the bird sanctuary from 1985–2006 was extracted from the guest log book at the cabin.

3.4 Counts of resident geese

3.4.1 Island counts

From May 22–June 4, 2005, 8 daily counts of pre-nesting territorial pairs and breeding geese were conducted by two observers, one observer scanning the nesting islands with binoculars or a spotting scope from lookout points while the other recorded notes on the number of paired, flocked, or single geese sighted. All islands in view were scanned for 10 to 45 minutes, the duration of counts depending on habitat and weather conditions, numbers of geese, and the size of area observed. From May 18–June 3, 2006, similar methods were used during 15 daily counts. A modification to that methodology in 2006 was that each of three observers counted geese (within the same time period and for an identical area) and came to a common agreement on the number of geese present.

3.4.2 Scan surveys of geese

Binoculars or a spotting scope were used to scan the pairs of geese on the islands to determine nest initiation. A pair was classified as "nesting" if the female was seen sitting on a nest (typically with her mate standing nearby) and classified as "not nesting" if no such evidence was observed.

On May 28, 2005, 5 scan samples, each of 10 Snow Goose pairs on Flat Island, were recorded to determine if geese had begun nesting. In 2006, we repeated the surveys 8 times between May 27 and June 2 and sampled both Fox Den and Flat islands. Thus, in total, 50 goose pairs were scanned in 2005 and 400 goose pairs were scanned in 2006 to document nest initiation.

We also wanted to determine if geese grazed frequently enough on the nesting islands to impact the surrounding habitat. Therefore, brief scan surveys of the nesting islands were carried out to document whether individual Snow Geese were feeding or not feeding. The observations were carried out for a total of 85 minutes on May 29–30, 2005, and May 28–June 2, 2006.

3.5 Plot and transect surveys of goose nests

Surveys of 11 plots (each 150 m × 150 m or 2.25 ha) in goose nesting habitats were conducted by 2–4 observers walking transects at 12.5-m spacing across the square plots. In 2005, an additional 6 transects (each from 400–900 m long and 10–20 m wide) were walked by two observers in more linear-shaped nesting habitats (e.g., lines of driftwood with little or no vegetation and willow-dominated levees). Due to time and logistic constraints, only 3 transects could be repeated in 2006. The plot and transect surveys were carried out from June 4–7 in 2005 and June 2–7 in 2006. Locations of plots and transects are indicated in Figure 2.

For both plot and transect surveys, the numbers of active nests and eggs, and the numbers of depredated nests were documented. Clutch size was determined for each incubated clutch. Incubated clutches were those where geese were observed to move off their nests when approached (or where down was abundant, eggs were warm, and a female was inferred to have been present as we approached). Immediately after discovery, active nests were covered with down and other nest material in order to reduce the vulnerability of eggs to avian predation and to prevent rapid cooling or overheating of eggs by the sun.

The loss of goose nests was assigned to specific predators based on the following criteria: (1) grizzly bear – bear tracks leading to destroyed nest and, typically, crushed eggs at the nest; (2) fox – tracks of red fox leading to nest, and a complete absence of eggs and shells; (3) avian – egg shells with holes apparently made by the bill of a raven, gull, or jaeger; and (4) unknown – the cause could not be categorized or represented a combination of bear, fox, and avian predation.

Similar information on clutch size and nest status/fate was recorded at additional nests encountered outside of the plots or transects.

3.6 Counts and observations of potential nest predators

Observations of potential goose or egg predators were recorded from the platform on the roof of the cabin and at areas visited during fieldwork. Numbers of avian predators were recorded daily. Data were summarized for the entire field season to provide an index of the relative abundance of each species of avian predator. The activity of mammalian predators sighted in the Snow Goose nesting area on Flat and Fox Den islands was also recorded. All species known to be predators of eggs, goslings, or adult geese at ARDMBS were counted, including grizzly bears, red foxes (*Vulpes vulpes*), wolves (*Canis lupus*), wolverines (*Gulo gulo luscus*), Common Ravens (*Corvus corax*), Glaucous Gulls (*Larus hyperboreus*), Parasitic Jaegers (*Stercorarius parasiticus*), other species of gulls or jaegers, Bald Eagles (*Haliaeetus leucocephalus*), and Golden Eagles (*Aquila chrysaetos*) (Armstrong 1995; Barry 1967).

Observations of grizzly bears were made from the time of arrival of the first bears (May 29 in 2005, May 30 in 2006) throughout the duration of the field work. Individual grizzly bears were identified on the basis of their size, colouration, and general appearance. Whenever bears were seen during the period 0700 to 2400 hrs, their movements and activities were recorded. Whenever possible, the numbers of nests destroyed by bears were recorded, as were the numbers and activities of avian predators following the bears.

3.7 Helicopter survey documenting goose productivity

Aerial counts of the number of Snow Geese present in ARDMBS were carried out on August 7, 2005, and July 21, 2006, when a Bell 206B helicopter was used to search all of the known brood-rearing areas in the delta (Armstrong 1995). Given the high visibility of the geese, it was relatively straightforward for the pilot and two observers to locate and then count the adult and young geese in the brood-rearing area.

3.8 Description of habitats and flooding

The percentage of land covered by different habitat types, percent vegetation cover, species of plants present, and the extent of mud flats, flood waters, ponds, and driftwood lines near plots, transects, and hiking routes were estimated and documented with photos. Observations on the extent of flooding, estimated ice and snow cover, and general habitat conditions in the delta were made with binoculars or a spotting scope, and during the helicopter flights to and from the cabin.

Increases in soil and water salinity have been implicated in the vegetation loss and habitat degradation observed in the Anderson River delta. In 2005, a soil sample was taken from southern Triangle Island and, in 2006, six soil and five water samples were collected at widely spaced locations on Flat and Fox Den islands. Also, in 2006, two soil samples and five water samples were taken on the east side of the Anderson River near the CWS cabin. The samples were analyzed for salinity (i.e., sodium and chlorine content) by the Taiga Environmental Laboratory, Department of Indian and Northern Affairs Canada, Yellowknife, Northwest Territories. The results were used to evaluate the potential impact caused by salt water flooding on the plant communities of the outer delta.

4. RESULTS

4.1 Weather, snow and ice cover, and flooding

From May 22–June 8, 2005, temperatures were generally cool at night, typically ranging from 1–3ºC with a few days with light frosts. Temperatures during the day ranged from 4–8ºC with the exception of warmer days (reaching 10–15ºC) on May 24 and June 5. From May 25 onwards, moderate to strong winds (20–45 km/hr) from northern and eastern directions were prevalent. Only a small amount of precipitation occurred during the study period, including light rain for a few hours on May 23–25 and snow on the night of May 25. Most days were partially or completely cloudy, but visibility was good except for some fog on four days and heat waves during midday after May 29.

In 2005, snow cover on the land was estimated as 15% on May 22, less than 5% on May 26 (present only on some north-facing slopes), and 0% thereafter. From May 22–29, ice cover on the river declined from about 70% to 50%. Breakup of the river ice occurred swiftly in the evening of May 29, with the river becoming completely ice-free overnight. Occasionally, until June 5, ice from the frozen river bottom rose to the surface and drifted downstream. On May 22, flooding, including significant deposition of ice, was extensive on all islands. Flood waters gradually retreated during May 31–June 4.

Conditions recorded on May 16 of each year indicated that the snowmelt was about a week earlier in 2006 than in the previous year. As well, the river ice broke up swiftly on May 22, 2006, one week earlier than in 2005. After breakup in 2006, prolonged cold winds, predominantly from northeast and northwest and ranging from 5–34 km/hr, delayed the advance of spring weather.

Thus, by the end of the first week of June of both years, phenological conditions appeared similar with leaf buds of willows and dwarf birch opening. From May 16–June 9, 2006, temperatures at night ranged from –4 to 3ºC, including seven nights with light frosts. Temperatures during the day ranged from 0–10ºC.

From May 16–21, 2006, Flat, Jaeger, Brant, Gull, and Triangle islands in the northern delta were >90% flooded, and only lines of driftwood and small areas of raised ground were visible. In addition, on May 20–22, extensive freshwater flooding occurred throughout the northern delta. On May 24, flood waters retreated quickly, and by May 30, only 10% of the northern islands were flooded. The remaining flood waters disappeared completely on June 1. Maps indicating the changes in extent of flooding during May 2006 are presented in Figure 3.

4.2 Spring migration of Lesser Snow Geese

4.2.1 Migration counts

According to local Inuvialuit hunters, few geese had passed through the outer Anderson River delta prior to our arrival on May 22, 2005, and May 16, 2006. Therefore, our counts, which spanned the remainder of the migration period, captured much of the goose movement through the study area. From May 22–29, 2005, Snow Goose counts in the main corridor (Figure 2) indicated 16 030 geese had migrated towards the east and northeast. Minimum daily passages ranged from 695 to 8454 geese, with peak numbers occurring on May 24 and 72% of the observed migration occurring on May 23 and 24. By May 30, 2005, migration through the corridor had ended (Table 1).

The peak of snow goose migration occurred about five days earlier in 2006 than 2005. From May 17–26, 2006, counts of Snow Geese were conducted in the same corridor and resulted in an estimated total of 33 072 migrating geese. Daily totals ranged from 594–15 612 geese, with peak numbers occurring on May 18 and about 74% of the total passage occurring on May 18–19. By May 26, 2006, the migration was complete (Table 1). According to the qualitative observations of local Inuvialuit hunters, we missed small numbers of migrating geese prior to migration counts in both years (Table 2). Therefore, we estimate that passages in the count corridor could have been as high as 20 000 and 40 000 Snow Geese in 2005 and 2006, respectively.

The total numbers of geese migrating through the outer Anderson River delta, including areas outside our main observation corridor, were higher than indicated by our counts. In 2005, Snow Geese were frequently seen migrating eastward across southern Wood Bay in the coastal area 3–5 km north of the cabin (specifically along a route from Brant Island to Gull Islets and to Grassy Point (Figure 2)). Although geese flying along this path were difficult to count, it was evident that large numbers followed the route. For example, on May 24, 2005, observations made at Grassy Point during active migration indicated several thousand Snow Geese passed through during a 4-hr period with warm southerly winds. In 2006, geese were once again observed migrating in the coastal area north of the cabin, although the numbers could not be determined due to poor visibility.

Overall, the greatest numbers of geese moved through the count corridor during the afternoon, although, during peak migration, large flights occurred during the morning and evening as well (Table 1). Based on ancillary observations, the numbers of migrating Snow Geese appeared to be much lower late at night (after 2400 hrs). Migrating geese occurred as singles, pairs, and flocks. The mean flock size (a flock defined as a group of 3 or more geese) was 7.68 ± SE 0.31 geese (n = 457 flocks) in 2005, 6.98 ± 0.31 geese (n = 885 flocks) in 2006, and 7.22 ± 0.23 overall (n = 1342 flocks). Flock size ranged from 3 to ~200 geese and most geese appeared to be paired.

In 2005, 6.7% of 4466 Snow Geese observed flying eastward through the count corridor returned from the area near Landfall Lake (an area frequented by resting or grazing geese) and flew westward towards southern Flat and Fox Den islands. Most of the returning geese (72.7%) occurred as isolated pairs separated from flocks, and were thought to be resident geese that nested in the delta. In 2006, 23.3% of 7191 Snow Geese flying eastward returned from the Landfall Lake area towards the nesting islands. A smaller proportion (48.8%) of the returning geese occurred as isolated pairs in 2006. Assuming all of the returning isolated pairs were local residents, the approximate percentage of local geese passing back and forth through the corridor would be 4.9% in 2005 and 11.3% in 2006.

4.2.2 Reports of Lesser Snow Goose migration by local hunters

In 2005, Inuvialuit hunters staying at the Anderson River cabin reported “very few” Snow Geese migrating during May 12–17 (Table 2). According to other Inuvialuit hunters communicating daily by bush radio from their goose hunting camps (near the Beaufort Sea coast, the Mackenzie River Delta, Tuktoyaktuk, Liverpool Bay, and Paulatuk on the mainland, and near Sachs Harbour on Banks Island), the Snow Goose migration was "fairly slow" before May 22 but "numbers increased" on May 22 and 23. From May 24–26, hunters reported "large numbers" of Snow Geese migrating along the coast. The migration "slowed down considerably" from May 27–28. After May 28, very few migrating Snow Geese were reported in the region, and most hunters in the Liverpool Bay area returned home on May 30. On May 31, 2005, the Snow Goose migration was reported as being over on the mainland and near Sachs Harbour on Banks Island (Table 2).

In 2006, the same Inuvialuit hunters (as in 2005) staying near the Anderson River cabin from May 12–17 reported the "first few" Snow Geese migrating through the area from May 13–15, "a few more geese" on May 16, and "large numbers" moving on May 17. On May 18, hunters communicating via bush radio reported "lots" of Snow Geese migrating in the Mackenzie Delta and around the community of Paulatuk. From May 20–26, "few" geese or "none at all" were reported throughout the region (Mackenzie Delta, Tuktoyaktuk Peninsula, Toker Point, Liverpool Bay, Nicholson Point, Paulatuk, and Sachs Harbour). On May 27, geese were migrating at Sachs Harbour, and from May 28–29, no geese were reported to be moving in the region except for a "few" on the Tuktoyaktuk Peninsula. The last few Snow Geese were reported on May 30 at Toker Point and Nicholson Point. In general, the reports from the Inuvialuit hunters corresponded well with our observations at the outer Anderson River delta in both years, identifying very similar peak periods and chronologies of migration (Tables 1 and 2).

4.3 Counts of resident Lesser Snow Geese

Many geese were already on territories upon our arrival at the study area on May 22, 2005. Counts during the first week or more of the study varied greatly by day and area, possibly because of departure of some geese for Banks Island and arrival of other geese from the south (Appendix 1). From May 22–June 4, scan counts of the islands in the outer delta (with exception of Canoe and Triangle islands) increased by 138% from 225 to 535 pairs, and the total number of geese increased by 65% from 648 to 1070 total geese (Appendix 1). Most territorial Snow Geese were concentrated in the eastern and south-central parts of Fox Den Island, and on Flat Island. Lack of visibility limited counts of the western portion and northwestern half of Fox Den Island, although, from the area that could be scanned, it appeared that territorial geese were thinly scattered in those areas (Figure 4). Goose numbers were extremely low on the Gull Islets, and Oil Drum, Brant, Jaeger, and Bluff islands, with a combined total of only 12 territorial pairs. Overall, based on our scan counts and additional transect counts made on Triangle and Canoe islands, we estimated that at least 736 nesting pairs (1472 individual geese) were present at Anderson River in 2005 (Table 3).

In 2006, as in the previous year, some territorial Snow Geese were already present when we arrived on the study area. At about the time of river breakup (May 22), rapidly rising flood waters from the Anderson River caused pre-nesting or nesting Snow Geese to move away from Flat, Jaeger, and Brant islands, and Oil Drum Island/Gull Islets. Flood waters retreated during May 24–30, 2006, allowing about 60 pairs to settle in the driftwood and raised banks on these islands (Appendix 1). The flooding apparently caused some crowding of nesting Snow Geese on southern, eastern and western Fox Den Island (northern Fox Den Island was under water). Snow Geese also nested on the mainland in the Snow Goose Creek area, and at least six pairs nested on the mainland east of the cabin. No nesting was observed in either of these two areas in 2005. A total of 1166 pairs of pre-nesting or nesting Snow Geese, and 2716 individual geese, were counted in the outer Anderson River delta in 2006 (Table 3). There was an increase of 58% in the number of pairs compared to 2005, and an 85% increase in the number of individual geese from 2005 to 2006.

The estimates presented in Table 3 are thought to be minimums, especially for poorly visible areas on Canoe Island, northern and western Triangle Island, and western Fox Den Island. During an aerial reconnaissance flight on June 7, 2005, we found no evidence of Snow Geese nesting on Boat Island or in the northern part of the Snow Goose Creek area. We could not see the southern Snow Goose Creek area, Tingmiak Lake, and Mitten Cove areas very well. However, previous helicopter counts (Wiebe Robertson and Hines 2006) and air photo surveys (Kerbes et al. 1999) have not recorded Snow Geese nesting in those areas. Few Snow Geese were seen on northern or western Triangle Island in 2006 during aerial surveys in early June (CWS, unpublished data). Therefore, our ground counts should have documented most of the nesting Snow Geese at ARDMBS during both years of study.

4.4 Ground searches documenting density and distribution of nesting Lesser Snow Geese

In both years of study, an area of less than 100 ha near plots 3, 4, 5, and 10 on southern Fox Den Island supported the highest concentration of nesting Snow Geese (Figures 2 and 4). Nest densities were lower in the western and northern parts of the island, and no geese nested near the southern tip of Fox Den Island. On Flat Island, most Snow Geese nested on raised river banks on the southeastern part of the island and in two driftwood lines on the west side of the island. Similarly, a driftwood line and an area of dead willows were used for nesting on Triangle Island, and a raised bank was used for nesting on Canoe Island.

In 2005, densities of Snow Goose nests in the 2.25 ha plots averaged 3.92 nests/ha (97 nests in 11 plots; range = 0–13.8 nests/ha) (Table 4). The highest densities were in plots north of Heart-shaped Lake on Fox Den Island (Plots 3, 4, 5, and 10). In this area, large numbers of nesting geese were observed outside plots as well, and many additional nests were found when observers walked to or from plots. Plots on Flat Island had much lower densities (a mean of 1.33 nests/ha).

The majority of nests on Flat, Triangle, and northeastern Fox Den islands were recorded in transects along narrow (8–25 m wide) sparsely vegetated driftwood lines stretching for 3450 m through the largely barren islands. The driftwood lines occurred along the high-water marks on the crest of raised banks or other high ground and consisted of beached logs, sticks, twigs, and wood debris. In 2005, Lesser Snow Goose nests were spaced in a fairly regular pattern along the driftwood lines at a mean nest density of 8.2 nests/100 m (n = 283 nests, Table 5). Nest densities on the different islands ranged from 4.2–13.3 nests/100 m (Table 5). In areas where vegetation cover was sparse or absent, such as mud flats on Flat and Triangle islands, 94% of all pairs nested in the driftwood lines (n = 153 nests).

Average nest density in plots in 2006 (3.96 nests/ha; 98 nests in 11 plots; range 0–21.3 nests/ha) was similar to 2005 (Table 4). As in 2005, nest densities were highest north of Heart-shaped Lake on Fox Den Island (Plots 10, 3, and 5), although Plot 4 in that area supported few nests. Nest densities were lower on Flat Island (a mean of 0.30 nests/ha) in 2006 (Table 4). This was probably due in part to the flooding in 2006, which prevented many geese from settling on Flat Island.

Because of time constraints, only three transect lines were checked for nests in 2006. Flooding prevented extensive nesting on Flat Island in 2006, and only 2 nests were found on transects there compared to 72 nests in 2005. Nest density was about the same on Transect 3 (eastern Fox Den Island) in both years of study (Table 5).

Overall, much of the increase in nesting numbers in Snow Geese observed at ARDMBS in 2006 was accommodated through increased numbers in parts of Fox Den Island (Tables 3–5).

4.5 Reproductive parameters and causes of nest loss for Lesser Snow Geese

4.5.1 Nest initiation dates

On May 26, 2005, Snow Geese appeared to initiate egg-laying on Flat Island, but due to poor weather and poor visibility, this could not be confirmed through detailed observation. Poor visibility prevented observations on May 27, but on the morning of May 28, 8 (16%) of 50 pairs on Flat Island were observed to be nesting, and by May 30, most pairs appeared to be nesting. Thus, the start of nesting was thought to have occurred on May 26 or 27, and peak of nest initiation was estimated to have occurred between May 28 and May 30.

In 2006, the first two nesting pairs were observed near the cabin on the east side of the Anderson River on May 21. Three days later, on May 24, a few Snow Geese appeared to be on nests on eastern Fox Den Island. On May 27, 56% of the Snow Goose pairs were on nests, and on May 28, 60% of the pairs were on nests. Thus, the peak of nest initiation would have occurred between May 24 and May 28 in 2006.

4.5.2 Clutch size

Clutch size during the early part of the nest incubation period averaged 3.93 eggs in 2005 (June 4–7), 3.66 eggs in 2006 (June 2–7), and 3.80 over both years (Table 6). Clutch size ranged from 1–8 eggs in each year.

4.5.3 Nest status at time of discovery

The status of nests at the time of our nest searches in 2005 and 2006 provided a useful index of nest success and causes of nest loss each year. In both years, a significant proportion of the Snow Goose nests had already been lost to predators by the time they were first visited by the field crew during the early incubation period. In 2005, only 59% of the nests (n = 284) visited were still active when first visited and the remaining nests (41%) had been depredated. In 2006, 64% of the nests (n = 224) were still active when first visited whereas the remaining nests (36%) had been depredated (Table 7).

4.5.4 Causes of nest loss

Grizzly bears were the most important nest predators, accounting for 87% of the observed nest failure in 2005, 75% of the failure in 2006, and 82% of the losses over both years. Red foxes, avian predators, and undetermined or multiple predators accounted for 7%, 4% and 6% of the nest losses respectively over the two years of study (Table 8).

Predation accounted for almost all of the recorded nest loss, but it is likely that flooding, which occurred very early in the nesting season before we could travel to the nesting islands, caused some additional nest failure in 2006. For example, on Flat Island, there were fewer pairs present following flooding in late May than there had been a few days previously, indicating the possible loss of some nests due to flooding. As well, four Snow Goose nests were found on June 2, 2006, on top of more than 1 m of beached river ice that had been covered with driftwood, dead grasses, gravel, and soil. The debris had likely been deposited when the ice was pushed up on the shore during breakup. The four nests undoubtedly failed because the underlying ice cracked and melted rapidly in early June. An additional nest, which had apparently met a similar fate, was found in the water beside collapsed ice and associated debris (Table 8). Hence, in 2006, at least five nests failed on Flat Island due to the geese nesting on beached ice. As well, we suspect that flooding and beached ice may have caused additional losses of nests on Triangle, Jaeger, and Brant islands, and possibly on northern Fox Den Island as well. Nevertheless, we suspect any losses caused by flooding would have been very minor compared to losses caused by predators.

4.5.5 Overall productivity and extrapolated estimates of egg and nest success

In 2005, the helicopter survey of Snow Goose broods and flocks of flightless adults was complicated by the large numbers of geese in the main brood-rearing and moulting areas near Snow Goose Creek. This led to movement and mixing of flocks and made it difficult to assess how many geese were present. Conservatively, we estimated at least 1000 young and 300 individual broods were present in the study area in 2005.

In 2006, 1596 adults and only 26 young were counted during the helicopter survey. Only two flocks (totalling 48 adults and 26 young) contained young. Assuming about 3 young per brood, fewer than 10 individual broods would have been present. An additional 1548 adults were counted in the 36 other flocks of flightless Snow Geese present in the area.

We estimated Snow Goose egg production in the outer delta was 2892 eggs in 2005 (assuming 736 nesting pairs × 3.93 eggs per clutch), and 4268 eggs in 2006 (1166 pairs × 3.66 eggs). Thus, the survival of eggs and young from incubation to the mid to late brood rearing stage was 35% or more in 2005 (i.e., >1000 goslings out of 2832 eggs), but only 0.6% in 2006 (26 goslings out of 4256 eggs). If, as has been previously reported in other studies of Snow Geese, nearly all eggs in successful clutches hatch, but fewer than half of the hatched goslings survive until midsummer (see Samelius et al. 2008 and references cited therein), nest success would have exceeded 70% in 2005 but would have been only 1–2% in 2006.

We were not present at ARDMBS throughout the entire nesting period in either 2005 or 2006. Nevertheless, as discussed below, we suspect that much of the between-year difference in production of young must have been due to grizzly bear predation of nests that occurred later in the incubation period in 2006.

4.6 Impact of predators on Lesser Snow Goose nesting success

4.6.1 Abundance of potential nest predators

Sightings of potential predators of goose eggs or nesting adults are summarized in Tables 9 and 10. Glaucous Gulls and Common Ravens were the most frequently encountered species of predatory birds, being sighted on >90% of the days that we were in the field (Table 9). Together Glaucous Gulls and Common Ravens made up 69% of the total sightings of avian predators (>89% of the total sightings if the observations of migrating Pomarine Jaegers are excluded from the calculation).

Grizzly bears were the most regularly encountered species of mammalian predator and were sighted on nearly half the days (17 of 36) we were in the field. There were very few sightings of other mammalian predators (Table 10).

4.6.2 Observations of grizzly bears within Lesser Snow Goose nesting areas

Ten different grizzly bears were present in the Anderson River Delta in 2005, and 7 individuals were present in 2006 (Table 11). Observations of the bears were carried out from the time of the arrival of the bears in the delta (May 29 in 2005, May 30 in 2006) until June 7 in 2005 and June 8 in 2006 (our final complete days in the field during the two years). Bears were recorded in the delta on 85% of the days we carried out detailed observations (8 of 10 days in 2005, 9 of 10 days in 2006). The number of bears present on any given day ranged from 0–9 in 2005 and 0–3 in 2006 and averaged 2.4 bears per day and 1.4 bears per day respectively during the two years. With the exception of one day in 2005 when 9 bears were present (see below), the average number of bears sighted per day was similar between years (1.7 bears per day over 9 days in 2005, 1.4 bears per day over 10 days in 2006). In 2005, most sightings (8 of 12) were of an apparently mated pair of bears seen on 8 of 10 days, whereas sightings were distributed more equally among bears in 2006 (Table 11).

In 2005, the first grizzly bears sighted were a distinctive pair of adults consisting of a large dark male and a brown female (Pair 2005-1 in Table 11). They were seen initially on May 29 near the high-density Snow Goose nesting site on southern Fox Den Island during the peak egg-laying period (May 27–30). Within 40 minutes of the arrival of the pair, two individual females (each with a year-old cub), a second pair of adults, and a single adult bear arrived separately in the same general area (Figure 5).

Based on our observations, it appeared that the latter seven bears may have detected the presence of Pair 2005-1 by scent. All seven bears left the area in a fairly direct and rapid manner. Some individuals were observed to stand frequently and look back in the general direction of Pair 2005-1 during their departure. The seven “other” bears were seen only on May 29, all observations occurring within a 210-minute period (1845–2215 hrs) and observations of five of the seven bears occurring only within a 40-minute interval (1850–1930 hrs). The seven bears were not observed again during our fieldwork. In contrast, Pair 2005-1 was observed on most days until June 7, when the pair left the outer delta and headed westward (Figure 5; Table 11). One other bear (2005-6) was sighted in 2005, but only very briefly on June 7. On June 8, no bears were detected in the outer delta during a helicopter reconnaissance carried out as we departed ARDMBS. Given the relatively high productivity of geese in 2005 (and assumed high nest success), it is possible that bears did not return to the nesting area after that date.

In 2006, the first grizzly bears, a pair of adults, appeared on May 30 on southern Fox Den Island shortly after the peak of nest initiation for Snow Geese (May 24–29). The adult pair apparently left the general area on May 31 and was not seen thereafter (Table 11). From June 2–9, 2006, another four individual adults and a smaller sub-adult were seen on the goose nesting areas at various times (Figure 6; Table 11). At least two bears were present on the nesting islands when we departed on June 9, and given the failure of geese to produce many young in 2006, we expect that grizzlies must have continued to forage within the goose colony after our departure.

A particularly interesting observation is the timing of the bears' arrival near the peak egg-laying period for Snow Geese in both years. The finding indicates that feeding at the goose colony could be part of a well-timed seasonal routine for local grizzly bears. In 2005 and 2006, most of the bear activity observed was in or near the Snow Goose nesting area (i.e., southern Fox Den Island, Canoe Island, Triangle Island, and the Snow Goose Creek area, Figures 5 and 6). The daily routine of adult bears appeared to be similar in both years. Typically, the bears spent the day sleeping or resting, walking a distance of a few hundred metres up to 2 km, eating the eggs from a few nests, and resting once again.

During the 89.8 total hours of observation over the two years of study, bears were moving or actively searching for goose nests for 42.1 hours (or 47% of the time) and destroyed 106 goose nests (2.5 nests per hour of activity) (Table 11). The bears spent the remaining time (about 47.7 hours or 53% of the time) resting or sleeping.

On Triangle Island in 2005, a grizzly pair (pair 2005-1) destroyed all 72 nests in a driftwood line and in dead willows, and failed to find only one nest on the island. The surviving nest was located 18 m from the driftwood line. When we visited the island, we easily followed the fresh tracks of the bears from nest to nest. In 2006, at least two bears searched for nests on Triangle and Canoe islands, apparently destroying most of the 96 goose nests there during the last two days of our stay (June 8–9). In the Snow Goose Creek area, bears also foraged on an unknown number of Snow Goose nests in 2006 and on an undetermined number of Brant nests in both years.

A sub-adult grizzly bear (bear 2006-5), present on the islands from June 5–6, 2006, was much more active than the other bears observed, covering a distance up to 4 km during sightings (Figure 6). This bear was seen destroying 12 goose nests in one 50-minute bout. The sub-adult apparently avoided other bears and was observed on two occasions to leave the area quickly when adult bears were present and returned after the adult bears left the area (Table 11).

The only obvious difference between years in the foraging behaviour of the grizzlies was related to the abundance of small mammals. The bears apparently took advantage of the high number of voles and lemmings present in 2005, whereas in 2006, when small mammal populations were low, bears were not observed digging up small rodent burrows. For example, in 2005, while walking from Plot 1 to Plot 2 on southern Fox Den Island (approximately 1.5 km including detours), we observed 55 locations where Pair 2005-1 had dug out small rodent burrows or, less frequently, roots of vascular plants. We had observed the bears digging frequently for long periods of time prior to our visit. We did not find fresh bear diggings or signs of small mammals along the same route in 2006. The abundance of small mammals may have provided a buffer against egg predation by bears and other predators in 2005 whereas low numbers of small mammals in 2006 possibly increased egg depredation.

Our presence at the Anderson River cabin was another factor that may have influenced grizzly bear predation of goose nests. The bears appeared to be aware of our presence at the camp and remained at least 2 km away from the cabin in both years of study (Figures 5 and 6). As a result, bears may have avoided the higher-density Snow Goose nesting areas on eastern Fox Den and Flat islands when we were present. Failure of many nests after we departed ARDMBS in 2006 supports this hypothesis.

4.7 Goose habitat

4.7.1 Overall habitat conditions and flooding

The mainland in the eastern half of the study area consisted of low shrub tundra and was characterized by scattered clusters of willow and dwarf birch (*Betula glandulosa*). Other plant cover included a lush undergrowth of herbs, forbs, lichens, mosses, and grasses. Sedge meadows, hummocks, and cotton grass (*Eriophorum*) tussocks occurred in low-lying areas near small wetlands, ponds, and lakes. About half of the study area consisted of partially vegetated or nearly barren islands. The northernmost islands (Triangle, Brant, Jaeger, Flat, and Oil Drum islands, and Gull Islets) and the northern part of Fox Den Island consisted largely of mud flats or bare ground. The presence of scattered stems of dead standing willows indicated that some of the present-day mud flats on Triangle, Flat and northern Fox Den islands were once vegetated. Salt-tolerant, turf-forming species of grasses (*Puccinellia*) and sedges (*Carex*) make up much of the plant cover remaining in this area. The southern and southeastern parts of Fox Den Island were well vegetated by willows, grasses, sedges, and a variety of other herbaceous plants. The well-vegetated western delta, including the Snow Goose Creek area, has extensive flats and heterogeneous lowlands with numerous channels, lakes, ponds, and tundra polygons.

From the time of our arrival on May 22 until May 30, 2005, the amount of land flooded on all islands declined from 70–90% to 15–20%. Raised banks and driftwood lines on Flat and Fox Den islands were quite visible. During May 31–June 4, flood waters retreated from the islands revealing extensive mud flats, particularly in the central parts of Flat, Fox Den and Triangle islands. The entire Snow Goose Creek area, however, was still 80–85% covered with shallow water on June 8 when we completed field work at Anderson River.

In 2006, the initial pattern of flooding was similar to that witnessed in 2005. On May 16–21, all islands in the northern delta were inundated, and only driftwood lines and raised ground were visible. After river ice breakup on May 22, fresh water flooding from the Anderson River completely covered all of the northern delta islands. Most flood waters retreated from the islands between May 24 and June 1 (Figure 3). In 2006, the two driftwood lines on western Flat Island were in slightly higher locations than in 2005. In both years, the changes in water levels caused by tides were noticeable on the shorelines of the islands and the river. Newly deposited driftwood on the islands, in the Snow Goose Creek area, and along the shores of Wood Bay included trunks of white birch (*Betula papyrifera*) and other large trees, probably from the Mackenzie River system.

The effect of salt-water flooding was evident in the form of beached sea ice and visible salt on the soil surface of Flat and Triangle islands in 2005. The absence of visible salt on Flat Island in 2006 was possibly caused by freshwater flooding from the Anderson River, which desalinized the top layer of the surface sediment.

Elevated concentrations of both sodium (Na) and chlorine (Cl) in water or soil are potential indicators of flooding by salt water. Soil samples from the northerly parts of the delta had high concentrations of Na and Cl, whereas very low concentrations of these ions were found on the eastern shore of the river (Figure 7). Concentrations of Na and Cl near the northern edge of abundant shrub cover on Fox Den Island were lower than in the barren areas of the outer islands but higher than on the eastern shore of the river (Figure 7).

Additional evidence of high salinity in the delta came from the 10 water samples collected at shallow ponds on Flat and Fox Den islands, and near the eastern shore of the Anderson River (Figure 8). Water samples from the islands had average concentrations of Na and Cl that were 223 and 530 times higher, respectively, than those recorded in the river. Another possible indicator of soil salinity was the widespread abundance of seedlings (about 1 cm tall) of an unidentified species (possibly *Salicornia*) on the drier mud flats on Flat Island on June 3, 2006, and the almost complete absence of other plants. This plant was not observed when we visited the same general area on June 6, 2005. We hypothesize that differences in germination dictated by weather or flooding accounted for the annual differences. Other differences in vegetation communities between years appeared to be minor.

Based on the above findings, it seemed that high soil salinity in flooded areas was a likely cause of the dead or dying vegetation on Flat, Triangle and Fox Den islands. The disappearance of habitat from such areas may limit the overall capacity of the outer delta to support nesting geese. In areas that formerly supported large numbers of geese (Barry 1967; Kerbes et al. 1999), nests are now restricted mainly to driftwood lines, the remaining well-vegetated areas on southern and eastern Fox Den Island, and the Snow Goose Creek area.

The flooding by sea water may have been facilitated by a break in the isthmus in 1964 that separated the former Nicholson Peninsula (now an island) from the mainland (Figure 1). Field assistants Billy and Eileen Jacobson (pers. comm.), local Inuvialuit with several decades of experience in the Anderson River region, offered similar observations on the loss of vegetation as well as a possible explanation of the cause. The Jacobsons reported that in recent years flooding caused by high winds blowing in from the Beaufort Sea had been frequent in the September to January period. As a result, broken, thin layers of sea ice have been deposited on parts of the outer Anderson River delta. These ice deposits are slow to melt in spring, and possibly delay the date of ice- and flood-free conditions over large parts of the traditional goose nesting areas. Another observation made by the Jacobsons was that the water in the river near the CWS cabin was sometimes undrinkable because of the heightened frequency of salt-water intrusion into the delta. This was in direct contrast to the situation a few decades previous when the water near the cabin, although turbid, was always fresh. Finally, the Jacobsons have the impression that storm surges and seasonally high tides have increased the flow of salt water into the delta because of the break in the isthmus at Nicholson Peninsula. This break, now about 1.2 km wide, is situated almost directly north of the nesting islands. Thus, Nicholson Peninsula no longer protects the Anderson River delta from storm surges the way it once did. The break in the Nicholson Peninsula occurred in August 1964 (Barry 1967:28) and has expanded greatly since then. Similar explanations of increasing salt-water flow into the delta have been offered by former CWS biologist Sam Barry (pers. comm. to R.G. Bromley in 2005), who has long-term experience at ARDMBS.

4.7.2 Nesting habitat

The highest densities of nesting Snow Geese were on southern and eastern Fox Den Island in well-vegetated habitat characterized by scattered to dense live willows (20–60 cm tall) and nearly continuous ground cover dominated by patches of tall grasses (Table 12). Such habitat occurred in level areas, on raised banks, and along driftwood lines. Also used for nesting were the highly interspersed complexes of land and water that occurred near Plots 2–6 on Fox Den Island. The latter habitats consisted of meadows (dominated by grasses and sedges), shallow ponds supporting beds of mare's tail (*Hippuris vulgaris*), small patches of wet lowland, and more elevated areas dominated by grasses and low (<30 cm tall) willows (Table 12). Nesting materials used by Snow Geese in these areas included grasses and some small twigs.

On the extensive mud flats and amongst the driftwood on Flat Island, the situation was much different. At the time of our field work, there was no vegetation present there except for a few tiny clumps of grasses and scattered chamomile (*Matricaria ambigua*) beginning its annual growth amongst the driftwood. Old dry stems of chamomile, 30–40 cm tall, occurred amongst some of the driftwood. Widely scattered stems of dead willow were present on the mud flats, and a thin layer of algae had developed in a flooded pond.

On Triangle Island, the only vegetation patches were extensive bands of *Puccinellia*, 20–100 m wide on both sides of a slough (near transect 5). Many stems of dead willows, partially buried in mud, were present on the southern part of the island (transect 6). On both Flat and Triangle islands, Snow Geese nested in high densities along the narrow driftwood lines, and a few other geese nested among the dead willows and on raised banks. Because of the scarcity of nest materials, Snow Geese used small sticks of driftwood and clumps of soil to construct nests. In five different nests, one or two shotgun shells had been incorporated as nest material.

Because of flooding in 2005, there was little potential for nesting in the area near Snow Goose Creek; however, geese appeared to nest there in 2006. The area consisted of extensive meadows as well as numerous temporary and permanent ponds. West of Snow Goose Creek, towards the uplands bordering the delta, the land was characterized by wet polygons.

Nesting habitats of Brant on southern Fox Den Island were at the edges of *Puccinellia* meadows near water or on tiny peninsulas in wetland/grassland complexes. Widely scattered pairs of Brant, suspected to be nesting, were present in similar habitat near Snow Goose Creek and on northern Triangle Island. In addition, a Brant nest was observed on a mud flat on Triangle Island and several Brant nests were present on mud flats in the Oil Drum Island/Gull Islets area. Large numbers of Brant, in dispersed pairs, occurred near the outer edge of mud flats on all islands. Although only observed from some distance with binoculars or spotting scopes, most pairs were thought to be nesting based on observations of the Brant aggressively chasing ravens and gulls.

4.7.3 Feeding habitat

Migration was under way when our fieldwork began in both years, so our information on the use of the nesting islands by spring staging Snow Geese is not complete. Island counts of geese from May 26–28, 2005, indicated that some use of the islands by migrating birds occurred as counts of geese on southern Flat and eastern Fox Den islands declined during the last 2–4 days of migration. In both years, scattered pairs and small flocks of Snow Geese rested and fed 1–2 km east of the cabin in wetlands and grass-shrub tundra around Landfall Lake (Figure 2). Up to 330 Snow Geese were present during any given count, but few geese grazed there after May 25, 2005, or May 26, 2006, respectively. A small proportion of the geese appeared to be resident pairs on foraging excursions from Flat and Fox Den islands. During the pre-nesting period, many Snow Geese around Landfall Lake grazed almost continuously, leaving abundant signs of feeding and grubbing of roots and rhizomes in sedge-hummock and cotton-grass tussock habitats. In May of both years, a few hundred Snow Geese stopped at Grassy Point during the major migration of thousands of geese. Numerous cropped shoots and floating graminoid stems were observed in flooded areas near shore. Dense accumulations of droppings provided strong evidence that the area had been grazed by geese before May 24 in 2005, and prior to May 26 in 2006. The purple and green coloration of fresh droppings indicated the geese had been feeding on berries before their arrival at Grassy Point (where there are no berries) as well as graminoid plants. In addition, at least 103 Brant foraged intensively in the Grassy Point area on May 30, 2005. Many of the pairs of Brant appeared to be local residents that moved back and forth between nesting areas and Grassy Point, whereas some flocks were likely migrants.

Other feeding areas, used by both Snow Geese and scattered pairs of Brant, were in meadows dominated by *Puccinellia*, other grasses, and sedges in a narrow 1-km-long stretch of coastline west of Grassy Point, on southern Fox Den Island, on central and northern Triangle Island, and near Snow Goose Creek. Several flocks of Snow Geese, consisting of as many as 22 non-breeders or failed breeders, were present in the northern Snow Goose Creek area on June 8, 2005.

High densities of goose droppings, and signs of grazing and grubbing, indicated that all of these areas had been heavily used by migrating and non-breeding geese. Despite the use by geese, the vegetation in the feeding areas appeared to be lush and healthy, and we saw no obvious signs that vegetation had been destroyed by overgrazing in these areas.

In both years, we frequently observed both nesting and non-nesting geese feeding in muddy areas where there was little or no detectable vegetation. For example, during 45 minutes of scans on May 29 and 30, 2005, 11% of 454 geese observed in the nesting area on Flat Island were feeding. During 40 minutes of observations of the nesting area made from May 28 to June 2, 2006, 73% of 297 geese were feeding. It was our impression that feeding activity in the area was occurring frequently enough that it could limit the recovery of vegetation.

4.8 Observations of spring goose hunting within and near Anderson River Delta Migratory Bird Sanctuary

A review of anecdotal records from the guest log book at the CWS cabin revealed that spring goose hunting occurred mainly outside the bird sanctuary from 1985–1993 when biologists, based at the cabin, conducted annual spring goose studies. From 1994–2005, however, when biological personnel were absent, egg collecting on Flat Island and spring hunting on or adjacent to nesting areas occurred during most or all years (Table 13).

From May 12–17, 2005, and May 9–17, 2006, five local Inuvialuit hunters hunted geese between the Anderson River cabin and the coast during the last five days of their stay (in both years) when the first geese arrived. They bagged only a few geese at the beginning of the migration, and there was no goose hunting elsewhere in the outer delta. Therefore, the potential impact of hunting on resident geese on the nesting islands was insignificant in 2005 and 2006.

4.9 Arrival, numbers, distribution, and nesting of Brant

Spring migration counts of Brant were not possible because of the relatively small numbers of Brant in the area and difficulties in distinguishing between migrants and residents. In 2005, the earliest arriving Brant were observed on May 24, and numbers increased until June 7. Overall, we estimated there were at least 260 territorial pairs of Brant present in the study area in 2005. In 2006, Brant were first seen on May 26, and numbers increased until the first few days of June, when we estimated at least 110 pairs were present (Appendix 2). The estimated total number of Brant present was 54% lower in 2006 (243 Brant) than in 2005 (526 Brant).

Most Brant were dispersed in isolated pairs and loose aggregations near the edges of ponds, flooded areas, and shorelines of the outer islands. Nesting by at least one pair of Brant was observed or suspected to occur on most islands in the outer delta. Although it was not feasible to count the number of nests directly, we suspect that most of the Brant pairs present in the outer delta were nesting. The largest concentrations of nesting Brant were on Flat Island and southern Fox Den Island during both years of study.

An additional observation of Brant occurred on May 30, 2005, when at least 103 Brant, in pairs or in small groups, flew from various points around Wood Bay to feed at Grassy Point. Many of these pairs displayed aggressive behaviour toward other Brant and may have been local breeders.

5. DISCUSSION

5.1 Reliability of estimates of goose numbers

Ground counts of geese on the outer islands of the Anderson River delta were repeated several times each year, greatly enhancing the reliability of the estimates of the nesting population. Nevertheless, not all parts of the study area were equally visible, which could have led to low counts in the more distant parts of the study area or in areas with some topographic relief. Hence, we expect our overall scan counts for these areas could have been low by 100 pairs or more.

Aerial counts of nesting pairs indicated that 287 and 1406 breeding pairs of Snow Geese were present in the sanctuary during 2005 and 2006 respectively, compared to our ground count estimates of 736 and 1166 during the two years (CWS, unpublished data). The aerial surveys, although potentially less precise in nature than repeated ground counts, offer more complete coverage of the entire study area. The aerial survey results roughly correspond with those from the ground counts, and follow a similar general pattern of lower nesting numbers in 2005 and higher nesting numbers in 2006. Some of the differences in survey estimates undoubtedly resulted from difficulties separating breeding pairs from non-breeding geese in both types of counts, and differences in survey timing relative to predation events.

5.2 Changes in numbers of Snow Geese and Brant at Anderson River Delta Migratory Bird Sanctuary, 1960–2006

A summary of population estimates for Snow Geese from 1960 until 2006 (Table 14) reveals the severity and timing of the decline in Snow Goose numbers at ARDMBS. Numbers of nesting geese were high in the 1970s through 1996, averaging 2577 indicated nesting pairs (range: 1394–4180 pairs). The number of nesting geese apparently dropped in 1997, and has averaged only 571 nesting pairs since then. Numbers of nesting and total geese have been highly variable since the mid-1990s, fluctuating around a much lower average population level than previously, but with no obvious indication of a continuing downward trend.

The number of Brant nesting at ARDMBS seems to have declined more steeply than the number of Snow Geese. Numbers of Brant exceeded 1200 nesting pairs frequently in the 1960s through early 1980s (Alexander et al. 1988) but by 1991–1993, only 400–600 pairs of nesting Brant were estimated to be present (Armstrong 1995). Thus, Armstrong (1995) concluded the population of nesting Brant may have declined by as much as 50% between 1980 and 1991. Comparing his observations to an earlier description of Brant nesting areas reported by Barry (1967), Armstrong (1995) surmised that the distribution of Brant had changed considerably between the 1960s and 1991 and that far fewer Brant were nesting on the northernmost islands in the delta. Our estimates that about 260 pairs of Brant were present within ARDMBS in 2005 and about 110 pairs were present in 2006, indicate the population decline has continued over the past decade or longer. Counts in 2005 and 2006 averaged only 15% of what they were a few decades earlier.

5.3 Habitat loss

Within the outer delta of the Anderson River, the only remaining areas with extensive vegetation cover are southern and southeastern Fox Den Island (Borstad et al. 2008). Most of Fox Den Island and all the northern islands (Triangle, Gull, Brant, Jaeger, and Flat islands) are very sparsely vegetated, consisting largely of unvegetated mud flats and levees. In these barren areas, most Snow Geese nested in the driftwood lines, using any available shelter and sparse nest material such as small sticks, twigs, wood debris, and clumps of soil. Compared to historic numbers, only comparatively small numbers of geese nest in those areas (Kerbes et al. 1999; Wiebe Robertson and Hines 2006). As evidenced by the high rate of nest destruction in the outer delta, the remaining nests are readily detected by foraging bears.

Habitat loss in the outer Anderson River delta was first reported by W. T. Armstrong (1995), who compared habitat conditions in 1991-1993 in some of the most important nesting islands (Brant, Flat, and Fox Den islands) to a description of the same area made by T. W. Barry some 30 years previously (Barry 1967:79). Armstrong reported there were now barren mud flats on the islands where willows and other vegetation had grown in the past. Since the early 1990s, worsening habitat conditions characterized by dead willows and very sparse plant cover have come to typify much of the former nesting area. Continuing degradation in habitat conditions noted by CWS staff led to an analysis of archived LANDSAT imagery to determine the amount and timing of vegetation change (Borstad et al. 2008). It has become apparent from this assessment that loss of habitat has been going on steadily since at least 1972 (when LANDSAT data were first collected) and that habitat loss has gradually spread inland from the coast. Overall vegetation indices for the outer islands declined by 38–45% between 1972 and 2003, and 5.7 km^2 of habitat has been lost or seriously degraded (Borstad et al. 2008). Vegetation loss has also occurred in the Western Delta (including Snow Goose Creek), where the extent of vegetation cover decreased by 18% (2.6 km^2). Borstad et al. (2008) reported that the total amount of degraded/lost habitat in all regions at ARDMBS was 8.8 km^2.

The remote sensing analysis describes the gradual loss of vegetation at Anderson River but does not directly reveal the causal factor(s). Several lines of evidence make it seem almost certain that high soil salinity is involved in the disappearance of vegetation. First, highly saline soils characterize the mud flats and formerly vegetated areas of the outer delta, whereas areas with vegetation have much lower salinity. As well, the observed juxtaposition of dead and healthy shrub communities on opposite sides of high-water lines defined by driftwood or other swash clearly points towards salt-water flooding as a dominant factor in habitat loss. Finally, there is evidence of vegetation die-offs caused by salt-water incursion elsewhere along the Beaufort Coast in Alaska (Reimnitz and Maurer 1979; Flint et al. 2008) as well as the Mackenzie Delta

(S. Solomon, pers. comm.; S. Kokelj, pers. comm.; CWS, unpublished). The soil sodium and chlorine concentrations in areas of dead vegetation at the ARDMBS (Na and Cl levels each typically exceeding 100 meq/l) are similar to those recorded in places with salt-killed vegetation in the outer Mackenzie River delta (S. Kokelj, pers. comm.).

There are several possible factors causing the high soil salinity at ARDMBS:

(1) The outer delta of the Anderson River is very low in elevation (much of it is <1 m above sea level). Sea level in the region has risen by more than 3 mm/yr over the past several decades (Intergovernmental Panel on Climate Change 2001; Manson and Solomon 2007), meaning that more land in the outer delta is now in contact with salt water for longer periods of time.

(2) Global climate change has brought about a reduction of ice cover in the Beaufort Sea, allowing for a longer ice-free season, a greater expanse of open water, and a potential for increased frequency and amplitude of storm surges. Recently, Lesack and Marsh (2007) reported how sea-level rise, reduced sea-ice cover, and enhanced storm surges could amplify flooding in the Mackenzie Delta. At the Anderson River delta, where freshwater flow is much lower than in the Mackenzie River, the potential for salt-water inundation is apt to be much greater. That is because in the Mackenzie Delta storm surges slow down and back up the high volume of freshwater flow but do not necessarily flood the delta with salt water.

(3) Local Inuvialuit feel that tidal water now flows further up the Anderson River than it did historically (Billy and Eileen Jacobsen, pers. comm.). They associate increased salt-water flooding in the Anderson River delta with the erosion (in 1964) of a channel through Nicholson Peninsula that formerly provided protection against storm surges coming off the Beaufort Sea. Extensive coastal erosion has been reported elsewhere along the Beaufort Coast (e.g., Manson and Solomon 2007; Mars and Houseknecht 2007) and possibly explains salt-killed vegetation in other areas as well (e.g., Reimnitz and Maurer 1979; Flint et al. 2008).

(4) Elsewhere in the Canadian Arctic, in the coastal lowlands near Hudson Bay, overgrazing by Snow Geese has led indirectly to elevated soil salinity (Iacobelli and Jefferies 1991; Abraham and Jeffries 1997). Similarly, grubbing by foraging Snow Geese, including the large numbers of staging Snow Geese en route to Banks Island, could cause further loss in plant cover or inhibit recovery of vegetation in the Anderson River delta. Although we found no obvious evidence of extensive

habitat loss being caused by goose grubbing, we did observe geese feeding in very sparsely vegetated sites near their nesting territories. It seems possible that feeding by geese could play an additional role in habitat loss or in preventing recovery of vegetation in such areas.

Increased flooding by salt water, perhaps facilitated by sea-level rise, increased impacts of storm surges driven by loss of sea-ice cover and the erosion of a channel through the narrow part of the Nicholson Peninsula, is an intuitively appealing explanation of habitat changes observed at ARDMBS. It is consistent with both the observed pattern of high soil salinity and vegetation loss in the outer Anderson River delta and observations of environmental change elsewhere in the region.

The buildup of ice deposits from winter storm surges has possibly exacerbated habitat loss, and the added pressure of feeding by Snow Geese during migration and nesting may limit the potential for recovery of the vegetation. During the last 30 years or more, concentrations of nesting Snow Geese have been highest in well-vegetated areas containing scattered to dense willows on eastern Fox Den Island (Barry 1967; Armstrong 1995; Kerbes et al. 1999; Billy Jacobson, pers. comm.). Barren mud flats now exist near most of those sites.

5.4 Effects of grizzly bears and other predators on goose populations

Over the two years of study, grizzly bears were responsible for 82% of the observed nest losses on the study area, and probably destroyed >25% of all Lesser Snow Goose nests present in 2005 and >80% of the nests present in 2006 (based on our rough approximation that 70% of the nests were successful in 2005 and only 1–2% of the nests were successful in 2006). In 2005, bears were last seen on the nesting islands on June 7. We did not detect any bears during our aerial reconnaissance when we departed ARDMBS on 8 June and, similarly, a field crew with the GNWT–Department of Environment and Natural Resources, Inuvik, did not spot grizzlies in the Anderson River delta in mid-June 2005 despite a very thorough helicopter search of the area as part of a bear-tagging program (M. Branigan, pers. comm.). The disappearance of bears from the Anderson River delta in early June apparently resulted in the good production of young witnessed in 2005. It coincided with a cyclic peak in the number of small rodents, which almost certainly acted as "buffer prey" and reduced the amount of egg depredation. Previously, Armstrong (1995) reported that the highest egg survival rate in the Anderson River delta occurred in a year (1993) when small mammal numbers were high. In 2006, at least two bears were still present in the goose nesting areas when our field crew departed from Anderson River on June 9. Very few Snow Goose goslings were counted during the July aerial productivity survey, suggesting that the bears must have continued to forage on goose eggs well into the incubation period, causing substantial nest losses. The effects of bear predation on goose nests in 2006 may have been exacerbated by the scarcity of small rodents that year, which would have provided little alternate prey.

There have been a number of written and anecdotal reports of grizzly bear activity in the outer Anderson River delta dating back as early as 1959 (Barry 1959, 1967; Armstrong 1995; this report Table 13). In June of 1985, five grizzly bears were observed in the delta. The bears were thought to have destroyed about 2500 goose, swan, and gull nests or approximately 10 000 eggs in the course of a week (S.J. Barry in Table 13). Armstrong (1995) reported “catastrophic” egg predation by grizzly bears in some parts of the nesting colonies occurred annually from 1991 through 1993. Other accounts were: June 10, 1995, hunters observed a grizzly bear eating goose eggs on southern Flat and eastern Fox Den islands; May 29, 1996, an egg collector was followed by a male grizzly bear eating eggs on Flat Island; May 29, 2003, hunters saw a very large grizzly bear on Flat Island; and May 13, 2004, hunters reported two “small” (i.e., subadult) grizzlies in the area. Previously, jaegers, foxes, gulls, and occasionally wolverines have been recorded as important predators of goose eggs at Anderson River (Barry 1967; Armstrong 1995). We also found that ravens were a frequent predator of goose eggs. Given the potentially high rates of nest predation that geese experience at the Anderson River delta, it may not be surprising that the breeding population has decreased over time. However, recent habitat degradation, flooding, and the concentration of nests further inland or along driftwood lines may have increased the opportunities for bears to find goose nests, a trend that, in the absence of intervention by humans, could trigger even higher egg predation in the future.

In this study, grizzly bears were aware of our presence and, for that reason, appeared to avoid the areas with high goose nesting densities on eastern Fox Den and Flat islands near the CWS cabin. In the past, however, bears apparently plundered eggs on Flat Island on some occasions despite hunters or researchers staying at the cabin. Our observations suggest that the presence of people may keep bears away in some years, thereby increasing the overall reproductive success of the geese.

6. MANAGEMENT IMPLICATIONS, RECOMMENDATIONS, AND CONCLUSIONS

Vegetation loss has occurred steadily over the past several decades in the outer Anderson River delta, apparently because of increased soil salinity. A probable cause of the change is increased or more frequent flooding of the delta by storm surges coming off the Beaufort Sea. Erosion of the isthmus of the Nicholson Peninsula, which formerly protected the delta from such storms, might be playing an important role in the increased flooding. As well, overgrazing by resident and staging Snow Geese could be further impacting vegetation recovery.

Whatever the cause or causes of increased salinity and vegetation loss, the net effect has been that habitat for nesting Snow Geese and Brant is disappearing in quantity and decreasing in quality. The amount of preferred habitat available to Snow Geese and Brant has been reduced, and the remaining nests of Snow Geese are concentrated in a smaller area and further inland than historically. Geese now appear to be especially vulnerable to nest destruction caused by grizzly bears, which show up in the delta each spring, and perhaps to other predators as well. Harvest of geese and eggs in the outer Anderson River delta may have been higher in the mid-1990s when the geese declined. We suspect that harvest of locally breeding birds, as occurred in 2005 and 2006, would have been diluted by the high proportion of migrants at the time that most of the hunting occurs. Nevertheless, limiting harvest remains one of the simplest ways of managing geese, and directing harvest towards the large numbers of Banks Island Snow Geese while protecting the local nesting population at Anderson River should be encouraged.

Faced with a situation of potentially irreversible habitat loss and increased predation by grizzly bears, successful management of the migratory bird sanctuary to maintain large populations of Snow Geese and Brant (as existed in the 1960s through the 1980s) will be difficult or impossible. Assuming that habitat loss becomes stabilized at its current level, it might be possible, however, to maintain populations of geese at recent levels by keeping goose harvest at a low level (as witnessed in 2005–2006) and reducing the rates of bear predation. We have estimated that an average annual nesting success of ~30% would be required to maintain a population of geese at current levels (J. Hines, CWS, unpublished). For an overall population of 2000 geese (breeders plus non-breeders), this means that about 200 clutches must be hatched successfully. Such average levels of productivity could be attained by maintaining moderate levels of production each year, or by attaining spikes in reproductive output once every few years. Our observations, and those of earlier investigators (e.g., Armstrong 1995, 1996) and local hunters, indicate that grizzly bears tend to avoid humans at ARDMBS. Hence, use of more passive forms of deterrents, such as human presence to keep bears away from nesting areas, is a potentially useful technique for improving goose nest success. Given the chances for enhanced nest success during periods of abundant buffer prey such as voles and lemmings, some focus on deterring bears during peaks of small rodents might prove to be most effective.

A number of recommendations for managing the goose populations in ARDMBS were previously proposed based on the preliminary results of our 2005–2006 study, an additional year of field work in 2007, and a review of previous research at the sanctuary (Hines 2008). The principal recommendations are reiterated below:

(1) Monitoring of nesting populations, distribution, and reproductive success of Lesser Snow Geese and Brant should be carried out at regular intervals.

(2) When numbers and nesting success of Snow Geese and Brant drop consistently below acceptable threshold levels, short-term means of increasing productivity should be evaluated. This could include passively deterring bears simply by the presence of humans near the colony or using more active means to deter bears. Management actions also would be dependent on the overall regional and continental numbers of Snow Geese and Brant at the time.

(3) The synergies among flooding, soil salinity, goose grazing, and other factors influencing habitat loss should be further assessed. Given potential for salt-water inundation elsewhere along the Beaufort coast, the information gathered should be valuable in conservation of important migratory bird habitat elsewhere in the region as well as at ARDMBS.

(4) The potential for habitat restoration should be evaluated.

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Table 1. Spring migration counts of Lesser Snow Geese at the outer Anderson River delta, Northwest Territories, 2005–2006

Date	Time of day*	Survey period (minutes)	Number of geese moving eastward	Number of geese moving westward	Migrating geese/minute	Total passage of geese
22-May-2005	Evening	70	258	2	3.66	1317
23-May-2005	Morning	88	343	6	3.83	1379
	Afternoon	190	663	105	2.94	1057
	Evening	30	53	4	1.63	588
	Total	***308***	***1059***	***115***	***3.06***	***3024***
24-May-2005	Morning	60	332	14	5.30	1908
	Afternoon	120	1738	60	13.98	5034
	Evening	60	263	11	4.20	1512
	Total	***240***	***2333***	***85***	***9.37***	***8454***
25-May-2005	Morning	120	212	34	1.48	534
	Afternoon	120	66	21	0.38	135
	Evening	60	29	12	0.28	102
	Total	***300***	***307***	***67***	***0.80***	***771***
26-May-2005	Morning	60	150	8	2.37	852
	Afternoon	120	136	6	1.08	390
	Evening	60	73	7	1.10	396
	Total	***240***	***359***	***21***	***1.41***	***1638***
27-May-2005	Morning	30	2	0	0.07	24
28-May-2005	Morning	30	25	0	0.83	300
	Afternoon	90	81	7	0.82	296
	Evening	120	33	0	0.28	99
	Total	***240***	***139***	***7***	***0.55***	***695***
29-May-2005	Morning	30	9	0	0.30	108
2005 Total		**1458**	**4466**	**297**	**2.86**	**16030**
17-May-2006	Morning	60	11	631	-10.33	-3720
	Afternoon	60	494	48	7.43	2676
	Evening	60	459	13	7.43	2676
	Total	***180***	***964***	***692***	***1.51***	***1632***
18-May-2006	Morning	60	1204	74	18.83	6780
	Afternoon	60	1167	30	18.95	6822
	Evening	60	378	43	5.58	2010
	Total	***180***	***2,749***	***147***	***14.46***	***15612***
19-May-2006	Morning	60	369	75	4.90	1764
	Afternoon	60	1052	58	16.57	5964
	Evening	60	175	12	2.72	978
	Total	***180***	***1,596***	***145***	***8.06***	***8706***
17-May-2006	Morning	60	11	631	-10.33	-3720
	Afternoon	60	494	48	7.43	2676
	Evening	60	459	13	7.43	2676
	Total	***180***	***964***	***692***	***1.51***	***1632***
18-May-2006	Morning	60	1204	74	18.83	6780

Date	Time of day*	Survey period (minutes)	Number of geese moving eastward	Number of geese moving westward	Migrating geese/minute	Total passage of geese
	Afternoon	60	1167	30	18.95	6822
	Evening	60	378	43	5.58	2010
	Total	***180***	***2749***	***147***	***14.46***	***15612***
19-May-2006	Morning	60	369	75	4.90	1764
	Afternoon	60	1052	58	16.57	5964
	Evening	60	175	12	2.72	978
	Total	***180***	***1596***	***145***	***8.06***	***8706***
20-May-2006	Morning	60	112	43	1.15	414
	Afternoon	60	149	27	2.03	732
	Evening	60	53	26	0.45	162
	Total	***180***	***314***	***96***	***1.21***	***1308***
21-May-2006	Morning	60	66	92	-0.43	-156
	Afternoon	60	152	51	1.68	606
	Evening	60	79	55	0.40	144
	Total	***180***	***297***	***198***	***0.55***	***594***
22-May-2006	Morning	60	71	50	0.35	126
	Afternoon	60	191	56	2.25	810
	Evening	60	84	39	0.75	270
	Total	***180***	***346***	***145***	***1.12***	***1206***
23-May-2006	Morning	60	36	61	-0.42	-150
	Afternoon	60	145	43	1.70	612
	Evening	60	108	29	1.32	474
	Total	***180***	***289***	***133***	***0.87***	***936***
24-May-2006	Morning	60	310	30	4.67	1680
	Afternoon	60	120	19	1.68	606
	Evening	60	15	21	-0.10	-36
	Total	***180***	***445***	***70***	***2.08***	***2250***
25-May-2006	Morning	60	148	27	2.02	726
	Afternoon	60	16	9	0.12	42
	Evening	60	17	3	0.23	84
	Total	***180***	***181***	***39***	***0.79***	***852***
26-May-2006	Morning	60	10	7	0.05	18
	Afternoon	60	0	5	-0.08	-30
	Evening	60	0	2	-0.03	-12
	Total	***180***	***10***	***14***	***-0.02***	***-24***
2006 Total		**1800**	**7191**	**1679**	**3.06**	**33072**

*Daily periods for data summary: Morning (0600–1200), Afternoon (1200–1800), Evening (1800–2400).

Table 2. Chronology of spring migration of Lesser Snow Geese in the Western Canadian Arctic, 2005–2006, as reported by Inuvialuit hunters

Year	Date	Extent of migration	Area
2005	May 12–17	very few geese	outer Anderson River Delta
	May 18	fairly slow migration	Mackenzie Delta, Tuktoyaktuk
	May 19	fairly slow migration	Paulatuk, Sachs Harbour
	May 20	fairly slow migration	Mackenzie Delta, Tuktoyaktuk
	May 21	fairly slow migration	Paulatuk, Sachs Harbour
	May 22–23	increase in numbers	throughout the region
	May 24–26	numbers peaking	throughout the region
	May 27	very few geese	Paulatuk, Sachs Harbour
	May 28–29	very few geese	throughout the region
	May 30	migration is over	Paulatuk
	May 31	migration is over	Sachs Harbour and regional
2006	May 12	no geese migrating	outer Anderson River Delta
	May 13–15	first few geese	outer Anderson River Delta
	May 16	a few more geese	outer Anderson River Delta
	May 17	large numbers of geese	outer Anderson River Delta
	May 18–19	large numbers of geese	Mackenzie Delta area
	May 20	few geese	Paulatuk, Brock River delta
	May 21–23	no geese migrating	throughout the region
	May 24	few geese	Tuktoyatuk, Liverpool Bay
	May 25	few geese	Tuktoyatuk, Mackenzie Delta
	May 26	few geese	Nicholson Point
	May 27	large numbers of geese	Sachs Harbour
	May 28	few geese	Tuktoyatuk
	May 29	no geese migrating	Tuktoyatuk, Toker Point
	May 30	last few geese reported	Toker Point, Nicholson Point
	May 31	migration is over	throughout the region

Table 3. Estimated numbers of Lesser Snow Geese using the Anderson River delta, Northwest Territories, during the nesting seasons of 2005 and 2006

Year	Survey Area	Pairs	Total
2005	Bluff Island	0	0
	Boat Island	0	0
	Brant Island	4	8
	Canoe Island	120	240
	Fox Den Island	393	786
	Gull Islets	3	6
	Jaeger Island	5	10
	Flat Island	138	276
	Triangle Island	73	146
	Mainland and Snow Goose Creek area	0	0
	East of cabin	0	0
	Total	**736**	**1,472**
2006	Bluff Island	0	3
	Boat Island	1	3
	Brant Island	7	42
	Canoe Island	46	135
	Fox Den Island	879	1758
	Gull Islets	0	9
	Jaeger Island	1	7
	Flat Island	47	189
	Triangle Island	54	108
	Mainland and Snow Goose Creek area	>126	450
	East of cabin	6	12
	Total	**1167**	**2716**

Table 4. Densities of Lesser Snow Goose nests (nests/ha) in survey plots in the outer Anderson River delta, Northwest Territories, 2005–2006

Year	Date	Plot Number	Number of active nests	Number of depredated nests	Total number of nests	Density (nests/ha)
2005	4-Jun	1	0	0	0	0.00
	4-Jun	2	0	9	9	4.00
	4-Jun	3	13	2	15	6.67
	5-Jun	4	10	4	14	6.22
	5-Jun	5	9	3	12	5.33
	5-Jun	6	0	0	0	0.00
	6-Jun	7	5	1	6	2.67
	6-Jun	8	2	1	3	1.33
	6-Jun	9	0	0	0	0.00
	6-Jun	10	26	5	31	13.78
	6-Jun	11	7	0	7	3.11
		All plots	**72**	**25**	**97**	**3.92**
2006	06-Jun	1	0	0	0	0.00
	06-Jun	2	0	5	5	2.22
	06-Jun	3	1	18	19	8.44
	07-Jun	4	2	0	2	0.89
	07-Jun	5	7	10	17	7.56
	06-Jun	6	0	0	0	0.00
	02-Jun	7	2	0	2	0.89
	02-Jun	8	0	0	0	0.00
	02-Jun	9	0	0	0	0.00
	07-Jun	10	46	2	48	21.33
	07-Jun	11	5	0	5	2.22
		All plots	**63**	**35**	**98**	**3.96**

Table 5. Linear densities (nests/100 m) of Lesser Snow Goose nests determined from transects situated on levees or lines of driftwood in the outer Anderson River delta, Northwest Territories, 2005–2006

Year	Date	Transect	Length (m)	# of active nests	# of depredated nests	Total # of nests	Density (nests/100 m)
2005	6-Jun	1	400	24	-	24	**6.00**
	6-Jun	2	650	46	2	48	**7.38**
	6-Jun	3	450	17	2	19	**4.22**
	7-Jun	4	900	120	-	120	**13.33**
	7-Jun	5	650	1	65	66	**10.15**
	7-Jun	6	400	0	6	6	**1.50**
		Total	**3450**	**208**	**75**	**283**	**8.20**
2006	2-Jun	1	400	0	0	0	**0.00**
	2-Jun	2	650	1	1	2	**0.31**
	7-Jun	3	450	19	5	24	**5.33**
		Total	**1500**	**20**	**6**	**26**	**1.73**

Table 6. Clutch sizes of Lesser Snow Geese in the Anderson River delta, 2005–2006

Year		Plots	Transects	Other areas	Total
2005					
	Number of nests	72	64	31	**167**
	Number of eggs	293	243	120	**656**
	Mean clutch size	4.07	3.80	3.87	**3.93**
	Range	1–7	1–8	1–7	**1–8**
	Standard Error	0.14	0.14	0.23	**0.09**
2006					
	Number of nests	62	20	63	**145**
	Number of eggs	212	79	239	**530**
	Mean clutch size	3.42	3.95	3.79	**3.66**
	Range	1–6	1–8	1–6	**1–8**
	Standard Error	0.16	0.39	0.15	**0.11**
Both years					
	Number of nests	134	84	94	**312**
	Number of eggs	505	322	359	**1186**
	Mean clutch size	3.77	3.83	3.82	**3.80**
	Range	1–7	1–8	1–7	**1–8**
	Standard Error	0.11	0.14	0.13	**0.07**

Table 7. Status of Lesser Snow Geese nests at the time of discovery at the outer Anderson River delta, 2005–2006

	2005		2006		Both years	
Status	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Active	167	58.8	144	64.0	311	61.1
Predator destroyed:						
Grizzly bear	102	35.9	61	27.1	163	32.0
Avian	6	2.1	2	0.9	8	1.6
Red fox	2	0.7	12	5.3	14	2.8
Undetermined	7	2.5	5	2.2	12	2.4
Flooding	0	0.0	1	0.4	1	0.2
Total	**284**	**100.0**	**225**	**100.0**	**509**	**100.0**

Table 8. Causes of Lesser Snow Goose nest failure at Anderson River delta, 2005–2006

	2005		2006		Both years	
Status	**Number of nests**	**Percent**	**Number of nests**	**Percent**	**Number of nests**	**Percent**
Grizzly bear	102	87.2	61	75.3	163	82.3
Avian predator	6	5.1	2	2.5	8	4.0
Red fox	2	1.7	12	14.8	14	7.1
Undetermined	7	6.0	5	6.2	12	6.1
Flooding	0	0.0	1	1.2	1	0.5
Total	**117**	**100.0**	**81**	**100.0**	**198**	**100.0**

Table 9. Sightings of potential avian predators of adult geese, young geese, or goose eggs at Anderson River Delta Migratory Bird Sanctuary, 2005–2006

Species	2005		2006		Both years			
	Number of days sighted	Total number sighted	Number of days sighted	Total number sighted	Number of days sighted	Total number sighted	Percent of field days sighted[a]	Birds sighted per day
Glaucous Gull	15	890	20	780	35	1670	97	46.39
Common Raven	15	52	18	83	33	135	92	3.75
Northern Harrier	8	27	17	35	25	62	69	1.72
Parasitic Jaeger	11	40	7	19	18	59	50	1.64
Short-eared Owl	9	15	7	10	16	25	44	0.69
Peregrine Falcon	6	6	8	17	14	23	39	0.64
Pomarine Jaeger[b]	5	40	7	570	12	610	33	16.94
Bald Eagle	2	2	7	7	9	9	25	0.25
Rough-legged Hawk	5	5	4	4	9	9	25	0.25
Long-tailed Jaeger	3	12	1	6	4	18	11	0.50
Golden Eagle	2	2	1	1	3	3	8	0.08
Mew Gull	1	1	1	1	2	2	6	0.06
Gyrfalcon	0	0	1	1	1	1	3	0.03
Herring Gull	1	1	0	0	1	1	3	0.03
Total		**1093**		**1534**		**2627**	**-**	**72.97**

[a] Percent based on 16 field days in 2005 and 20 field days in 2006.

[b] Flocks of migrating birds observed passing through the area.

Table 10. Sightings of mammalian predators of adult geese, young geese, or their eggs at Anderson River Delta Migratory Bird Sanctuary, 2005–2006

Species	2005		2006		Both years			
	Number of days sighted	Total number sighted	Number of days sighted	Total number sighted	Number of days sighted	Total number sighted	Percent of field days sighted[a]	Mammals sighted per day
Grizzly bear	8	24	9	14	17	38	47	1.06
Red fox	1	1	2	4	3	5	8	0.14
Wolf	0	0	1	1	1	1	3	0.03
Wolverine	1	1	0	0	1	1	3	0.03
Total	**10**	**26**	**12**	**19**	**22**	**45**	**-**	**1.25**

[a] Percent based on 16 field days in 2005 and 20 field days in 2006.

Table 11. Grizzly bear observations at Anderson River Delta Migratory Bird Sanctuary, 2005–2006

2005

Bear ID	**Parameter**	**May 29**	**May 30**	**May 31**	**Jun 1**	**Jun 2**	**Jun 3**	**Jun 4**	**Jun 5**	**Jun 6**	**Jun 7**	**Total**	**Days seen**
Pair #1	Minutes observed	290	200	126	156	150			6	120	40	1088	8
	Nests destroyed	13	1	17	11	5			0	11	0	58	
Female + cub #2	Minutes observed	210										210	1
	Nests destroyed	0										0	
Female + cub #3	Minutes observed	30										30	1
	Nests destroyed	0										0	
Pair #4	Minutes observed	40										40	1
	Nests destroyed	0										0	
Bear #5	Minutes observed	40										40	1
	Nests destroyed	0										0	
Bear #6	Minutes observed										5	5	1
	Nests destroyed										0	0	
All bears	Number observed	9	2	2	2	2	0	0	2	2	3	**-**	-
(10 individuals)	Minutes observed	610	200	126	156	150	0	0	6	120	45	**1413**	-
	Nests destroyed	13	1	17	11	5	0	0	0	11	0	**58**	-

2006

Bear ID	**Parameter**	**May 30**	**May 31**	**Jun 1**	**Jun 2**	**Jun 3**	**Jun 4**	**Jun 5**	**Jun 6**	**Jun 7**	**Jun 8**	**Total**	**Days seen**
Pair #1	Minutes observed	498	505									1003	2
	Nests destroyed	0	6									6	
Bear #2	Minutes observed				350	493						843	2
	Nests destroyed				13	1						14	
Bear #3	Minutes observed						590	310				900	2
	Nests destroyed						1	14				15	
Bear #4	Minutes observed							85	481	100	150	816	4
	Nests destroyed							12	1	0	0	13	
Bear #5 + #6	Minutes observed								411			411	1
	Nests destroyed								0			0	
All bears	Number observed	2	2	0	1	1	1	2	3	1	1	**-**	**-**
(7 individuals)	Minutes observed	498	505	0	350	493	590	395	892	100	150	**3973**	**-**
	Nests destroyed	0	6	0	13	1	1	26	1	0	0	**48**	-

Table 12. Habitat descriptions of plots and transects surveyed in the outer Anderson River delta in 2005 and 2006

Plot/transect	Location	Habitat description
Plot 1	SE-Fox Den Island	50% grassy + scattered willow 20–40 cm tall; 50% willow 50–60 cm tall + scattered grassy areas; 3 wet spots = total of 20 m × 10 m; 1 old driftwood line on E-border of plot; 0.25 ha cut off by river in NE-corner of plot.
Plot 2	SW-Fox Den Island	30% wetland + ponds + scattered willow 10–30 cm tall + scattered grass/sedge-patches; 70% grass/sedge + scattered willow 10–30 cm tall.
Plot 3	SW-Fox Den Island	35–40% shallow ponds + aquatic plants; 60–65% grass/sedge + scattered willow 10–20 cm tall, well vegetated; flood lines in NE corner of plot.
Plot 4	SE-Fox Den Island	60% water, abundant mare's tail (*Hippuris vulgaris*); 40% grass/sedge (*Puccinellia sp.*) + scattered willow 10–20 cm tall, some flood lines.
Plot 5	SE-Fox Den Island	30% water, dense growth of mare's tail; 33% driftwood line + willow 20–40 cm tall; 37% grass/sedge + scattered willow 20–25 cm tall.
Plot 6	SE-Fox Den Island	20% water – mostly shallow ponds with mare's tail; 50% tall grass + sedge + scattered willow 20–30 cm tall.
Plot 7	South-Flat Island	97% mud flats; 3% driftwood line; no vegetation; 1 mud pool 10 m × 4 m outside plot; tiny cluster of few green sedges in SE-corner at a nest.
Plot 8	South-Flat Island	95% mud flats, no vegetation; 5% driftwood line, no vegetation.
Plot 9	South-Flat Island	10–15% flood water + green algae; 85–90% mud flats; few stumps of dead willow; few clumps (15–25 cm in diameter) of *Puccinellia* sp.
Plot 10	East-Fox Den Island	60% willow 50–60 cm tall, 1/3 of willow mixed with rich grasses 40–50 cm tall; <2% water; 3% driftwood line in muddy areas; 25% dry bare ground + scattered grass; <10% dry slough.
Plot 11	East-Fox Den Island	NE corner = 0.01% patch of 20 m × 15 m willow 30–60 cm tall with grasses, + 75 sqm grass; 1% driftwood line + dead willow; 2% shallow flood water; 97% bare mud flats with scattered dead willows and few grasses.
Transect 1	Central-Flat Island	Narrow driftwood line (200 m × 10 m) in bare mud near shore, scattered stumps of dead willow, no vegetation except for a lots of new green chamomile (5 cm tall) and last year's dried chamomile (30–40 cm tall) grew in high densities in parts of the driftwood zone.
Transect 2	SW-Flat Island	Narrow driftwood line (200 m × 10 m) in bare mud near shore, scattered stumps of dead willow, no vegetation except for a lots of new green chamomile (5 cm tall) and last year's dried chamomile (30–40 cm tall) grew in high densities in parts of the driftwood zone.
Transect 3	East-Fox Den Island	Narrow strip (450 m × 12 m) of driftwood line + dense willows 30–60 cm tall + scattered grass along river mud bank (2–3 m above shore).
Transect 4	East-Canoe Island	Dense willow 30–60 cm tall growing along or on driftwood line on top of a mud bank 2–3 m above the river.
Transect 5	Central-Triangle Island	Driftwood line along slough with extensive *Puccinellia sp.* bands of 20–100 m wide on each side; lots of dead willow stumps in the driftwood line and in mud flats, not one live willow or any vegetation; visible white salt on drier ground.
Transect 6	South-Triangle Island	100% low-lying mud flats + scattered clumps of dead willows 30–60 cm tall (no driftwood), visible salt, no live willows or any vegetation.

Table 13. Notes extracted from the cabin guest log book at the Anderson River Delta Migratory Bird Sanctuary, 1985–2005.

Date	Notes
9 May 1985	Hunters: family "just passing through" [on way to Stanton].
30 June 1985	Quote from Sam Barry: "5 grizzly bears are in the area. In the course of a week, they destroyed 2500 Snow Goose, Brant, swan and Glaucous Gull nests – an equivalent of 10,000 eggs!" [based on observations in late-May to June].
20 May 1985	5 Hunters: "passing through".
22 May 1987	Hunters: family "passing through going home to Stanton".
5 May 1988	Hunters: family had lunch on way to Stanton.
22 May 1989	4 Hunters: "Camped one night while hunting (lots of water, and too much mud)".
15 May 1992	3 Hunters visiting.
13 May 1993	4 Hunters: "Gotta go geese are flying".
25 May 1993	JO: Hunters were spring goose hunting for several days at the Lagoon 6 km E-NE of Grassy Point along the coast;
2 June 1993	T. Armstrong and CWS students stay at the cabin for waterfowl studies this spring (every spring from 1991–1993).
12 May 1994	Hunters: family here enroute to Stanton – "few days cleaning up …. the cabin".
4 May 1995	Hunters: family here enroute.
4 June 1995	Hunters: family arrived by snowmobile from Tuk and will stay at the cabin for a month.
10 June 1995	Grizzly Bear: 1 bear eating goose eggs 1 km up river from cabin; "everything is early this year".
3 May 1996	Hunters: family arrived from Tuk for spring at the cabin.
17 May 1996	5 Hunters: came from Tuk, camp 4 miles NE of cabin towards Stanton, visited cabin.
18 May 1995	Hunters: several arrived at the cabin yesterday from Nallok and "… can't wait until all the geese fly."
19 May 1996	7 Hunters: arrived at the cabin and "probably will stay until we got enough geese".
23 May 1996	Hunters: "we, the crew that arrived on 17th May/96 are now leaving to Tuk at midnight with 7 sleds and 270+ geese; the river is still not busted but the weather is very hot".
29 May 1996	Joachim Obst: people visit family of hunters staying at the cabin all spring: they harvested over 100 goose eggs today on Flat Isl.; one egg collector was followed by male grizzly bear for a while – then bear turned away; bear was eating eggs; the family intended to stay at the cabin all spring and get a few more geese and eggs.
13 May 1997	Hunters: 6 people overnighted (2+ hunters).
17 May 1997	Hunters: 6 different people overnighted.
20 May 1997	Hunters: one of the above parties overnighted.
21 May 1997	Hunter: 1 staying at Wood Bay visiting cabin enroute from Tuk.
25 May 1997	Hunters: 2 overnighted – no geese.
27 May 1997	Hunters: family visited – thanks to family staying here.
30 May 1997	JO: Hunter family staying here collecting goose eggs and hunting geese until June 2.
13 May 1998	Hunters: family arrived from Tuk for spring at the cabin.
?? May 1998	2 Hunters: "first time hunt geese here … geese haven't really started yet".
21 May 1998	5 Hunters: "first day of goose hunting".
?? May 1998	Hunter(s): "Goose hunting", "got my load here".
23 May 1998	Hunters: 3 people "picked 102 eggs when we got to the boat we had 75 left". 3 hunters: "about 200 geese, here for one week and going back tonight".
12 May 2000	Hunters: family arrived for spring at the cabin.
1 June 2000	3 hunters here – lots of snow yet.
3 June 2000	Hunters: "waiting for geese. Cold late spring. 4 hunters camping at Mason [river] hoping to get 500 geese". Several other hunters stopping en route.
7 May 2002	Hunters: family arrived for spring at the cabin.
23–30 May 2002	Hunters: "lots of geese. Just when the fun started on 30th very nice day also a lot of geese".
4 June 2002	Hunters: family left for Tuk.
12 May 2003	Hunters: family arrived for spring at the cabin.
25 May 2003	7 visiting hunters: "Geese flying, shot my load but still want more".
29 May 2003	Hunter(s): 1 very large [grizzly] bear about 10–11 feet on Flat Island.
13 May 2004	Hunters: family arrived for spring at the cabin – 2 small grizzlies.
12–17 May 2005	Hunters: family here for spring goose hunting May 12–17, 2005.

Table 14. Estimated number of nesting and non-breeding Snow Geese present at the Anderson River Delta Bird Sanctuary, 1960–2006

Year	Indicated nesting pairs	Indicated nesting birds	Non-nesting birds	Total birds	Method (source)
1960	?	?	?	8000	Reconnaissance (Barry 1967)
1976	1913	3826	1017[a]	4843	Air photo survey (Kerbes 1986)
1981	4180	8360	878[a]	9238	Air photo survey (Kerbes 1986)
1987	3593	7186	507[a]	7693	Air photo survey (Kerbes et al. 1999)
1995	1804	3607	2359[a]	5966	Air photo survey (Kerbes et al. 1999)
1996	1394	2788	660	3448	Helicopter survey (Wiebe Robertson and Hines 2006)
1997	403	806	2682	3488	Helicopter survey (Wiebe Robertson and Hines 2006)
1998	298	596	2409	3005	Helicopter survey (Wiebe Robertson and Hines 2006)
1999	123	246	860	1106	Helicopter survey (Wiebe Robertson and Hines 2006)
2000	571	1142	1158	2300	Helicopter survey (Wiebe Robertson and Hines 2006)
2001	664	1327	988	2315	Helicopter survey (Wiebe Robertson and Hines 2006)
2002	929	1857	?	1857	Air photo surveys (CWS, unpublished data)
2003	251	502	385	887	Helicopter survey (CWS, unpublished data)
2004	13	26	1085	1111	Helicopter survey (CWS, unpublished data)
2005	287	574	489	1063	Helicopter survey (CWS, unpublished data)
2005	746	1492	?	1492	Ground surveys (this report)
2006	1406	2812	1183	3995	Helicopter survey (CWS, unpublished data)
2006	1167	2334	382	2716	Ground surveys (this report)
Mean[b]	**1189**			**3770**	
1976–1996 Mean	**2577**			**6238**	
1997–2006 Mean	**495**			**2113**	

[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] Values from helicopter surveys in 2005 and 2006 used in calculating mean numbers.

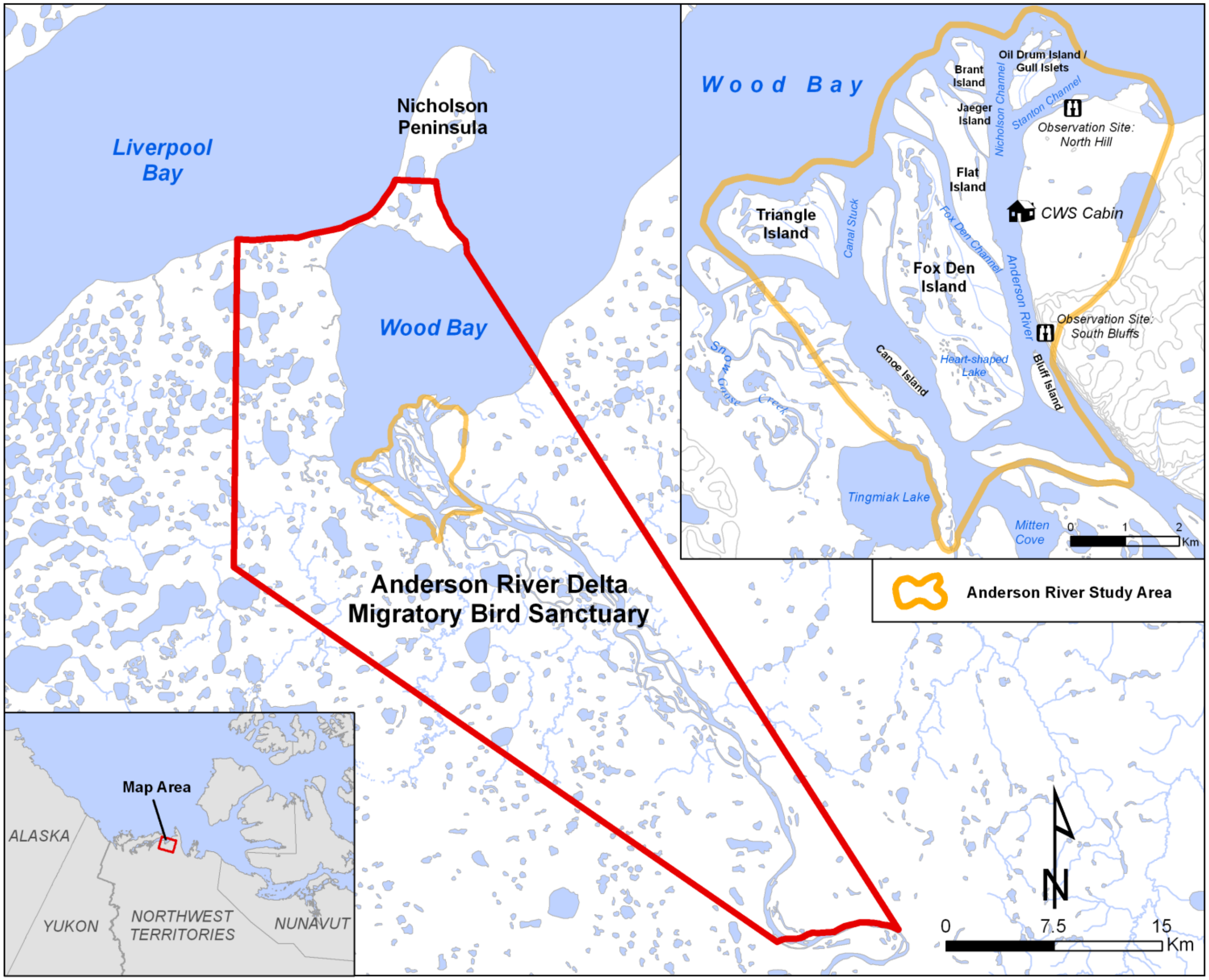

Figure 1. Location of the Anderson River Delta Migratory Bird Sanctuary, Inuvialuit Settlement Region, Northwest Territories

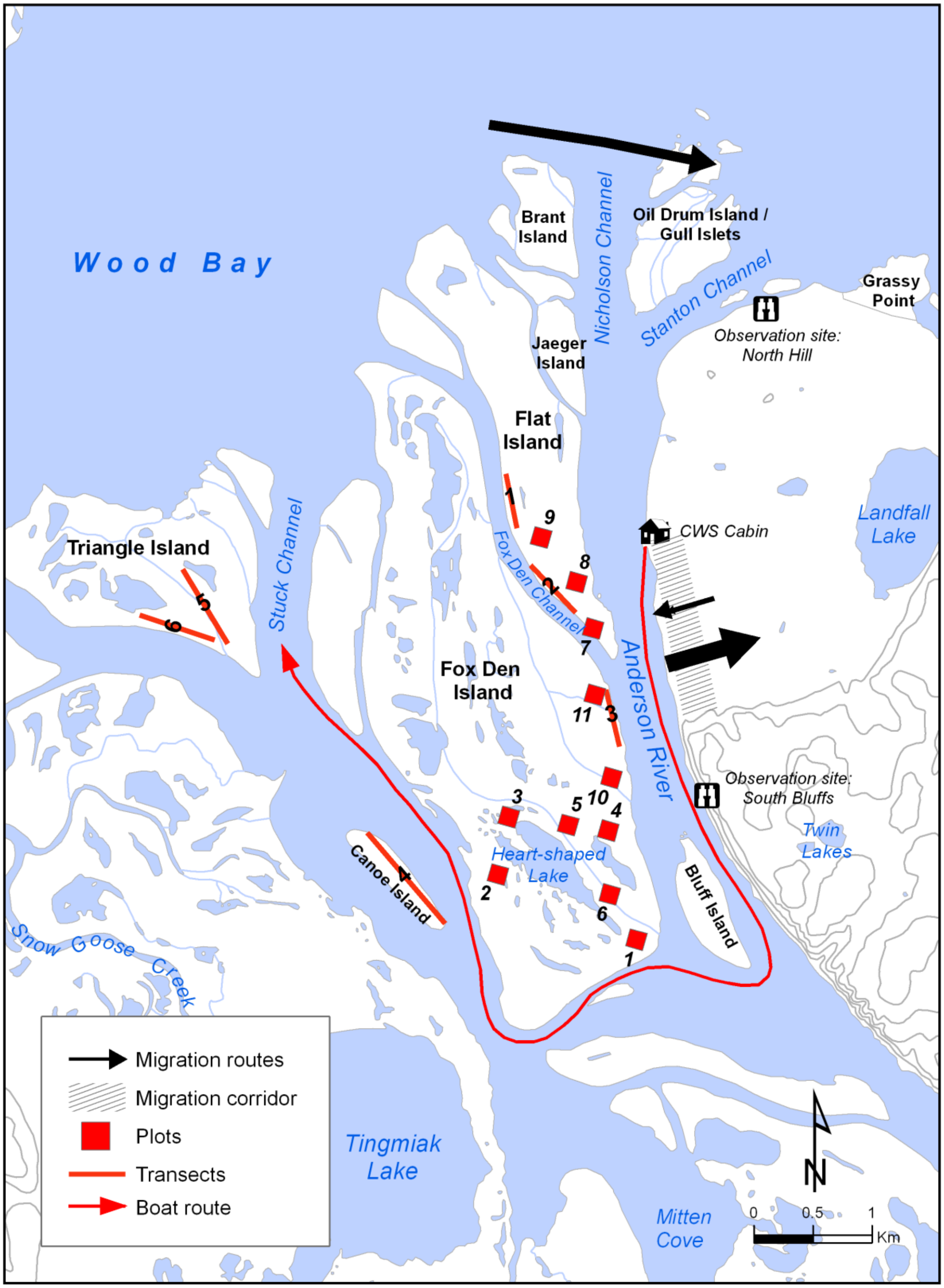

Figure 2. Map of the outer Anderson River delta area showing place names and geographic features referred to in the text

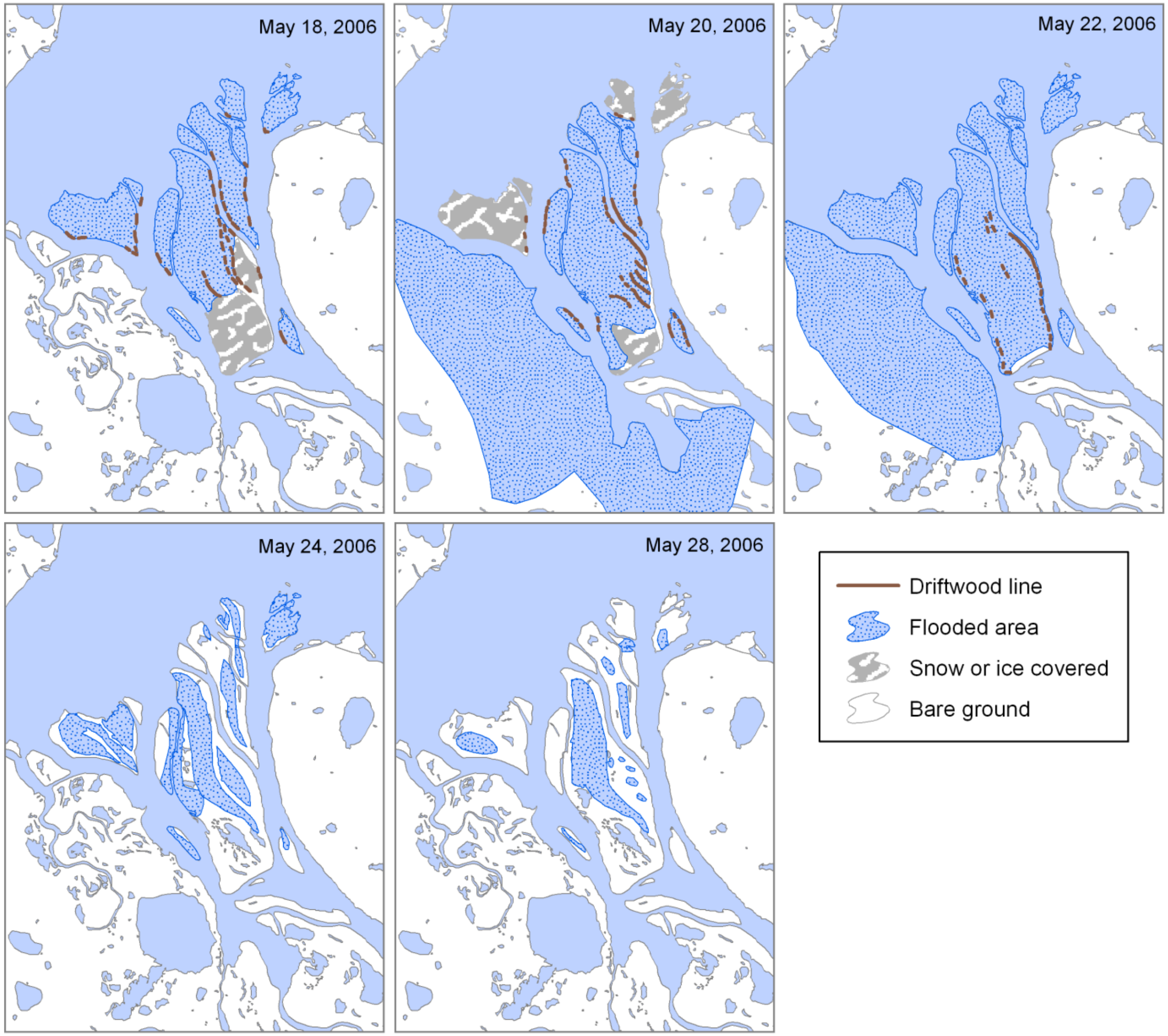

Figure 3. Maps indicating the extent of spring flooding in the outer Anderson River delta, 2006

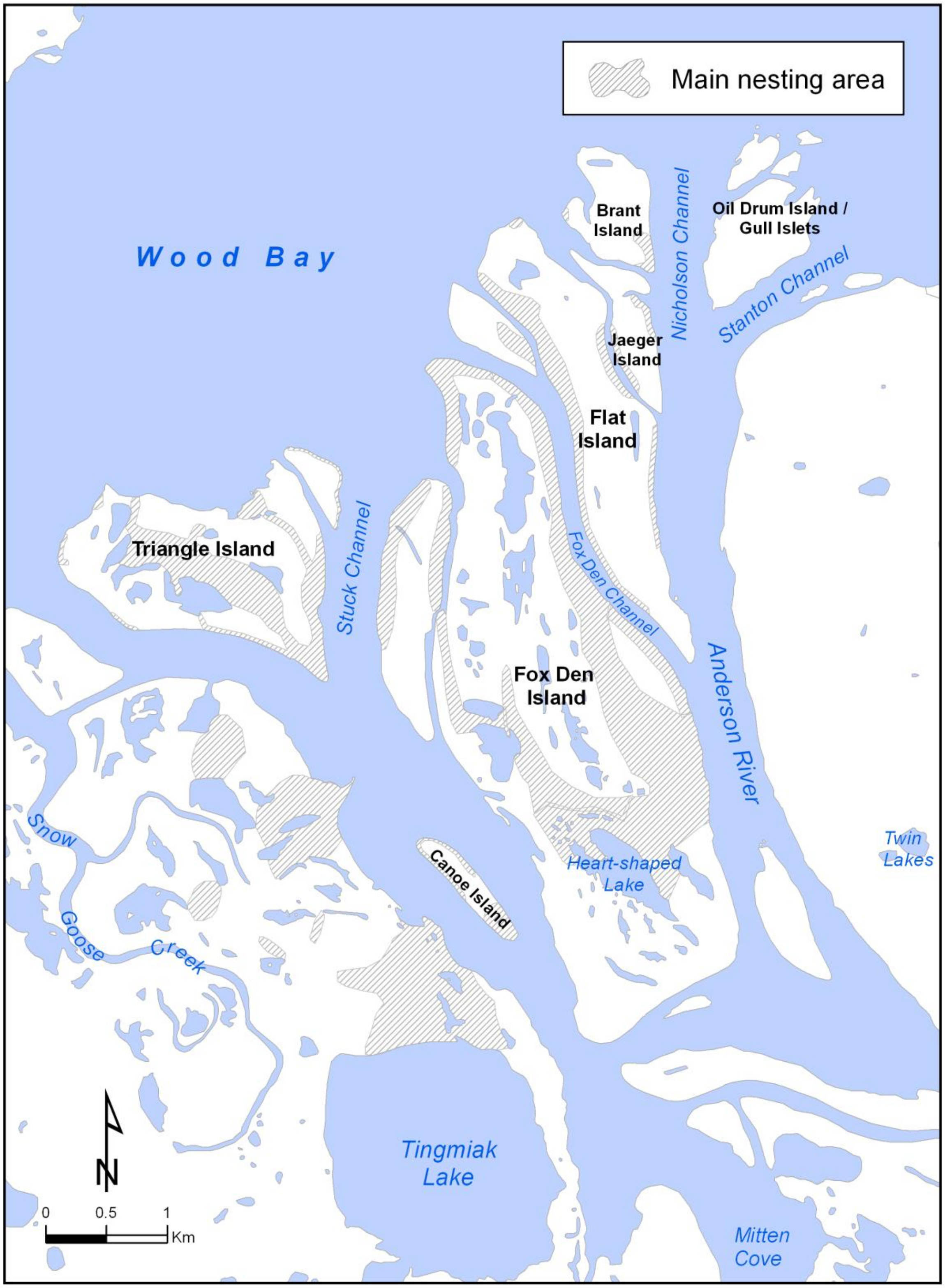

Figure 4. Primary nesting area for Lesser Snow Geese in the outer Anderson River delta, 2005–2006

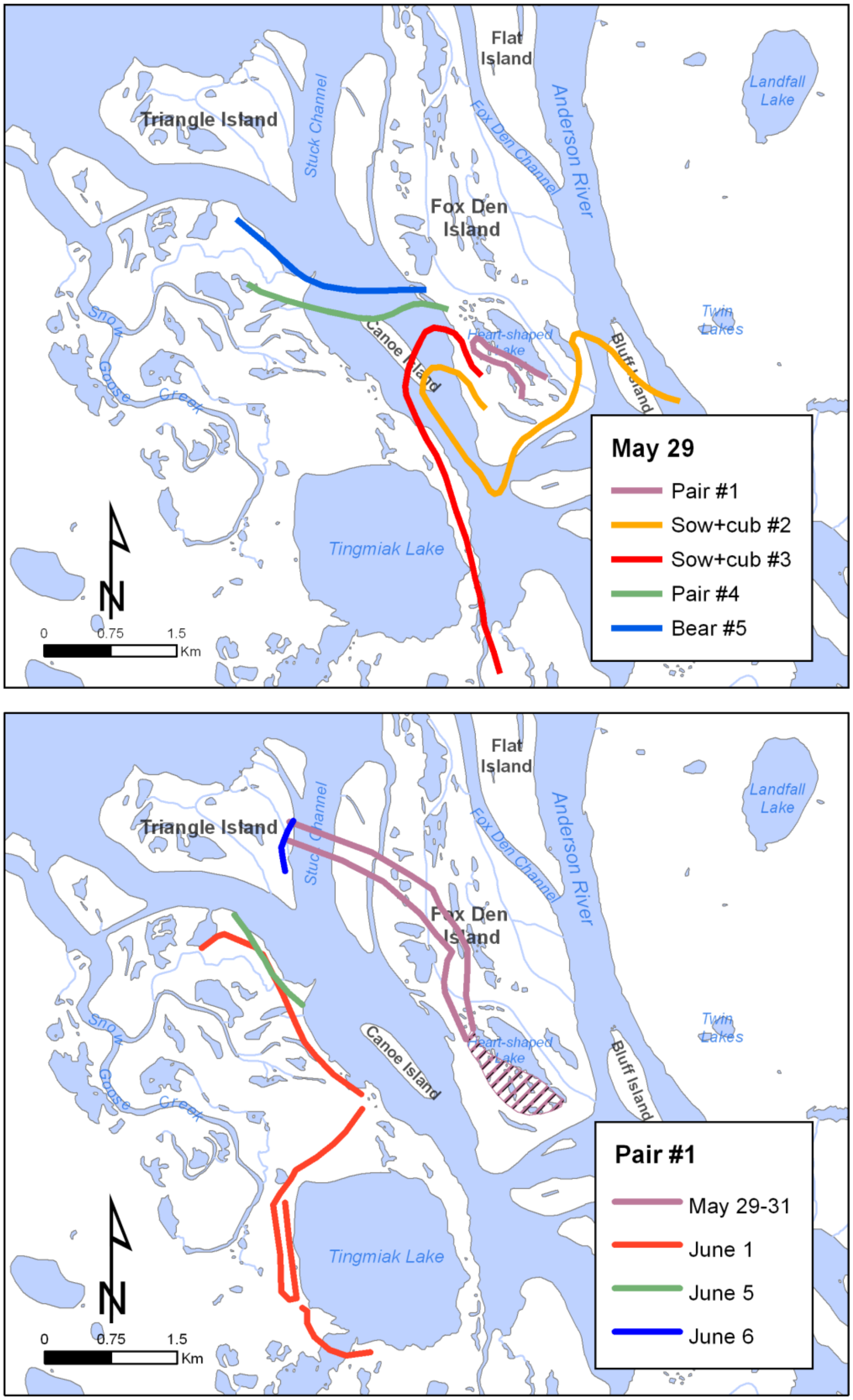

Figure 5. Observed movements of grizzly bears in the Anderson River delta, spring 2005

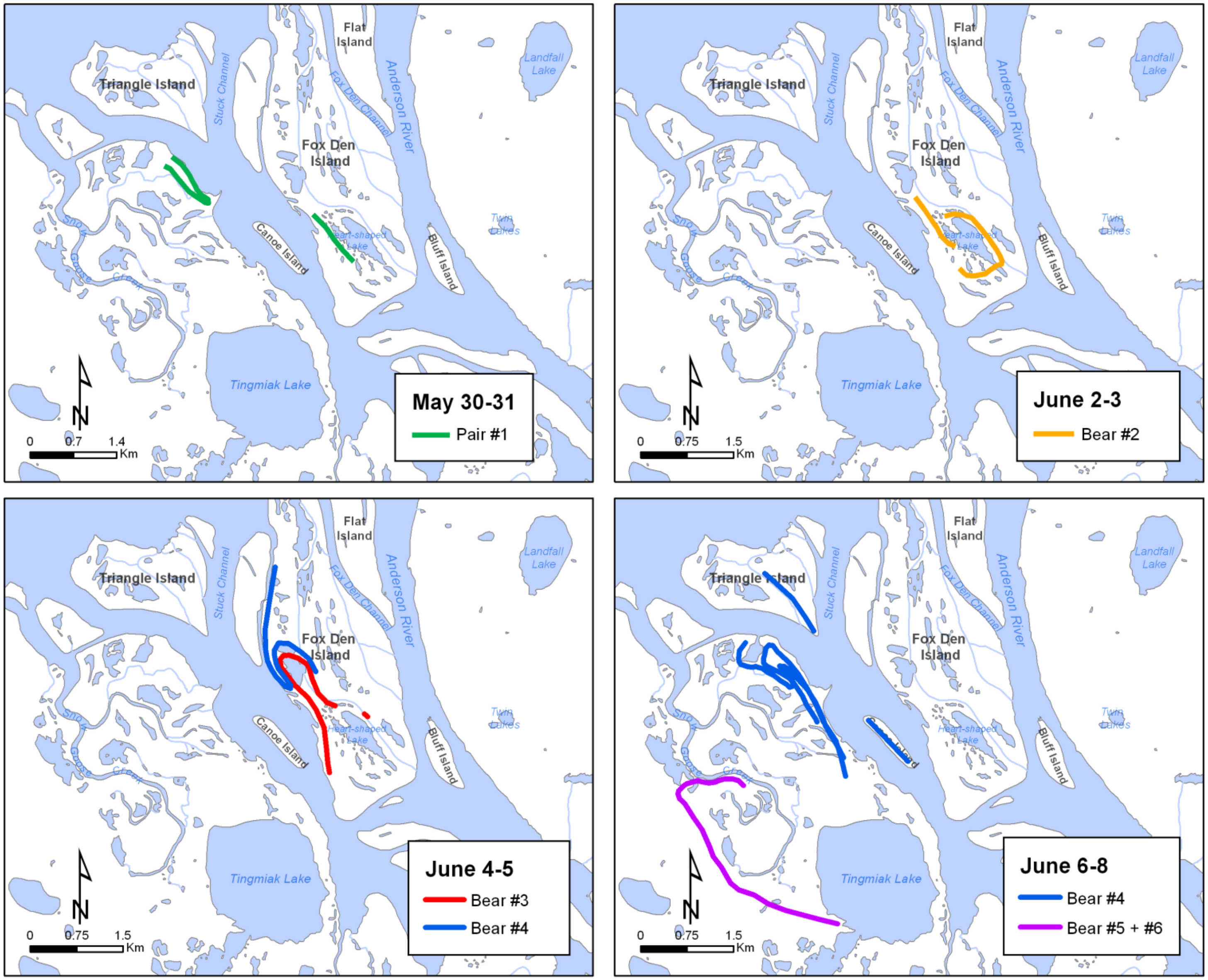

Figure 6. Observed movements of grizzly bears in the Anderson River delta, spring 2006

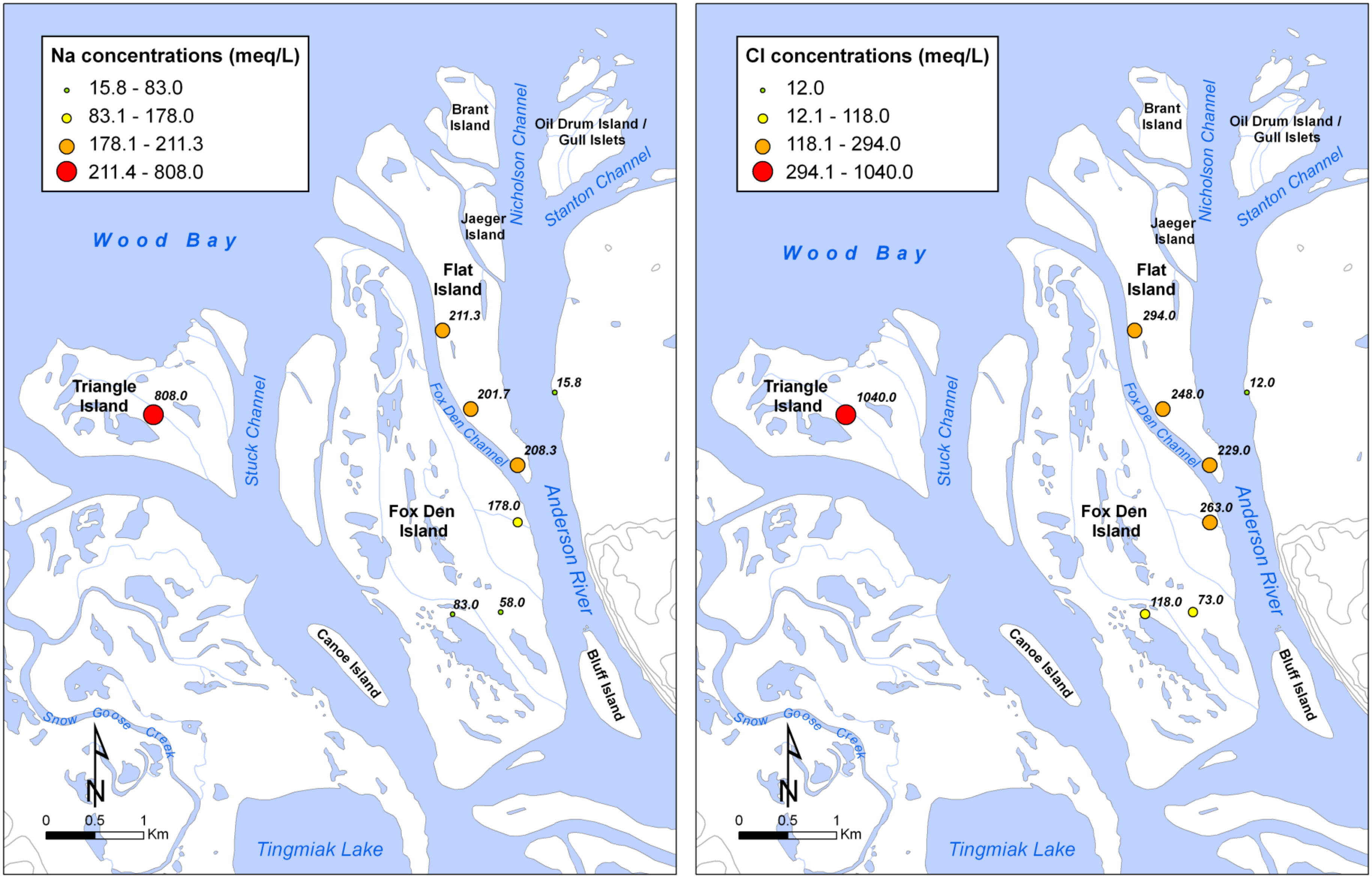

Figure 7. Sodium (Na) and chlorine (Cl) concentrations in soil samples collected in the Anderson River delta, 2005–2006

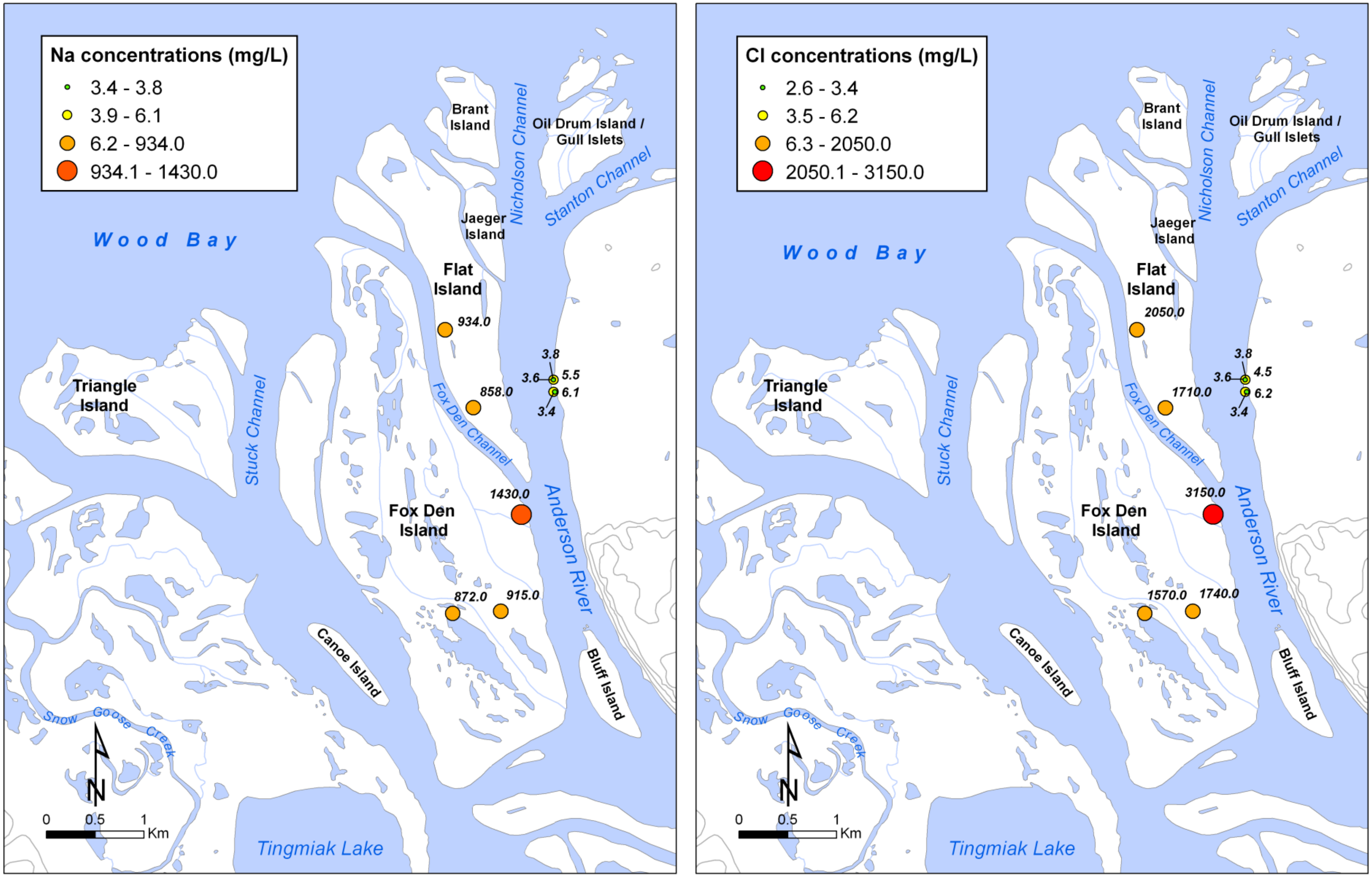

Figure 8. Sodium (Na) and Chlorine (Cl) concentrations in water samples collected in the Anderson River delta, 2006

Appendix 1. Counts of Lesser Snow Geese during the pre-nesting and nesting period in the outer Anderson River delta, 2005–2006

Date	Survey area	Number of pairs	Number of singles	Geese in flocks	Total
22-May-05	northern Flat, Jaeger, Brant islands	0	0	48	48
22-May-05	southern Flat Isl. and eastern Fox Den Isl.	225	0	150	600
23-May-05	southern Flat Island	50	2	30	132
23-May-05	eastern Fox Den Island	60	2	16	138
23-May-05	southern Fox Den Island	83	1	34	201
23-May-05	Bluff Island	16	0	0	32
25-May-05	northern Flat, Jaeger, Brant islands	89	10	0	188
25-May-05	southern Flat Island	47	0	6	100
26-May-05	southern Flat Island	63	2	0	128
26-May-05	eastern Fox Den Island	242	9	0	493
26-May-05	Bluff Island	2	0	0	4
28-May-05	northern Flat, Jaeger, Brant islands	112	12	8	244
28-May-05	southern Flat Island	30	0	0	60
28-May-05	eastern Fox Den Island	166	8	0	340
30-May-05	Gull Island	3	0	0	6
03-Jun-05	entire Flat Island	138	0	0	276
03-Jun-05	southern and eastern Fox Den Island	298	1	0	597
04-Jun-05	Brant Island	4	0	0	8
04-Jun-05	Jaeger Island	5	0	0	10
04-Jun-05	southern Fox Den Island	198	0	0	396
04-Jun-05	entire Fox Den, Flat, Jaeger and Brant islands	535	0	0	1070
17-May-06	Brant Island	5	1	10	21
17-May-06	Flat Island	22	5	38	87
18-May-06	Bluff Island	0	33	0	33
18-May-06	Brant Island	5	2	0	12
18-May-06	Fox Den Island	0	1775	0	1775
18-May-06	Flat Island	17	2	18	54
19-May-06	Brant Island	2	1	5	10
19-May-06	Grassy Point	0	859	0	859
19-May-06	Flat Island	22	9	5	58
20-May-06	Bluff Island	0	4	0	4
20-May-06	Fox Den Island	0	984	0	984
20-May-06	Flat Island	6	0	4	16
22-May-06	Flat Island	0	0	0	0
22-May-06	Jaeger Island	0	0	0	0
22-May-06	Brant Island	0	0	0	0
22-May-06	Gull Islets	0	0	0	0
22-May-06	Triangle Island	0	0	0	0
22-May-06	North Fox Den Island	0	0	0	0
22-May-06	East Fox Den Island	0	442	0	442
24-May-06	Brant Island	13	1	0	27

Date	Survey area	Number of pairs	Number of singles	Geese in flocks	Total
24-May-06	Canoe Island	0	100	0	100
24-May-06	Fox Den Island	0	1411	0	1411
24-May-06	Gull Islets	2	0	0	4
24-May-06	Flat Island	35	34	7	111
25-May-06	Brant Island	6	2	0	14
25-May-06	Gull Islets	2	0	0	4
25-May-06	Jaeger Island	8	7	0	23
25-May-06	Flat Island	54	16	5	129
26-May-06	Brant Island	8	3	0	19
26-May-06	Jeager Island	9	2	16	36
26-May-06	Flat Island	62	5	0	129
27-May-06	Bluff Island	0	6	0	6
27-May-06	Boat Island	1	0	0	2
27-May-06	Brant Island	2	0	0	4
27-May-06	Canoe Island	0	101	0	101
27-May-06	Fox Den Island	0	1562	0	1562
27-May-06	Jaeger Island	17	1	0	35
27-May-06	Flat Island	22	3	0	47
27-May-06	Triangle Island	0	34	0	34
28-May-06	Boat Island	0	0	0	0
28-May-06	Brant Island	2	0	0	4
28-May-06	Canoe Island	0	124	0	124
28-May-06	Fox Den Island	0	1644	0	1644
28-May-06	Jaeger Island	7	2	0	16
28-May-06	Flat Island	43	10	3	99
28-May-06	Triangle Island	22	0	0	44
29-May-06	Brant Island	7	0	3	17
29-May-06	Jeager Island	2	0	8	12
29-May-06	Flat Island	33	19	31	116
31-May-06	Bluff Island	0	3	0	3
31-May-06	Brant Island	10	0	18	38
31-May-06	Canoe Island	0	145	0	145
31-May-06	Fox Den Island	0	1646	0	1646
31-May-06	Flat Island	26	1	92	145
31-May-06	Triangle Island	0	47	0	47
01-Jun-06	Brant Island	5	5	20	35
01-Jun-06	Gull Islets	0	0	9	9
01-Jun-06	Jaeger Island	1	0	5	7
01-Jun-06	Flat Island	40	15	95	190
02-Jun-06	Brant Island	8	4	29	49
02-Jun-06	Jaeger Island	0	1	6	7
02-Jun-06	Flat Island	53	14	68	188
03-Jun-06	Canoe Island	46	0	0	92
03-Jun-06	Fox Den Island	879	0	0	1758
03-Jun-06	Triangle Island	54	0	0	108
03-Jun-06	Snow Goose Creek	126	450	0	450

Appendix 2. Counts of Brant during the pre-nesting and nesting period in the outer Anderson River delta, 2005–2006

Date	Survey area	Number of pairs	Number of singles	Brant in flocks	Total
24-May-05	Gull Islets	2	1	0	5
26-May-05	Bluff Island	11	0	0	22
26-May-05	East Fox Den Island	1	4	4	10
28-May-05	Jaeger Island	0	0	30	30
28-May-05	North portion less islets	7		0	14
28-May-05	South East Fox Den Island	11	0	0	22
30-May-05	Brant Island	1	0	5	7
30-May-05	Grassy Point	0	0	103	103
30-May-05	Gull Islets	10	0	4	24
30-May-05	Jaeger Island	0	0	64	64
03-Jun-05	Brant Island	2	1	0	5
03-Jun-05	East Fox Den Island	50	1	0	101
03-Jun-05	Jaeger Island	3	0	0	6
04-Jun-05	Brant Island	3	0	0	6
04-Jun-05	Jaeger Island	3	0	0	6
07-Jun-05	Brant Island	5	0	0	10
07-Jun-05	Flat Island	185	0	0	370
07-Jun-05	Jeager Island	3	0	0	6
07-Jun-05	Triangle Island	4	7	0	15
26-May-06	Brant Island	1	0	0	2
29-May-06	Jeager Island	0	0	9	9
29-May-06	North Flat Island	0	0	61	61
31-May-06	Flat, Jaeger and Brant islands	12	0	0	24
31-May-06	North Fox Den Island	0	11	0	11
31-May-06	South Fox Den Island	0	20	0	20
01-Jun-06	Brant Island	11	3	13	38
01-Jun-06	North Flat Island	6	0	0	12
02-Jun-06	Brant Island	8	1	28	45
02-Jun-06	Flat, Jaeger and Brant islands	25	0	8	58
02-Jun-06	North Flat Island	24	4	0	52
03-Jun-06	Fox Den Island	47	11	8	113
03-Jun-06	Snow Goose Creek	7	0	0	14

www.ec.gc.ca

Additional information can be obtained at:

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TTY: 819-994-0736
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