BROOD MOVEMENTS AND DISTRIBUTION OF EASTERN PRAIRIE POPULATION (EPP) CANADA GEESE (*BRANTA CANADENSIS INTERIOR*) IN NORTHERN MANITOBA: POTENTIAL INFLUENCE OF INCREASED SNOW GOOSE (*CHEN CAERULESCENS CAERULESCENS*) ABUNDANCE

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ROBERT RICHARD NACK

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This is to certify that I have examined this copy of a master's thesis by

Robert Richard Nack

And have found that it is complete and satisfactory in all respects, and that any and all revisions required by the final examining committee have been made.

David E. Andersen

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Name of Faculty Advisor

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Signature of Faculty Advisor

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Date

GRADUATE SCHOOL

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CHAPTER ONE

DISTRIBUTION OF EASTERN PRAIRIE POPULATION CANADA GOOSE BROODS NEAR CAPE CHURCHILL, MANITOBA, 1977-2002: POTENTIAL INFLUENCE OF INCREASED SNOW GOOSE ABUNDANCE

ABSTRACT

In 2001 and 2002, we conducted aerial surveys to compare indices of Eastern Prairie Population (EPP) Canada goose (*Branta canadensis interior*) brood distribution and abundance near Cape Churchill, Manitoba with those obtained in 1977 and 1978. Since the late 1970s, many of the coastal salt marsh areas used for brood-rearing have been degraded as a result of increased foraging pressure from locally breeding and migrating light geese [snow geese (*Chen caerulescens*) and Ross's geese (*C. rossii*)] and the density of nesting Canada geese has declined. The mean Canada goose brood density across the entire survey area in 2001-2002 was not different from 1977-1978 (difference between means ± 95% CI; 0.20 broods/km^2 ± 0.36); however, the mean brood density in the southern portion of the survey area was significantly higher in 2001-2002 than in 1977-1978 (0.45 ± 0.39). In 2002, the mean snow goose brood density was higher than the mean Canada goose brood density (27.31 ± 10.92), with higher densities of snow geese in northern coastal flats/beach ridge areas and higher densities of Canada geese in southern coastal flats/beach ridge areas. The mean number of Canada goose broods observed on 15 traditional brood-rearing areas decreased since 1977 (-8.67 ± 6.19) and the mean number of snow goose broods observed increased (43.91 ± 38.22). Canada goose broods appear to have shifted use of brood-rearing areas in response to reduced food availability, direct interactions with snow geese on brood-rearing areas, or both. Loss and degradation of brood-rearing habitat may be a factor in declines in nest density of Canada geese and has implications for EPP management.

INTRODUCTION

The density of EPP Canada geese nesting near Cape Churchill, Manitoba declined by a factor of approximately 4.5 from 1976-1979 ($\bar{x}$ = 38.7 nests/km^2) to 1993-1996 ($\bar{x}$ = 8.5 nests/km^2; Walter 1999), and has remained low since 1996 (D. E. Andersen, unpublished data). Trends in breeding population estimates derived from annual EPP aerial breeding ground surveys indicate that decreases in nest density appear to be restricted to the vicinity of Cape Churchill (Humburg et al. 2000). A number of hypotheses have been suggested for this decline in nest density including: investigator disturbance at nest sites, dispersal of breeding females to new nesting areas, a shift in brood-rearing areas and subsequent use of new areas by first-time breeders, increased arctic fox (*Alopex lagopus*) predation, and inter-specific competition with lesser snow geese (Walter 1999). Walter (1999) evaluated these hypotheses in light of existing information, and concluded that arctic fox predation and direct and indirect competition with snow geese on brood-rearing areas were the most likely causes for observed declines in nest density.

Since the late 1960s, the Mid-Continent Population (MCP) of lesser snow geese has increased three-fold (Abraham and Jefferies 1997). Snow goose use of traditional EPP brood-rearing areas has increased dramatically and salt marsh habitats have been degraded by both locally breeding and migrating light geese (Abraham et al. 1996, Walter 1999, Sammler 2001). Didiuk (1979) studied the brood movements and distribution of EPP Canada geese nesting near Cape Churchill. Aerial surveys revealed 15 distinct brood-rearing areas distributed along the western coast of Hudson Bay from Cape Churchill to 16 km south of the mouth of the Broad River (92°47.5'W 58°7.5'N;

Fig. 1). These coastal areas were used extensively by Canada geese during brood rearing and were characterized by lush stands of salt-tolerant sedges (*Carex* spp.) and grasses (predominantly *Puccinellia phyraganodes*).

Research by Didiuk (1979) was conducted prior to the presence of nesting lesser snow geese on the study area and intense foraging pressure by light geese on coastal salt marsh habitat (A. Didiuk, personal communication). Prior to 2001, 0-2 snow goose nests were located annually during nest searching on the study area. In 2001 and 2002, 55 and 6 snow goose nests were located during nest searching, respectively. Canada goose nests outnumbered snow goose nests on the study area; however, observations of Canada geese using traditional coastal salt marshes during the brood-rearing period have decreased, while observations of snow geese have steadily increased (Walter 1999, Sammler 2001). Snow geese from the breeding colony at La Pérouse Bay, Manitoba (15 km from the study area) use salt marsh habitat upon arrival in the spring through the end of the brood-rearing period in mid-August. Salt marshes are also used as spring and fall staging areas for geese nesting farther north and molt migrant Canada geese (*B. c. maxima*) in the summer months. Thus, coastal brood-rearing areas have experienced degradation as a result of grazing and grubbing by large numbers of geese (Abraham and Jefferies 1997, Walter 1999).

The localized decline in nest density of EPP geese is of concern to managers because if the population size of light geese continues to increase, the area over which habitat degradation could occur is also likely to increase. Continued habitat degradation may result in reduced densities of breeding EPP Canada geese over a larger area. In addition, information on the effects of increasing light goose population size on other species is largely lacking (Ankney 1996, Abraham and Jefferies 1997). Because of the change in habitat condition and the presence and increasing abundance of snow geese during the brood-rearing period, we repeated aerial brood surveys conducted by Didiuk (1979) in 1977 and 1978 to assess the potential impacts of light geese on EPP Canada geese at Cape Churchill. The objectives of our survey were to: 1) identify areas that currently support high densities of Canada goose broods, 2) relate Canada goose brood densities to the distribution of snow goose broods, and 3) compare current distribution of Canada goose broods (in the presence of snow geese) to distribution of Canada goose broods observed by Didiuk (1979) in the absence of snow geese.

STUDY AREA

The Cape Churchill (Nestor One) study area (48 km^2) is located 8 km south of Cape Churchill and within 5 km of the Hudson Bay coastline in northern Manitoba (Allen 1996, Fig. 1). The study area is approximately 15 km southeast of the La Pérouse Bay snow goose colony and lies within the Hudson Bay Lowland region. The region is characterized by low relief, continuous permafrost, poor drainage, numerous relict beach ridges, coastal marshes, and coastal tundra vegetation (Wellein and Lumsden 1964, Walter 1999). Major habitat types include; coastal salt marsh, beach ridge/sedge meadow, and interior sedge meadow (Didiuk 1979). Foraging geese intensively use the salt marsh habitat during the brood-rearing and migration periods. Beach ridge/sedge meadow habitat consists of freshwater sedge meadows and lakes between sand and gravel beach ridges. Interior sedge meadow habitats consist of numerous shallow water bodies and lowland areas dominated by sedges and grasses (Didiuk and Rusch 1998).

METHODS

Aerial brood survey

East/west transects were initiated at Cape Churchill and terminated at the mouth of the Broad River (72.5 km of coastline). Transects were spaced at 2.4 km intervals and extended 20 km inland from the coast of Hudson Bay (31 lines total, Fig. 1). The survey area was divided into 5 strata, each covering 14.5 km of Hudson Bay coastline. The area surveyed in stratum 1 was smaller than that in strata 2-5 because transects were terminated at the eastern coast of La Pérouse Bay. Aerial survey transects were established following the methods described by Didiuk (1979).

In 2001 and 2002, a fixed-wing aircraft (Partenavia PN-68 Observer) was used to conduct brood surveys. The aircraft was flown 30-45 m above ground level at approximately 160 km/hr, depending on wind speed and direction. In 2001, 2 observers (opposite sides) recorded Canada geese observed with and without broods within a 200 m strip on each side of the aircraft. Observations were categorized by 1-minute intervals. In 2002, 1 observer recorded Canada geese and a second observer recorded snow geese observed with and without broods, within 200 m of 1 side of the aircraft. Observers practiced estimating the strip distance from the air by flying over landmarks known to be 200 m apart. Adults were considered to have broods if they; 1) were observed with goslings, 2) were observed in a group that contained goslings, or, 3) exhibited behavior indicative of brood presence (e.g., mouth open, flared wings, flightless, or hiding). The number of broods in a group of adult birds with goslings was calculated by dividing the total number of adults by 2 (assuming each pair had a brood). Brood numbers were rounded up if an odd number of adults was present in a group with goslings (i.e., 5 adults

= 3 broods). Adults were considered to be without broods if they were observed; 1) on water without goslings, 2) flying, or 3) in a group without goslings. Criteria used to identify and count geese with broods were consistent with those used by Didiuk (1979). Brood aggregation increases throughout the brood-rearing period and is assumed to increase the detectability of broods on survey transects (Didiuk 1979). Therefore, we also calculated the proportion of broods observed in groups. A visibility correction factor for undetected broods was not used by Didiuk (1979) or in this study.

Median hatch dates on the Nestor One study area (D. Andersen, unpublished data) were used to determine timing of aerial surveys in 1977-1978 and in 2001-2002. We used a combination of egg floatation (Westerkov 1950, Walter and Rusch 1998) and candling techniques (Weller 1956) to estimate nest age and hatch dates (28-day incubation period) for all nests located during the incubation period.

Coastal brood-rearing area surveys

In 2002, 15 traditional brood-rearing areas identified by Didiuk (1979) were surveyed by helicopter (Bell 206 Jet Ranger) during the brood-rearing period. The survey was initiated at the eastern side of La Pérouse Bay and followed the coastline to approximately 16 km south of the mouth of the Broad River (89 km total). Coastal brood-rearing areas were identified on 1:50,000 topographical maps of the Hudson Bay coastline (Fig. 1). Brood-rearing areas were divided into 3 strata (5 areas each) from north to south along the coast of Hudson Bay (Fig. 1). Two observers were used to count both Canada geese and snow geese with and without broods. The same criteria used in aerial brood surveys (above) were used to identify and count broods. Survey data were compared to similar surveys conducted in 1977 and 1978 (Didiuk 1979).

DATA ANALYSIS

Brood density estimates on survey transects were calculated by dividing the total number of broods observed on each transect by the area surveyed (km^2). The area surveyed was calculated by multiplying each transect length by 0.2 (200 m strip). Brood densities were calculated for each transect and mean transect densities in each stratum (1-5) were used for statistical analysis. We identified 2 distinct habitat types within the survey area; coastal flats/beach ridge and interior sedge meadow. The coastal flats/beach ridge habitat extended approximately 5 km inland from the coast of Hudson Bay. The interior sedge meadow area bordered the coastal flats/beach ridge habitat on the west and extended another 15 km inland to the tree line (Fig. 1). Data were analyzed using analysis of variance (ANOVA) and Tukey's highly significant difference (HSD) *post hoc* test for multiple comparisons was used to identify significant differences among individual strata or between habitat types. Differences in brood densities among strata and between habitat types were analyzed using 2-way analysis of variance (ANOVA). For all statistical tests used, we considered P-values < 0.05 to indicate significance, and used P-values < 0.10 to identify trends.

Strata 1 and 2 encompass the Cape Churchill study area and historically had the highest brood densities in the survey area (Didiuk 1979). Data were compared between 2001-2002 and 1977-1978 at 3 levels: strata 1-5, strata 1-2, and strata 3-5. Data collected 12 days post-median hatch in 1977 and 1978 were used in comparisons with data collected 19 and 12 days post-median hatch in 2001 and 2002, respectively. We report differences between mean density values ± 95% confidence intervals (CI) for comparisons between 2001-2002 and 1977-1978. Significant differences were noted if 95% CI around the mean difference did not include 0.

Coastal brood-rearing area surveys were flown ≤4 times in 1977 (17, 24, 34, and 46 days post-median hatch), once in 1978 (10 days post-median hatch), and twice in 2002 (5 and 36 days post-median hatch). When possible, the mean number of broods observed in each coastal brood-rearing area was used for statistical comparison. In some cases, uncontrollable circumstances prevented all areas from being flown an equal number of times. For example, in 1978, only the 7 northern areas were surveyed due to late spring phenology and poor gosling production. We report differences between mean brood counts ± 95% CI to compare 2002 with 1977 and 1978.

RESULTS

Canada goose brood densities

Canada goose brood densities were not significantly different among strata ($F_{4,57} = 1.47$, $P = 0.22$) or between coastal flats/beach ridge and interior habitat types ($F_{1,60} = 1.53$, $P = 0.22$; Table 1) in 2001-2002. However, statistically significant habitat type x stratum interaction terms suggested an increase in brood densities in coastal flats/beach ridge habitat in strata 3-5 ($F_{4,52} = 4.10$, $P = 0.01$).

Spring phenology was similar between 1977-1978 and 2001-2002, with early and late years in each time period (Table 1). The number of broods observed in groups (> 1 pair) in 2001-2002 (0.64) was significantly higher than in 1977-1978 (0.32; $\chi^2_1 = 20.40$, $P < 0.001$), even though surveys were flown at approximately the same day post-median hatch date. The mean Canada goose brood density across the entire survey area in 2001 and 2002 was not different than in 1977 and 1978 (difference between means = 0.20 ± 0.36) and the mean brood density in strata 1-2 was similar to 1977-1978 (-0.16 ± 0.69). In strata 3-5, the mean brood density was significantly higher in 2001-2002 than in 1977-1978 (0.45 ± 0.39, Table 1).

Snow goose brood densities

In 2002, the mean snow goose brood density across the entire survey area was higher than the mean Canada goose brood density (Table 2). This trend was observed in strata 1-2, strata 3-5, coastal habitat, and interior habitat (Table 2). Statistically significant habitat type x stratum interaction terms indicated highest densities of snow geese in coastal flats/beach ridge areas in stratum 2 ($F_{4,52}$ = 3.20, P = 0.02). In 1977 and 1978, the mean density of snow goose broods across the entire survey area (strata 1-5), strata 1-2, and strata 3-5 was considerably lower than in 2002 (Table 3).

Coastal brood-rearing area surveys

Surveys of 15 traditional Canada goose coastal brood-rearing areas were flown on 9 July 2002 and repeated on 9 August 2002. The mean number of broods observed between July and August surveys remained unchanged for Canada (difference between means = 0.57 ± 3.76) and snow goose broods (-27.60 ± 45.05). The mean number of snow goose broods was higher than the mean number of Canada goose broods during both July (53.43 ± 59.86) and August (27.97 ± 21.51) surveys. The mean number of snow goose broods was highly variable because >200 broods were counted on some areas and 0 on others. An inverse relationship existed between Canada goose and snow goose broods on traditional brood-rearing areas. The mean number of Canada goose broods was highest in stratum 3 ($F_{2,12}$ = 2.43, P = 0.13) and the mean number of snow goose broods was significantly higher in stratum 2 than in strata 1 and 3 ($F_{2,12}$ = 5.78, P = 0.02; Table 4).

The mean number of Canada goose broods using traditional brood-rearing areas in 2002 was lower than the mean number of broods observed in 1977 (-8.67 ± 6.19; Table 4) and to a lesser extent in 7 areas surveyed in 1978 (-2.43 ± 3.24). In 2002, the mean number of Canada goose broods was lower in stratum 1 (-11.60 ± 3.69), stratum 2 (-2.78 ± 17.58), and stratum 3 (-1.63 ± 13.57) than in 1977 (Table 4). This change in use of brood-rearing areas paralleled a decline in nest density on the core study area (portions of strata 1-2) between 1977 (33 nests/km^2) and 2002 (6 nests/km^2) (D. E. Andersen, unpublished data).

The mean number of Canada goose broods was higher than the mean number of snow goose broods in 1977-1978 (8.91 ± 3.97); however, in 2002, snow goose broods outnumbered Canada goose broods (41.54 ± 38.86). Although variable, the mean number of snow goose broods in stratum 2 was higher than stratum 1 (95.80 ± 108.53) and stratum 3 (101.20 ± 94.58) in 2002 (Table 4). Brood-rearing areas in stratum 2 included a large salt marsh area on the study area that received high foraging pressure from geese. The mean number of snow goose broods using coastal brood-rearing areas was significantly higher in 2002 than in 1977 (43.91 ± 38.43; Table 4).

DISCUSSION

In 2001-2002, fixed-wing surveys revealed highest densities of Canada goose broods in coastal flats/beach ridge habitat south of areas (strata 1 and 2) that traditionally had highest nest densities (Didiuk 1979). These southern areas (strata 3-5) also experienced a significant increase in use by Canada goose broods since 1977-1978. A higher number of broods observed in groups suggests that broods were more easily detected in 2001-2002; however, brood densities over the entire survey area remained unchanged since 1977-1978. High variation in brood density estimates in 2001-2002 and 1977-1978 resulted from observations of large family groups of geese in interior sedge meadow survey areas (Didiuk 1979).

Data from 15 coastal brood-rearing areas surveyed in 2002 were compared with data from 1977. Spring phenology was “early” in 1977 and “late” in 2002; however, brood density estimates across the entire survey area were similar between 2002 ($\bar{x}$ = 1.06, SE = 0.23) and 1977 ($\bar{x}$ = 1.01, SE = 0.21). Brood density estimates were unusually high for a late year in 2002; however, the 2002 breeding grounds survey also reported a higher number of breeding birds and nesting effort than in recent years (D. Humburg, unpublished data). A significant decrease in the number of Canada goose broods on northern coastal brood-rearing areas (stratum 1) since 1977 and no subsequent increase in broods on other brood-rearing areas suggests that Canada goose broods are using freshwater sedge meadows adjacent to southern coastal salt marshes. Humburg et al. (2000) also observed increased densities of nesting Canada geese at the mouth of the Broad River, which defined the southern border of our survey area.

The inverse relationship between Canada goose and snow goose brood densities from north to south in the coastal flats/beach ridge habitat suggests that Canada geese have shifted use of brood-rearing areas in response to reduced food availability, direct interactions with snow geese on brood-rearing areas, or both. Additional evidence supports an inverse relationship between densities of Canada and snow goose broods on the study area. Currently, intensive snow goose banding efforts at La Pérouse Bay are concentrated in areas north of the Broad River (J. McRae, personal communication) and EPP banding drives, formerly conducted on the study area, have shifted to coastal areas south of the Broad River and near the town of Churchill (M. Gillespie, Manitoba Conservation, personal communication).

Snow geese are highly dependent on salt marsh vegetation during the nesting and brood-rearing periods, (Bazely and Jefferies 1989, Gadallah and Jefferies 1995, Kerbes et al. 1990, Kotanen and Jefferies 1997, Srivastava and Jefferies 1996, Williams et al. 1993) and competition for limited salt marsh vegetation resulted in direct movement to the coast from nest sites following hatch (Walter 1999; R. Nack, personal observation). Although not obvious from coastal area surveys, the density of snow goose broods on traditional coastal Canada goose brood-rearing areas appeared to decrease throughout the brood-rearing period (R. Nack, personal observation). This suggests that snow geese forage on salt marsh vegetation available early in the brood-rearing period, but disperse as forage availability decreases. Coincident with increased use of traditional Canada goose brood-rearing areas by snow geese, Canada geese appear to have changed their use of brood-rearing habitats. It is likely that degradation of traditional brood-rearing areas has resulted in this change, as physical displacement of Canada geese by snow geese is unlikely and interactions between species were brief and rarely confrontational (Walter 1999; R. Nack, personal observation, B. Pezzanite, personal communication).

The loss of salt marsh habitat and subsequent reduction in forage quality and quantity is believed to be responsible for decreased gosling survival and growth, and body size of snow geese nesting at La Pérouse Bay and the McConnell River, Nunavut, Canada (Aubin et al. 1993, Cooch et al. 1991, Cooch et al. 1993, Gadallah and Jefferies 1995, Williams et al. 1993). Reduced forage availability and quality is also thought to be responsible for the smaller body size (Leafloor et al. 1998) and late summer gosling mortality (Leafloor et al. 2000) of Canada geese nesting on Akimiski Island, Nunavut. Although a long-term change in body size has not been observed in breeding EPP Canada geese (Walter 1999; R. Nack, unpublished data), geese that remain faithful to traditional brood-rearing areas as foraging conditions decline may experience reduced fitness (e.g., reductions in gosling growth rate and survival) that could lead to a decline in recruitment and nest density.

Canada geese nesting on the Cape Churchill study area appeared to avoid the effects of increased snow goose abundance by changing brood-rearing areas. This will likely continue if snow geese continue to use and permanently degrade areas formerly used by Canada geese for brood rearing. Current brood movement data show that 18 of 41 radio-marked Canada goose broods traveled south of the study area, but remained within 15 km of the nest site (R. Nack, unpublished data). If first-time breeders nest in areas where they were reared, then a temporal shift in nest density toward areas south of the study area is possible. The dispersal distance for first-time breeders at Cape Churchill is unknown; however, reproductive parameters (i.e. decreased egg size, increased clutch size, increased body size) indicate older Canada geese are breeding on the study area (Walter 1999). Leafloor (1998) found several instances of long distance natal dispersal (≥70 km) by breeding Canada geese that were banded as goslings. MacInnes and Lieff (1968) reported natal dispersal distances of 5 km and 10.5 km for McConnell River Canada geese; however, they felt most geese returned to nest in the same general area in subsequent years. A shift toward brood-rearing areas south of the study area may contribute to the observed decrease in the density of nesting EPP Canada geese on Cape Churchill.

MANAGEMENT IMPLICATIONS

The effects of increasing snow goose populations on other bird species and the localized decline in nest density of EPP Canada geese are of concern to managers. Historical evidence suggests that Canada geese use coastal salt marsh areas in the presence of low densities of snow geese (Didiuk 1979). Our survey results reveal that EPP Canada geese have changed how they use brood-rearing habitat compared to the late 1970s. This change appears related to increasing snow goose numbers, use of habitats by snow geese that were previously used by Canada geese, and reduced food availability. Highest densities of Canada goose broods presently occur in areas that in 1977 and 1978 had the lowest brood densities. A significant increase in overall brood densities between 1977-1978 and 2001-2002 has not been observed, which indicates a shift in the use of brood-rearing habitat has occurred.

Our observations at Cape Churchill may give some indications of how other areas may be impacted by increasing density of breeding and foraging snow geese. For example, numbers of snow geese nesting at the Broad River have increased from 110 nesting pairs in 1997 to 668 nesting pairs in 2002 (D. Humburg, unpublished data). If the number of snow geese breeding near the mouth of the Broad River continues to increase, saline and freshwater marshes in the vicinity and south of the Broad River may continue to be degraded, resulting in reduced use of these areas by Canada geese during the brood-rearing period. The degradation of brood-rearing habitat and competition with snow geese could continue to have an impact on EPP Canada geese and other bird species, and the area over which snow geese could negatively impact Canada geese during the brood-rearing period is likely to increase.

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Table 1. Results of aerial brood surveys for Canada geese flown near Cape Churchill, Manitoba in 1977-1978 and 2001-2002.

	1977	1978	2001	2002
Spring phenology	Early	Late	Early	Late
Median hatch date	14 June	1 July	18 June	4 July
Days post-hatch[a]	12	12	19	12
Strata 1-5[b]	1.01 (0.21)	0.49 (0.08)	0.83 (0.17)	1.06 (0.23)
Strata 1 & 2[b]	1.39 (0.47)	0.41 (0.11)	0.32 (0.12)	1.18 (0.42)
Strata 3-5[b]	0.74 (0.13)	0.55 (0.11)	1.21 (0.25)	0.92 (0.27)
Interior habitat[b]			0.77 (0.19)	0.79 (0.32)
Coastal habitat[b]			1.05 (0.42)	1.35 (0.37)

[a] Timing of aerial surveys used for comparison.

[b] Broods/km^2 (SE).

Table 2. Mean densities (broods/km^2) of snow and Canada goose broods near Cape Churchill, Manitoba in 2002[a].

Area	Snow geese	SE	Canada geese	SE	Mean difference (± 95% CI)
Strata 1-5	28.36	5.34	1.06	0.23	27.31 ± 10.92
Strata 1& 2	51.22	9.18	1.18	0.42	50.04 ± 20.22
Strata 3-5	11.86	2.35	0.97	0.27	10.89 ± 5.81
Coastal Habitat	45.52	7.02	1.35	0.37	44.18 ± 14.27
Inland Habitat	18.03	5.73	0.79	0.32	17.24 ± 11.80

[a] Aerial survey flown 12 days post-median hatch (median hatch = 4 July 2002).

Table 3. Snow goose brood densities (broods/km^2) from aerial surveys conducted in 1977, 1978, and 2002 near Cape Churchill, Manitoba.

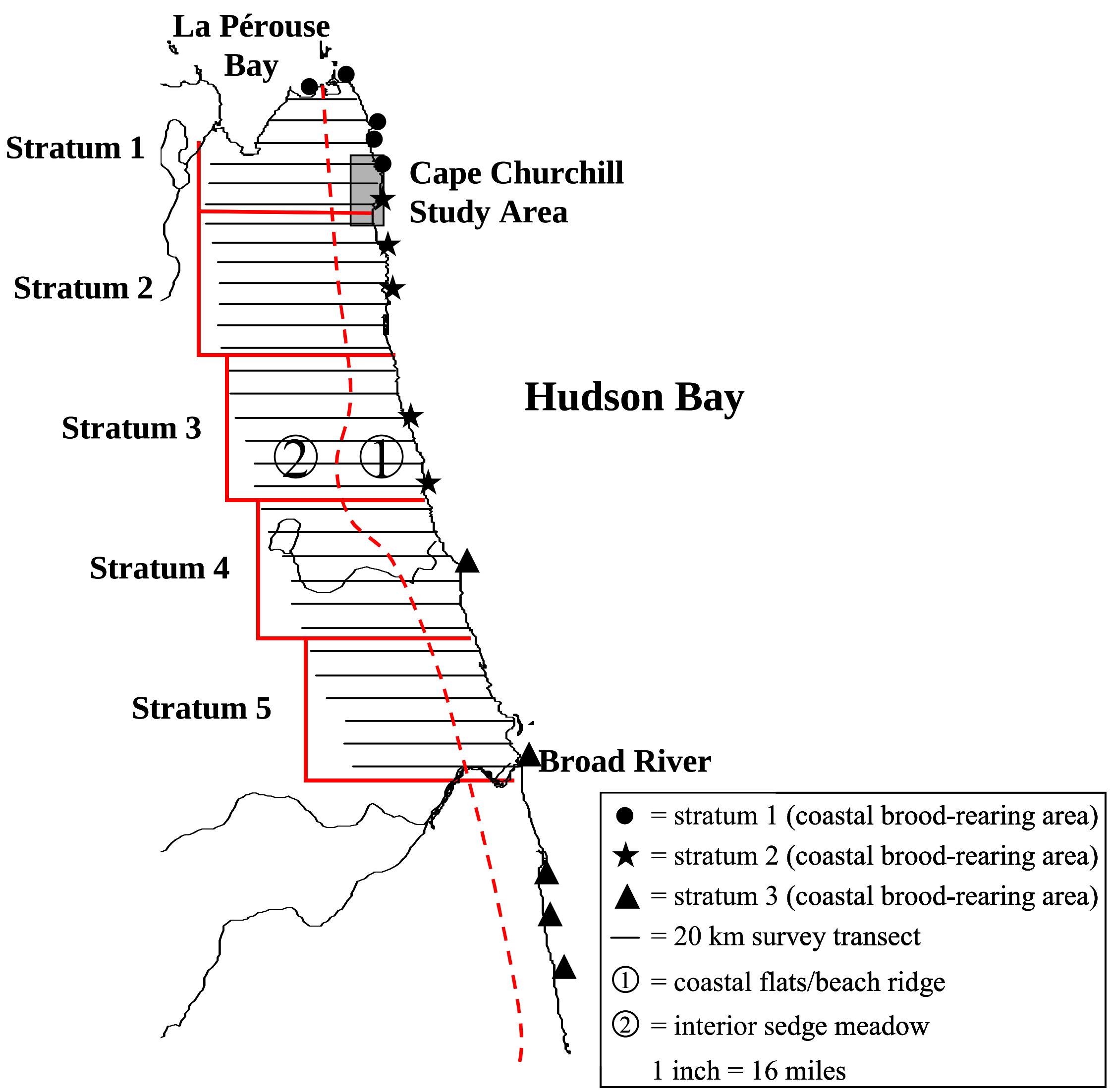
	1977		1978		2002	
Area	Density	SE	Density	SE	Density	SE
Strata 1-5	0.77	0.52	1.99	1.05	28.36	5.34
Strata 1 & 2	1.83	1.21	4.77	2.39	51.22	9.18
Strata 3-5	0.01	0.01	0.00	0.00	11.86	2.35

Table 4. Mean number of Canada and snow goose broods counted on 15 traditional Canada goose brood-rearing areas in 2002 and 1977.

		Stratum[a]							
		1		2		3		1-3	
Year	Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
2002	snow geese	15.80	5.04	111.50	39.44	10.40	10.15	45.93	17.74
	Canada geese	2.00	1.14	2.80	1.16	8.40	3.52	4.40	1.41
1977	snow geese	5.40	4.69	0.50	0.50	0.20	0.20	2.02	1.56
	Canada geese	13.80	1.24	15.50	5.15	10.20	2.06	13.07	2.13

[a] Coastal brood-rearing areas are divided into strata 1-3 from north to south.

Fig. 1. Aerial survey transects and coastal brood-rearing areas used to estimate Canada goose brood densities in 2001 and 2002. Coastal brood-rearing areas were not surveyed in 2001.



CHAPTER TWO

BROOD MOVEMENTS AND DISTRIBUTION OF EASTERN PRAIRIE POPULATION (EPP) CANADA GEESE IN NORTHERN MANITOBA: POTENTIAL INFLUENCE OF INCREASED SNOW GOOSE ABUNDANCE

ABSTRACT

Wildlife managers and population biologists are concerned about the impacts that increasing light goose [snow geese (*Chen caerulescens caerulescens*) and Ross's geese (*C. rossii*)] populations and subsequent habitat degradation are having on other bird species. Since the late 1970s, use of traditional Eastern Prairie Population (EPP) Canada goose (*Branta canadensis interior*) brood-rearing areas by light geese has increased significantly near Cape Churchill, Manitoba and the density of nesting EPP Canada geese has declined. Degradation of brood-rearing habitat has been hypothesized as a cause of the decline in EPP breeding density, as natal dispersal to more distant brood-rearing areas may influence future recruitment into the local breeding population. During the summers of 2000-2002, we documented EPP Canada goose brood movements and use of brood-rearing habitat for comparison with similar data collected in 1976-1978 (Didiuk 1979), prior to high densities of light geese and consequent habitat degradation on the study area. In 2000-2002, 26 of 40 (65%) female Canada geese with broods used freshwater sedge meadow habitat adjacent to traditional brood-rearing areas in coastal salt marsh habitat. Only 5 of 27 geese nesting in beach ridge/sedge meadow habitat made initial movements to salt marsh brood-rearing areas used in 1976-1978, when 20 of 21 radio-marked broods moved to salt marsh habitat. In 2000-2002, 30 geese with broods made initial movements away from traditional salt marsh brood-rearing habitat – 10 of these broods eventually moved to salt marsh habitats later in the brood-rearing period (mean date = 22 days post-median hatch). Mean brood home range size from 2001-2002 in coastal and inland habitats nearly doubled compared to the mean brood home range size during 1976-1978. EPP Canada geese currently use brood-rearing habitat other than the

coastal salt marshes they used prior to habitat degradation by light geese. A shift in the use of brood-rearing habitat could potentially reduce nest densities on the study area if first-time breeders nest closer to distant brood-rearing areas. The impact of alternative brood-rearing habitat on gosling growth and survival for EPP geese is unknown, but foraging in poorer quality brood-rearing habitat may also contribute to the observed decline in nesting density.

INTRODUCTION

Since the late 1960s, the Mid-Continent Population (MCP) of lesser snow geese has increased in size three-fold (Abraham et al. 1996, Abraham and Jefferies 1997). This dramatic increase in the number of light geese (lesser snow geese and Ross's geese) has been accompanied by significant habitat degradation as a result of grazing and grubbing by geese (summarized in Abraham and Jefferies 1997). In southern James and Hudson Bays, upwards of 35% of salt and freshwater marshes has been destroyed, and another 30% has been severely damaged as a result of grazing and grubbing by geese (Abraham and Jefferies 1997). It is not clear how long it would take for these habitats to recover in the absence of high foraging pressure by geese, but minimum estimates of 30-50 years have been suggested (summarized in Batt 1997).

The consequences of high numbers of MCP light geese and concurrent habitat degradation for other species is not clear and information regarding impacts on other species is lacking (Ankney 1996, Abraham and Jefferies 1997). Neither the effect of light geese on specific Canada goose brood-rearing habitats, nor the direct or indirect effects of snow geese on Arctic-nesting Canada geese in general, are well documented. However, since the late 1960s, research and monitoring efforts on EPP Canada geese have been conducted near Cape Churchill, Manitoba as part of the management efforts for this population, and provide a historic context in which to interpret potential impacts of increasing light goose numbers on other sub-arctic nesting birds.

From 1976-1996, nesting density of EPP Canada geese declined by a factor of 4.5 and has remained low since 1996 (Allen 1996, Walter 1999, D.E. Andersen unpublished data). Prior to 2001, ≤2 snow goose nests were located annually during nest searching on the study area. In 2001 and 2002, 55 and 6 snow goose nests were located during nest searching, respectively (D. E. Andersen, unpublished data). Canada goose nests outnumbered snow goose nests on the study area; however, snow geese have become numerically dominant on historic EPP Canada goose brood-rearing areas in coastal salt marsh habitats (Walter 1999, Sammler 2001). Walter (1999) hypothesized that degradation of brood-rearing habitat by snow geese may have contributed to decreased nesting density of EPP Canada geese.

Habitat degradation in the nearby La Pérouse Bay snow goose colony (Fig. 1) has resulted in snow geese moving their broods long distances to forage in salt marsh habitats that were formerly used primarily by EPP Canada geese for brood rearing (Kerbes et al. 1990, Ganter et al. 1996, Jano et al. 1998). Large numbers of snow geese foraging in brood-rearing areas can lead to long-term changes in vegetation (Ganter et al. 1996; Jano et al. 1998). Historic Canada goose brood-rearing areas in coastal salt marsh habitat near Cape Churchill have been highly impacted by snow goose foraging through removal of salt marsh vegetation (mainly *Carex subspathacea* and *Puccinellia phryganodes*), resulting in high evaporation rates at the soil surface and consequent development of hypersaline conditions that few plant species can tolerate (Srivastava and Jefferies 1996).

Snow geese are colonial nesters and first-time breeders tend to nest closer to brood-rearing areas than to the area of their natal nest (Cooke and Abraham 1980, Ganter and Cooke 1998). Canada goose females also show strong fidelity to breeding sites and brood-rearing areas (Zicus 1981, Lessells 1985, Anderson et al. 1992, Allen 1996, Sjoberg and Sjoberg 1998); however, the level of interaction between snow geese and Canada geese on traditional Canada goose brood-rearing areas is unknown. Didiuk

(1979) documented the distribution and movements of EPP Canada goose broods on Cape Churchill, prior to use of EPP brood-rearing areas by high densities of snow geese and the presence of nesting snow geese on the study area. Extensive data exist on both snow geese and Canada geese at Cape Churchill for the last 25 years, making it possible to investigate the effects of increasing densities of snow geese on Canada geese during the brood-rearing period (Rusch et al. 1996). Our objectives were to (1) document current patterns (in the presence of snow geese) of use of brood-rearing habitats by Canada geese at Cape Churchill, (2) compare those patterns to historical (in the absence of snow geese) patterns, and (3) provide a description of the habitat in current Canada goose brood-rearing areas.

STUDY AREA

The EPP breeding range encompasses approximately 54,000 km^2 in northern Manitoba and highest densities of breeding Canada geese have been observed in a narrow strip of coastal habitat adjacent to Hudson Bay (Malecki 1976, Walter 1999). The Cape Churchill (Nestor One) study area is located within this coastal strip of tundra habitat and the intensively searched core study area (48 km^2) is within 5 km of the Hudson Bay coastline (Allen 1996, Fig. 1). The Nestor One base camp is approximately 60 km east-southeast of the town of Churchill, Manitoba, Canada and located within Wapusk National Park (11,475 km^2). The study area lies within the Hudson Bay Lowland region and is characterized by low relief, continuous permafrost, poor drainage, numerous relict beach ridges, coastal marshes, and coastal tundra vegetation (Wellein and Lumsden 1964, Walter 1999). Major habitat types include; coastal salt marsh, beach ridge/sedge meadow, and interior sedge meadow (Didiuk 1979).

Intertidal coastal salt marshes, ~0.5 km wide, are found in discrete areas adjacent to Hudson Bay and near the mouths of streams. Swards of *Puccinellia phryganodes* and *Carex supspathachea* historically dominated these areas at Cape Churchill and were intensively grazed by Canada geese with broods (Didiuk 1979, Walter 1999). Although *Puccinellia phryganodes* is still found in small quantities, the salt marsh habitat on the study area has shifted to a complex dominated by moss (*Amblystegium tenax*) and willow (*Salix brachycarpa*) (Appendix A). Foraging activities of large numbers of geese during the breeding season quickly reduce available vegetation to the ground level. Breeding Canada geese and light geese, as well as molt migrant giant Canada geese (*B.c. maxima*), use snow-free salt marsh habitats from arrival in the spring through the fall migration period.

Beach ridge/sedge meadow habitat consists of freshwater sedge meadows and lakes between sand and gravel beach ridges that parallel the coastline and extend approximately 5 km inland from Hudson Bay. Beach ridges immediately adjacent to Hudson Bay are dominated by sea lime grass (*Elymus arenarius*), three-toothed saxifrage (*Saxifraga tricuspidata*), stemless raspberry (*Rubus acaulis*), and *Festuca rubra*. Inland beach ridges are dominated by white mountain-aven (*Dryas integrifolia*), lapland rose-bay (*Rhododendron lapponicum*), and purple saxifrage (*Saxifraga oppositifolia*) (Brook 2001). Freshwater sedge meadows located between beach ridges are dominated by sedges (primarily *Carex aquatalis*) and moss (mostly *Sphagnum* spp.) in wet areas.

Moist peat and small hummocks adjacent to beach ridges support a number of plant species (Appendix A).

Interior sedge meadow habitats consist of numerous shallow water bodies and lowland areas dominated by water sedge (*Carex aquatalis*), where the water table is at or near the surface. The interior sedge meadow habitat begins at the end of the beach ridge/sedge meadow habitat (approximately 5 km inland) and extends another 15 km inland to the tree line. Large lakes surrounded by a lowland shrub community, few dry upland areas, and extensive freshwater sedge meadows characterize interior sedge meadow habitat. Herbaceous species found in the interior sedge meadow habitat are similar to species found in sedge meadows located in the beach ridge/sedge meadow habitat. Flat-leaved willow (*Salix planifolia*), arctic blueberry (*Vaccinium uliginosum*), and scrub birch (*Betula glandulosa*) make up the shrub community observed around the periphery of water bodies (Appendix A; E. Punter, unpublished data). Areas degraded by intense shoot pulling by geese also occur in the interior sedge meadow habitat (Kerbes et al. 1990). For a more complete description of vegetation and landforms associated with the Hudson Bay lowlands and Wapusk National Park see Brook (2001).

METHODS

Nest Searching

The core study area was divided into 23 intensively searched units, with boundaries identified by beach ridges or lakes. All units were searched once during each of the 2000-2002 field seasons and have been intensively searched annually since 1976 (Rusch et al. 1996). To locate nests, 6 investigators distributed themselves across an entire unit and used binoculars to aid in locating Canada goose and other bird nests. On initial nest visits, 4” x 6” orange flags were placed 10 m north of the nest bowl, locations were marked on a field map, and nest data were recorded (i.e. clutch size, egg size and weight, nest age, flush distance, habitat). We used a combination of egg floating (Westerkov 1950, Walter and Rusch 1997) and candling techniques (Weller 1956) to calculate nest age at the initial nest visit. In addition, we recorded observations of known nest predators (parasitic jaeger [*Stercorarius parasiticus*], herring gull [*Larus argentatus*], arctic fox [*Alopex lagopus*], polar bear [*Ursus maritimus*]) and universal transverse mercator (UTM) coordinates from a global positioning system (GPS) unit. Based on a 28-day incubation period, nests were revisited on or subsequent to the predicted hatch date to determine nest fate, which was categorized as successful, destroyed, or abandoned. A nest was considered successful if at least one gosling hatched, as indicated by the presence of goslings or eggshells and intact membranes in the nest. Nests were classified as destroyed if there were no egg shell fragments in the nest, egg shells showed evidence of bill holes from avian predators, or if only a few small shell fragments with attached membranes remained in the nest. Fox scat, urine scent, and tracks near the nest were recorded to aid in determining nest fate. Nests were considered abandoned if found with intact eggs that were cold to the touch.

Trapping

A subset of active nests found during nest searching was revisited 4-5 days prior to the predicted hatch date. Nests included in the subset were located in the same habitat described by Didiuk (1979) and distributed evenly across the study area. After flushing the female, a modified bow style trap (Salyer 1962, Shaiffer and Krapu 1977, Allen 1996, Walter 1999) was placed at the nest. The trap was fired using a remotely triggered system at distances < 500 m from the nest location (similar to Shaiffer and Krapu 1977; Appendix B).

Trapped females were fitted with metal leg bands (U. S. Fish & Wildlife Service) and orange neck collars with white lettering (U. S. Fish & Wildlife Service). Radio transmitters (Advanced Telemetry Systems [ATS], Isanti, MN; use of trade names does not imply endorsement by the U.S. Geological Survey or the University of Minnesota) with 5-inch whip antennas were epoxied to the collars and fitted on the goose so the antenna would point down along the breast after release. Collars were fastened around the neck of the goose using rivets and vinyl cement (Bond 634, New Herms Inc., Duluth, GA). The total weight of the collar and transmitter was 58 g (< 4% body weight). Measurements of the culmen, tarsus, skull, gape, wing chord, mid-wing, and mass were taken at the time of capture (Moser and Rusch 1988, Dzubin and Cooch 1992). Morphological measurements were used to calculate pre-laying body mass, structural size, and an index to condition for comparison with similar data collected by Moser and Rusch (1988) and Walter (1999).

Radio Telemetry

Ground-based telemetry was used to locate radio-collared females following their departure from nest sites. Initially, a 13-element directional antenna was mounted on a 12.2 m (40 ft) tower to monitor early movements of individual broods and document presence or absence of unsuccessful nesting and brood-loss birds on the study area. The 13-element antenna received signals ≤6 km and permitted telemetry work when poor weather prevented work in the field.

Ground-based telemetry equipment consisted of 2 receivers and 2 three-element yagi antennas each mounted on a 3.1 m piece of conduit to improve the range of signal reception (≤4 km). Locations were calculated by inputting UTM coordinates of receiver stations and bearings to the transmitter into a laptop computer. Receiver stations were strategically distributed throughout the study area, within walking distance of camp. Station locations were in areas that would allow us to locate the greatest number of birds and cause the least amount of disturbance to the area (e.g. high points – beach ridges, rocks, pingos, etc.). UTM coordinates of receiver stations were derived from hand-held GPS units and bearings were taken in the direction half way between null readings. Two-way radios were used to relay receiver locations and animal bearings between investigators. Prior to fieldwork, investigators took estimated and true bearings to 5 transmitters from 3 different receiver locations and calculated the standard deviation of angle error among these bearings for use in the XYLOG telemetry program, which estimated the transmitter location and a 95% error ellipse around the location (Dodge and Steiner 1986, White and Garrott 1990).

A helicopter (Bell 206 Jet Ranger) equipped with 2 H-antennas, a scanning receiver, and GPS unit was used to locate and visually identify radio-collared females from the air. Aerial telemetry flights were flown opportunistically, depending on weather and helicopter availability (range: 1-15 days between flights). The number of goslings in each brood was recorded and used to estimate gosling survival during the brood-rearing period (R. Nack, unpublished data). Brood location coordinates were recorded and a 250 m radius circle was flown around the location, counting numbers of snow and Canada geese with and without broods. To evaluate goose densities in current brood-rearing areas, we repeated the 250 m circle around a point randomly located 250-1000 m away from the brood location.

Vegetation Measurements

Aerial telemetry locations of radio-marked broods were revisited ≥4 weeks post-median hatch to measure vegetation and provide a description of current brood-rearing habitat. Timing of vegetation measurements coincided with the peak growing period for vegetation in the area (R. Jefferies, personal communication). A 1 x 1 m plot was used to describe vegetation at the brood location and at 50 m intervals on a transect in a random direction from the brood location. Transects were terminated at water bodies, beach ridges, distinct changes in vegetation, or at a maximum distance of 200 m. A turf sample (10 x 10 cm) was taken from the center of the 1 x 1 m plot at the brood location.

The 10 x 10 cm turf sample taken in beach ridge/sedge meadow habitat was later reduced to 7.5 x 7.5 cm (Jefferies and Abraham 1994). Above-ground biomass (AGB) was calculated by removing dead material from each turf sample and clipping the remaining live vegetation at the sod level. The clipped vegetation was then dried at room temperature and weighed (Jefferies and Abraham 1994). Abundance and dominance of cover and vegetation types was estimated using an 80 x 80 cm grid, nested within the 1 x 1 m plot. The 80 x 80 cm grid was divided into 16 cells (20 x 20 cm). Abundance was assessed based on the presence or absence of a cover or vegetation type in cells and dominance was a quantitative assessment, based on surface area coverage, of a cover or vegetation type in cells. Cover and vegetation types included all plant species, bare ground, gravel, and water. Measurements of abundance and dominance were limited to 4 cover or vegetation types each. Relative abundance and relative dominance of each cover or vegetation type was calculated by dividing the number of cells in which the cover or vegetation type was present and/or dominant by the total number of available cells at each brood location. The number of goose feces within the 1 x 1 m plot was also recorded to index goose activity in the area.

The same vegetation measurements were repeated at a paired random point and used to evaluate habitat patches used by Canada goose broods within each brood-rearing area. Random points were located > 200 m (when possible) from the brood location and in the same habitat patch. Habitat patches were restricted to the habitat containing each brood location with boundaries defined by large beach ridges (> 300 m wide), lakes (> 2 ha), or a dramatic change in habitat. Habitat patches most often consisted of large freshwater sedge meadows, beach ridges, or coastal salt marshes; however, vegetation data were not analyzed separately for each habitat type (sedge meadow, beach ridge, salt marsh) because most aerial brood locations were located in freshwater sedge meadows.

DATA ANALYSIS

Initial brood movements were assigned to habitat type using the first telemetry location of the brood >0.5 km from the nest site. We assumed all successful nesting radio-collared females located on the study area still had broods at that time, unless they were observed without broods. Brood-rearing habitat (salt marsh, beach ridge/sedge meadow, or interior sedge meadow) was assigned to individual broods when ≥50% of ground and aerial-based telemetry locations occurred in that habitat type. Brood home range size was estimated using the Animal Movement extension in ArcView 3.2a (Environmental Systems Research Institute, Inc.). A minimum convex polygon (MCP) was used to estimate brood home range size from both ground and aerial-based telemetry locations and for comparison with historical data (Didiuk 1979, Didiuk and Rusch 1998). Nest locations were not included in estimates of brood home range size because some broods moved a considerable distance from the nest site and did not return.

Data collected during aerial telemetry flights at the brood location and a paired random point were compared using differences between means ± 95% confidence intervals (CI). Significant differences were indicated if 95% CI around the mean difference did not include 0. The distribution of snow geese in current brood-rearing areas was evaluated using a chi-square test to compare the proportion of observations with 0 snow geese within 250 m of Canada goose broods and a paired random point. Chi-square tests were also used to compare initial movements and use of habitat by Canada goose broods between 1976-1978 and 2000-2002.

Habitats in current brood-rearing areas were described by calculating the relative abundance and relative dominance of each cover or vegetative type found at brood locations and paired random points. The mean relative abundance and relative dominance values for each cover or vegetative type were used to rank cover or vegetation types in order of abundance and dominance. Differences in vegetation measurements collected at brood locations and paired random points in the same habitat patch (AGB, feces counts, relative abundance, relative dominance) are reported using mean differences ± 95% CI.

RESULTS

Current Brood Movements

We observed movements of 40 radio-collared female Canada geese that successfully hatched clutches on the study area (Table 1). The mean interval between departure from nest sites and the initial brood location was 8 days post-hatch (range: 2-17 days) and the mean distance traveled from nest sites was 3.4 km (SE = 0.5). Initial movements of 30 geese with broods were within the beach ridge/sedge meadow habitat (> 1 km inland) and 10 geese with broods moved directly to traditional brood-rearing areas in salt marsh habitat on the study area. We documented brood movements and habitat use for 27, 46, and 35 days post-median hatch in 2000, 2001, and 2002, respectively. From 2000-2002, the percentage of broods using salt marsh, beach ridge/sedge meadow, and interior sedge meadow habitat throughout the brood-rearing period was 28, 65, and 8%, respectively (Table 1).

In 2000, spring phenology and weather conditions contributed to one of the latest median-hatch dates on record, the lowest estimate of nest success since 1976, and gosling production well below the long-term mean (D. E. Andersen, unpublished data). Two of 10 (20%) radio-collared Canada geese successfully hatched eggs and these broods were followed throughout the brood-rearing period. One brood used salt marsh habitat within 2 km of the nest site and the other used beach ridge/sedge meadow habitat approximately 2.5 km from the nest site (Table 1).

In 2001, 26 of 31 (84%) radio-collared geese successfully hatched a clutch. Nine of 16 geese that reared broods in beach ridge/sedge meadow habitat moved to a large sedge meadow ─ lake complex ~4 km southwest of the study area and 7 of these birds eventually moved to coastal salt marsh habitat at approximately 22 days post-median hatch (Fig. 2). Eight geese with broods used traditional brood-rearing areas in coastal salt marsh habitat for the duration of the brood-rearing period. Two geese with broods moved to interior sedge meadow habitat and were last observed 11 and 12 km southwest of their respective nest locations (Table 1).

In 2002, spring phenology and weather conditions contributed to the second latest median hatch date since 1976. However, nest density, nest success, and gosling production were not as negatively impacted as expected based on goose reproduction in years with similar phenology (D. E. Andersen, unpublished data). Twelve of 29 (41%) radio-collared geese successfully hatched a clutch. Brood movements to the beach ridge/sedge meadow – lake complex and eventually to the Hudson Bay coastline (similar to 2001) were observed with 3 of 9 geese that used beach ridge/sedge meadow habitat for brood-rearing. The remaining 6 geese with broods used freshwater sedge meadows in close proximity (<3 km) to nest sites in beach ridge/sedge meadow habitat (Fig. 3). Two geese with broods used traditional salt marsh habitat and 1 brood moved to interior sedge meadow habitat approximately 11 km from the nest site (Table 1). One radio-marked goose with her brood quickly moved to the sedge meadow – lake complex in beach ridge/sedge meadow habitat southwest of the study area following hatch and was observed 11 km from the nest site. During the 8-day interval between aerial telemetry flights, this goose and brood returned to the study area and were last observed 0.6 km from the nest site.

One goose was radio-collared in both 2001 and 2002, and successfully hatched a clutch of 6 and 4 eggs, respectively. Nest sites were located 250 m apart and brood-rearing areas were in close proximity to the nest site. In 2001, brood movements were observed in coastal areas consisting of salt marsh (6 telemetry locations) and beach ridge/sedge meadow habitat (7 locations). In 2002, the goose and brood used a freshwater sedge meadow (13 locations) approximately 2.5 km south of the nest site and was observed on 2 occasions in salt marsh habitat. Another female was trapped in every year of this study; however, only successfully hatched a clutch in 2001. The mean distance between successive nest locations was 150 m.

Unsuccessful nesting females with radio collars (n = 30) either left the study area (n = 22), or remained on the study area in flocks of unsuccessful nesting or non-breeding geese (n = 8). These results are also consistent with Didiuk (1979), who reported that geese failing in reproduction moved to the coast prior to leaving on molt migration.

Historical Comparison of Brood Movements

Initial brood movements from 2000-2002 were drastically different from those documented by Didiuk (1979). Didiuk (1979) observed 20 of 21 (95%) radio-collared geese that were trapped on nests in beach ridge/sedge meadow habitat moving their broods to distinct brood-rearing areas in coastal salt marsh habitat and commented that almost all unmarked nesting pairs moved to these same areas. During 2000-2002, we observed 5 of 27 (19%) geese with broods, trapped on nests in the same habitat reported by Didiuk (1979), moving directly to these traditional brood-rearing areas ($\chi^2_1 = 117.8$, $P < 0.001$; Table 2). Geese with broods that immediately moved to the traditional brood-rearing areas remained in coastal areas with occasional forays (<2 km) to inland sedge meadows. This pattern was consistent with that reported by Didiuk (1979). Geese trapped on nests in coastal units in 2000-2002 were excluded from this comparison because coastal units were not searched for nests in 1976-1978.

Habitat used by Canada geese with broods throughout the brood-rearing period was also significantly different from Didiuk (1979). Didiuk (1979) had 2 of 12 (17%) radio-marked geese raise broods in beach ridge/sedge meadow habitat, whereas 26 of 40 (65%) radio-marked geese with broods used beach ridge/sedge meadow habitat from 2000-2002 ($\chi^2_1 = 47.6$, $P < 0.001$). In 2000-2002, 12 of 40 (30%) radio-marked geese with broods were never observed in traditional brood-rearing areas; even though nest sites were located ≤4 km from these areas. Inland movements from nest sites and subsequent movements to coastal salt marsh habitat by radio-marked broods were not observed in 1976-1978; however, unmarked geese with broods (<25) were observed moving towards the coast at 28-35 days post-median hatch (Didiuk 1979).

In 1976-1978, radio-marked geese with broods using the beach ridge/sedge meadow habitat had larger mean home ranges at 50 days post-median hatch than geese with broods using salt marsh habitat (Didiuk 1979, Didiuk and Rusch 1998). Mean home range size was also larger in beach ridge/sedge meadow habitat than in salt marsh habitat in 2000-2002 (difference between means = 402 ± 66 ha). The mean brood home range size in 2000-2002 was significantly larger than the mean home range size observed in 1976-1978 in both habitat types (Table 3).

Habitat in Current Brood-rearing Areas

Cover and vegetation measurements were taken at 78 brood locations and at paired random points to provide a description of current brood-rearing areas. Cover and vegetation types most abundant in current brood-rearing areas were: sedge (*Carex* spp.), moss (mainly *Sphagnum* spp.), willow (*Salix* spp.), tufted bulrush (*Scirpus caespitosus*), and white mountain-aven (*Dryas integrifolia*). The most dominant cover and vegetation types in these same areas were: moss, sedge, white mountain-aven, willow, and bare ground (Table 4).

There was no difference in the relative abundance of sedge, moss, and white mountain-aven; however, willow and tufted bulrush were more abundant at random points than at the brood location (Table 4). Sedge, moss, and white mountain-aven were equally dominant at brood locations and paired random points; however, willow and bare ground were more dominant at random points within the habitat patch (Table 4). There was no difference in the number of goose feces (0.01 ± 0.52) or above-ground-biomass (0.03 ± 0.06) between brood locations and paired random points.

Distribution of Snow Geese

There was no difference in the mean number of snow geese counted within 250 m of a Canada goose brood location and a paired random point (difference between means = 5.31 ± 5.75), and the proportion of observations with snow geese within 250 m of a Canada goose brood was not significantly different from random points (χ^2_1 = 0.04, *P* = 0.84).

DISCUSSION

Current movements and use of brood-rearing habitat by EPP Canada geese with broods are different from movement and habitat use prior to the presence of snow geese on traditional EPP brood-rearing areas and snow geese nesting on the study area. The change in brood-rearing habitat use likely occurred because of reduced forage availability and high densities of snow geese in traditional brood-rearing areas (Nack and Andersen, In Review). Because Canada geese show fidelity to brood-rearing areas and may also breed near areas where they were reared (Zicus 1981, Lessells 1985, Bruggink et al. 1994, Sjoberg and Sjoberg 1998), changes in use of brood-rearing habitat may have contributed to the observed decline in nesting densities of EPP Canada geese near Cape Churchill.

Areas currently used most frequently by EPP geese for brood-rearing are located in beach ridge/sedge meadow habitat adjacent to degraded salt marsh habitat. Aerial brood surveys conducted in 2001-2002 also revealed highest densities of Canada goose broods in freshwater sedge meadows south of the study area, adjacent to coastal salt marshes (Nack and Andersen, In Review). These areas consist of freshwater sedge meadows and beach ridges in close proximity to permanent water bodies with well-defined shorelines. In 2001, broods moved throughout the beach ridge/sedge meadow area; whereas, in 2002, broods remained more sedentary in these areas. Hughes et al. (1994) assigned greater snow goose (*Chen caerulescens atlantica*) broods on Bylot Island to 3 groups: sedentary, shifters, and wanderers. Sedentary broods used a single concentrated area, shifters made use of >1 area, and wanderers had no concentrated area of activity. Using these criteria, most EPP Canada goose broods at Cape Churchill appear to be either sedentary or wanderers. Sedentary broods used freshwater sedge meadows in close proximity to the nest site or moved directly to traditional brood-rearing areas along the coast of Hudson Bay. Broods classified as "wanderers" moved throughout the beach ridge/sedge meadow habitat with no concentrated areas of activity; however, concentrated areas of activity were difficult to identify if a brood left the study area. Eventual brood movements to the coast coincided with feather molt and Hudson Bay likely provided refuge for flightless adults from ground predators. Brood movements to the coast may also result from declining densities of snow goose broods on traditional coastal Canada goose brood-rearing areas late in the brood-rearing period (R. Nack, personal observation).

Arctic-nesting geese are known to selectively use vegetation high in nutrient content (Gadallah and Jefferies 1995, Owen 1980, Sedinger 1984, Sedinger and Raveling 1984) and numerous studies have attributed reduced growth rates and adult body size in geese to a reduction in the quality or quantity of available forage plants (Sedinger and Raveling 1986, Cooch et al. 1991, Sedinger and Flint 1991, Larsson and Forslund 1992, Aubin et al. 1993, Lindholm et al. 1994, Leafloor et al. 1998). EPP Canada geese with broods that use degraded brood-rearing areas may experience lower rates of gosling growth and survival than goslings reared in less degraded habitat. Hill (1999) found Canada goose goslings (*B.c. interior*) on Akiminski Island, Nunavut in areas with snow geese to be 20% lighter and ninth primary and body length each shorter than in areas without snow geese. There was a significant relationship between band recoveries of goslings in above average condition and higher body mass, indicating that only goslings in the best condition survived to fledging and left the island (Hill 1999). Gosling condition was related to the amount of food resources on the island and the level of resource availability varied annually (Patton 2001). Gosling growth and survival for EPP Canada geese have not been intensively studied (Walter 1999), but this scenario is plausible for Canada geese that remain faithful to deteriorating brood-rearing habitat.

Captive snow goose goslings at La Pérouse Bay either maintained or lost weight when fed a diet of vegetation found in freshwater sedge meadow areas (*Carex aquatilis, Festuca rubra, Carex* x *flavicans*) and gained or maintained weight when fed nutrient-rich salt marsh vegetation (*Puccinellia phryganodes* or *Carex subspathacea*; Gadallah and Jefferies 1995). Current use of freshwater sedge meadows by Canada goose broods and no apparent change in adult body size suggests that EPP Canada geese are less reliant on salt marsh vegetation for growth and development than snow geese (Walter 1999; J. Leafloor, personal communication). As a result, Canada goose broods may travel farther and forage on less-preferred, lower quality freshwater species to meet the dietary requirements previously provided by salt marsh vegetation. A change in the distribution of vegetation necessary for gosling growth and development may explain the two-fold increase in brood home range size between 1976-1978 and 2000-2002. The increase in home range size may also result from Canada geese traveling farther to distance themselves from large aggregations or high densities of snow geese. There was no difference between the mean number of snow geese counted within 250 m of brood locations and paired random points, suggesting a uniform distribution of both species in brood-rearing areas. However, aerial brood surveys conducted in 2001-2002 revealed higher densities of Canada geese with broods in areas with fewer snow geese and Canada geese with broods were rarely observed in mixed flocks with snow geese (Nack and Andersen, In Review). Snow goose broods significantly out-numbered Canada goose broods in coastal and inland habitats on Cape Churchill, making it difficult for Canada goose broods to separate themselves from snow geese.

Female-biased philopatry to breeding areas by Canada geese is well known (MacInnes and Lief 1968, Surrendi 1970, Zicus 1981, Anderson et al. 1992, Allen 1996, Leafloor 1998, Sjoberg and Sjoberg 1998, Hughes et al. 2000). Allen (1996) found that EPP Canada geese at Cape Churchill initiated nests a mean distance of 295 m from their nest site the previous year. Mean distances between nest locations for 2 collared birds in this study were 250 m and 150 m. EPP Canada geese with breeding experience exhibit philopatry to particular areas; however, it is unclear if first-time breeders return to the vicinity of natal nest sites or brood-rearing areas to nest.

Fidelity to brood-rearing areas has been reported in a number of dispersal studies on arctic-nesting geese (Cooke and Abraham 1980, Larsson and Forslund 1992, Lindberg and Sedinger 1997, Ganter and Cooke 1998). Younger breeding birds at the La Pérouse Bay snow goose colony nest at the colony periphery because of degraded brood-rearing habitat in core areas of the colony (Ganter and Cooke 1998). Likewise, Walter (1999) hypothesized that EPP Canada geese nesting closer to brood-rearing areas at the periphery of the study area may be responsible for the observed decline in nest density. During this study, 13 of 17 (76%) radio-marked Canada geese with broods that nested in the southern half of the study area moved south of the study area, but remained within 12 km (7.5 mi) of the nest site. Aerial brood survey data indicated brood densities increased significantly in areas ≥15 km south of the study area since 1976-1978 (Didiuk 1979; Nack and Andersen, In Review). Densities of nesting Canada geese at the mouth of the Broad River, 58 km (36 mi) south of the study area, have increased 26% from 1987-1995 and returned to levels observed in the 1970s (Walter 1999, Humburg et al. 2000). Given these data, it is possible that, over time, first-time breeders have progressively nested farther south, in proximity to locations where they were reared.

MANAGEMENT IMPLICATIONS

Historically, coastal salt marsh habitat was used extensively by EPP Canada geese for brood-rearing. However, since 1976-1978, EPP Canada geese have shifted use of brood-rearing areas and brood home range size has nearly doubled concurrent with the loss and degradation of traditional brood-rearing habitat resulting from snow goose foraging. During this same time period, density of nesting EPP Canada geese on the study area has declined dramatically. Coastal tundra habitats support the highest breeding densities of EPP Canada geese, and if habitat degradation and consequent changes in habitat use for brood-rearing negatively impact recruitment and/or survival, population-level effects may result. Lower nest density, fidelity to brood-rearing areas of low quality, and low gosling survival and growth rates could all affect EPP Canada goose population dynamics, and have implications for how this population is managed. Waterfowl biologists use EPP Canada geese observed in coastal regions during breeding ground surveys to index annual production and future breeding potential (Humburg et al. 2000). Production estimates may not adequately index recruitment into the fall population if densities of breeding geese continue to decline in coastal regions.

Current efforts to reduce increasing light goose populations concentrate on increasing the harvest of adult breeding birds. Management efforts include a 1999 conservation order that allowed a spring hunting season, liberal bag limits, unplugged shotguns, and the use of electronic calls. These actions have increased the harvest of light geese (T. J. Moser, personal communication); however, it is unclear if the number of breeding birds is declining and how long it will take for damaged habitat to recover. Our results suggest that the current population size of light geese and degree of habitat degradation will continue to impact sympatric EPP Canada geese on the breeding grounds. The scale over which these impacts are evident is not known, but will likely continue to increase if light goose populations continue to increase.

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Table 1. Summary of nest fate and habitat use for radio-collared Canada geese with broods near Cape Churchill, Manitoba from 2000-2002.

Parameter	2000	2001	2002	Total
No. trapped	10	31	29	70
No. hatched clutches	2	26	12	40
Beach ridge/sedge meadow[a]	1	16	9	26
Coastal salt marsh[a]	1	8	2	11
Interior sedge meadow[a]	0	2	1	3

[a] Habitat used during the brood-rearing period.

Table 2. Habitat type of first telemetry location and the mean distance traveled away from nest sites by radio-marked Canada geese with broods in 2000-2002 and in 1976-1978.

Years	n^a	Salt marsh	Beach ridge/ sedge meadow	Interior sedge meadow	Mean	SE
2000-2002	27	5	22	0	3.4	0.5
1976-1978	21	20	1	0	2.3	0.2

[a] Canada geese nesting in beach ridge/sedge meadow habitat; excluding coastal areas not searched in 1976-1978.

Table 3. Mean minimum convex polygon home range size (ha) for Canada goose broods near Cape Churchill, Manitoba in 1976-1978 and in 2000-2002.

	1976-1978[a]			2000-2002[b]			
Habitat type	*n*	Mean	SE	*n*	Mean	SE	Mean difference (± 95% CI)
Salt marsh	7	297	43	11	617	60	320 ± 61.13
Beach ridge/ sedge meadow	5	584	92	20	1019	148	435 ± 148.08

[a] Mean MCP home range at 50 days post median hatch date.

[b] Mean MCP home range at 38 (2000), 45 (2001) , and 35 (2002) days post median hatch date.

Table 4. Mean relative abundance and relative dominance estimates for cover and vegetation types found in current Canada goose brood-rearing areas near Cape Churchill, Manitoba, 2000-2002.

		Random Point		Brood location		
Cover Type	Parameter	Mean	SE	Mean	SE	Mean difference (± 95% CI)
Sedge	Abundance	0.70	0.04	0.69	0.04	0.01 ± 0.06
	Dominance	0.13	0.02	0.15	0.02	0.02 ± 0.03
Moss	Abundance	0.52	0.03	0.48	0.03	0.04 ± 0.07
	Dominance	0.23	0.02	0.24	0.02	0.01 ± 0.05
Willow	Abundance	0.35	0.03	0.30	0.02	0.05 ± 0.05
	Dominance	0.10	0.01	0.06	0.01	0.04 ± 0.03
Tufted bulrush	Abundance	0.28	0.03	0.18	0.02	0.10 ± 0.08
	Dominance					
White mountain-aven	Abundance	0.23	0.04	0.16	0.04	0.08 ± 0.09
	Dominance	0.08	0.02	0.06	0.02	0.02 ± 0.03
Bare ground	Abundance					
	Dominance	0.22	0.02	0.10	0.02	0.13 ± 0.05

Figure 1. Map of the Cape Churchill study area (Nestor One) in relation to the town of Churchill, La Pérouse Bay, and the mouth of the Broad River.

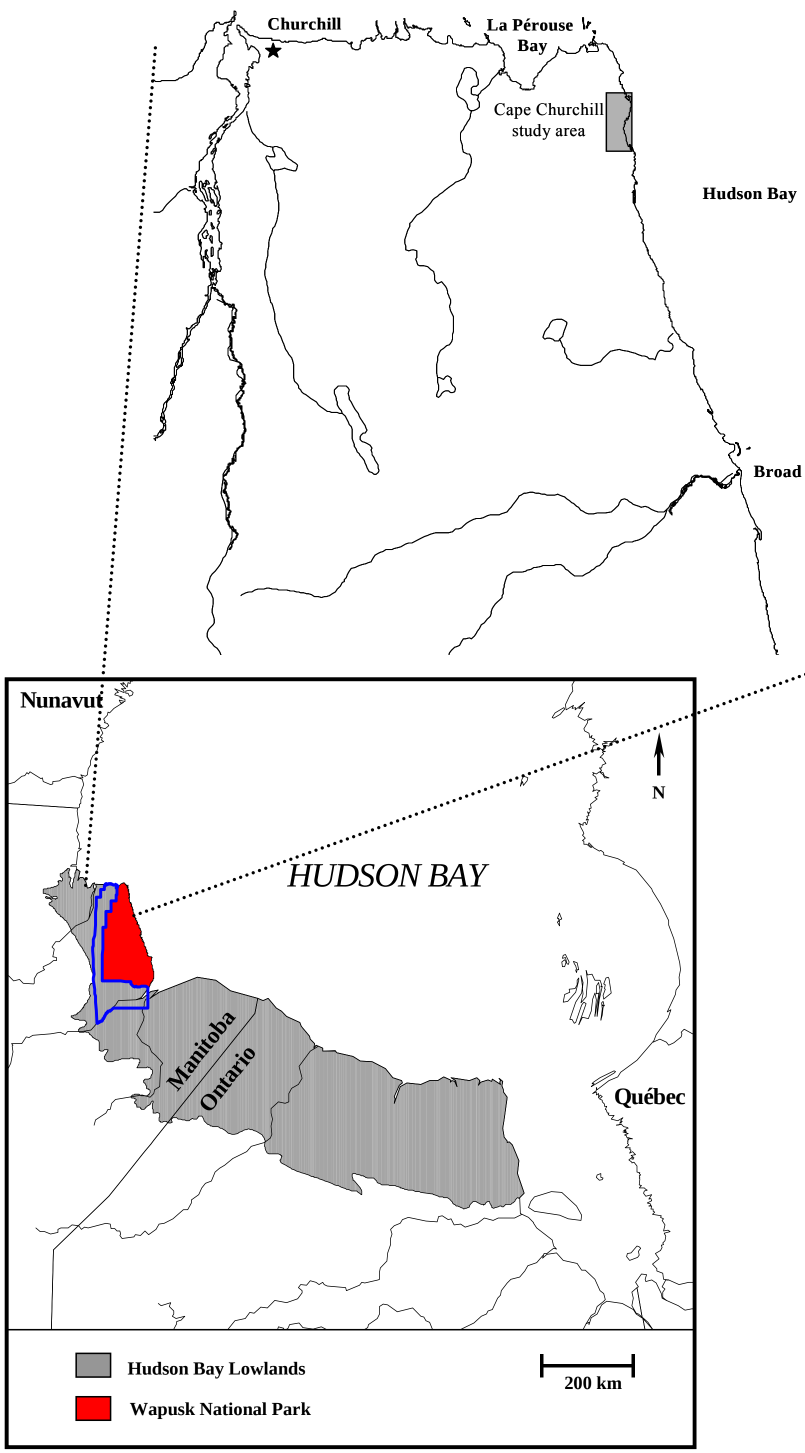


Figure 2. Telemetry locations and home range of 1 Canada goose brood showing movement to a sedge meadow ─ lake complex within the beach ridge/sedge meadow habitat and return to the coast later in the brood-rearing period.

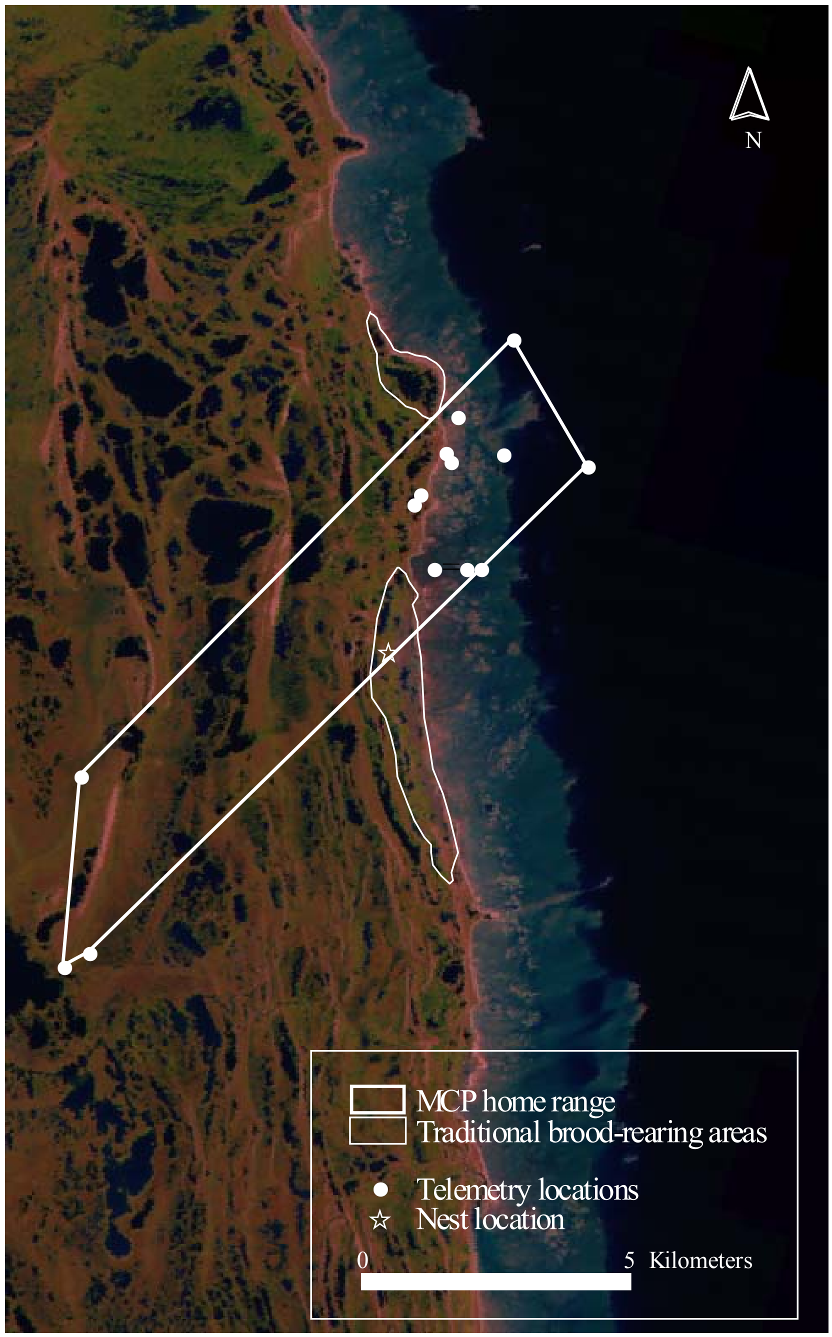
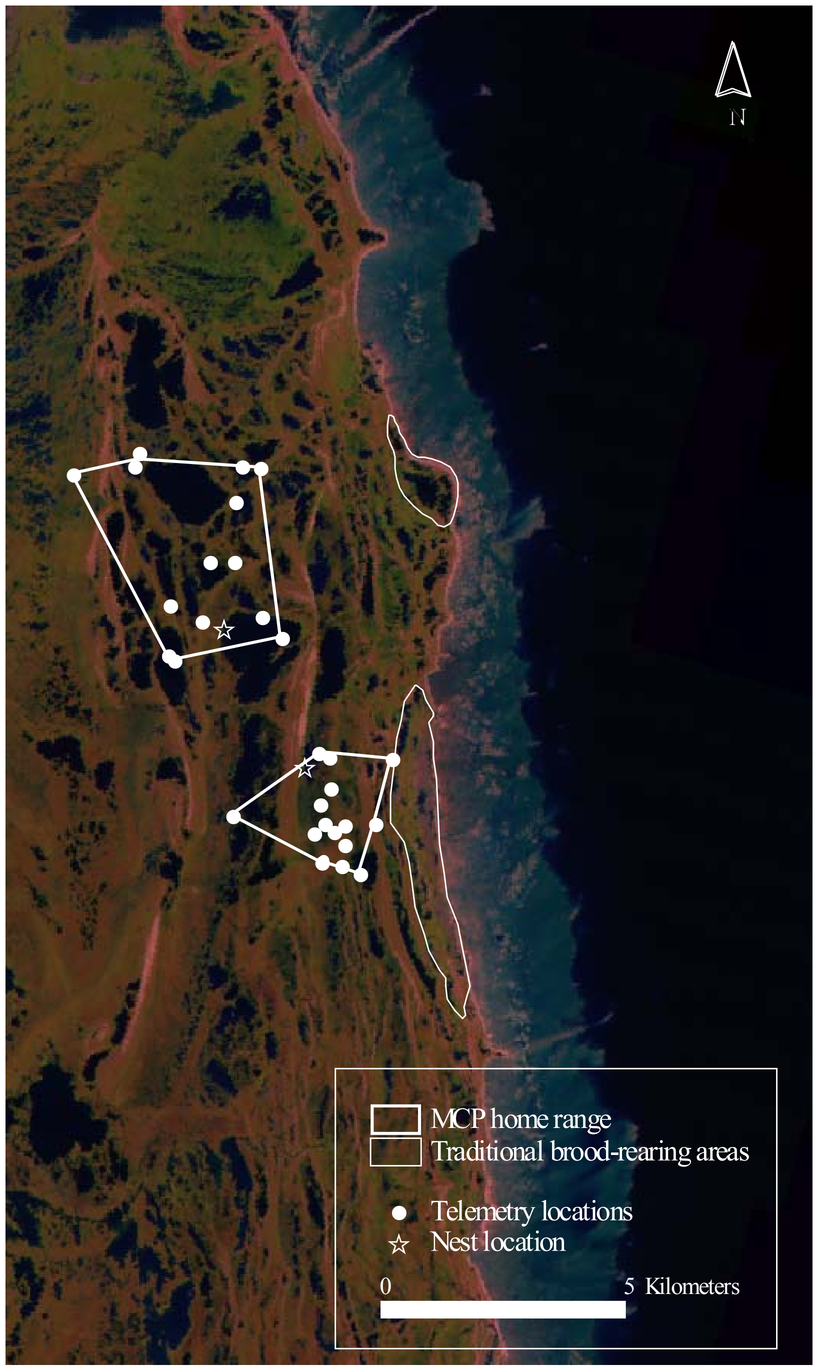


Figure 3. Telemetry locations and home ranges of 2 Canada goose broods that used freshwater sedge meadows in close proximity to nest locations in beach ridge/sedge meadow habitat.



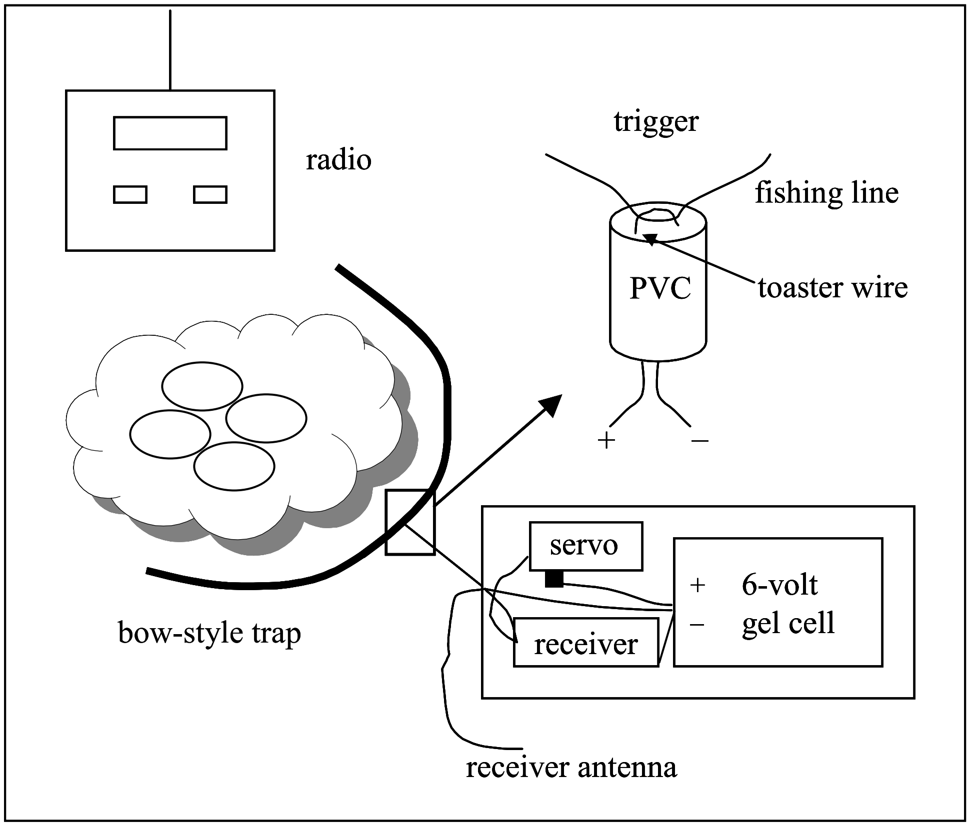
APPENDIX A.

Vegetation associated with 3 habitat types found on the Cape Churchill study area in 2002 (E. Punter, unpublished data).

Coastal salt marsh	Beach ridge (coastal or inland)	Freshwater sedge meadow
Puccinellia phryganodes	*Elymus mollis* (C)	*Carex aquatilis*
Salix brachycarpa	*Rubus acaulis* (C)	*Carex vaginata*
Pohlia spp.	*Linum lepagii* (C)	*Scirpus caespitosus*
Potentilla palustris	*Festuca rubra* (C)	*Vaccinium uliginosum*
Hippurus vulgaris	*Saxifraga tricuspidata* (C, I)	*Andromeda polifolia*
Primula egalikensis	*Matricaria ambigua* (C)	*Salix reticulata*
Primula stricta	*Achillea nigrescens* (C)	*Salix arctophila*
Eleocharis acicularis	*Potentilla anserine* (C)	*Carex capillaris*
Ranunculus hyperboreus	*Potentilla multifida* (C)	*Juncus alpinus*
Senecio congestus	*Senecio pauperculus* (C)	*Pinquicula vulgaris*
Ranunculus lapponicus	*Stellaria longipes* (C, I)	*Salix lanata*
Menyanthes trifoliata	*Casteleja raupii* (C)	*Pedicularis lapponucum*
Juncus balticus	*Trisetum spicatum* (C)	*Bartsia alpina*
Carex aquatilis	*Botrychium lunaria* (C)	*Salix brachycarpa*
Saxifraga caespitosa	*Dryas integrifolia* (I)	*Parnassia palustris*
Chrysosplenium tetandrum	*Rhododendron lapponicum* (I)	*Poa arctica*
Amblystegium tenax	*Lesquerella arctica* (I)	*Poa alpigena*
Encalypta rhaptocarpa	*Androsace septentrionalis* (I)	*Carex gynocrates*
Ceratodon purpureus	*Carex maritime* (I)	*Polygonum viviparum*
	Draba glabella (I)	*Rubus acaulis*
	Draba nivalis (I)	*Saxifraga hirculus*
	Saxifraga oppositifolia (I)	*Rhododendron lapponica*
	Minuartia rubella (I)	*Dryas intergrifolia*
	Carex glacialis (I)	*Salix candida*
	Shepherdia Canadensis (I)	*Betula glandulosa*
		Rubus chamaemorus
		Vaccinium vitis idea
		Salix planifolia

APPENDIX B.

Remotely triggered trap systems used to capture nesting Canada geese in 2001-2002.



Radio control (R/C) airplane components were used to develop a trapping system that would maximize trapping efficiency and minimize the weight of equipment carried in the field. PVC triggers consisted of a piece of toaster wire epoxied in a small piece of PVC pipe (~ 1.5 cm dia.). Monofilament fishing line was fed through the toaster wire and around the spring-loaded arms of the bow trap. The trigger was connected to a rechargeable 6-volt battery in a waterproof container using ~18" of speaker wire. An 8-channel receiver and servo were also located in the waterproof container and secured using Velcro. The receiver was connected to and powered by a 6-volt battery. Upon signal reception, the servo arm rotates and pushes a switch that completes the circuit with the toaster wire and battery. The toaster wire is heated, melts the monofilament, and releases the arms of the trap. Four traps can be operated from 1 4-channel radio using the set-up described above. Receiver crystals were necessary to specify a unique frequency for each trap. This trapping system proved reliable under all weather conditions (rain, cold, wind); however, static electricity during lightning storms is believed to have inadvertently fired 2 traps. Traps were capable of being fired ≤1380 m if the direct path from radio to receiver was unobstructed and ≤1000 m if the view was obstructed by vegetation, ground, etc. The 6-volt battery lasted ≤8 days before it needed to be recharged. A complete list of equipment required to operate 4 traps is listed below.

Equipment	Quantity	Price ($US ea.)
Hitec® Laser 4 4-channel FM radio – 72 MHz	1	$126.99
Includes:		
Servo (1.6” x 0.8” x 1.5”)	4	
8 Channel Receiver (2.3” x 1.39” x 0.85”)	1	
Receiver Crystal (72 MHz)	1	
8 Channel Receiver	3	$52
Receiver Crystal	3	$11
Waterproof container (9” x 5” x 4”)	4	$3
6-volt battery (4.5 AH)	4	$12
Power switch (Radio Shack)	4	$2
Bow-style trap	4	
PVC trigger	4	
Speaker wire		