

DISTRIBUTION OF AUTUMN-STAGING LESSER SNOW GEESE ON THE NORTHEAST COASTAL PLAIN OF ALASKA

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Abstract.—We conducted aerial surveys of Lesser Snow Geese (*Chen caerulescens caerulescens*) during autumn staging on the coastal plain of the Arctic National Wildlife Refuge (ANWR) in northeast Alaska from late August through September, 1982–1993. We evaluated numbers and distribution of Snow Geese that staged on the ANWR, compared abundance of birds among 5 × 5-km cells used frequently (5–8 yr), periodically (3–4 yr), or infrequently (1–2 yr), and examined distribution changes within years. Maximum numbers of Snow Geese observed annually were highly variable (range 12,828–309,225). Snow Goose flocks occurred across 605,000 ha of the coastal plain, but used some areas more frequently than others. Frequently used cells (38 of 363 cells in the study area) were non-randomly distributed and primarily occurred on the central coastal plain between the wet coastal and steep foothills regions. Abundance of geese was greatest in frequently used, intermediate in periodically used, and lowest in infrequently used cells. Within years, Snow Goose numbers and flock locations varied between surveys, possibly because geese moved to different foraging areas during staging. The widespread distribution and annual variability in numbers of Snow Geese on the coastal plain was likely because birds used foraging habitats that were spatially and temporally heterogeneous. The ANWR coastal plain is an important component of the fall-staging area used by Snow Geese that nest in the western Canadian Arctic. Management decisions that affect the region should reflect its value to migrating Snow Geese.

DISTRIBUCIÓN DE *CHEN CAERULESCENS* A TRAVÉS DE SU CONGREGACIÓN OTONAL

Sinopsis.—Se condujeron muestreos aéreos del ganso *Chen caerulescens* durante la congregación otoñal de estas aves en la planicie costanera del Refugio de Vida Silvestre del Artico

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(RVSA) en el noreste de Alaska. De fines de agosto a septiembre de 1982 a 1993, se evaluó los números y la distribución de especies en el refugio. Además, se comparó la abundancia de aves entre celdas de 5×5 km utilizadas frecuentemente (5–8 años), periódicamente (3–4 años) o raras veces (1–2 años) y se examinaron los cambios en distribución a través de los años. El número máximo de aves observadas anualmente varió grandemente (alcance 12,828–309,225). Se encontraron bandadas de gansos a través de 605,000 ha de la planicie costera; unas áreas fueron más utilizadas que otras. Las celdas de uso frecuente (38 de 363) no se distribuyeron al azar. Estas se encontraron principalmente en la planicie costera central entre las regiones costera húmeda y en lugares empinados de regiones montañosas. La abundancia de aves fué mayor en las celdas de uso frecuente, menor en las de uso periódico y mínimo en las poco usadas. Cada año los números de aves y la localización de las bandadas variaron entre muestreos, debido, posiblemente, a que las aves se movieron a diferentes localidades de forrajeo durante su estadía. La amplia distribución y la variabilidad anual en el número de gansos en la planicie del refugio es posible porque las aves utilizan para forrajear habitat espacial y temporalmente heterogéneos. La planicie costera del RVSA es un componente importante del área de congregación otoñal de los gansos que anidan en el ártico canadiense oriental. Las decisiones de manejo que afecten a la región deben reflejar la importancia del área para la congregación otoñal de estos gansos.

Before autumn migration, 150,000–450,000 Lesser Snow Geese (*Chen caerulescens caerulescens*) (hereafter Snow Geese) of the Western Canadian Arctic Population (WCAP) stage on the coastal plain of the Beaufort Sea from the Bathurst Peninsula, Northwest Territories, Canada to the Hulahula River in eastern Alaska, USA (Johnson and Herter 1989). Snow Geese arrive in Alaska from the Canadian portion of the staging area between late August and early September (Johnson and Herter 1989). Within Alaska, the staging area includes the coastal plain of the Arctic National Wildlife Refuge (ANWR) (Fig. 1). During staging, Snow Geese increase lipid reserves (Patterson 1974) by foraging primarily on tall cotton-grass (*Eriophorum angustifolium*) and northern scouring rush (*Equisetum variegatum*) (Brackney and Hupp 1993). Snow Geese remain on the ANWR until snow storms and sustained freezing temperatures in mid-to late September cause them to migrate east to Canada and south along the Mackenzie River (Barry 1967).

Energy leasing was proposed for the coastal plain of the ANWR (Clough et al. 1987) and exploration is ongoing near the Mackenzie River Delta. Human activity associated with resource development may disturb or displace Snow Geese (Barry and Spencer 1976) while they are building lipid reserves necessary for migration (Bélanger and Bédard 1989, 1990; Davis and Wisely 1974; Patterson 1974). To assess the potential effects of resource development, distribution data were needed for the ANWR to identify areas where Snow Geese were likely to occur during staging. We examined distribution and abundance of Snow Geese that staged on the ANWR, 1982–1993. Our objectives were to: (1) estimate the numbers of individuals that occurred annually on the ANWR, (2) determine the frequency of use (in years) of individual 25-km² cells, and evaluate the spatial distribution of areas used at different frequencies, (3) compare abundance of geese in regions that were used frequently to regions used periodically or infrequently, and (4) examine changes in spatial distribution within years.

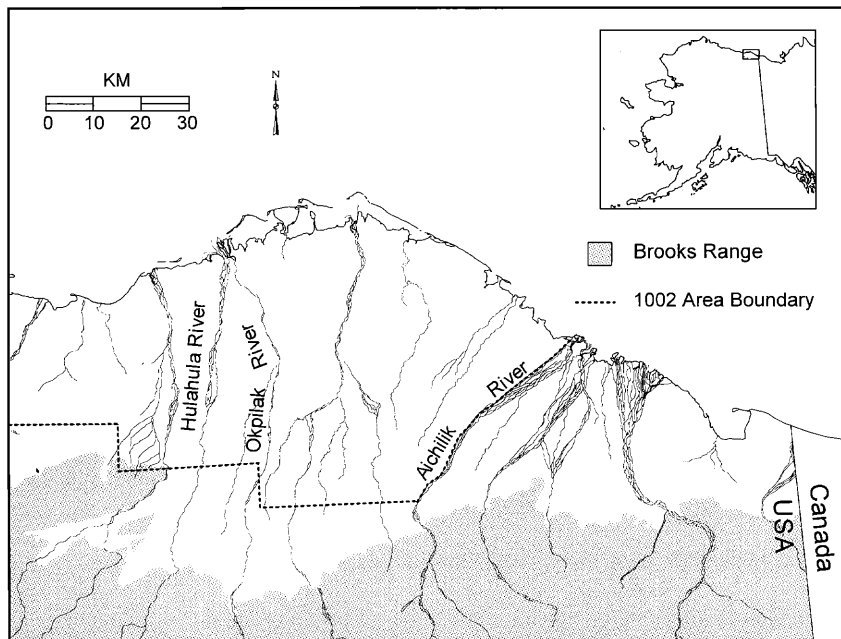


FIGURE 1. The study area on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Includes the northern edge of the Brooks Range, and the east and south boundaries of the 1002 Area, delineated for potential petroleum leasing.

STUDY AREA

The ANWR study area, located in northeast Alaska (69–70°N, 141–145°W), was bounded by the Beaufort Sea to the north, Brooks Range to the south, the Canadian border on the east, and the Saddlerochit Mountains and coastal tundra on the west (Fig. 1). The 1002 Area, identified for potential oil development in the Alaska National Interest Lands Conservation Act (Clough et al. 1987), extended from the Aichilik River in the east to the Canning River, approximately 85 km west of the staging area (Fig. 1).

The ANWR coastal plain is flat near the coast with elevation and topographic relief increasing toward the mountains. Much of the flat coastal and wide flood plain regions consist of low-centered polygons and unpatterned wet meadows dominated by sedges (*Carex* spp.) and tall cotton-grass (Walker et al. 1982). The rolling hills of the central coastal plain are a mosaic of well-drained uplands and high-centered polygons, intermixed with low-centered polygons, wet meadows, and thaw lakes (Jorgenson et al. 1994, Walker et al. 1982). Uplands are dominated by tussocks (*Eriophorum vaginatum*) and shrubs (*Salix* spp., *Betula nana*). Hilly regions to the south are primarily unpatterned upland tundra with linear water tracks (Walker et al. 1982) draining the slopes. Vigorous stands of tall cotton-grass and water sedge (*Carex aquatilis*) occur in thermokarst pits and on the lower slopes of water

tracks. Detailed descriptions of the ANWR coastal plain are in Felix and Reynolds (1989) and Walker et al. (1982).

METHODS

Aerial surveys.—We conducted aerial surveys of Snow Goose flocks on the coastal plain of the ANWR during autumn-staging in late August and September, 1982–1993. Pre- and post-survey reconnaissance flights were conducted to assess arrival and departure dates, and relative abundance of geese on the ANWR. Observers in field camps in 1984–1985 and 1988–1993, and incidental reports from fixed-wing and helicopter pilots flying over the study area, provided additional information on Snow Goose abundance. Surveys were initiated following a major influx of geese, and at least one survey was conducted during the period when reconnaissance flights and field observers suggested that the numbers had reached an approximate peak.

From 1–3 surveys were conducted each year by observers in a single-engine, high-wing Cessna or Helio-Courier aircraft. Each survey covered the ANWR coastal plain from Marsh Creek, west of the Hulahula River, to the Canadian border. Surveys were flown at 200 km/h, approximately 150 m above ground level. We estimated the number of Snow Geese in flocks as they flushed. Flock locations were marked on either 1:250,000 or 1:63,360 topographic maps and later transferred to a digitized base-map. Point locations for Snow Geese observed during 1983 were not available. Bad weather prevented surveys in 1990 and 1991.

Spatial distribution of frequency of use classes.—We superimposed a grid of 363 5 × 5-km cells over the digitized map of flock locations, and totaled the number of birds within a cell for each survey. We classified the frequency of use for each cell according to the number of years geese were observed within it: no use (0 yr), infrequent use (1–2 yr), periodic use (3–4 yr), or frequent use (≥5 yr). For years in which there was more than one survey, we used the survey in which the greatest number of birds was observed.

To test whether neighboring cells were spatially autocorrelated (i.e., likely to have similar frequencies of use), we used a join-count statistic (Upton and Fingleton 1985:158). For each cell, frequency classes of neighboring cells (top, bottom, left, right) were determined. A cell could have two, three, or four neighbors depending on its position in the grid (corner, side, or interior, respectively). We summed the number of neighbors in each pair-wise combination of frequency classes across the study area. The observed number in each combination was then compared to the expected number for a random distribution using a z-statistic and a two-tailed 95% confidence interval (Upton and Fingleton 1985:158).

Abundance in frequency of use classes.—We examined whether the mean number of Snow Geese within cells differed among frequency of use classes. We used one survey from each year (largest survey in years with more than one estimate) to calculate mean abundance by dividing the total number of birds observed in a cell in all years by the number of years Snow Geese were observed in the cell. We then compared mean abun-

TABLE 1. Dates of survey flights, total Snow Geese counted, and mean and standard error of flock sizes observed during surveys with the greatest number of geese (high count) on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Asterisks (*) indicate the date of the high count in years when multiple surveys were conducted. Mean flock size estimate for 1983 was determined from photographic counts of 15 Snow Goose flocks.

| Year | Survey dates | High count | \bar{x} flock size | SE |
|------|------------------------------|------------|----------------------|-------|
| 1982 | September 14*, 17 | 118,434 | 1579 | 213.2 |
| 1983 | August 28, September 12*, 21 | 12,828 | 214 | 53.8 |
| 1984 | September 13*, 20 | 93,062 | 642 | 60.4 |
| 1985 | September 1, 12* | 309,225 | 1059 | 80.9 |
| 1986 | September 5*, 8, 12 | 214,995 | 2867 | 365.3 |
| 1987 | September 6, 10*, 14 | 100,224 | 1542 | 181.2 |
| 1988 | September 8 | 50,689 | 780 | 109.5 |
| 1989 | September 8 | 61,529 | 810 | 103.2 |
| 1990 | no surveys | | | |
| 1991 | no surveys | | | |
| 1992 | September 8 | 60,700 | 778 | 100.7 |
| 1993 | September 9 | 89,500 | 716 | 85.8 |

dance among frequency of use classes with a non-parametric analysis of variance (Kruskal-Wallis test), and made pair-wise comparisons of mean abundance with Wilcoxon rank tests (Conover 1980) using the NPARIWAY procedure in SAS (SAS Institute Inc 1988a). We used non-parametric tests because we could not meet the assumptions of equal variances and normality necessary for analysis of variance (Conover 1980, Ott 1984).

Within-season movements.—Multiple surveys, separated by ≥ 5 d, conducted from 1984–1987, were examined for within-year changes in Snow Goose distribution. For each year, we correlated the number of Snow Geese observed in a cell during the first survey with the number observed in the same cell during the last survey using Kendall's tau-b correlations with the CORR procedure in SAS (SAS Institute Inc. 1988b). We included only cells in which Snow Geese were observed during at least one survey. We interpreted a lack of a significant correlation to indicate that use of cells varied randomly between surveys.

RESULTS

Aerial survey counts.—Numbers of Snow Geese observed annually on the ANWR during peak staging were highly variable and ranged from 12,828 in 1983 to 309,225 in 1985 ($\bar{x} = 111,119$; Table 1). Mean flock sizes varied among years from 214 to 2867 geese/flock in 1983 and 1986 respectively (range 5–13,417; Table 1). However, flock sizes may have been biased upward because of intermixing of flocks as they flushed from the ground.

Spatial distribution of frequency of use classes.—Snow Geese were observed within a 605,000-ha area of the ANWR coastal plain from just west of the Hulahula River to the Canadian border, and inland as far as the

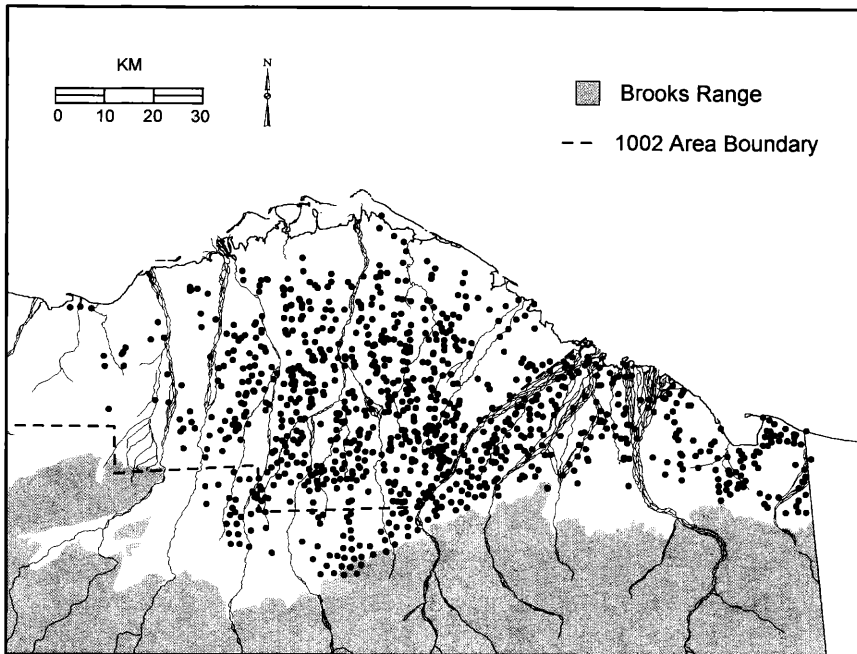


FIGURE 2. Locations of Snow Goose flocks observed during surveys with the greatest number of geese, 1982–1993, on the coastal plain of the Arctic National Wildlife Refuge, Alaska.

front slope of the Brooks Range (Fig. 2). Of the 363 5×5 -km cells in the study area, 122 were not used by Snow Geese, 129 were used infrequently, 74 were used periodically, and 38 were used frequently (Fig. 3). The 1985 survey accounted for 36% (47 of 129) of all Snow Goose observations in infrequently used cells.

Neighboring cells were likely to belong to the same frequency of use classes, and not to different frequency classes (Table 2). The results were significant for all combinations of classes with the exception of the combination of infrequently and periodically used cells. Thus, cells that were used at different frequencies occurred in different regions of the ANWR coastal plain, and regions of frequent use bordered regions of periodic use (Fig. 3). Areas that were used frequently occurred in the central coastal plain. Periodically used areas were widely distributed across the central coastal plain. Areas that were not used, or were used infrequently, occurred primarily along the coast, western edge of the staging area, or in the foothills adjacent to the Brooks Range (Fig. 3).

Abundance in frequency of use classes.—Mean number of Snow Geese observed within cells differed among frequency of use classes ($\chi^2 = 17.18$, $P = 0.0002$; Table 3). Wilcoxon ranks of the mean number of geese in frequently used cells was significantly higher than ranks in infrequently and periodically used cells (frequent and periodic \bar{x} scores = 66.3 and

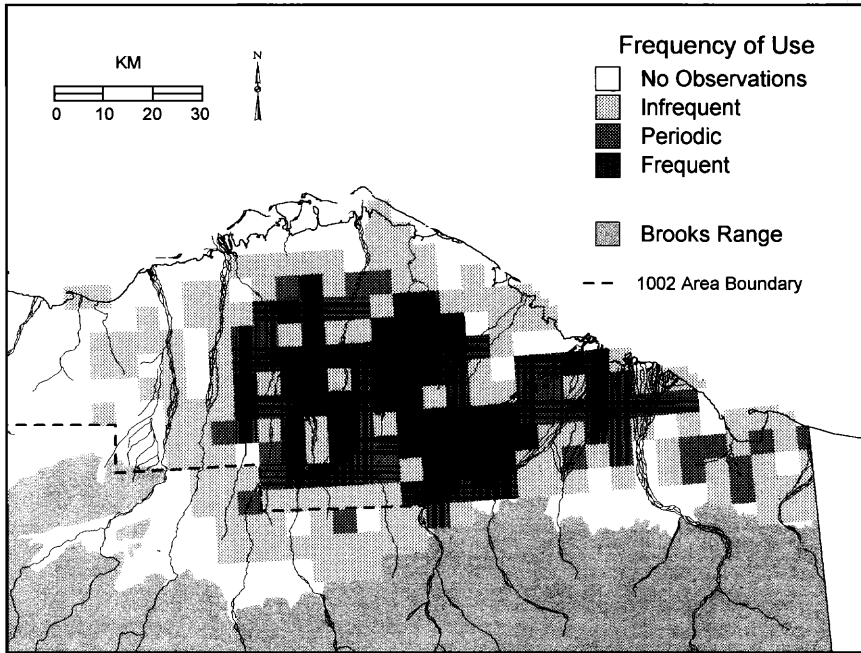


FIGURE 3. Frequency of use of 5×5 -km cells by Snow Goose flocks on the coastal plain of the Arctic National Wildlife Refuge, Alaska, during surveys with the greatest number of geese, 1982–1993. Cells were used infrequently (1–2 yr), periodically (3–4 yr), or frequently (≥ 5 yr).

TABLE 2. Spatial autocorrelation of the relationship between neighboring 5×5 -km cells that were not used (NONE), used infrequently (1–2 yr, INFR), used periodically (3–4 yr, PERI), or used frequently (≥ 5 yr, FREQ) by Snow Geese on the coastal plain of the Arctic National Wildlife Refuge, Alaska. A positive z -value indicated a greater than expected number of neighbor-pairs for a combination of use classes, and a negative z -value indicated fewer than expected neighbor-pairs. Asterisks (**) indicate significance at $P < 0.05$.

| Combinations | Neighbor-pairs | | Variance | z-Value |
|--------------|----------------|----------|----------|---------|
| | Observed | Expected | | |
| NONE–NONE | 124 | 75 | 36.4 | 8.01** |
| INFR–INFR | 118 | 88 | 39.7 | 4.67** |
| PERI–PERI | 60 | 27 | 18.1 | 7.52** |
| FREQ–FREQ | 30 | 7 | 5.9 | 8.94** |
| NONE–INFR | 135 | 163 | 91.7 | -3.04** |
| NONE–PERI | 22 | 91 | 56.4 | -9.31** |
| NONE–FREQ | 2 | 47 | 31.0 | -8.31** |
| INFR–PERI | 95 | 98 | 59.5 | -0.56 |
| INFR–FREQ | 37 | 51 | 32.6 | -2.67** |
| PERI–FREQ | 53 | 29 | 21.5 | 5.06** |

TABLE 3. Mean and total abundance of Snow Geese in 5×5 -km cells used infrequently (1–2 yr), periodically (3–4 yr), or frequently (≥ 5 yr) on the coastal plain of the Arctic National Wildlife Refuge, Alaska. Mean cell abundance was calculated by totaling the number of geese counted within a cell in all years, and dividing by the number of years geese were observed in the cell.

| Use class | <i>n</i> cells | \bar{x} of mean cell abundance | SE | Range of mean cell abundance | Range of geese observed in cells ^a |
|------------|----------------|----------------------------------|-------|------------------------------|---|
| Infrequent | 129 | 1669 | 223.4 | 22–14,000 | 8–14,000 |
| Periodic | 74 | 1634 | 163.2 | 84–8527 | 32–15,158 |
| Frequent | 38 | 1873 | 159.6 | 598–5579 | 48–24,929 |

^a The lowest and highest number of Snow Geese counted in any cell and year for each frequency of use class.

51.5, respectively, $z = 2.29$, $P = 0.0221$; and frequent and infrequent \bar{x} scores = 109.3 and 76.5, respectively, $z = 3.674$, $P = 0.0002$). Thus, cells that were used most frequently were also used by larger numbers of geese (Table 3). The mean number of Snow Geese in periodically used cells was slightly lower than the mean in cells that were used infrequently (Table 3). However, when the numbers were ranked for the Wilcoxon test, the results indicated that more geese occurred in periodically than infrequently used cells (\bar{x} scores = 115.9 and 94.0, respectively; Wilcoxon $z = 2.551$, $P = 0.0108$).

Within-season movements.—Total number of geese on the study area, mean number of geese/cell, and the number of cells used by geese varied between surveys within years (Table 4). The number of Snow Geese within

TABLE 4. Kendall's tau-b correlations among aerial surveys within seasons. Cell use for each year included the total number of 5×5 -km cells used by Snow Geese during each survey, and cells used in only one or both surveys. Total geese is the total number of Snow Geese observed during a survey, and mean geese is the mean number of Snow Geese per cell. Correlations compared the number of geese observed in a cell in the first survey with the number of geese observed in the same cell in the last survey on the coastal plain of the Arctic National Wildlife Refuge, Alaska.

| Year | Survey date (September) | Number of cells used | | | Total geese/survey | Mean geese/cell | SD | Correlation coefficient | <i>P</i> |
|------|-------------------------|----------------------|------------|--------------|--------------------|-----------------|------|-------------------------|----------|
| | | Total for survey | One survey | Both surveys | | | | | |
| 1984 | 13 | 89 | 50 | 39 | 93,062 | 782 | 1104 | -0.097 | 0.1524 |
| | 20 | 69 | 30 | | 46,022 | 387 | 630 | | |
| 1985 | 1 | 106 | 42 | 64 | 154,668 | 773 | 1605 | -0.201 | 0.0043 |
| | 12 | 158 | 94 | | 309,225 | 1546 | 2500 | | |
| 1986 | 5 | 51 | 34 | 17 | 214,995 | 2945 | 4490 | -0.338 | 0.0001 |
| | 12 | 39 | 22 | | 166,870 | 2286 | 4618 | | |
| 1987 | 6 | 42 | 33 | 9 | 53,330 | 847 | 959 | -0.425 | 0.0001 |
| | 14 | 30 | 21 | | 39,560 | 628 | 1322 | | |

cells in the first survey in 1984 was not significantly correlated with the number observed during the last survey (Table 4). However, in 1985, 1986, and 1987 the number of geese within a cell during the first survey was negatively correlated with the number observed during the second survey. Though correlation coefficients were low (Table 4), these results suggest that areas used during the early period of staging were less likely to be used later.

DISCUSSION

We observed Snow Geese in widely dispersed flocks across 605,000 ha of the ANWR coastal plain, which was part of a larger staging area that extended across 700 km of the Beaufort Sea coast (Johnson and Herter 1989). We believe the major determinants of Snow Goose distribution on the ANWR were the dispersion and availability of foraging habitats. When feeding on tall cotton-grass Snow Geese consumed large amounts of forage and selected feeding sites that were small, patchily distributed, and comprised a small percentage of the landscape (Hupp et al. 1996). The availability of forage may have varied temporally (within and among years) as well as spatially due to the effects of tall cotton-grass removal by Snow Geese (Brackney and Hupp 1993), and because snow and ice often covered parts of the staging area which reduced access to feeding habitats. In contrast to the dispersed and variable distribution of Snow Geese on the ANWR coastal plain, geese occur in large numbers and exhibit high annual fidelity when staging in areas where food resources are more uniformly distributed (e.g., Giroux and Bédard 1988, Reed et al. 1989).

Numbers of Snow Geese on the ANWR varied among years because of annual differences in the distribution of the WCAP across the entire staging area. In some years most geese remained in Canada and numbers observed on the ANWR were low (e.g., 1983). In other years (e.g., 1985) a high proportion of the WCAP staged on the ANWR. Weather and reproductive success may influence annual distribution of geese (Koski 1977, Patterson 1974). Annual variation in numbers of geese on the ANWR may also have been influenced by availability of berries (Barry 1967) and tall cotton-grass in Canada. Changes in distribution within a season may have been related to changes in forage availability as staging progressed. In 3 of 4 years we found that numbers of geese in a cell were negatively correlated between surveys on different dates. Because pre-migratory geese are hyperphagic (Drent et al. 1979, Hupp et al. 1996, Madsen 1985, McLandress and Raveling 1981) they may rapidly reduce forage in a local area. Snow Geese may have moved away from areas that were used during the early part of staging because forage was less available.

Most (84%) of the ANWR study area where geese occurred was used infrequently or periodically. A small portion (16%) was frequently used. On average, more geese occurred in frequently used cells than in infrequently or periodically used cells. We believe some areas of the ANWR were used more frequently and by larger numbers of geese because feeding habitat was more consistently available. If weather conditions during

migration to the staging area, goose population size, or proximity to the nesting colony had affected distribution of frequently used cells, Snow Geese likely would have occurred primarily along the eastern part of the study area where geese first arrived from Canada. Instead, frequently used areas were in the central ANWR coastal plain ≥ 50 km west of the Canadian border. Thus geese bypassed a large part of the eastern refuge in order to reach areas that were frequently used. The frequently used central coastal plain between the Okpilak and Aichilik rivers consisted of low, rolling ridges with high densities of thermokarst pits (Walker et al. 1982) in which tall cotton-grass was readily available (Hupp et al. 1996). Feeding habitat may have been less available in the flatter coastal and steeper foothills areas that were used periodically or infrequently, but were important in 1985 when more than 300,000 Snow Geese staged on the ANWR.

The coastal plain of the ANWR is an important component of the entire WCAP staging area, especially in years when high reproductive success, favorable weather, or limited habitat availability in Canada cause large numbers of geese to move into Alaska. Over 80% of areas that Snow Geese frequently used on the ANWR were located on the 1002 Area where petroleum leasing has been proposed. In those areas there is potential for human activities to disturb staging geese during late August and September. While the potential for disturbance of Snow Geese in infrequently or periodically used areas would be less, disturbance could occur in years when there are large numbers of geese on the ANWR. Management decisions for the ANWR coastal plain should reflect the importance of the area to autumn-staging Snow Geese.

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