Migration, fidelity, and use of autumn staging grounds in Alaska by Cackling Canada Geese *Branta canadensis minima*

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Cackling Canada Geese were studied annually (1985-88) on autumn migration staging areas in Alaska during a period of rapid population growth. Geese concentrated at two estuaries (Ugashik Bay and Cinder Lagoon) along the north side of the Alaska Peninsula. Birds arrived on the staging areas in late September, numbers peaked during mid-October, and departure occurred by late October or early November. Annual peak counts combined for the two staging areas ranged from 16,000-54,000 geese, or from 23-120% of the autumn population index. Up to 30,000 geese were recorded at each estuary, but relative use of the two staging areas varied among years. Within-year fidelity to staging areas was high; only three of 242 neck-banded geese seen more than once were observed at both areas within a season. Between-year fidelity to staging areas was highest among hatching-year females (11 of 11) and adult males (14 of 17), lowest among hatching-year males (4 of 9), and intermediate among adult females (18 of 28). Use of the two staging areas was independent of family status, reproductive status, and age. Late arrivals on the staging areas consisted of a higher proportion of single and paired birds than of geese in family groups. Most geese departed the staging grounds with the onset of freezing conditions and the passage of low pressure systems that produced winds favourable for migration. Transoceanic flights to the wintering grounds in Oregon and California were completed in about 48 h. During years with mild weather on the breeding grounds and years with early freezing conditions on the staging areas, few geese staged on the Alaska Peninsula, indicating that geese can sometimes obtain sufficient energy reserves to migrate directly from the breeding grounds without stopping on the staging areas. Only 25% of the area used for staging is legally protected. Use of unprotected areas may become increasingly important if the population continues to increase.

Keywords: Alaska, Cackling Canada Goose, Autumn Staging, Migration, Population, Site Fidelity, Weather

Study of geese at migrational staging areas generally has lagged behind that of other periods in the annual cycle. The remoteness of sites, difficulties of working at northern latitudes in autumn, and the brevity of the staging period have all contributed to lack of studies. Nonetheless, knowledge of how geese use autumn staging areas is important because these areas provide resources necessary for juveniles to complete their structural development (Wypkema & Ankney 1979) and for geese to build reserves used on migration (Prevett *et al.* 1979; Wypkema & Ankney 1979; Thomas & Prevett 1980; Sedinger & Bollinger 1987; van Eerden *et al.* 1991).

After breeding on the Yukon-Kuskokwim Delta of western Alaska, Cackling Canada Geese *Branta canadensis minima* move south to estuaries along the north side of the Alaska Peninsula. There they

congregate before migrating to their primary wintering grounds in central California and southern Oregon (Nelson & Hansen 1959; Sedinger & Bollinger 1987). The population has increased markedly following a precipitous decline that began in the mid-1970s and continued through the mid-1980s (O'Neill 1979; Raveling 1984; King & Derksen 1986). Effective population management requires an understanding of the extent and use of the staging grounds. Our objectives were to identify specific areas used for autumn staging by Cackling Canada Geese, compare the relative importance of areas, assess the degree of fidelity to staging areas, and describe the timing and patterns of migration at these areas.

Study area

Ugashik Bay and Cinder Lagoon are two adjacent 100 km^2 estuaries on the north side of the Alaska Peninsula in upper Bristol Bay (**Figure 1a**). Ugashik Bay (57°30'N, 157°33'W), fed by the Ugashik River, is predominantly shallow intertidal mud and sand flats bordered by several large but disjunct vegetated intertidal communities, extending inland about 20 km (**Figure 1b**). Cackling Canada Geese used three broadly defined habitats: (1) braided coastal strand south of and just inside the mouth of the bay, which consists of extensive mats of predominantly Creeping Alkaligrass *Puccinellia phryganodes* and Purple Sandspurry *Spergularia canadensis*, (2) graminoid meadows, which occur inside the bay along most of the shoreline and inland for several 100 m (see Sedinger & Bollinger 1987), and (3) a smaller area of sand and gravel bars, shallow brackish ponds 10-30 cm deep, and tidal sloughs and mudflats vegetated with Four-leaf Marestail *Hippuris tetraphylla* and Pendant Grass *Arctophila fulva*.

The Cinder Lagoon study area (57°20'N, 158°05'W), located 40 km southwest of Ugashik Bay, also included the adjacent Hook Lagoon (30 km2) estuary (**Figure 1c**); the two lagoons are hereafter referred to collectively as Cinder Lagoon unless otherwise specified. The Cinder Lagoon area includes: (1) extensive flats of Creeping Alkaligrass and Four-leaf Marestail in upper Hook Lagoon and near the mouth of Mud Creek, (2) tidal, wet sedge and graminoid meadows along the south shore of Hook Lagoon, the mouth of Mud Creek, and the southeast shore of Cinder Lagoon; and (3) an extensive area of shallow brackish ponds between Hook and Cinder lagoons.

The proximity of the Bering Sea and the Alaska Range dramatically influences the weather at the study areas. Major autumn storms move eastward across the Alaska Peninsula an average of four times during September and six times during October each year (Brower *et al.* 1988). Seventy-nine percent of all recorded winds during October exceed 20 km/h and 52% are out of the northwest quadrant. The long-term average mean maximum and minimum temperatures during 1-15 October at Port Heiden, 45 km southwest of Cinder Lagoon, are 6.0 and 0.5°C, respectively. The mean maximum and minimum temperatures drop to 3.5 and -3.0°C during the last half of the month (Leslie 1988; NOAA 1980-1988).

Methods

Field studies

Geese were studied on the ground at Ugashik Bay from 1985-88 and at Cinder Lagoon from 1986-88. From two to four biologists were present at each area from the last week of September, before most geese had arrived, until most geese had departed for the wintering grounds. Effort was divided about equally between the two sites. Observers worked from a single, fixed camp at Ugashik Bay each year (**Figure 1b**). At Cinder Lagoon, camps were located at different sites each of the three years. In 1987 two camps were run concurrently at Cinder Lagoon, one in upper Hook Lagoon and the other between Hook and Cinder lagoons (**Figure 1c**).

We assessed number of geese, migration chronology, and bird distribution

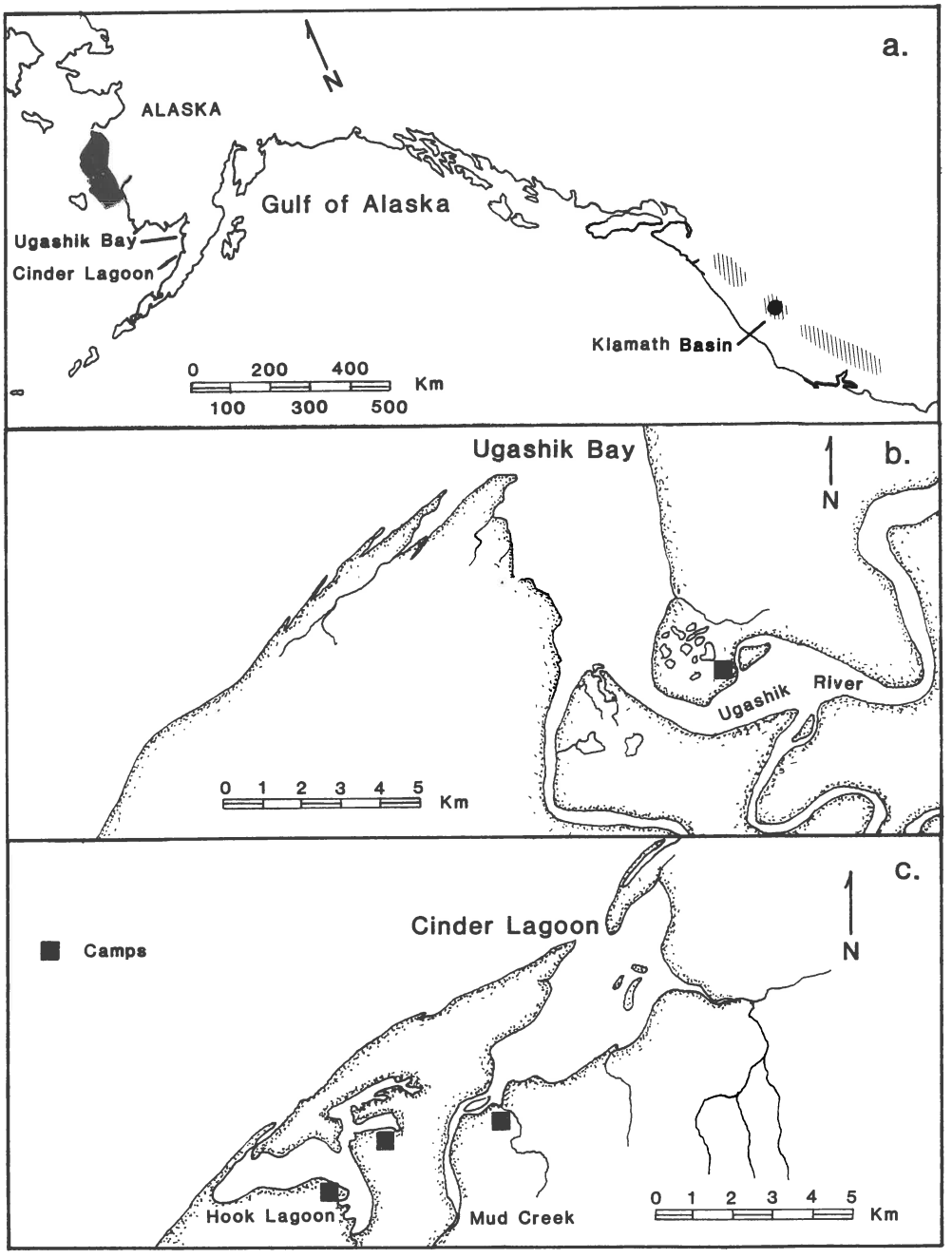

Figure 1. Major breeding (shaded) and wintering (cross-hatched) areas (1a) of Cackling Canada Geese in relation to autumn staging areas at Ugashik Bay (1b) and Cinder Lagoon (1c). Dark squares show field camps and the dark circle the principal area used by geese upon initial arrival on the wintering grounds.

primarily from aerial surveys flown over both areas several times each season. Each 100 km^2 estuary and adjacent coastal meadows were completely covered by fixed, figure "S" transects. Two or three observers counted geese from single-engine, fixed-wing aircraft at an average ground speed of 160 km/h and an altitude of 90 m. During each survey we plotted locations of flocks on colour infra-red photographs of the areas (scale 1:60 000).

We also systematically counted geese from the ground on a 1,000 ha area within Ugashik Bay and a 450 ha area at Cinder Lagoon. Early morning feeding flights of geese were monitored daily from the cabin at Ugashik Bay. From a 4 m tower near the central camp at Cinder Lagoon (**Figure 1c**), we used 20-60 X spotting scopes and Questar telescopes to obtain daily counts of geese (use of trade names does not imply endorsement by the National Biological Service). We also counted geese on both areas when low-flying aircraft or Bald Eagles *Haliaeetus leucocephalus* caused all geese to take flight. We included these counts in our analyses if they were substantially higher than our counts of birds on the ground.

We also used spotting scopes and Questar telescopes to observe geese that had been neck-banded on the breeding or wintering grounds (see Raveling *et al.* 1990 for a description of neck-bands). We searched for marked birds daily within large, accessible concentrations of geese, but also in more remote portions of each estuary. We assigned status (family, paired, single, or unknown) to those geese based on observations of interactions with other marked birds of known age and sex (after Raveling 1970).

We assigned information on arrival and departure of geese from nearly continuous observations during daylight hours on days on which these events were detected. We noted behaviour, heading of travel, and altitude of arriving and departing birds. We estimated altitudes in relation to where cloud ceilings intersected known elevations on nearby mountains. Information on time of arrival of geese on the wintering grounds came from aerial surveys and daily ground counts (see Raveling & Zezulak 1991 for details).

Analyses

To examine geographic and between-year variation in the intensity of use of the two staging areas, we first laid a fixed grid over the photos on which we had mapped the locations of all flocks observed during aerial surveys. Each square cell of the grid represented 14.5 ha. To determine which areas within each estuary were used most heavily, we calculated and mapped for each cell the average density of geese observed during all aerial surveys. To compare the relative concentration of birds on the two staging areas during each survey, we calculated the density (D) of geese per ha on each area as $D = N/(C*14.5)$, where N = total number of geese observed, C = number of cells used by geese on that survey, and 14.5 = area of each cell in ha. Densities were compared between the two areas for the 17 paired aerial surveys using Wilcoxon Signed Rank Test; differences among years were tested for each site using Kruskal-Wallis Test (Ostle & Malone 1988).

To determine whether the composition of geese using the two staging areas varied in relation to age or sex, we constructed a series of hierarchical loglinear models (Norusis 1990) to analyze the proportions of neck-banded geese observed each year. Partial chi-squares were examined to evaluate interactions between two or more factors. First, we tested whether the proportions of hatching-year birds varied between the two sites or among the three years observers were at both sites. We then compared the proportion of hatching-year birds observed on staging grounds with the proportion of young originally banded on the breeding grounds over the four-year period. Only birds observed on staging areas the same year they were neck-banded were included in these two analyses. Finally, we tested whether the age composition (hatching-year, yearling, and adult) of neck-banded geese differed between the two staging areas. For this analysis we included all neck-banded geese of known age regardless of their year of banding; some individuals were resighted in more than one year.

We also used a hierarchical loglinear model to examine use of the two staging areas by birds that had been neck-banded on the breeding grounds to see if there were any differences in age, sex, or banding location. Geese were classified as sub-adult (hatching-year or yearling) or adult and if they had been banded at one of five major areas on the breeding grounds: Kokechik Bay (61°40'N, 165°40'W), Ninglikfak River (61°30'N, 165°40'W), Old Chevak (61°20'N, 165°30'W), Manokinak River (61°10'N, 165°00'W), and Azun River 61°00'N, 164°50'W). We also used Pearson's chi-square statistic (Ostle & Malone 1988) to test whether use of the two staging areas depended on either the type of flock in which geese had been banded (brood *v* moulting) or their family status (single or paired birds *v* those associated with family groups).

Because of between-year differences in the timing and span of arrival of geese on staging areas, arrival times of neck-banded geese were classified as early, middle or late based on whether they occurred within the first, middle two, or last quartile of the frequency distribution of first sightings of neck-banded geese each year. Timing of arrival among geese associated with family groups was then compared with that of single or paired geese using Pearson's chi-square statistic. Minimum length of stay was calculated as the difference between first and last observations of neck-banded geese; only those observed more than once in a given year were included. Differences in length of stay between geese associated with family groups and those observed as pairs or singles were compared with the Median Test (Conover 1980).

Between-year fidelity was defined as the proportion of neck-banded geese observed in two successive years that returned to the same staging area they had used the first year. Individuals observed more than two years were included only once. A Binomial Test (Ostle & Malone 1988) was used to test the hypothesis that geese were equally likely to return to the same or different area the following year ($H_0 : p = 0.5$ *v* $H_1 : p \neq 0.5$). We tested against a value of $p = 0.5$ since the average number of geese recorded during paired aerial surveys did not differ between the two sites ($P = 0.42$). A hierarchical loglinear model was constructed to test the independence of fidelity rate from sex and age (hatching-year *v* older). Fidelity rates of adult males and females were compared using Pearson's chi-square statistic.

We used SPSS Inc. (1990) and SAS Institute Inc. (1988) software packages for statistical analyses and present all values as ± the standard error of the mean. Values of $P < 0.05$ were considered statistically significant.

Results

Arrival

Generally less than 1% of the peak populations of Cackling Canada Geese were present during the last week of September (**Figure 2**). Marked increases in numbers of geese occurred during the second week of October in 1985, 1986, and 1988, and the fourth week of October in 1987. Following the initial mass arrivals, waves of birds continued to arrive at both areas. We recorded 16 mass immigrations of geese, totalling about 55,000 birds (**Table 1**). During 12 immigrations, arrival coincided with tailwinds of up to 40 km/h from the north and northwest. The four other mass arrivals occurred when winds were westerly or southerly at 0-10 km/h.

We plotted the arrival paths of several flocks of geese migrating across Bristol Bay. During three major daylight immigrations to Cinder Lagoon (10 October 1986, 26 October 1987, and 28-29 October 1987), totalling about 12,000 birds, flocks exhibited similar patterns of arrival and dispersal over the area. Among 111 flocks, which averaged 107 ± 7 birds, 99 (89%) were first detected when about 3-5 km out over Bristol Bay approaching the mainland from the west or southwest just below the lowest layer of clouds. Among these, 81 flocks made landfall just south of the mouth of Hook Lagoon (**Figure 1c**), and the remainder came ashore 3-5 km north of Hook Lagoon. An additional 12 flocks, totalling 1,700 birds, arrived well

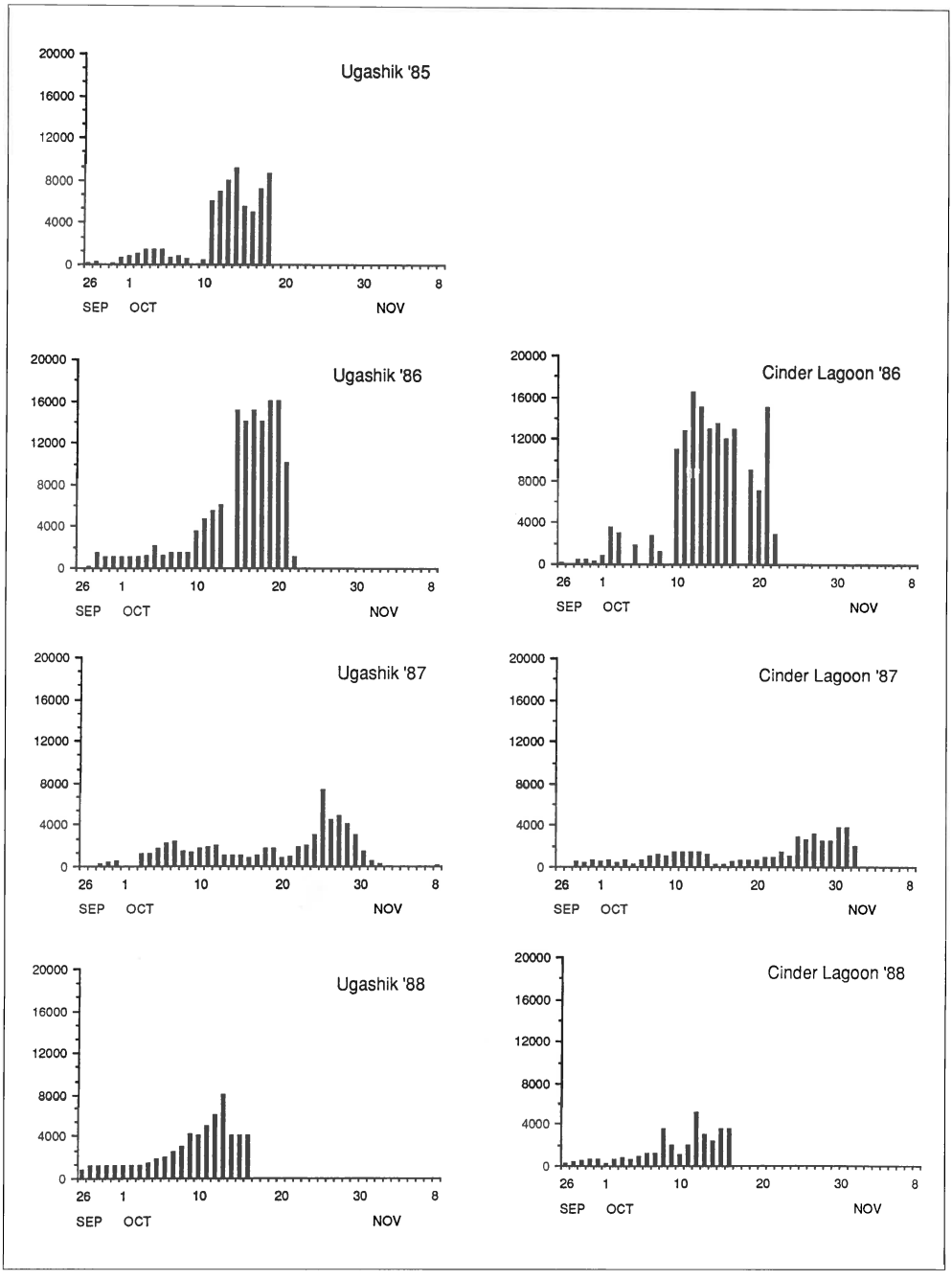

Figure 2. Temporal occurrence and numbers of Cackling Canada Geese recorded during ground counts at Ugashik Bay and Cinder Lagoon, Alaska, 1985-1988. The vertical dashed line represents the onset of freezing conditions.

inland 4-6 km south of Hook Lagoon.

We also recorded several flocks overflying Cinder Lagoon in 1987. On 28 October, we monitored the flight of a radio-telemetered bird first detected several kilometres out over Bristol Bay. It passed over Cinder Lagoon at about 1,000 m altitude in a flock of 350 geese and was recorded for an additional 15 minutes heading east until the signal was lost, suggesting that the flock continued across the Alaska Range (**Figure 5**). That day we watched two other flocks of geese arrive from over Bristol Bay and fly east over Hook Lagoon toward the mountains without stopping at Cinder Lagoon.

Table 1. Weather conditions during periods of observed arrival of Cackling Canada Geese, 1985-1988.

Area	Dates	Geese Time of Arrival[a]	*n*	Weather conditions Wind dir	Wind speed (km/h)	Visibility (km)	Cloud Cover (%)	Cloud Ceiling (m)
Ugashik Bay								
1985	10-11 Oct	2000-0600	5-7000	NNW	15-25	65	80	2000
1986	10-11 Oct	1600-0600	4-5000	NW	15-20	30	90	500
	14-15 Oct	1500-0600	8-10000	NNW	25-30	10-15	90	500
1987	21-22 Oct	2300-0400	1-2000	NW	5-15	15-30	80-100	150
	24-25 Oct	2200-1000	3-4000	SW	0-5	65	70	2000
	27 Oct	1400-1600	1000	W	0-10	65	50	1500
1988	10-11 Oct	2000-0300	2000	NNE	25-30	15-25	100	150
	12 Oct	1500-1700	2000	N	10	65	80	1000
Cinder Lagoon								
1986	10 Oct	1300-1900	6000	NW	5-10	25-30	100	750
	14-15 Oct	2200-0500	5-8000	NW	25-40	15	70-100	500
1987	26 Oct	0730-2330	2000	NW	0-5	50	50	1000
	28-29 Oct	1000-0900	4000	WSW	0-5	50	50	1500
	31 Oct	1600-1630	1000	WNW	10-15	30-50	80	500
1988	7-8 Oct	2000-0600	3000	NW	5-20	50-65	40	1200
	11-12 Oct	2200-0600	3000	NNE	5-15	30	90	900
	14 Oct	1500-2200	2000	WSW	0-5	30-65	80	1800

[a] All times Alaska Daylight Time.

Table 2. Numbers of Cackling Canada Geese recorded during aerial surveys of Ugashik Bay and Cinder Lagoon, Alaska, 1985-1988.

Survey Date		Location Cinder Lagoon	Ugashik Bay	Total
1985	12 October	1668	11017	12685
	14 October	27500	12000	39500
	19 October	2250	120	2370
1986	28 September	—[a]	2311	2311
	5 October	2500	3000	5500
	11 October	18000	6900	24900
	15 October	29500	24200	53700
	21 October	21000	19000	40000
	22 October	3010	1050	4060
1987	5 October	1019	3614	4633
	14 October	1021	4792	5813
	25 October	6330	21086	27416
	27 October	7330	11788	19118
	1 November	7550	215	7765
	8 November	0	365	365
1988	9 October	2626	4580	7206
	12 October	9544	6788	16332
	14 October	4830	5568	10398

[a] Not surveyed on this date.

Use of Staging Areas

Numbers

Aerial surveys showed geese to be about equally divided between the two areas during the four years, although relative use and peak numbers varied between years (**Table 2**). At Cinder Lagoon, peak numbers were about 30,000 in 1985 and 1986, but less than 10,000 in both 1987 and 1988. At Ugashik Bay the peak was less than half that at Cinder Lagoon in 1985, similar in 1986 and 1988, but almost three times greater in 1987. During the four years of study, 1985-1988, combined peak counts at Ugashik Bay and Cinder Lagoon were 120%, 104%, 50%, and 23% of the respective autumn population counts on the wintering grounds (J. Bartonek, unpubl. data).

Preferred areas and densities

Geese used about 2,300 ha of Cinder Lagoon (**Figure 3**) and 2,600 ha of Ugashik Bay (**Figure 4**). Analysis of flock locations during paired aerial surveys (n = 17) showed geese used preferred areas in similar densities (P = 0.47) at Cinder Lagoon (30 ± 6 birds/ha) and Ugashik Bay (25 ± 4 birds/ha). Densities did not differ significantly among years at Ugashik Bay (P = 0.45) or at Cinder Lagoon (P = 0.06).

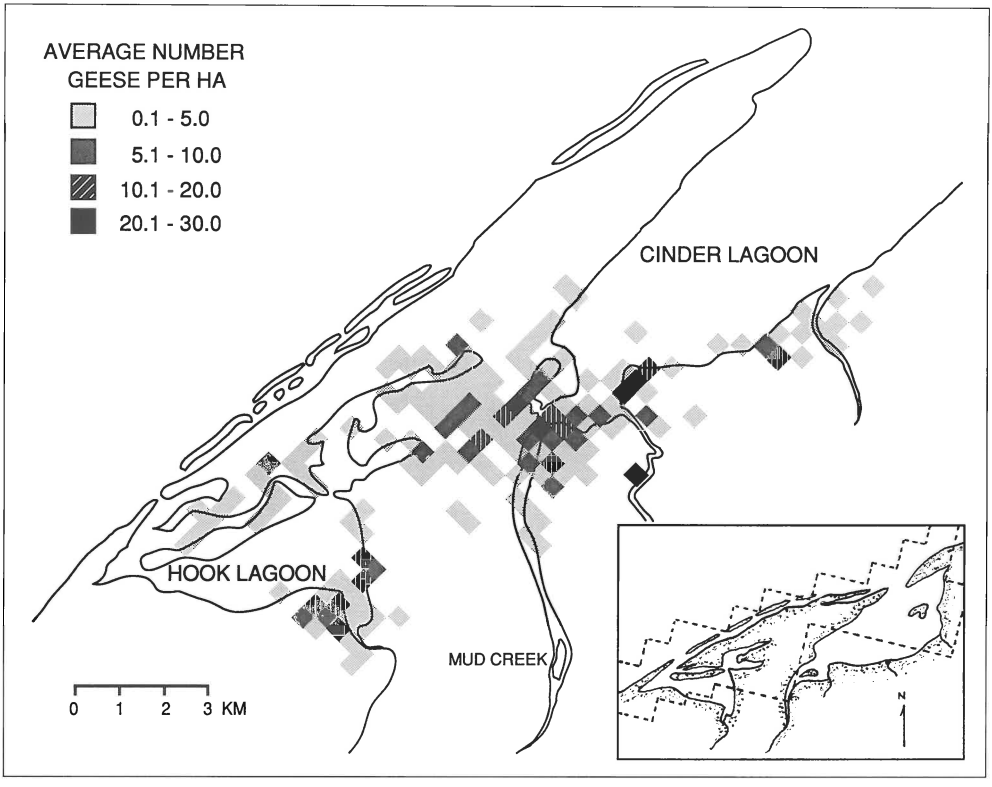

Figure 3. The distribution and relative density of Cackling Canada Geese using Cinder Lagoon, Alaska, 1985-1988. Average densities within 14.5-ha blocks are shown for the 16 aerial surveys on which geese were recorded. The dashed line (inset) encloses the majority of the Alaska State Critical Habitat Area (see discussion).

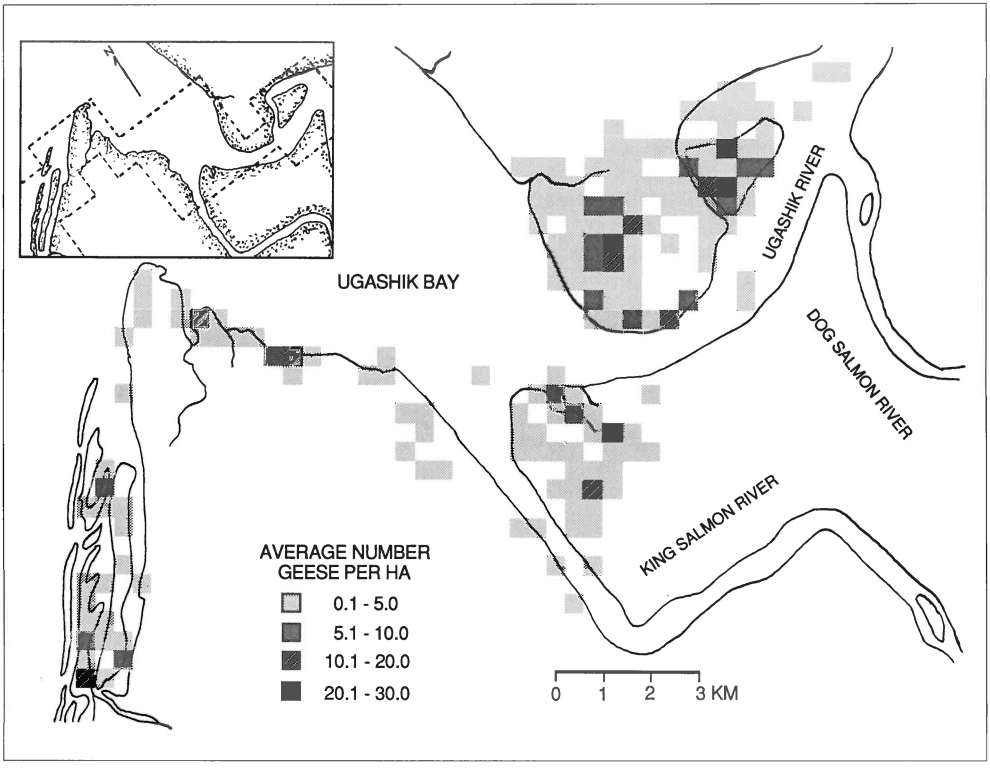

Figure 4. The distribution and relative density of Cackling Canada Geese using Ugashik Bay, Alaska, 1985-1988. Average densities within 14.5-ha blocks are shown for the 16 aerial surveys on which geese were recorded. The dashed line (inset) encloses the majority of the Alaska State Critical Habitat Area (see discussion).

Relation to age and reproductive status

Among the 290 geese that were observed on staging grounds the same year they were neck-banded, the proportion of hatching-year birds was similar between Ugashik Bay and Cinder Lagoon (**Table 3**; $P = 0.31$), and did not vary significantly among the three years observers were at both areas ($P = 0.53$). Overall, the proportion of young birds recorded at the two staging areas combined was similar to that with which they had originally been banded on the breeding grounds in each of the four years ($P = 0.33$). Among geese of any age group, we found no discernible pattern of association between banding location in Alaska and use of staging areas the same autumn.

When all neck-banded resightings were examined, regardless of the year or location of banding, age composition was found to be similar between Ugashik Bay and Cinder Lagoon. From 1986-1988, when observations were conducted at both sites, 25% of the 568 resightings were of hatching-year birds, 12% were of yearlings, and 63% were of older birds. Sample sizes of young birds were too small to examine possible sex-related differences in age composition between the two sites.

Use of the two staging areas was not related to reproductive status. Most (98%) of the 222 geese that had been neck-banded on the breeding grounds and seen on the staging areas had been marked in

Table 3. Percent hatching-year (HY) Cackling Canada Geese among those neck-banded on breeding grounds in Alaska and among those resighted the same year at Ugashik Bay and Cinder Lagoon, Alaska, 1985-1988.

	Banded in Alaska		Resighted at Ugashik Bay		Resighted at Cinder Lagoon		Resighted Combined	
Year	*n*	% HY	*n*[a]	%HY	*n*[a]	%HY	*n*[a]	%HY
1985	585	29	64	20	-[b]	-[b]	64	20
1986	449	59	34	59	41	63	74	62
1987	535	69	38	66	72	67	109	67
1988	342	60	17	41	24	67	40	58

[a] Total number of birds from each year's cohort of neck-banded geese that were resighted on staging areas.
[b] No on-ground studies at Cinder Lagoon in 1985.

brood flocks rather than moulting flocks, and this percentage did not vary between the two staging areas (P = 0.34). Likewise, the proportion of marked birds in family groups did not differ between Cinder Lagoon (65% of 162) and Ugashik Bay (53% of 126) (P = 0.63).

Timing of arrival on staging areas did differ between marked geese associated with family groups and birds identified as singles or pairs (P = 0.02). Although similar proportions of the two groups (25%) arrived early each season, 26% of the pairs and singles constituted late arrivals, compared with only 14% of those in family groups. Average length of stay on staging grounds did not differ between family and non-family groups (P = 0.09).

Fidelity to staging areas and sites

Only three of 242 neck-banded geese observed more than once in a season were seen at both Cinder Lagoon and Ugashik Bay, indicating high fidelity to a particular staging area. Within-year fidelity to localized sites within a staging area was also high. In 1987, the only time two sites (3 km apart) were monitored simultaneously within Cinder Lagoon, only 18% of 91 neck-banded geese were seen at both sites.

Fidelity to staging areas was less pronounced between years than within years. Seventy-two percent of the 65 marked geese seen in two successive years were observed at the same staging area the following year (**Table 4**), more than expected by random assortment (P = 0.0005). Fidelity rate was not independent of age and sex (P = 0.04), and varied within age class by sex (P = 0.002). All 11 hatching-year females that were resighted as yearling birds returned to the same staging area they had used the previous year (P = 0.001). Young males, in contrast, exhibited the lowest rate of fidelity, with four of nine hatching-year birds returning to the same staging area their second year (**Table 4**). Older males, however, exhibited significant fidelity; 14 of the 17 (82%) resighted birds returned to the same staging area the following year (P = 0.01). This fidelity rate did not differ significantly (P = 0.19) from that of adult females (64%).

Table 4. Interannual fidelity of male and female hatching-year and adult Cackling Canada Geese to fall staging areas on the Alaska Peninsula, 1985-1988.

	Interannual use of areas		
Age first sighted	Same area	Different area	*P*-value[b]
Hatching-year			
Females	11	0	0.001
Males	4	5	1.00
Adult[a]			
Females	18	10	0.19
Males	14	3	0.01

[a] Adults were considered yearling birds (second-year) and older.
[b] Two-tailed probability when testing the hypothesis that geese were equally likely to return to the same or a different area in a subsequent year (H_0: $P = 0.5$ *v.* H_1: $P \neq 0.5$).

Among five marked pairs whose members were both seen in more than one year, three pairs returned together to the same staging area and one pair returned together to a different staging area. In the fifth pair, which split up, the male returned to the staging area it had used the previous year whereas the female was observed at the other staging area.

Departure

The general timing of departure of geese from Ugashik Bay and Cinder Lagoon was similar between sites but quite variable among years. All birds had departed by the fourth week of October in 1985 and 1986, the first week of November in 1987, and the second week of October in 1988 (**Figure 2** and **Table 2**). During 1985, 1986, and 1988, the departure was abrupt and usually occurred within a 24-48 h period, but during 1987 departure was protracted over a 5-7 day period (**Figure 2**).

During 1986, most geese departed from both Ugashik Bay and Cinder Lagoon in mass nocturnal migrations (cf. **Table 2**, 21-22 October); in 1988 a large departure from Cinder Lagoon was also recorded on the night of 13 October. During other years, flocks were observed departing during daylight hours under specific weather conditions (**Table 5**). In 1985 and 1987, for example, diurnal departures of geese generally coincided with freezing temperatures, ceilings from 500-1500 m, horizontal visibility exceeding 50 km, and winds that were either light and variable

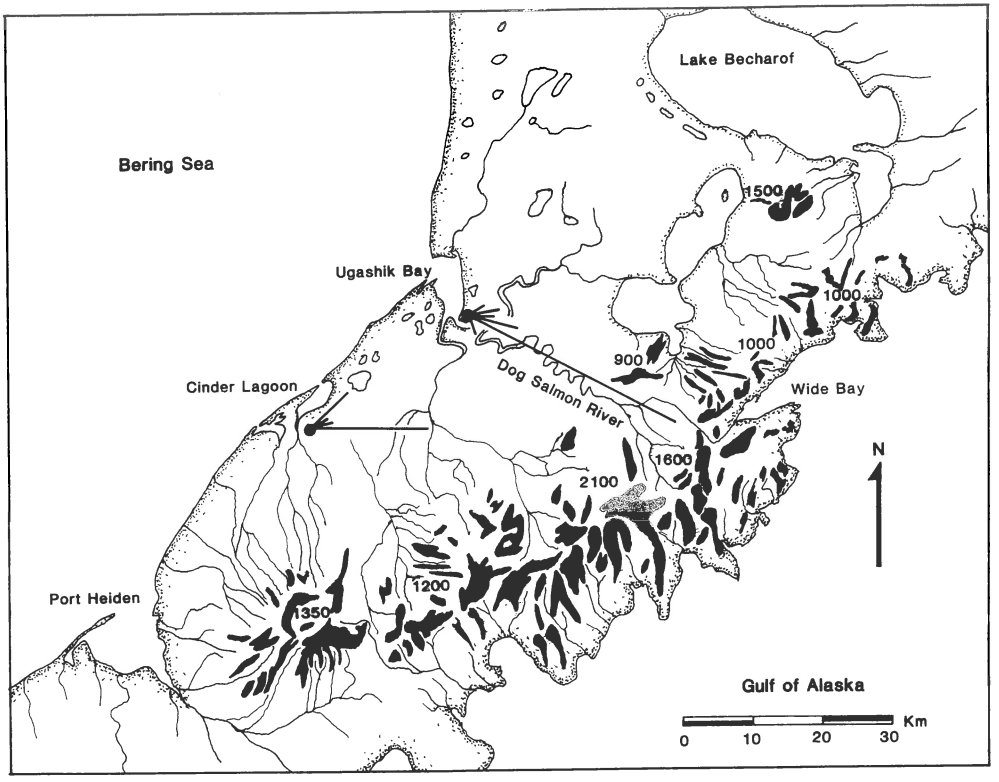

Figure 5. Proportion of flocks of Cackling Canada Geese departing in different directions from Ugashik Bay (n = 44 flocks) and Cinder Lagoon (n = 13 flocks), Alaska, 1985-1988. Elevation of peaks in the Alaska Range in meters. Shaded areas show elevations above 900 m.

Table 5. Weather conditions during periods of observed diurnal departure of Cackling Canada Geese, 1985-1988[a].

Area	Dates	Time of Departure[b]	Geese *n*	Flocks *n*	Temp (°C)	Weather conditions: Wind speed	Wind speed (km/h)	Visibility (km)	Cloud Cover (%)	Cloud Ceiling (m)
Ugashik Bay										
1985	16 Oct	1500-1930	4100	20	1	W	35-45	55	70	350
	17 Oct	1450-1620	870	9	-3	WNW	25-30	60	80	600
1987	27 Oct	0830	1600	1	-3	Var.	0-3	55-70	20	2000
	29 Oct	1700-1800	450	2	-6	NE	0-3	55-70	60	1500
1988	9 Oct	1600-1800	975	6	-4	NNE	2-5	60	50	500
	12 Oct	1800-1930	2100	4	-4	N	0-3	60	80	750
	13 Oct	1450	1750	2	-5	NW	0-5	50	20	1500
Cinder Lagoon										
1987	26 Oct	1600	520	3	2	NW	0-5	55	50	1000
	28 Oct	1300-1700	890	5	0	W	0-3	50	50	1500
	31 Oct	1700-1800	630	5	7	WNW	10-15	50-60	100	150

[a] No direct observations of birds departing Ugashik Bay in 1986 or Cinder Lagoon in 1988.
[b] All time Alaska Daylight Time.
[c] Var.= variable wind direction.

or from the northwest quadrant in speeds greater than 10 km/h (**Table 5**). In 1988, freezing conditions occurred much earlier than in previous years at both areas and departure patterns differed (**Figure 2**). Only a few geese departed from each area when the lakes began to freeze in early October. New birds continued to arrive and most remained on the staging areas until 16 October even though lakes and most substrates were frozen and local winds, ceilings, and visibilities were similar to conditions recorded during migration in previous years.

Most (74%) of the flocks observed departing during daylight headed in an easterly or southeasterly direction towards a pass through the Alaska Range connecting the upper Dog Salmon River and Wide Bay (**Figure 5**). At Ugashik Bay, a few small flocks departed to the northeast where, because of low ceilings, they were unlikely to have crossed the Alaska Range until near Lake Becharof. At Cinder Lagoon, a few flocks departed to the northeast towards Ugashik Bay.

Migration and weather systems

In all years, the major departures of geese occurred in conjunction with weather systems favourable for migration across the northeast Pacific Ocean to the wintering grounds (**Figure 6**). In 1985, about 4,000 geese departed from Ugashik Bay on 16 October (**Table 5**). This departure occurred just ahead of the passage of a low-pressure trough over the Alaska Peninsula and an associated low pressure system centred in the north Gulf of Alaska. Geese flying across the Pacific Ocean would have encountered westerly tailwinds of 45-55 km/h over the next 48-72 h along most of their migration to the wintering grounds (**Figure 6a**).

The night and early morning departure of over 35,000 geese on 21-22 October 1986 (**Table 2**) also coincided with the passage of a low pressure system south of the Alaska Peninsula and into the Gulf of Alaska (**Figure 6b**). If geese had flown south of its centre, they would have been aided by tailwinds of 40-60 km/h on their passage to the wintering grounds.

In 1987, the largest departure of geese occurred between 26 and 27 October. Rather than leaving with strong tailwinds, geese that departed around 0900 h on 27 October encountered variable and light winds associated with a low pressure system centred well east of the Alaska Peninsula (**Figure 6c**). By 0900 h on 28 October (**Figure 6d**) this system had moved north and a second, deeper low pressure system had moved rapidly into the southern Gulf of Alaska. Birds migrating across the Pacific Ocean would have been just east of the centre of the low pressure system at this time, and would have encountered strong (30-60 km/h) southwesterly winds.

In 1988, geese departed over a 5-7 day period associated with weather systems similar to those recorded in 1985 and 1986. On 9 October, geese departed from Ugashik Bay while a low pressure system was centred in the Gulf of Alaska. Winds across the northeastern Pacific were 30-55 km/h from the north and northwest (**Figure 6e**), but changed to westerly at 20-30 km/h over the next 48 h as the system tracked northeast. On 12-13 October, about 4000 birds left Ugashik Bay (**Table 5**) in association with 30-45 km/h tailwinds (**Figure 6f**). During the next 48 h, this system remained stationary as high pressure built off the coast of California and Oregon; this resulted in westerly and southwesterly winds at 20-35 km/h.

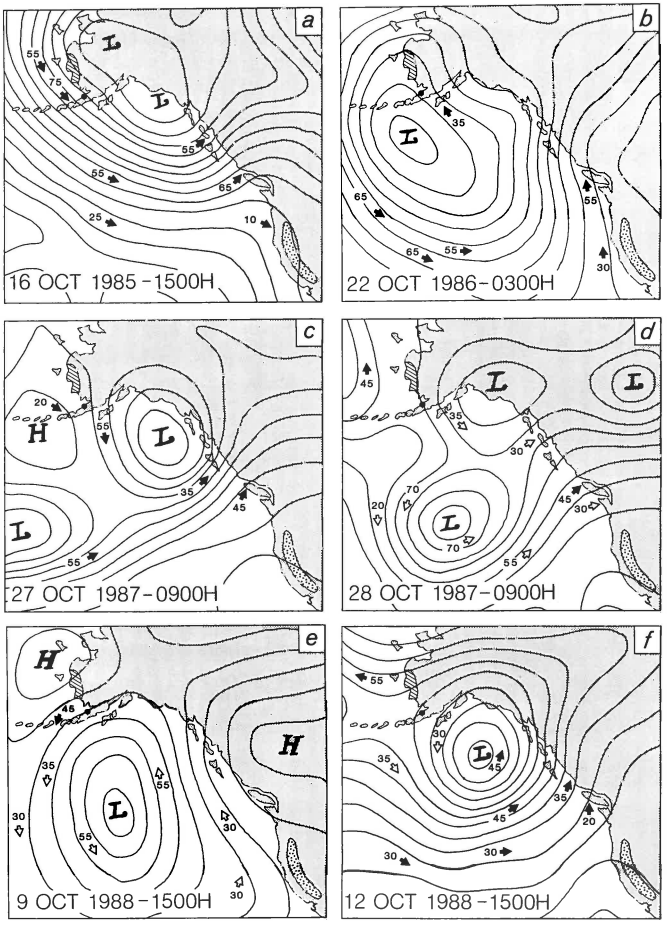

Figure 6. Selected weather charts showing conditions during which Cackling Canada Geese migrated from the Alaska staging grounds. Circulation patterns based on 850 mb (= 1500 m altitude above sea level) constant pressure. Arrows show direction and velocity (km/h) of measured winds (open = at surface; dark = at 850 mb). H and L indicate the centre of high and low pressure systems, respectively.

Table 6. Relationship between known periods of departure of Cackling Canada Geese from autumn staging grounds and arrival of the population on the wintering grounds in California, 1985-1988.

Event	Year			
	1985	1986	1987	1988
Departure from staging areas[a]	16-17 Oct	21-22 Oct	27-31 Oct	9-13 Oct
Arrival on wintering grounds[b]				
First arrival	mid-Oct	16 Oct	22 Oct	10 Oct
First major arrival	22 Oct	27 Oct	1 Nov	18 Oct
Peak numbers	31 Oct	3 Nov	4 Nov	22 Oct
Known transit period of marked geese[c]	15-18 Oct	15-18 Oct	31 Oct-1 Nov	15-16 Oct

[a] Dates when geese were first observed departing from staging areas.
[b] Date of arrival in the Klamath Basin [from D. Raveling, 1985-1987; J. Weldon and J. Hainline (pers. comm.) for 1988].
[c] The dates each year between which 2-4 individually neck-banded geese were last seen on the staging grounds and first seen on wintering grounds.

Arrival on the wintering grounds

The first geese arrived in the Klamath Basin around the middle of October each year, sometimes preceding our first observed departures from the staging grounds (**Table 6**). The major arrival of geese on the wintering grounds consistently occurred 3-6 days after major departures from the staging grounds each year. Observers recorded peak populations on the wintering grounds 4-9 days after the first major arrival of geese. The maximum transit time for 11 neck-banded geese was between two and three days.

Discussion

Between-year use of staging areas

During 1985 and 1986, the two staging areas we studied on the Alaska Peninsula supported most of the population of Cackling Canada Geese. In some years the entire population uses the staging grounds simultaneously, while in others use is staggered, or portions of the population bypass the staging grounds entirely. Some Cackling Canada Geese also sometimes stage at Port Heiden estuary immediately southwest of Cinder Lagoon (**Figure 5**). However, no more than a few thousand geese have ever been recorded at this site during aerial surveys (R. Gill & R. Butler, unpubl. data) or ground observations (T. Pogson, unpubl. data). We are aware of no historical data that indicate that any other sites in Alaska have ever been used as staging areas by Cackling Canada Geese.

Several factors may contribute to the between-year variability that we recorded in seasonal timing, duration, and intensity of use of autumn staging areas. Observed patterns of use depend on the numbers of geese that come to staging areas, their arrival times, and their departure times. These parameters all vary between years and appear to be influenced by conditions on both breeding and staging grounds. In 1985, 1986 and 1988, peak arrival of geese on the staging areas coincided with the onset of freezing conditions on the breeding grounds in early or middle October. In 1987, however, when numbers did not peak on the staging grounds until late October, milder conditions may have induced geese to remain longer on the breeding grounds. The mean daily temperature during October 1987 on the Yukon-Kuskokwim Delta breeding grounds was 2.6°C above the 30-year average (National Oceanic and Atmospheric Administration 1980-1988). In addition, crowberries *Empetrum nigrum*, which are a preferred autumn food of Cackling Canada Geese (C. Ely, unpubl. data; Nelson & Hansen 1959; C. P. Dau *in* Sedinger & Bollinger 1987), were unusually abundant that autumn on the breeding grounds and geese remained there until late October (C. Ely, unpubl. data).

Similarly, no major departures of geese from staging areas were recorded until ponds and vegetated intertidal substrates began to freeze, despite the variability in

timing of freezing from early to late October in any given year. Although some Cackling Canada Geese were recorded on wintering grounds before flocks were observed departing from the staging grounds, no major arrivals were ever recorded on wintering grounds before mass emigrations were observed from the Alaska Peninsula. Thus, the low numbers of geese observed at Ugashik Bay and Cinder Lagoon in some years, such as 1987 and 1988, are likely to be more a function of fewer geese coming to the staging areas than of high turnover rates there.

We contend that during some years many birds overfly, or stop only briefly at, Ugashik Bay and Cinder Lagoon and continue directly to the wintering grounds; *contra* Sedinger & Bollinger (1987), who believed that Cackling Canada Geese could not complete their autumn migration without benefit of nutrients acquired on the staging grounds. Our contention is supported by the 1987 observation of geese remaining on the breeding grounds into late October (C. Ely, pers. comm.); the low numbers recorded on the staging areas compared to totals recorded during the co-ordinated autumn survey on the wintering grounds; direct observations of several flocks of geese overflying Cinder Lagoon; and the compressed, late arrival on the wintering grounds in early November that year.

We suspect that some geese also bypassed the staging areas in 1988, although conditions there and on the breeding grounds that year were markedly different than in 1987. In 1988, mean daily temperatures on the Yukon-Kuskokwim Delta during October were 1.4°C below the long-term average (NOAA 1980-1988). On 5 and 10 October, all ponds and marshes froze at Ugashik Bay and Cinder Lagoon, respectively, and remained frozen. The numbers of staging geese increased with the onset of these early freezing conditions and continued to build for 5-10 days. Although the peak numbers never exceeded 10,000 birds at either staging area, no major arrivals on the wintering grounds were recorded during this period to suggest that geese were arriving on the staging areas as others were departing. Peak numbers on the wintering grounds, however, were recorded earlier in 1988 than in any other year of study, suggesting that the onset of freezing conditions on breeding areas and staging areas is an important factor in determining the seasonal timing of autumn migration for most of the population.

The prolonged use of staging areas by 23% of the estimated autumn population of geese during freezing conditions in 1988 suggested that they had yet to acquire sufficient energy reserves to complete their migration. During this period, geese fed almost exclusively on Creeping Alkaligrass and Four-leaf Marestail on unfrozen intertidal areas, but some foraged in freshwater areas for brief periods in mid-afternoon when vegetation thawed. Use of these staging areas may be critical for at least portions of the population during years in which cold weather limits the availability of forage in western Alaska.

Migration routes and behaviour

A direct overwater autumn migration route by Cackling Canada Geese was first proposed by Nelson & Hansen (1959) on the basis of banding data. More recently, Sedinger & Bollinger (1987) compared weights of geese from Ugashik Bay and weights of geese newly arrived on wintering grounds. They concluded that the average difference in weight closely matched the estimated amount of lipids required to complete a direct overwater flight requiring about 72 h.

Our study corroborates a direct overwater autumn migration route and suggests that migration has evolved in association with predictable weather patterns and is generally aided by winds. We found that most Cackling Canada Geese time their departure from the Alaska Peninsula with the passage of major weather systems, which occur regularly about every five days during October (Brower *et al.* 1988). As these systems move, moderate to strong westerly winds prevail across most of the Gulf of Alaska and the northeastern Pacific

Ocean. If Cackling Canada Geese migrate at about 58 km/h, which is the estimated speed of minimum cost of transport (Sedinger & Bollinger 1987), they would require about 48 h to travel the 2,800 km between staging and wintering areas.

We believe such a ground speed is easily achieved and likely exceeded (cf. Wege & Raveling 1983, Dau 1992) with the aid of tail winds. Winds associated with migration were generally 25-45 km/h at the surface and often double that at about 1,500 m altitude (= 850 mb). It is not uncommon for migratory birds, including some species of geese, to seek altitudes with the most favorable wind direction and velocity (Richardson 1978; 1990; Williams 1985; Kerlinger & Moore 1989; Piersma & Jukema 1990). Indeed, Pacific Brant *Branta bernicla* migrating across the Gulf of Alaska each autumn from the Alaska Peninsula fly at an average altitude of 1,150 m (Dau 1992). An approximately 48 h passage is further supported by observations of 11 neck-banded geese seen on the wintering grounds 48-72 h after they were last seen on the staging grounds.

Our observations indicate that in some years geese encounter unfavourable weather conditions en route that alter their flight path and timing of arrival on the wintering grounds. In 1987, arrival of geese on the wintering grounds was protracted, and many birds were seen at nontraditional sites in southern British Columbia, Washington, and Oregon (J. Bartonek, pers. comm.). The northward shift in arrival that year coincided with the rapid movement of a low pressure system into the Gulf of Alaska from the south while birds were en route to the wintering grounds. This storm likely forced birds ashore north of California. How frequently such events occur is unknown, and their effect on mortality is unclear. A substantial portion of first year mortality among Barnacle Geese *Branta leucopsis* occurs during their 3000-km overwater migration each autumn (Owen & Black 1989). On one occasion unfavourable weather over the Norwegian Sea during migration was attributed as a cause of a prolonged migration period and the scattering of flocks to nontraditional places (Owen & Black 1989).

The behaviour of Cackling Canada Geese arriving on and departing from the staging areas in daylight hours suggested that they used visual landmarks. Most birds arriving at Cinder Lagoon first flew to the mouth of Hook Lagoon or passed near it before dispersing to different sites within the estuary complex. Even flocks that first made landfall north of Hook Lagoon flew an additional 6-9 km south to the mouth of the lagoon before dispersing inland instead of flying directly inland to their final destinations. Birds may have keyed on a prominent hill (60 m tall) just south of Hook Lagoon, the only such landmark along the immediate coast. Wege & Raveling (1983) presented evidence that migrating Canada Geese *B. c. maxima* used local landmarks to determine the final approach to their destination.

The departure route used by geese during migration from the Alaska Peninsula provides the only passage through the central Alaska Range that is below 175 m in elevation. On days when low clouds covered the Bering Sea side of the Alaska Peninsula, the sky on the Gulf of Alaska side was often partly cloudy or mostly sunny. When such conditions existed, a prominent patch of bright blue sky provided a strong visual cue about weather conditions and a route of departure from Ugashik Bay and Cinder Lagoon through the Wide Bay pass.

Fidelity to sites

The low rates of interchange of neck-banded geese between two parts of Cinder Lagoon in 1987 suggests strong fidelity on staging grounds, even to sub-areas. Some temporary displacement or migration of birds may have been caused by disturbance, primarily from Bald Eagles and aircraft (Gill & Kincheloe 1993). Raveling (1969) found that Mississippi Flyway Canada Geese *B. c. interior* consistently used the same areas for roosting and feeding and that disturbance was a key factor influencing their use of new areas. Pacific Brant *B. bernicla* staging

in autumn at Izembek Lagoon, Alaska, that had bred in different regions, remained segregated throughout the lagoon (Reed *et al.* 1989).

Between-year fidelity to staging areas among all age and sex classes of geese was high (72%), and comparable to the 78% between-year fidelity seen by Raveling (1979) in wintering Giant Canada Geese *B. c. maxima* and the 56-89% wintering fidelity recorded for Atlantic flyway populations (Hestbeck *et al.* 1991). The high between-year fidelity to staging areas exhibited by yearling females contrasted markedly with the apparently random dispersal of yearling males between the two staging areas. This difference may be a consequence of female-biased philopatry, a pattern which has been documented among other populations of geese (Cooke *et al.* 1975; Greenwood 1980; Lessells 1985; Rohwer & Anderson 1988). The patterns of between-year fidelity to staging areas that we observed among yearling and adult geese suggests that (1) choice of staging area by yearling females may be strongly related to the parental staging area; (2) choice of staging area by yearling males may be less influenced by parental choice; and (3) use of staging areas in subsequent years by paired adults may continue to be strongly traditional but subject to change with change of mates. Additional studies of natal and breeding dispersal rates, timing of pair formation, and timing of family group disintegration would aid in understanding the use of the staging areas by different age and sex classes.

The prolonged arrival of single and paired Cackling Canada Geese on the staging grounds compared with those in family groups differed somewhat from patterns that have been reported for other species of geese in autumn. In Pacific Brant, non-or failed-breeders apparently arrive before family groups (Jones 1964; C. P. Dau, pers. comm.). In Lesser Snow Geese *Anser c. caerulescens*, yearlings precede family groups to the staging grounds and, along with failed-breeding adults, remain after family groups have departed (Lumsden 1975). In Greater Snow Geese *A. c. atlanticus* there is considerable annual variation in the temporal distribution of families and non-breeders (H. Boyd & A. Reed *in* Gauvin & Reed 1987:7). Reported variation in timing of migration among yearling Giant Canada Geese (Raveling 1976) implies a tendency for earlier migration of non-family members to wintering areas. Our results should be taken cautiously until more is understood about the between-year variability in use of brood-rearing and moulting areas by Cackling Canada Geese on the Yukon-Kuskokwim Delta.

Management implications

The Alaska Department of Fish and Game (1983) has designated major portions of both Ugashik Bay (50 km^2) and Cinder Lagoon (93 km^2) as State Critical Habitat Areas (SCHA) largely to protect Cackling Canada Geese (**Figure 3,4**). About 75% of all areas used by geese during our study were outside the boundaries of these SCHAs. In terms of numbers of birds, only about a third of the geese recorded at Ugashik Bay and Cinder Lagoon occurred on these protected areas. Furthermore, about 75% of the Ugashik Bay SCHA and half of the Cinder Lagoon SCHA were not used by geese at all.

We found no changes in geographic patterns of use of the two staging areas between 1985 and 1988 although the population of geese more than doubled during this period (autumn population index increased from 32,000 to 70,000, J. Bartonek, unpubl. data). Cackling Canada Geese, particularly females, were highly faithful to particular staging areas both within and among years. It is important that areas traditionally used by geese within these two estuaries be protected adequately during this critical premigratory staging period. Clearly, we need to examine and adjust the boundaries of the State Critical Habitat Areas, particularly if the population continues to increase.

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