NEST-SITE SELECTION BY EMPEROR GEESE AND CACKLING CANADA GEESE

MARGARET R. PETERSEN[1]

ABSTRACT.—Differences were found in habitat structure between nest sites of Emperor Geese (*Chen canagicus*) and Cackling Canada Geese (*Branta canadensis minima*) during a 5-year study (1982–1986) at Kokechik Bay, Alaska. Emperor Geese tended to select sites that afforded concealment from avian predators before incubation began. Cackling Canada Geese tended to select sites that enhanced avoidance of mammalian predators. Emperor Geese selected sites in areas away from open water, with tall dead vegetation adjacent to the nest site. Cackling Canada Geese selected sites close to shores of smaller ponds having more islands, and sometimes nested on islands, evidently enhancing avoidance of mammalian predators. During springs with heavy snow cover (>50% of surface covered on 25 May), both species selected sites appreciably different from sites selected during springs with light snow cover (<25% on 18 May). During heavy snow years, both species selected sites with more short, dead vegetation. Emperor Geese differed from Cackling Canada Geese by selecting sites with more shrubs and were farther from ponds. Cackling Canada Geese tended to nest closer together than Emperor Geese. Differences in structural habitat characteristics at nest sites of Cackling Canada Geese were not related to nesting success, but successful Emperor Geese selected nest sites with more and taller dead vegetation than unsuccessful pairs. Although it was possible to identify "typical" nest sites of Emperor Geese and Cackling Canada Geese, many sites were used by both species. Factors such as the amount and duration of snow cover, drainage patterns, presence or absence of islands, and type and abundance of egg predators play important roles in influencing nest-site selection and ultimately the distribution and abundance of Emperor Geese and Cackling Canada Geese. *Received 18 July 1989, accepted 15 Nov. 1989.*

Emperor Geese (*Chen canagicus*) and Cackling Canada Geese (*Branta canadensis minima*) nest primarily along the coastal fringe of the Yukon-Kuskokwim (Y-K) Delta, Alaska (Bellrose 1976). Geese nesting on the Y-K Delta received increased attention as their populations declined (O'Neill 1979, Petersen and Gill 1982, Raveling 1984, King and Derksen 1986, Pamplin 1986). The general nesting habitat and nest-site characteristics for these two species were described by Mickelson (1975) and Eisenhauer and Kirkpatrick (1977), but there have been no quantitative studies of nest sites of either species. Waterfowl nesting success of upland species may (e.g., Schranck 1972, Livezey 1981, Jackson et al. 1988) or may not (e.g., Glover 1956, Keith 1961, Dwernychuk and Boag 1972) be correlated with vegetative cover at nest sites, but the effect of cover at Emperor Goose and Cackling Canada Goose nests was unknown. My

[1] U.S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center, 1011 East Tudor Road, Anchorage, Alaska 99503.

objectives were to: (1) evaluate structural features of nest sites of geese and to contrast those with features of sites not selected for nests, (2) evaluate the effect of snow conditions and the timing of nest initiation on structural features of nest sites, and (3) evaluate the relationship between features of nest sites and nesting success. These data are necessary to gain a more complete understanding of the influence of habitat and spring phenology on nesting distribution and success of nests of Emperor Geese and Cackling Canada Geese.

METHODS

Study area. —The 190-ha study area was at Kokechik Bay, 19 km NE of Hooper Bay, Alaska (63°39′N, 165°51′W). The flora, fauna, and physical features of the study area were described by Holmes and Black (1973), Eisenhauer and Kirkpatrick (1977), and Jackson (1981). The study area contains lowland, intermediate, and upland tundra similar to that described by Ely and Raveling (1984). Lowland tundra was less than 0.5 m above mean high tide and dominated by grasses and sedges; upland tundra was generally higher in elevation (to 1.5 m), and characterized by prostrate willows (*Salix* sp.), dwarf birch (*Betula nana*), and Labrador tea (*Ledum palustre*), and contained pingos similar to those described by Burns (1964); intermediate tundra contained plants characteristic of both upland and lowland tundra.

Data collection. —Measurements were obtained at each Emperor Goose and Cackling Canada Goose nest site and at a randomly determined site within 15 m of each nest immediately after the hatching period in early- to mid-July. Random sites were selected along a 30-m line running north and south through each nest site. The exact location was selected by using a random number table which included numbers 1 through 30. Random sites located in ponds or in standing water (marsh) were excluded, and new sites were randomly determined. Measurements of vegetation within a 1-m radius surrounding a nest or random site included (1) height of the tallest dead vegetation (±1.0 cm), (2) cover provided by dead vegetation surrounding the nest with a "Jones board" (Jones 1968) (i.e., vegetation present when the nest was initiated), and (3) proportions to the nearest 20% of tall vegetation (>0.5 m), short vegetation (<0.5 m), and shrubs. A score of 48 with the Jones board indicated no cover and 0 indicated complete cover. The proportions of tall and short vegetation and shrubs were estimated visually.

Measurements of physical features recorded for nests and random sites were: (1) distance (±0.1 m) to open water, (2) distance (±0.1 m) to marsh (standing water), (3) size (±1 ha) of the nearest pond, (4) number of islands in the nearest pond, (5) height (±1 cm) of the site above the water level of the nearest pond, (6) distance (±1 m) to the nearest nest of a conspecific, (7) distance (±1 m) to the nearest nest of the same species, and (8) when a site was on a pingo, the height (±1 cm) of the site below the top of the pingo. Distances greater than 50 m between goose nests and the sizes of ponds were measured from aerial photographs (1:5280 scale). The height of sites above normal pond water levels and below the tops of pingos were measured using a line level.

Nests were considered successful if one or more eggs hatched. Evidence of hatch included vocal or pipped eggs, goslings in the nest, or the presence of shell membranes from hatched eggs. Eleven Emperor Goose nests were excluded from the analysis of the characteristics of hatched and unsuccessful nests because I influenced their fates as part of another study.

Snow conditions. —Snow cover (%) on the study area in 1983–1986 was visually estimated from a four-m tall tower from the birds arrival to peak of nest initiation. In addition, oblique

photographs were taken each year from that same location on alternate days. Photographs taken in 1982 were matched to those dates in 1983–1986 with similar-appearing conditions and to the corresponding percentage of snow cover used for comparison between 1982 and other years.

Statistical analysis.—I used programs from SPSS^x (1986) to perform all statistical tests and to determine descriptive statistics. Most variables from random sites and nest sites had severely skewed distributions, and transformations to normalize the data (Sokal and Rohlf 1981) were ineffective. Because distributions of data within a variable were not always similar, I used Kolmogorov-Smirnov two-sample tests (Siegel 1956) to compare nest sites and random sites within species, nest sites between species, successful and unsuccessful nest sites within species, and nest sites used in heavy and light snow conditions between species. When appropriate, similar tests were used to compare random sites near Emperor Goose and Cackling Canada Goose nest sites. No significant differences were found ($P > 0.05$), thus all random sites were used when comparing random sites to nest sites. I used χ^2-tests (Sokal and Rohlf 1981) to evaluate the re-use of nest sites.

RESULTS

Comparison of nest sites and random sites.—Emperor Goose nest sites differed from random sites in one vegetative and four of six physical features (Table 1, Fig. 1). Emperor Goose nest sites had significantly larger amounts of shrubs near them than random sites ($Z = 4.8$, $P < 0.001$), were farther from open water ($Z = 1.85$, $P < 0.01$), were near ponds with fewer islands ($Z = 1.97$, $P < 0.001$), were higher above pond water levels ($Z = 4.8$, $P < 0.001$), and were positioned lower along the sides of pingos ($Z = 1.41$, $P < 0.05$). In contrast, nest sites of Cackling Canada Geese differed from random sites in three of five vegetative features (Table 1, Fig. 1); nest sites had shorter dead vegetation ($Z = 1.39$, $P < 0.05$), more short vegetation ($Z = 2.04$, $P < 0.001$), and less shrub ($Z = 1.71$, $P < 0.01$) than did random sites. Physical features were significantly different at random sites than at Cackling Canada Goose nest sites; nest sites were higher relative to pond water levels ($Z = 2.92$, $P < 0.001$), closer to open water ($Z = 4.50$, $P < 0.001$), farther from marsh areas ($Z = 2.22$, $P < 0.001$), closer to ponds with more islands ($Z = 3.15$, $P < 0.001$), and tended to be at smaller ponds ($Z = 1.70$, $P < 0.01$).

Interspecific differences in nest sites.—Nest sites selected by Emperor Geese and Cackling Canada Geese differed in three of five vegetative and five of six physical features (Table 1, Fig. 1). Emperor Geese selected nest sites that had taller dead vegetation ($Z = 1.68$, $P < 0.01$), less short vegetation ($Z = 2.34$, $P < 0.001$), and more shrub ($Z = 3.15$, $P < 0.001$). They were also farther from water ($Z = 2.86$, $P < 0.01$), closer to marsh areas ($Z = 2.43$, $P < 0.001$), near larger ponds ($Z = 2.37$, $P < 0.001$), near ponds with fewer islands ($Z = 4.5$, $P < 0.001$), and higher relative to pond water levels ($Z = 2.38$, $P < 0.001$) than nest sites selected by Cackling Canada Geese.
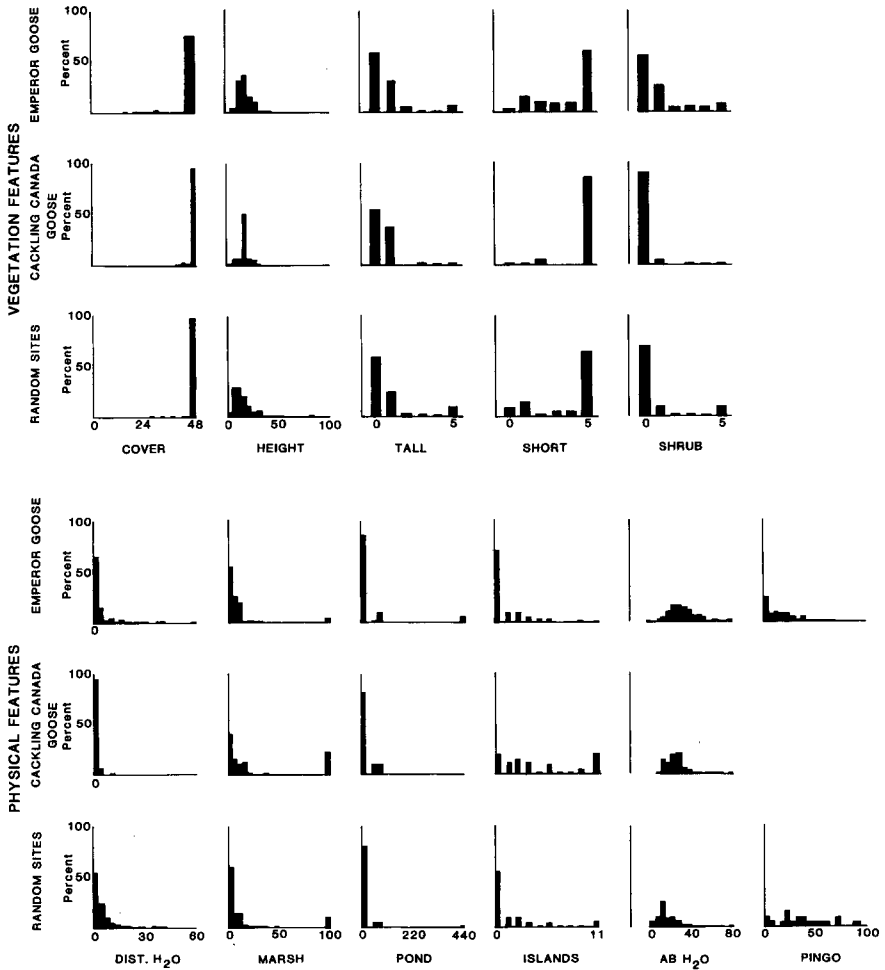
FIG. 1.   Features of nest sites and random sites. Cover = cover score; height = height of dead vegetation (cm); tall = tall vegetation score; short = short vegetation score; shrub = ` shrub score; dist. H_2O = distance to open water (m); marsh = distance to marsh (m); pond = size of pond (ha); islands = number of islands in nearest pond; ab H_2O = height of site above pond water levels (cm); pingo = height of site below pingo top (cm).

Influence of snow conditions on nest-site selection.—Snow conditions on the study area varied among years and influenced timing of nest initiation (Fig. 2). Conditions in 1982, 1985, and 1986 were similar, with snow cover >75% on 18 May and still exceeding 50% on 25 May (heavy snow years). Snow conditions were similar in 1983 and 1984, with snow

TABLE 1
SIMILARITIES AND DIFFERENCES OF VARIABLE MEASUREMENTS BETWEEN RANDOM SITES AND NEST SITES

	Random sites	Emperor Goose nest sites	Cackling Canada Goose nest sites
Number of sites	300	197	117
Vegetative features			
Cover score	47.8 ± 0.10[a]	46.4 ± 0.37	47.8 ± 0.10
	(28–48)	(16–48)	(38–48)
Height of dead vegetation (cm)[b,c]	11.3 ± 0.52	11.4 ± 0.51	9.7 ± 0.63
	(0–80)	(0–45)	(0–50)
Tall vegetation score (0–5)	0.9 ± 0.09	0.8 ± 0.09	0.7 ± 0.10
	(0–5)	(0–5)	(0–5)
Short vegetation score (0–5)[a,b]	3.8 ± 0.11	3.8 ± 0.12	4.5 ± 0.12
	(0–5)	(0–5)	(0–5)
Shrub score (0–5)[b,c,d]	0.8 ± 0.09	1.1 ± 0.11	0.2 ± 0.08
	(0–5)	(0–5)	(0–5)
Physical features			
Distance to open water (m)[b,c]	4.67 ± 0.377	4.70 ± 0.580	1.29 ± 0.188
	(0.1–42.6)	(0.2–57.0)	(0.2–13.6)
Distance to marsh (m)[b,c]	11.85 ± 1.263	8.68 ± 1.098	21.06 ± 2.628
	(0.1–100)	(0.5–100)	(0.4–100)
Size of pond (ha)[b,c]	31.6 ± 4.97	39.8 ± 7.69	19.9 ± 2.49
	(1–438)	(1–438)	(1–87)
Number of islands in nearest pond[b,c,d]	1.8 ± 0.17	0.7 ± 0.11	4.1 ± 0.38
	(0–11)	(0–11)	(0–11)
Height of site above pond water levels (cm)[b,c,d]	19.4 ± 0.93	32.1 ± 1.13	25.5 ± 1.21
	(−18–156)	(−4–86)	(8–90)
Height of site below pingo top (cm)[c,e]	34.5 ± 4.84	19.8 ± 3.23	9.0 ± 5.5
	(0–86)	(0–63)	(3–20)
Distance to nearest goose nest (m)		88.0 ± 4.04	94.0 + 6.61
		(13–317)	(9–529)
Distance to nearest goose nest of same species (m)		105.9 ± 5.00	123.8 ± 8.98
		(13–469)	(9–642)

[a] All values are means ± one standard error; the range is in parentheses.
[b] Cackling Canada Goose nest sites significantly different from random.
[c] Emperor Goose nest sites significantly different from Cackling Canada Goose nest sites.
[d] Emperor Goose nest sites significantly different from random.
[e] Data from 24 random, 31 Emperor Goose nest, and 3 Cackling Canada Goose nest sites.

cover not exceeding 25% in May (light snow years) from the time of arrival of the geese through nest initiation. In heavy snow years, Emperor Geese selected nest sites that had shorter dead vegetation ($Z = 3.9$, $P < 0.001$), more shrubs ($Z = 2.56$, $P < 0.001$), and were farther from ponds

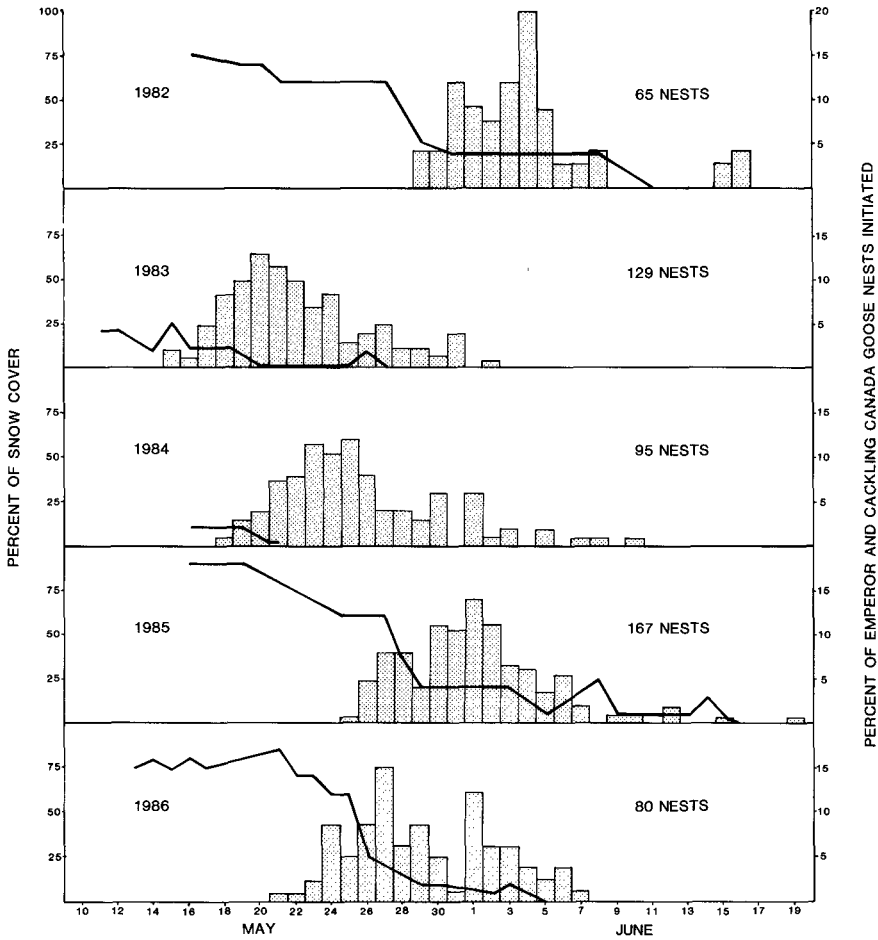FIG. 2. Amount of snow cover (solid line) and proportions of nests (bars) initiated in each year from mid-May to early-June.

($Z = 1.94$, $P < 0.001$) than in light snow years (Fig. 3A). Nest sites selected by Cackling Canada Geese in heavy snow years had shorter dead vegetation ($Z = 2.16$, $P < 0.001$) and were closer to other Cackling Canada Goose nest sites ($Z = 1.37$, $P < 0.05$) than in light snow years (Fig. 3A).

Emperor Geese did not re-use nest sites, whereas Cackling Canada Geese frequently re-used nest sites. Re-use of nest sites by Cackling Canada Geese appeared to be related to snow conditions; re-use of old nest sites was more frequent (42.9% of 156) in years with heavy snow con-
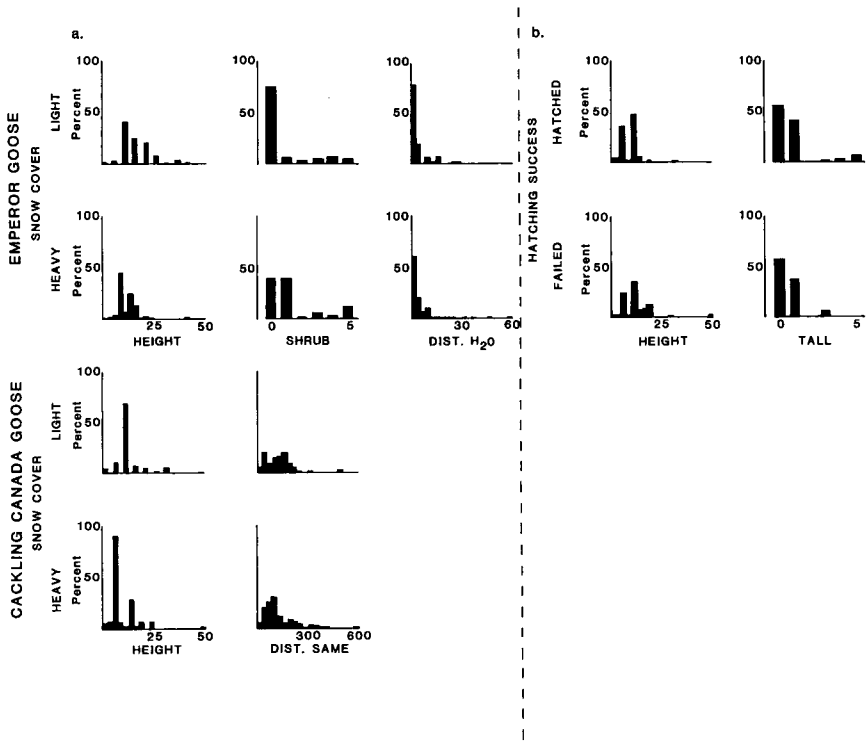
FIG. 3. Proportions of each value for each variable significantly different ($P < 0.05$) at nests (A) during heavy and light snow conditions and (B) at successful and unsuccessful nest sites. Captions on graphs the same as Fig. 1 except dist. same = distance to nearest goose nest of the same species (m).

ditions than in years (19.4% of 98) with light snow conditions ($\chi^2 = 15.0$, df $= 1, P < 0.005$).

Nest-site selection and time of nest initiation. — In springs with heavy snow cover, the earliest-nesting Emperor Geese selected more elevated nest sites relative to pond water levels (Fig. 4). As the season progressed and other sites became available (through the thawing and drying of those sites), Emperor Geese selected lower nest sites. This trend was suggested but not significant in years with light snow cover. Cackling Canada Geese selected sites that were higher above pond water levels early in the season and selected lower sites later in the spring in both heavy and light snow seasons (Fig. 4).

Characteristics of successful and unsuccessful nest sites. — Successful nest sites of Emperor Goose differed significantly from unsuccessful nest sites
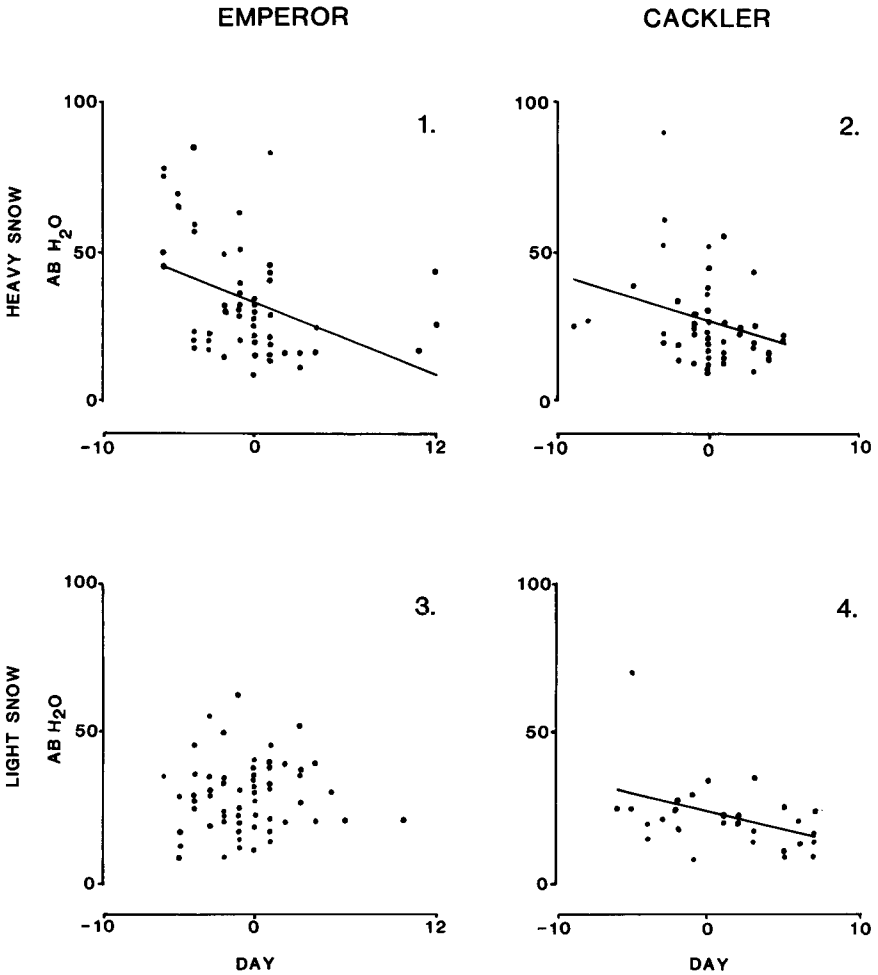
EMPEROR   CACKLER

FIG. 4.   Relation between date of nest initiation for Emperor Geese and Cackling Canada Geese and height of the nest above pond water levels in years with heavy and light snow cover. 0 represents the model initiation date. Statistics are as follows: 1. $N = 58$, $r = -0.369$, $P < 0.005$; 2. $N = 51$, $r = -0.280$, $P < 0.055$; 3. $N = 63$, $r = 0.060$, $P > 0.10$; 4. $N = 31$, $r = -0.391$, $P < 0.01$.

by the height of the dead vegetation ($Z = 1.40$, $P < 0.05$) and by having more tall vegetation ($Z = 1.58$, $P < 0.05$) (Fig. 3B). Successful and unsuccessful nests of Cackling Canada Geese had similar vegetative and physical features.

DISCUSSION

Habitat features. —Nest sites used by either Emperor Geese or Cackling Canada Geese were not distinguishable by vegetative cover when compared to random sites. Sites available to geese in the general area rarely contained sufficient tall, dense grasses, sedges, or shrubs to provide complete cover to conceal such a large bird (Fig. 5 above). Emperor Geese selected sites with more shrubs than did Cackling Canada Geese or that were found at random sites, but shrubs rarely provided concealment of the nest. Shrubs were generally the understory to grasses and sedges (Fig. 5 below) and only along the sides of some pingos in upland habitat were shrubs tall enough to provide cover to nests. These sites were infrequently used; only 17% of Emperor Goose nests and 3% of Cackling Canada Goose nests were located on pingo sides. Cackling Canada Geese tended to select sites with more shorter, dead vegetation than random sites, although much of the vegetation was too short to provide concealment from mammalian or avian predators. This observation is consistent with studies of larger subspecies of nesting Canada Geese that suggest that geese select nest sites with less vegetation, enhancing visibility by geese (e.g., Sherwood 1968, Kaminski and Prince 1977), and with Mickelson (1975) who suggested that Cackling Canada Geese avoid areas with tall, dead grass which reduces visibility. Emperor Geese did not use sites with significantly taller, dead vegetation than available at random sites. This is in contrast to Mickelson's (1975) conclusions that Emperor Geese use sites with tall vegetation. It seems that both Emperor Geese and Cackling Canada Geese select nest sites which are not concealed and that have good visibility.

The physical feature that appears to be the most influential in nest site selection for both species and in the timing of nest initiation is the height of the nest site above pond water levels. The data presented here supports the suggestions of Eisenhauer and Kirkpatrick (1977), Mickelson (1975), and Dau and Mickelson (1979) that nests initiated early are at higher locations than nests initiated later in a season, a pattern that was particularly evident here in springs with heavy snow cover. Accordingly, it seems likely that nest-site selection by Emperor Geese and Cackling Canada Geese is dependent on snow-free, dry locations.

If height of the site alone were a key aspect in nest-site selection, then sites on top of pingos should have been favored. This selection did not occur; geese that did nest on pingos selected the sides rather than the tops of these mounds. A factor limiting the availability of such nest sites could be the depth of soil that is thawed when a female goose investigates a site and attempts to dig a nest scrape. Burns (1964) found that soils with little litter accumulation (grass covered) had thawed more than soils with great-
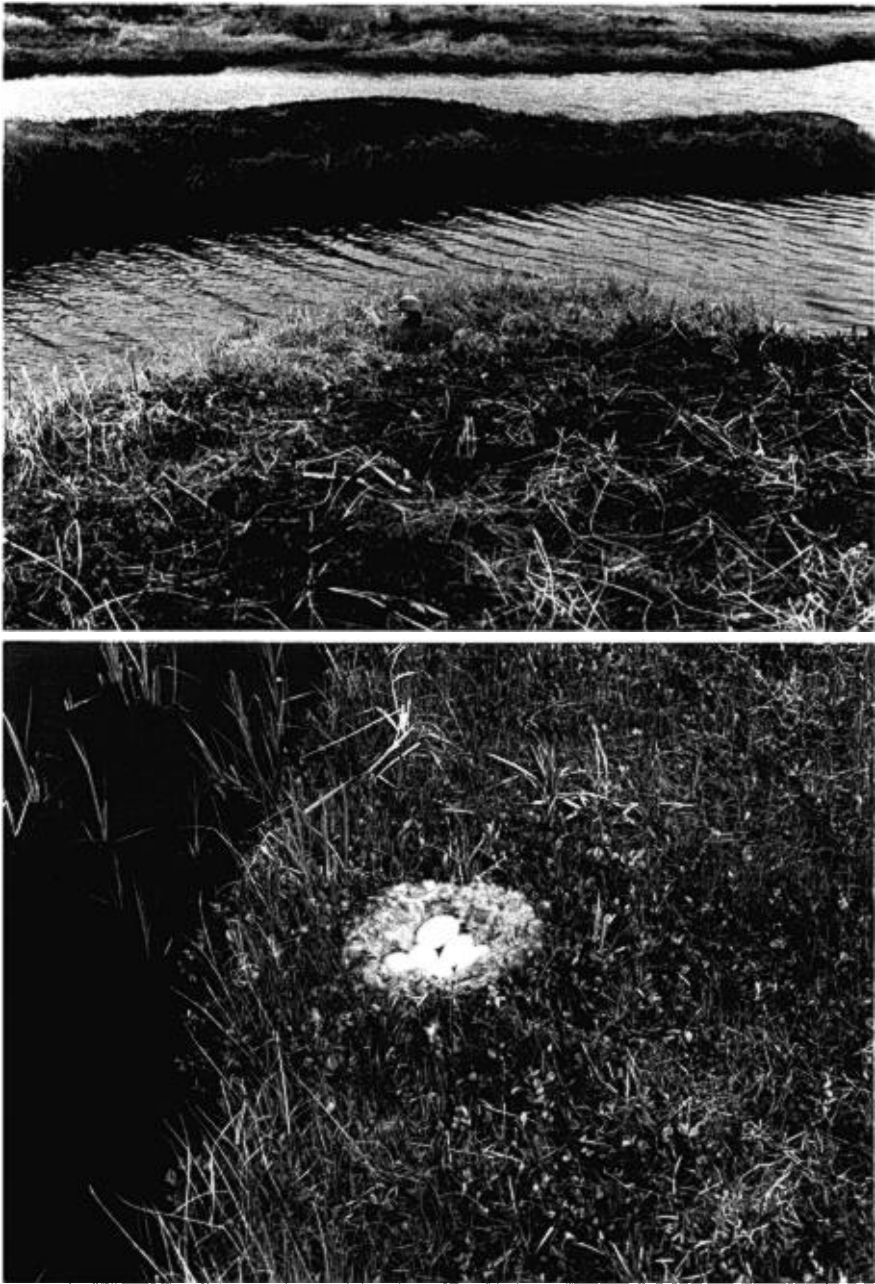
FIG. 5.   Typical nest site of Emperor Geese showing: (above) the lack of abundant tall vegetation for nest concealment and (below) shrubs as an understory to short vegetation.

er litter accumulation (heath atop pingos). Depth of thawed soil (or soil temperature) may possibly be an important factor in nest-site selection, and perhaps the timing of nest initiation, by Emperor Geese and Cackling Canada Geese.

Emperor Geese and Cackling Canada Geese selected substantially different nest sites. This observation is not unexpected, because Cackling Canada Geese are about two-thirds the size of Emperor Geese (Palmer 1976) and have evolved different anti-predator nesting strategies (Mickelson 1975, Thompson and Raveling 1987). However, I was unable to detect differences in features of the nest habitat which reliably separate the two species. Distributions of the values of the various features overlapped, and a few (N = 10) Cackling Canada Geese used nest sites that were used by Emperor Geese in previous years.

Effect of snow cover on nest-site selection. —Although the amount of snow cover had a measurable effect on habitat features of nest sites, the primary differences between years were the greater proportion of nests re-used by Cackling Canada Geese when snow cover was most extensive and differences in timing of nest initiation by both species. Underlying factors may include the availability of suitable nest sites and the proportion of older, more experienced geese that nest in years with heavy snow cover (late years). Sites available to Lesser Snow Geese (*Chen caerulescens caerulescens*) for nesting were restricted in some years because of heavy snow cover (Cooke and Abraham 1980), and during such late seasons a smaller proportion of young Lesser Snow Geese nest (Finney and Cooke 1978). It is also possible that fewer young Cackling Canada Geese may nest in late seasons with heavy snow cover. Individually marked Cackling Canada Geese used the same nest sites in successive years (Mickelson 1975, Petersen, unpubl. data). Thus the higher proportion of re-used nest sites in heavy snow conditions may represent a higher proportion of older, more experienced geese.

Habitat features associated with nesting success. —Successful Emperor Geese appear to select nest sites that provide at least minimal concealment from predators. Emperor Geese successfully defend their nests against arctic foxes (*Alopex lagopus*) (R. M. Anthony, pers. comm., Petersen, unpubl. data), and losses of eggs to foxes in most areas was comparatively low (Mickelson 1975, Eisenhauer and Kirkpatrick 1977). Fox predation on the Kokechik Bay study area in 1982–1986 was higher than that reported by Mickelson (1975) or Eisenhauer and Kirkpatrick (1977), with most of the losses of eggs occurring during three of the five seasons. In those years, foxes tended to remove eggs from all nests within an area. For example, in 1986 only 7 of 58 (12.1%) nests in a 190-ha area had one or more eggs hatch; an adjacent 227-ha area of similar habitat had

56 of 88 (63.6%) nests successful. Evidently, features of the habitat did not influence predation by arctic foxes during those seasons.

Losses to avian predators, primarily Parasitic Jaegers (*Stercorarius parasiticus*) and Glaucous Gulls (*Larus hyperboreus*), are the primary causes of egg mortality of Emperor Geese (Mickelson 1975, Eisenhauer and Kirkpatrick 1977). From the first until the penultimate egg, Emperor Geese are infrequently at the nest (Petersen, unpubl. data) and, when they leave, conceal the eggs and nest with vegetation from the immediate vicinity (Eisenhauer and Kirkpatrick 1977, Krechmar and Kondratiev 1982). During this 5–7-day period prior to incubation nests are susceptible to avian and mammalian predators, and the presence of tall grasses at the nest may provide additional material necessary to conceal the eggs and nest. After the clutch is complete, losses of eggs to avian predators are apparently diminished by almost constant incubation by the geese (Thompson and Raveling 1987). Thus the selection of nest sites with tall, dead grasses may be in response to avian and mammalian predation early in the nesting period.

None of the habitat features I measured was important for identifying successful and unsuccessful Cackling Canada Geese nests. Other studies (Mickelson 1975, Thompson and Raveling 1987, Petersen unpubl. data) showed that Cackling Canada Geese that nest on islands are more successful than those nesting on shorelines or on islands that have been connected to shore, presumably because foxes are reluctant to swim to islands. The physical and vegetative features that I measured were similar for random sites at all locations; the features of each nest site were similar regardless of the location. Apparently, the features immediately surrounding the nest sites of Cackling Canada Geese do not influence their success. The selection of a particular island and the timing of nest initiation within a year is strongly influenced by snow melt and drainage patterns of ponds, whereas the tendency to use islands that are suitable for nest sites is strongly influenced by lower predation rates of nests on islands.

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