ARCTIC GEESE DURING BROOD-REARING ON THE CENTRAL YUKON-KUSKOKWIM DELTA: ANALYSIS OF PATTERNS OF DISTRIBUTION

by

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ABSTRACT

In July 1985 two systematic aerial surveys were flown over the coastal fringe of the central Yukon-Kuskokwim Delta, Alaska, to examine the patterns of distribution of four species of geese during brood-rearing: Pacific black brant (Branta bernicla nigricans), cackling Canada geese (Branta canadensis minima), emperor geese (Chen canagica), and greater white-fronted geese (Anser albifrons). A second major objective was to develop a survey method to provide an annual index to the number of young produced in this major nesting area.

During the two surveys 12,844 geese were counted in 695 flocks. Brant and cackling geese were the most commonly recorded, followed by emperor geese and white-fronted geese. No major temporal changes occurred in geographic distribution. The most heavily used areas during brood-rearing for all four species of geese combined were: the Kokechik River drainage, the lowlands of southern Kokechik Bay, and the coastal area from the Manokinak River south to the northern part of Nelson Island. On a broad geographic basis, the same areas that supported high nesting concentrations in 1985 also supported the highest numbers of geese during brood-rearing. There was a pronounced void of geese along both the Kashunuk River and Aphrewn River drainages that could not be satisfactorily explained by impacts of human harvest or disturbance alone.

Among nine major complexes of habitat that were identified, brant were largely restricted to the most coastal sedge and graminoid meadows throughout the study area. Cackling geese and emperor geese both used a wider array of habitats but concentrated in graminoid meadows and the intermediate tundra complex. Emperor geese were most commonly observed on or adjacent to bays, rivers and sloughs. Most of the white-fronted geese were observed in the intermediate tundra complex, with few recorded coastally or farther inland. This pattern of coastal zonation of species appeared to have changed relatively little from that recorded during the past 60 years.

All four species coalesced into significantly larger flocks between the two surveys. The patterns of flocking appeared to be related to two major factors: the inherent sociality of each species and the nesting success experienced that year. Brant formed the largest flocks, followed by cackling Canada geese, white-fronted geese, and emperor geese. The proportion of flocks that contained young ranged from a low of 23% for white-fronted geese to a high of 81% for emperor geese. During the process of aggregation of flocks between the two surveys, it appeared that some mixing of brood flocks and adult molting flocks occurred.

The survey method used in 1985 was found to be inadequate for gathering data on the production of young because of the difficulty of counting young in large flocks during a single pass along the transect. The line transect method did, however, indicate that three major factors influenced the number of geese observed during the survey: 1) distance of the flock from the flight path; 2) size of the flock; and 3) the tendency of geese to move away from the plane. Survey methods are being designed to address these problems and to collect information on adult:young ratios in 1986.

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C. M. Handel and R. E. Gill, Jr.

The coastal zone of the central Yukon-Kuskokwim Delta is the major breeding area for four species of geese: Pacific black brant (Branta bernicla nigricans), cackling Canada geese (Branta canadensis minima), emperor geese (Chen canagica) and greater white-fronted geese (Anser albifrons). Recently a large research program has been developed to determine the status of these species, whose populations have all suffered dramatic declines (Raveling 1984). Several earlier studies had addressed the ecology of these species in detail during nesting (Eisenhauer and Kirkpatrick 1977, Eisenhauer 1977, Ely and Raveling 1984, Mickelson 1975, Raveling 1978, Raveling 1979) but only a single study had focused on any of these species on the breeding grounds after the young had hatched (Sedinger 1984b, Sedinger and Raveling 1984). Their study was limited to that of cackling Canada geese at one site on the Delta. Almost nothing is known about the distribution of geese on the Delta during the brood-rearing period, how mobile they are, what habitats are important or what factors influence the survival of the adults and their young.

In July 1985 a study was begun to address several of these questions. The primary objectives of the pilot study were to:

1. delineate the current distribution of brant, cackling Canada geese, emperor geese and white-fronted geese during brood-rearing along the coastal zone of the central Yukon-Kuskokwim Delta;
2. analyze the patterns of distribution in relation to (a) habitats, (b) nesting distribution, (c) densities of predators, and (d) proximity to areas of human use;
3. determine whether distributional patterns or use of habitats change during the brood-rearing period;
4. determine if seasonal mortality of young can be measured from aerial surveys;
5. develop a survey method to provide an annual index of the number of young produced; and
6. determine a method to predict what additional areas within this coastal zone will be important for brood-rearing once the populations have recovered.

The primary method employed in this study was an intensive, systematic aerial survey of the coastal zone during the brood-rearing period. Results of this preliminary effort will be analyzed and evaluated for efficiency in meeting these objectives.

METHODS

DATA COLLECTION

A series of 53 east-west transects (Fig. 1) spaced at about 2-km intervals and totalling about 1600 lineal km was flown twice during the brood-rearing period (6-11 July and 25-28 July). One-third of these transects were replicates of those flown during the nesting period to determine nesting densities of the four species of geese (Butler and Malecki 1986). Most goslings were estimated to be from 1-2 weeks old during the first survey and from 3-4 weeks old during the second survey, based on information gathered from ground studies (Stehn et al. 1985). Surveys were flown in an amphibious Cessna 185 at 46 m altitude and at an air speed of about 185 km/hr. Navigation along transect lines was maintained by LORAN C and prominent, visual landmarks.

The same two observers conducted both brood-rearing surveys and did not change positions within the aircraft since visibility differed out the front right and left rear windows. Visibility was obscured immediately beneath the plane, with a 30° shadow cast on the right side and a 35° shadow on the left side. The shadow differed on the two sides because the floats on the plane obscured more of the view from the left rear window than from the right front window. For purposes of analysis the 'center line' was assumed to lie where visibility began; the area under the plane was ignored. In order that a modified method of line transect analysis (Burnham et al. 1980) could be used, eight parallel zones were delimited on each side of the plane using markers on the struts and windows as follows:

Zone	Distance from 'center line' (m)
1	0-10
2	11-25
3	26-45
4	46-75
5	76-120
6	121-200
7	201-500
8	> 500.

No birds were able to be seen farther than 1000 m, so that was judged to be the outer bound of zone 8. These zones of unequal widths were chosen because their bounds subtended approximately equal viewing angles (6-9° each) and because the accuracy in determining distance from the plane was judged to be more a function of determining the correct sighting angle (from the horizontal to the bird) than determining the actual lineal distance from the 'center line' to the bird. A clinometer was used periodically to verify individual sighting angles.

For each transect the following data were recorded: 1) date, 2) time started and ended, 3) observer, 4) observer's position in the plane, 5) transect number, 6) transect leg number (used when there were two or more discrete units of one transect, e.g., on opposite sides of a bay, and 7) direction headed.

For each sighting of a goose or a prospective predator (mammal, jaeger, gull, raptor) on a transect, the following data were recorded: 1) species, 2) number of adults in the flock, 3) presence or absence of young and the exact number of young if possible, 4) zone, 5) elapsed time since the beginning of that transect (to nearest second), 6) microhabitat, 7) behavior, and 8) number of pairs represented, when possible to determine (used especially for birds that were obviously associated and that were in different zones or habitats or engaged in different behaviors).

Fourteen categories were recognized for microhabitat: 1) intertidal mud, sloughbank or riverbank; 2) mud edge of a pond or lake; 3) river or slough; 4) pond or lake; 5) vegetated pond edge, e.g., covered with thick stands of *Carex aquatilis*; 6) *Hippuris tetraphylla* bed; 7) wet graminoid meadow; 8) dwarf shrub tundra; 9) island vegetated with *Elymus arenarius*; 10) island vegetated with other graminoid species; 11) island vegetated with dwarf shrub tundra; 12) sand beach or dunes; 13) dried mud pond bottom; and 14) stand of willows or other low shrubs.

Nine categories of behavior were recognized: 1) standing or roosting; 2) walking or running; 3) sitting; 4) swimming; 5) flying; 6) flushing from water or land; 7) incubating on an obvious nest; 8) brooding; and 9) diving.

All data were recorded on a microcassette recorder and later transcribed to data sheets and entered into a minicomputer for summary and analysis. Elapsed time was recorded with stop watches synchronized between the two observers. When densities of birds were high, data on species, number of adults, presence of young and zone received highest priority. Other data sometimes went unrecorded. An attempt was made to record all geese within zone 1 and as many as possible in the other zones closest to the plane.

DATA ANALYSIS

Identification of habitat complexes. - In order to analyze the general distribution of geese during brood-rearing in relation to habitat, we identified and mapped the occurrence of seven major and two minor habitat complexes within the study area (Fig. 2). LANDSAT maps of vegetation at the 1:250,000 scale were used as a base. Our characterizations were verified by comparing the LANDSAT maps with notes we recorded on habitat during aerial surveys and during ground surveys of various sections of the study area.

Habitat complexes were delimited primarily on the basis of the types of vegetation, ponds and lakes that they contained. Most of these zones consisted of an interdigitation of several distinct habitat types, and it was the pattern of interspersion that was used to characterize the various complexes. Boundaries separating these complexes were thus in some places arbitrarily located because complexes often graded into each other. In general, however, boundaries were defined by major features easily detected visually on the LANDSAT maps.

Preliminary descriptions of vegetation subclasses by Tande and Jennings (1985) and by Talbot et al. (1985) for portions of the study area were consulted for consistency. Our classifications often incorporated several of the smaller, more discrete vegetative units that they described. For this study we recognized the following nine habitat complexes:

Sedge meadow (SM). This habitat type was dominated by sedges, primarily *Carex ramenskii* near the coast and *C. Lyngbyaei* and *C. aquatilis* farther inland. It occurred mainly along the coast and along banks of major rivers; lower levels were regularly flooded. This habitat contained relatively few ponds, which were very small and brackish. The *C. ramenskii* meadows were strongly dissected by tidal sloughs and areas of bare mud.

Graminoid meadow (GM). This zone was dominated by a mixture of sedges and grasses, primarily *C. rariflora*, *C. ramenskii*, and *Calamagrostis canadensis*. Prostrate willows (*Salix fuscescens*) were also common. This zone was at a slightly higher elevation than the tidal sedge meadow zone but in some places graded into it. Graminoid meadows were characterized by numerous small- to medium-sized, shallow ponds (usually < 60 cm deep).

Intermediate tundra complex (INT). This zone occurred where graminoid meadows and elevated dwarf shrub tundra were interdigitated. Islands (pingos) and short ridges of dwarf shrub tundra were surrounded by meadows that had various compositions of sedges, grasses, forbs, mosses and lichens. Lakes were generally small (< 10 ha) and shallow (60-100 cm deep).

Medium lake tundra complex (MLT). This zone contained a higher proportion of dwarf shrub tundra than the intermediate tundra complex did but was distinguished primarily by the presence of deeper, medium-sized (15-50 ha) lakes. Wet meadows again were interdigitated with the large, higher ridges of dwarf shrub tundra.

Patterned lake tundra complex (PLT). This was a very distinctive zone found over old beach deposits (Hoare and Condon 1968) between Hooper Bay and Angyoyaravak Bay. Its vegetation was similar to that found in the intermediate tundra complex, with a mixture of graminoid meadows and dwarf shrub tundra. It was characterized, however, by very regularly patterned lakes arranged in rows parallel to the coast and decreasing in size from large lakes (up to 200 ha) inland to medium-sized ponds close to the coast.

Dwarf shrub tundra complex (DST). This zone encompassed areas above storm-tide lines and was dominated by lichens, mosses and typical upland heath plants: prostrate willows (*Salix* sp.), dwarf birch (*Betula nana*), alpine blueberry (*Vaccinium uliginosum*), lingonberry (*V. vitis-idaea*), crowberry (*Empetrum nigrum*), and Labrador tea (*Ledum palustre*). Large expanses of elevated tundra were interspersed with freshwater meadows. Lakes varied widely in size within this zone but were generally larger and deeper than those found in more coastal habitats.

Montane complex (MTN). This zone was found around the few mountains and hills of the study area and encompassed three major habitats: moist, tall shrubs, mainly mountain alders (*Alnus crispa*) and willows (*Salix* sp.) at the base of the hillsides; dwarf shrub tundra along the sides and tops of the hills; and scarcely vegetated rock outcroppings at the peaks.

Sand (S). A few areas of almost pure sand occurred above mean high water on beaches or in sand dunes in the study area. Most were scarcely vegetated. Dominant plant species in vegetated sand dunes included beach rye grass (*Elymus arenarius*), seabeach sandwort (*Honckenya peploides*) and beach pea (*Lathyrus maritimus*).

Mud (M). Only one large area of scarcely vegetated mud that occurred above mean high water was mapped on the study area; that occurred on the east side of the large, unnamed island in the Ninglik River (Fig. 2). Smaller sections of mud were treated as parts of the vegetative zones adjacent to them. Low mats of the sedge *Carex subspathacea* and the alkali grass *Puccinellia phryganodes* often formed along the upper reaches of mudflats adjacent to tidal sedge meadows.

The study area was divided into four major geographic regions, whose boundaries roughly delimited the river drainages that emptied into four major bays: Kokechik Bay, Hooper Bay, Angyoyaravak Bay, and Hazen Bay (Fig. 3). Areas of each habitat complex were measured with a polar planimeter and converted to percentages for the four geographic regions. The relative amounts of each habitat complex sampled along the transect lines agreed very closely with the total amount of each habitat complex present (Table 1). For these calculations areas of water on ponds, lakes and rivers were considered part of whatever complex they were in. Water in large rivers was divided in half between adjacent habitat types; water within large bays traversed by transects was excluded from analysis. Sightings of all geese were each assigned to a habitat complex depending upon which complex the aerial transect intersected at the time of the sighting.

Densities of geese. - Only preliminary analyses of the line transect data have been completed. For this report the distribution of sightings of flocks of geese rather than of total individuals has been analyzed first because of the potential bias of differing detectability of flocks of different sizes. The probability of sighting a flock within a particular zone out from the transect line was plotted for each species to determine 1) how detectability of the birds decreased with distance from the center line and 2) if birds tended to move away from the flight path of the plane. This probability was calculated using the following formula:

$$P_i = n_i/(w_i \cdot \sum_{k=1}^{i} n_i)$$

where P_i = the probability of sighting a flock in zone i,
n_i = the number of flocks seen in zone i, and
w_i = the width of zone i in meters.

When multiplied by the width of each zone, these probabilities add up to 100%.

To examine the distribution of geese in relation to habitat and geographic area, we calculated an index of density for geese observed within the first 200 m of each side of the plane, recognizing that biases in detectability due to flock size and movement away from the plane both caused this index to be an inaccurate reflection of the true density of the birds. This index was calculated simply as the number of birds seen within 200 m of each side of the plane divided by the area covered (400 m times the length of the transects).

RESULTS

DISTRIBUTION OF GEESE DURING BROOD-REARING

Geographic distribution. - During the first aerial survey, 6-11 July 1985, 405 flocks of geese totalling 4,875 individuals were observed (Tables 2 and 3). On the second survey, 25-28 July, almost twice as many geese were seen (7,969 birds) but in fewer flocks (290 flocks). During both surveys brant and cackling Canada geese were the most commonly recorded birds, followed by emperor geese and white-fronted geese (Table 3).

Preliminary analyses revealed no major changes in geographic distribution between the two surveys for any of the four species. Brant, as expected, were found mainly near the coast, with areas of concentration along the south coast of Kokechik Bay, near the mouth of the Azun River, and in the Kigigak Island/Nelson Island area (Fig. 4). Minor concentrations were observed near the north coast of Angyoyaravak Bay, inland of the Kashunuk River, and near the mouth of the Manokinak River. Although the number of brant identified during the second survey was only about half that observed during the first (Table 3), we felt that a large number of geese unidentified to species because of their distance from the plane were probably brant.

Canada geese were observed all the way from the coast to the inland extent of some of our transects. From the air, however, we were unable to discern cackling from Taverner's Canada geese (B. canadensis Taverneri) and it is likely that some of the more inland sightings were of the latter subspecies. During the banding drives Rod King and Margaret Petersen (pers. comm.) identified flocks of Taverner's Canada geese on the study area in the Kokechik River drainage. Our data on distribution must be viewed with caution, therefore, when delimiting boundaries of the occurrence of cackling geese.

Major concentrations of Canada geese, however, were probably of cackling geese because of their proximity to the coast. Highest concentrations were found in the Kokechik River area and between the coastal brant areas and the bluffs of south Kokechik Bay (Fig. 4). Other important areas included the lower reaches of the Manokinak, Anerkochik and Azun rivers; the Naskonat Peninsula; and Nelson Island. Smaller concentrations occurred between the Tutakoke and Aphrewn rivers and north of Angyoyaravak Bay.

Emperor geese were much more widely dispersed across the study area than any of the other species. There were a few small but notable concentrations in the Kokechik Bay area--along the mudflats, near Komoiarak Slough, and along the middle stretch of the Kokechik River itself (Fig. 5). A broader area of concentration encompassed the zone from the Manokinak River to the north side of the Naskonat Peninsula. Large numbers were also observed bordering the Ninglick River.

Greater white-fronted geese were the least commonly observed of all species (Tables 2 and 3), although they occurred throughout the study area. Few of these birds were observed within 5 km of the coast; most occurred at least 15 km inland (Fig. 5). Although there were no specific areas of concentration, the greatest numbers of this species were found between the Manokinak and Azun river drainages.

When rough indices of 'densities' of geese are calculated using only the number of birds recorded within 200 m of each side of the plane, it is clear that Kokechik Bay and Hazen Bay were used by greater concentrations than either of the other two regions (Table 4). Specifically, the most heavily used areas during brood-rearing for all four species of geese combined were: the Kokechik River drainage, the lowlands of southern Kokechik Bay, and the area from the Manokinak River south to the northern part of Nelson Island.

Comparison with nesting distribution. - Detailed comparisons with data on the distribution of these four species of geese during nesting (Butler and Malecki 1985) have not yet been made. Initial results, however, show that, on a broad geographic basis, the same areas that supported high nesting concentrations also supported the largest numbers of geese during brood-rearing.

For cackling Canada geese the most important areas during both periods included the Kokechik River drainage; the coastal area between the Kashunuk River and Hazen Bay; the Manokinak and Azun river drainages; the Naskonat Peninsula; and portions of north Nelson Island. For emperor geese there appeared to be some disparity in the location of the densest areas, but the Kokechik River drainage and the coast from the Manokinak River to north Nelson Island were important during both periods. Butler and Malecki (1985) found high nesting densities between the Kashunuk River and Hazen Bay but we found no notable concentrations there. Greater white-fronted geese were observed in the lowest numbers of all four species during both nesting and brood-rearing, but the Kokechik River drainage and Hazen Bay region supported the highest numbers during both periods.

Use of different habitat zones. - 'Densities' of geese observed within 200 m of each side of the plane were calculated to look at patterns of habitat use. For the first survey this included 2,756 birds and for the second survey, 3,917 birds (Tables 5 and 6). Three major findings were immediately apparent: not all habitats within each region were being used by geese; use of habitats differed among the four species; and each species was consistent in its patterns of habitat use between the two surveys although some minor variations did occur.

Brant were largely restricted to sedge and graminoid meadows throughout the study area, with highest concentrations occurring in Kokechik Bay and Hazen Bay (Tables 7 and 8). It should be noted that the meadows designated as 'graminoid' in Kokechik Bay were actually a combination of pure sedge meadows at the immediate coast grading into graminoid meadows farther inland. In other regions these two habitats were more distinct, but it was the more coastal, purer stands of Carex ramenskii that were used most heavily during nesting and early brood-rearing by brant. Between Angyoyaravak and Hooper bays, an area of patterned lake tundra was also favored by brant during both surveys. Almost no brant were observed in other types of habitat.

Cackling Canada geese, in contrast, used a wide variety of habitats in all regions but concentrated in graminoid meadows and the intermediate tundra complex, where graminoid meadows met patches of upland dwarf shrub tundra (Tables 7 and 8). The highest concentrations encountered were in the intermediate tundra complex of the Kokechik River drainage during the second survey, when several large flocks were observed. Similarly, high indices of abundance during the first survey reflected a few large flocks encountered in graminoid meadows south of the Tutakoke River and in patterned lake tundra north of Angyoyaravak Bay. The few Canada geese seen on dwarf shrub tundra may have been of the Taverner's subspecies.

Emperor geese showed a much more consistent pattern of habitat use between the two surveys. Graminoid meadows and intermediate tundra of Kokechik Bay and sedge and graminoid meadows of Hazen Bay were by far the most important habitat complexes used (Tables 7 and 8). In all areas emperor geese were most commonly observed on or adjacent to bays, rivers and sloughs.

Most of the white-fronted geese were observed in the intermediate tundra complex during both surveys (Tables 7 and 8). Few were recorded coastally in either sedge or graminoid meadows or in dwarf shrub tundra farther inland.

For all four species combined, highest concentrations of geese were found in the graminoid and sedge meadows of both Kokechik and Hazen bays, as well as in the intermediate tundra complex of Kokechik Bay. In the Angyoyaravak Bay region, graminoid meadows south of the Tutakoke River and patterned lake tundra between Angyoyaravak and Hooper bays were also important. All other habitats appeared to host lower concentrations of geese during brood-rearing.

PATTERNS OF AGGREGATION OF GEESE

Flock sizes. - Almost twice as many geese were counted on the second survey as on the first (Table 3), although there was a marked drop in the total number of flocks they comprised (Table 2). This resulted from the statistically significant increase in flock size that occurred for all four species between the two surveys (Table 9).

Brant formed the largest flocks, averaging about 25 adults per flock during early brood-rearing and almost double that by late July. Cackling

Canada geese also showed a marked increase in flock size between the two surveys, from about 11 birds to 32 birds per flock. During the first survey emperor and white-fronted geese both occurred in very small flocks, averaging only about 3 adults; by the second survey white-fronted geese had coalesced into relatively large flocks averaging about 19 adults whereas flocks of emperors had also increased but averaged only half that size.

Some of these species showed a marked tendency to form loose aggregations of smaller flocks. Among emperor geese in particular, several pairs with young would often be closely associated with each other along a stretch of mudbank. It is not known how much of this aggregation may have been induced by the disturbance of the plane. Even when all these loosely aggregated groups are treated as single flocks, however, the average flock size does not change much for any of the species (cf. Tables 9 and 10).

Species composition of flocks. - Only ten of the flocks observed during the two surveys contained more than one species of goose (Table 11). Numbers of adults in these ranged from two pairs to 175 individuals. Three of the flocks consisted of only adults, young were present in 6 of the flocks and we could not determine if young were present in the last. Birds of all four species occurred in mixed flocks but the most common associations were between brant and emperor geese and between cackling and emperor geese.

Age composition of flocks. - The proportion of all flocks that contained young of the year ranged from a low of 23% for white-fronted geese to a high of 81% for emperor geese (Table 12). For all four species there was no significant change in this proportion between the two surveys.

During the first survey, in early brood-rearing, although the size of flocks without young averaged larger than the size of those with young for all four species of geese, these differences were not significant because of the large variation in flock sizes (Table 13). Later in brood-rearing, however, flocks of Canada geese without any young were significantly larger than those with young ($P < 0.01$, Mann-Whitney U test). For emperor geese the trend was reversed: the few flocks of emperor geese without young during the second survey were significantly smaller than those with young ($P < 0.05$, Mann-Whitney U test). For brant and white-fronted geese flocks of adults with and without young had grown to approximately equal sizes by the second survey.

By late brood-rearing, there was a definite shift in the proportion of adults in flocks of pure adults and in flocks that also contained young (Fig. 6). During the first survey, only 21% of the adult brant observed were in flocks with young, but by the second survey this had increased significantly to 44% ($P < 0.001$, $X^2 = 155.46$, df = 1). For cackling geese, there was a slight shift in the opposite direction: the percent of adults occurring in flocks with young decreased from 18% to 14% ($P < 0.05$, $X^2 = 5.49$, df = 1). Almost all emperor geese were in mixed flocks of adults and young during both surveys, although the proportion did increase significantly from 76% to 95% between early and late brood-rearing ($P < 0.001$, $X^2 = 100.27$, df = 1). White-fronted geese showed changes very similar to those of brant, with the proportion of adults in flocks containing young increasing from 14% to 39% ($P < 0.01$, $X^2=7.81$, df=1).

Age composition in relation to flock size. - Brant, cackling, and white-fronted geese, all of which had a large proportion of flocks without young in 1985, showed a similar pattern of flock coalescence between the two surveys. For all three species, the largest flocks observed during the first survey contained only adults (Fig. 7). By the second survey, however, after groups had coalesced, flocks containing young showed a more even distribution in size, although the largest flocks of cackling and white-fronted geese still contained only adults.

Flocks of emperor geese also coalesced into larger groups but their largest flocks all contained young of the year during both surveys (Fig. 7). The largest flocks of adults observed without any young were limited to fewer than 10 birds during both surveys.

Productivity of geese. - We found that, using our survey methods, we were not able to obtain accurate ratios of adults:young for any flocks containing more than six adults. For most of the larger flocks we were able to determine only whether or not any young were present. This information alone was not sufficient to allow us to assess the production of young or the mortality of young between the two surveys.

The only information we obtained on seasonal mortality of young was data comparing the average number of young occurring in what we discerned to be individual family groups during the two surveys. No significant differences in brood sizes were found between surveys for any of the species (Table 14), although sample sizes were very small for all species except emperor geese because of the coalescence of most geese into larger flocks. For brant, cackling and emperor geese with young, brood size averaged from 3.2 to 3.6 young per pair during the two surveys combined (Table 14). This compares with average clutch sizes of 4.4 ($\pm$ 0.2, n = 98) for brant, 5.1 ($\pm$ 0.3, n = 17) for cackling geese and 6.4 ($\pm$ 0.5, n = 14) for emperor geese during laying in 1985 (Stehn 1986). Sample sizes for white-fronted geese were too small for a meaningful comparison of clutch size (n = 2) and brood size (n = 1). What proportion of breeding pairs had lost all their eggs or young before our surveys was not determined this year for any of the species. Thus, the average number of young per pair that still had at least one young alive during our surveys was undoubtedly much higher than the actual average number of young produced by all pairs that attempted to breed in 1985.

DISTRIBUTION OF PREDATORS DURING BROOD-REARING

These data have not yet been analyzed, but good information was obtained on the distribution and density of avian predators. We recorded 1,283 sightings of glaucous gulls (Larus hyperboreus), 22 sightings of long-tailed jaegers (Stercorarius longicaudus) and 91 sightings of parasitic jaegers (S. parasiticus). In contrast, we have very little information on the distribution or abundance of foxes because we had a total of only six sightings of the two species (*Alopex lagopus* and *Vulpes vulpes*) during both surveys combined. We also had two sightings of river otters (*Lutra canadensis*). Planned analyses include an examination of the data for any correlations between density of avian predators and density of geese during brood-rearing.

HUMAN USE OF GOOSE HABITATS DURING BROOD-REARING

Patterns of current use by humans of different geographic areas in relation to the distribution of geese have not yet been examined. We recorded 18 sightings of temporary camps, 7 sightings of boats and 5 sightings of humans during the two surveys combined. Analyses will probably involve examining the distribution of geese during this period in relation to the accessibility of these areas by humans using traditional means of transportation.

EVALUATION OF METHODS AND DEVELOPMENT OF SURVEY TECHNIQUE

Distribution of sightings as a function of sighting distance. - For each species of goose a histogram was plotted for the two aerial surveys showing the relative probability of sighting a flock of that species within each of the eight transect zones out from the plane (Fig. 8). These probabilities have been corrected for the amount of area covered in each zone; i.e., if distance away from the plane had had no effect on the distribution or detectability of the birds, the bars within each graph would have been of uniform height. In contrast, there was marked departure from uniformity. Six of the eight histograms showed a similar pattern--lower relative frequencies of sightings in the zones closest to the plane, increasing to maximum frequencies at distances of 50-100 m, and then decreasing markedly at greater distances (Fig. 8). This pattern suggested two concurrent and confounding phenomena: movement of the birds away from the plane (cf. Burnham et al. 1980, Fig. 50) and decreasing detectability of birds at increasing distances from the plane.

Analyses of these line transect data are now in progress to determine whether we can sort out the effect of movement from the effect of decreasing detectability. Other analyses will include 1) how flock size affects detectability, 2) how microhabitat affects detectability, and 3) how densities calculated by line transect analysis compare with densities calculated from the fixed-width strip transect method traditionally employed in waterfowl surveys (e.g., Butler and Malecki 1986).

Systematic vs. stratified sampling. - The survey effort in 1985 used systematic sampling because nothing was assumed about the distribution of geese during brood-rearing. Initial results have shown that geese are more concentrated in certain geographic zones and habitats than in others and that stratified sampling would be more efficient.

Determination of production and mortality of young. - Methods used this year were found inadequate to assess either the ratio of adults to young or the mortality of young between the two surveys. Observers did not have enough time during a single pass along the transect line to obtain accurate counts of young, especially those in large flocks and those in flocks at distances far from the flight line. Any deviations from the flight line to obtain such counts would have biased the results of our censuses of flocks along the transect because additional flocks would have been observed and counted that would have otherwise gone undetected.

Ground-truthing of results. - No attempt was made during the pilot study to correlate observations from the air with any on the ground. The line transect method assumes that all animals within the zone closest to the center line were counted. This assumption needs to be tested. We felt that there was a difference in detèctability among the four species of geese at greater distances from the plane but we do not know if this was true in the first zone.

DISCUSSION

DISTRIBUTION AND HABITAT USE

The most notable characteristic of distribution of geese during brood-rearing in 1985 was their pattern of coastal zonation, which was closely tied to the coastal zonation of habitats along the central Yukon-Kuskokwim Delta. Brant were concentrated in sedge and graminoid meadows immediately adjacent to the coast and heavily influenced by tidal action. Cackling Canada geese were found slightly more inland in graminoid meadows and in the intermediate tundra complex, where meadows were interspersed with islands and ridges of dwarf shrub tundra. Emperor geese were more widely distributed than either brant or cackling Canada geese, although they occupied much of the same habitats as the latter species. Emperor geese were particularly noted to concentrate along mudflats, rivers and sloughs. Greater white-fronted geese occupied the driest, most inland habitats of all four species although they, too, were widely distributed but found most frequently in the intermediate tundra complex.

This broad pattern of coastal zonation of geese during the breeding season was described by the earliest biologists to work in the area (Dufresne 1924, Murie 1924, Gillham 1941, Spencer et al. 1951) and appears to have remained fairly unchanged over the past 60 years. Use of particular habitats during brood-rearing was not described in detail for any of the species of geese until studies were undertaken in the early 1970's but, again, our findings appear consistent with those described earlier. The only discrepancies appear to be those wrought by major changes in densities and geographic distribution of the geese.

The only detailed descriptions of habitat use by brant during brood-rearing on the Yukon-Kuskokwim Delta are those of Eisenhauer (1977) from the Kashunuk River area. He found that each year about 3000 family groups of brant moved northward from their nesting colony immediately after hatch to a major brood-rearing area in sedge meadows 2-8 km from the mouth of the river. Earlier, Mickelson (1975) had noted that brant nesting along the lower Kashunuk moved to the river itself and to its tidal sloughs during brood-rearing. In 1985, there was an almost complete void of brant in the entire Kashunuk River region but we found brant using similar habitats in other areas, particularly in south Kokechik Bay and around the Naskonat Peninsula, Kigigak and Nelson islands. The absence of brant near the Kashunuk River could easily be attributed to poor nesting success due to severe fox predation (J. Sedinger, pers. comm.) and to the substantial decline in the colony that has recently occurred--from about 15,000 birds in 1981 (Byrd et al. 1982) to about 2,000 birds in 1984 (Sedinger 1984a).

Current use of habitat by cackling Canada geese during brood-rearing was consistent with that recorded traditionally: on a broad scale they used the same habitats (predominantly graminoid meadows and intermediate tundra habitat) for both nesting and brood-rearing. Birds nesting in meadows within the intermediate tundra complex along the Kashunuk River in the early 1970's moved their young an average of only 1.1 km to brood-rearing areas vegetated by short grasses and sedges (Mickelson 1975). Similar habitats had been used in the 1940's, when Gillham (1941) reported banding large numbers during brood-rearing in intermediate tundra habitats.

The movement of emperor geese from inland nesting areas towards the coast via sloughs and rivers during brood-rearing has also long been documented. As early as 1924 it was noted that mudflats of Kokechik Bay and the riverbanks and sloughbanks of the Kokechik River drainage were used by large numbers of emperor geese (Dufresne 1924, Murie 1924). Concentrations on the south side of the bay were found to peak in mid-August (Eisenhauer and Kirkpatrick 1977). Other large brood-rearing areas were documented along the inside bends of the Kokechik River and smaller ones were located along small rivers and sloughs and sometimes along inland pools (Frazer and Kirkpatrick 1979). In 1985 a ground-based study confirmed that emperor geese concentrated in lowlands within 400 m of the coast in Kokechik Bay, where the birds fed on *Puccinellia phryganodes* and *Carex subspathacea* growing on the mudflats (Laing 1986).

Virtually no historical data are available on the habitats used by white-fronted geese during brood-rearing. Mickelson (1975) indicated that they reared their young near the heads of sloughs where dense cover was available. Earlier biologists simply noted their relative scarcity and their tendency to nest farther inland than the other species (Dufresne 1924, Murie 1924, Gillham 1941, Spencer et al. 1951), trends that continued to hold in 1985. In a preliminary ground-based study in the Kashunuk River area in 1985, Ely et al. (1985) found that white-fronted geese reared their young an average of 1.8 km from where they nested. They found that brood-rearing areas were located near the heads of sloughs in intermediate habitats characterized by large numbers of shallow ponds.

Thus, it appears that white-fronted geese, like cackling Canada geese, move minimal distances to brood-rearing areas after their young hatch, and remain largely in intermediate habitats or graminoid meadows where they nested. Emperor geese and brant move their broods longer distances (2-12 km) to more coastal habitats.

Unfortunately, no studies provide the quantitative information necessary to assess changes in densities or geographic distribution of geese during brood-rearing across the Delta. In 1985, both our aerial surveys revealed that certain geographic areas sustained relatively high concentrations of geese during brood-rearing: the lower Kokechik River drainage, the lowlands of south Kokechik Bay below the bluffs, and coastal areas between the Manokinak River and north Nelson Island. These corresponded closely to the broad areas found by Butler and Malecki (1985) to support the highest numbers of geese during nesting.

During brood-rearing there was a notable scarcity of geese of all species around both the Kashunuk and Aphrewn river drainages. This pattern of distribution cannot be attributed to the impact of humans alone; although the Kashunuk River area has traditionally received heavy traffic and hunting pressure by humans (Murie 1924, Gillham 1941, Eisenhauer 1977), the lower Aphrewn River area has been used relatively little by humans during the birds' breeding season because of its remoteness from villages. The void of geese in these areas also does not appear linked to an absence of or gross changes in appropriate habitats. Without comparable quantitative data on the historic distribution of geese, it is difficult to determine if declines have occurred fairly evenly across the study area or if these pockets of scarcity are the result of certain factors operating on specific portions of populations that used to be more evenly distributed across the coastal fringe of the Delta.

PATTERNS OF AGGREGATION

The most distinct temporal change in distribution detected was the aggregation of all four species into larger flocks between the two surveys. A schematic representation of a characteristic distribution of 250 individuals of each species among typical flocks during the two surveys illustrates well the differences among the species (Fig. 9). The resulting patterns of flocking appeared to be a product of two major factors: the inherent sociality of each species (indirectly related to nesting distribution and 'colonial' tendencies) and the nesting success each species experienced in 1985.

Early in brood-rearing, white-fronted and emperor geese, the most dispersed nesters (Eisenhauer and Kirkpatrick 1977, Ely 1979), were in the smallest flocks (Fig. 9). Cackling Canada geese, which have been described as semi-colonial nesters in some areas (Mickelson 1975), had formed flocks of intermediate size whereas brant, truly gregarious nesters (Eisenhauer 1977), had already coalesced into large flocks. In 1985, emperor and white-fronted geese also experienced higher nesting success than the other two species, with 66% and 60% of their nests hatching at least one young, respectively (Stehn 1986). Nesting success of brant (37%) and cackling Canada geese (44%)

across the central Delta were both relatively low in 1985 (Stehn 1986), with both species experiencing almost complete nesting failure in some areas (Ely et al. 1985; J. Sedinger, pers. comm.). For both brant and cackling geese the flocks of adults during early brood-rearing that had no young in them averaged much larger than those that contained young, although the differences were not statistically significant because of the large variations in flock size (Table 13). Nevertheless, these data suggest that failed breeders had longer times during which to aggregate into larger flocks than the successful breeders did, and thus that nesting success in a given year may have a substantial influence on the distributional patterns of geese during brood-rearing.

For brant, emperor and white-fronted geese the size of flocks with young increased much more, proportionately, than the size of flocks with no young between the two surveys (Table 13). This resulted in a significant increase for these three species in the proportion of adults that were in flocks that contained young (Fig. 6). The interesting implication is that, during the process of aggregation of flocks between the two surveys, there was probably some mixing of brood flocks and adult molting flocks. Since we were not able to get accurate ratios of adults:young in these flocks, we were unable to assess how extensive such mixing may have been. This phenomenon may have resulted from a few pairs with young joining nearby larger molting flocks of adults. Mixing could also have been an artifact of disturbance from the plane or it could have been a result of the relatively low reproductive success in 1985 and the inability of family groups to find other nearby brood flocks with which to associate. Historically, however, it has been found that family groups have remained separate from molting flocks of failed breeders or nonbreeders throughout the brood-rearing period, although some subadults have often been found associating with family groups (Eisenhauer 1977; Eisenhauer and Kirkpatrick 1977; Frazer and Kirkpatrick 1979; C. Lensink, unpubl. data). Further studies on the ground of marked geese during brood-rearing are needed to determine under what conditions such mixing might occur. Chronology of breeding failures and genetic relatedness of successful breeders and unsuccessful birds may be important factors to consider.

ASSESSMENT OF SURVEY METHODS

One long-range objective of this study is to design the simplest method possible for accurately assessing the annual production of young geese on the central Yukon-Kuskokwim Delta. Ideally such a survey would have the following attributes: 1) it would be timed to occur after most mortality of young had taken place; 2) it would need to be done only once each season; 3) the effort would be stratified to emphasize the areas of highest densities of geese; 4) it would be simple to conduct, using one or a few strips of fixed width chosen to optimize the accuracy of detection of the birds; and 5) it would be fairly insensitive to differences among observers.

We have found that we need to estimate two parameters separately: 1) densities of flocks with and without young and 2) the ratio of young:adults within the flocks containing young. Together, these two parameters will yield the number of young produced within a given study area. We found that it was not possible to estimate the second parameter accurately without leaving the transect line and thereby ruining our estimate of the first parameter. A secondary sampling scheme is currently being devised.

Preliminary analyses also indicated that there were three major factors that influenced the number of geese that were observed during our aerial surveys: 1) the distance of the flock from the plane, 2) the size of the flock and 3) a tendency of the geese to move away from the plane as it approached. In addition, it appeared that interactions among these factors may have been significant. For example, larger flocks may have moved less than smaller flocks because they were less mobile or felt more protected than the geese in smaller flocks. If there is typically significant movement out of a 200-m wide strip, we may be precluded from using the numbers recorded along a simple strip transect as an index of densities of geese and as an annual assessment of production of young. The problem of movement is now being analyzed and experiments using ground-to-air comparisons are being devised to investigate its magnitude in the 1986 field season.

If we can use secondary sampling to estimate ratios of young:adults in brood flocks, we feel that the best time to conduct a survey of this type will be when the young are three to four weeks old. There are several reasons for this: 1) our data and other studies indicate that most mortality of young has already occurred by then (Mickelson 1975, Eisenhauer 1977, Ely et al. 1985, Laing 1986); 2) there is still enough of a difference in size and plumage between adults and young for observers to detect the presence of young easily; and 3) by then geese have aggregated into larger flocks, which are easier to detect than small flocks, thereby increasing sample sizes for a given level of survey effort.

PLANS FOR 1986 FIELD SEASON

The basic study design in 1986 will remain the same as that used in 1985 so that comparisons can be made easily, but several important changes and additions will be made. First, survey efforts will be stratified to emphasize geographic areas of high concentrations of geese. In addition, a secondary sampling effort, probably employing photography, will be made to measure the ratios of adults:young in brood flocks of various sizes. Finally, experimental flights will be made over ground crews in towers to assess 1) how geese respond to the plane, 2) how significant the movement problem is, and 3) how accurate our counts are.

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Table 1. Relative composition of habitats sampled along aerial transects (Samp) compared with the relative percentages that actually occurred (Act) within each region of the study area. The lineal km of transects flown and the actual area encompassed in each region are presented at the bottom of the table.

	Percent composition of each region									
	Kokechik		Hooper		Angyoyaravak		Hazen		Total	
Habitat	Samp	Act	Samp	Act	Samp	Act	Samp	Act	Samp	Act
Sedge meadow	0	0	11.2	11.4	14.2	10.0	14.8	10.0	11.7	8.4
Graminoid meadow	11.3	8.9	21.7	22.9	29.9	29.6	47.8	47.5	34.9	33.7
Intermediate tundra	41.0	47.6	30.7	31.9	27.0	27.6	23.6	25.8	28.1	31.0
Patterned lake tundra	0	0	8.5	2.1	10.2	8.8	0	0	2.9	1.7
Medium lake tundra	8.4	8.9	2.4	5.1	18.7	23.1	12.6	14.7	11.1	13.4
Dwarf shrub tundra	33.5	24.0	24.3	26.6	0	0	1.3	1.8	10.2	9.6
Montane	5.7	8.9	0	0	0	0.8	0	0.1	0.9	1.8
Sand	0	1.6	1.2	0	0	0	0	0	0.2	0.3
Total	99.9	99.9	100.0	100.0	100.0	99.9	100.1	99.9	100.0	99.9
Lineal km sampled	267		267		234		852		1620	
Total area (km^2)		607		530		516		1654		3307

Table 2. Total number of flocks of four species of geese observed on two aerial surveys during brood-rearing in 1985.

	Survey		
Species	6-11 July	25-28 July	Total
Brant	99	27	126
Cackling Canada geese	109	115	224
Emperor geese	153	92	245
White-fronted geese	22	19	41
Unidentified geese	22	37	59
Total	405	290	695

Table 3. Total number of adults of four species of geese observed on two aerial surveys during brood-rearing in 1985.

Species	Survey		
	6-11 July	25-28 July	Total
Brant	2,432	1,248	3,680
Cackling Canada geese	1,169	3,821	4,990
Emperor geese	428	951	1,379
White-fronted geese	63	366	429
Unidentified geese	783	1,583	2,366
Total	4,875	7,969	12,844

Table 4. 'Densities' of geese (#/km^2) observed in different regions of the study area on 400-m wide transects during two aerial surveys in the brood-rearing period in 1985.

Date and Region	Brant	Canada Geese	Emperor Geese	White-fronted Geese	Total[a]
Survey 1 (6-11 July)	0.85	0.62	0.20	0.03	1.70
Kokechik Bay	0.44	0.27	0.48	0.03	1.22
Hooper Bay	0	0.05	0.06	0.01	0.12
Angyoyaravak Bay	0.07	0.94	0.05	0.03	1.09
Hazen Bay	1.47	0.81	0.20	0.04	2.52
Survey 2 (25-28 July)	0.43	1.47	0.31	0.10	2.42
Kokechik Bay	0.08	5.21	0.54	0.27	6.12
Hooper Bay	0.03	0.01	0.08	0.08	0.19
Angyoyaravak Bay	0.23	0.19	0.01	0	0.43
Hazen Bay	0.71	1.11	0.39	0.08	2.50

[a] Note that total includes geese unidentified to species.

Table 5. Numbers of geese observed in different habitats and regions of the study area on 400-m wide transects during the first aerial survey in the brood-rearing period (6-11 July 1985). Note that only habitats in which geese were observed are presented in this table. Areas of all habitats sampled are listed in Table 1.

Region and Habitat	Brant	Canada Geese	Emperor Geese	White-fronted Geese	Total[a]
Kokechik Bay					
Graminoid meadow	74	4	62	0	140
Intermediate tundra	43	58	64	7	172
Medium lake tundra	0	0	2	0	2
Dwarf shrub tundra	0	11	0	1	12
Hooper Bay					
Sedge meadow	0	2	0	0	2
Graminoid meadow	0	0	1	0	1
Intermediate tundra	0	2	4	3	9
Patterned lake tundra	0	10	10	0	20
Angyoyaravak Bay					
Sedge meadow	2	0	4	2	8
Graminoid meadow	7	147	7	0	161
Patterned lake tundra	8	71	0	4	83
Medium lake tundra	0	2	0	0	2
Hazen Bay					
Sedge meadow	1131	32	49	1	1213
Graminoid meadow	119	593	97	6	817
Intermediate tundra	0	43	22	25	90
Medium lake tundra	0	22	2	0	24
Total	1384	997	324	49	2756

[a] Note that total includes geese unidentified to species.

Table 6. Numbers of geese observed in different habitats and regions of the study area on 400-m wide transects during the second aerial survey in the brood-rearing period (25-28 July 1985). Note that only habitats in which geese were observed are presented in this table. Areas of all habitats sampled are listed in Table 1.

Region and Habitat	Brant	Canada Geese	Emperor Geese	White-fronted Geese	Total[a]
Kokechik Bay					
Graminoid meadow	20	53	15	0	94
Intermediate tundra	0	1322	130	65	1517
Medium lake tundra	0	2	0	0	2
Dwarf shrub tundra	0	13	0	8	21
Hooper Bay					
Intermediate tundra	0	2	6	20	28
Patterned lake tundra	8	0	15	0	23
Angyoyaravak Bay					
Graminoid meadow	52	34	2	0	88
Intermediate tundra	0	10	0	0	10
Patterned lake tundra	2	0	0	0	2
Hazen Bay					
Sedge meadow	481	105	96	0	857
Graminoid meadow	72	741	231	47	1098
Intermediate tundra	0	94	0	24	118
Medium lake tundra	55	2	2	0	59
Total	690	2378	497	164	3917

[a] Note that total includes geese unidentified to species.

Table 7. 'Densities' of geese (#/km^2) observed in different habitats and regions of the study area on 400-m wide transects during the first aerial survey in the brood-rearing period (6-11 July 1985).

Region and Habitat	Brant	Canada Geese	Emperor Geese	White-fronted Geese	Total[a]
Kokechik Bay					
Graminoid meadow	6.2	0.3	5.2	0	11.7
Intermediate tundra	1.0	1.3	1.5	0.2	3.9
Medium lake tundra	0	0	0.2	0	0.2
Dwarf shrub tundra	0	0.3	0	<0.1	0.3
Hooper Bay					
Sedge meadow	0	0.2	0	0	0.2
Graminoid meadow	0	0	<0.1	0	<0.1
Intermediate tundra	0	<0.1	0.1	0.1	0.3
Patterned lake tundra	0	1.1	1.1	0	2.2
Angyoyaravak Bay					
Sedge meadow	0.2	0	0.3	0.2	0.6
Graminoid meadow	0.3	5.3	0.3	0	5.8
Patterned lake tundra	0.8	7.4	0	0.4	8.7
Medium lake tundra	0	0.1	0	0	0.1
Hazen Bay					
Sedge meadow	22.4	0.6	1.0	<0.1	24.1
Graminoid meadow	0.7	3.6	0.6	<0.1	5.0
Intermediate tundra	0	0.5	0.3	0.3	1.1
Medium lake tundra	0	0.5	<0.1	0	0.6

[a] Note that total includes geese unidentified to species.

Table 8. 'Densities' of geese (#/km^2) observed in different habitats and regions of the study area on 400-m wide transects during the second aerial survey in the brood-rearing period (25-28 July 1985).

Region and Habitat	Brant	Canada Geese	Emperor Geese	White-fronted Geese	Total[a]
Kokechik Bay					
Graminoid meadow	1.7	4.4	1.3	0	7.8
Intermediate tundra	0	30.0	3.0	1.5	34.5
Medium lake tundra	0	0.2	0	0	0.2
Dwarf shrub tundra	0	0.4	0	0.2	0.6
Hooper Bay					
Intermediate tundra	0	<0.1	0.2	0.6	0.9
Patterned lake tundra	0.9	0	1.6	0	2.5
Angyoyaravak Bay					
Graminoid meadow	1.9	1.2	<0.1	0	3.1
Intermediate tundra	0	0.4	0	0	0.4
Patterned lake tundra	0.2	0	0	0	0.2
Hazen Bay					
Sedge meadow	9.5	2.1	1.9	0	17.0
Graminoid meadow	0.4	4.6	1.4	0.3	6.7
Intermediate tundra	0	1.2	0	0.3	1.5
Medium lake tundra	1.3	<0.1	<0.1	0	1.4

[a] Note that total includes geese unidentified to species.

Table 9. Mean number of adults per flock (± SE) for four species of geese observed on two aerial surveys during brood-rearing in 1985.

Species	Survey: 6-11 July	Survey: 25-28 July	Significance[1]
Brant	24.6 ± 6.6[2]	46.2 ± 15.6	$P < 0.01$
Cackling Canada geese	10.7 ± 3.1	32.4 ± 5.1	$P < 0.001$
Emperor geese	2.8 ± 0.3	10.3 ± 1.6	$P < 0.001$
White-fronted geese	2.9 ± 0.9	19.3 ± 5.8	$P < 0.001$
Unidentified geese	35.6 ± 14.4	42.8 ± 8.3	$P < 0.01$

[1] Mann-Whitney U test.
[2] See Table 1 for sample sizes.

Table 10. Mean number of adults in all 'aggregated' flocks of four species of geese observed on two aerial surveys during brood-rearing in 1985. Closely associated groups are treated as loosely aggregated flocks.

Species	6-11 July			25-28 July		
	N	$\bar{X} \pm$ SE	Range	N	$\bar{X} \pm$ SE	Range
Brant	92	26.4 ± 7.1	1-400	27	46.2 ± 15.6	1-400
Cackling Canada geese	99	11.8 ± 3.4	1-300	105	38.4 ± 6.2	1-350
Emperor geese	114	3.4 ± 0.3	1-30	72	13.2 ± 2.1	1-75
White-fronted geese	22	2.9 ± 0.9	1-22	18	20.3 ± 6.1	1-110

Table 11. Composition of flocks containing more than one species of goose on two aerial surveys during brood-rearing in 1985. The symbol following the species indicates the presence (+) or absence (0) of young. U indicates unknown.

Survey	Species 1	Species 2	Species 3
6-11 July	16 Brant (+)	1 Emperor goose (U)	
	2 Brant (+)	2 Emperor geese (+)	
	8 Brant (+)	12 Emperor geese (+)	
	6 Cackling geese (0)	2 White-fronted geese (0)	
25-28 July	50 Emperor geese (U)	75 Cackling geese (U)	50 Brant (U)
	25 Brant (0)	2 Emperor geese (+)	
	19 Cackling geese (0)	2 Emperor geese (0)	
	10 Cackling geese (0)	20 Emperor geese (+)	
	8 Cackling geese (U)	2 Emperor geese (+)	
	40 Cackling geese (0)	10 Emperor geese (0)	

Table 12. Percent of flocks of four species of geese observed with young on two aerial surveys during brood-rearing in 1985. The number of flocks for which the presence or absence of young could be determined is in parentheses.

	Survey		
Species	6-11 July	25-28 July	Total
Brant	51.7% (89)	45.5% (22)	50.5% (111)
Cackling Canada geese	34.5% (87)	33.3% (93)	33.9% (180)
Emperor geese	77.1% (140)	86.4% (88)	80.7% (228)
White-fronted geese	15.8% (19)	31.3% (16)	22.9% (35)
Unidentified geese	57.1% (14)	40.0% (15)	48.3% (29)
Total	72.2% (349)	54.7% (234)	55.4% (583)

Table 13. Average number of adults in flocks with and without young for four species of geese observed on two aerial surveys during brood-rearing in 1985.

	6-11 July		25-28 July	
Species	With young	Without young	With young	Without young
Brant	8.9 ± 1.5 (46)[1]	35.1 ± 12.8 (43) NS[2]	42.7 ± 18.5 (10)	45.9 ± 32.5 (12) NS
Cackling geese	2.9 ± 0.4 (30)	7.2 ± 1.7 (57) NS	14.3 ± 3.4 (31)	45.5 ± 8.8 (62) P<0.01
Emperor geese	2.8 ± 3.6 (108)	3.1 ± 0.4 (32) NS	10.1 ± 1.6 (76)	3.3 ± 0.9 (12) P<0.05
White-fronted geese	1.7 ± 0.3 (3)	1.9 ± 0.3 (16) NS	25.4 ± 7.3 (11)	18.0 ± 9.4 (5) NS

1 $\bar{X} \pm SE(n)$

2 Statistical significance of difference between flocks with and without young, using Mann-Whitney U test (NS = not significant).

Table 14. Average brood size within individual family groups of four species of geese during two aerial surveys. Data presented as $\bar{X} \pm$ SE (n). No significant differences were found for any of the species in brood size between the two surveys (Mann-Whitney U test).

Species	6-11 July	25-28 July	Combined
Brant	3.3 ± 0.4 (10)	2.0 (1)	3.2 ± 0.4 (11)
Cackling Canada geese	3.0 ± 0.4 (12)	4.4 ± 0.5 (7)	3.6 ± 0.3 (19)
Emperor geese	3.2 ± 0.2 (44)	3.6 ± 0.3 (32)	3.4 ± 0.2 (76)
White-fronted geese	4.0 (1)	--	4.0 (1)

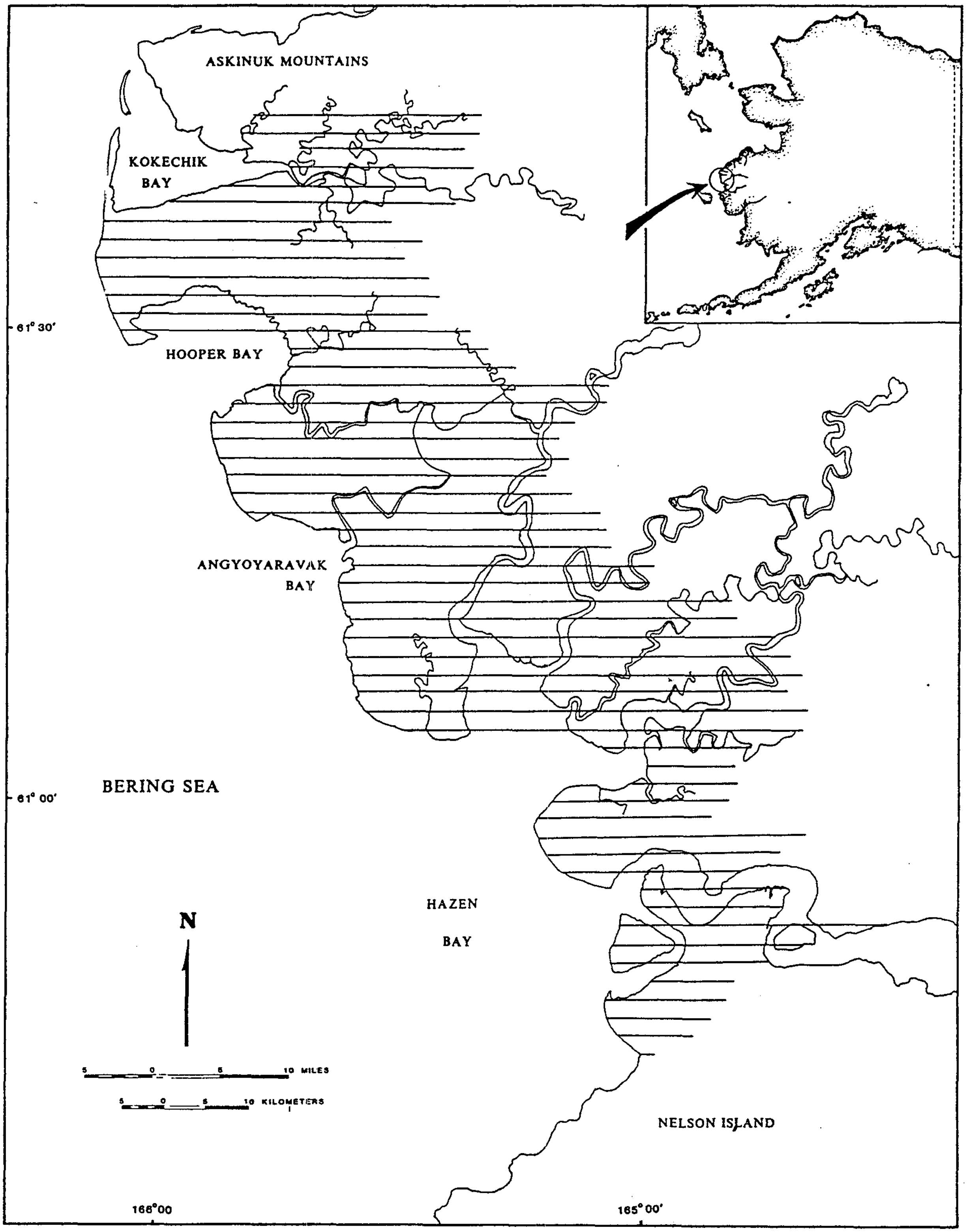

Figure 1. Location of aerial transects flown on the central Yukon-Kuskokwim Delta, Alaska, during two brood-rearing surveys in 1985.

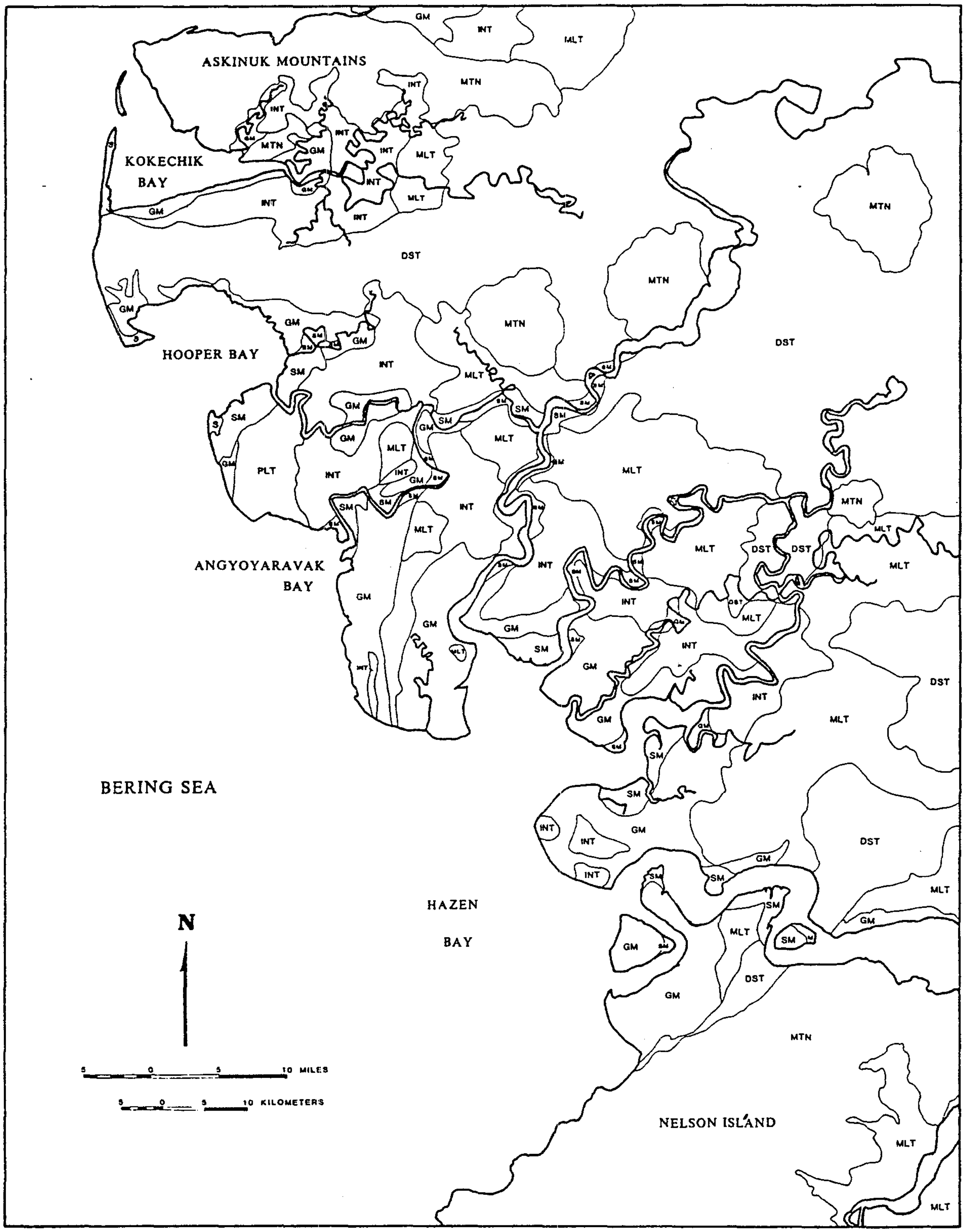

Figure 2. Habitat complexes identified on the central Yukon-Kuskokwim Delta, Alaska. SM = sedge meadow; GM = graminoid meadow; INT = intermediate tundra; MLT = medium lake tundra; PLT = patterned lake tundra; DST = dwarf shrub tundra; MTN = montane; S = sand; M = mud.

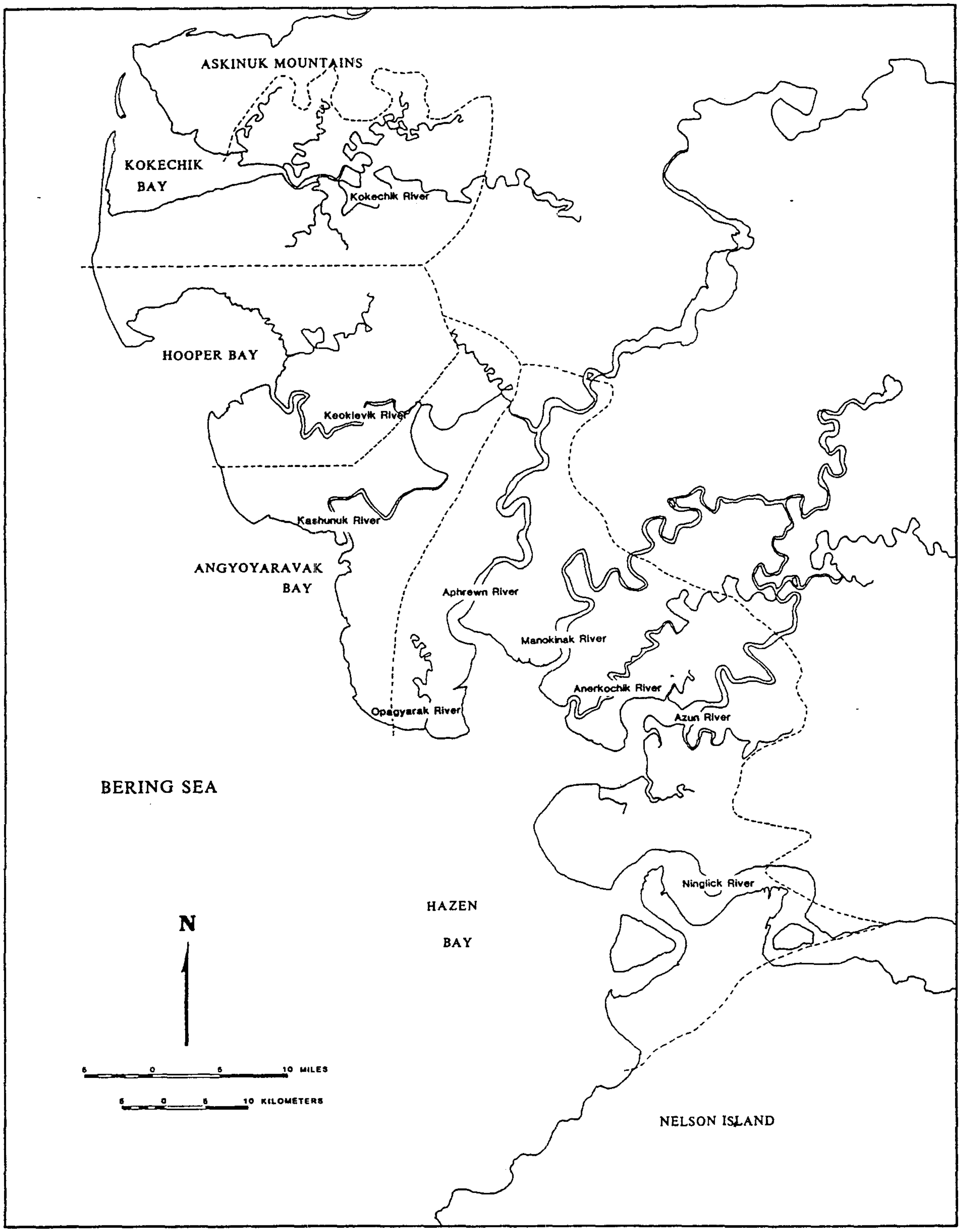

Figure 3. Boundaries of four major geographic regions of the study area.

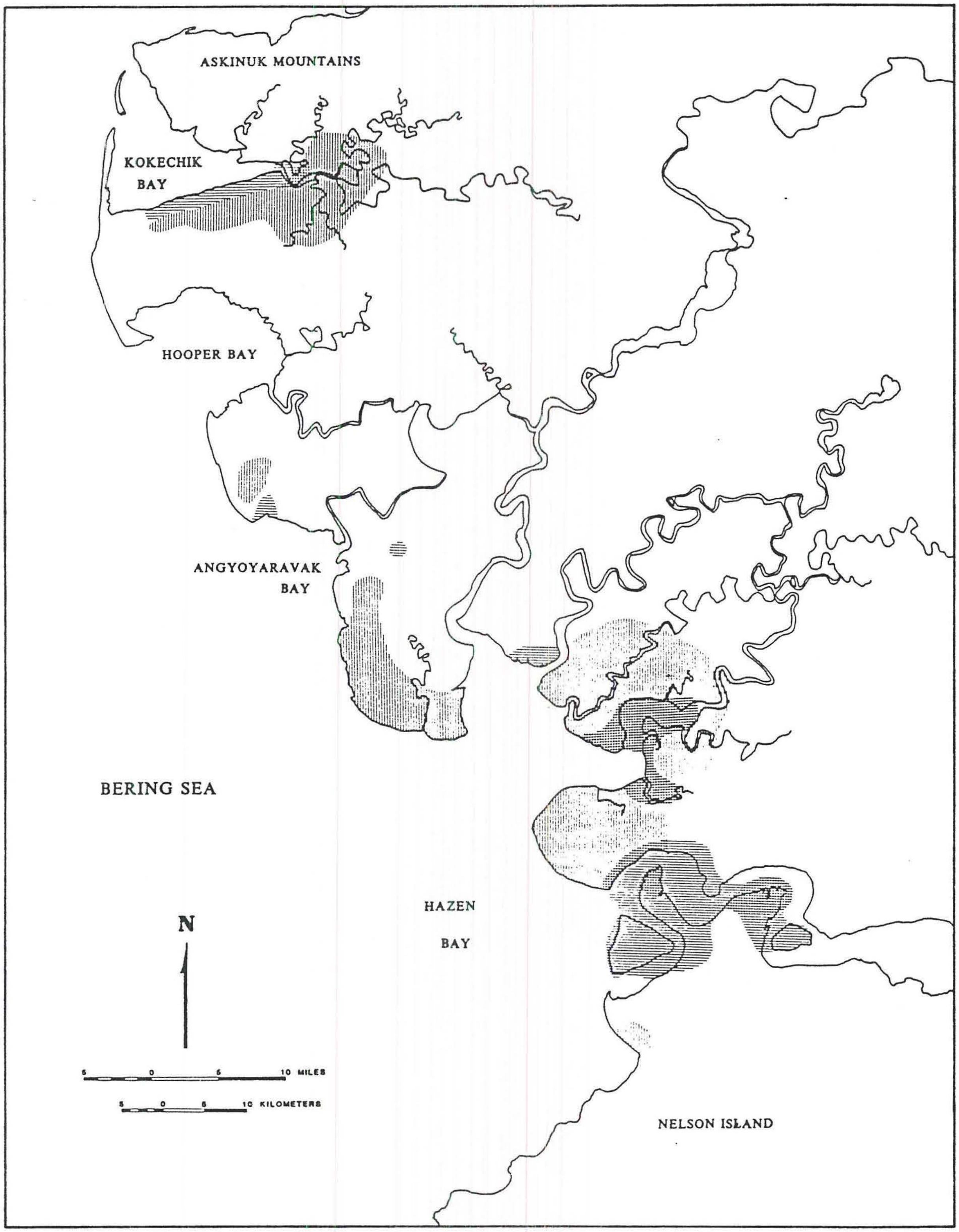

Figure 4. Primary areas where brant (horizontal shading) and cackling Canada geese (vertical shading) were found concentrated during two aerial surveys in the brood-rearing season in 1985.

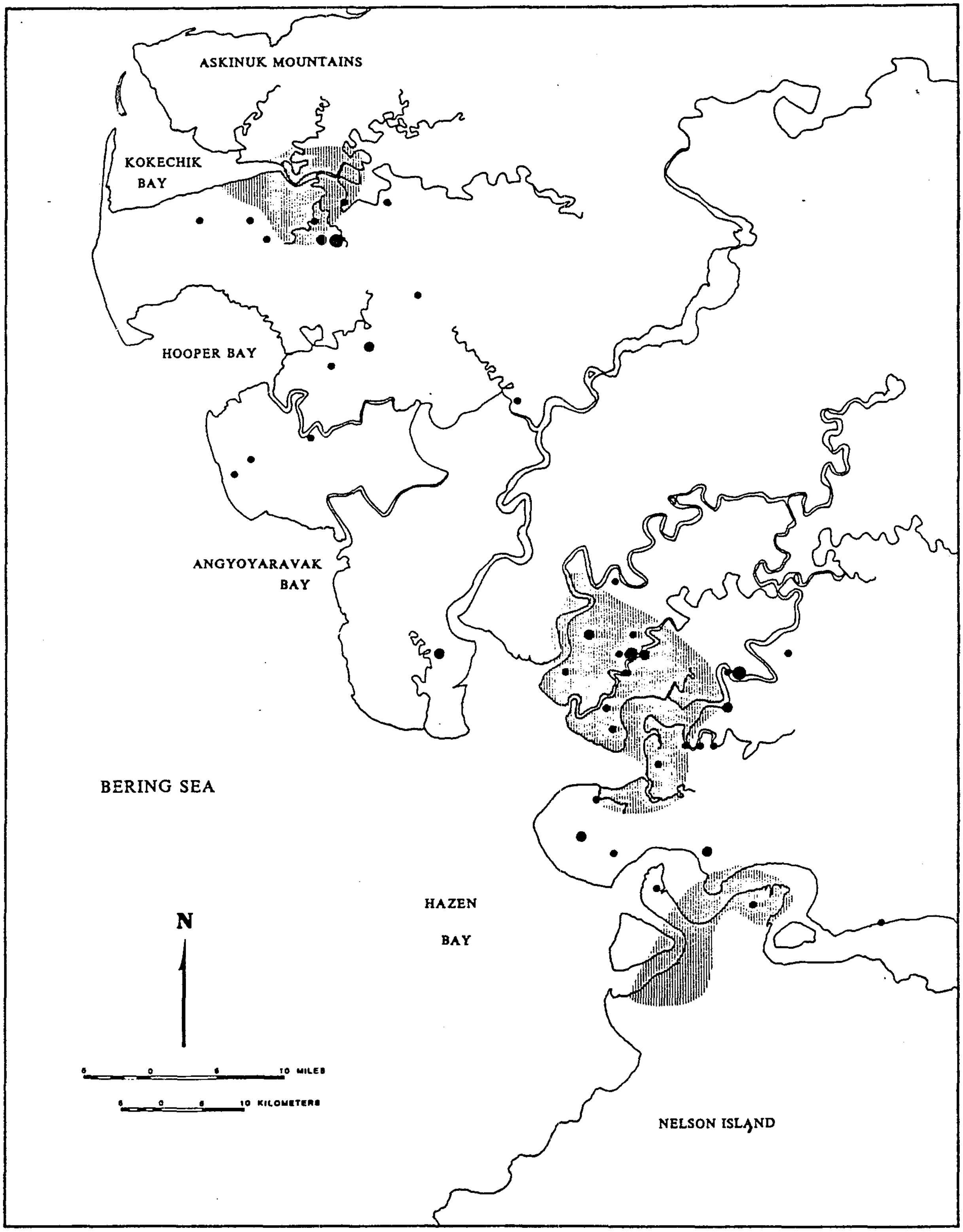

Figure 5. All sightings of greater white-fronted geese (solid circles) and primary areas where emperor geese were found concentrated (vertical shading) during two aerial surveys in the brood-rearing season in 1985. The smallest circle represents flocks of 10 or fewer geese; the middle, 11-25; and the largest, 26-110.

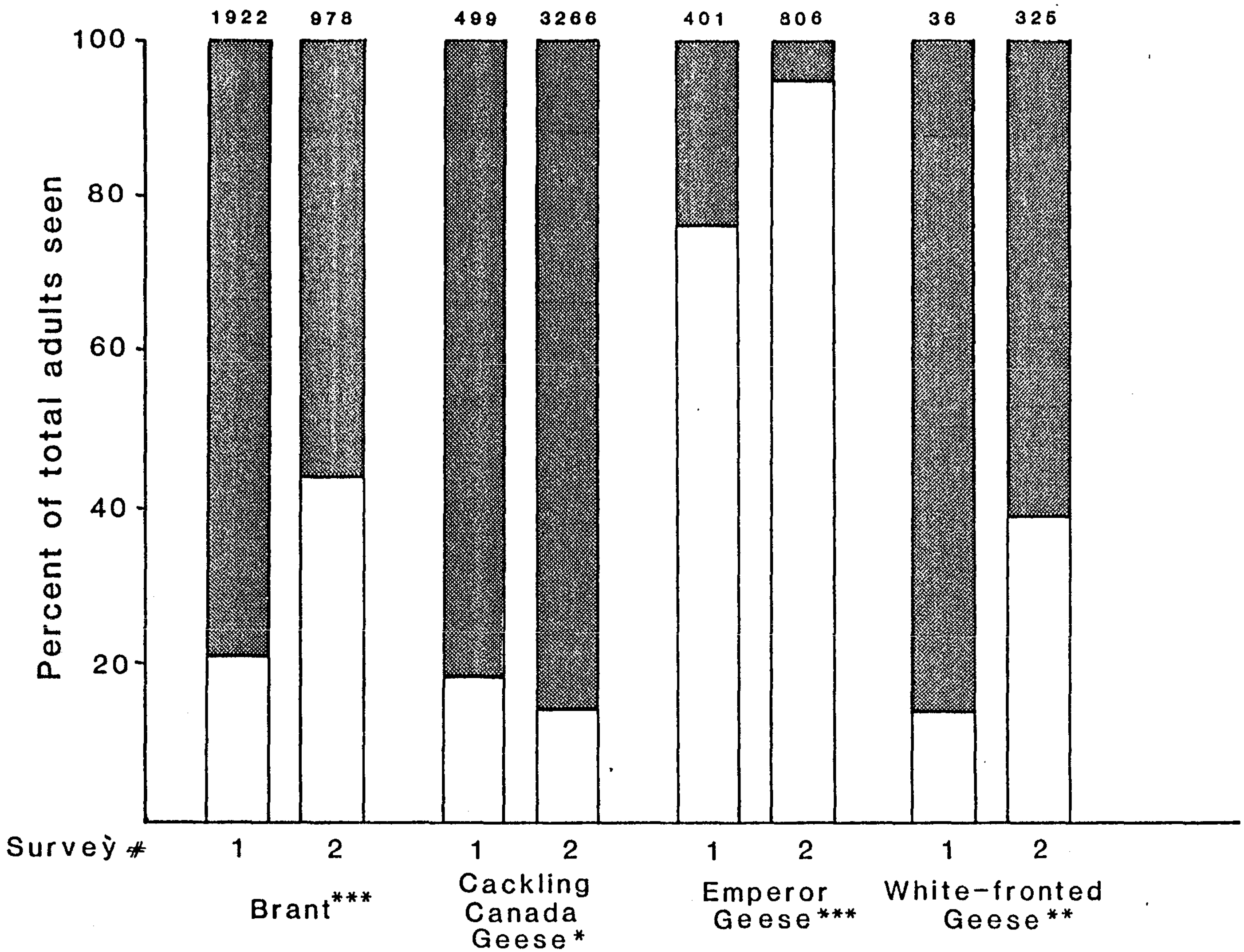

Figure 6. Percent of all adult geese observed during two aerial surveys that were in flocks with young (open bars) and in flocks of only adults (solid bars). Adults in flocks for which we could not determine the presence or absence of young have been excluded. Numbers above bars are the total number of adults included in analysis. Number of stars indicates the level of significance of the difference for each species between surveys (Chi-square test): * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

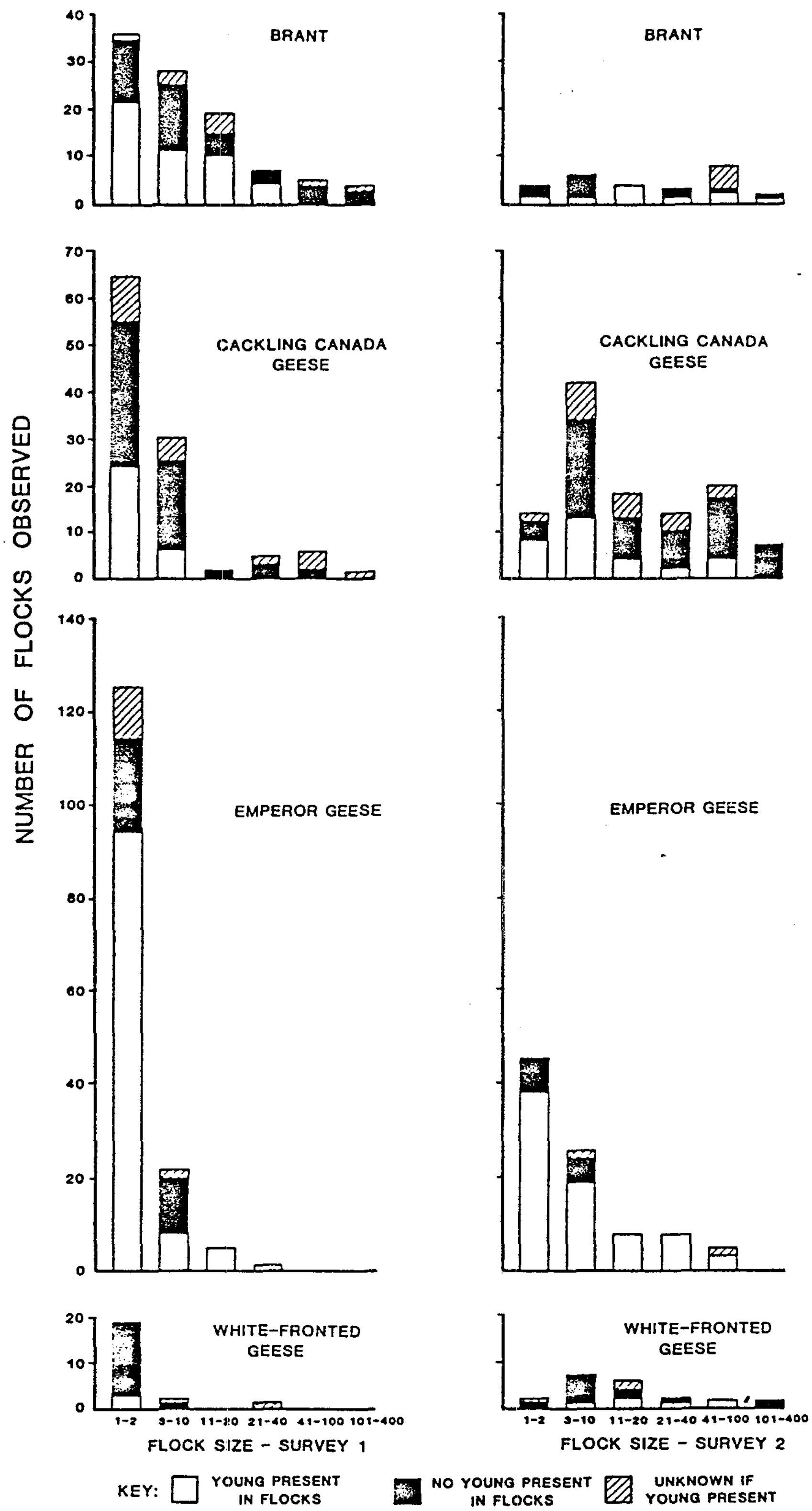

Figure 7. Size distribution of flocks of brant, cackling Canada, emperor and white-fronted geese with and without young during the first (6-11 July) and second (25-28 July) aerial surveys in 1985.

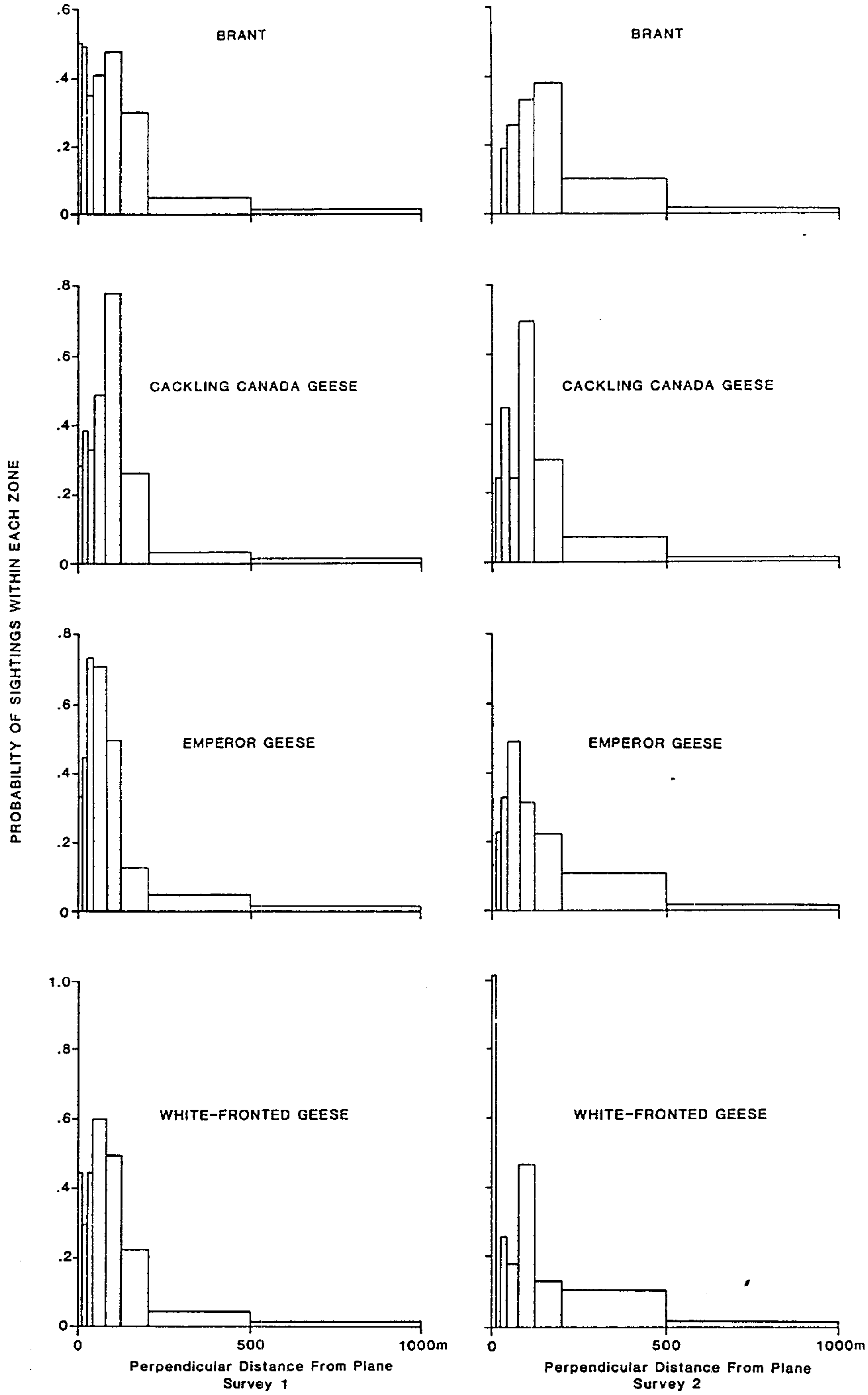

Figure 8. Percent probability of sighting a flock of brant, cackling Canada, emperor or white-fronted geese within each of eight transect zones during two aerial surveys in brood-rearing. The boundaries of each zone are given in Methods. The areas of each histogram add up to 100% probability.

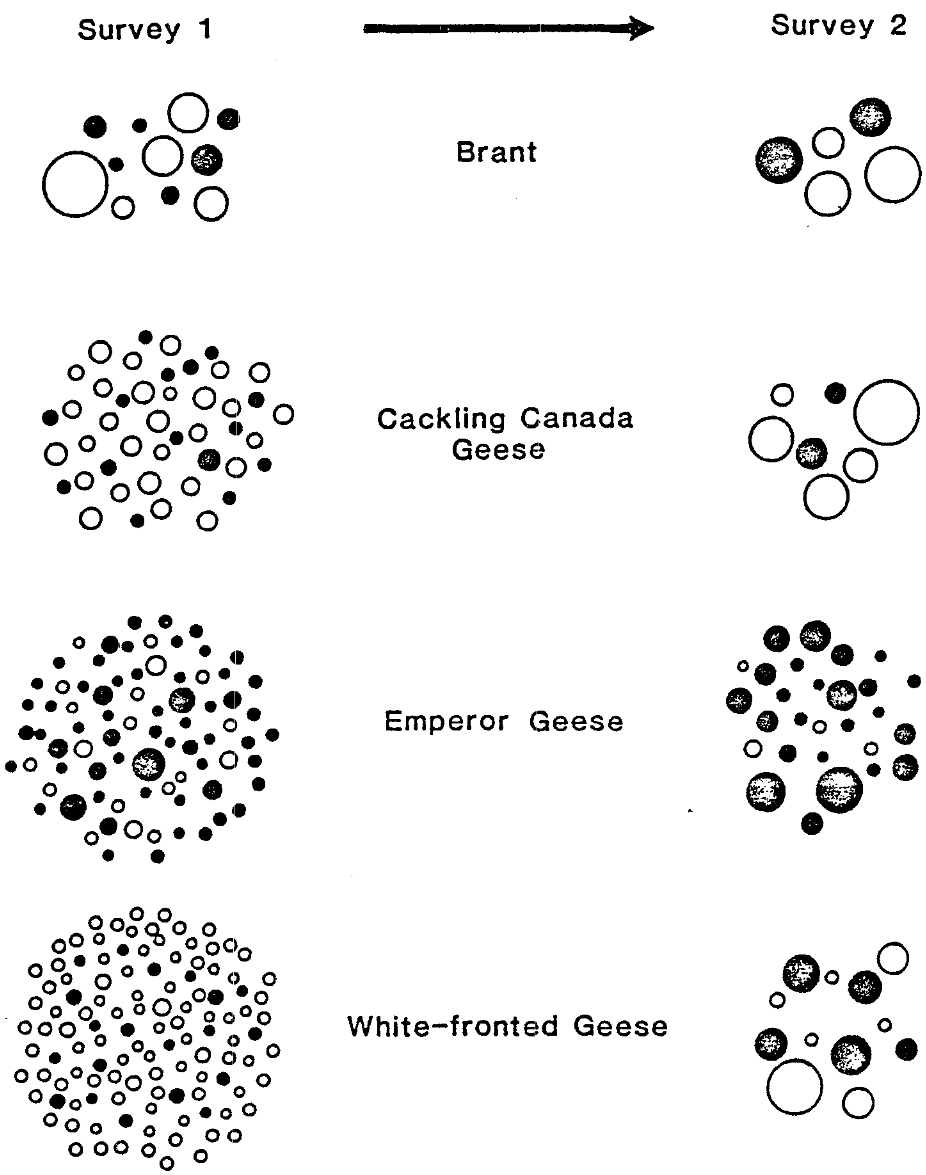

Figure 9. Schematic representation of typical flocking patterns shown by four species of geese during early (survey 1) and late (survey 2) brood-rearing in 1985. Solid circles show flocks with young; open circles, flocks without young. The area of each circle is proportional to the size of the flock, with the smallest representing one bird and the largest, 100 birds. Each group depicts a typical distribution of 250 adults of each species in flocks of various sizes with and without young. These diagrams illustrate only typical size and composition of flocks, not geographical distribution or density.