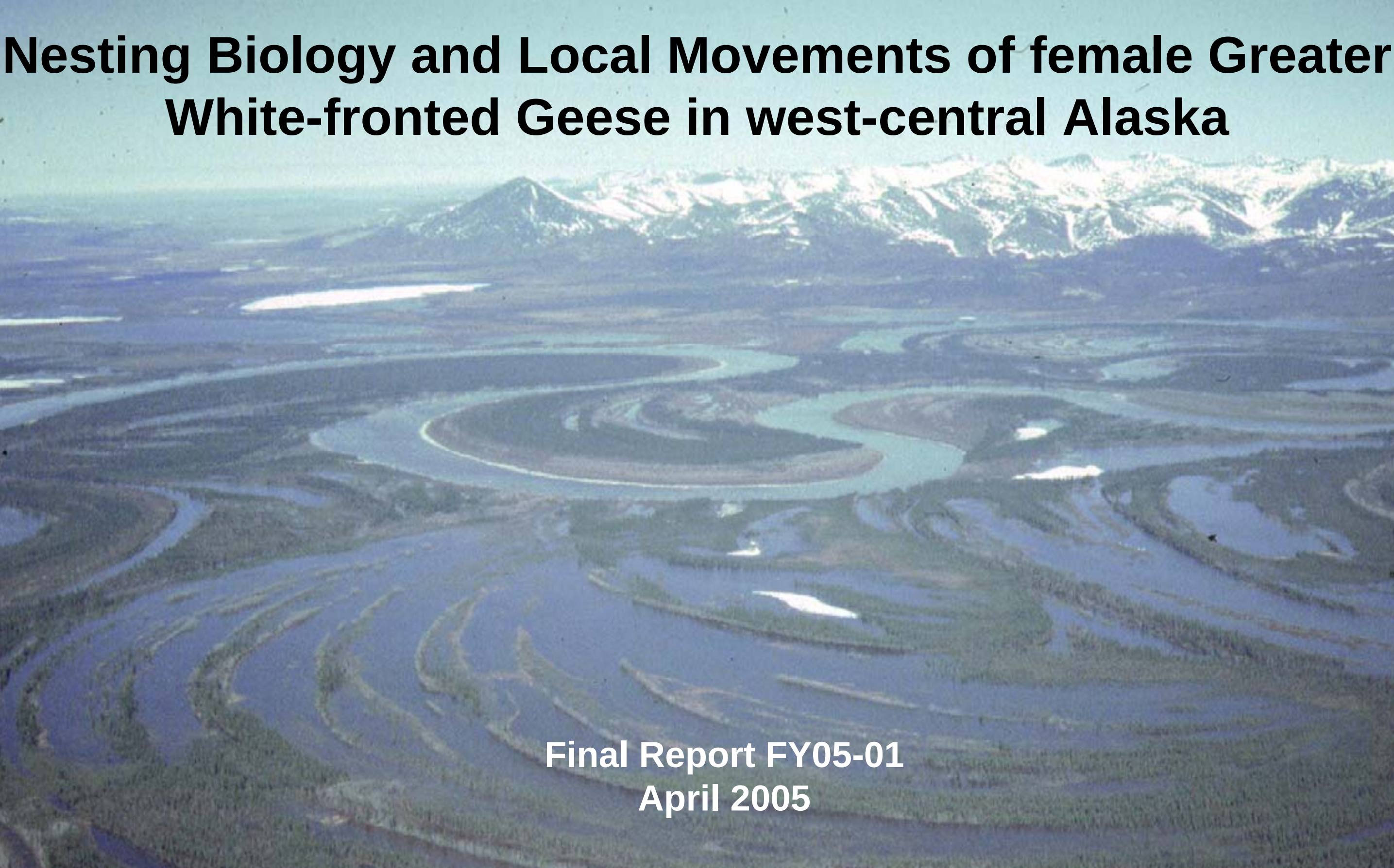
Nesting Biology and Local Movements of female Greater White-fronted Geese in west-central Alaska



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NESTING BIOLOGY AND LOCAL MOVEMENTS OF FEMALE GREATER WHITE-FRONTED GEESE IN WEST-CENTRAL ALASKA

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ABSTRACT

During the 1990's abundance of Greater White-fronted Geese (*Anser albifrons*) that nest in west-central Alaska declined. This segment of the Mid-continent population is unique because it nests in the boreal forest and taiga, and has an earlier breeding and migration chronology than its more abundant tundra-nesting counterpart. We initiated a study in 1994 to determine nesting and brood-rearing habitat, evaluate potential effects of flooding on productivity, and provide preliminary information on predation. Molting females (n=92) that were likely to have bred near their molting area (as indicated by brood-patch) were fitted with VHF radio transmitter collars at three study areas along the Koyukuk, Kanuti and Innoko Rivers in west-central Alaska. Locations of marked geese were determined by aircraft searches during the summers of 1995-98 and 2002-04. Of the 92 radio-marked females, 41 returned to the study area in subsequent years; 25 attempted nesting, and 14 reared broods. Four of these geese returned to nest close to the site of the previous year's nest; two nested within 41 m. Eight of the 92 radioed females died of predation on the breeding grounds. Thirty-three nests were located, 22 by radio, 11 from nest searches. Nest initiation averaged 11 May, while hatching averaged 13 June. A third of the nests were in uplands not susceptible to flooding. Most nests (55%) were in Open Low Scrub habitats; 35% were in Needleleaf Forest and Woodland habitats, and 10% were in Graminoid-Herbaceous Meadows. Nests were often equidistant from large waterbodies and were usually on a small hummock or near the base of a shrub or tree. Nests averaged 273 m from the nearest waterbody, and 4.6 km from nearest river. Brood-rearing habitat included a greater proportion of Water, Graminoid and Low Scrub land cover classes than other available habitat. Riparian wetlands were important to brood-rearing. The nest site was always located on the periphery of the brood-rearing home range. Distance from nest site to the center of the brood-rearing home range averaged 4.3 km (SE=0.7). Brood-rearing area averaged 21 km^2 (SE=7). Geese that nested in uplands tended to move their broods a longer distance from the nest to the brood-rearing area. Departure from the brood-rearing area to the pre-migratory staging area occurred in early August. Interior Alaska white-fronts marked along the lower Koyukuk River made a northwesterly pre-migratory staging movement to estuaries of the Kotzebue Sound coastline before migrating southeastward to Canada. White-fronts marked along the upper Koyukuk, Kanuti, and Innoko Rivers migrated directly to the southeast. Fall departure from west-central Alaska was usually complete by the end of August.

Keywords: *Anser albifrons frontalis,* Greater White-fronted Goose, nesting, brood-rearing, staging, predation, Koyukuk River, Kanuti River, Nowitna River, Innoko River, Selawik River, Kotzebue Sound

INTRODUCTION

The Mid-continent population of Greater White-fronted Geese breeds throughout tundra habitats from Hudson Bay in Canada to the North Slope of Alaska, and south into boreal forest and taiga of interior and northwest Alaska (Bellrose 1980, Ely and Dzubin 1994, Nieman et al. *in prep*.). Greater White-fronted Geese from interior and northwest Alaska differ from geese in other portions of the mid-continent population by their nesting habitat, which is mainly within the boreal forest and taiga or forest-edge, and by an earlier nesting phenology, relative to their tundra-nesting counterparts (Spindler et al. 1999, Ely and Schmutz 1999). Greater White-fronted Geese breeding in interior and northwest Alaska migrate earlier in spring and fall and use a more southerly and westerly wintering area that extends into the highlands of northern Mexico, compared to tundra-nesting White-fronted Geese (Ely and Schmutz 1999, Nieman et al. *in prep*).

Declining abundance of Greater White-fronted Geese in parts of interior Alaska, in the 1990's (Spindler et al. 1999) prompted a study of survival rates using band recovery analysis. From that work, Ely and Schmutz (1999) reported lower annual survival of interior and northwest Alaska-banded White-fronted Geese relative to North Slope Alaska and Canadian segments of the Mid-continent population. Reasons for the regional decline in abundance and reduced survival in the 1990's were unknown, but Spindler et al. (1999) and Ely and Schmutz (1999) hypothesized it could be a result of earlier nesting and migration of the interior and northwest Alaska White-fronted Geese, relative to the tundra-nesting segments of the population. Possible factors influencing abundance on the breeding grounds include flooding of riparian areas (suppresses productivity) or subsistence hunting and predation (reduces recruitment and survival). Therefore, we sought to describe Greater White-fronted Goose breeding ground characteristics and conditions in west-central Alaska. Objectives of this study were to identify the preferred nesting and brood-rearing habitats; determine breeding chronology and susceptibility of nests to flooding; describe movements of female Greater White-fronted Geese and their broods; and evaluate return rates, mortality, and predation on the breeding grounds.

STUDY AREA AND METHODS

Study area

The study area included portions of the Innoko, Nowitna, Kanuti, and Koyukuk river drainages in west central Alaska (Figure 1). These river valleys include a diverse mosaic of boreal forest and scrubland vegetation types interspersed with numerous riparian floodplain and non-riparian bog wetlands. The study area was expanded to include the coastal estuaries of Kotzebue Sound in northwest Alaska once it was determined that some geese moved to the coast for pre-migratory staging. River floodplains draining into these estuaries include the Kiwalik, Buckland, Selawik, Kobuk and Noatak Rivers. More detailed descriptions of habitats using satellite-derived imagery are given for the west-central Alaska areas by Talbot and Markon (1986, 1988) and for Kotzebue Sound by Craighead et al. (1988).

Capture and relocation

Geese were captured during the molt in July 1994, 1995, 1996, and 2002. Capture methods included drive trapping, assisted by a minimum of three float-equipped airplanes as described by Lobpries (1980). Ground crews assisted by a boat and a dog captured molting geese along the Kanuti River in 1996 (Martin 1999). To increase the likelihood that relocation efforts might lead to a nest in the subsequent spring, we only marked female geese with a brood patch. A 50-gram VHF radio transmitter (ATS Model number 3630) was affixed with epoxy to a 42-mm inside diameter plastic neck collar (Hines at al. 1999). Transmitters included a duty cycle timer programmed to transmit only during months that geese were expected to be on the breeding grounds, which extended battery life up to three nesting seasons. Geese were relocated following capture using aircraft radio-telemetry techniques (Samuel and Fuller 1994). Relocation flights generally occurred weekly between late April and mid-August. At each relocation, coordinates were determined by GPS. Flock size, brood size, and molting status were recorded whenever possible. An aerial determination was made for wetland habitat type (mud bar, sand bar, recently vegetated mud bank, older vegetated mud bank, river channel, slough channel, oxbow connected to river, oxbow not connected to river, wetland complex connected to river, and wetland complex not connected to river) estuary). Special efforts were made to search for missing radioed birds in areas well beyond the capture locations. Intensive aerial searches were conducted within 100 km of all capture locations. Additional intensive searches were conducted in the Selawik, Kobuk, and Noatak River drainages; Northern Seward Peninsula; North Slope from Prudhoe Bay west to Barrow and south to Umiat; Yukon Flats; upper Tanana River basin; Yukon River floodplain from Tanana to St. Mary's; all of Nowitna NWR and surroundings; Melozitna River drainage; the entire Innoko River basin; and the upper Kuskokwim River drainage (*see* Figure 1). While conducting the extensive statewide aerial transects for the Alaska-Yukon Waterfowl Breeding Population Survey, crews of the USFWS Division of Migratory Birds scanned for missing birds across Alaska and Yukon during 1995, 1996 and 1997.

When relocation flights had determined that most radioed females were stationary, an indication that nesting was in progress, a ground telemetry search was conducted to locate incubating females on nests. Nest visits were timed late in the incubation period to minimize possible abandonment. In an effort to find additional nests, ground crews (up to four individuals and a dog), searched the vicinity near known nest sites. Nest site characteristics were recorded following the techniques described by Densmore et al. (*in prep*). Field description of vegetation near and surrounding the nest followed the Alaska Vegetation Classification (Viereck et al. 1992). Nest initiation dates were estimated by floating eggs and backdating (Westerkov 1950, Barry 1967).

Analysis

For each year post-marking, apparent return rates (the ratio of birds returning to the study area each year to the total in the radio-marked sample) were determined by methods described by Marshall et al. (1999). Brood rearing ranges were delineated by including all location points that occurred within the nesting and brooding-molting periods as determined from aerial and ground observation. Minimum convex polygon (MCP; Mohr and Stumpf 1966, Samuel and Fuller 1994) home ranges were determined during the brood-rearing period. The MCP ranges were generated using the animal movement extension in Arc View (Hooge and Eichenlaub 1997, Environmental Systems Research Institute, Inc. 2002). Availability of habitat was determined from 30 m pixel-scale Landsat digital land cover imagery (prepared by U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and Ducks Unlimited, Inc., 2002). Imagery from separate projects to map each of Koyukuk, Nowitna, Kanuti, Northern Innoko, Selawik and Innoko NWRs and their surroundings was merged into a single land cover map which totaled 20.4 million ha. Available habitat was defined as habitat within the elevation utilized by geese (Johnson 1980, Aebischer et al. 1993). A digital elevation model of Alaska with 300 m pixel scale was clipped to include only areas within the range of elevations observed in the goose brood rearing home ranges. Elevation clipping indicated available habitat of 14.2 million ha. The merged imagery table was imported into a spreadsheet and percentage of each vegetation class was calculated.

To analyze brood-rearing habitat use, the MCP home range boundary for each goose was overlaid on the Landsat imagery and the land cover types within each home range were clipped using the ArcView grid tool extension (Environmental Systems Research Institute, Inc. 2002, Jenness 2004). The table for each new grid from the MCP was exported to an Arc View database file and the percentage of each land cover type was calculated. The 52 land cover classes occurring with the sample of MCP grids were lumped into 10 classes (Deciduous Forest, Emergent Graminoid, Graminoid, Mixed Needleleaf/Deciduous, Needleleaf, Low Scrub, Tall Scrub, Tundra, Water, and Other [bare ground, mud, sand rock scree, fire scars]). Habitat selection was determined by taking the difference between the proportion of each class included within a brood rearing range (use) and the proportion of each class in the surrounding area (availability). Averaged over all ranges, a positive difference indicated selection for the given habitat and a negative difference indicated selection against a given habitat (Pietz and Tester 1983, Thomas and Taylor 1990). Statistical significance of these selection differences was tested with analysis of variance (ANOVA) and Tukey’s multiple comparisons (SPSS 1997). For analysis of habitat selection we assumed that inclusion of a habitat class within a brood-rearing range polygon represented “use” of that habitat, however, we recognized that the extent of use within polygons could vary from rarely used sites to sites that are used daily.

For each brood-rearing range we determined the distance from the nest site to the center of the range using GIS-determined centroids. Distance between each goose nest site and its corresponding brood-rearing centroid was calculated using the ArcView Animal Movement extension (Hooge and Eichenlaub 1997).

RESULTS

Capture locations and general movement patterns of marked birds

A total of 92 female Greater White-fronted Geese was captured and marked for this study: 1994- lower Koyukuk River (12); 1995- lower Koyukuk River (30), Kanuti River (20); 1996- Todatonten Lake (10); 2002- Innoko River (20). The lower Koyukuk capture sites were located south and east of Huslia (Willow Lake, south to lower Dulbi River and oxbow lakes near Three Day Slough) as described by Lobpries (1979). In the upper Koyukuk River drainage, marking occurred along the Kanuti River and at Todatohnten Lake in 1996 as described by Martin (1999). In 2002 capture efforts focused on the lower Innoko River-lower Iditarod River confluence (Innoko NWR) (n=20).

A total of 770 separate relocations of radio-marked geese was obtained from aerial relocation flights 1994-2004. We recognized five seasonal periods related to behavior and movement on the breeding grounds: (1) pre-nesting, from first spring observations until 15 May; (2) nesting- 16-May-10 June; (3) brood-rearing- 10 June-4 July; (4) molting and fledging- 5 July-7 August; fall staging- 8 August until departure on fall migration (Figure 2). Following capture in early July the radio-marked females generally remained in their molting areas until fledging and fall staging movements occurred in August (Figure 3). In spring, marked females were usually first detected on the nesting grounds, or in a location enroute to the nesting grounds. Nesting was documented on and/or near Koyukuk, Nowitna, Kanuti, and Innoko NWR's (Figure. 4). After the hatch, usually mid-June, brooding females remained within a brood-rearing area until fledging or loss of brood. We documented eight fall pre-migratory staging areas or migration stopovers used in August after fledging: Innoko-Iditarod River, Kotzebue Sound, Willow Lake, Todatonten Lake, Lower Nowitna River, Lake Minchumina, Minto Flats, and Yukon Flats.

Elevations utilized by marked geese (as determined by digital elevation model) ranged from 19 to 254 m, and 93% of all goose radio relocations were within this elevation range. Most (48) of the remaining locations (57) were at elevations under 19 m in the coastal staging areas.

Fidelity and return to nesting areas

Eight individuals were not detected by radio within two weeks after marking and were censored from further analyses. It is unknown how many of these geese were missing due to radio failures or immediate dispersal to unknown locations.

At Koyukuk, approximately half of the radio marked birds were detected on the study area the following year (Table 1). Half of these geese were found nesting the first year after marking. Fewer returns were detected in subsequent years. Return rates were similar among capture locations (Table 1).

Approximately half, (41 of 84) non-censored radio-marked female Greater White-fronted Geese were detected on the study area the summer after marking (Table 1, Figure 4). Just over a third (39%) of the returning geese were found nesting the first year after marking. Seventeen (20%) of the original 84 non-censored marked females were detected on the study area the second summer after marking, of which eight (10%) were found nesting. Three females (5%) were detected three years after marking, of which two (3%) were found nesting.

Four marked individuals were documented nesting in two or more years. Two of the four repeat nests were within 41 m of a previous year's nest site. The mean distance between nests of repeat nesters was 2.5 km (± 1 km SE). During three consecutive years one individual had nest sites located within 4.9 km.

Mortality

Mortalities included deaths from predation, hunting and unknown causes. Predation of radio-marked Greater White-fronted Geese by otters, foxes, and bears was documented. Local residents reported observations of Bald Eagle predation on adult geese and Northern Pike predation on goslings. We determined that eight (10%) of 84 non-censored marked individuals were killed by predators, while nine (11%) were killed by hunters (Table 2). There were five mortalities from unknown causes.

Breeding chronology

In the approximate center of the study area, average arrival date of Greater White-fronted Geese, based on long-term (n=21 years) observations at Galena, was 23April (± 1.2 SE). Initiation of nest incubation, figured by egg floating and backdating, ranged from 30 April to 21 May, with an average of 11 May (± 0.9 SE, n=31, Figure 5). Lower Koyukuk birds initiated nesting about a week earlier (mean = 9 May, n=20) than the more northern upper Koyukuk/Kanuti birds (mean = 17 May, n=5). Similarly, hatching was a week earlier on the lower Koyukuk (mean =11 June, n=20) compared to the upper Koyukuk/Kanuti (mean = 19 June, n=5). Average hatching date for all nests was estimated to be 13 June (± 0.9 SE, Figure 6). Two Nowitna nests were estimated to have hatched on 5 June and 15 June; the sole Innoko nest was observed hatching on June 5. Three nests were examined on the date of hatch (7 June 1995 near Dulbi River, 9 June 1998 at Birch Lake near Huslia, and 5 June 2004 near the confluence of Innoko and Iditarod Rivers).

Brood rearing began at hatching in early June (Figure 1). Molt typically began in the first week of July and fledging usually occurred by the first week of August. Daily counts of Greater White-fronted Geese at Willow Lake, near Huslia, began to decline during the first week of August as adults regained flight and their young fledged. Departure to staging areas occurred shortly after birds were flying.

Non-breeders and failed breeders began molting earlier than breeders. Failed breeders usually departed the nesting area within one to two weeks of nest failure and moved to a molting area by late June. For example, in 2003 four non-breeding or failed breeding geese were in nesting habitat on the Nowitna on 3 June, but by 24 June they were all located in molting flocks along the Innoko River near their capture locations the previous year. In 2004, two early June breeders observed on Nowitna were found at Innoko on 28June in molting flocks. A female that nested near Birch Lake-Willow Lake, in the lower Koyukuk in 1996, was found molting on 19 July near the Selawik River-Tagagawik River confluence. Non-breeders were usually observed able to fly by the second or third week of July. On average, fall staging movements were first detected by mid-August (mean=12 August ± 1 day SE, Table 3, Figure 2).

Nest searches

The average distance females flushed from the nest when observers approached was 6.0 m ± 0.1 m SE. Minimum flushing distance was 1 m and maximum was 50 m. Eleven nests were found by people or dogs searching, while 22 nests were found using radio-telemetry.

Productivity

Thirty-three nests were located for nesting studies (Figure 4, Appendices 1-4). Average clutch size was 5.5 ± 0.17 SE (Figure 8). Mean clutch size varied little among years from a low of 5.25 (± 0.48 SE, n=4) in 1995 to a high of 5.75 (± 0.25 SE, n=4) in 1998. The maximum number of nests found in a given year was 14 in 1996. We were able to check seven nests for hatching success in 1996; all appeared successful three weeks after the nest was found. The egg total on 29-30 May was 39; the egg membrane count on 21 June was 24, indicating an approximate hatching success of 61% (n=7).

Nest site characteristics

Most (55%) nests were in Open Low Scrub habitats; just over a third (35%) were in Forest and Woodland habitats; 10% were in Graminoid Meadows (Table 4). Open Scrub habitats included Mixed Shrub-Sedge Tussock Bog, Open Low Ericaceous Shrub Bog, and Open Low Shrub Birch-Willow Shrub Bog. The forested habitats included Black-Spruce-Tamarack Forest and Black Spruce Woodland. Meadows were Mesic Bluejoint or Mesic Bluejoint-Shrub with mixtures of sedges, horsetails, and minimal shrub growth. Six of the 33 nests were located in recent (<20 year old) burns. Locations and detailed descriptions of vegetation communities observed at each nest site are in Appendices 1 and 2.

Half (16 of 33) the nests were in floodplain locations that showed evidence of recent flooding (debris in trees or bushes, etc). Five nests were in the floodplain in areas that did not show evidence of flooding. Twelve nests (36%) were in upland areas not susceptible to flooding. Nests were usually not close to permanent water bodies (273 m ±65 m SE, Appendix 3), and, frequently, nests were conspicuously equidistant from several large waterbodies. The most frequent type of proximal waterbody was a lake, followed by small pond, small creek, wet meadow, slough, and river. The average distance to nearest active river channel was 4.6 km (± 0.4 km SE).

As noted above, nests were in generally open habitats that were often surrounded by denser shrub or forest types. Overhead cover averaged 7% (± 2% SE). The nearest tree averaged 148 m (± 33 m SE) from the nest. The nearest tree was most often *Betula papyrifera*, followed by *Picea mariana* and *P. glauca*. Diameter of nearest tree averaged 10.6 cm (± 1.6 cm SE); height averaged 8.7 m (± 1.1 m SE). Nests were often on a slight mound or hummock (n=10), or at the base of a shrub clump (n=13); the remainder were either in the open or within dense shrub clusters. The distance of nearest shrub to nest averaged 1.1 m (± 0.4 m SE). In order of occurrence, most frequent nearest shrub species were: *Betula glandulosa/nana, Myrica gale, Chamaedaphne calyculata, Ledum decumbens* and *Salix* (*S. bebbiana, S. planifolia, S. glauca*). Nearest shrub height averaged 1.0 m (± 0.3 m SE), and stem diameter averaged 0.9 cm (± 0.2 cm SE). Ground cover within a 1m radius of nests was comprised of Moss/Lichen (32.3 % ± 5% SE), Shrubs (31.6% ± 4% SE), dead graminoids (19.3% ± 4% SE, and live graminoids (10% ± 3% SE).

Brood-rearing areas

Nineteen brood-rearing areas of radio-marked Greater White-fronted Geese were located, and for ten of these we were able to obtain >10 locations during the brood-rearing period (Figure 9). Marked females moved their broods some distance from the nest site. The mean distance from the nest site to the center of these estimated brood-rearing ranges was 4.3 km (± 0.7 km SE). Average area encompassed by these ranges was 21.0 km^2 (± 6.9 km^2 SE). The nest site was frequently at an extreme end of the brood rearing range (Figure 10). If the nest was at an upland site not within river floodplain habitats, the brood was moved to the floodplain (n=11 geese). In the area of highest nesting density, east of the Koyukuk River near Huslia, the brood rearing areas of five geese overlapped in the same year, and all of these ranges included at least a portion of Willow Lake (Figure 10). Also, in the same area, two geese utilized the same brood-rearing area in a subsequent year. We also observed one goose along the Kanuti River that used the same brood-rearing area in three successive years.

Brood-rearing habitat

Wetland habitat use. A majority of relocations during the brood-rearing period (62%), and throughout the summer (56%), occurred at wetland complexes connected to a river (Table 3). River-connected oxbow lakes, and wetland complexes not connected to rivers, were also frequently used. Wetland habitats with varying water levels, such as sloughs and river-connected oxbow lakes ("drawdown lakes") with extensive areas of re-vegetating mudflats appeared to offer a steady supply of new growth of grasses, sedges, rushes and horsetails in late June-July as the water levels receded following late May-early June high water. We also observed frequent use of lakes and wetlands with complex shoreline patterns and drained-lake basins with extensive mudflat shores in areas without a proximal river connection. *Calamagrostis canadensis* Bluejoint Meadow was the most frequently used wetland vegetation type (discernable from the air) during brood-rearing (49%), and during the entire summer (33%). The next-most frequently used habitat types during brood-rearing were Open Low Scrub/Graminoid Meadow mixture and Black Spruce Woodland (Table 4).

Land cover habitat selection. During the brood-rearing period, female radio-marked Greater White-fronted Geese used land cover classes in proportions that differed significantly from their availability (ANOVA, $p < 0.001$, Tables 7, 8). Brood-rearing areas contained a greater percentage of Water, Herbaceous-Graminoid Meadow and Low Scrub cover types than surrounding available habitat (Table 8, Figure 11). Conversely, brood rearing areas contained less Needleleaf Woodland/Forest, Deciduous Forest, Tundra, and Tall Scrub cover types than the surrounding available habitat.

Fall Staging

For most radio-marked Greater White-fronted Geese a fall pre-migratory staging movement of at least 20 km from the molting area was detected by mid-August (mean August 12 ± 1 day SE). Most (83%) radio-collared white-fronted geese marked on the lower Koyukuk made a pre-migratory staging movement to the Kotzebue Sound coastline, a distance of 220-320 km to the northwest away from their ultimate fall staging areas in Prairie Canada (Table 3, Figure 3). In contrast, none of the upper Koyukuk (Todatonten and Kanuti), nor Innoko radio-collared birds were documented making a staging movement away from the fall migration direction. We identified Todatonten Lake as a main molting and staging site for geese of the upper Koyukuk but we also observed three individuals staging or in migration stopover in riparian areas along the Yukon River near the villages of Beaver and Stevens Village (Figures 1 and 3 2). Similarly, females radio-marked at Innoko molted and staged there, and appeared to move directly towards their ultimate migration route. By 21 August, 2002, two Innoko marked geese were observed on Minto Flats, one was detected on the lower Nowitna River, and one was observed near Kaiyuh Slough.

DISCUSSION

Fidelity and return to nesting areas

Annual return rates of about 50% for our sample of radio-marked female Greater White-fronted Geese were surprisingly consistent between the two main breeding areas studied, Koyukuk and Kanuti, and the primary molting area studied, Innoko. This occurred even though the first interval from marking until subsequent nesting season included four different years, with presumably different overwinter survival conditions. The pattern for nesting diverged: for the two main breeding areas studied, Koyukuk and Kanuti, about a fourth of the marked sample nested in the first nesting season, while only ten percent of the Innoko-marked sample nested in the first nesting season. This was expected because the Innoko was not believed to contain a large breeding population, but rather a molting area that supports birds from widely dispersed breeding areas of interior Alaska (Oates and Klosiewski 1993, C.R. Ely, unpubl. data). In general, Greater White-fronted Geese show a high degree of natal philopatry and fidelity to breeding and molting sites (Ely and Dzubin 1994).

Comparative return rate data for Greater White-fronted Geese are lacking, however, our return rates were lower than those observed for Emperor Geese and Canada Geese in Alaska. Hupp et al. (*in prep.*) estimated return rates of 56-88% for 316 female Canada Geese marked in Anchorage (rates varied mostly by year and not by type of transmitter implanted). Among 136 female Emperor Geese marked on the Yukon-Kuskokwim Delta, Hupp et al. (*in prep*.) observed a return rate of 68%, of which 26% nested. The estimated Emperor return rate was higher but the percent of marked birds returning to nest was similar to that observed in this study. Our return rates were slightly higher than those reported for female mallard and gadwall dabbling duck species (Lokemoen et al. 1990, Johnson et al. 1992) but lower than those reported for two seaduck species Common Goldeneye (Eadie and Lumsden 1995) and Harlequin Duck (Robertson et al. 2000, and Goudie and Jones 2003).

Survival and Mortality

We observed nearly equal number of deaths due to predation (n=8) during the summer as hunting mortalities (n=9) determined by band and collar recoveries year-round. Using banding data from the 1990's Ely and Schmutz (1999) calculated an annual survival rate of ~0.60, however, they cautioned that this rate could be imprecise due to low reporting rate, and/or, artificially low due to neck collar-related mortality (Alisauskas and Lindberg 2002). Hines et al. (*in prep*) and Schmutz (2003) suggested that the low survival rate could stem from hunting mortality or a combination of non-hunting mortality factors such as predation, disease, and collar effects. Survival rates of mid-continent Greater White-fronted Geese seem to be highly dynamic (Schmutz and Ely 1999, Alisauskas 2002 Schmutz 2003). Indeed, subsequent to this study, flyway-wide monitoring of the Mid-continent population began to show a widespread decline in abundance and survival after 2000 (Nieman et al. 2004, Alisauskas 2002, respectively), a reversal of an apparent flyway-wide increasing trend in the mid-1990's.

Breeding chronology

All stages of the Greater White-fronted Goose breeding cycle in west-central Alaska were approximately 3-4 weeks earlier than those reported for other Mid-continent breeders in arctic Alaska and Canada (Barry 1967, Ely and Dzubin 1994, Bromley et al. 1995). Peak nest initiation in the first half of May in west-central Alaska was similar to that reported for more southern locations in Alaska used by Pacific Flyway White-fronted Geese (e.g. Tule Greater White-fronted geese in Cook Inlet, and Yukon-Kuskokwim Delta, Ely and Dzubin 1994).

Productivity

Average clutch size of 5.5 eggs over the six years in this study was greater than the long-term mean clutch sizes observed elsewhere in the Alaskan and Canadian arctic and at the Yukon-Kuskoskwim Delta (Ely and Dzubin 1994). Our limited data on hatching success (~61%) also indicated good production. Long-term (1983-2004) age ratio data from July surveys indicated ~50% percent young along the Dulbi River (Koyukuk NWR), Kaiyuh Slough-Khotol River (Northern Innoko NWR) and Nowitna River (Nowitna NWR, Unpubl. goose productivity float survey data, Koyukuk/Nowitna NWR). The July productivity data suggest a level that is far greater that the 18-year mean of 23% young observed during fall staging in Saskatchewan (Ely and Dzubin 1994). Productivity, therefore, did not seem to be limiting abundance of Greater White-fronted Geese in west-central Alaska, and perhaps high recruitment has compensated for low survival.

Nesting and brood-rearing

Within our boreal forest-dominated study area Greater White-fronted Geese most frequently nested in Open Low Scrub followed by Forest/Woodland habitats and Graminoid Herbaceous Meadows. These habitats are in some ways similar in appearance to the shrubby, treeline and bog habitats of Pacific Flyway Greater White-fronted Geese in the Bristol Bay lowland (Ely and Dzubin 1994) and Tule Greater White-fronted Geese near Cook Inlet (Densmore et al. *in prep*.). The extent of shrub and woodland habitat used for nesting cover by these small population segments contrasts with the more open tundra habitats used by the majority of the Pacific and Mid-continent White-fronted Goose populations (Barry 1967, Ely and Raveling 1984, Ely and Dzubin 1994, Bromley et al. 1995).

The highest nesting density that we encountered was in a scrub bog habitat (Birch Lake-Willow Lake) of the lower Koyukuk River valley that receives periodic flood waters. The lower Koyukuk floodplain has experienced an extent of riparian flooding that we estimated may have influenced goose production in ten of the past 21 years, while the Nowitna and Northern Innoko (Kaiyuh) experienced such floods in only three of 21 years (Appendix 5). The Koyukuk receives most of its spring floodwaters as snowmelt from the Brooks Range (Meyer 1995, Brabets et al. 2000). Because of its northern latitude, the Brooks Range usually releases peak snowmelt in an intense short duration pulse from late May to mid- June. Such snowmelt flooding usually occurs well into the incubation period determined in this study. Except for occasional mid-summer glacial meltwater peaks and late summer rains, the Yukon, Tanana, and Kuskokwim Rivers usually receive their highest water levels from peak snowmelt that occurs by early May, which is well before the beginning of incubation. In the present study just over a third (36%) of nests were located in upland sites not subject to flooding. The upland nests we found were widely dispersed and may serve as a mechanism to maintain productivity in years when flooding occurs. Six of the 13 upland nest sites were located in recent wildland fire burns. Such burns locally improve vegetative productivity and open up the boreal Forest/Woodland vegetation enough to provide forest clearings sufficient for nesting of Greater White-fronted Geese. The influences of flooding and cyclic fire are widely recognized as important ecosystem driving forces in the interior (Viereck 1970, Johnson 1992) and it is possible that our observed use of these habitats was related to their increased productivity.

Average brood-rearing home ranges estimated in this study were large (21 km^2) and relatively far from the nest site (4.3 km) compared to the ranges (1.1 km^2) and distances (2.2 km) documented for Greater White-fronted Geese on the Yukon-Kuskokwim Delta by Ely et al. (1985). However, larger ranges and distances from nest to center of range were reported for Greater Snow Geese in the Canadian arctic (Hughes et al. 1994) and for Canada Geese in Washington (Eberhardt et al. 1989). In our study all nests were located some distance away from the center of the brood rearing range, which is similar to findings elsewhere for White-fronted (Ely et al. 1985, Densmore et al. *in prep*) and Snow Geese (Hughes et al. 1994). This behavior was particularly dramatic for two upland nesters that brought their broods 8 and13 km (in the lower Koyukuk and Kanuti areas, respectively) to reach riparian floodplain habitats where they reared their broods. We suspect this behavior may be an adaptation to reduce risk of nest flooding

(Ely and Raveling 1984), while utilizing relatively rich forage resources in the floodplains during brood rearing. This partitioning of space according to breeding stage may also minimize predation. Similarly, the pattern of nest establishment equidistant from waterbodies could be an effort to avoid predators along lakeshores (e.g. foxes and otters).

We found that brood-rearing areas contained a greater proportion of Water and Low Scrub and Graminoid land cover classes compared to available habitat. Densmore et al. (*in prep*) found that nesting habitats of Tule Greater White-fronted Geese near Cook Inlet, AK included more Low Shrub and Herbaceous classes than available habitat. Both studies suggested selection against Deciduous Forest, Needleleaf Forest/Woodland and Tall Shrub habitats.

Along the lower Koyukuk River, forage species documented in the diet of Greater White-fronted Geese during the brood-rearing period included: *Acrtophila fulva; Beckmannia erucaeformis; Calamagrostis canadensis; Carex aquatilis; C. rostrata; C. canadensis; Deschampsia caespitosa; Eleocharis acicularis; Eriophorum spp.; Equisetum fluviatile; E. arvense; Juncus arcticus; Rorippa palustris;* and *Senecio congestus* (Person 2001). We found that these species occur most frequently on the gradual shorelines of river-connected oxbow lakes (“drawdown lakes”) where extensive grazing lawns were observed in areas with the highest intensity of goose brood-rearing.

We documented brood-rearing ranges of five different radio-marked geese that overlapped one another in the same year and encompassed at least part of Willow Lake, a particularly rich floodplain area connected to the lower Koyukuk River east of Huslia. Willow Lake is adjacent to Birch Lake, the area of highest nesting density that we encountered in this study. Ely et al. (1985) did not observe overlap of brood-rearing home ranges of Pacific Greater White-fronted Geese nesting on the Yukon-Kuskowkim delta, but Hughes et al. (1994) did observe such overlap in Greater Snow Geese in the Canadian arctic.

Nest sites selected by Greater White-fronted Geese in west-central Alaska averaged 273 m from the nearest waterbody, while Densmore et al. (*in prep*) observed an even greater average distance to nearest waterbody (789 m) for Tule Greater White-fronted Geese. As with the Tule Geese, the interior Alaska Greater White-front Goose nests we found were frequently located on a small mound or hummock, or at the base of a shrub or tree. Floristic descriptions of the boreal forest and scrub bog habitats used by the Tule Geese south of the Alaska Range were strikingly similar to nest surroundings used by interior White-fronts in west-central Alaska; however, we observed greater overhead cover (7%) for interior Alaska nests compared to Tule nests (0.1%, Densmore et al. *in prep*).

Fall Staging

A majority of the lower Koyukuk birds moved in mid-August to stage along the coastal estuaries of Kotzebue Sound, a distance of 220-320 miles. In contrast, the upper Koyukuk, Kanuti, and Innoko birds, which were marked further inland, apparently staged in their molting area and migrated directly southeast, stopping briefly in wetlands and riparian habitats along Yukon and Tanana Rivers. Easterly and westerly molt migrations have been reported (Ely and Dzubin 1994), but opposite direction pre-migratory staging in fall has not been reported for Greater White-fronted Geese. Opposite direction pre-migratory staging along river deltas of the Kotzebue Sound area coastline was observed for Tundra Swans near Selawik, and similar to this study, the farther inland nesting swans did not stage, but instead migrated directly to the southeast (Spindler and Hall 1991).

The coastal estuaries of Kotzebue Sound used by Greater White-fronted Geese for fall staging contain extensive Halophytic Wet Grass Meadows of *Puccinellia phyrganodes, Carex ramenskii, C. subspathacea, C. mackenziei, C. Glareosa, Elymus arenarius,* and *Triglochin palustris* (Person 2001). These species were documented in the diet of staging Greater White-fronted Geese, however, Person (2000) did not find significant differences in August nutritive value of these coastal graminoids compared to those utilized and available to geese at the same time along the Koyukuk River. In the present study we observed large (50-300) flocks of Greater White-fronted Geese alternately grazing in the Meadows and flying to upland Tundra areas to feed on berries. Major plant species in the Tundra areas included *Eriophorum vaginatum, Ledum palustre, Sphagmum* spp. with the berry-producing *Vaccinium uliginosum, V. vitis-idaea, Rubus chamaemorous,* and *Empetrum nigrum* (Person 2001). We observed these berry producers at peak of fruiting along the coast in mid-August when geese were present. The same berry producing species also occur inland along the Koyukuk River valley but we observed the inland berry crops to have passed their prime production by mid-August. Also, berry-producing shrubs inland along the Koyukuk River tend to grow in denser scrub habitats which might subject foraging geese to a greater risk or predation relative to the more open Tundra habitats near the coast.

Management implications and recommendations

The decline in abundance of Greater White-fronted Geese observed in west-central Alaska during the 1990's was probably not related to poor production because this study documented adequate production and hatching success. While riparian flooding was recognized as a cause of reduced production, we also found that more than a third of nests occurred in areas not susceptible to flooding, a strategy that may allow the population to partially compensate for loss of production in years of riparian flooding. Overall, production monitoring efforts that occur late in the brood-rearing period (float and aerial surveys in July) documented age ratios of ~50% young that were probably sufficient to allow for population growth (Spindler et al. 1999).

Differences in hydrological patterns between the Koyukuk floodplain and other river floodplains in the study area are important to consider when planning future monitoring efforts. For example, the aerial surveys of nesting habitat and breeding pairs conducted by Division of Migratory Birds in mid-late May might note that minimal flooding has occurred on the Koyukuk at the time of the survey, and could prematurely conclude that it is a good year for production. A damaging flood event can still greatly suppress production along the Koyukuk and Kanuti Rivers two weeks after these surveys are complete. The refuge will need to keep Migratory Birds apprised of conditions that may change after the late May breeding pair survey. This is one important reason why the refuge should maintain the annual goose float surveys.

Riparian wetlands in the boreal forest region are important to many species of waterfowl, including Greater White-fronted Geese. It is crucial that wildlife managers work to maintain natural water regimen in these floodplains, because the annual flooding and seasonal variations in water levels in riparian wetlands ("drawdown lakes") may be critical to maintenance of productive brood-rearing habitat. Similarly, maintenance of a natural fire regime seems important as the clearings within Needleleaf Forest/Woodland juxtaposed near flood plain wetlands were used for nesting.

Predation and hunting were noted as equally important mortality factors in our radio-marked sample. It is possible that predation of nesting adults, combined with subsistence hunting on the breeding grounds and sport hunting further south in the flyway led to the population decline in the 1990's. Predation and hunting mortality may be highly dynamic and will likely need continuous monitoring through programs such as annual banding and periodic band recovery survival analysis. Similarly, the refuge should continue to monitor population trends and productivity and compare these to regional and continental trends.

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Table 1. Return of female greater white-fronted geese radio-marked in west central Alaska 1994-2002.

Period/Area	Koyukuk 1994,95	Kanuti 1996	Innoko 2002	Total
Radio-marked	42	30	20	92
Censored	1	7	0	8
Marked less censored	41	23	20	84
Returned following year	20 (49%)	11 (48%)	10 (50%)	41 (49%)
Nested following year	10 (24%)	5 (22%)	1 (5%)	16 (19%)
Returned second year	7 (17%)	6 (26%)	5 (25%)	17 (20%)
Nested second year	3 (7%)	3 (13%)	2 (10%)	8 (10%)
Returned third year	2 (5%)	1 (4%)	-	3 (5%)
Nested third year	1 (2%)	1 (4%)	-	2 (3%)

Table 2. Known mortalities, 1994-2004, of female Greater White-fronted Geese radio-marked in west-central Alaska, 1994-2002.

Factor/Area	Koyukuk	Kanuti	Innoko	Total
Radio-marked	42	30	20	92
Censored	1	7	0	8
Marked less censored	41	23	20	84
Killed by hunter[a]	3 (7%)	3 (13%)	3 (15%)	9 (11%)
Killed by predator[b]	7 (17%)	1 (4%)	0	8 (10%)
Unknown mortality[c]	4 (10%)	0	0	4 (5%)
Total mortality	14 (34%)	4 (17%)	3 (15%)	21 (25%)

[a] Determined by band recovery or returned collar.
[b,c] Determined by telemetry observations.

Table 3. Staging movements, 1994-2004, of female Greater White-fronted Geese radio-marked in west-central Alaska, 1994-2002.

Area	Koyukuk	Kanuti	Innoko	Total
Present before staging	36	23	20	59
Kotzebue Sound coastline	30 (83%)	0	0	30 (51%)
Yukon River, Yukon Flats	0	3 (13%)	0	3 (5%)
No staging detected	6 (17%)	20 (87%)	20 (100%)	33 (56%)

Table 4. Distribution of 33 Greater White-fronted Goose nests found in west-central Alaska, 1995-2004 according to Alaska Vegetation Classification (Viereck et al.1992) (includes 4 repeat nesters).

Viereck level IV Class	Description	Number of nests
	Forest and woodland	
I A 2 h	Open Needleleaf Forest: Black Spruce-Tamarack	1
I A 3 d	Open Needleleaf Woodland: Black Spruce	10[a]
	Scrub	
II C 2 b	Open Low Scrub: Mixed Shrub-Sedge Tussock Bog	1
II C 2 d	Open Low Scrub: Shrub birch-Ericaceous Shrub Bog	5[b]
II C 2 e	Open Low Scrub: Open Low Ericaceous Shrub Bog	10
II C 2 f	Open Low Scrub: Open Low Shrub Birch-Willow Bog	2
	Herbaceous	
III A 2 b	Mesic Graminoid Herbaceous: Bluejoint-Herb Meadow	1
III A 2 c	Mesic Graminoid Herbaceous: Bluejoint-Shrub Meadow	3[c]
Total		33

[a] Includes repeat nests of two individual geese.
[b,c] Includes repeat nest of one individual goose.

Table 5. Use of wetland habitat types by marked female Greater White-fronted Geese, according to season, based on aerial radio-telemetry relocations, 1994-2004. Highest frequency of use indicated by bold type.

Seasonal Category	Wetland Habitat type	Observations	%
Pre-nesting	Older vegetation on mud bank, taller than 0.25 m	2	6
	Recently vegetated mud bank, < 0.25 m tall	1	3
	River channel, flowing	2	6
	River oxbow, connected to river	1	3
	River oxbow, not connected to river	3	9
	Slough, slow current	3	9
	Wetland complex connected to river	**11**	**33**
	Wetland complex not connected to river	10	30
Nesting	Mud bar	3	10
	Recently vegetated mud bank, < 0.25 m tall	1	3
	River channel, flowing	4	13
	River oxbow, connected to river	1	3
	Wetland complex connected to river	**11**	**37**
	Wetland complex not connected to river	**10**	**33**
Brood rearing/Molt	Mud bar	2	1
	River channel, flowing	9	5
	River oxbow, connected to river	38	21
	Slough, slow current	2	1
	Wetland complex connected to river	**114**	**62**
	Wetland complex not connected to river	20	11
Fledging	River channel, flowing	4	14
	River oxbow, connected to river	3	10
	Slough, slow current	1	3
	Wetland complex connected to river	**18**	**62**
Staging	Recently vegetated mud bank, < 0.25 m tall	6	12
	River channel, flowing	5	10
	River oxbow, connected to river	2	4
	River oxbow, not connected to river	1	2
	Slough, slow current	1	2
	Wetland complex connected to river	**30**	**60**

All seasonal categories combined	Observations	%
Mud bar	5	2
River oxbow, connected to river	45	14
River oxbow, not connected to river	4	1
Older vegetation on mud bank, taller than 0.25 m	2	1
River channel, flowing	24	7
Recently vegetated mud bank, < 0.25 m tall	8	2
Slough, slow current	7	2
Wetland complex connected to river	**184**	**56**
Wetland complex not connected to river	48	15
Total	327	100

Table 6. Use of wetland vegetation types by marked female Greater White-fronted Geese, according to season, based on aerial radio-telemetry relocations, 1994-2004. Highest frequency of use indicated by bolded type.

Observation Categories	Vegetation type	Observations	%
Pre-nesting	Black spruce	3	9
	***Calamagrostis candadensis* grass meadow**	**13**	**39**
	Carex rostrata-aquatilis wet sedge meadow	3	9
	Equisetum-Carex	1	3
	Graminoid dwarf/low shrub	9	27
	Low shrub	1	3
	Tall shrub	1	3
	Tundra lake	1	3
	Upland willow-spruce	1	3
Nesting	Black spruce	13	16
	***Calamagrostis candadensis* grass meadow**	**31**	**38**
	Carex rostrata-aquatilis wet sedge meadow	9	11
	Equisetum-Carex	1	1
	Eriophorum vaginatum tussock meadow	2	2
	Graminoid dwarf/low shrub	19	23
	Low shrub	2	2
	Tundra lake	1	1
	Upland willow-birch	2	2
	Upland willow-spruce	2	2
Brood rearing/Molt	Black spruce	3	7
	***Calamagrostis candadensis* grass meadow**	**21**	**49**
	Coastal tundra	1	2
	Emergent *Carex* vegetation	1	2
	Equisetum-Carex	6	14
	Graminoid dwarf/low shrub	2	5
	Low shrub	1	2
	Tall shrub	4	9
	Upland willow-spruce	4	9
Fledging	*Calamagrostis candadensis* grass meadow	1	11
	Coastal tundra	**3**	**33**
	Emergent *Carex* vegetation	1	11
	Estuarine meadow	2	22
	Tundra lake	1	11
	Upland tundra	1	11
Staging	*Calamagrostis candadensis* grass meadow	4	11
	Carex rostrata-aquatilis wet sedge meadow	1	3
	Coastal tundra	4	11
	Emergent *Carex* vegetation	1	3
	Estuarine meadow	**24**	**67**
	Graminoid dwarf/low shrub	1	3
	Tall shrub	1	3

All seasonal categories combined	Observations	%
Black spruce	19	9
***Calamagrostis candadensis* grass meadow**	**70**	**33**
Carex rostrata-aquatilis wet sedge meadow	13	6
Coastal tundra	8	4
Emergent Carex vegetation	4	2
Equisetum-Carex	6	3
Eriophorum vaginatum tussock meadow	2	1
Estuarine meadow	27	13
Graminoid dwarf/low shrub	31	15
Low shrub	4	2
Tall shrub	6	3
Tundra lake	3	1
Upland tundra	7	3
Upland willow-birch	2	1
Upland willow-spruce	7	3
Total	209	100

Table 7. Brood rearing area habitat characteristics for 19 radio-marked female Greater White-fronted geese in west-central Alaska 1995-2004. Area and percent habitat composition of minimum convex polygon ranges is compared to overall habitat availability as determined by land cover classes within study area. The highest percentage of habitat class for each goose brood rearing area is shown in bold.

				Habitat use by land cover class									
Goose ID	**Year**	**n**	**Area (ha)**	**Deciduous Forest**	**Emergent**	**Herbaceous Graminoid**	**Low Scrub**	**Mixed Ndl/Decid**	**Needleaf Wodland**	**Other**	**Tall Scrub**	**Tundra**	**Water**
01	1996	15	1 015	0.01	2.28	11.78	35.05	0.03	5.87	0.00	0.67	0.00	**44.31**
04	1995	3	10	5.41	5.41	9.01	20.72	7.21	**38.74**	0.90	1.80	0.90	9.91
12	1995	6	12 114	3.30	1.75	3.39	12.74	3.64	**65.67**	0.07	1.48	0.85	7.11
15	1996	15	253	0.00	2.45	18.03	24.70	1.06	**50.43**	0.00	0.50	0.53	2.31
25	1996	15	487	14.71	1.74	6.79	13.10	12.34	**29.97**	0.41	3.53	0.94	16.48
29	1996	15	4 911	0.39	2.91	18.32	**41.07**	0.71	9.75	0.82	2.50	0.01	23.52
29	1998	10	1 258	0.34	3.91	15.27	**36.27**	0.32	8.81	0.00	2.00	0.03	33.06
30	1996	11	3 435	21.45	0.54	1.74	20.08	0.00	**33.71**	4.92	4.84	7.13	5.58
32	1996	7	3 941	0.40	2.54	12.84	**51.24**	0.62	15.25	0.01	3.91	0.02	13.17
39	1996	13	6 101	10.66	0.45	4.70	18.32	9.76	**42.37**	1.20	3.25	0.78	8.51
41	1996	14	994	0.01	3.03	9.48	30.41	0.05	5.91	0.00	0.61	0.00	**50.50**
41	1997	15	1 369	0.01	2.44	8.52	29.52	0.08	5.11	0.00	0.49	0.00	**53.83**
42	1996	16	813	0.01	1.75	9.84	28.66	0.02	4.28	0.00	0.55	0.00	**54.88**
45	1996	4	1 063	13.50	1.67	1.11	5.92	0.00	**73.04**	0.02	0.53	0.25	3.98
45	1997	6	393	0.50	1.01	0.41	**55.96**	0.00	11.78	11.25	10.98	5.95	2.17
50	1997	3	13	9.09	0.70	5.59	1.40	0.00	**74.83**	0.00	2.80	2.80	2.80
52	1996	6	379	7.81	1.00	7.48	**51.33**	0.00	14.02	0.02	4.03	8.04	6.26
53	1996	5	1 152	30.03	3.32	1.44	9.44	0.00	**37.11**	0.06	6.85	0.30	11.45
73	2004	3	272	**23.18**	0.00	4.13	21.63	0.00	19.18	0.00	12.50	9.19	10.19
	Mean	9.58	2 104	7.41	2.05	7.89	26.71	1.89	28.73	1.04	3.36	1.99	18.95
	SE		685.20	2.13	0.31	1.26	3.58	0.85	5.42	0.62	0.79	0.71	4.28
	95%C.I.			4.18	0.60	2.48	7.02	1.67	10.62	1.22	1.55	1.39	8.38
Available	**Habitat**			13.61	0.46	2.73	23.01	1.43	38.99	3.44	6.08	7.21	3.23

Table 8. ANOVA and multiple comparisons (Tukey) of difference between habitat use (brood rearing ranges of 19 marked female Greater White-fronted Geese) and available habitat in west-central Alaska 1995-2004. Differences based on percent habitat composition of minimum convex polygon ranges compared to overall habitat availability as determined by land cover classes within study area.

ANOVA				
Source	SS	DF	MS	F
Between groups	9133	9	1015	7.748
Within groups	23575	180	131	
Total	32708	189		

Tukey										
	Deciduous	**Emergent**	**Graminoid**	**Low Shrub**	**Mixed Ndl/Decid**	**Needleaf**	**Other**	**Tall Shrub**	**Tundra**	**Water**
Difference between use and availability	-10.26	-6.19	-5.22	-2.72	-2.40	0.45	1.59	3.70	5.15	15.92

Tukey similar groups

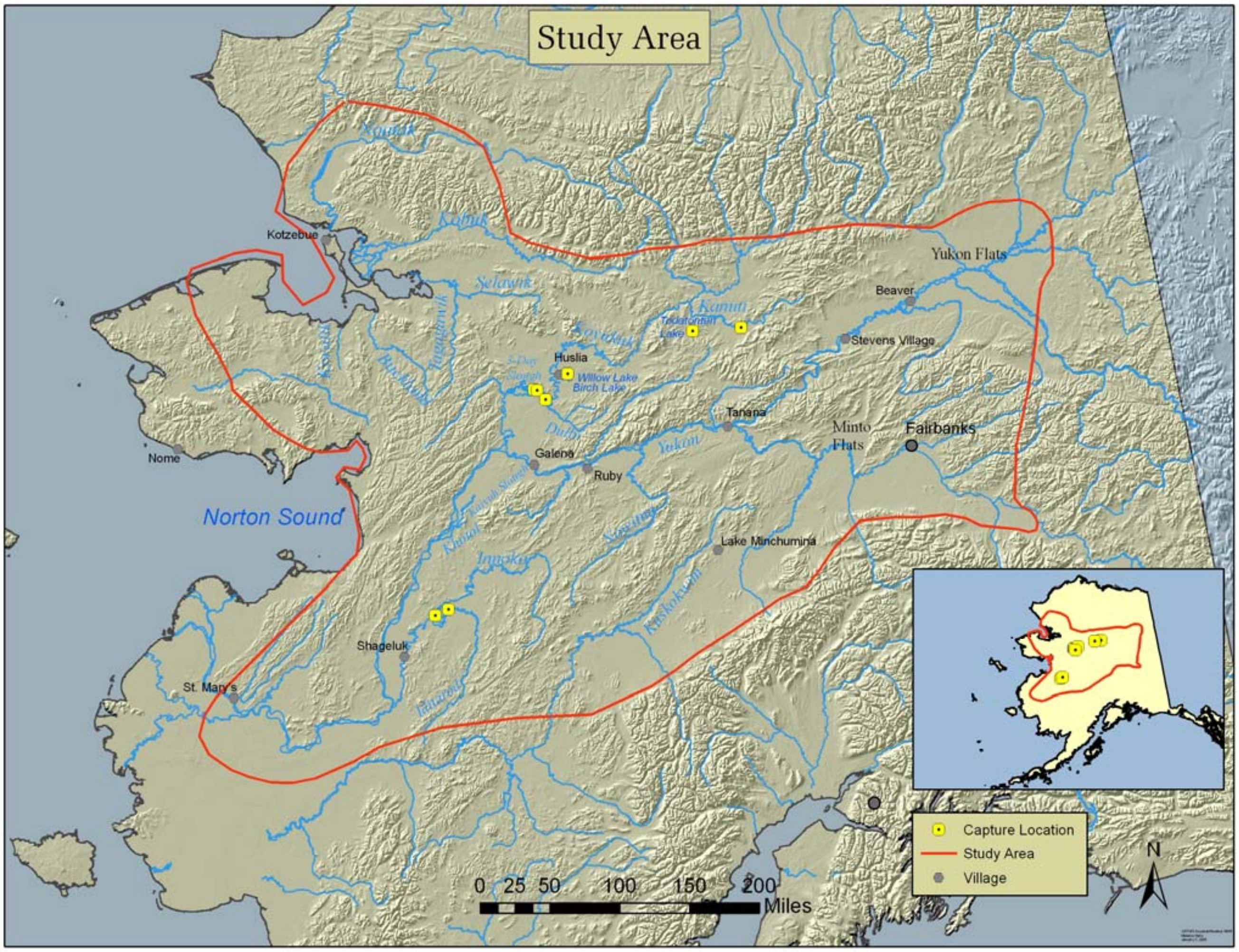


Figure 1 Study area, capture locations, and telemetry search area, west-central Alaska, 1994-2004.

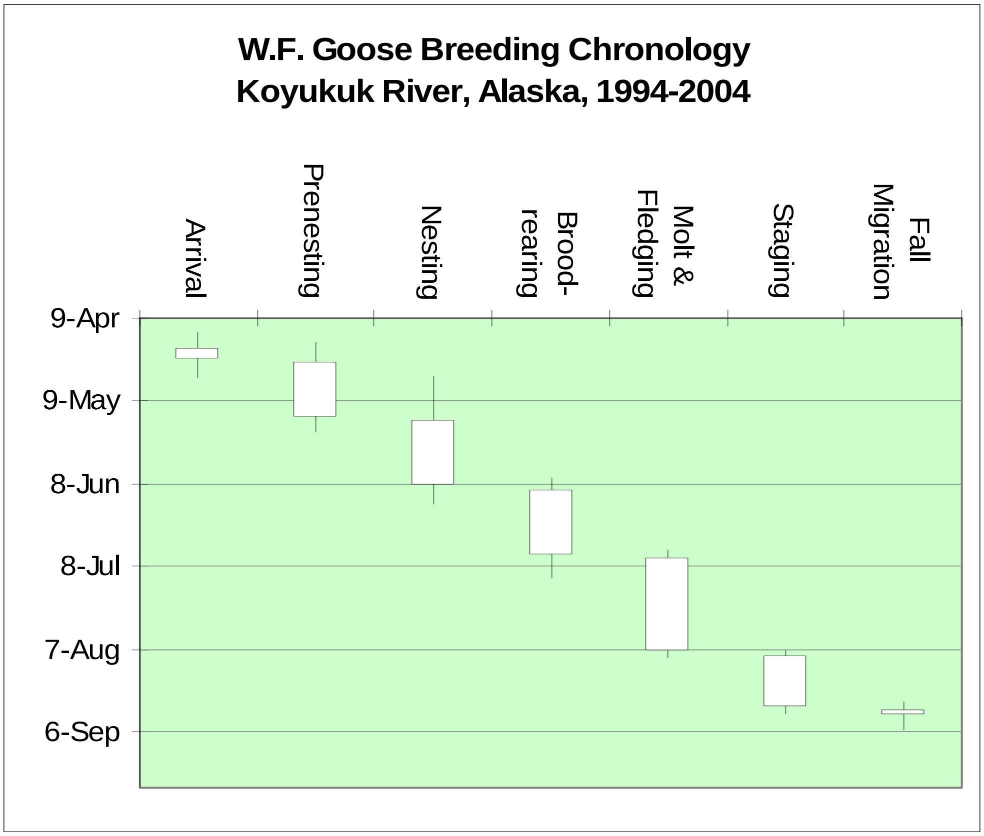


Figure 2. Breeding chronology of Greater White-fronted Geese, Koyukuk River, Alaska, based on radio-telemetry observations 1994-2004.

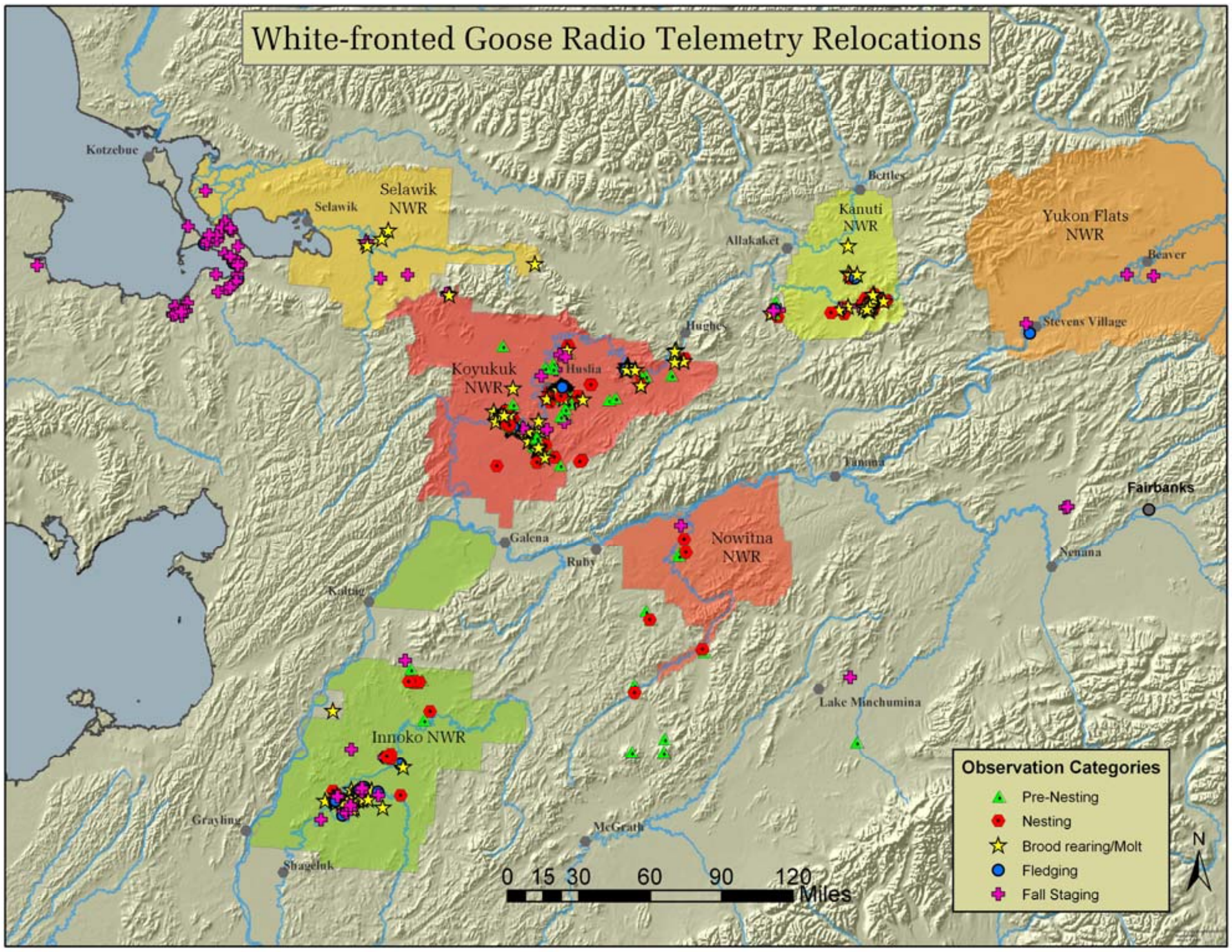


Figure 3. Study area and radio telemetry relocations, 1994-2004, of 92 Greater White-fronted Geese marked in west-central Alaska 1994-2002.

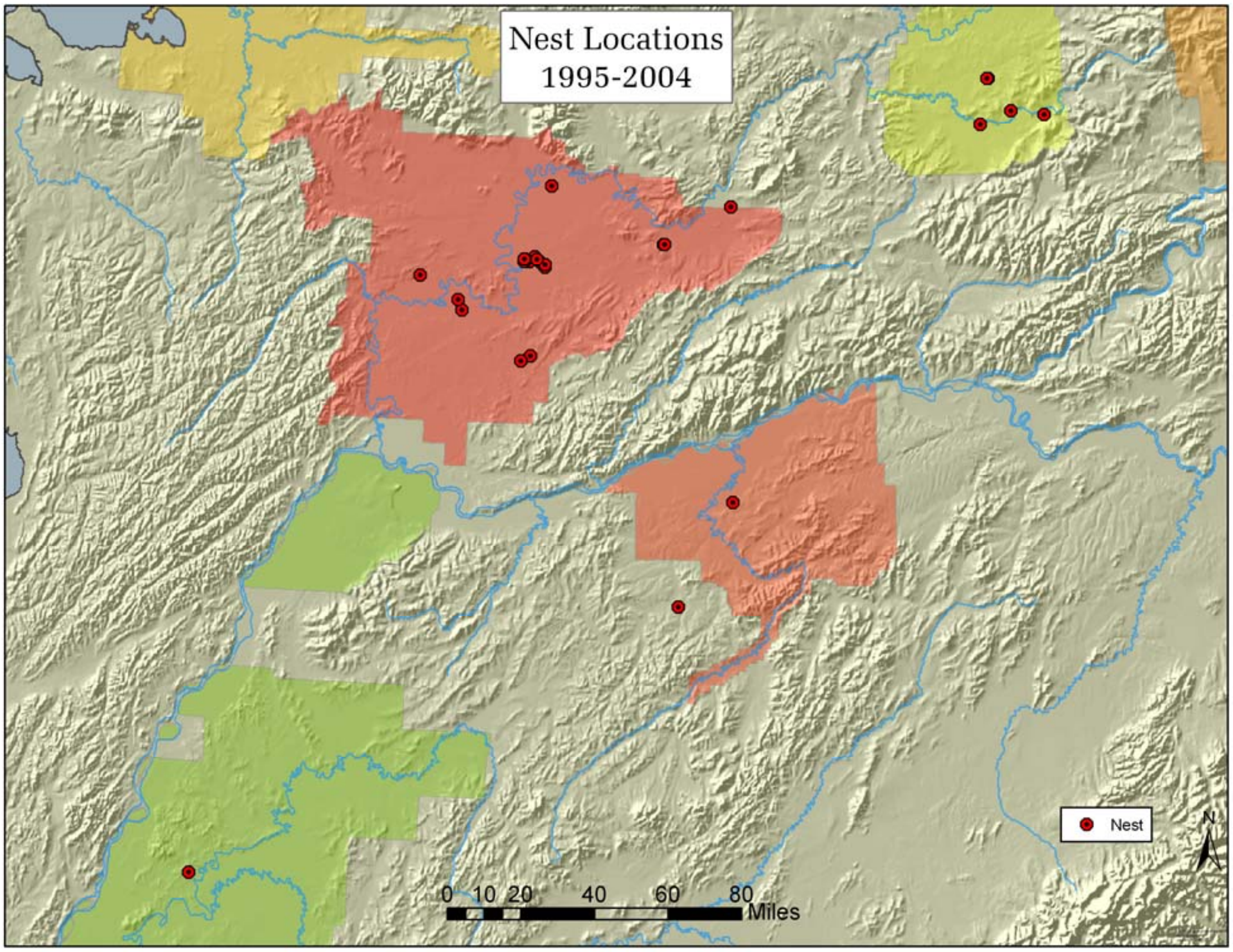


Figure 4. Locations of 33 Greater White-fronted Goose nests found in west-central Alaska, 1995-2004.

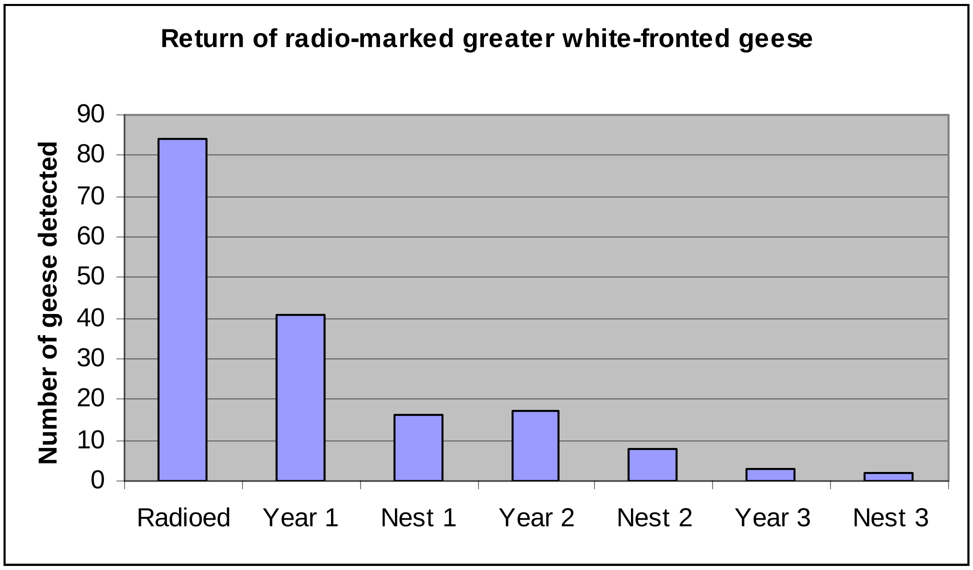


Figure 5. Return of radio-marked Greater White-fronted Geese in west-central Alaska. Of 92 birds marked in 1994, 1995, 1996, and 2002, eight transmitters were not detected within two weeks after marking and were censored from the analysis.

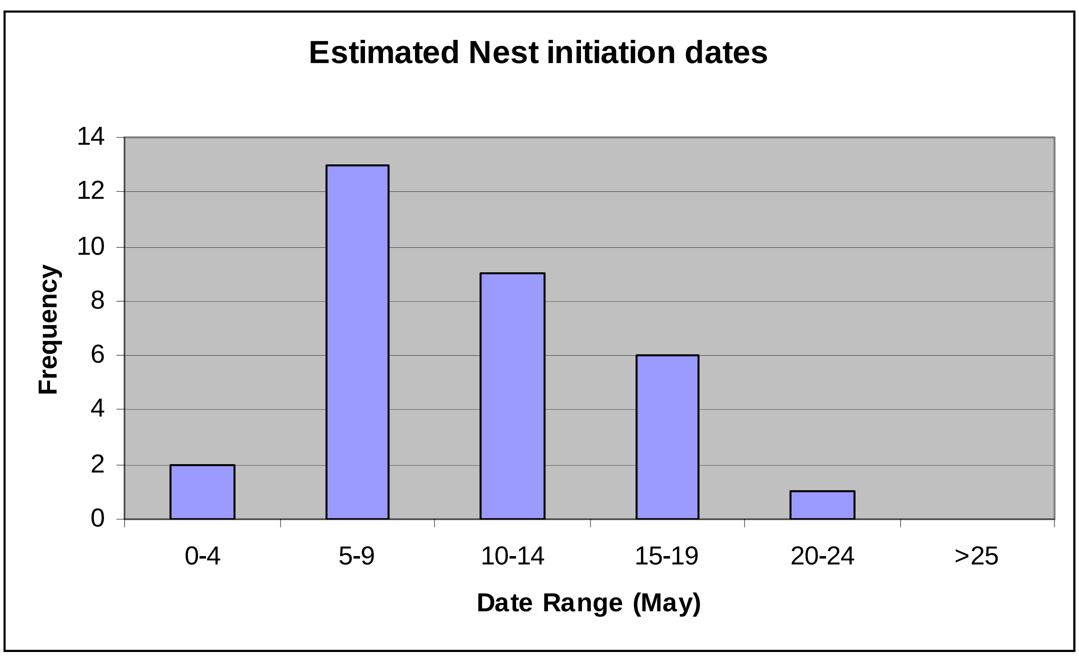


Figure 6. Estimated nest initiation dates for 31 Greater White-fronted Goose nests found in west-central Alaska, 1995-2004.

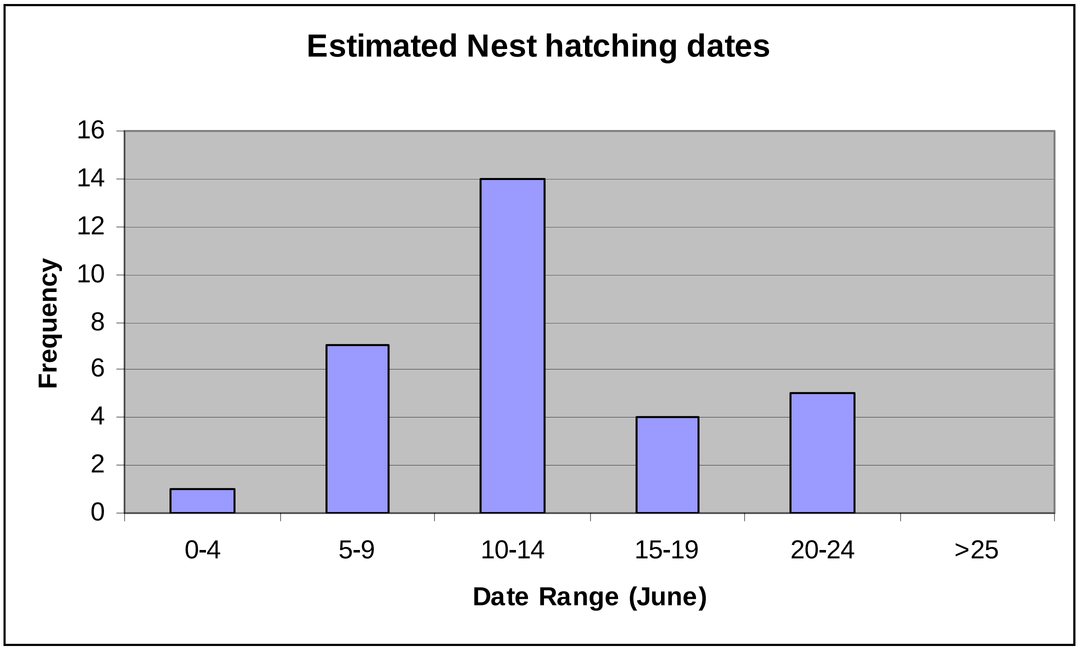


Figure 7. Estimated hatch dates for 31 Greater White-fronted Goose nests found in west-central Alaska, 1995-2004.

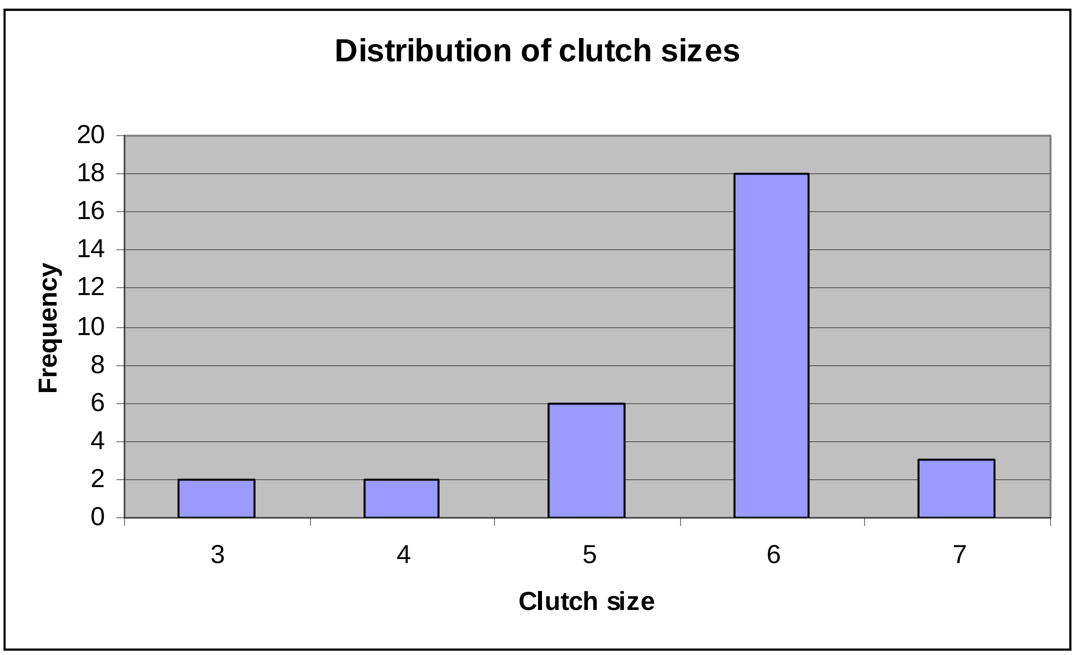


Figure 8. Clutch size distribution for 33 Greater White-fronted Goose nests found in west-central Alaska, 1995-2004.

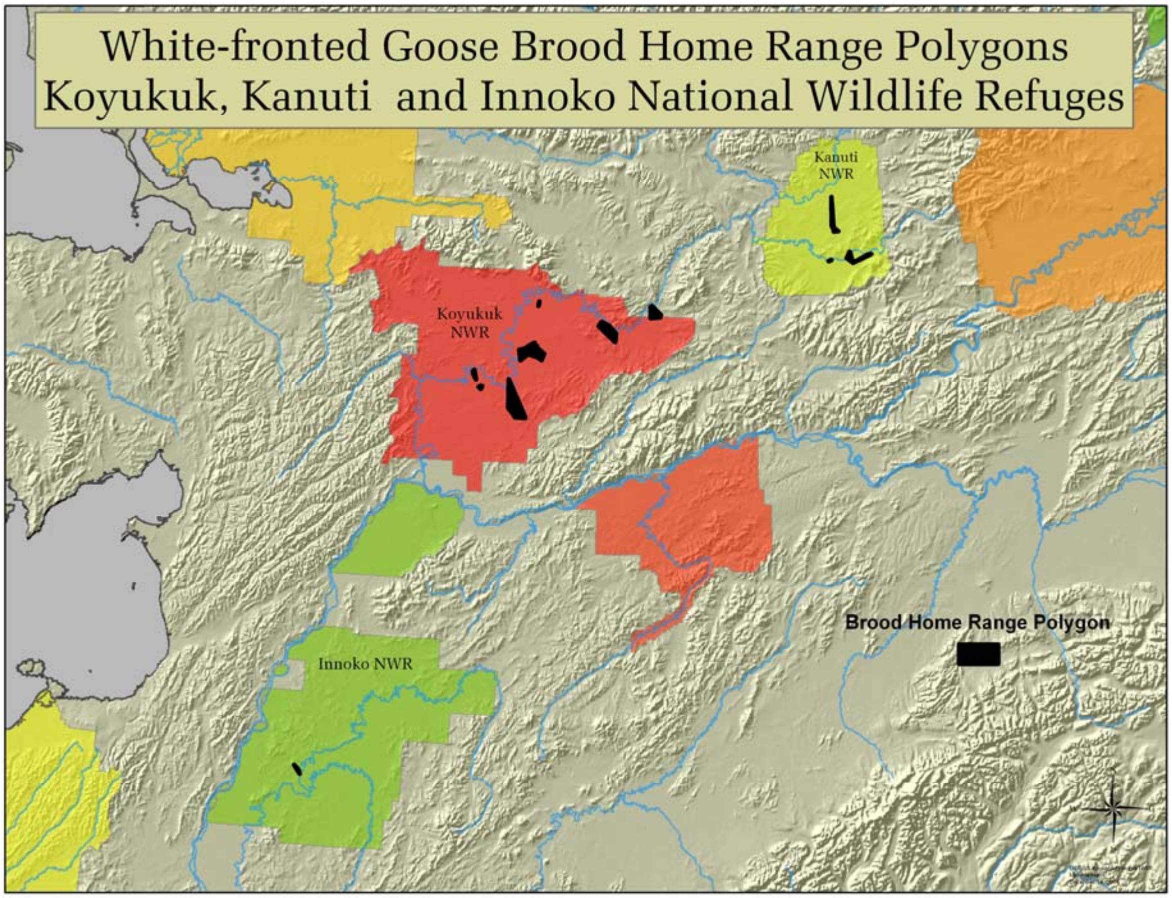


Figure 9. Aggregated 1994-2004 brood-rearing home range polygons based on radio-telemetry relocations of 19 marked Greater White-fronted Geese, west-central Alaska.

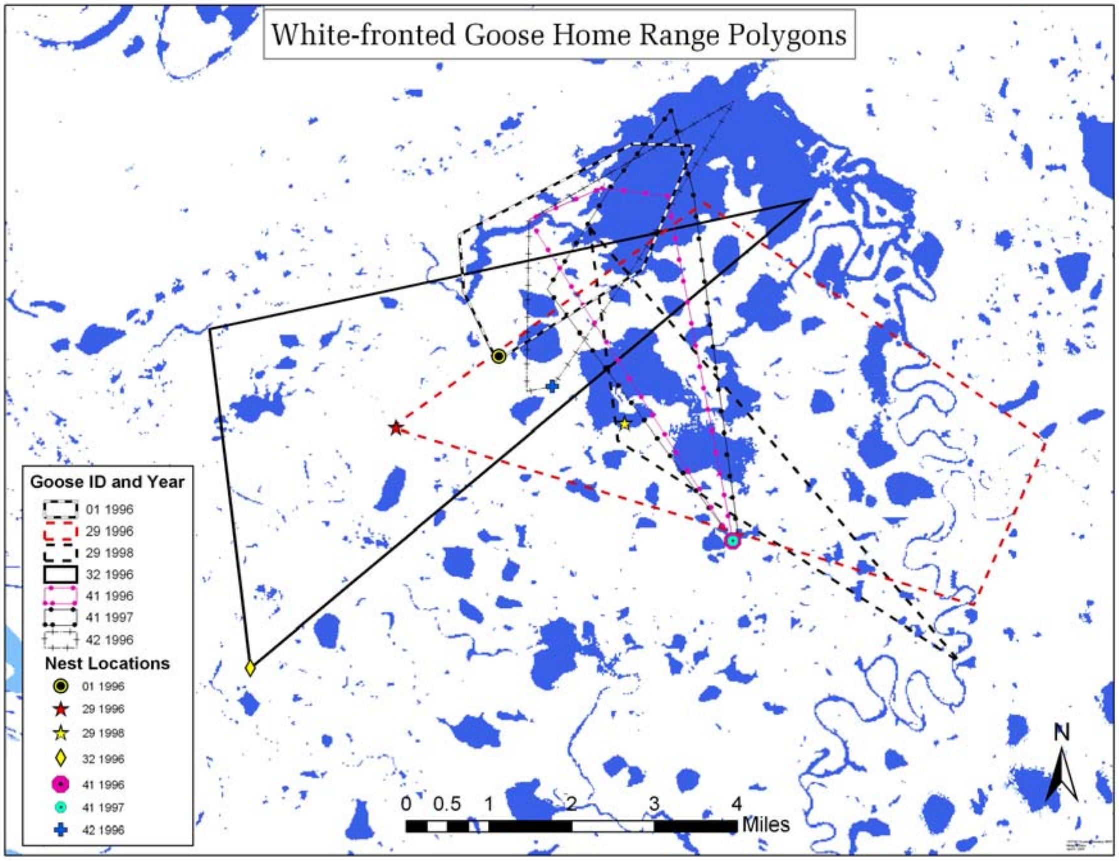


Figure 10. Brood-rearing home range overlap of seven radio-marked Greater White-fronted Geese in the highest density nesting area, Willow Lake, Koyukuk NWR, west central Alaska, 1996-97. Nests were most frequently located at the periphery of the brood rearing range.

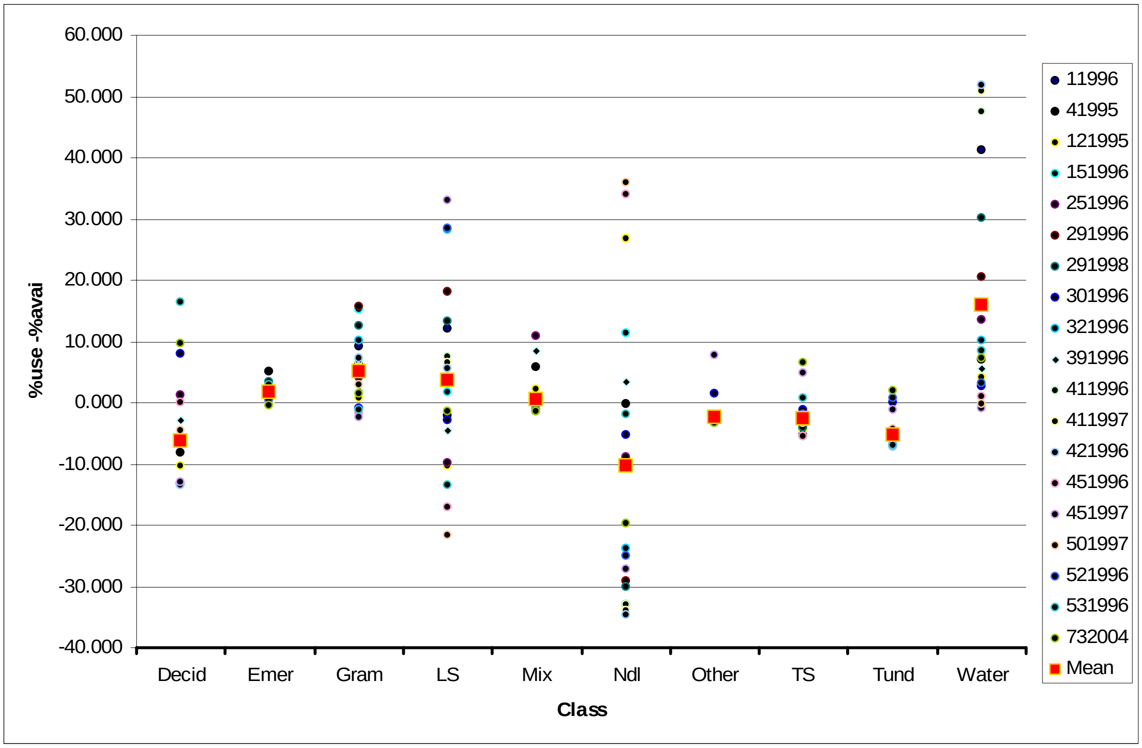


Figure 11. Scatterplot of differences in brood rearing habitat use *vs*. availability by 19 radio-collared nesting female Greater White-fronted Geese in west-central Alaska, 1994-2004. Positive values indicate selection for the habitat class and negative values indicate selection against. Landsat-derived land cover classes are (left to right): Deciduous Forest; emergent Graminoid; Graminoid; Low Scrub; Mixed Needleleaf-Deciduous Forest/Woodland; Needleleaf Forest/Woodland; Other (bare ground, mud, sand, rock scree, fire scars, etc.); Tall Scrub; Tundra; and Water. Mean difference for each class indicated by square; legend on right indicates goose ID number and year of nesting. See also Table 8.

Photo 1. Aerial view of high density nesting habitat for Greater White-fronted Geese near Huslia, Koyukuk NWR, west-central Alaska. In the foreground is Birch Lake, where ten nests were found 1996-1998. Willow Lake, a major brood-rearing area is in the background. This part of the refuge contains a large expanse and a wide variety of river-connected wetlands, non-connected wetlands, along with adjacent upland shrub and woodland habitats.

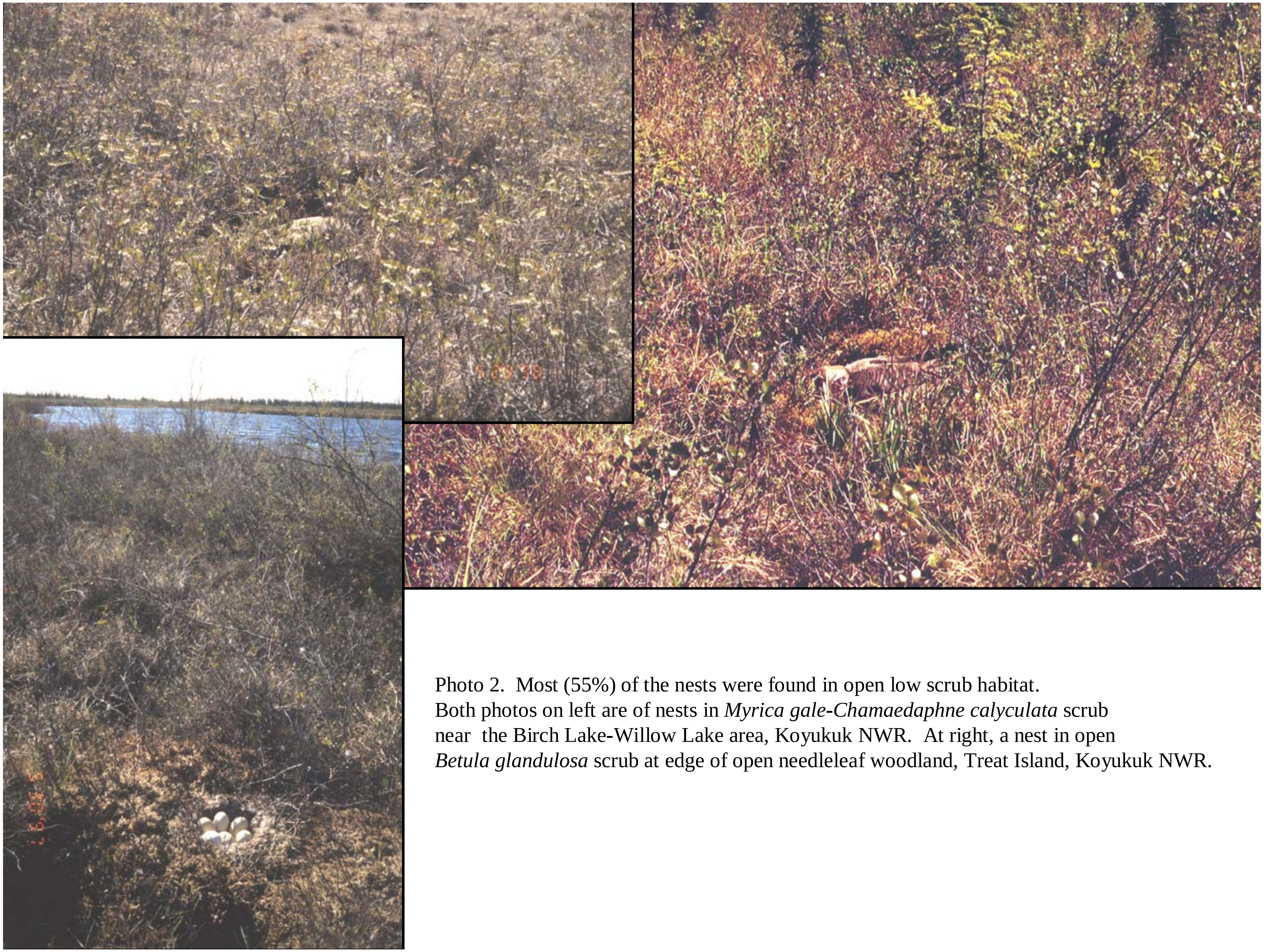


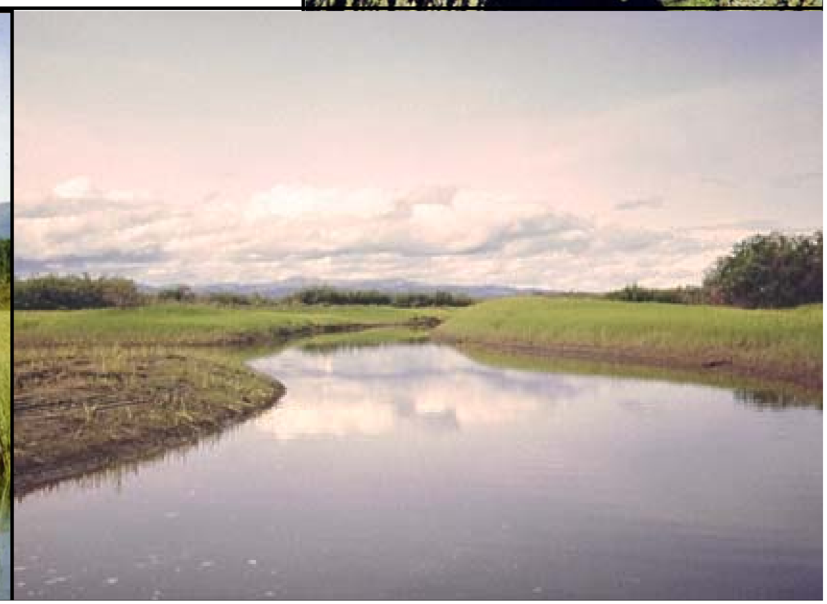
Photo 2. Most (55%) of the nests were found in open low scrub habitat. Both photos on left are of nests in *Myrica gale-Chamaedaphne calyculata* scrub near the Birch Lake-Willow Lake area, Koyukuk NWR. At right, a nest in open *Betula glandulosa* scrub at edge of open needleleaf woodland, Treat Island, Koyukuk NWR.

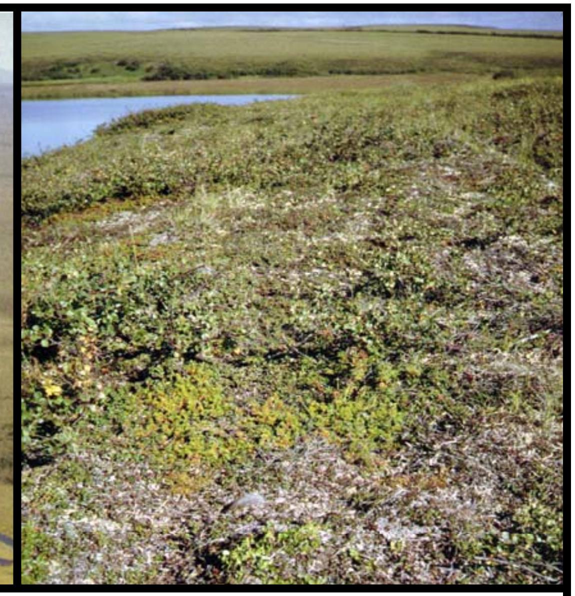
Photo 3. Just over a third (35%) of nests were in open needleleaf forest and woodland habitats. Also, more than a third (35%) of all nests found were in uplands and were not subject to flooding. In two consecutive years (1996 and 1997) G39 nested at this spot (circle) on Bear Mountain, between Hughes and Huslia. Both years it moved its brood 12 km to reach the Koyukuk River floodplain for brood rearing.

Photo 4. Effects of flooding on Koyukuk NWR at Treat Island. During the study, floods affected nesting in about half of the years. An estimated 48% of nests were located in the Koyukuk River floodplain.

Photo 5. Ten percent of nests were in graminoid meadows. G29 nested in two consecutive years in this meadow near Willow Lake, Koyukuk NWR, west-central Alaska.

Photo 6. Examples of brood-rearing habitat.
Top left, connnected oxbow along Koyukuk River;
Top right, small slough adjacent Three Day Slough
(circle indicates location of female with brood);
Bottom left, emergent *Carex rostrata* zone; and
Bottom right, new growth on exposed mud
banks along Dulbi Slough following June
high water. All photos are Koyukuk NWR.





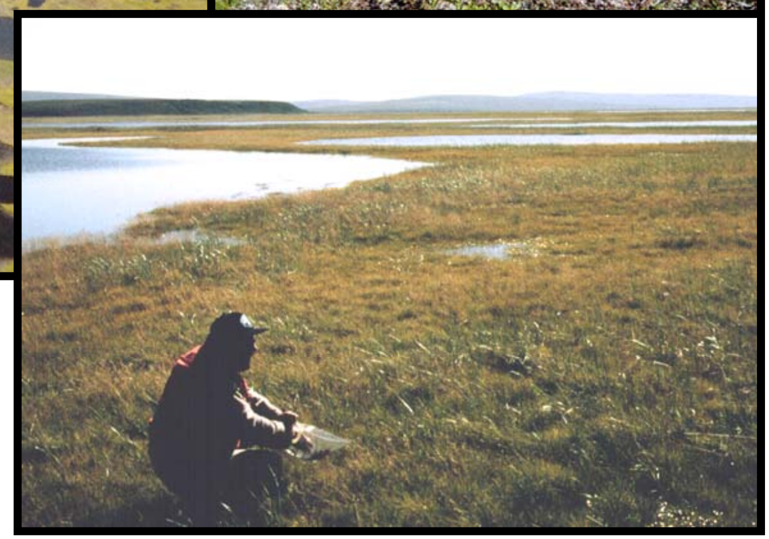


Photo 7. In August, most (83%) female geese marked along the lower Koyukuk River made a northwesterly staging movement to Kotzebue Sound, where tidal halophytic wet grass meadows (top left and bottom right) and upland tundra habitats (top right) were used.