Nesting habitat of the Tule Greater White-fronted Goose *Anser albifrons elgasi*

ROSEANN V. DENSMORE[1], CRAIG R. ELY[1], KAREN S. BOLLINGER[1], SHEILA KRATZER[2], MARK S. UDEVITZ[1], DANIEL J. FEHRINGER[3] & THOMAS C. ROTHE[4]

[1]U.S. Geological Survey, Alaska Science Center, 1011 East Tudor Road, Anchorage, Alaska 99503 USA.
Emails: roseann_densmore@usgs.gov; craig_ely@usgs.gov; mark_udevitz@usgs.gov
[2]U.S. Fish and Wildlife Service, National Wetlands Inventory Office, 1011 East Tudor Road, Anchorage, Alaska 99503, USA.
[3]Ducks Unlimited, Western Regional Office, 3074 Gold Canal Drive, Rancho Cordova, California 95670, USA.
[4]Alaska Department of Fish and Game, 525 W. 67th Avenue, Anchorage, Alaska 99518, USA.

Abstract

This paper presents the first information on the availability and use of nesting habitat by the rare Tule Greater White-fronted Goose *Anser albifrons elgasi*. The breeding range was sampled by marking geese with radio transmitters on wintering and moulting areas, and tracking them to nest sites in Alaska. Nesting habitat was described at the scales of ecoregion, wetland ecosystem (National Wetlands Inventory (NWI) maps), vegetation type within wetland (Alaska Vegetation Classification (AVC) maps based on satellite imagery), and nest site. Tule Greater White-fronted Goose nests were located in boreal forest wetlands in the upper Cook Inlet Basin ecoregion. Nesting Tule Greater White-fronted Geese selected NWI Palustrine Seasonally Flooded wetlands and used NWI Palustrine Saturated wetlands in proportion to availability. Within these wetlands, Tule Greater White-fronted Geese used Needleleaf Forest, Low Shrub and Herbaceous (mostly graminoid) AVC classes for nest sites in proportion to availability. Most (93%) Tule Greater White-fronted Geese nested > 75 m from open water ponds or lakes, and many nested in wetlands with little or no open water. Tule Greater White-fronted Geese nest only in a small breeding area near the most human-impacted area of the state, and continued development may limit the use of suitable nesting habitat.

Key words: Alaska, *Anser albifrons elgasi,* boreal forest, breeding distribution, nesting, Tule Greater White-fronted Goose.

©Wildfowl & Wetlands Trust

With a population of < 7,000, the Tule Greater White-fronted Goose *Anser albifrons elgasi*, is among the rarest waterfowl in North America and one of few considered to be at risk by the International Union for the Conservation of Nature and Natural Resources (IUCN) and by Wetlands International (Pacific Flyway Council 1991; Callaghan & Green 1993; Threatened Waterfowl Specialist Group 2001). Little is known about its nesting ecology. The first nests were discovered in 1979 in wetlands adjacent to Redoubt Bay on the west side of Cook Inlet in south central Alaska, but only 11 nests were located in ground searches because of difficult access and the thick vegetative cover (Timm *et al.* 1982; Wege 1984; Ely & Dzubin 1994) (Fig. 1). Aerial surveys were not conducted between 1983 and 1992, but a 1992 survey indicated a major decrease in the number of geese using the west side of Cook Inlet (Campbell 1992). In 1994, birds that were fitted with radio transmitters were located breeding in the upper Susitna River drainage in south central Alaska, and research was initiated to document the importance of this area.

Most habitat-related studies of waterfowl have been limited to only part of the range of the species because of physical, temporal or fiscal constraints. Such studies have usually been plot-based, with plot locations determined after preliminary investigations have indicated local densities to be high enough to warrant ground-based search efforts. While such studies are useful in providing large sample sizes for basic breeding parameters and information on nesting densities in a small portion of the breeding range, inferences on habitat use and overall breeding densities may be biased by initial plot selection (Alldredge & Ratti 1986; Thomas & Taylor 1990). Distribution information based on aerial surveys is fraught with similar difficulties and by visibility problems in forested areas (Merendino *et al.* 1995). This potential bias was reduced in this study by fitting birds with radio transmitters on wintering and moulting areas, tracking them to breeding locations in Alaska, and visiting the nest sites of females with transmitters. The high relocation rate the following summer (> 90%) of birds fitted with radio transmitters in Alaska ensured that the nesting study encompassed most of, if not the entire, breeding range. The objective was to describe Tule Greater White-fronted Goose nesting habitat at different spatial scales, at levels of ecoregion, wetland ecosystem, vegetation cover type within wetland ecosystem, and nest site.

Methods

Capture, marking and relocation

In 1994, 1995, and 1996, Tule Greater White-fronted Geese were captured with rocket nets and fitted with conventional VHF transmitters whilst on their primary wintering grounds at the Delevan and Sacramento National Wildlife Refuges in the Central Valley of California (39°20'N, 122°21'W), and at a major spring staging area on Summer Lake Wildlife Management Area in central Oregon (42°50'N, 120°45'W). In July 1996, birds were also fitted with transmitters on the main moulting area in the Kahiltna River Valley, Alaska (62°25'N,

©Wildfowl & Wetlands Trust

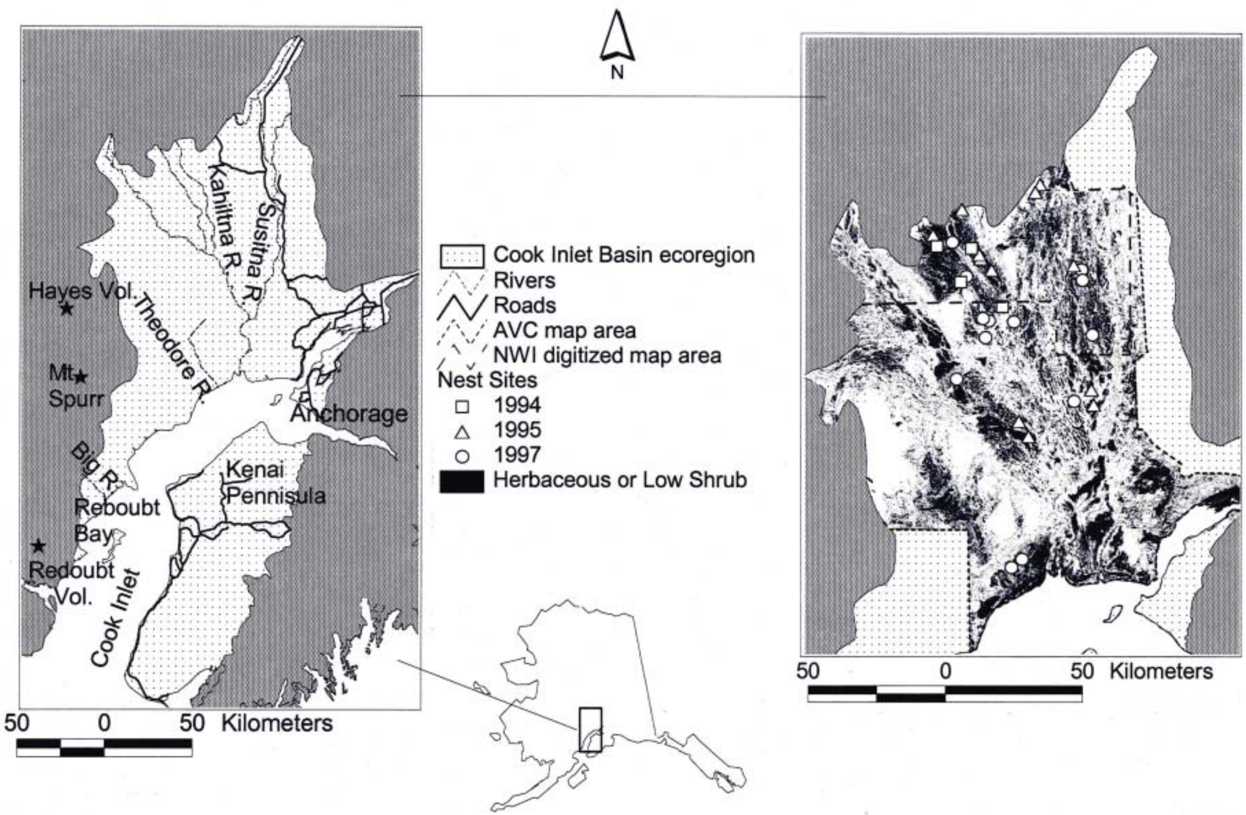

Figure 1. The locations of nest sites of Tule Greater White-fronted Geese with radio transmitters within the Cook Inlet Basin ecoregion, Alaska, 1994–1997. Within the area mapped by the Alaskan Vegetation Classification (AVC) system, the shaded area shows the distribution of the Herbaceous and Low Shrub vegetation cover types, and the dashed line indicates the area in the northern Susitna Valley that is covered by National Wetland Inventory (NWI) digitised maps.

©Wildfowl & Wetlands Trust

151°11'W). Aerial telemetry surveys began in Alaska before the arrival of geese in Cook Inlet in mid-April. Surveys were conducted during pre-nesting, nesting, brood rearing/moulting and autumn staging from 1994 to 1997 inclusive. Surveys were flown in Cook Inlet, drainages of the Copper River, and wetlands west and north of the Alaska Range from April to July inclusive (Ely *et al.* 2006). Probable nest sites were identified from the air, and telemetry was used to find incubating females. Nests were then located on the ground, and nest sites were photographed on the ground and from the air. These sites were then mapped from GPS locations, and locations were verified with the aerial and ground photographs.

Nesting habitat

The overall nesting area was first described with the Unified Ecoregions of Alaska system (Nowacki *et al.* 2002). The wetland ecosystems in which nests occurred were then described with the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) classification system (Cowardin *et al.* 1979). The NWI 1:63,360 or 1:40,000 scale maps for the study area were prepared using 1:60,000 colour-infrared photography, soil surveys and data obtained during field investigations (U.S. Fish and Wildlife Service 1993, 1995, 1999, 2002). The minimum size of mapped areas ranged from 0.4 ha to 1.2 ha. NWI maps were not available for six nests; for these nests colour-infrared photos and aerial and ground photos taken at the nest sites were used to classify habitats into NWI classes.

Table 1. Nest sites used by Tule Greater White-fronted Geese with radio transmitters by National Wetlands Inventory (NWI) classifications, and by Alaska Vegetation Classification (AVC) classes within each NWI classification, Susitna Valley and adjacent coastal lowlands, Alaska, 1994, 1995 and 1997.

	AVC Class			
NWI classification	Needleleaf Forest	Low Shrub	Herbaceous	Total
Palustrine Saturated	3	5	6	14
Palustrine Seasonally Flooded	1	6	6	13
Palustrine Semi-permanently Flooded	0	2	1	3
Total	4	13	13	30

The vegetation cover types that were used for nesting within the wetland ecosystems were then described according to the Susitna Military Operations Area Earth Cover Classification (ECC) map (Ducks Unlimited 2001). The ECC map used LANDSAT TM imagery at a resolution of approximately 0.09 ha (30 x 30 m pixels). Cover classes were based on the Alaska

©Wildfowl & Wetlands Trust

Table 2. National Wetland Inventory (NWI) classifications used by nesting Tule Greater White-fronted Geese with radio transmitters, Susitna Valley and adjacent coastal lowlands, Alaska, 1994, 1995 and 1997.

NWI classification	Description
Palustrine Saturated	Erect, rooted herbaceous vegetation (primarily sedges and grasses), mixed with scrub/shrub vegetation (primarily Dwarf Birch and ericaceous shrubs), and may include Black Spruce trees. Water table is at or just below the soil surface, but surface water is seldom present.
Palustrine Seasonally Flooded	Similar vegetation, but surface water present for extended periods, especially early in the growing season. When surface water is absent, soil is saturated.
Palustrine Semi-permanently Flooded	Dominated by erect, rooted herbaceous hydrophytes, with surface water present throughout the growing season. These areas are often referred to as marshes, sloughs or string bogs. The Tule Greater White-fronted Goose nests were in string bogs, composed of bog ridges (strangs) dominated by shrubs, and wet hollows (flarks) dominated by sedges.

Table 3. Availability and use of National Wetlands Inventory classifications by nesting Tule Greater White-fronted Geese with radio transmitters in the northern Susitna Valley portion of the nesting area, Alaska, 1994, 1995 and 1997. [a]Confidence interval on proportion of nests in habitat type (Neu *et al.* 1974). Confidence intervals that do not encompass the availability percent value indicate either selection or avoidance of that type. [b]Other wetlands include Palustrine Temporarily and Semi-permanently Flooded wetlands. Semi-permanently Flooded wetlands were not used by nesting geese with radio transmitters in the northern Susitna Valley portion of the nesting area.

	Availability		**Nests**		
NWI classification	km^2	%	No.	%	**95% CI[a]**
Palustrine Saturated	400	13	5	33	2.9–63.7
Palustrine Seasonally Flooded	616	20	10	67	36.6–97.1
Other wetlands[b]	206	7	0	0	not used
Upland	1823	60	0	0	not used

©Wildfowl & Wetlands Trust

Vegetation Classification (AVC), which is based primarily on the structure of the dominant vegetation (Viereck *et al.* 1992).

Nests were revisited after hatch (7–15 June) in 1995 and 1997, and the vegetation and substrate around the nest were described within the following categories: vascular plants by taxon, mosses by taxon or unidentified mosses, lichens, litter, bare ground and water. Percentage cover for the vegetation and substrate categories was estimated within a 1-m radius of the nest. Eight line transects were taken in a radius from the nest, and the presence of vegetation and substrate categories at points 1 m, 4 m, 7 m and 10 m from the nest was recorded. The distance from the nest to the nearest tree or tall shrub was measured, the species of the tree or shrub was recorded, and the height and basal diameter were measured. Nest visibility from overhead was evaluated in 1995 and 1997 with an ocular estimate of the percentage of the nest that was under live or dead vegetation. In 1997, nest visibility from a horizontal viewpoint was also measured. A pole divided into 10-cm-wide bands was placed vertically in the centre of the nest. The pole was observed from the end of each vegetation transect (10 m from nest), and each 10-cm interval was recorded as 0%, 25%, 50%, 75% or 100% visible. Mean cover from 0–50 cm above the ground was calculated for each direction. The average of the eight directions was calculated to provide an estimate of the mean percentage of the nest that was visible from a distance of 10 m in all directions. The distance from the nest site to the nearest body of water $\geq$ 0.5 ha in area was measured. For nest sites in forested wetlands, the distance from the nest to the nearest wetland without trees was measured.

Statistical analysis

Data from 1994, 1995 and 1997 were combined for analysis because the sample sizes were too small to make statistical comparisons between years. Analysis followed the methodology described by Neu *et al.* (1974) to compare nesting habitat use and availability. At the level of wetland ecosystem, analysis was limited to the 15 nests in the northern half of the nesting area (hereafter referred to as the northern Susitna Valley) because only that area was covered by digitised NWI maps (U.S. Fish and Wildlife Service 1995, 1999, 2002) (Fig. 1). The available digitised NWI maps and the ECC maps were overlaid to analyse use and availability of the different vegetation cover types within wetlands. The ECC maps of vegetation cover classes provided the only digitised coverage for the whole nesting area. These data therefore were used to generate a map of habitat distribution, and to provide an estimate of habitat availability and use for all 30 nest sites. Since the AVC cover types used on the ECC maps were based on vegetation structure, a cover type could occur in both wetland ecosystems and in well-drained upland areas not used by geese, and habitat availability could be overestimated. The combination of NWI maps and ECC maps provided a crosswalk between the two classification systems and an estimate of the proportion of vegetation cover types not in wetlands. Throughout the text, means $\pm$ s.e. are reported.

©Wildfowl & Wetlands Trust

Table 4. Availability and use of Alaska Vegetation Classification (AVC) classes within National Wetlands Inventory classifications (Palustrine Saturated and Seasonally Flooded) used by Tule Greater White-fronted Geese with radio-transmitters nesting in the northern Susitna Valley portion of the breeding area, Alaska, 1994, 1995, and 1997. [a]Confidence interval on proportion of nests in habitat type (Neu *et al.* 1974). Confidence intervals that do not encompass the availability percent value indicate either selection or avoidance of that type. [b]Other includes Mixed Needleleaf/Deciduous Forest, Deciduous Forest, Tall Shrub, sparse or unvegetated classes, urban and agriculture.

	Availability		**Nests**		
AVC class	km^2	%	No.	%	**95% CI**[a]
Needleleaf Forest	265	26	2	13	0–35.2
Low Shrub	209	21	7	47	14.5–78.9
Herbaceous	271	27	6	40	8.4–71.6
Other[b]	270	26	0	0	not used

Table 5. Availability and use of Alaska Vegetation Classification (AVC) classes by nesting Tule Greater White-fronted Geese with radio transmitters within the Susitna Valley and adjacent coastal wetlands, Alaska, 1994, 1995 and 1997. [a]Confidence interval on proportion of nests in habitat type (Neu *et al.* 1974). Confidence intervals that do not encompass the availability percent value indicate either selection or avoidance of that type. [b]Other includes Mixed Needleleaf/Deciduous Forest, Deciduous Forest, Tall Shrub, sparse or unvegetated classes, urban and agriculture.

	Availability		**Nests**		
AVC class	km^2	%	No.	%	**95% CI**[a]
Needleleaf Forest	1,803	15	4	14	0.0–30.0
Low Shrub	1,240	10	13	43	19.0–67.6
Herbaceous	1,151	10	13	43	19.1–67.7
Other[b]	7,788	65	0	0	Not used

Table 6. Crosswalk of National Wetlands Inventory (NWI) classifications within Alaska Vegetation Classification (AVC) classes for the northern Susitna Valley portion of the nesting area, comparing extent and proportion of each AVC class within habitats used and not used by nesting Tule Greater White-fronted Geese with radio transmitters. [a]Other wetlands include Palustrine Temporarily and Semi-permanently flooded wetlands. Semi-permanently Flooded wetlands were not used by nesting geese with radio transmitters in the northern Susitna Valley portion of the nesting area. [b]Other AVC classes include Deciduous Forest, Mixed Needleleaf/Deciduous Forest, Tall Shrub, open water, sparse or unvegetated, urban and agriculture.

	NWI classifications							
	Nesting habitats				Habitats not used			
	Palustrine Saturated		Palustrine Seasonally Flooded		Other wetlands[a]		Upland	
AVC class	km^2	%	km^2	%	km^2	%	km^2	%
Needleleaf Forest	135	21	130	19	25	4	364	56
Low Shrub	67	18	143	40	44	12	109	30
Herbaceous	71	18	200	50	75	19	50	13
Other[b]	127	7	143	8	70	4	1499	81

Results

Capture, marking and relocations

In 1994, 14 of 15 of the adult females fitted with radio transmitters on the wintering grounds were relocated in the study area in Alaska, and four nests were found. In 1995, 28 of the 30 adult females fitted with radio transmitters on wintering and staging areas were relocated in Alaska, and 12 nests were found. In 1996, only two females were fitted with radio transmitters, both were relocated in Alaska, and no nests were found. In 1997, 34 of the 38 females with radio transmitters were relocated in Alaska, and 14 nests were found, nine of which were of females captured the preceding July in Alaska and the other five were of females captured on staging or wintering areas (Ely *et al.* 2006). In late May and early June in 1994, 1995 and 1997, 29 of the 30 nests were visited (in 1997, the nest of one goose with a radio transmitter was not found on the ground, even though the nest was pinpointed and the brood was later observed from the air.) Nest sites of Tule Greater White-fronted Geese fitted with radio transmitters in 1994, 1995, and 1997 were located on the western side of the Susitna River within the watersheds of the glacial Tokositna, Kahiltna and Yentna Rivers, and within the coastal lowlands between the Susitna and Theodore Rivers (Ely *et al.* 2006).

Nesting habitat

The nesting area used during the study (1994–1997) and the previous (1979–1982) nesting area were located within the Cook Inlet Basin ecoregion, defined by Nowacki *et al.* (2002) as the "level to rolling terrain" from Cook Inlet to an elevation of approximately 600 m (Fig. 1). Climate and geomorphology distinguish the Cook Inlet Basin Ecoregion from other ecoregions of Alaska. The relatively moderate climate is subject to maritime and continental weather systems. Temperature and precipitation are intermediate between those of southeastern Alaska and interior and western Alaska. Annual precipitation ranges from 38 cm to 68 cm. Mean summer (June, July and August) minimum and maximum temperatures are 7.7 °C and 19.4 °C, respectively. Permafrost is limited or absent. Geomorphology is distinct because, unlike most non-mountainous ecoregions of Alaska, the area was covered by ice and flooded by proglacial lakes several times during the Pleistocene, and was not ice-free until approximately 10,000 yr BP (Schmoll & Yehle 1986). A complex mosaic of wetlands, including numerous lakes and ponds, has developed in areas of stagnant ice topography, ground moraines and outwash plains. Black Spruce *Picea mariana* occurs on many wetland areas as open stands or scattered small trees, and is present in the ecotone between wetland and upland areas.

All 30 nests were located in wetlands classified as Palustrine under the NWI system, commonly referred to as bogs, muskegs, fens, marshes and swamps. The three Palustrine classifications in which nests occurred had similar floristic composition, but the relative importance of plant species and the water regime differed between the classifications. (Tables 1 & 2). The NWI habitat classifications used by nesting geese comprised 31% of the area of digitised NWI maps. At this scale, Tule Greater White-fronted Geese selected the Palustrine Seasonally Flooded wetland classification for nest sites, and their use of Palustrine Saturated Wetlands did not differ from availability (Table 3). Within Palustrine Wetlands, Tule Greater White-fronted Geese nested in Needleleaf Forest, Low Shrub and Herbaceous vegetation cover classes (Table 1). These three cover classes constituted 73% of the Palustrine Seasonally Flooded and Palustrine Saturated Wetlands within the area of digitised NWI maps, and their use did not differ from their proportional availability at this scale (Table 4). At the scale of the entire nesting area, with the larger sample size of 30 nests, Tule Greater White-fronted Geese selected the Low Shrub and Herbaceous AVC classes for nest sites, and used Needleleaf Forest approximately in proportion to availability (Table 5). The vegetation cover classes used for nesting covered 4,194 ha in a mosaic pattern (Table 5, Fig. 1). However, the crosswalk based on the northern Susitna Valley showed that, in this area, 47% of the area of these three vegetation cover classes was in upland or wetland types not used for nesting (667/1,413 km^2; Table 6). Thus,

©Wildfowl & Wetlands Trust

available nesting habitat is overestimated if only AVC vegetation cover classes are used to define nesting habitat.

Nest sites were located in, or on the edge of, Shrub and Herbaceous wetlands. The four nests in Needleleaf Forest were ≤ 20 m from Shrub and Herbaceous wetland. Nest sites were usually not associated with lakes or ponds. In 1994, one nest was on the edge of a small pond, and in 1997 one nest was located on the edge of an island in a small lake and one nest was on the edge of a beaver pond, but the remaining nests were 789 ± 118 m (range 90–2,700 m) from a water body 0.5 ha or larger in size.

Vegetation composition was similar for 25 nest sites located in 1995 and 1997. Sphagnum moss *Sphagnum* spp. occurred around 97% of the nests. Tree-sized and/or shrub-sized Black Spruce and Dwarf Birch *Betula nana* occurred at 80–90% of the nest sites. Ericaceous shrubs present around ≥ 50% of nest sites included Bog Rosemary *Andromeda polifolia*, Black Crowberry *Empetrum nigrum*, Marsh Labrador Tea *Ledum palustre*, Small Cranberry *Vaccinium oxycoccus* and Bog Blueberry *V. uliginosum*. Graminoids were common at all nest sites, with sedge *Carex* spp., Bluejoint Grass *Calamagrostis canadensis* and cottongrass *Eriophorum* spp. at 92%, 68% and 64% of the nest sites, respectively. Graminoids dominated, and ericaceous shrubs were largely lacking around two nests, one adjacent to a beaver pond and one in a saturated meadow on a slope. Forbs were a minor component on all nest sites. The floristic composition of the vegetation within the area 1–10 m from the nest was similar among the wetland types.

Most Tule Greater White-fronted Goose nests (93%) were built on top of hummocks. In 1997, hummocks with nests were 32 ± 3 cm high, with a north–south diameter of 144 ± 18 cm, and east–west diameter of 131 ± 13 cm. Fifty-five percent of the nests were within 1 m of standing water, 17% were 1–10 m from standing water, and the remaining nests were above saturated wetlands without surface water nearby. Most nests (86%) were located ≤ 1 m from the base of a tree (21 near Black Spruce, two near Paper Birch *Betula papyrifolia*) or tall shrub (two near alder *Alnus* sp.). Most (19) of these trees and shrubs were short (≤ 2 m) but six nests were near taller trees (2–5 m). There was little or no vegetative cover over the nests, but the nests were more obscured from a horizontal viewpoint. The percentage of the nest obscured from overhead was 0.1 ± 0.1 (n = 12) in 1995 and 5.0 ± 1.3 (n = 13) in 1997. The percentage of the nest obscured from a distance of 10 m was 70.4 ± 7.0 (n = 13) in 1997.

Discussion

The study area most likely encompassed the breeding area of Tule Greater White-fronted Geese. During this multi-year research effort, > 90% of more than 100 Tule Greater White-fronted Geese fitted with radios on wintering, staging and moulting areas were relocated the following summer in Alaska (Ely *et al.* 2006). Furthermore > 85% of birds with radio transmitters were relocated during the nesting period (15 May – 15 June); a very high relocation rate given the likelihood of undetected losses due to

©Wildfowl & Wetlands Trust

mortality and radio failure. The sample of nests found was relatively low, probably because (1) nest loss occurred prior to nest visits, (2) some of the females with transmitters were likely sub-adults and not capable of nesting (Ely & Dzubin 1994), and (3) not all adults attempted to breed (Sedinger *et al.* 2001).

The breeding area of the Tule Greater White-fronted Goose in the Cook Inlet Basin ecoregion is geographically distinct from that of other Greater White-fronted Goose sub-species (Ely & Dzubin 1994), and it is defined by similar geomorphology, climate and vegetation (Nowacki *et al.* 2002). The climate is milder and wetter than that in the breeding areas of other sub-species in North America and Greenland (Fox & Stroud 1981; Ely & Dzubin 1994). During this study, Tule Greater White-fronted Geese nested in freshwater wetland areas in the Susitna Valley and in the lowlands bordering Cook Inlet between the Susitna and Theodore Rivers. Most nest sites were in open wetlands dominated by low shrubs and graminoids, and with scattered stunted trees or tall shrubs. Nest sites within Black Spruce-forested wetlands were close to unforested wetlands, usually in the ecotone between forested and unforested wetland. The Tule Greater White-fronted Goose nest sites found in 1980–1981 near Redoubt Bay on the west side of Cook Inlet were mostly in graminoid-dominated brackish and freshwater wetlands where ground searches were concentrated (Timm *et al.* 1982), and were similar to the nesting habitat of Greater White-fronted Geese *Anser albifrons frontalis* on the Yukon-Kuskokwim Delta (Ely & Raveling 1984). It was not possible to determine whether there was a real difference in habitat use between Redoubt Bay and the study area, or if the apparent difference was an artifact of the sampling design in the earlier study. This was because the Redoubt Bay area contained extensive low-shrub wetlands similar to those in the northern Cook Inlet Basin, and these could not be searched effectively for nests. Observations did suggest, however, that nests might have been located in this habitat (Timm 1982).

Historically, Tule Greater White-fronted Geese may have shifted their breeding area many times in response to volcanic eruptions. Four volcanoes on the west side of the breeding area, Hayes, Spurr, Redoubt and Illiama, deposited major tephra falls on the Cook Inlet Basin approximately 70 times during the Holocene (Riehle 1985). Tule Greater White-fronted Geese may have moved from their breeding area near Reboubt Bay in response to the December 1989 eruption of Redoubt Volcano. This eruption covered the breeding area on the west side of Cook Inlet with thick ash layers and mudflows, and covered the Susitna Valley with a thin layer of ash (Brantley 1990).

The location of Tule Greater White-fronted Goose nest sites in or on the edge of open areas within a forested region is similar to that of other geese that nest in boreal and temperate forest biomes (Raveling & Lumsden 1977; Bruggink *et al.* 1994; Mowbray *et al.* 2002). However, Tule Greater White-fronted Geese differ from most geese in that they do not require nearby permanent water for nest sites. In contrast, Greater White-fronted Geese on the Yukon-

©Wildfowl & Wetlands Trust

Kuskokwim Delta and most Canada Geese select nest sites near permanent water (Ely & Raveling 1984; Mowbray *et al.* 2002). Other descriptions of waterfowl nesting habitat in boreal forest have considered bogs and fens without permanent water nearby as unsuitable habitat (Heglund 1992; Rempel *et al.* 1997) or too rare for habitat use analysis (Merendino *et al.* 1995).

Tule Greater White-fronted Geese apparently rely on their dark, cryptic plumage for protection from avian predators because of the lack of overhanging vegetation on the breeding grounds. However, they select microsites where vegetation conceals the nest from a horizontal viewpoint, providing protection from terrestrial predators, including Nearctic Ermine *Mustela erminea*, American Marten *Martes americana*, Canada Lynx *Lynx canadensis*, Red Fox *Vulpes vulpes*, River Otter *Lutra canadensis*, Coyote *Canis latrans*, Grey Wolf *Canis lupus* and American Black Bear *Ursus americanus*. The tree and shrub vegetation around most Tule Greater White-fronted Goose nests was darker than the dead graminoids around most Greater White-fronted Goose nests on the Yukon-Kuskokwim Delta, where the geese are correspondingly lighter in colour (Krogman 1979). One distinctive characteristic of Tule Greater White-fronted Goose nests is that they are usually built near the base of a small tree, usually a Black Spruce. Nests of a southern population of White-fronted Geese in the Andyr region of Russia were also often built near the base of a small tree, usually a Dwarf Siberian Pine *Pinus pumila* (Krechmar 1986). Trees may simply have been associated with other microsite characteristics that made the site desirable for a nest, or they may have provided physical structure desirable to the goose for concealment or improved nest microclimate.

Tule Greater White-fronted Geese are at risk because of the small size of the population, and because their breeding area, the Cook Inlet Basin, is quite small compared to the breeding areas of most waterfowl. Tule Greater White-fronted Geese use a variety of wetlands, and these wetlands cover extensive parts of their breeding area. However, the Cook Inlet Basin is the most populated region in Alaska, with the greatest extent of urban development, summer recreational activities and agricultural land. Gas and oil wells and related facilities are present along the west side of Cook Inlet, in Cook Inlet itself and on the northern portion of the Kenai Peninsula. Nest sites were not located near seemingly suitable habitat in the developed and high-use areas east of the Susitna River. In contrast, various subspecies of Canada Geese readily nest in proximity to humans, including Lesser Canada Goose *Branta canadensis parvipes* in Anchorage (York *et al.* 2000). Tule Greater White-fronted Geese are more wary of humans during the nesting season than during the spring and autumn migration, when they use coastal marshes near areas of human activity (Timm *et al.* 1982). Future studies should evaluate factors potentially limiting habitat use by breeding Tule Greater White-fronted Geese, and should include an analysis of proximity of nests to human disturbance subject to habitat availability.

©Wildfowl & Wetlands Trust

Acknowledgements

We greatly appreciated the help of D. Orthmeyer and J. Takekawa, who led the trapping efforts at wintering areas. Lt. Col. T. Lillie kindly arranged funding through the Legacy programme of the United States Air Force. J. Payne and F. Reid helped organise and prepare the earth cover classification. J. Sarvis and R. West assisted with field work and programme implementation. D. Derksen provided support and direction for the project. J. Hupp, R. Gill and W. Eldridge assisted in aerial tracking. K. Joly contributed to the map figure. The manuscript benefited from comments from D. Derksen, P. Flint and E. Taylor.

References

Alldredge, J.R. & Ratti, J.T. 1986. Comparison of some statistical techniques for analysis of resource selection. *Journal of Wildlife Management* 50: 157-165.

Brantley, R.S. 1990. The eruption of Redoubt Volcano, Alaska, December 14, 1989–August 31, 1990. U.S. Geological Survey Circular 1061, Books and Open-File Reports Section, U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225.

Bruggink, J.G., Tacha, T.C., Davies, J.C. & Abraham, K.F. 1994. Nesting and brood-rearing ecology of Mississippi Valley population Canada Geese. *Wildlife Monographs* 126.

Callaghan, D.A. & Green, A.J. 1993. Wildfowl at risk, 1993. *Wildfowl* 44: 149-169.

Campbell, B.H. 1992. *Cook Inlet and Anchorage urban area goose survey report*. Alaska Department of Fish and Game, Anchorage, Alaska.

Cowardin, L.M., Carter, V., Golet, F.C. & LaRoe, E.T. 1979. *Classification of wetlands and deepwater habitats of the United States.* U.S. Fish and Wildlife Service Report FWS/OBS-79/31, Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C.

Ducks Unlimited, Inc. 2001. *Susitna MOA Earth Cover Classification.* U.S. Bureau of Land Management, Alaska State Office, Anchorage, Alaska.

Ely, C.R. & Dzubin, A.X. 1994. Greater White-fronted Goose (*Anser albifrons*). *In* A. Poole & F. Gill (eds.), *The Birds of North America* No. 131. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Ely, C.R. & Raveling, D.G. 1984. Breeding ecology of Pacific White-fronted Geese. *Journal of Wildlife Management* 48: 823-837.

Ely, C.R., Bollinger, K.S., Hupp, J.W., Derksen, D.V., Terenzi, J., Takekawa, J.Y., Orthmeyer, D.L., Rothe, T.C., Petrula, M.J. & Yparraguirre, D.R. 2006. Traversing a boreal forest landscape: summer movements of Tule Greater White-fronted Geese. *Waterbirds* 29: 43-55.

Fox, A.D. & Stroud, D.A. 1981. *Greenland White-fronted Goose study, report of the 1979 expedition to Eqalungmuit Nunat, West Greenland.* National Library of Wales, Aberystwyth, Wales, UK.

©Wildfowl & Wetlands Trust

Heglund, P.J. 1992. Patterns of wetland use among aquatic birds in the interior boreal forest region of Alaska. Ph.D. Dissertation, University of Missouri, Columbia, Missouri.

Krechmar, A.V. 1986. Nesting ecology of Greater White-fronted Goose *Anser albifrons* in different parts of its geographic range. *Journal of Zoology* 55: 889-900.

Krogman, B.D. 1979. A systematic study of *Anser albifrons* in California. *In* R.L. Jarvis & J.C. Bartonek (eds.), *Management and biology of Pacific Flyway geese*, pp. 22-43. Oregon State University Bookstores Inc., Corvallis, Oregon.

Merendino, M.T., McCollough, G.B. & North, N.R. 1995. Wetland availability and use by breeding waterfowl in southern Ontario. *Journal of Wildlife Management* 59: 527-532.

Mowbray, T.B., Ely, C.R., Sedinger, J.S. & Trost, R.E. 2002. Canada Goose (*Branta canadensis*). *In* A. Poole & F. Gill, (eds.), *The Birds of North America* No. 682. The Birds of North America, Inc., Philadelphia, PA.

Neu, C.W., Byers, C.R. & Peek, J.M. 1974. A technique for analysis of utilization-availability data. *Journal of Wildlife Management* 38: 541-545.

Nowacki, G., Spencer, P., Fleming, M., Brock, T. & Jorgenson, T. 2002. Unified Ecoregions of Alaska: 2001. U.S. Geological Survey, Open File Report 02-297, http://agdc.usgs.gov/data/projects/fhm

Pacific Flyway Council. 1991. *Pacific Flyway Management Plan for the Tule White-fronted Goose*. Pacific Flyway Study Committee Report, U.S. Fish and Wildlife Service, Portland, Oregon.

Raveling, D.G. & Lumsden, H.G. 1977. *Nesting ecology of Canada geese in the Hudson Bay lowlands of Ontario: evolution and population regulation.* Ontario Ministry of Natural Resources Fish and Wildlife Research Report 98, Ministry of Natural Resources, Ontario, Canada.

Rempel, R.S., Abraham, K.F., Gadawski, T.R., Gabor, S. & Ross, R.K. 1997. A simple wetland classification for boreal forest waterfowl. *Journal of Wildlife Management* 61: 746-757.

Riehle, J.R. 1985. A reconnaissance of the major Holocene tephra deposits in the Upper Cook Inlet Region, Alaska. *Journal of Volcanology and Geothermal Research* 26: 37-74.

Schmoll, H.R. & Yehle, L.A. 1986. Pleistocene glaciation of the upper Cook Inlet basin. *In* T.D. Hamilton, K.M. Reed & R.M. Thorson (eds.), *Glaciation in Alaska, the geologic record*, pp. 193-218. Alaska Geological Society, Anchorage, Alaska.

Sedinger, J.S., Lindberg, M.S., & Chelgren, N.D. 2001. Age-specific breeding probability in Black Brant: effects of population density. *Journal of Animal Ecology* 70: 798-807.

Thomas, D.L. & Taylor, E.J. 1990. Study designs and tests for comparing resource use and availability. *Journal of Wildlife Management* 54: 322-330.

Threatened Waterfowl Specialist Group. 2001. Threatened waterfowl species and sub-species. *TWSG News* 13: 2-4.

Timm, D.E. 1982. *Annual report of survey and inventory activities – waterfowl.* Alaska Department of Fish and Game, Juneau, Alaska.

©Wildfowl & Wetlands Trust

Timm, D.E., Wege, M.L. & Gilmer, D.S. 1982. Current status and management challenges for Tule White-fronted Geese. *Proceedings of the North American Wildlife Conference* 47: 453-463.

U.S. Fish and Wildlife Service. 1993. *National Wetlands Inventory maps for Tyonek B3, C2, C3, D1, D2, D3, D4, Talkeetna A1, B1* (hardcopy). http://wetlands.fws.gov.

U.S. Fish and Wildlife Service. 1995. *National Wetlands Inventory maps for Talkeetna B2, B3* (hardcopy and digitised). http://wetlands.fws.gov.

U.S. Fish and Wildlife Service. 1999. *National Wetlands Inventory maps for Talkeetna C1, C2* (hardcopy and digitised). http://wetlands.fws.gov.

U.S. Fish and Wildlife Service. 2002. *National Wetlands Inventory maps for Talkeetna A1, B1* (digitised). http://wetlands.fws.gov.

Viereck, L.A., Dyrness, C.T., Batten, A. & Wenzlick, A.R. 1992. *The Alaska Vegetation Classification.* U.S. Forest Service General Technical Report PNW-GTR-286, U.S. Forest Service, Portland, Oregon.

Wege, M.L. 1984. Distribution and abundance of Tule Geese in California and southern Oregon. *Wildfowl* 35: 14-20.

York, D.L., Cummings, J.L. & Wedemeyer, K.L. 2000. Movements and distribution of radio-collared Canada Geese in Anchorage, Alaska. *Northwestern Naturalist* 8: 11-17.