ALPINE AVIAN MONITORING PROGRAM, 2000

THIRD ANNUAL REPORT

Prepared for

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EXECUTIVE SUMMARY

- ARCO (now PHILLIPS Alaska, Inc.) and its partner Anadarko Petroleum Corporation (Anadarko) were granted permits for construction of the Alpine Development Project on the Colville Delta on 13 February 1998. Construction of a portion of the gravel footprint began that spring. The development relied on aircraft and winter ice roads for transport of supplies and personnel. As a stipulation of the construction permits, PHILLIPS and Anadarko agreed to a monitoring program beginning in 1998 to study disturbance of waterfowl by aircraft in the area of the oilfield. In this annual report, we describe the results of the third year of data-collection (2000 field season), specific to the disturbance study. Included in summaries and analyses, where appropriate, are data from 1996 and 1997, two years of baseline studies conducted prior to initiation of this monitoring program. A final report with a synthesis of annual results will be produced after data are collected in 2001.
- Spring temperatures were cold and snow melt was delayed in 2000, making it the latest nesting season since we began collecting data in the Alpine project area in 1995. Average daily temperatures in the Kuparuk Oilfield (~25 km east of the delta) did not get above freezing during 15–31 May 2000. The Colville River broke up relatively late on 8 June, and ice jams caused extensive flooding on the delta during the second week of June, which made some nesting areas in the Alpine project area inaccessible for several days.
- The Alpine Development Project underwent the heaviest construction activity in 2000, with well-drilling, construction of oil-processing facilities, major structural modifications on the pads, and high levels of aircraft traffic. Oil began flowing through the sales pipeline in November 2000. The Alpine camp population varied between approximately 400 and 700 people during the summer season, up from 140–180 people in 1999. The number of aircraft (fixed-wing and helicopter) landings and takeoffs during the nesting season doubled from 1999 to 2000. An average of 44 aircraft landings and takeoffs per day occurred during the 2000 nesting season (1 June to 15 July) at the Alpine airstrip.
- Among the aircraft that used the Alpine airstrip in 2000, generally four-engine aircraft produced the loudest noise levels followed by single-engine aircraft, twin-engine aircraft, helicopters, and vehicles. Most aircraft produced higher noise levels on takeoffs than on landings. During two different monitoring periods, 7% and 14% of all aircraft landings and takeoffs produced exceedances (sound ≥85 dBA for ≥2 sec). Four-engine aircraft (C-130 and DC-6) had the highest rates of exceedances (75% and 42%, respectively), and the lowest rates were for twin-engine planes (10% for Twin Otters and CASA Aviocars) and helicopters (4%). Helicopters landed farther from the noise monitors than did fixed-wing aircraft, so noise levels and exceedance rates were probably underestimated. Vehicles had the lowest exceedance rates, producing exceedances during <1% of all occurrences.
- In 2000, 63 nests of large waterbirds were found in the common ground-search area (10.6 km² searched every year). The highest number of nests was found in 1997 and the lowest (when adjusted for search effort) was found in 2000, probably because of the cold spring temperatures and extensive flooding that occurred in the Alpine project area. The most abundant nests belonged to Greater White-fronted Goose (White-fronted Goose), Northern Pintail, and Long-tailed Duck. No Spectacled Eider nest was located in the common ground-search area during 2000, although one nest was found outside that area in 1998 and 1999. In 2000, the density of nests was lower within 1,000 m of the airstrip than between 1,000 and 2,000 m of the airstrip; however, densities were lowest 500–1,000 m from the airstrip, highest 1,000–1,500 m from the airstrip, and intermediate <500 m and >1,500 m from the airstrip. The mean distance of nests from the airstrip did not differ among years, despite varying levels of disturbance from 1996 to 2000.

- The distribution of White-fronted Goose nests in 2000 followed the same pattern as the distribution of all nests mentioned above. Likewise, the distance of White-fronted Goose nests from the airstrip did not differ among years. Similar to the habitats used in previous years, White-fronted Goose nests in 2000 occurred in 3 of 17 habitats; Wet Sedge–Willow Meadow and Aquatic Sedge with Deep Polygons were preferred and Moist Sedge–Shrub Meadow was used in proportion to its availability. Nearest neighbor distances between White-fronted Goose nests indicated nests were clumped, but there was no indication that nearest neighbor distances (assumed to indicate density) were linearly related to distance from the airstrip.
- Four Tundra Swan nests were found in the common ground-search area in 2000, and the number of nests has not varied much since 1996 (4–5 nests). The nest closest to the airstrip (448 m) was in the same location from 1998 to 2000 and hatched each year. The distance of swan nests from the airstrip did not differ among years between 1996 and 2000.
- Incubation constancy was recorded for White-fronted Geese at 21 nests with artificial eggs containing temperature sensors and at 3 nests with video cameras. Females at successful nests spent 98% of the time incubating, averaged 1.4 recesses/d at 16 min/recess, and spent 22 min/d off the nest. Females at failed nests spent significantly less time incubating, took more recesses, had longer recesses, and spent more time off the nest. The airstrip did not appear to affect those differences in nesting behavior, because the mean distance from the airstrip of successful (1,092 m) and failed nests (1,206 m) did not differ.
- Incubation constancy by White-fronted Geese decreased at both failed and successful nests with increased landings and takeoffs of fixed-wing aircraft and with increased wind speed, and constancy increased with increasing duration of vehicle activity. At failed nests, incubation constancy also increased with increasing duration of pedestrian activity. All the disturbance variables were significant ($P < 0.05$) in the final models except number of aircraft landings and takeoffs ($P = 0.08$); however, individual coefficients were low and the amount of variance explained was small (Adj. $R^2 \leq 0.26$), indicating that other factors also were affecting incubation constancy.
- None of four incubating geese monitored in 2000 by video was observed taking recesses during aircraft landings or takeoffs. Geese concealed on nests most often in response to aircraft (68% of all concealments) and less often to vehicles (10%), non-predatory birds (7%), pedestrians (5%), and predators (<1%). However, of the potential sources of disturbance on the airstrip, geese appeared to be more sensitive to pedestrians (36% of all pedestrian occurrences elicited concealment) than aircraft or vehicles. On average, the shortest concealments were in response to aircraft (1.4 min) and the longest concealments were in response to other birds (9.5 min).
- Of two Tundra Swan nests monitored by video camera in 2000, the nest closest to the airstrip and the infield road was successful, while the nest farthest from the airstrip failed. Incubation constancy at the successful nest was high (99%), because the swans at that nest took less than one recess/d and recess length averaged 5.7 min. The other nest failed the day after the camera was installed.
- Average clutch sizes for all large waterbird species found nesting in 2000 were within ranges reported in the literature and within the range of sizes found in previous years. The size of clutches of White-fronted Goose nests in 2000 were not related to their distance from the airstrip. The mean distance from the airstrip of successful and failed goose nests was nearly identical. Only 38% of the White-fronted Goose nests hatched in 2000, about the same percentage that hatched in 1999 but half that in 1997 and 1998. Three of four Tundra Swan nests (75%) hatched in 2000, which is similar to percentages from previous years (60–100%). Only 12% of 17 duck nests hatched in 2000, nearly the same as in 1998 but exactly half the percentage that hatched in

1999. We suspect the low hatching success of duck and goose nests in 2000 was related to the late thaw and extensive flooding of the study area in combination with high levels of nest predation.

- More nests (248) were found on permanent bird plots in 2000 than in 1998 (196 nests) or 1999 (169 nests). The predominant nesting species in 2000 were Pectoral Sandpiper, Lapland Longspur, Semipalmated Sandpiper, and Red-necked Phalarope. The mean number of nests found on treatment plots (≤1,500 m from the airstrip, $\bar{x}$ = 24.5 nests) did not differ significantly from the mean number found on reference plots (>1,500 m from the airstrip, $\bar{x}$ = 16.8 nests). There were no significant relationships between the number of nests of the five most common species and the distance of plots from the airstrip, but total nests of all species decreased with increasing distance from the airstrip ($P = 0.01$).
- Similarly, logistic regressions of habitat variables for shorebird nests in 2000 produced models in which the odds of nests occurring were higher in plots closest to the airstrip. Pectoral Sandpiper and all shorebird nests were more likely to occur in areas of high relief and Semipalmated Sandpiper nests were more likely to occur in areas of open low willow. The occurrence of waterfowl and White-fronted Goose nests increased with increasing sedge marsh cover. Polygons were a common component of nest sites for all waterfowl. Passerine nests were more likely to occur in areas with polygons and areas with abundant open low willow.
- In 2000, 7,423 waterbirds were recorded in the survey area (10 surveys combined), which was intermediate to numbers counted in 1998 (highest number) and 1999 (lowest number). The number of species observed, the distributions of those species, and the patterns of use of lakes appeared to be similar among years. In all three years, the greatest number of waterbirds were seen in mid-to-late June and again in mid-to-late August, with the least number of birds counted in the middle of July. Ducks were the most numerous birds counted, among which Northern Pintails and scaup were most abundant. Lakes within tapped basins were the most heavily used waterbodies during all periods, attracting 71% of the waterbirds recorded during 2000.
- From 1998 to 2000, video cameras recorded egg predation by foxes at three nests and by avian predators at seven nests. Based on video records, foxes were more active in the survey area in 1999 and 2000 than in 1998, and based on observations, fox activity in 1998 was similar to 1997. Red foxes were first observed in the study area on a regular basis in 1999, but were less numerous than arctic foxes. We suspect increased fox predation accounted partially for the low hatching success of geese and ducks in 1999 and 2000. Avian predators were seen most frequently on video in 1998 and least frequently in 2000. The number of avian predator nests (2–4 Parasitic and Long-tailed jaeger and Glaucous Gull nests, combined) was similar among years, but in 1998–1999, Common Ravens were suspected to be nesting on Pad 1, and a nest was found in 2000. In all years, Parasitic Jaegers accounted for most of the avian predation of eggs that was identified during nest searching and on video.
- Sixty-two fox dens have been located over 8 years of surveys between the western edge of the Colville Delta and the western edge of the Kuparuk Oilfield. Nine dens were used by red foxes and the rest were used by arctic foxes. Of 50 arctic fox dens that were checked in 2000, 30% were occupied at some point by litters, which was below the average occupancy rate since 1993. On the delta, 14 arctic fox dens were checked and 36% were occupied. Mean litter size of arctic foxes was 4.4 pups and for red foxes was 3 pups. Compared to the range of occupancy rates and mean litter sizes from previous years, fox productivity was low to average in 2000 and did not indicate any obvious response of foxes to construction activities.

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ACKNOWLEDGMENTS

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INTRODUCTION

Oil exploration has occurred on the Colville River Delta (hereafter, the Colville Delta or the delta) intermittently over the last several decades. The Alpine Development Project is the first oilfield development to occur west of the Kuparuk Oilfield and the first on the Colville Delta. Abundant and rich wildlife and fish fauna inhabit the Colville Delta, providing subsistence and commercial resources that support two isolated communities: the native village of Nuiqsut and the Helmericks' family homesite. The delta is a regionally important nesting area for Yellow-billed Loons, Tundra Swans, Brant, and Spectacled Eiders (Rothe et al. 1983, North et al. 1984, Meehan and Jennings 1988; see Appendix A for scientific names). The delta also provides breeding habitat for a wide array of other waterfowl, as well as passerines, shorebirds, gulls, jaegers, and owls. Baseline wildlife studies were conducted on the delta in the 1970s and 1980s by the U.S. Fish and Wildlife Service (e.g., Markon et al. 1982, Simpson et al. 1982, Simpson 1983, Rothe et al. 1983, Meehan 1986). In the 1990s, ARCO Alaska, Inc. (ARCO) began collecting pre-development data on wildlife (Smith et al. 1993, 1994; Johnson 1995; Johnson et al. 1996, 1997, 1998, 1999a) and fish resources (Moulton 1996, 1998). Similar baseline wildlife studies were conducted in 2000, both north (Johnson et al. 2000b) and south (Burgess et al. 2000) of the Alpine project area. The physical, biological, and human resources of the delta were summarized in an environmental evaluation of the Alpine development (ARCO 1997).

ARCO (now PHILLIPS Alaska, Inc.) and its partner Anadarko Petroleum Corporation (Anadarko) were granted permits for construction of the Alpine Development Project on the central portion of the Colville Delta on 13 February 1998 (Department of Army, U.S. Army Corps of Engineers, Permit Evaluation and Decision Document: Application No. 2-960874—Alpine Development Project. 60 pp). Construction of a portion of the gravel footprint began that spring. The development relied on aircraft and winter ice roads for transport of supplies and personnel. Although the effects of roads and oilfield development on tundra birds have been well studied (e.g., Meehan 1986, Troy 1988, Murphy and Anderson 1993, TERA 1993), the responses of birds to aircraft activity, particularly the concentrated activity at a landing strip, are poorly understood. As a stipulation of the construction permits, PHILLIPS and Anadarko agreed to a three-year monitoring program to study disturbance of waterfowl by aircraft in the area of the oilfield. The intent was to collect data during three phases of development: prior to construction in 1998 (for use as a baseline), during construction in 1999, and during normal airstrip operation in 2000. Portions of the gravel footprint were in place by spring 1998 and were being reworked by several pieces of large equipment, however, thereby eliminating the pre-construction year in the original study schedule. ABR, Inc., was contracted to conduct the study beginning in May 1998, and the goals of this study were refined in discussions with the U.S. Fish and Wildlife Service. The study was designed to identify potential effects of noise and disturbance from aircraft on all birds (including shorebirds and passerines) during the nesting season and the potential effects on large waterbirds during the brood-rearing season, when any disturbance would have the greatest impacts on productivity. For documentation of pre-construction conditions, the study will rely on data collected in the Alpine project area during 1996 and 1997 (Johnson et al. 1997, 1998). The specific objectives of the monitoring program are

1. to monitor sources of potential disturbance in the Alpine project area including aircraft, vehicles, pedestrians, and noise;
2. to investigate the abundance, distribution, and fate of nests of large waterbirds and evaluate the relationships of these variables with distance from the airstrip;
3. to monitor a sample of nesting birds for changes in behavior that may result from disturbance from aircraft landings and takeoffs;
4. to identify changes in nest densities of all avian species on breeding-bird plots at different locations relative to the airstrip;
5. to monitor nearby lakes for changes in numbers of waterbirds throughout the breeding season; and

6. to monitor fox activity and pup production at fox dens on the delta and adjacent areas.

In this annual report on the avian monitoring program at the Alpine Development Project, we detail the results of the third year of data-collection (Johnson et al. 1999a, 2000a). 2000 was a construction year for the Alpine Development Project, with well-drilling, construction of oil-processing facilities, major structural modifications on the pads, and high levels of aircraft traffic. Oil began flowing through the sales pipeline in November 2000. We describe here the conditions in the development area and factors that influenced use of the area by birds during the breeding season that are specific to the conditions of the project during this construction year. We present summary comparisons with data from previous years where appropriate and within-year analyses of potential disturbance effects. Comprehensive among-year comparisons of data have not been conducted, because these analyses cannot be completed until all years of data have been collected; data collection should be concluded in 2001. Comprehensive multi-year analyses will be presented with a thorough evaluation of disturbance effects in a final synthesis report.

STUDY AREA

The Alpine project area is located on the central Colville Delta, between the Niglik (Nechelik) and Tamayagiaq (Tamayayak) channels, and can be described approximately as the area within 5 km of the Alpine airstrip (Figure 1). Lakes and ponds are dominant physical features of the Colville Delta. Most waterbodies are shallow (e.g., polygon ponds ≤ 2 m deep), so they freeze to the bottom in winter but thaw by June. Deep ponds (>2 m deep) with steep, vertical sides are common on the delta but are uncommon elsewhere on the Arctic Coastal Plain. Lakes >5 ha in size are common and cover 16% of the delta's surface (Walker 1978). Some of these large lakes are deep (to 10 m) and freeze only in the upper 2 m; ice remains on these lakes until the first half of July (Walker 1978). Several other types of lakes, including oriented lakes, abandoned-channel lakes, point-bar lakes, perched ponds, and thaw lakes, occur on the delta (Walker 1983).

Many lakes on the delta are "tapped" (Walker 1978), in that they are connected to the river by narrow channels that are caused by thermokarst decay of ice wedges between the river and adjacent lakes and by the migration of river channels (Walker 1978). Channel connections allow water levels in tapped lakes to fluctuate more dramatically than those in untapped lakes, resulting in barren or partially vegetated shorelines and allowing salt water to intrude into some of these lakes. River sediments raise the bottom of these lakes near the channel, eventually exposing previously submerged areas and reducing the flow of riverine water to the most extreme flood events. Because tapped lakes and river channels are the first areas of the delta to become flooded in spring, they constitute important staging habitat for migrating waterfowl (Rothe et al. 1983).

The delta has an arctic maritime climate (Walker and Morgan 1964). Winters last ~8 months and are cold and windy. Spring is brief, lasting only ~3 weeks in late May and early June, and is characterized by the flooding and breakup of the river. In late May, water from melting snow flows both over and under the river ice, resulting in flooding that peaks during late May or the first week of June (Walker 1983). Breakup of the river ice usually occurs when floodwaters are at peak levels. Water levels subsequently decrease in the delta throughout the summer, with the lowest levels occurring in late summer and fall, just before freeze-up (Walker 1983). Summers are cool, with temperatures ranging from –10° C in mid-May to +15° C in July and August (North 1986). Summer weather is characterized by low precipitation, overcast skies, fog, and persistent winds that come predominantly from the northeast. The rarer westerly winds usually bring storms that often are accompanied by high, wind-driven tides and rain (Walker and Morgan 1964). The Colville Delta is described in more detail by Johnson et al. (1999a).

The completed oilfield development includes a gravel airstrip (~1.8 km long) and two gravel pads (Alpine Pad 1, a drill site and processing facility, and Alpine Pad 2, a drill site), all connected by ~3 km of gravel road (Figure 1). The total area estimated to be covered with gravel fill is ~37 ha (91 ac). A sales-quality pipeline to the

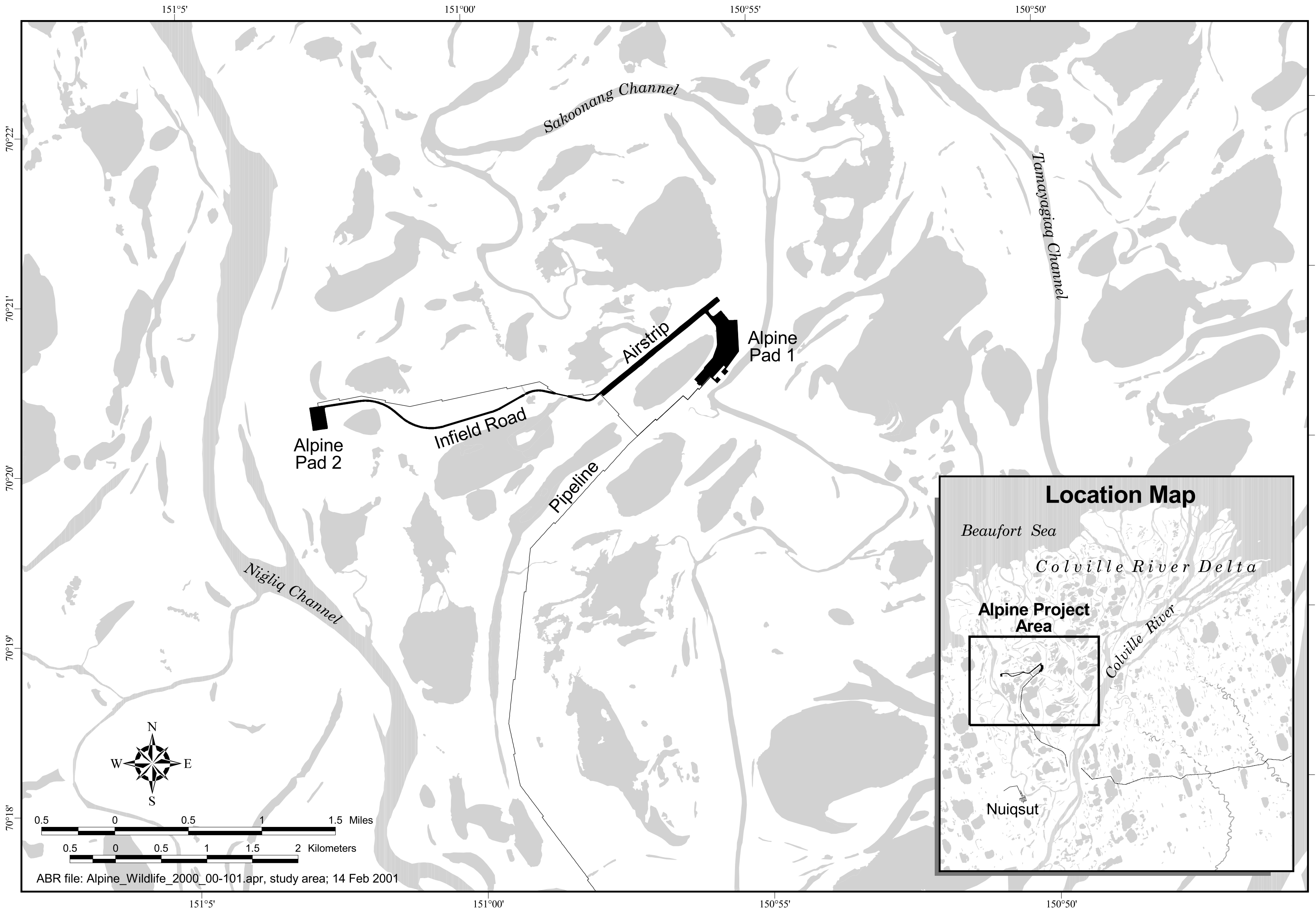

Figure 1. Study area map showing the Alpine project area, Colville River Delta, Alaska, 2000.

Kuparuk Oilfield connects this development to existing infrastructure in the Kuparuk Oilfield. No all-season road is planned to access the Alpine facilities from the Kuparuk Oilfield; materials, equipment, and personnel will travel by air or overland on ice roads during winter.

METHODS

To identify the effects of aircraft disturbance on avian use of the Alpine project area, aircraft needs to be isolated from other forms of disturbance and birds exposed to aircraft compared with those that are not exposed. Although on the surface this would seem a simple process, in practice there are many confounding factors unrelated to aircraft: predators; weather; noise from construction and drilling; vehicles, machinery, and people active on the airstrip in the absence of aircraft; and research and cleanup activities on the tundra. To help identify the operational effects, we have incorporated elements of a before-after-control-impact design (BACI; Stewart-Oaten et al. 1986) and gradient analysis (Ellis and Schneider 1997). The BACI design calls for sampling before and after an impact in control and impacted areas; replicating these samples in the before and after periods increases our ability to detect differences. To evaluate annual variation and evaluate potential effects from the second year of construction, data from 1996–1999 (Johnson et al. 1997, 1998, 1999b, 2000) will be compared with data from the current field study, where appropriate. The gradient design requires sampling over some continuous measure from a point source; in this case, distance from the airstrip and levels of activity (e.g., number of landings and takeoffs) were used as gradients of potential disturbance. In this report, gradient and other analyses on nesting data from individual years are presented, but BACI-style analyses will be delayed until the operational year data (2001) have been collected and analyzed. The analyses have been and will be conducted on all large species nesting in the project area; a single species, Greater White-fronted Goose (specifically because their nests are relatively abundant and well-distributed in the project area); bird species nesting on breeding-bird plots; and on individual nesting pairs (in evaluations of nesting behavior). Because the responses of several species of birds and numerous parameters are being evaluated, conclusions will necessarily be based on the "weight of evidence", with more weight placed on analyses that evaluate population responses to potential aircraft disturbance.

CONDITIONS IN THE STUDY AREA

Conditions in the study area were recorded to assess factors such as weather, timing of snowmelt, and human activity that could affect avian use of the Alpine project area and annual comparisons. Snow and ice conditions in the Alpine project area were monitored during lake surveys. Daily mean temperatures were summarized into thaw-degree days (the number of degrees above 0° C) from weather records kept at the Kuparuk Oilfield. Several factors were used to gauge the phenological development of the season: the number of thaw-degree days in the last half of May and the first half of June, the date of snowmelt, the date meltwater formed on lakes, the date shallow lakes became ice-free, the first date of midge (Chironomidae) emergence, the first date of mosquito (*Aedes* spp.) emergence, and first dates of egg hatch for nesting birds.

Initial construction of the Alpine facilities (primarily gravel-pad construction of the airstrip and Pad 1) began during winter 1998. Prior to construction, surveyors, hydrologists, botanists, and wildlife biologists conducted pre-development evaluations in the project area (Table 1). Because human activity has varied among the years of study, it was necessary to document the timing and extent of the activity each year. In 2000, we used records kept by Alpine air traffic control (ATC) of aircraft and vehicles on the airstrip, or our video recordings for pedestrians and for periods when vehicle traffic was not recorded. Aircraft were classified as four engines (Douglas DC-6 or Lockheed C-130 Hercules), two engines (deHavilland Twin Otter, CASA Aviocar, or Cessna 441 Conquest), single engines (Cessna 207 and 185), or helicopter (Bell 206 Long Ranger and Jet Ranger). Vehicles were classified as machinery (graders, bulldozers, compactors, cranes, and loaders), large trucks (≥1-ton axle rating), and small trucks (pickups, "Suburbans", and single-person all-terrain vehicles [ATVs]).

Table 1. Current and past summer construction status of Alpine development project, Colville River Delta, Alaska, 1996–2000.

Year	Construction Activity	Equipment	Human Activity	Facility Status	Aircraft
1996	none	None	surveyors, hydrologists, biologists	none	helicopter
1997	none	None	surveyors, hydrologists, biologists	none	helicopter
1998	airstrip improvement	3 pieces of road equipment	surveyors, hydrologists, biologists, equipment operators	airstrip and Pad 1 gravel in place with one permanent structure	helicopter
1999	facility in place, drilling on Pad 1, construction, airstrip maintenance	Vehicles, various types of road equipment, drill rig	surveyors, hydrologists, biologists, equipment operators, construction workers	airstrip, camp, and drilling operational; Pad 1 and airstrip under construction; Pad 2 gravel and pipeline in place; in-field road partially complete	helicopter, Twin Otter, Caravan, C-207, DC-6
2000	facility in place, drilling on Pad 1, construction, pad and road maintenance	Vehicles, various types of road equipment, construction equipment, drill rig	surveyors, hydrologists, biologists, equipment operators, construction workers	airstrip, camp, and drilling operational, oil production equipment and modules being installed; additional housing and modules in place; in-field road and bridges in place but requiring surface improvements; Pad 1 drilling; Pad 2 storage and fuel depot for helicopters	3 helicopters, C-207, C-185, 2 Twin Otters, CASA, Conquest, 3 DC-6s, C-130

NOISE MONITORING

Noise conditions were monitored in the Alpine project area with two Larsen-Davis Model 870 Sound Level Meters. The sound monitors recorded noise levels on the south side of the airstrip from 8 June to 20 August and 14–15 September. Each monitor was calibrated when deployed and again when data were downloaded to a laptop computer every several weeks. One monitor was placed approximately mid-way along the airstrip, 329 m from the access road (Figure 2). On 15 July, a second monitor was placed near the access road to the airstrip (181 m away). Each monitor was placed 40 m perpendicular distance from the airstrip. All sound measurements were recorded in A-weighted decibels (dBA). The monitors recorded for each exceedance or noise event the time, date, and seconds of duration and dBA for sound exposure levels (SELs) of noise that exceeded 85 dBA for durations ≥2 sec, as well as other sound metrics. SELs are measurements of sound energy over periods of time when the noise exceeds a prescribed level and are functions of both the loudness of noise as well as the duration of noise.

Noise measurements were removed from analysis when the monitor was out of calibration and when average hourly wind speed was >15 mph (recorded by ATC at the Alpine airstrip), assuming that sound levels at these times were influenced by wind-generated noise. Exceedances with durations ≥10 min and those that occurred every minute for ≥1 h were also removed, under the assumption that these events were generated by wind, some unknown source (none could be assigned to

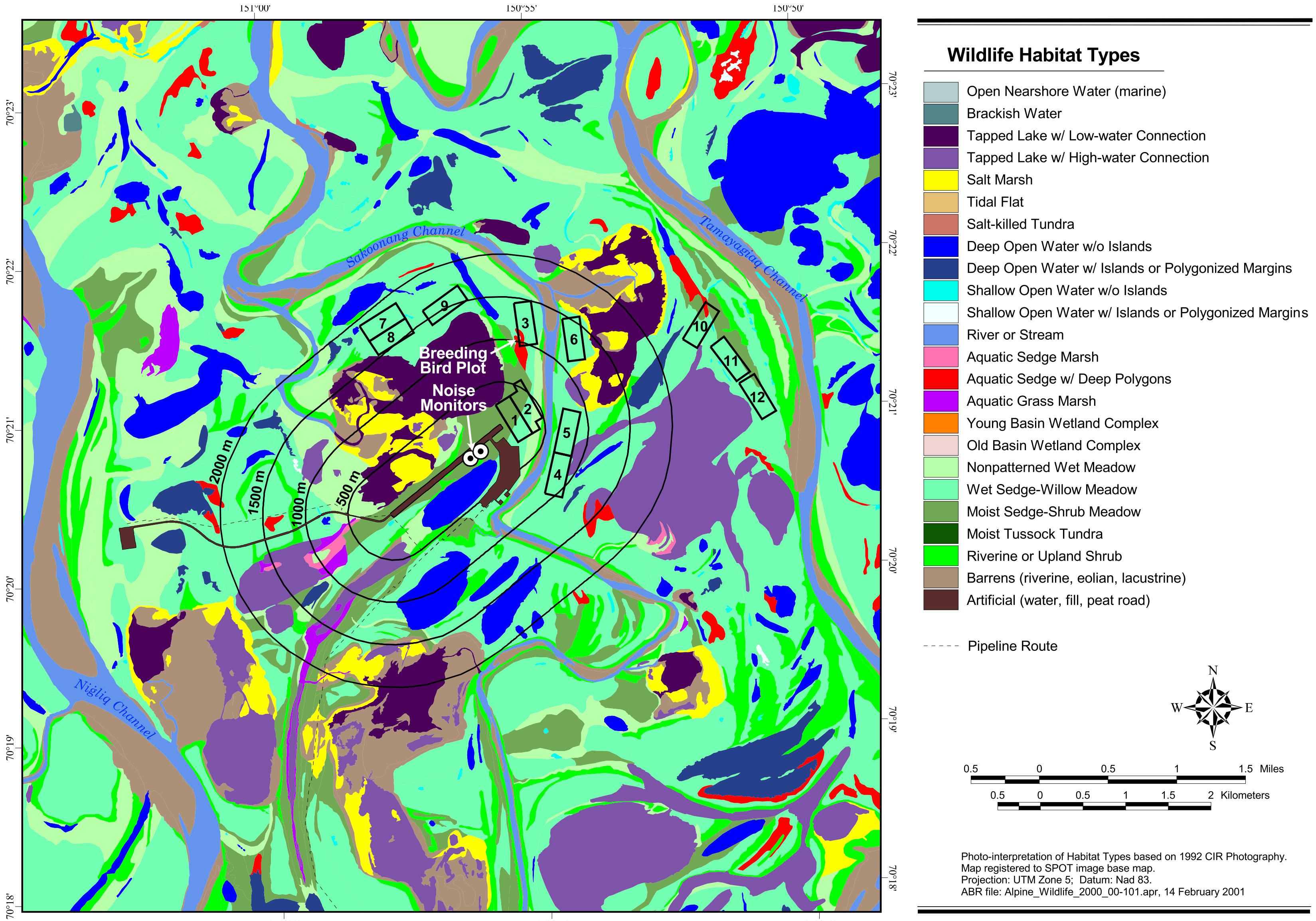

Photo-interpretation of Habitat Types based on 1992 CIR Photography.
Map registered to SPOT image base map.
Projection: UTM Zone 5; Datum: Nad 83.
ABR file: Alpine_Wildlife_2000_00-101.apr, 14 February 2001

Figure 2. Habitats, breeding-bird plots, noise monitor locations, and 500-m buffers around the airstrip in the Alpine project area, Colville River Delta, Alaska, 2000.

aircraft, vehicles, or other activities monitored by video cameras and ATC), or malfunction of the monitors.

A source (aircraft or vehicle) was assigned to time-specific noise events that occurred during landings and takeoffs of aircraft or while vehicles were active on the airstrip. Because the recorded time of aircraft (time of landing and takeoff) and vehicles (time of arrival and departure from the airstrip) might not have corresponded with the time recordings on the monitors (time-record error), 2 min was subtracted from all arrival times and added to all departure times (i.e., a 4-min "buffer"). An additional time buffer was added to aircraft times because their recorded times likely were not the times these sources were closest to the noise monitors, and other activities such as engine starts, taxiing, and approaches occurred before and after liftoff and touchdown times. These time buffers were specific to each aircraft type and were based on time records on videotape of the period before and after arrival and takeoff that engines were operating and, therefore, producing noise. The maximum times observed during our videotaped sample were applied to our buffers (Appendix C). For example, for the DC-6, the principal cargo plane used in 2000, 8 min were added to arrival times (i.e., a DC-6 took ≤8 min from touchdown to taxi, park, and shut its engines off) and 10 min subtracted from takeoff times. One min was subtracted from all aircraft arrival times and added to all aircraft takeoff times to include noise that might have been recorded just before touchdown or just after takeoff. No additional time adjustments were made for vehicles because their arrival and departure times effectively bracketed the time they were on the airstrip. Exceedance events were assigned to an aircraft or vehicle if the noise record occurred within the time buffer around a potential source. Occasionally, a noise event occurred within more than one source buffer; in these cases, the source was assigned that occurred closest in time to the noise event. If a noise event occurred outside all the time buffers placed on aircraft and vehicles, the source was unknown, because we were unable to determine whether wind or some unrecorded aircraft, vehicle, or activity on the airstrip, Pad 1, or tundra produced these noise records. Noise events were summarized for each type of aircraft and vehicle during the nesting and brood-rearing seasons. The average SEL (logarithmic), average duration of the exceedance (arithmetic), and proportion of aircraft and vehicles that produced exceedances were summarized.

NEST DENSITIES AND NESTING SUCCESS

Nest searches on the ground were conducted using the same techniques used in the Alpine project area in 1996–1999 (Johnson et al. 2000a). The survey area in 2000 was restricted to the area adjacent to the airstrip, Pad 1, and a portion of the road leading to Pad 2 (Figure 1). We searched on foot within 10 m of the shorelines of all waterbodies, and in all intervening habitat we searched with ~10-m spacing between observers walking zig-zag paths. Six to eight observers searched for nests of all ducks, geese, Tundra Swans, loons, gulls, terns, and other large birds (including ptarmigan, Common Snipe, and Bar-tailed Godwit). For each nest, the species, distance to nearest waterbody, waterbody class, habitat type, and, if the bird flushed, the number of eggs in the nest were recorded. In 2000, the nest search was conducted between 15–23 June. Some waterbird nests were located during the surveys of the breeding-bird plots, lake surveys, and video-camera maintenance. For the purposes of annual density comparisons, only nests found during the nest search and in the breeding-bird plots that were within the nest-search area were used, unless specifically stated otherwise. Breeding-bird plots were searched only one time by dragging ropes (see methods for breeding-bird plots, below), and although the method of locating nests differs from our foot searches, we believe the two techniques produce similar results for large nesting birds such as swans, ducks, and geese.

All nest locations were mapped on 1:18,000-scale color aerial photographs and the locations found in 2000 added to the existing GIS database containing locations found in 1992–1999. For most nests of waterbirds within 1,000 m of the airstrip, their exact locations were recorded using a GPS. GPS locations also were collected on nests within 200 m of the pipeline transportation system south of Pad 1 and within 200 m of the infield pipeline and road to Pad 2. Down and feather samples were collected from all waterfowl nests after hatch or failure. For those nests that were unattended and could not be identified to species, the down and feather samples were used to make preliminary identifications. Nine researchers experienced with nesting tundra birds compared these unknown samples with samples from known nests and identified them to species when possible. The assessments were compiled and nest samples receiving ≥75% of the assignments to one species were so identified with the modifier "probable". All others were recorded as unidentified.

Nest sites of waterbirds in the ground-search area were revisited after hatch (on 11–16, 18–23 and 28 July) to determine their fate. Nests were classified as successful if egg membranes that had thickened and were detached from the eggshells were found, or for loons, if a brood was associated with a nest site. Any sign of predators at the nest (e.g., fox scats or scent, broken eggs with yolk or albumen) was identified and recorded. During revisits to nests, broods in the area were recorded opportunistically on 1:18,000-scale color aerial photographs.

To facilitate comparisons of the distribution and density of nests among years, the area that had been searched in common in 1996–2000 (henceforth, "common ground-search area") was delineated and then the number of nests by species that occurred there was calculated with GIS. Distributional comparisons were made for nests occurring within four distance buffers (500, 1,000, 1,500, and 2,000 m) around the airstrip. In 1995, the search effort was less intensive (focusing on Spectacled Eiders, Johnson et al. 1996) than in subsequent years, so the results of that year's nest survey will not be discussed in the context of density comparisons.

Because the amount of effort (number of personnel and hours) spent searching for nests, as well as the total area searched, varied among years, nest-search effort was calculated for annual comparison. Nest-search effort was calculated for each year by summing the number of hours spent searching in the common ground-search area. Because records were not kept specifically for the common ground-search area in 1996–1998, the effort was estimated by multiplying the total number of hours searched by the ratio of the common ground-search area (10.6 km²) to the total area searched in each year (17.2 km², 14.3 km², and 14.8 km², in 1996, 1997, and 1998, respectively). In 1999 and 2000, the hours spent in the common ground-search area were recorded directly. The search effort was used to adjust the number and density of nests found each year to a common standard. The standardized numbers and densities of nests were calculated by multiplying each by the ratio of the search effort in 1996 (our lowest number of hours) divided by the search effort for each year:

$$\text{standardized nests}_{\text{year}} = \text{nests}_{\text{year}} \cdot (\text{search effort}_{1996} / \text{search effort}_{\text{year}}).$$

Therefore, numbers of nests and nest densities for 1997–2000 were adjusted downward to the levels that would have been found using the same effort as in 1996.

Statistical analyses were conducted with Microsoft® Excel or SPSS (SPSS, Inc., v. 10.0, Chicago, IL). Variances were tested for homogeneity, distributions were evaluated for normality, and plots of residuals were reviewed prior to final analysis. Parametric two-sample *t*-tests and one-way ANOVAs or their nonparametric equivalents (Mann-Whitney U or Kruskal-Wallis tests, respectively) were used depending on whether the data satisfied assumptions of normality and homogeneity of variances that are required for traditional parametric tests. Nearest-neighbor distances between Greater White-fronted Goose nests were measured with ArcView (ESRI v3.0a, Redlands, CA) and the distances analyzed for distributional patterns with a nearest-neighbor analysis (Clark and Evans 1954, modified by Krebs 1989).

HABITAT CLASSIFICATION AND MAPPING

The Alpine project area was classified and mapped for wildlife habitats as part of the Colville wildlife studies (Johnson et al. 1999a). Detailed methods for the mapping and classification were presented by Johnson et al. (1996), and the accuracy of the habitat map was assessed by Jorgenson et al. (1997). In 2000, the habitat map was reviewed and some revisions and refinements were made to the existing classifications.

The habitat classification was based on those landscape properties that we considered to be most important to wildlife: shelter, security (or escape), and food. In our classification, wildlife habitats on the delta are not equivalent to vegetation types. In some cases, dissimilar vegetation types with similar surface forms were combined because selected wildlife species either did not use them or used them to similar extents. Conversely, wildlife use may differ between habitats with similar vegetation based on relief, soil characteristics, associated fauna, or other factors not reflected by plant species composition. Classification systems of wildlife habitat for the same region may differ, depending on the wildlife species or species-groups being considered. Our study concentrated on breeding waterbirds that use waterbodies and wet and moist tundra. A comparison of habitat classifications previously used in this region illustrated some of the differences among various systems (Johnson et al. 1996: Appendix Table A8).

HABITAT SELECTION

Because the Greater White-fronted Goose (henceforth, White-fronted Goose) was a focal species in our disturbance analyses, habitat selection was investigated as one factor that could affect its nest distribution. Quantitative analyses of habitat selection were based on the locations of nests found during ground surveys each year from 1996 to 2000. Use was calculated as the percentage of the total number of nests that was observed in each habitat. The availability of each habitat was the percentage of that habitat in the survey area common among the four years.

Significant habitat selection (i.e., use ≠ availability) was tested by conducting Monte Carlo simulations (Haefner 1996, Manly 1997) in Microsoft® Excel. Each simulation used random numbers (range 0–100) to choose a habitat from the cumulative relative frequency distribution of habitat availability (0–100%). The number of "random choices" used in each simulation was equal to the number of nests from which percent use was calculated. One thousand simulations were conducted and the frequency distribution of use for each habitat was summarized by percentiles. Habitat preference (i.e., use > availability) was defined to occur when the observed use was greater than the 97.5 percentile of simulated random use. Conversely, habitat avoidance (i.e., use < availability) was defined to occur when the observed use was less than the 2.5 percentile of simulated random use. These percentiles were chosen together to achieve an alpha level (Type I error) of 5% for a two-tailed test. Habitats with nonsignificant selection (i.e., observed use ≥ 2.5 and ≤ 97.5 percentiles) were deemed to have been used approximately in proportion to their availability. The simulations and calculations of percentiles were conducted in a Microsoft® Excel spreadsheet on a personal computer.

NEST ATTENDANCE AND BEHAVIOR

Egg thermistors and time-lapse video cameras were used to monitor nest attendance for a sample of focal species nesting in the Alpine project area in 2000. Egg thermistors only were placed in 37 White-fronted Goose nests, whereas cameras were placed at four White-fronted Goose and two Tundra Swan nests. Egg thermistors were deployed in White-fronted Goose nests occurring over a range of distances from the airstrip, so that distance could be used as a continuous variable in tests of disturbance effects around the airstrip. White-fronted Goose and Tundra Swan nests closest to the airstrip were selected to be monitored with cameras, so that we could monitor reactions to aircraft in the area with the highest potential for disturbance impact.

Thermistors were implanted in domestic goose eggs that had the contents removed and an internal coating of epoxy added to strengthen the shell. A temperature probe with a 6-ft lead (TMC6-HA) was glued into each egg, and the lead connected to a data-logger (HOBO® H8 temperature logger, Onset Computer Corp., Pocasset, MA). A large nail was attached to the bottom of each egg using layers of canvas cloth coated with epoxy. The nail was pushed into the ground under the nest so that the egg could not be removed by a predator or rolled out of the nest by the incubating female.

Egg thermistors were deployed on the day the nest was found or shortly thereafter. After installing an egg thermistor, the cable and data-logger were buried under vegetation and organic soil to conceal them from predators. The egg thermistor and the rest of the clutch was covered with down and nesting material from the nest. The data-loggers were programmed to record the temperature (°C and °F) of the egg at 5-min intervals and had data-storage capacities sufficient to record the entire incubation period. After hatch (or failure), each nest was checked to judge its fate and retrieve the egg thermistor. One data-logger was placed in a shaded location and programmed to record ambient temperature at 10-min intervals.

Five Sony CCD-TR 516 video camera recorders were used to monitor nests. Cameras were controlled by a programmable electronic board (LJ&L Products, Ringgold, LA) and powered by one 12V, 33 amp-hour battery (Power Sonic PS-12330) connected to a solar battery charger (Uni-Solar MBC-262). Each unit, including the battery, was housed in a weatherized plastic case with a plastic window (LJ&L Products, Ringgold, LA). For deployment at the nest, the case was strapped to an aluminum sawhorse stand and secured with guy lines to stakes to stabilize the camera during windy conditions. The solar battery charger also was staked to the ground near the unit. The video camera was placed a minimum of 45 m from the nest and the zoom lens was used to center the nest in a field of view approximately 2–5 m across at the nest site. During setup, a 5.5-cm video monitor (Citizen ST055) was connected to the video camera to act as a viewfinder for reviewing camera aim and recording. Each camera recorded 2 sec of videotape (Sony or Fuji P6-150) every minute continuously throughout the day. The date and time were recorded in Alaska Daylight Time (ADT) and displayed on the videotape at each recording interval. Each videotape lasted approximately 5.5 d before it required replacing.

Three types of nest attendance activity were distinguished from the videotapes based on definitions used by Cooper (1978): incubation, breaks, and recesses. Time on the nest is composed of incubation (also known as sitting spells), when the female is sitting on the nest, and breaks, when the female changes position or stands above the nest and rearranges the eggs and nesting material. Periods off the nest, when the female is standing beside the nest or when she is away from the nest and out of the camera view completely, are recesses. To identify incubation, breaks, and recesses at nests monitored with egg thermistors, the same decision rules developed in 1998 from two White-fronted Goose nests monitored with both an egg thermistor and a time-lapse camera were used (see Appendix B for details of activity classification from temperature records). Nesting behavior seen on videotape was compared with nesting behavior determined from patterns of egg temperatures recorded by thermistors at each of four nests monitored by both (3 nests from 1999 and 1 nest from 2000) using the Wilcoxon signed ranks test.

In addition to recording nest attendance, cameras were used to record nesting behavior, occurrences of predation, and other disturbances at nests. The time and duration of any periods that predators were observed near or at the nest were recorded. Potential nest predators in the Alpine project area include Glaucous Gulls, jaegers, Snowy Owls, Common Ravens, and arctic and red foxes. If the incubating bird reacted to the predator by standing over the nest, the event was identified as a defense break (Hawkins 1986) and included in time on nest. Other potential sources of direct disturbance at the nest included humans, aircraft, vehicles, caribou, and non-predatory birds (e.g., swans, geese, and ducks). At all nests monitored by video cameras, alert and concealment postures were identified, and at the two Tundra Swan nests, incubation exchanges were noted between the male and female birds. Incubation exchanges were included in time off the nest.

For all nests monitored with egg thermistors and/or time-lapse cameras, we calculated incubation constancy (the percentage of time that a female bird spends on the nest per day), the frequency of incubation breaks and recesses, and total time off the nest and pooled the data for all nests active on each day before hatch or day before failure (sample unit = nest · d [1 nest monitored for 1 d]). Mean recess length was calculated by pooling all recesses from all active nests each day. The length of incubation breaks could not be measured with egg thermistors because breaks were shorter than the 5-min interval between recordings. Any days of partial monitoring, which included the day the egg thermistor and/or camera was installed, the day of hatching, and any days when data were not collected due to equipment malfuntion, operator error, or logistical constraints, were eliminated from the data. Days or portions of days when off-airstrip human activities near the nest potentially could have affected the daily activity pattern of the incubating bird were also eliminated. Off-airstrip human activity was exclusively pedestrian traffic on the tundra (biologists, surveyors, and cleanup personnel), and was not related to normal operations of the aircraft, the airstrip, or its maintenance. Because the objective of this nest monitoring was to identify the effects of aircraft and other airstrip activities on nesting behavior, unrelated human disturbance that could confound the evaluation was identified. Thirty min were subtracted from the beginning and added to the end (i.e., the duration was increased by 60 min) of the period human activity occurred within 200 m of a nest to account for any change of the bird's activity as the pedestrians approached or departed; this time period was defined as "disturbed", whether a response to the pedestrians was detected or not. If the incubating bird was flushed from the nest because of off-airstrip human activity, the bird was considered disturbed until 30 min after it resumed normal incubation. If the total amount of disturbed time in a day was greater than 150 min (the approximate interval between recesses or breaks plus 60 min), the day was eliminated from the analysis, under the assumption that the normal schedule of recesses and breaks was probably affected. If the total amount of disturbed time was less than 150 min, that time period was subtracted from the daily total time of egg thermistor or video monitoring, and the remaining portion of the day was used for calculations. The time that poor viewing conditions (e.g., heavy fog, moisture on the lens, or too little or too much light for correct photographic exposure) prevented us from judging whether the female was incubating or off the nest also was subtracted from the total time of video monitoring. In such cases, incubation constancy was calculated as the percentage of time the bird was observed incubating out of the total time the nest was visible.

Differences in nesting activities between successful and failed White-fronted Goose nests were tested using data from egg thermistors. The incubation data were transformed to meet assumptions for parametric statistical testing, and *t*-tests used to evaluate differences between successful and failed nests.

DISTURBANCE MONITORING

The airstrip was included in the view of four of the video cameras, and the infield road in the view of one camera. The time that people, aircraft, and vehicles entered and exited each camera view was recorded. Aircraft and vehicle arrival and departure times also were recorded by Alpine ATC. Airstrip activities were summarized using arrival and departure times for aircraft and vehicles recorded by ATC and any additional aircraft or vehicles seen on the videotapes. The occurrence of vehicles on the infield road, and of people on the airstrip, the infield road, and the tundra were obtained from the videotapes only. The frequency of occurrence of each activity by day for the nesting period was calculated (monitored with cameras 11 June–14 July). In addition, for people and each type of vehicle, we calculated the amount of time they were on the airstrip and the cumulative number of person- or vehicle-minutes (the summation of the time each person or vehicle type was present). Because ATC did not record when vehicles were parked on the airstrip, vehicle-minutes may include time when vehicles were parked.

The relative effect of potential disturbance sources (aircraft, vehicles, and people, predators, and large birds [geese, swans, ducks, and loons]) on the incubation behavior of White-fronted geese was analyzed for four geese monitored with video cameras. The occurrence and duration of concealment postures was summarized for periods when aircraft, traffic, and people were on the airstrip and occasions when predators or large birds were in the video view. For aircraft and vehicles, we used the same buffers around arrival and departure times that were designed for the noise analysis (see NOISE MONITORING) to account for the time that aircraft or vehicles were active on the airstrip (e.g., taxiing, warming engines) beyond the point in time they were recorded arriving or departing. Because most people on the airstrip were walkers or joggers and their presence usually was detected for only one recording interval on the video, we subtracted 30 min before and added 30 min after their time of appearance to represent actual time spent on the airstrip. For predators and large birds, no time adjustments were made to the arrival and departure times. If a concealment posture occurred during multiple disturbance events, the source was assigned that occurred closest in time to the onset of concealment. If a concealment posture occurred outside the time bracketing the disturbance events, the source was identified as unknown. To examine the relative sensitivity of nesting geese to aircraft, vehicles, and pedestrians on the airstrip, we calculated the rate of concealment (i.e., the percentage of all events of one source that elicited concealment postures) for each disturbance source.

The effects of disturbance variables on the nesting activities of geese monitored with egg thermistors were analyzed in several steps. All data were summarized by nest and day. Measures of nesting activities from egg thermistors included incubation constancy, time off nest, number of recesses, and number of incubation breaks. Disturbance variables that potentially could affect nesting activities, that is, frequency of landings and takeoffs by type of fixed-wing aircraft and helicopters, total time that road machinery, large trucks, small trucks, and pedestrians were on the airstrip, total time that pedestrians were on the tundra, mean temperature, and mean wind speed were evaluated. A matrix of Pearson correlation coefficients were used to examine pairwise correlations (Pearson's *r*) between nest-attendance variables. Because these variables were highly correlated, a single variable was chosen that was significantly different between successful and failed nests (i.e., incubation constancy) to serve as a response variable for modeling effects of disturbance on nesting activities. Likewise, pairwise correlations between disturbance variables were examined to select a subset of variables with low intercorrelations (generally, $|r| < 0.50$) that represented distinct types of potential disturbance. Censoring highly correlated variables helped control multicollinearity in subsequent forward, stepwise multiple regression analysis (alpha-to-enter = 0.10, alpha-to- remove = 0.15) of incubation constancy on potential disturbance variables. A univariate general linear modeling procedure was used to test whether the slope of the relationships between incubation constancy and the disturbance variables selected in the stepwise regression were the same for successful and failed nests. If they were not, separate stepwise multiple regression analyses were conducted for successful and failed nests, based on the subset of disturbance variables that previously were identified as having low intercorrelations and being useful predictors of incubation constancy.

BREEDING-BIRD PLOTS

Twelve plots that were established in 1998 were sampled for nesting birds in 2000 with the same methods as in 1998 and 1999 (Johnson et al. 2000a). Plots measured 200 x 500 m (10 ha) and were marked by two rows of surveyor's lath that delineated 50 x 50 m grids (Figure 3). Six 10-ha plots ("treatment" plots) were placed in locations that were expected to be exposed to loud noise during aircraft landings and takeoffs from the airstrip; that is, locations near (≤1,000 m) the airstrip (plots 1, 2, 4, and 5) or directly in the flight path (plots 3 and 6; Figure 2). The remaining six plots ("reference" plots) were located away from the airstrip (>1,500 m). The habitat classification map was used to choose locations for the plots in an attempt to match the habitat composition between the treatment and reference plots. Three treatment and three reference plots were placed in areas of the Wet Sedge–Willow Meadow habitat class (plots 4–9) and the remaining plots were placed in areas of mixed habitat, predominantly Wet Sedge–Willow Meadow with varying proportions of Moist Sedge–Shrub Meadow and Aquatic Sedge with Deep Polygons (Figure 2). Missing and broken plot markers were replaced and locations recorded of nests encountered opportunistically on 8–11 June 2000. Each plot was sampled once between 17 and 24 June. A rope 53-m long was dragged between two people (one walking the centerline while the other walked the outer border of the grid) followed by an observer walking near the middle of the rope. When a bird was flushed, all three people stopped and observed. If the bird would not return to its nest, the observers moved away or used the terrain as cover until the bird returned. For each nest found, we recorded the species, the number of birds present, the number of eggs or young, the surface form (e.g., polygon rim or center, island, nonpatterned) and habitat at the nest, and its location by grid number and quadrant within the grid (Figure 3).

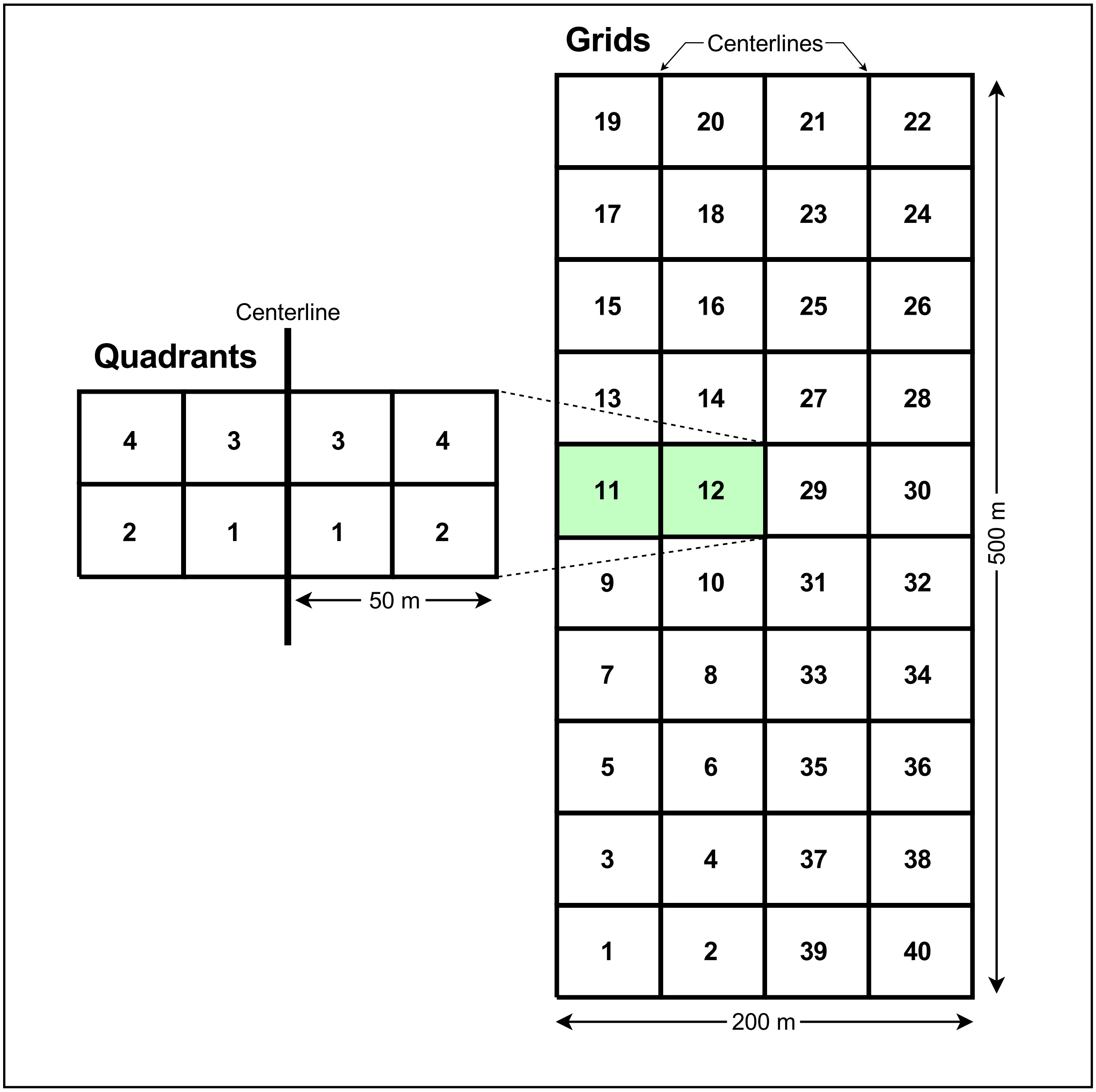

Figure 3. Diagram of layout for breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 2000.

HABITAT ASSOCIATIONS

During July and August 1999, habitat variables were measured on the breeding-bird plots to describe nesting habitat (Johnson et al. 2000a). Habitat variables were described at two scales: grids (50 x 50 m) and quadrants (25 x 25 m). Grids were classified by vegetation type and surface features including surface form (polygon, disjunct polygon, dune, nonpatterned), relief (low, high, none), polygon centers (low, high, none), and polygon density (low, high, none) (see Jorgenson et al. 1997 for definitions). For each quadrant, we estimated the coverage of water and up to three vegetation types and estimated the modal relief (from water level to highest point) and modal water depth in centimeters. Water containing ≥15% vegetation cover was classified as a vegetation type (e.g., Aquatic Grass Marsh, Aquatic Sedge Marsh). The distance of the plots (centroid of each plot) were measured to the closest point on the airstrip using GIS. Kruskal-Wallis tests were used to evaluate the null hypotheses that surface relief, water depth, proportion of water, and proportions of vegetation cover by vegetation association did not differ among plots. Whether these characteristics differed between treatment and reference plots also was evaluated using Mann-Whitney U tests. The null hypotheses that the frequency of occurrence for surface features (i.e., surface form, polygon centers, and polygon density) did not differ between treatment and reference plots were tested with chi-square tests.

To compare the number of nests between treatment and reference plots for all birds combined and for each of the five most common species individually, *t*-tests were used. To examine the relationship between frequency of nests and distance from the airstrip, the number of nests per plot was regressed on distance from plot to airstrip for each of the five most common species and for all species combined. Stepwise logistic regression was used (Hosmer and Lemeshow 1989) to analyze the relationship between habitat characteristics and the occurrence (presence/absence) of bird nests within our 480 study grids (40 grids/plot). As was done for 1998 and 1999 (Johnson 2000a), separate regressions were run for the following species or species groups: all waterfowl, White-fronted Goose, all shorebirds, Pectoral Sandpiper, Semipalmated Sandpiper, all passerines, and Lapland Longspur. The pool of potential explanatory variables included both continuous and categorical habitat characteristics. Continuous variables were surface relief (cm), water cover (%), water depth (cm), and cover (%) of eight vegetation types (i.e., wet sedge meadow, wet sedge willow, moist sedge shrub, sedge marsh, grass marsh, open low willow, *Dryas* tundra, and partially vegetated mud). Distance to the airstrip was transformed into a categorical variable with four levels (≤780 m, 781–1,430 m, 1,431–2,412 m, and >2,412 m) because the measure of distance was from the plot centroid rather than the individual quadrant, and the latter was the experimental unit for nest occurrence. Other categorical habitat variables included surface form, the nature of polygon centers, and polygon density.

The initial approach to building explanatory models to predict nest occurrence based on a subset of habitat characteristics was to perform forward stepwise logistic regressions with probability to enter = 0.20 and probability to remove = 0.40. The 95% confidence intervals (CIs) then were examined for the odds ratios of selected parameters. The odds ratio derives from the estimated regression coefficient (specifically, odds ratio = Exp[β]), and describes the change in probability of response corresponding to a unit change in the explanatory variable. For example, in a model that describes nest occurrence of Semipalmated Sandpipers, if the odds ratio for open low willow (% vegetation cover) is 1.044, there is a predicted 4.4% increased probability that at least 1 Semipalmated Sandpiper nest will occur per grid for each 1% increase in open low willow cover. As a further illustration, if the odds ratio for water depth (cm) in the same model is 0.977, there is a predicted 2.3% decreased probability (i.e., 1.000 – 0.977) that at least 1 Semipalmated Sandpiper nest will occur per grid for each 1.0 cm increase in water depth. An odds ratio of 1.0 suggests that a potential explanatory variable has no effect on the response (in this example, the occurrence of ≥1 nest). The inclusion of 1.0 in the 95% CI for a logistic regression odds ratio suggests that the associated habitat characteristic may not be useful for predicting nest occurrence. These CIs were examined for variables selected by our forward stepwise procedure, and variables removed for which the CI spanned 1.0. If this condition applied to >1 variable in an individual model, variables were removed sequentially, starting with the variable with the highest *P* value for its regression coefficient, and the model refit until all remaining variables met the selection criteria. The significance of each final model was tested with a likelihood-ratio statistic, and assessed classification performance with a 2-way classification table for observed versus predicted outcomes.

SEASONAL USE OF LAKES

In 2000, ten surveys of lakes in the Alpine project area were conducted to assess seasonal use of lakes by large waterbirds (Figure 4). Numbers from the Emergency Response Grid (Moulton 1998; Moulton, pers. comm.) were used to identify the lakes covered in these aerial surveys. A Bell 206 Long Ranger helicopter was used to fly surveys during June (3 surveys), July (4), and August (3). Flight altitude and speed varied, depending on weather, visibility, and other factors. In general, altitude was 45–90 m above ground level, and speed was ~123 km/h but was reduced when necessary to count or identify groups of birds. A single observer was seated in the front left side of the helicopter. Observations were recorded with a small, hand-held, cassette-tape recorder and/or on a schematic map of the study area. In addition to numbers and species of waterbirds using the lakes and lake margins, any nests or broods of waterbirds also were noted. All tape-recorded information was transcribed to data forms soon after the completion of the aerial survey.

FOX DEN MONITORING

Aerial and ground-based surveys were used to evaluate the distribution and status of arctic and red fox dens on the Colville River Delta in 2000, continuing the annual monitoring effort begun in 1992 across the entire delta and adjacent coastal plain. Den status and pup presence at known dens were assessed on helicopter-supported ground visits during 28 June–2 July, then we returned to active dens during 10–13 July to count pups. Most survey effort focused on checking dens found in previous years (Smith et al. 1993, 1994; Johnson et al. 1996, 1997, 1998, 1999a), although opportunistic searches for dens in suitable habitats also were conducted while transiting between known dens. Soil disturbance from foxes digging at den sites, and fertilization resulting from feces and food remains, results in a characteristic, lush flora that makes perennially used sites easily visible from the air after "green-up" of vegetation (Chesemore 1969, Garrott et al. 1983a).

During ground visits, evidence of use by foxes was evaluated and the species using the den confirmed. Fox sign was examined to assess den status (following Garrott 1980): presence or absence of adult or pup foxes; presence and appearance of droppings, diggings, tracks, trampled vegetation, shed fur, and prey remains; and signs of predation (e.g., pup remains). Dens were classified into four categories (following Burgess et al. 1993), the first three of which are considered to be "occupied" dens:

1. *natal*—dens at which young were whelped, characterized by abundant adult and pup sign early in the current season;
2. *secondary*—dens not used for whelping, but used by litters moved from natal dens later in the season (determination made from sequential visits or from amount and age of pup sign);
3. *active*—dens showing evidence of consistent, heavy use, and suspected to be natal or secondary dens, but at which pups were not seen; or
4. *inactive*—dens with either no indication of use in the current season or those showing evidence of limited use for resting or loafing by adults, but not inhabited by pups.

Because foxes commonly move pups from natal dens to secondary dens, repeated observations are needed to classify den status with confidence. Since 1996, a concerted effort has been made annually to confirm den occupancy and to count pups. Based on the initial assessment of den activity, the observations during 10–13 July were devoted to counting pups at as many active dens as possible. Observers were dropped off by helicopter at suitable vantage points several hundred meters from den sites, from which they conducted observations with binoculars and

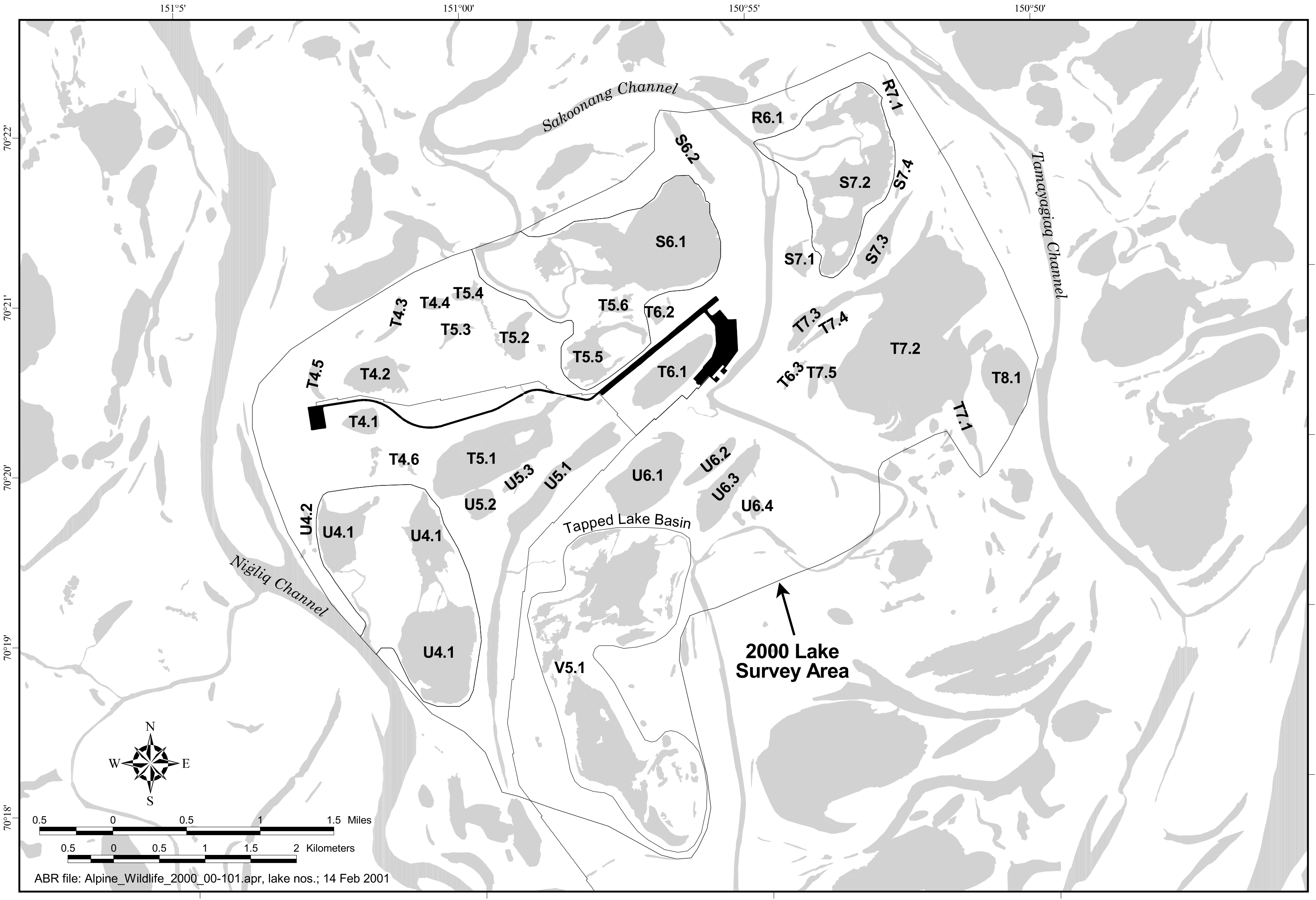

Figure 4. Lake numbers and boundary for lake surveys conducted in the Alpine project area, Colville River Delta, Alaska, 2000. Groups of lakes outlined within the boundary represent basins containing Tapped Lakes (both High- and Low-water Connections).

spotting scopes over periods of 2.5–4 hours. Observations usually were conducted early and late in the day, when foxes tend to be more active.

RESULTS AND DISCUSSION

CONDITIONS IN THE STUDY AREA

PHENOLOGICAL TIMING

The timing of snow and ice melt on the delta can be highly variable among years. The 2000 breeding season was unusual among recent years because of the extent that weather and river conditions delayed the onset of nesting for birds in much of the study area. Spring temperatures were colder and snow melt in 2000 was later relative to other years we have worked on the delta. Average daily temperatures in the Kuparuk Oilfield (~25 km east of the delta) did not get above freezing during 15–31 May 2000, making it the coldest year during this period since we began surveys on the delta in 1992 (Figure 5). Temperatures warmed steadily in early June above those achieved in 1999 and were similar to temperatures in 1997. During 11–15 June 2000, snow cover averaged 40% and 54% (range = 10–85%) in two caribou survey areas west and south of the Kuparuk Oilfield (adjacent to the Colville River) (ABR, unpubl. data). During the same period in 1999, these two survey areas had <15% snow cover (Lawhead and Johnson 2000). In addition to late snow melt, the Colville River broke up relatively late on 8 June, and ice jams caused extensive flooding on the delta during the second week of June, which made some nesting areas in the Alpine project area inaccessible for several days. On 22 June 2000 (the first lake survey), Tapped Lakes with Low Water Connections (henceforth, tapped basins) had been extensively and deeply flooded by river discharge, hastening ice melt in the shallowest portions; however, deeper sections of the basins remained frozen. With the exception of lake U5.1 (see

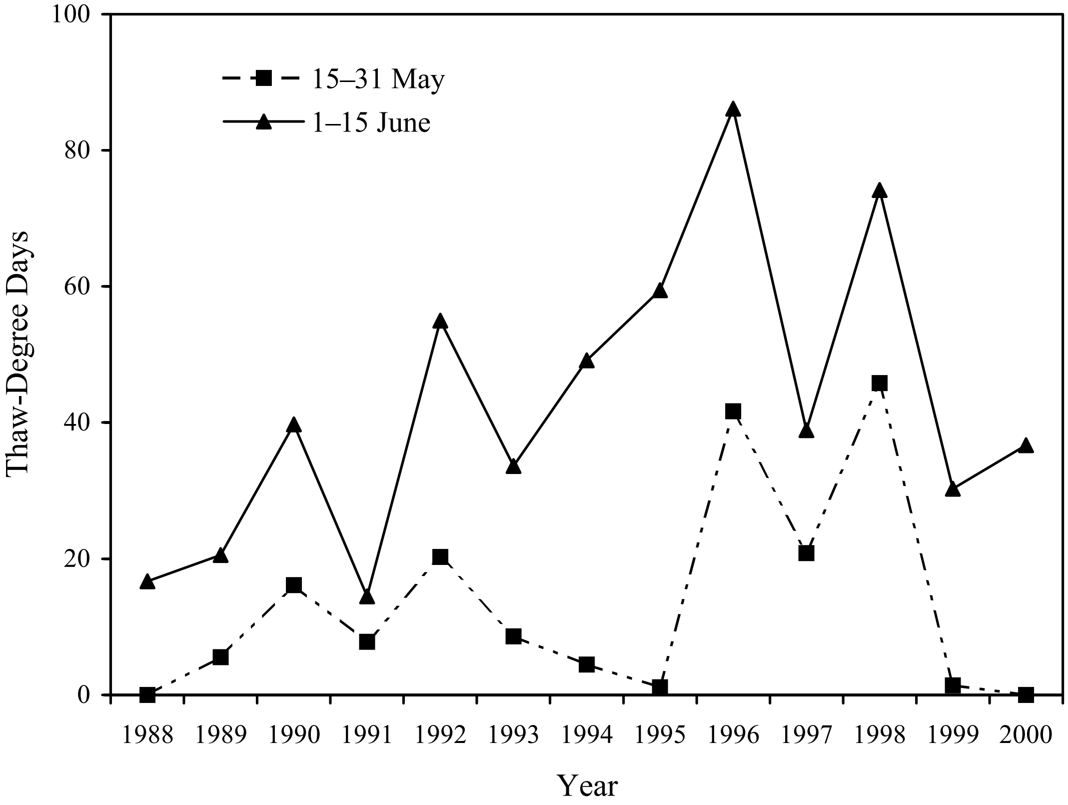

Figure 5. Number of thaw-degree days recorded for 15 May–15 June in the Kuparuk Oilfield, Alaska, 1988–2000. Thaw-degree days are calculated by summing the number of degrees above 0° C for daily mean temperature.

Figure 4), which also had been inundated by flood-waters and was almost completely thawed, all other lakes remained solidly frozen, about 7–10 d later than in 1999. Open water in many lakes was restricted to narrow shore leads, in some cases the low-lying polygon fields bordering lakes were flooded by snow melt.

By 30 June, the deeper portions of tapped basins had lost nearly all of their ice cover. The extent of ice cover of other lakes also had diminished; the deeper lakes still retained significant amounts of ice. Shallow (< ~1.5m), restricted embayments of the larger lakes were thawing more rapidly than main bodies of lakes and all lakes had open water leads along shore. In some of the mid-sized lakes, wind-driven masses of ice were overriding downwind shorelines. With the exception of Lake T7.2, all ice cover in the Alpine area had melted by 7 July, only 1 d later than in 1999. Although temperatures in late May were colder in 2000 than in 1999, temperatures rebounded in early June 2000, accelerating the thawing of lake ice and likely contributing to the late but rapid breakup of the Colville River, which flooded extensive areas.

Many of the lakes in the Alpine project area had been covered by the flood waters of the Colville River during spring breakup. The ice cover on these lakes was overlayed by deposits of mud, silt, and other debris. After the ice melted, many of these lakes were left turbid and containing varying amounts of driftwood and other flotsam. In some cases, the increased turbidity lasted throughout the entire summer.

Midges first were observed on 16 June with large-scale emergence occurring on 24 June. The first mosquito was seen on 20 June with moderate mosquito activity occurring on 22 June. These dates were earlier than in 1999, when large numbers of midges and mosquitos did not become active until 26 and 28 June, respectively, probably because early June temperatures in 1999 were cooler than in 2000 (Figure 5). However, the nesting season was delayed in comparison to 1999, which also was a relatively late year. The first observation of hatching in 2000 was at a Lapland Longspur nest on 23 June, which was 4 d later than in 1999 (Johnson et al. 2000a). In 2000, Greater White-fronted Geese were not observed on nests before 15 June, and the earliest hatch date was 8 July with a mean hatch date of 10 July ($n = 12$). In 1999, the first White-fronted Goose nest (4 eggs) was found on 8 June, the first hatch at a goose nest was on 2 July, and mean hatch date was 5 July ($n = 16$). The 2000 nesting season probably was the latest season since we began collecting data in the Alpine project area in 1995. In 2000, the nesting season was approximately 4–7 d later than in 1999. The 1999 nesting season was estimated to be similar in timing to 1997, but a week later than in 1998 and 1996 (Johnson et al. 2000a).

Another index to the lateness of the nesting season was the delayed development of Tundra Swan and loon young, which take longer than other species on the delta to become capable of flight. Young swans were judged to be unusually small during our brood-rearing survey on 17–19 August, and during the staging survey on 16 September, family groups were observed still to be on nesting territories. No young were observed in flocks, which usually form by mid-September prior to migration and freeze-up. During the same staging survey, loon adults were observed in flight, but none were observed on lakes attending young. These observations suggest that few swan or loon young may have survived to the beginning of migration, if freeze-up occurred during the second or third week of September, as it has in most years.

HUMAN ACTIVITY

The Alpine project area was under full construction in 2000 (Table 1). During late winter and early spring 2000, ice roads and pads were completed and equipment and materials were transported to Pad 1. Ice roads were closed to general traffic on 14 May (exceptions were made for rolligons and track vehicles on one route until 22 May), after which all materials and personnel were transported by aircraft, primarily DC-6s and Twin Otters. A Bell 206 LR helicopter flew in the project area from late May to early October, landing on the tundra just southwest of the airstrip access road. By June 2000, all gravel was in place and the bridges to Pad 2 were complete, but the road to Pad 2 was too soft for regular truck traffic until later in the summer (Figure 1). Pad 1 contained all the modules needed for operation plus a 300-man camp, two temporary camps, a drill rig, and separate rig camp. During summer, Pad 2 was used for storage, but was not under construction until after the nesting season. The camp population varied between approximately 400 and 700 people during the summer season, up from 140–180 people in 1999 (M. Couey pers. comm.). Exact counts of vehicles and mobile equipment were not available but numbers were at least twice those operating in 1999. The number of aircraft (fixed-wing and helicopter) landings and takeoffs during the nesting season doubled from 1999 to 2000. In 2000, the mean daily rate of aircraft landings and takeoffs from 1 June to 15 July was 44.3/d ($n = 45$ d, Table 2), similar to the rate from 16 July to 26 August ($\overline{x} = 39.2$/d, $n = 42$ d; Appendix F4). During 13 June to 6 July 1999 (the period of time during which aircraft were monitored by our videocameras), the mean rate was 20 landings and takeoffs/d ($n = 24$ d; see Table 10 in Johnson et al. 2000a). Helicopters and Twin Otters made equivalent numbers of trips to Alpine in 2000 (both $\overline{x} = 20$ landings and takeoffs/d), but in 1999 most flights were by helicopters ($\overline{x} = 16$/d, $n = 24$ d) rather than by Twin Otters ($\overline{x} = 3$ landings and takeoffs/d, $n = 32$ d).

NOISE MONITORING

From 8 June through 15 July 2000, we recorded 145 noise events (exceedances) that could be assigned to a known source and 261 events with no identifiable source (Table 3); multiple exceedances were sometimes recorded for the same source. The greatest number of exceedances (31) and the highest SEL (111 dBA) were recorded for departing DC-6s. The longest mean duration of exceedances (9 sec) was produced by C-130 Hercules landing, but the maximal duration was from a Twin Otter landing (13 sec). In general, four-engine aircraft produced the highest exceedances, followed by single-engine aircraft, twin-engine aircraft, and helicopters. The helicopter is the only source evaluated that did not use the airstrip, so measurements were probably diminished by the distance of the monitor to its landing and takeoff location (~330 m until 16 July, then ~180 m). Most aircraft produced higher exceedances on takeoffs than on landings. Only 10 exceedances could be assigned to vehicles and, with the exception of loaders and water trucks, vehicle sources had lower SELs than did aircraft.

After nesting (16 July–20 August), the noise monitors recorded 189 exceedances that were assigned to sources and 255 exceedances with no identifiable source (Table 3). The same general trends for SELs among aircraft were observed as during the nesting period. Notable exceptions were that one single-engine Cessna 207 produced the highest SEL (143 dBA) and longest average duration (19 sec), helicopters had higher SELs than did twin-engine aircraft, and twin-engine aircraft (130 exceedances) produced many more exceedances than did four-engine aircraft (15). The SEL value for the Cessna 207 probably is an aberrant measurement and likely was caused by a calibration error in the monitor.

Exceedances with unidentifiable sources may have been caused by wind or unrecorded activities (e.g., heavy equipment, construction, or drill rig operation at Pad 1). Unidentifiable exceedances also could have occurred when aircraft flew over noise monitors but did not land. The helicopter sometimes flew over the airstrip without landing or landed at places on the tundra other than at the helipad, but we did not have a way to record aircraft activity that did not occur in the view of our video cameras or land and takeoff at the airstrip. Similarly, some of the noise events to which we assigned a source based on coincident timing may have been produced by wind or activities on Pad 1 (e.g., heavy equipment or drill rig activity). However, by restricting our source assignments to windows of time that we know aircraft and vehicles were operating, we believe we have attributed noise events to sources conservatively.

Although the noise monitors were on location continuously from 8 June to 20 August, valid noise data were collected only during portions of that time (80%). To compare the relative noise produced by the different sources (aircraft or vehicles), the percentage of occurrences was calculated of each source that produced exceedances during valid recording sessions (i.e., monitor was in calibration, wind speeds ≤15 mph). During the nesting season, 7% of all aircraft events (95 of 1,354 landings and takeoffs) during valid recording sessions produced noise events (Table 4). C-130 Hercules had the highest exceedance rates; the monitor recorded 100% of eight landings and takeoffs as exceedances. DC-6s

Table 2. The type and frequency of aircraft using the airstrip during nest monitoring in the Alpine project area, Colville River Delta, Alaska, 2000. Frequency for aircraft includes takeoffs and landings. Data are from Alpine air traffic control records and this study.

	Aircraft Type						
Date	C-130 Hercules	DC-6	CASA	Twin Otter/ Conquest[a]	Cessna 207	Helicopter	Total
1 June	0	0	0	30	0	28	58
2 June	0	2	0	26	0	40	68
3 June	0	4	0	20	0	30	54
4 June	0	0	0	20	0	28	48
5 June	0	0	0	36	0	26	62
6 June	0	0	0	32	2	16	50
7 June	0	6	0	16	0	26	48
8 June	0	0	0	16	0	24	40
9 June	0	2	0	16	0	24	42
10 June	0	2	0	4	0	10	16
11 June	0	6	0	6	0	28	40
12 June	0	2	0	34	0	20	56
13 June	0	0	0	14	0	16	30
14 June	0	2	0	18	0	22	42
15 June	0	0	0	18	0	24	42
16 June	0	4	0	24	0	10	38
17 June	0	6	0	14	0	26	46
18 June	0	0	0	10	0	44	54
19 June	0	0	0	30	2	26	58
20 June	0	6	0	48	0	30	84
21 June	0	6	0	22	0	32	60
22 June	0	0	0	18	0	26	44
23 June	0	4	0	22	2	16	44
24 June	2	10	0	14	0	30	56
25 June	6	0	0	8	0	22	36
26 June	0	4	0	32	0	14	50
27 June	0	2	0	22	0	16	40
28 June	0	4	0	20	0	22	46
29 June	0	2	0	22	0	16	40
30 June	0	0	0	20	0	26	46
1 July	0	4	0	12	0	8	24
2 July	0	0	0	6	2	8	16
3 July	0	0	0	36	0	6	42
4 July	0	2	0	20	0	10	32
5 July	0	2	0	22	0	10	34
6 July	0	0	0	18	0	8	26
7 July	0	2	0	18	0	6	26
8 July	0	4	0	10	0	18	32
9 July	0	0	6	8	0	16	30
10 July	0	0	8	30	0	12	50
11 July	0	2	10	24	0	4	40
12 July	0	2	8	23	0	16	50
13 July	0	0	8	25	0	12	44
14 July	0	4	2	20	0	26	52
15 July	0	2	10	12	0	32	56
Daily Mean	0.2	2.2	1.2	20.4	0.2	20.2	44.3
Total	8	98	52	916	8	910	1,992

[a] Takeoffs did not always equal landings because aircraft periodically stayed overnight at Alpine.

Table 3. Mean (logarithmic) sound exposure levels (SEL) in A-weighted decibels (dBA) and the duration (sec) of noise events exceeding 85 dBA for at least 2 secs recorded at noise monitors from two locations around the Alpine airstrip, Colville River Delta, Alaska, 2000. Events were averaged separately at each monitor and the highest mean was reported.

		Nesting (8 June–15 July)					Post-nesting (16 July–20August)					Total Monitoring Period (8 June–20 August)				
		SEL		Duration			SEL		Duration			SEL		Duration		
Aircraft/Vehicle	Land/Depart	$\bar{x}$	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Max	$\bar{x}$	Max	*n*
Aircraft																
Helicopter	Landing	82.8	95.5	3.2	12.0	29	101.6	113.4	4.9	19.8	17	97.4	113.4	3.8	19.8	46
	Departing	84.4	93.5	2.9	7.1	11	94.1	103.7	5.5	35.0	30	93.0	103.7	4.8	35.0	41
Cessna 185[a]	Departing	-	-	-	-	-	143.0	143.0	19.2	19.2	1	143.0	143.0	19.2	19.2	1
Cessna 207[a]	Departing	99.8	99.8	5.2	5.2	1	-	-	-	-	-	99.8	99.8	5.2	5.2	1
All Single-engine Planes	Departing	99.8	99.8	5.2	5.2	1	143.0	143.0	19.2	19.2	1	140.0	143.0	12.2	19.2	2
Twin Otter	Landing	92.9	100.8	5.4	13.2	12	96.6	108.5	5.2	31.1	40	95.9	108.5	5.3	31.1	52
	Departing	96.0	107.3	3.4	7.9	31	96.5	107.8	4.9	25.7	64	96.3	107.8	4.4	25.7	95
CASA	Landing	-	-	-	-	-	93.7	96.9	5.3	9.2	10	93.7	96.9	5.3	9.2	10
	Departing	-	-	-	-	-	97.5	103.0	10.4	64.6	12	97.0	103.0	9.4	64.6	12
All Twin-engine Planes	Landing	92.1	100.8	5.4	13.2	12	96.2	108.5	5.4	31.1	50	95.7	108.5	5.4	31.1	62
	Departing	96.0	107.3	3.4	7.9	31	97.3	107.8	8.4	197.8	80	97.3	107.8	6.9	197.8	120
C-130 Hercules	Landing	98.0	98.8	8.8	9.6	4	99.3	102.6	10.7	11.4	3	98.6	102.6	9.6	11.4	7
	Departing	89.7	90.8	2.5	2.9	4	-	-	-	-	-	89.7	90.8	2.5	2.9	4
DC-6	Landing	98.1	106.3	5.2	7.8	12	103.3	107.7	7.6	17.6	5	100.4	107.7	5.9	17.6	17
	Departing	103.6	110.6	6.4	11.9	31	104.8	110.7	6.3	12.1	7	103.8	110.7	6.4	12.1	38
All Four-engine Planes	Landing	98.1	106.3	6.1	9.6	16	102.2	107.7	8.7	17.6	8	99.9	107.7	7.0	17.6	24
	Departing	103.1	110.6	6.0	11.9	35	104.8	110.7	6.3	12.1	7	103.4	110.7	6.0	12.1	42
Vehicles[b]																
Loader	-	91.6	96.4	2.8	3.9	3	-	-	-	-	-	-	-	-	-	-
Water Truck	-	87.6	87.6	2.1	2.1	1	-	-	-	-	-	-	-	-	-	-
Bus	-	66.5	66.5	3.5	3.5	1	-	-	-	-	-	-	-	-	-	-
All Large Trucks	-	84.6	87.6	2.8	3.5	2	-	-	-	-	-	-	-	-	-	-
Suburban	-	76.7	76.7	3.8	3.8	1	-	-	-	-	-	-	-	-	-	-
Unidentified Small Truck	-	73.3	76.9	2.4	3.1	4	-	-	-	-	-	-	-	-	-	-
All Small Trucks	-	74.3	76.9	2.6	3.8	5	-	-	-	-	-	-	-	-	-	-
Unidentified[c]		96.6	118.2	2.1	16.4	261	103.0	116.4	9.0	607.2	255	110.8	118.2	6.7	607.2	516

[a] Noise exceedence recorded during departure only.
[b] Vehicle data were not collected before 11 June or after 15 July.
[c] Exceedance events that occurred when no aircraft or vehicle was recorded.

Table 4. Number of takeoffs and landings that produced noise events exceeding 85 dBA for at least 2 secs recorded at noise monitors from two locations around the Alpine airstrip, Colville Delta, Alaska, 2000.

Aircraft	Nesting (8 June–15 July)			Post-nesting (16 July–20 August)			Total Monitoring Period (8 June–20 August)		
	No. Noise Events	No. of Takeoffs and Landings	% Aircraft Detected	No. Noise Events	No. of Takeoffs and Landings	% Aircraft Detected	No. Noise Events	No. of Takeoffs and Landings	% Aircraft Detected
Helicopter	11	621	2	32	397	8	43	1,018	4
Cessna185	-	-	-	1	5	20	1	5	20
Cessna 207	1	6	17	0	4	0	1	10	10
Twin Otter	38	608	6	67	456	15	105	1,064	10
Conquest	0	2	0	-	-	-	0	2	0
CASA	0	34	0	16	117	14	16	151	10
C-130 Hercules	8	8	100	1	4	25	9	12	75
DC-6	37	75	49	11	39	28	48	114	42
Total	95	1,354	7	128	1,022	12	223	2,371	9

occurred more frequently (75 landings and takeoffs) than C-130s, but only 49% (37) produced exceedances. Twin Otters (608 landings and takeoffs) and helicopters (621) occurred most often at the airstrip, but their exceedance rates (6% and 2%, respectively) were lower than the overall rate for all aircraft during the same period. Vehicles on the airstrip rarely (<0.5%) caused exceedances; only 5 (bus, loader, pick-up, Suburban, and watertruck) of 1,458 vehicle occurrences caused exceedances.

After nesting (16 July–20 August), 12% of all aircraft occurrences (128 of 1,022 landings and takeoffs) produced noise events (Table 4). Although the overall exceedance rate nearly doubled during this period, not all aircraft had corresponding increases. The exceedance rates (28%) for DC-6s (11 of 39) and C-130s (25%, 1 of 4) both decreased after nesting. Helicopters, Twin Otters, and CASAs (Aviocar, a twin-engine, turbo-prop airplane) all had increases in detection rates after the nesting season. Changes in exceedance rates might be related to weather conditions. Humidity, wind direction, and wind speed, all affect how sound was propagated, but probably a larger factor was the effect wind had on where aircraft landed and tookoff from the airstrip relative to the monitor locations. Aircraft usually landed and departed into the wind, so changes from easterly to westerly winds affected both the amount of taxiing and the end of the strip at which aircraft were under full power. Some aircraft, such as Twin Otters, needed a short length of the airstrip, because of their high lift-to-weight ratios, and had wide latitude in where on the airstrip they landed or tookoff. Landing and takeoff locations on the airstrip were not recorded and, therefore, that variable could not be controlled in our analysis of exceedances. Nonetheless, as might be expected, the highest rates of exceedances during the entire period monitored were for the largest aircraft, C-130s and DC-6s (75% and 42%, respectively), and the lowest rates were for twin-engine turbine planes (10% for Twin Otters, 10% for CASAs, and 0% for Cessna Conquests) and helicopters (4%). As mentioned earlier, helicopters did not land on the airstrip, so their exceedance rate and SEL values probably were lower as a function of greater distance to the sound monitors.

NEST DENSITIES AND DISTRIBUTION

ALL SPECIES

In 2000, we searched 13.3 km² around the Alpine airstrip (Figure 6), which overlapped extensively with the areas searched in previous years (for 1996 and 1997 boundaries, see Johnson et al. 1998: Figure 10; for the 1998 boundaries, see Johnson et al. 1999b: Figure 5; for the 1999 boundaries, see Johnson et al. 2000a: Figure 5). The area that was searched in common in all years (common ground-search area) comprised 10.6 km². The search effort in the common ground-search area varied among years; the number of hours searching was highest in 1999 (429 h) and lowest in 1996 (218 h) (Table 5). After adjusting for the annual levels of search effort, the number of nests found was highest in 1997 (63 nests) and lowest in 2000 (36 nests). As mentioned earlier, 2000 had the coldest spring of the previous four years (Figure 5) and that, combined with extensive flooding in the search area during nest initiation, probably caused a reduction in nesting. 1999 also had a cold spring but no noticeable flooding of nesting areas, and more nests (49) were found than in 2000. More nests (52) were found in 1998, a year that was warmer than 1999 and 2000. Spring temperatures were not a perfect predictor, however, because 1997 had the highest number of nests and also experienced a relatively cold spring. Other weather factors such as snow cover and wind also may affect the date of nest initiation and nest numbers, but we do not have adequate data at this time to make annual comparisons.

In the common ground-search area, we found the nests of 21 species (not including ptarmigan, which were not recorded in 1998) between 1996 and 2000, but only five of these species nested in all five years (Table 5). In 2000, we found nests of 11 species. The largest number of species (15) found was in 1998. In each year, the most abundant large waterbird nesting in the common ground-search area was the White-fronted Goose (22–28 nests, standardized for search effort). Ducks also were abundant, with Northern Pintails and Long-tailed Ducks the most common nesting ducks. We found 2–5 nests of Tundra Swans within the common ground-search area each year. Nests of Pacific Loons (1–3 nests) were found in 4 of 5 years, those of Red-throated Loons (1–4 nests)

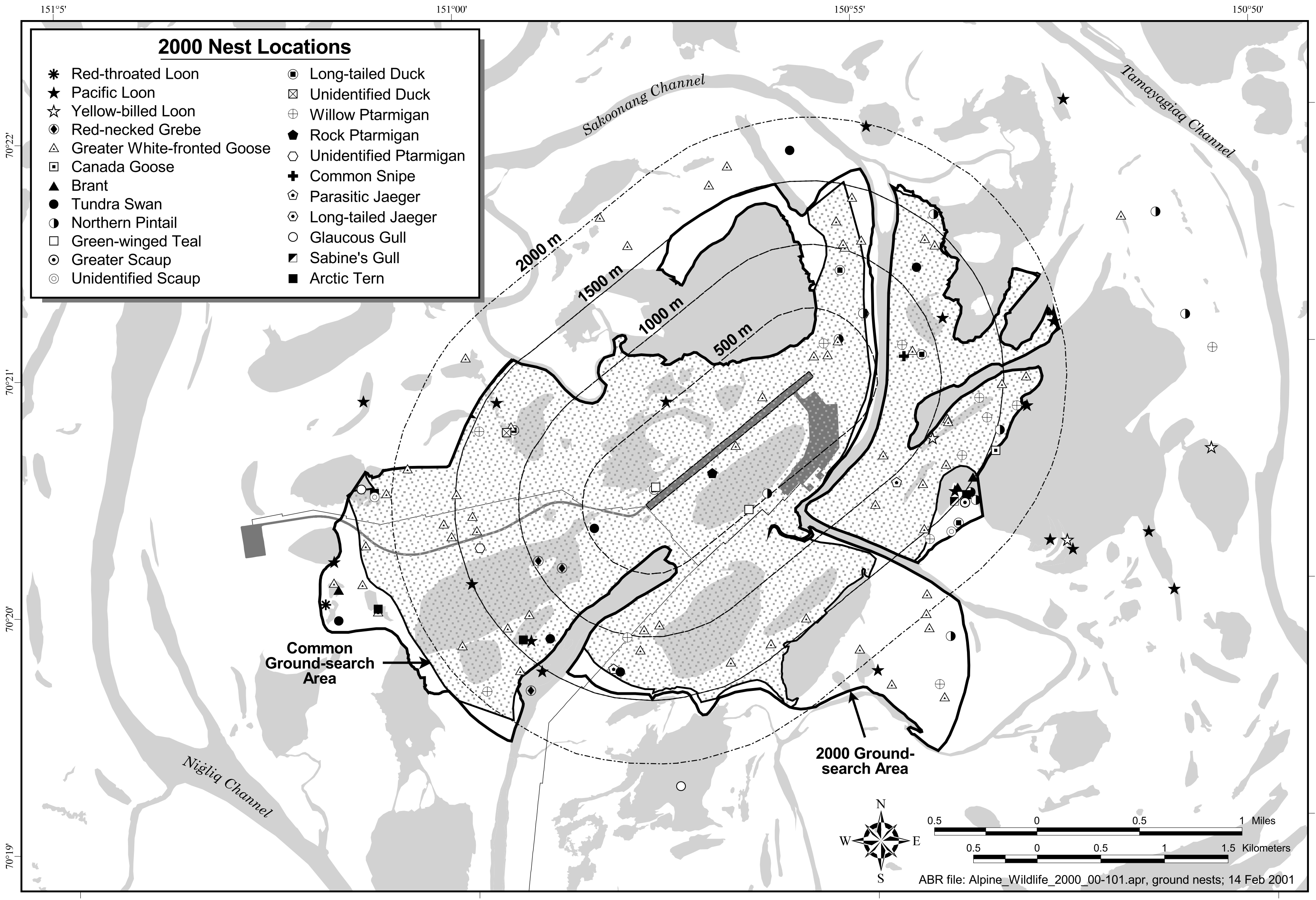

Figure 6. Locations of nests found during nest searches in the Alpine project area, Colville River Delta, Alaska, 2000. Stippled area is the common ground-search area.

Table 5. Numbers and densities, standardized by search effort, of nests of selected species found within the common ground-search area in the Alpine project area, Colville River Delta, Alaska, 1996–2000. Search area boundary is displayed in Figure 6. Unstandardized numbers and densities are presented in Appendix D1.

	Common Ground-search Area (10.6 km²)									
	Standardized Number of Nests					Standardized Density (nests/km²)				
Species	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Red-throated Loon	1	4.0	0.7	0	0	0.1	0.4	0.1	0	0
Pacific Loon	2	3.2	0	2.5	0.6	0.2	0.3	0	0.2	0.1
Yellow-billed Loon	1	0.8	0	0	0	0.1	0.1	0	0	0
Red-necked Grebe	0	2.4	1.5	1.0	0.6	0	0.2	0.1	0.1	0.1
Greater White-fronted Goose	25	28.1	23.2	26.9	22.0[a]	2.4	2.7	2.2	2.5	2.1[a]
Brant	1	3.2	0.7	1.0[b]	0	0.1	0.3	0.1	0.1[b]	0
Tundra Swan	5	3.2	3.6	2.0	2.3	0.5	0.3	0.3	0.2	0.2
Northern Shoveler	0	0	3.6[a]	0	0	0	0	0.3[a]	0	0
Northern Pintail	2	3.2	5.1[a]	4.1[a]	2.8[a]	0.2	0.3	0.5[a]	0.4[a]	0.3[a]
Green-winged Teal	1	0	0.7	1.0[a]	1.1[a]	0.1	0	0.1	0.1[a]	0.1[a]
Greater Scaup	0	0.8	0.7	0	0	0	0.1	0.1	0	0
Lesser Scaup	0	0	0.7	0	0	0	0	0.1	0	0
Unidentified scaup	0	0	0	0.5[a]	0	0	0	0	<0.1	0
Long-tailed Duck	6	7.2	3.6[a]	2.5[a]	2.3[a]	0.6	0.7	0.3[a]	0.2[a]	0.2[a]
Unidentified duck	0	0	2.2	1.0	0.6	0	0	0.2	0.1	0.1
Willow Ptarmigan	1	8.8	nd	8.1	3.9	0.1	0.8	nd	0.8	0.4
Rock Ptarmigan	0	0	nd	0	0.6	0	0	nd	0	0.1
Unidentified ptarmigan	0	0	nd	1.5	0.6	0	0	nd	0.1	0.1
Sandhill Crane	0	0	0	0.5	0	0	0	0	0	0
Bar-tailed Godwit	0	0	1.5	1.0	0	0	0	0.1	0.1	0
Common Snipe	0	0.8	0	0	0.6	0	0.1	0	0	0.1
Parasitic Jaeger	1	0.8	1.5	1.0	1.1	0.1	0.1	0.1	0.1	0.1
Long-tailed Jaeger	1	0	0.7	0.5	0.6	0.1	0	0.1	0	0.1
Glaucous Gull	0	0.8	0	0	0	0	0.1	0	0	0
Sabine's Gull	1	0	0	0	0	0.1	0	0	0	0
Arctic Tern	0	4.0	2.2	3.0	1.1	0	0.4	0.2	0.3	0.1
Search hours	218	271	300	429	387					
Adjusting ratio[c]	1.0	0.8	0.7	0.5	0.6	1.0	0.8	0.7	0.5	0.6
Standardized total[de]	47	62.7	52.3	48.8	35.5	4.4	5.9	4.9	4.6	3.4
Total number of species[e]	12	14	15	14	11					

[a] Includes nests identified from feather and down samples.

[b] Includes nest identified from down and nest characteristics.

[c] $\text{Ratio}_{\text{year}}$ = search hours_{1996}/ search $\text{hours}_{\text{year}}$.

[d] Standardized $\text{total}_{\text{year}}$ = adjusting $\text{ratio}_{\text{year}} \cdot$ total $\text{nests}_{\text{year}}$.

[e] Does not include ptarmigan or unidentified ducks.

were found in 3 of 5 years, and nests of Yellow-billed Loons (1 nest) were found only during the ground search in 1996 and 1997 (two nests were found after nest searching in 1998 and 2000). In 1999, we recorded the first nest of a Sandhill Crane and the first sightings of Horned Grebes (no nest was found) within the common ground-search area. We have found 1–2 nests of Red-necked Grebes in this area every year since 1997. Red-necked Grebes are considered uncommon on the Arctic Coastal Plain (Brackney and King 1994), and Gerhardt et al. (1988) classified the species as a visitant to the delta ("a nonbreeding species without a definable seasonal pattern"). Prior to our discovery of a nest in the southern part of the delta in 1996 (Johnson et al. 1997), we were aware of only one other record of a Red-necked Grebe nesting in this area. In 1949, a nest was found south of the delta, at the junction of the Itkillik and Colville rivers (Nelson 1953).

Because of the variation in search effort among years in the common ground-search area, the annual pattern in actual numbers of nests found differed from the pattern in standardized numbers; in 2000 (387 search h), we found 63 nests (5.9 nests/km², not standardized for effort), which was the lowest number since 1996 (47 nests) (Appendix D1). Within the total area searched in 2000 (13.3 km²), we found 90 nests (6.8 nests/km²) of 16 species (not including ptarmigan), which was a nest density similar to that in 1997 and 1998 (Figure 6, Appendix D2).

The most abundant large waterbird nesting in 2000 in the total area searched in the Alpine project area (13.3 km², Figure 6) was the White-fronted Goose (51 nests, not standardized for effort; Appendix D2). One Canada Goose nest was found in 2000; the first record of these birds nesting in the Alpine project area was in 1998, and they appear to have begun nesting on the delta only recently (Johnson et al. 1999b). Ducks also were numerous, led by Northern Pintails (8 nests), Long-tailed Ducks (5), Green-winged Teal (2) and Greater Scaup (1). Five Tundra Swan nests were found in the 2000 search area. No Spectacled Eider nests were located in the Alpine project area in 2000, although a nest was found in both 1998 and 1999, and a Spectacled Eider brood was observed there in 1993 (Smith et al. 1994). We also found 12 Willow Ptarmigan nests in the nest search area. In 2000, we found one Red-necked Grebe nest on a lake within 1,000 m of the Alpine airstrip (Figure 6), and two additional nests were found in the surrounding area during lake surveys.

Within 2,000 m of the airstrip, we found 88 nests in 2000 (Table 6, Figure 6). The density of nests in 2000 was lowest (3.7 nests/km²) between 500 and 1,000 m of the airstrip and highest (10.1 nests/km²) between 1,000 and 1,500 m. The distribution of nest densities around the airstrip in 1999 followed the same pattern (Johnson et al. 2000a). Habitat distribution, as defined by our map of the project area (Figure 2), did affect the variation in densities of nests among the distance buffers around the airstrip in 2000. Most of the nests found in the search area were in three habitats: Wet Sedge-Willow Meadow (55 of 88 nests, 62%), Moist Sedge-Shrub Meadow (14 nests, 16%), and Aquatic Sedge with Deep Polygons (11 nests, 12%). The density of nests within these three habitats combined still was lowest in the 500–1,000-m buffer (5.5 nests/km²), but the density in the nearest buffer (≤500 m) was similar to that in the 1,000–1,500-m and 1,500–2,000-m buffers (14.4 nests/km², 15.2 nests/km², and 15.4 nests/km², respectively). After the final year of data collection, we will compare the distribution of nest densities in distance buffers among all years to evaluate changes that might be related to disturbance.

To further evaluate the effects of the airstrip on nest distribution, we compared the mean distance of nests from the airstrip in 2000 with the distance of nests from the airstrip's current location in years prior to its construction (1996 and 1997) and during construction (1998 and 1999). Despite varying levels of human activity in the project area from 1996 to 2000 (Table 1), the distance of nests from the airstrip did not differ significantly among years (using data from only the common ground-search area, one-way ANOVA, $P = 0.55$). The mean distance from the airstrip was highest in 1997 ($\overline{x} = 1{,}173$ m, $n = 78$), before the airstrip was built, and lowest in 1998 ($\overline{x} = 1{,}031$ m, $n = 72$), when the airstrip was in place (Table 7). The lack of a significant difference or trend over time in distance from the airstrip suggests that there has been no overall change in nest distribution during construction in the Alpine project area.

Table 6. Nest densities of selected species found within exclusive distance buffers around the Alpine airstrip, and the mean distance from the airstrip, during the nest search of the Alpine project area, Colville River Delta, Alaska, June 2000.

	Density (nests/km²) by Distance Buffer						
						Distance (m) from Airstrip	
Species	0–500 m	500–1,000 m	1,000–1,500 m	1,500–2,000 m	Total Nests	Mean	Range
Pacific Loon	0	0	0.2	0	1	1,421	
Red-necked Grebe	0	0.3	0	0	1	957	
Greater White-fronted Goose	2.0	1.3	5.8	4.4	43	1,218	32–1,998
Canada Goose	0	0	0	0.4	1	1,545	
Brant	0	0	0.5	0	2	1,453	1,427–1,480
Tundra Swan	0.4	0	0.7	0	4	1,051	448–1,298
Northern Pintail[a]	0.8	0.3	0	1.7	7	1,097	344–1,601
Green-winged Teal[b]	0.8	0	0	0	2	270	55–485
Greater Scaup	0	0	0	0.4	1	1,548	
Unidentified scaup	0	0	0	0.4	1	1,628	
Long-tailed Duck[c]	0.4	0.7	0.2	0.4	5	912	49–1,616
Unidentified duck	0	0	0.2	0	1	1,233	
Willow Ptarmigan	0.4	0.3	1.2	1.3	10	1,257	248–1,920
Rock ptarmigan	0.4	0	0	0	1	79	
Unidentified ptarmigan	0	0	0.2	0	1	1,350	
Common Snipe	0	0.3	0	0	1	729	
Parasitic Jaeger	0	0	0.5	0	2	1,168	1,053–1,284
Long-tailed Jaeger	0	0.3	0	0	1	624	
Sabine's Gull	0	0	0.2	0	1	1476	
Arctic Tern	0	0	0.2	0.4	2	1,474	1,431–1,517
Area (km^2) searched	2.5	3.0	4.2	2.3	11.9		
Total density	5.3	3.7	10.1	9.6	7.4		
Total nests	13	11	42	22	88	1,167	32–1,998

[a] Includes probable Northern Pintails nests (4) determined from feather and down samples.

[b] Includes a probable Green-winged Teal nest determined from feather and down samples.

[c] Includes a probable Long-tailed Duck nest determined from feather and down samples.

Table 7. Test of annual differences in mean distances of nests from the airstrip in the common ground-search area of the Alpine project area, Colville River Delta, Alaska, 1996–2000.

	Distance (m)					
Year	$\bar{x}$	SE	*n*	Test	*F*	*P*-value
All Species						
1996	1,064	84.0	47			
1997	1,173	71.9	78			
1998	1,031	64.4	72			
1999	1,087	52.0	96			
2000	1,110	65.7	63			
All Years	1,095	29.5	356	ANOVA	0.67	0.62
Greater White-fronted Goose						
1996	1,040	113.8	25			
1997	1,172	101.7	35			
1998	1,110	102.6	32			
1999	1,095	69.8	53			
2000	1,201	81.9	39			
All Years	1,127	40.2	184	ANOVA	0.45	0.77

GREATER WHITE-FRONTED GOOSE

Within the common ground-search area in 2000, 22 White-fronted Goose nests (standardized for effort) were found, the lowest number of nests found since surveys began in 1996; the highest number (28 nests) was found in 1997 (Table 5). As mentioned earlier, 2000 had a colder spring and later thaw than in previous years, and large portions of the study area were flooded by the Colville River when nest initiation would normally occur (see CONDITIONS IN THE STUDY AREA). We suspect that weather conditions and flooding had a negative effect on the number of White-fronted Goose nests in 2000. The actual number of nests in 2000 (not standardized for effort) found within the common ground-search area (39 nests, 3.7 nests/km^2) and in the total area searched (51 nests or 3.8 nests/km^2) also was less than that found in 1999 in those respective search areas but comparable to numbers found in 1996–1998 (Appendices D1 and D2). However, we spent more time searching in 2000 than in 1996–1998, which is why 2000 had a lower standardized nest count. The densities of White-fronted Goose nests in the Alpine project area are high compared with historical data collected on the delta. In the early 1980s, the USFWS reported mean densities of 1.8 nests/km^2 in scattered plots across the delta (Simpson et al. 1982) and a maximum of 6.6 nests/km^2 at one site on the western delta (Rothe et al. 1983), which were among the highest densities recorded for White-fronted Geese on the Arctic Coastal Plain of Alaska at that time. Ground searches elsewhere on the delta in 2000 indicated that densities of White-fronted Goose nests also were high south of the Alpine project area (6.2 nests/km^2 in the CD South study area; Burgess et al. 2000) and on the outer delta (9.8 nests/km^2 in the CD North study area; Johnson et al. 2000b).

White-fronted Geese nested in 3 of 17 available habitats in the common ground-search area in 2000 (Table 8). Two habitats, Wet Sedge–Willow Meadow and Aquatic Sedge with Deep Polygons, were preferred (use was significantly greater than availability). Nesting White-fronted Geese avoided (use was significantly less than availability) Nonpatterned Wet Meadow. Most nests (28 of 39, 72%) found in 2000 were in Wet Sedge–Willow Meadow, but Moist Sedge–Shrub Meadow (8 nests, 20%), and Aquatic Sedge with Deep Polygons (3 nests, 8%) also were used frequently. Habitat selection varied annually from 1996 to 1999, but in all years, Wet Sedge–Willow Meadow was preferred for nesting (Appendix D3). Aquatic Sedge with Deep

Table 8. Habitat selection by Greater White-fronted Geese during nesting in the Alpine project area, Colville River Delta, Alaska, 2000. Only nests found in 2000 within the common area searched in all four years (1996–2000) are included.

Habitat	Area (km²)	No. of Nests	Use (%)	Availability (%)	Monte Carlo Results[a]
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.6	ns
Tapped Lake w/ High-water Connection	0.80	0	0	7.6	ns
Salt Marsh	0.62	0	0	5.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.90	0	0	8.5	ns
Deep Open Water w/ Islands or Polygonized Margins	0.10	0	0	0.9	ns
Shallow Open Water w/o Islands	<0.01	0	0	<0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.01	0	0	0.1	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0.08	0	0	0.8	ns
Aquatic Sedge w/ Deep Polygons	0.12	3	7.7	1.1	prefer
Aquatic Grass Marsh	0.10	0	0	1.0	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	0.96	0	0	9.0	avoid
Wet Sedge–Willow Meadow	4.39	28	71.8	41.2	prefer
Moist Sedge–Shrub Meadow	1.16	8	20.5	10.9	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.63	0	0	5.9	ns
Barrens (riverine, eolian, lacustrine)	0.18	0	0	1.7	ns
Artificial (water, fill, peat road)	0.31	0	0	2.9	ns
Total	10.64	39	100	100	

[a] Significance calculated from 1,000 simulations at $\alpha = .05$; ns = not significant, prefer = significantly greater use than availability, avoid = significantly less use than availability.

Polygons also was preferred in 1996 and 1999. Within these habitats, most nests (85%) occurred on polygon rims or small hummocks, microsites similar to the nesting sites reported by Simpson et al. (1982). Nests ranged from <1 to 500 m ($\overline{x}$ = 72.2 m, $n = 55$) from the nearest permanent waterbody.

During the nest search in 2000, we found 43 White-fronted Goose nests ≤2,000 m from the airstrip ($\overline{x}$ = 1,218 m, range = 32–1,998 m; Table 6). Thirty-four nests (79%, 5.3 nests/km^2) were >1,000 m from the airstrip, compared to 9 nests (21%, 1.7 nests/km^2) ≤1,000 m of the airstrip. The lowest density of nests occurred in the 500–1,000-m buffer (1.3 nests/km^2) and the highest density was found in 1,000–1,500-m buffer (5.8 nests/km^2). The higher densities in the two farthest buffers around the airstrip did not appear to be related to the distribution of habitats around the airstrip (Figure 7). The most frequently used nesting habitats for White-fronted Geese were Wet Sedge–Willow Meadow, Moist Sedge–Shrub Meadow, and Aquatic Sedge with Deep Polygons (Table 8). However, the pattern of density of White-fronted Goose nests in these habitats within each distance buffer (5.5, 2.7, 9.6, and 7.3 nests/km^2 in the nearest to farthest buffers, respectively) was similar to the pattern among distance buffers irrespective of habitat (Table 6). A similar trend in density of White-fronted Goose nests among distance buffers was found in 1999 (Johnson et al. 2000a), but has not been evaluated in the other years.

We measured nearest-neighbor distances between White-fronted Goose nests each year as another indicator of distribution pattern and nest density. The pattern of nest distribution in each year was clumped ($R \leq 0.0001$, $-13.93 \leq Z \leq -9.57$, $P < 0.0001$, where a random pattern has $R = 1.0$). Nearest-neighbor distances were not related to the distances of nests from the airstrip in 1998–2000, or to its current location in 1996 and 1997 (separate simple linear regressions for each year, $P > 0.70$, $r^2 < 0.01$); that is, nest density did not exhibit any trend along a distance gradient in any single year.

As reported earlier for nests of all species combined, we found no annual pattern in the distance of White-fronted Goose nests relative to the airstrip (Table 7). The distance of nests from the airstrip did not differ significantly among years (one-way ANOVA, $P = 0.77$). The mean distance of nests in 2000 (1,201 m, $n = 39$) was only slightly greater than the mean distances in 1996 (1,040 m, $n = 25$), 1997 (1,172 m, $n = 35$), 1998 (1,110 m, $n = 32$), and 1999 (1,095 m, $n = 53$).

One response of nesting White-fronted Geese suggested a negative response to the Alpine airstrip, and that was lower densities of nests were found within 1,000 m of the airstrip than between 1,000–2,000 m from the airstrip. However, the similarity among years of distances of White-fronted Goose nests from the airstrip, the lack of relationship between nearest-neighbor measurements and distance to the airstrip, and the consistent pattern of habitat use among years suggests that the addition of construction activities and aircraft flights in 1998–2000 were no more or less disruptive to nest establishment than the levels of human activity that occurred in 1996 and 1997. In all these years, surveyors and hydrologists, as well as the biologists participating in this study, worked in the Alpine project area, undoubtedly disturbing some of the birds nesting near the site of the present airstrip. One caution we advise in interpreting these results is that we have not taken into account the possible interactions of habitat and the variety of scales over which a response might be expressed. After collection of nesting data in 2001, we will conduct a multi-year analysis that will test for effects within different habitats and distance zones (e.g., within 500 m of the airstrip), to sort out changes in nest distribution that might be obscured by the size and habitat distribution of the project area.

TUNDRA SWAN

In 2000, four Tundra Swan nests (0.4 nests/km^2) were found in the common ground-search area (Appendix D1), and five nests (0.4 nests/km^2) were found in the total area searched (Appendix D2). Similar numbers of swan nests were found in the common ground-search area during all five years (range = 3–5 nests) (Appendix D1). The sample sizes of nests were too small to test for annual habitat selection, but in 2000 four of five nests occurred in habitats that were significantly preferred over a 7-year period on the Colville Delta (Johnson et al. 2000b): three nests were in Wet Sedge–Willow Meadow and one nest was in Moist Sedge–Shrub Meadow. One nest

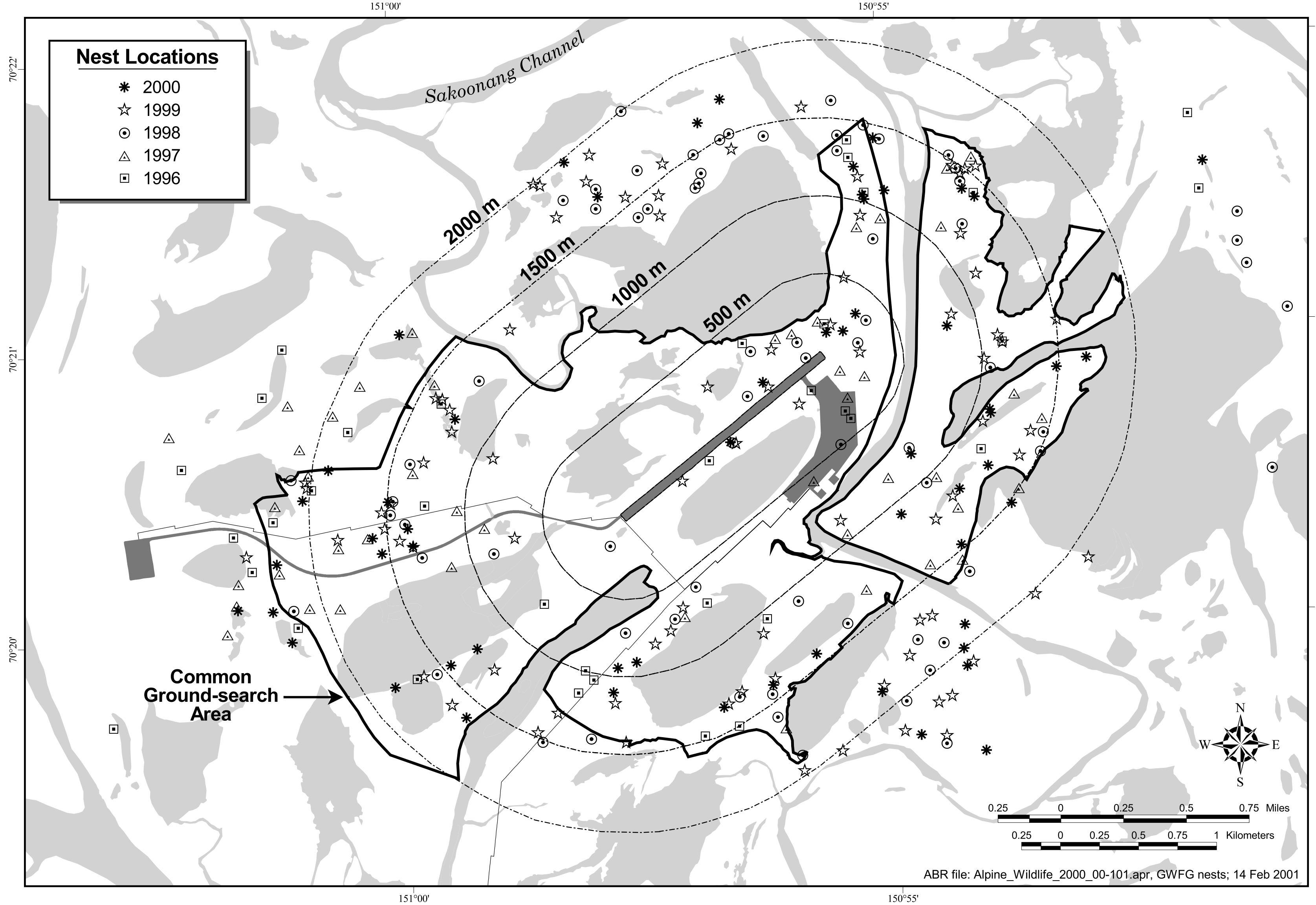

Figure 7. Locations of Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 1996–2000.

was found in Riverine or Upland Shrub, which was used in proportion to its availability on the Colville Delta.

The distance of nests from the airstrip did not differ significantly between 2000 ($\bar{x}$ = 1,051 m, n = 4), 1999 ($\bar{x}$ = 1,054 m, n = 4), 1998 ($\bar{x}$ = 916 m, n = 5), 1997 ($\bar{x}$ = 1,212 m, n = 4), or 1996 ($\bar{x}$ = 958 m, n = 5) (ANOVA, P = 0.91). The closest nest to the airstrip in 1999 and 2000 was on the same mound each year and measured 448 m from the western end of the airstrip (Figure 6); this site was also occupied annually in 1995–1998. Despite the nest's proximity to the airstrip and its location under the takeoff and approach patterns of aircraft, three eggs hatched successfully in this nest in 2000. In 1998, the closest nest site was 159 m from the northeast end of the strip, where a helicopter landed daily during much of the nesting season. This nest site was probably not traditional, because the nest mound was less than 20 cm (8 in) high, and it had not been used during 1995–1997 (Johnson et al. 1998: Figure 9). The nest was in a breeding bird plot and was disturbed during 2 d of nest searching, resulting in prolonged concealment on the nest and incubation recesses off the nest. This nest also hatched successfully in 1998, although it was not reused in subsequent years.

NESTING BEHAVIOR AND DISTURBANCE MONITORING

GREATER WHITE-FRONTED GOOSE

In 2000, we deployed one egg thermistor in each of 37 White-fronted Goose nests (Figure 8). Of these 37 egg thermistors, we obtained temperature data for 21 nests from the time of deployment to the time of brood departure or nest failure. Of the remaining 16 nests, 3 nests failed within 24 h after we deployed the egg thermistor, 8 nests produced erroneous readings because their thermistors were repositioned where they were not consistently incubated, and at the remaining 5 nests, no data were collected because of equipment failure or installation error. Four nests with egg thermistors also were monitored simultaneously with time-lapse video cameras, however, at three of these nests, thermistors produced erroneous readings or recorded no data. Nesting activities for these three nests were calculated from video recordings (Appendices E1–E3). The mean distance of nests monitored with egg thermistors to the airstrip was 1,321 m (range = 32–2,597 m, n = 37) and the mean distance of nests monitored with video cameras was 108 m (range = 32–194 m, n = 4).

Nest Attendance

Incubation constancy in 2000 was measured using data obtained from egg thermistors or video cameras at 12 White-fronted Goose nests that were successful and at 12 nests that subsequently failed. Successful female White-fronted Geese spent an average of 98.5% of their time incubating (n = 229 nest · d; Table 9). Each bird maintained high nest-attendance during the monitoring period, sometimes incubating 1–2 d without a recess. Mean number of recesses for successful nests was 1.4 recesses/d (n = 229 nest · d; Table 10). The daily number of recesses was relatively constant until 5 d before hatching, when recess frequency increased to an average of >2 recesses/d (Figure 9). Mean recess length for each of those 5 d did not differ from the overall average (16.0 min/recess, n = 315 recesses). Eighteen days before hatch, one goose took a 75-min recess, which boosted the mean recess length to twice that of other days; however, mean time off nest on that day did not deviate from the overall average (22.0 min/d n = 229 nest · d). In 1999, successful geese (n = 12 nests) spent a slightly greater proportion of time incubating (99.0%) because they took fewer recesses (0.9 recesses/day, n = 228 nest · d) (Johnson et al. 2000a). Mean recess length for successful geese in 1999 (15.9 min/recess, n = 200 recesses) was the same as in 2000, but in 1999, geese spent less time off the nest (13.9 min/day, n = 228 nest · d).

Most of the nesting parameters we measured with egg thermistors and video cameras in 2000 differed between successful and failed nests (Table 10). White-fronted Geese at failed nests spent significantly less time incubating ($\bar{x}$ = 96.1%, P < 0.001) than geese at successful nests ($\bar{x}$ = 98.5%). Mean recess length at failed nests ($\bar{x}$ = 24.0 min/recess) was longer (P < 0.001) than at successful nests ($\bar{x}$ = 16.0 min/recess). Mean number of recesses (2.5 recesses/d, P < 0.001) and mean time off the nest (56.5 min/d, P < 0.001) for failed nests were about 2–3× greater than the corresponding values for successful nests.

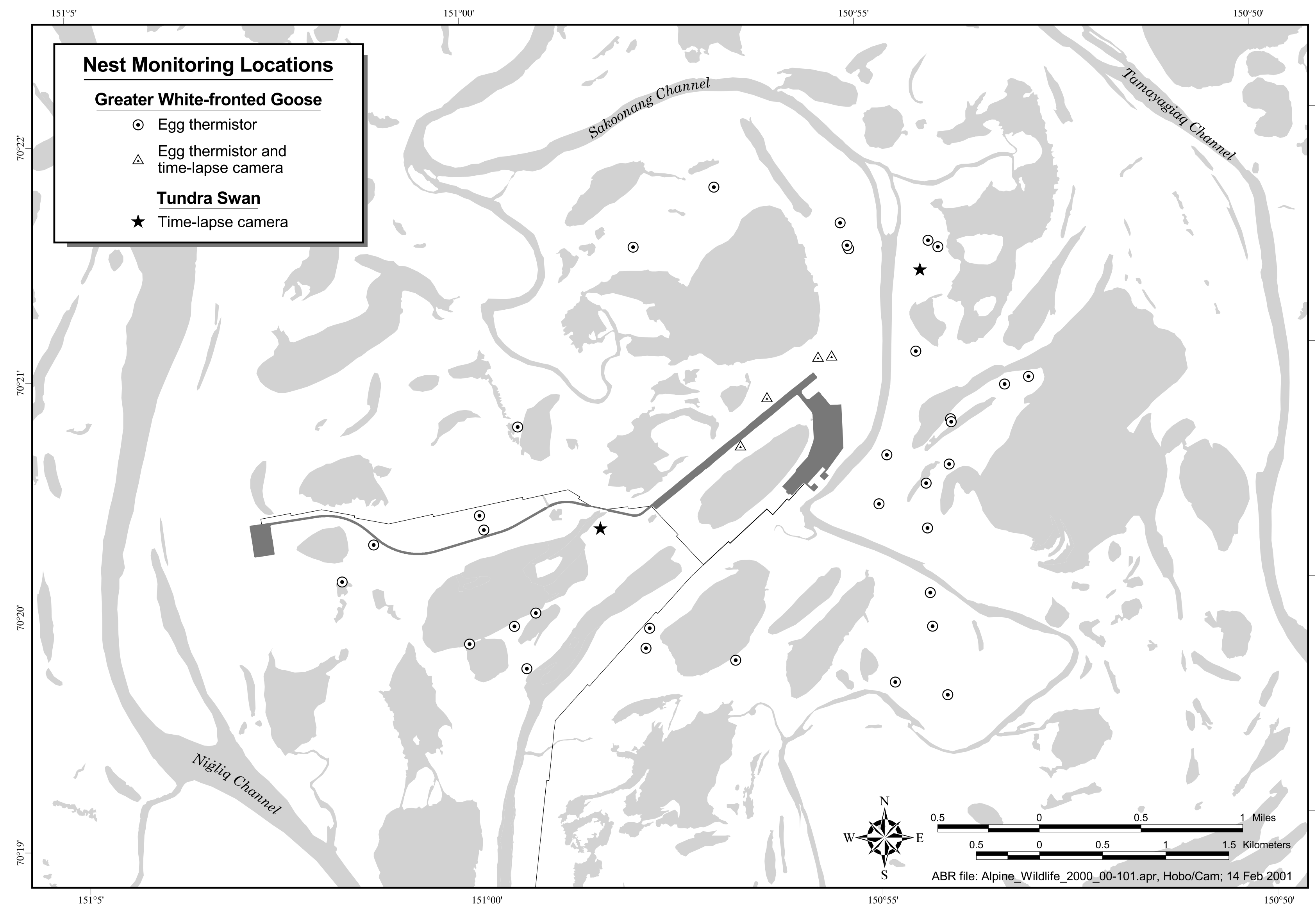

Figure 8. Locations of thermistor eggs and time-lapse cameras in the Alpine project area, Colville River Delta, 2000.

Table 9. Mean incubation constancy (% of time) of Greater White-fronted Geese at successful and failed nests, as determined from egg thermistors (1 recording interval/5 min) and video cameras (2-sec recording/1 min) in the Alpine project area, Colville River Delta, Alaska, 2000.

Day Before Hatch	Successful		Day Before Failure	Failed	
	%	*n*		%	*n*
			25	97.9	1
			24	96.7	2
23	99.7	2	23	95.5	3
22	99.4	3	22	98.1	3
21	99.3	6	21	100.0	3
20	98.9	4	20	98.8	4
19	99.3	9	19	99.1	4
18	98.6	9	18	99.0	4
17	99.2	9	17	99.2	5
16	98.8	11	16	98.6	6
15	99.8	12	15	99.0	6
14	99.5	12	14	98.5	7
13	99.3	12	13	98.6	8
12	99.4	12	12	98.4	8
11	98.8	12	11	98.0	9
10	99.2	12	10	97.7	8
9	99.0	12	9	98.5	11
8	98.6	12	8	98.1	12
7	98.8	11	7	96.6	11
6	98.4	10	6	97.5	11
5	96.7	11	5	95.2	12
4	97.3	12	4	94.7	11
3	96.3	12	3	93.6	11
2	96.1	12	2	91.5	11
1	97.0	12	1	81.7	11
Hatch			Failure		
Overall Mean	98.5	229	Overall Mean	96.1	182

n = number of nests monitored each day

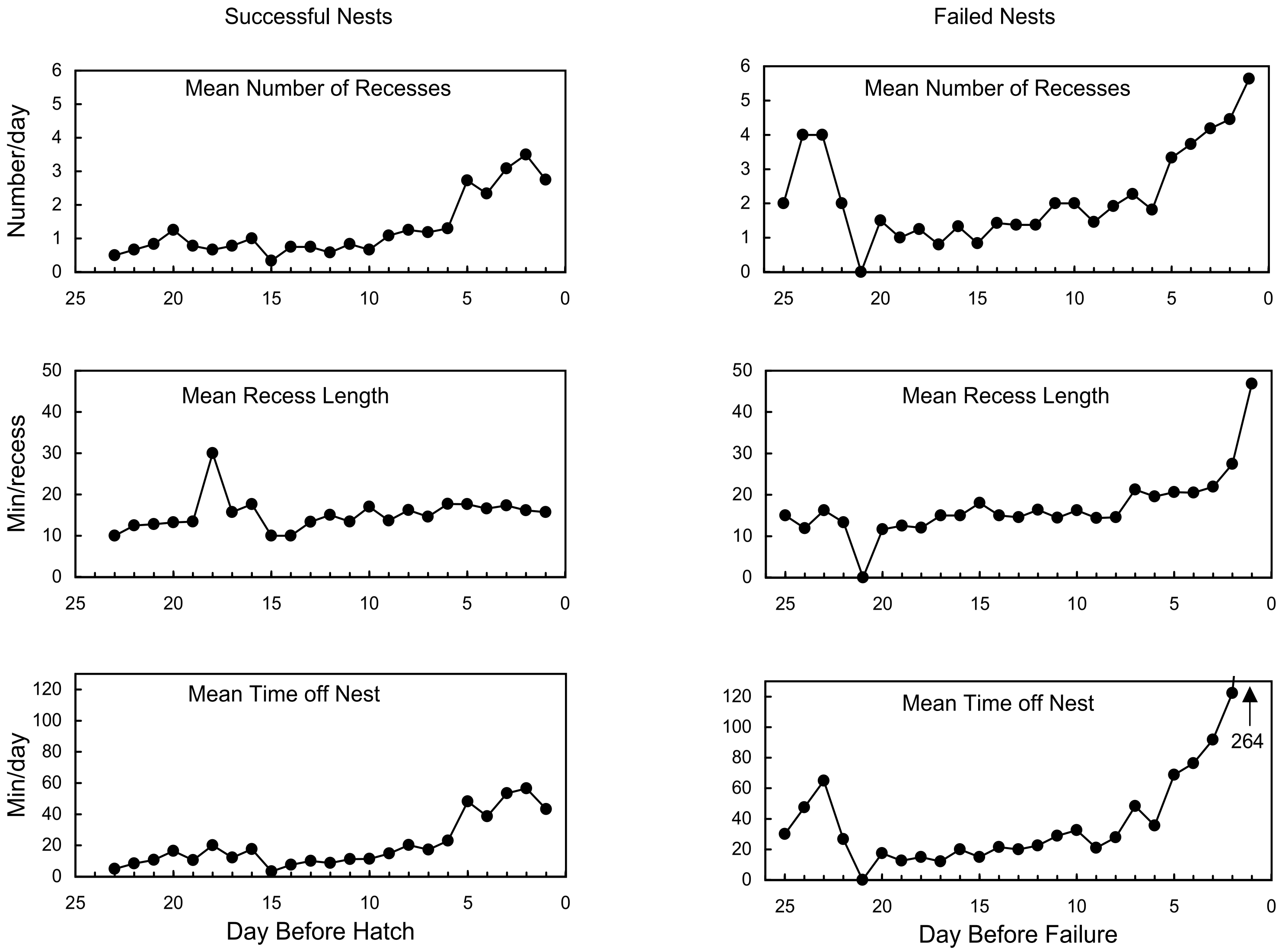

Figure 9. Mean frequency, length, and total time of incubation recesses for 12 successful nests and 12 failed nests of Greater White-fronted Geese monitored by egg thermistors (1 temperature recording/5-min interval) and video cameras (2-sec recording/1 min) in the Alpine project area, Colville River Delta, Alaska, 2000.

Table 10. Comparison of nesting activities at Greater White-fronted Goose nests that hatched (n = 12) and failed (n = 12). Nests were monitored with egg thermistors and/or video cameras in the Alpine project area, Colville River Delta, Alaska, 2000. Statistical tests were conducted with an independent-samples *t*-test.

	Successful			Failed			*t*-test		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	t	df	P
Incubation Constancy (%/d) (arcsine transformation)	98.5	2.0	229	96.1	8.0	182	4.51	277.2	< 0.001
Recess Frequency (no./d) (square root transformation)	1.4	1.8	229	2.5	3.0	182	4.25	347.6	< 0.001
Recess Length (min/recess) (logarithmic transformation)	16.0	6.3	315	24.0	41.4	448	4.47	752.2	< 0.001
Time Off Nest (min/d) (square root transformation)	22.0	28.7	229	56.5	108.5	182	4.60	285.3	< 0.001
Break Frequency (no./d) (logarithmic transformation)	10.0	6.5	229	9.3	5.7	182	0.83	408.4	0.41

As the nests approached the day of failure, increasing trends were evident in both the number of recesses and time off nest (Figure 9). In 1999, geese at failed nests also spent less time incubating than successful geese. Mean recess frequency, recess length, and time off the nest were higher at failed nests in 2000 than at failed nests in 1999.

Distance from the airstrip was similar ($t = 0.44$, 22 df, $P = 0.67$) for failed nests ($\bar{x}$ = 1,206 m, SD = 583, n = 12) and successful nests ($\bar{x}$ = 1,092 m, SD = 690, n = 12). Similarly, distance from Pad 1 did not differ ($t = 1.52$, 14.7 df, $P = 0.15$) between failed nests ($\bar{x}$ = 1,062 m, SD = 459, n = 12) and successful nests ($\bar{x}$ = 1,584 m, SD = 1,097, n = 12), suggesting that airstrip and pad-associated activities were not a factor in the failure of nests monitored with thermistors and video cameras. We caution, however, that we did not test for differences in habitat quality for nesting geese as a function of distance to the airstrip. If such differences exist, they may confound this analysis. We plan to incorporate habitat characteristics as a covariate in multi-year analyses after the final year of data collection.

One White-fronted Goose nest in 2000 and three nests in 1999 were monitored simultaneously with egg thermistors and time-lapse video cameras. For these four geese, calculations of incubation constancy and mean recess frequency, length, and time off nest from the video recordings all were similar to calculations derived from the egg thermistors (Appendix E4; Johnson et al. 2000a). A comparison of daily incubation behavior recorded by video and thermistor monitoring indicated no significant differences in total recess time, number of recesses, or incubation constancy (Wilcoxon signed ranks test of 79 nest·d, $-0.05 \le Z \le 0.91$, $P \ge 0.36$ for all four tests). However, we counted significantly more breaks with video camera monitoring ($\bar{x}$ = 17.4 breaks/d, SD = 8.80, n = 79 nest·d) than we did at the same nests monitored with thermistors ($\bar{x}$ = 9.91 breaks/d, SD = 4.50, n = 79 nest·d) (Wilcoxon signed ranks test, $Z = -5.95$, $P < 0.001$), because the average length of breaks ($\bar{x}$ = 1.3 min, SD = 0.73, n = 971 breaks determined from video monitoring) was shorter than the interval recorded by thermistor data loggers (5-min intervals). Thus, the thermistors provided good estimation of incubation constancy and recesses, but underestimated the number of incubation breaks.

Effects of Disturbance

Predators, aircraft, and people were easily identifiable disturbance sources during nesting. From the video recordings, we were able to identify defense breaks, concealment postures, and disturbance recesses in response to these sources of disturbance. We recorded a total of three defense breaks at two White-fronted Goose nests that were reactions to a fox near the nest. Two breaks occurred when an arctic fox was <10 m from the nest and the female and male reacted for 1 recording interval by standing and flapping their wings. The other break occurred when a fox was <15 m from the nest and female stood alert for 1 recording interval, while the male stood flapping its wings. On seven other occasions at three of the nests, the female and male showed similar defensive postures (flapping of wings), but we saw no predators on the video. On five occasions a fox was seen <50 m from a nest and both geese responded for 1–4 min with alert or concealment postures. On nine occasions a fox was >50 m from a nest and the female had no reaction, was alert, or was on recess.

In 2000, in contrast to 1999, we did not observe on video any instances of geese taking recesses during aircraft landings or takeoffs or during vehicle traffic (Johnson et al. 2000a). However, at a nest monitored by a thermistor, the female took a prolonged recess that possibly was in response to a helicopter. That recess was 75 min long and occurred at the same time a helicopter landed and unloaded people at a site ~1000 m from the nest.

At the four White-fronted Goose nests monitored by video in 2000, we calculated the frequency and duration of concealment postures by each female in response to aircraft, vehicles, people, predators, and other large birds (loons, swans, geese, or ducks) (Table 11). Of these five types of disturbance, concealment postures for all four females occurred most often (379 of 557 concealments, 68%) when aircraft were taxiing, landing, or taking off. For three of the females, the second highest frequency (8–16%) of concealment postures occurred when vehicles were present on the airstrip. Mean time spent concealing by all four females during aircraft events was less ($\overline{x}$ = 1.4 min, *n* = 379) than that for the other known disturbances (range = 2.3–9.5 min). The longest mean time spent concealing ($\overline{x}$ = 9.5 min, *n* = 37) was in response to other birds. At three nests, females concealed when large birds (most often other White-fronted Geese) were feeding or loafing near the nest. All four females responded to the presence of predators that were in the camera view by concealing, and the mean duration of these concealment postures was 3.6 min (*n* = 5). The high percentage of concealment behaviors occurring in response to aircraft events was largely because aircraft events were the most common (2,533 of 4,552 records or 56%) source of potential disturbance (Appendix F1). For all nests combined, female geese had the highest rate of concealment in response to pedestrians (36% of all pedestrian events elicited concealment postures), but rates varied among nests. At three of the four nests, the highest rate of concealment (26–65%) occurred during pedestrian events. At the fourth nest, the concealment rate was higher during aircraft events (24%) than during pedestrian events (18%). This female probably was more responsive to aircraft because of its location; the nest was in the flight path for landings and takeoffs, but was the farthest nest from the airstrip, which might explain its decreased responsiveness to pedestrians. The rate of concealment among the four nests decreased with increasing distance from the airstrip for aircraft (Pearson's r = -0.56, P = 0.44) and traffic events (r = -0.88, P = 0.12), but the relationship was significant (r = -0.96, P = 0.04) only for pedestrian events. Similar results were found in a study of nesting geese around roads in the Lisburne Development Area of Prudhoe Bay; female White-fronted Geese nesting close to roads spent less time in normal incubation postures and more time in concealment postures (Murphy and Anderson 1993).

When we deployed the egg thermistors in White-fronted Goose nests, we flushed the incubating females from the nests. In 2000, the interval from the time we left the nest after installing an egg thermistor to the time the female returned to incubate averaged 150 min (range = 10–852 min, *n* = 31). A similar amount of time was spent away from the nest after thermistors were installed in 1999 ($\overline{x}$ = 143 min, *n* = 41), but less time was spent in 1998 ($\overline{x}$ = 94 min, *n* = 19). The length of time that we were at the nest ($\overline{x}$ = 25 min, range = 8–71 min) and in the vicinity after the thermistor was installed probably affected the amount of time that the female was away. Generally we were searching for nests in the area, so it could have taken several hours before we were no longer visible from the nest site. During other research activities, we flushed three female White-fronted Geese from nests previously equipped with egg thermistors. In these instances, we covered the eggs with nest material and departed the area soon (5–45 min) after the bird was flushed. These females were off the nest for 25, 30, and 55 min after these three disturbances,

Table 11. The occurrence and duration of concealment postures in response to sources of disturbance at four Greater White-fronted Goose nests monitored with time-lapse video cameras in the Alpine project area, 2000. Nests 001, 914, and 917 were successful and nest 002 failed.

				Concealment Postures					
						Duration (min)			
Nest No.	Distance from Airstrip (m)	Total Days Monitored	Disturbance	No.	%	Sum	%	$\bar{x}$	SD
002	32	4.7	Aircraft	47	59	90	24	1.9	2.4
			Vehicle	13	16	51	14	3.9	4.8
			Pedestrian	2	3	2	1	1.0	0
			Fox	1	1	8	2	8.0	–
			Large Bird[a]	10	13	184	49	18.4	12.5
			Unknown	6	8	40	11	6.7	9.7
			Total	79	100	375	100	4.7	7.8
917	77	16.3	Aircraft	115	71	186	63	1.6	2.2
			Vehicle	17	10	37	13	2.2	2.1
			Pedestrian	16	10	46	16	2.9	3.4
			Fox	1	1	2	1	2.0	–
			Large Bird[a]	0	0	–	–	–	–
			Unknown	14	9	24	8	1.7	2.4
			Total	163	100	295	100	1.8	2.3
001	130	17.0	Aircraft	71	61	90	37	1.3	0.7
			Vehicle	7	6	8	3	1.1	0.4
			Pedestrian	5	4	9	4	1.8	1.3
			Fox	2	2	7	3	3.5	0.7
			Large Bird[a]	16	14	85	35	5.3	5.4
			Unknown	15	13	46	19	3.1	5.9
			Total	116	100	245	100	2.1	3.2
914	194	22.7	Aircraft	146	73	178	52	1.2	0.8
			Vehicle	16	8	26	8	1.6	2.2
			Pedestrian	6	3	12	4	2.0	2.0
			Jaeger	1	<1	1	<1	1.0	–
			Large Bird[a]	11	6	84	25	7.6	8.9
			Unknown	19	10	41	12	2.2	5.0
			Total	199	100	342	100	1.7	3.1
All Nests Pooled		60.7	Aircraft	379	68	544	43	1.4	1.6
			Vehicle	53	10	122	10	2.3	3.0
			Pedestrian	29	5	69	5	2.4	2.7
			Predator[b]	5	<1	18	<1	3.6	2.7
			Large Bird[a]	37	7	353	28	9.5	10.2
			Unknown	54	10	151	12	2.8	5.5
			Total	557	100	1,257	100	2.3	4.1

[a] Includes loons, swans, geese, and ducks.

[b] All concealment postures were in response to foxes, except for one to a jaeger.

and later, all three nests hatched. While nest searching in the breeding bird plots, we flushed five different geese off nests six times (one goose was flushed twice), and our presence in the area (range = 225–560 min) resulted in some prolonged recesses ($\overline{x}$ = 127 min, range = 35–195 min). Four of these five geese returned to the nest while we were still working within 500 m. Of these five nests, three failed and two were successful. Temperature patterns from the egg thermistors indicated that the geese at the failed nests resumed normal incubation behavior after disturbance and for ≥7 d before failure occurred.

We used nest-attendance data from thermistor-monitored White-fronted Goose nests to quantitatively evaluate the effects of different potential disturbance factors. Vehicle traffic on the airstrip was monitored by video camera and by Alpine ATC (Appendix F2). Vehicle traffic on the infield road was monitored only by video camera (Appendix F3). We used airstrip traffic in our analyses of all nests, because the airstrip was closer to most nests, had more traffic, and was used by aircraft and, therefore, had a higher probability of disturbing nesting geese. Pedestrian traffic on the airstrip, infield road, and tundra was monitored by video (Appendix F4), but we used the pedestrian data from only the airstrip and tundra. Aircraft were recorded during the nesting season by Alpine ATC and by video (Table 2), but after nests hatched video monitoring was suspended. After hatch, we gathered data on aircraft and vehicle use of the airstrip from Alpine ATC (Appendix F5). However, we have no data on the amount of pedestrian traffic after cameras were shutdown and late-night vehicle traffic on the airstrip was not counted after ATC shutdown (between ~2200 and 0100 h until 0500 h depending on when the last aircraft departed and first aircraft arrived).

Three of four nest-attendance variables that were measured on a per-day basis differed between successful and unsuccessful nests (Table 10). Further, these three variables, i.e., incubation constancy, recess frequency, and time off nest, were highly correlated (pairwise Pearson's $|r| > 0.90$, $P < 0.001$; Appendix G1). We chose incubation constancy as an index of nest attendance, and used stepwise linear regression to examine the effects of specific types of potential disturbance on nesting behavior. To reduce the likelihood of multicollinearity affecting our modeling process, we examined a matrix of Pearson correlation coefficients for disturbance and weather variables (Appendices G2 and G3). We selected variables that represented different types of potential disturbance and had relatively low intercorrelations (generally, $|r| < 0.5$). Our reduced set of variables—number of landings and takeoffs of fixed-wing aircraft and helicopters, cumulative time that vehicles and pedestrians were on the airstrip, cumulative time that pedestrians were on the tundra, wind speed, and air temperature—were summarized for each day. Although mean daily temperature and mean wind speed were significantly correlated ($r = -0.56$, $P < 0.001$), we retained both in the analysis because each had high potential for affecting incubation constancy independently, and, therefore, could confound any relationships between human-caused disturbance and incubation constancy. Our final multiple regression model included mean wind speed ($P < 0.001$), cumulative time that vehicles were on the airstrip ($P < 0.001$), cumulative time that pedestrians were on the tundra ($P < 0.001$), and number of landings and takeoffs of fixed-wing aircraft ($P = 0.03$) as explanatory variables (Appendix G4).

We used a univariate general linear modeling procedure to test if the slopes of the relationships between the disturbance variables selected in the stepwise regression of incubation constancy were the same for successful and failed nests (Appendix G5). The slopes for number of takeoffs and landings of fixed-wing aircraft were the same for both nest fates ($P = 0.62$). However, the slopes for mean wind speed ($P = 0.02$), cumulative time that vehicles were on the airstrip ($P = 0.01$), and cumulative time that pedestrians were on the tundra ($P = 0.01$) differed between nest fates. Therefore, we conducted separate stepwise regressions for successful and failed nests, based on the subset of disturbance variables selected previously (Appendix G4). For both successful and failed nests, incubation constancy had a negative relationship with mean wind speed and number of takeoffs and landings of fixed-wing aircraft, and a positive relationship with cumulative time that vehicles were on the airstrip (Table 12). Incubation constancy also had a positive relationship with cumulative time that

Table 12. Final multiple-regression models of incubation constancy (arcsine transformed) on potential disturbance variables for 12 successful and 12 failed Greater White-fronted Goose nests monitored by egg thermistors in the Alpine project area, Colville River Delta, Alaska, 2000.

	Regression Coefficients				Model Statistics				
Independent Variables	β	SE	t	P	F	df	P	R^2	Adj.R^2
Successful nests									
Constant	1.570	0.025	63.63	0.000	14.16	3, 225	<0.001	0.16	0.15
Mean wind speed	-0.009	0.002	-5.22	<0.001					
Cumulative time of vehicles on airstrip	<0.001	<0.001	2.30	0.022					
Number of Airplanes	-0.001	0.001	-1.79	0.075					
Failed nests									
Constant	1.533	0.043	35.67	<0.001	17.04	4, 177	<0.001	0.28	0.26
Mean wind speed	-0.018	0.004	-4.86	<0.001					
Cumulative time of vehicles on airstrip	<0.001	<0.001	4.21	<0.001					
Cumulative time of pedestrians on tundra	<0.001	<0.001	3.84	<0.001					
Number of Airplanes	-0.001	0.001	-1.79	0.075					

pedestrians were on the tundra (i.e., higher constancy with more pedestrian time) at failed nests only ($P < 0.001$); no relationship between these variables was observed for successful nests ($P = 0.31$). This result suggests that geese at failed nests may have experienced more disturbance from pedestrians, and/or reacted more often to this disturbance by taking fewer recesses. However, all of the coefficients in the final models were small, indicating low levels of effects. Further, the models themselves explained only 26% of the variance in incubation constancy for failed nests and 15% of the variance for successful nests, suggesting that environmental or disturbance variables other than the ones we measured may affect incubation constancy.

We caution that further analyses will be required to fully evaluate the effects of disturbance on incubation constancy and, ultimately, on nest success. We did not include distance from nests to the source of disturbance as a covariate in the analyses presented here because our sample size would have been inadequate for meaningful statistical analysis in this one-year sample of thermistor-equipped nest sites. We acknowledge that response to disturbance may vary as a function of distance, and plan to use our multi-year data set to investigate the effects of vehicles, aircraft, pedestrians, and noise on nest attendance and success as a function of distance after the final season of data collection.

TUNDRA SWAN

Of the two Tundra Swan nests that we monitored with time-lapse video cameras in 2000, one hatched and the other failed. The successful nest was 448 m from the airstrip and 145 m from the infield road, and the failed nest was 1,173 m from the airstrip (Figure 8). The successful nest was monitored for 21 d (Appendix E5) and the failed nest was monitored for 1.3 d. Mean daily incubation constancy for the successful nest was 99.2% (n = 17 d) (Table 13). Swans nesting in the same location in 1999 also were monitored with a video camera and incubation constancy was nearly identical (99.1%, $n = 22$). Mean number of recesses at this nest was the same in 1999 and 2000 (0.6 recesses/d). In 2000, mean recess length was shorter (5.7 min/recess) than in 1999 (10.4 min/recess), but mean time off the nest was similar both years (11.8 min/d in 2000, 12.1 min/d in 1999). In 2000, we observed 64 incubation exchanges between the male and female birds, slightly higher than the number (50 exchanges) observed in 1999. Mean daily number of exchanges in 2000 was 3.6 exchanges/d and mean time off the nest for exchanges was 8.1 min/d; both values were higher than for exchanges recorded for this nest in 1999 (Johnson et al. 2000a).

Table 13. Summary of nesting activities at Tundra Swan nest 701 monitored with a video camera at 1-min intervals in the Alpine project area, Colville River Delta, Alaska, 2000. The nest was 448 m from the Alpine airstrip.

	$\bar{x}$	SD	n
Incubation Constancy (%/d)	99.2	<0.1	17
Recess Frequency (no./d)	0.6	0.9	17
Recess Length (min/recess)	5.7	2.7	11
Time Off Nest (min/d)	11.8	6.7	17
Break Frequency (no./d)	21.7	5.3	17
Time on Break (min/d)	23.9	6.5	17
Exchange Frequency (no./d)	3.6	1.2	17
Time on Exchange (min/d)	8.1	3.9	17
Defense Frequency (no./d)	0.2	0.4	17
Time Disturbed[a] (min/d)	3.7	15.3	17

[a] Disturbance time is the number of minutes people were on the tundra near the nest (as determined from video cameras and field notes) plus 30 minutes before and after to account for their approach to and departure from nest.

One Tundra Swan nest failed the day (18 June) after we set up the video camera. This nest was in one of the breeding-bird plots and our nest-searching activities (≤500 m from the nest) on the plot caused the swan to be off the nest 4 times during a 9.5-h period. Mean time off the nest during these four disturbance recesses was 91 min (range = 59–119 min). Each time a swan left the nest, we covered the eggs with nesting material. We recorded on video two occurrences of predation that occurred at this nest during these disturbance recesses. A jaeger visited the nest 26 min after the swan left on the second recess and stayed at the nest for approximately 5 min. The jaeger was pecking at the eggs, possibly eating them, during four of five recording intervals. A swan returned to the nest 93 min after the jaeger visit. Predation by a red fox occurred 49 min after the swan left on the fourth recess and 5 min after we were picked up by helicopter. The fox made two trips to the nest for eggs. A swan returned to the nest 30 min after the fox and attended the nest for 396 min before leaving on recess. After 108 min, a swan returned and stayed at the nest for 104 min before leaving permanently.

On the video recordings of the successful Tundra Swan nest, we observed three defensive breaks by the incubating swan when foxes approached the nest. During all three encounters, a fox was on the nest mound and the incubating swan stood and held its position above the nest. Each encounter lasted 1 recording interval and each time the swans successfully deterred the fox. Prior to one encounter, the mate of the incubating swan moved onto the nest mound in the recording interval before the fox appeared and stayed on the mound for 16 min. A fox was seen running behind the nest (25–50 m) on two additional occasions and the incubating swan became alert (1 event) and had no noticeable reaction (1 event). We observed three additional defensive breaks, but no predators were seen on the videos. During each of these three breaks, the incubating swan and its mate reared up and flapped their wings. This behavior was observed in previous years in reactions to other swans flying over (Johnson et al. 2000a).

Human activities in the vicinity of the successful swan nest included people walking on the infield road and people on the tundra. The duration of the activities and distance of the activity to the nest varied. The swans responded to these activities by concealing on the nest or by "sneaking-off" (i.e., walking slowly with head down in a crouched position and using surface relief for concealment) the nest but remaining beside it. We recorded 36 groups (maximal size = 3 people) of people walking on the infield road on 7 of 25 d that the camera was recording (Appendix F4). During each event, the incubating swan concealed and remained on the nest. Our research activities accounted for seven of the eight occurrences of people on the tundra ≤200 m of this nest. Some activities, such as servicing the camera, were short in duration ($\overline{x}$ = 20 min, n = 5), while other activities, such nest searching, kept people in the vicinity for 30 and 105 min. During one event, the swan sneaked-off the nest when one person came into view 150 m from the nest. The swan resumed incubating 10 min after the person left the area (out of view of the nest). During the remaining seven events, the swan concealed and remained on the nest.

CLUTCH SIZE AND NEST FATE

ALL SPECIES

Despite our efforts to find nests without disturbing incubating birds, some were flushed from their nests. For those that were flushed, we recorded clutch sizes and then covered the eggs with down and nest material to conceal them from predators. Several species had a single clutch or mean clutch size of 2.0 eggs: Red-throated Loon, Pacific Loon, Rock Ptarmigan, Parasitic Jaeger, Long-tailed Jaeger, Sabine Gull, and Arctic Tern (n = 1–4 nests), whereas clutch sizes for various duck species varied from 3 to 10 eggs (n = 1–8 nests) (Table 14). Clutch sizes were intermediate for geese (3.0–4.0 eggs, n = 1–54 nests), Tundra Swans (2.7 eggs, n = 6 nests), and Willow Ptarmigan (7.4 eggs, n = 12 nests). All clutch sizes were within the range of numbers that are reported in the literature (Baicich and Harrison 1997).

We revisited nest sites of waterfowl in July 2000 (after the hatch) to determine the fate of nests in the ground-search area (Table 15). We did not determine the fate of nests on inaccessible islands, as was the case for one Red-necked Grebe nest. Of the 17 duck nests found in the project area (including nests found during activities other than

Table 14. Clutch sizes of nests found during ground nest searches in the Alpine project area, Colville River Delta, Alaska, 2000.

	Clutch size		
Species	$\bar{x}$	SE	*n*
Red-throated Loon	2.0	-	1
Pacific Loon	2.0	0	3
Greater White-fronted Goose	3.8	0.18	54
Canada Goose	4.0	-	1
Brant	3.0	0.58	3
Tundra Swan	2.7	0.47	6
Northern Pintail[a]	5.6	1.12	8
Green-winged Teal[a]	8.0	0	2
Greater Scaup	10.0	-	1
Unidentified scaup	3.0	-	1
Long-tailed Duck	6.0	0.41	4
Willow Ptarmigan	7.4	0.36	12
Rock Ptarmigan	2.0	-	1
Unidentified ptarmigan	5.0	-	1
Common Snipe	3.0	-	1
Parasitic Jaeger	2.0	0	2
Long-tailed Jaeger	2.0	-	1
Sabine's Gull	2.0	-	1
Arctic Tern	2.0	0	4

[a] Includes probable nests determined from feather and down samples.

Table 15. The number, fate, and mean distance from the airstrip of nests of selected species found during the nest search and in the breeding-bird plots in Alpine project area, Colville River Delta, Alaska, 2000. Only nests with known fates were included.

	Successful Nests				Failed Nests			
			Distance (m)				Distance (m)	
Species	No.	%	$\bar{x}$	SE	No.	%	$\bar{x}$	SE
Pacific Loon	-	-	-	-	1	100.0	1,421	-
Greater White-fronted Goose	21	37.5	1,426	149	35	62.5	1,444	96
Canada Goose	1	100.0	1,545	-	-	-	-	-
Brant	2	66.7	1,453	27	1	33.3	2,507	-
Tundra Swan	3	75.0	1,442	620	1	25.0	1,173	-
Northern Pintail[a]	1	14.3	1,601	-	6	85.7	1,252	405
Green-winged Teal[a]	-	-	-	-	2	100.0	270	215
Greater Scaup	-	-	-	-	1	100.0	1,548	-
Unidentified Scaup	-	-	-	-	1	100.0	1,628	-
Long-tailed Duck	1	20.0	832	-	4	80.0	931	332
Unidentified duck	-	-	-	-	1	100.0	1,233	-
All ducks	2	11.8	1,216	384	15	88.2	1,079	201
Common Snipe	-	-	-	-	1	100.0	729	-
Parasitic Jaeger	1	100.0	1,053		-	-	-	-
Sabine's Gull	-	-	-	-	1	100.0	1,476	-
Arctic Tern	1	50.0	2,260	-	1	50.0	1,517	-
Total nests	31	35.6	1,434	117	56	64.4	1,349	86

[a] Includes probable nests determined from feather and down samples.

the nest search) for which we determined fate, only 2 (12%), one Northern Pintail and one Long-tailed Duck, were successful. The fate of duck nests in 2000 did not appear to be influenced by their distance from the airstrip (Table 16). Failed nests were slightly closer ($\bar{x}$ = 1,079 m, $n = 15$) to the airstrip than were successful nests ($\bar{x}$ = 1,216 m, $n = 2$), and although the difference was not significant (Mann-Whitney U test, $Z = -0.44$, $P = 0.72$), the small sample size of successful nests limits the conclusions from this comparison.

GREATER WHITE-FRONTED GOOSE

The mean clutch size of White-fronted Geese in 2000 was 3.8 eggs ($n = 54$ nests), similar to the values reported in other studies on the Colville Delta (Simpson et al. 1982; Simpson 1983; Smith et al. 1993, 1994). In the Alpine project area, the mean clutch size in 1995–1999 ranged from 3.7 to 4.1 eggs (Johnson et al. 2000a). In 2000, proximity to the Alpine airstrip did not have a detectable effect on clutch size; distance of nests to the airstrip explained <0.01% of the variance ($r^2 = 0.007$, $P = 0.55$).

Of 56 White-fronted Goose nests found throughout the project area in 2000 (including nests found during activities other than the nest search) with known fates, 21 (38%) hatched successfully, and 35 (62%) failed (Table 15). The success rate in 2000 was slightly better than that in 1999 (35%), but was approximately half that recorded during 1997 and 1998 (82% and 71%, respectively) and lower than that reported in 1981 and 1982 on the delta (57% and 54%, respectively; Simpson et al. 1982, Rothe et al. 1983). As described earlier, the 2000 nesting season began with cooler temperatures and had a later thaw than previous years, and flooding made large portions of the study area unavailable when nest initiation normally would occur (see CONDITIONS IN THE STUDY AREA). We also observed an increase in fox activity at nests (see PREDATORS section below); therefore we suspect that a combination of weather conditions and predation had a negative effect on both the number of White-fronted Goose nests and their fate. The proximity of White-fronted Goose nests to the airstrip had little effect on their fate in 2000; the distances from the airstrip of successful ($\bar{x}$ = 1,426 m, $n = 21$) and failed nests ($\bar{x}$ = 1,444 m, $n = 35$) were virtually identical (two sample t-test, $P = 0.92$, Table 16).

TUNDRA SWAN

Clutch sizes of Tundra Swan nests averaged 2.7 eggs in 2000 ($n = 3$ nests). In 1996–1999, the mean clutch sizes ranged from 3 to 4 eggs (n = 4–6 nests each year). Because sample sizes and the range of clutch sizes were small, we did not test for relationships between clutch size and distance to the airstrip. Mean clutch size in 2000 was lower than those recorded in other studies on the Colville Delta; in 1981, mean clutch size was 3.6 eggs ($n = 28$) (Rothe et al. 1983) and in 1982 it was 3.4 eggs ($n = 43$) (Simpson et al. 1982).

In 2000, three of four (75%) Tundra Swan nests with known fate in Alpine project area were successful. The failed nest was 1,173 m from the airstrip, closer than the three successful nests ($\bar{x}$ = 1,442 m). In 1997–1999, success rates for swan nests ranged from 60% to 100% (Johnson et

Table 16. Tests of mean distances of nests of ducks and Greater White-fronted Geese from the airstrip between their fates in the Alpine project area, Colville River, Alaska, 2000. Nests were found between 15–23 June during the nest search and in the breeding-bird plots.

	Distance (m)					
Nest Fate	$\bar{x}$	SE	n	Test	Statistic (Z or t)	P-value
All Ducks						
Successful	1,216	384	2			
Failed	1,079	201	15	Mann-Whitney	-0.44	0.72
Greater White-fronted Goose						
Successful	1,426	149	21			
Failed	1,444	96	35	two-sample t test	-0.10	0.92

al. 2000a). Success rates in the Alpine project area were comparable to those of earlier studies conducted over a broad portion of the delta; in 1981, nesting success was 91% for 32 nests (Rothe et al. 1983) and it was 70% for 43 nests in 1982 (Simpson et al. 1982).

BROOD-REARING

We did not conduct a specific survey for broods of large waterbirds in the Alpine project area during 2000. Broods were recorded opportunistically during nest fate checks in early July and during a ground search for loon broods in August. We recorded 24 broods belonging to 10 species in the ground-search area (Figure 10). We saw broods of Red-throated Loon, Red-necked Grebe, White-fronted Goose, Tundra Swan, Northern Pintail, Greater Scaup, King Eider, Red-breasted Merganser, Glaucous Gull, and Arctic Tern.

BREEDING-BIRD PLOTS

We found 248 nests belonging to 18 species of birds on the 12 breeding-bird plots we sampled in 2000 (Table 17). The predominant nesting species were Pectoral Sandpiper (70 nests, 28% of all nests), Lapland Longspur (51 nests, 21%), Semipalmated Sandpiper (47 nests, 19%), Red-necked Phalarope (17 nests, 7%), and Greater White-fronted Goose (10 nests, 4%). The total number of nests per plot ranged from 9 to 34 (90–340 nests/km^2) and averaged 20.7 nests (206.7 nests/km^2). We found more nests in 2000 than we did in 1999 (169 nests) or 1998 (196 nests). Approximately the same number of species were represented in each annual sample, although the relative abundance of individual species has varied. In 1999, Lapland Longspurs (62 nests, 37% of all nests) and Semipalmated Sandpipers (37 nest, 22%) were most common, and only 24 Pectoral Sandpiper nests (14% of all nests) were located. In contrast, Pectoral Sandpipers were most common in 1998 (61 nests, 31% of the total), followed by Lapland Longspurs (49 nests, 25%), and Semipalmated Sandpipers (21 nests, 11%). The number of White-fronted Goose nests located in 2000 was similar to the number located in 1999 (9 nests, 5%), but less than 1998 (16 nests, 8%). The number of shorebird nests declined from 116 in 1998 to 85 in 1999, but then nearly doubled to 160 in 2000 because of the marked increase in Pectoral Sandpipers, and, to a lesser extent, Red-necked Phalaropes (3 nests in 1999 and 17 nests in 2000) and Semipalmated Sandpipers (37 nests in 1999 and 47 nests in 2000). The number of all waterfowl nests, in contrast, was similar in 2000 (15 nests) and 1999 (14 nests), after declining from 24 in 1998.

More nests were found on treatment plots ($\overline{x}$ = 24.5 nests, SD = 6.7, $n = 6$) than on reference plots ($\overline{x}$ = 16.8 nests, SD = 8.2, $n = 6$) in 2000, although the difference was not significant ($t = 1.78$, 10 df, $P = 0.11$) (Table 18). Nests were also more abundant on treatment than reference plots in 1998 and 1999, and similarly the difference in 1998 was not significant ($P = 0.38$), whereas in 1999 the difference was significant ($P = 0.05$). Among the five most common nesting species (i.e., Greater White-fronted Goose, Pectoral Sandpiper, Semipalmated Sandpiper, Lapland Longspur, Red-necked Phalarope), we did not observe a significant difference in number of nests between treatment and reference plots during 2000 ($P \geq 0.06$). Results for the previous 2 years were similar; the only significant difference was for Semipalmated Sandpipers during 1999, which were more common in treatment plots than reference plots ($P = 0.04$).

The number of nests per plot among these five most common species in 2000 did not appear to be related to distance from plots to the airstrip (simple linear regressions, $P \geq 0.06$; Table 19). However, total nests of all species declined as a function of increasing distance to the airstrip ($r^2 = 0.56$, $P = 0.01$) (Table 19). Similarly, we did not detect a relationship between nest densities for Greater White-fronted Geese, Pectoral Sandpipers, Semipalmated Sandpipers, or Lapland Longspurs and distance to the airstrip (each year tested separately) during 1998 or 1999 ($r^2 \leq 0.30$, $P \geq 0.06$). In contrast to our results for 2000, we did not detect a relationship between total nests for all species and distance to airstrip during 1998 ($P = 0.23$) or 1999 ($P = 0.18$). It should be noted, however, that distance to the airstrip was measured from the center of each plot. We did not measure distances from quadrants or grids, and therefore cannot rule out the possibility of finer scale (i.e.,

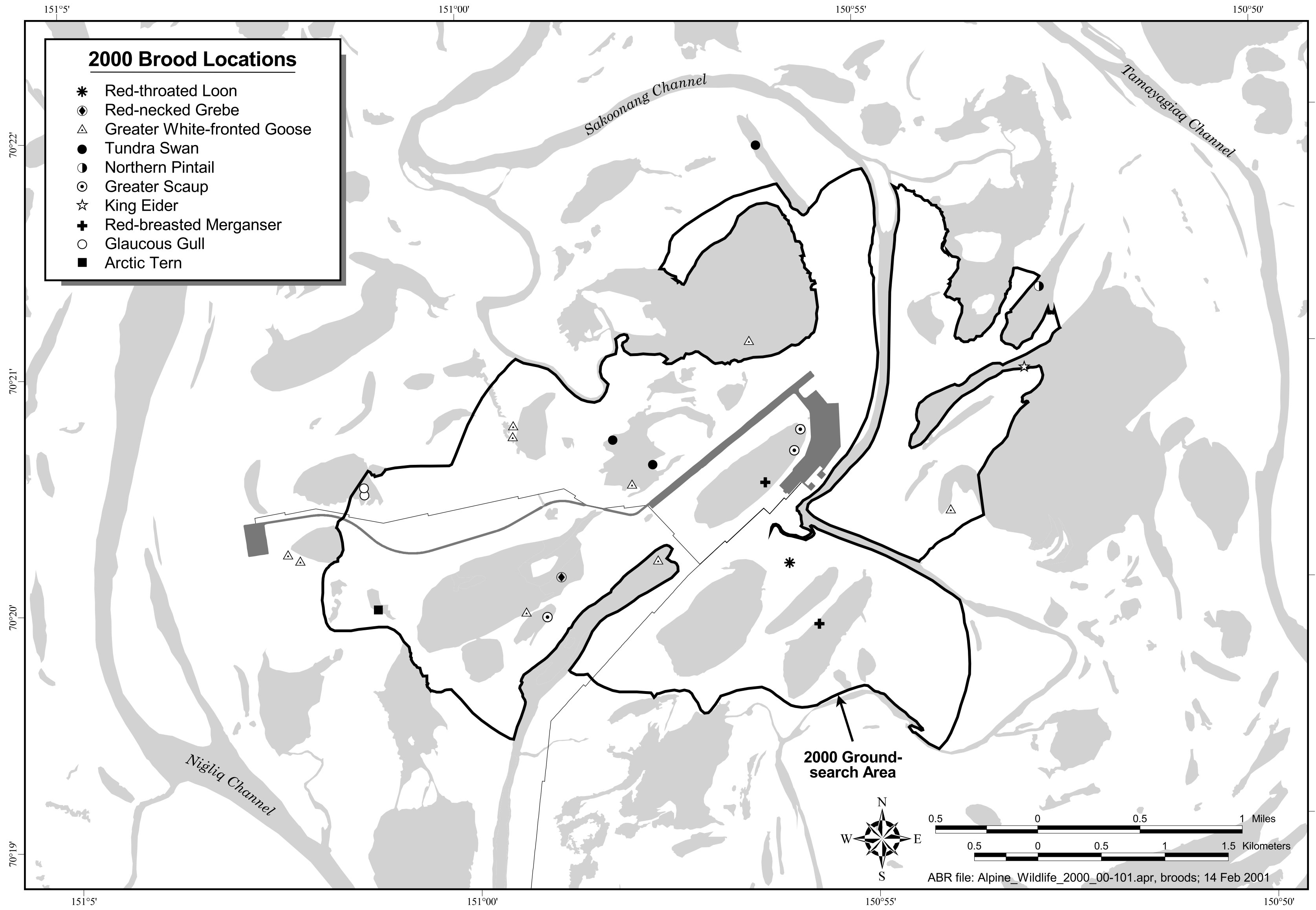

Figure 10. Locations of broods found incidentally during nest-fate checks in the Alpine project area, Colville River Delta, Alaska, 2000.

Table 17. Numbers and densities of nests found on 10-ha plots in the Alpine project area, Colville River Delta, Alaska, 2000. Plots <1,500 m from the airstrip were classified as treatment plots and those >1,500 m were classified as reference plots.

	Treatment Plot Number						Reference Plot Number							
Species	1	2	3	4	5	6	7	8	9	10	11	12	Total Nests	Mean Density (nests/km^2)
Greater White-fronted Goose	2	0	3	1	1	1	0	1	0	1	0	0	10	8.3
Tundra Swan	0	0	0	0	0	1	0	0	0	0	0	0	1	0.8
Northern Pintail	0	0	0	0	0	0	0	0	0	0	0	1	1	0.8
Unidentified Duck	0	2	0	0	1	0	0	0	0	0	0	0	3	2.5
Willow Ptarmigan	1	0	0	0	0	0	0	1	1	0	0	1	4	3.3
Unidentified ptarmigan	0	1	0	0	0	0	0	0	0	0	0	0	1	0.8
American Golden Plover	1	0	0	0	1	0	1	0	1	0	0	0	4	3.3
Semipalmated Sandpiper	3	6	2	3	8	5	4	10	2	2	1	1	47	39.2
Pectoral Sandpiper	10	4	8	5	7	4	6	9	8	2	5	2	70	58.3
Dunlin	1	0	0	1	1	0	0	0	1	0	0	0	4	3.3
Stilt Sandpiper	2	0	0	1	0	0	1	0	0	0	0	0	4	3.3
Long-billed Dowitcher	0	0	0	1	3	0	2	0	0	0	0	1	7	5.8
Common Snipe	0	0	0	0	1	0	0	0	0	0	0	0	1	0.8
Red-necked Phalarope	2	2	0	0	3	3	1	2	2	0	1	1	17	14.2
Red Phalarope	1	0	1	0	0	1	2	1	0	0	0	1	7	5.8
Arctic Tern	0	0	0	1	0	0	0	0	0	0	0	0	1	0.8
Yellow Wagtail	2	2	0	0	2	0	0	0	0	0	0	0	6	5.0
Savannah Sparrow	0	3	1	1	0	1	0	0	0	0	0	0	6	5.0
Lapland Longspur	4	5	3	3	6	6	3	7	3	4	2	5	51	42.5
Common Redpoll	1	0	0	0	0	1	0	0	0	0	1	0	3	2.5
Total Nests	30	25	18	17	34	23	20	31	18	9	10	13	248	
Density (nests/km^2)	300	250	180	170	340	230	200	310	180	90	100	130	206.7	
Number of Species	12	6[a]	6	9	10[a]	9	8	7	7	4	5	8	18[a]	

[a] Minimum does not include unidentified ducks and unidentified ptarmigan.

Table 18. Two-sample *t*-tests of mean numbers of nests of the most prevalent species on treatment ($n = 6$) and reference ($n = 6$) breeding bird plots, Alpine project area, Colville River Delta, Alaska, 1998–2000.

	Treatment		Reference			
Species/Year	$\bar{x}$	SD	$\bar{x}$	SD	t	P-value
Greater White-fronted Goose						
1998	1.0	1.1	1.7	1.5	-0.88	0.40
1999	1.0	1.7	0.5	0.8	0.66	0.53
2000	1.3	1.0	0.3	0.5	2.12	0.06
Pectoral Sandpiper						
1998	5.7	2.4	4.5	2.5	0.82	0.43
1999	2.5	2.4	1.5	1.8	0.84	0.42
2000	5.5	1.5	5.2	2.8	0.26	0.80
Semipalmated Sandpiper						
1998	2.3	1.4	1.2	1.9	1.20	0.26
1999	4.0	1.7	2.2	1.0	2.31	0.04
2000	4.5	2.3	3.3	3.4	0.69	0.50
Lapland Longspur						
1998	4.3	1.4	3.8	1.7	0.56	0.59
1999	5.5	1.6	4.8	1.0	0.85	0.41
2000	4.5	1.4	4.0	1.8	0.54	0.60
Red-necked Phalarope						
1998	0.8	0.8	1.2	1.0	-0.66	0.53
1999	0.3	0.5	0.2	0.4	0.62	0.55
2000	1.7	1.4	1.2	0.8	0.79	0.45
Total Nests						
1998	17.7	2.8	15.0	6.5	0.92	0.38
1999	17.0	6.5	11.2	1.2	2.18	0.05
2000	24.5	6.7	16.8	8.2	1.78	0.11

Table 19. Simple linear regression models of number of nests per breeding-bird plot on distance to the airstrip for the five most abundant species, Alpine project area, Colville River Delta, Alaska, 2000. Nests of 18 species were found on plots in 2000.

	Regression Coefficients				Model Statistics			
Species/model parameters	β	SE	*t*	*P*	*F*	df	*P*	R^2
Greater White-fronted Goose								
Constant	1.453	0.511	2.85	0.017	1.98	1, 10	0.189	0.17
Distance to Airstrip	>-0.001	<0.001	-1.41	0.189				
Pectoral Sandpiper								
Constant	8.193	1.302	6.29	<0.001	4.42	1, 10	0.062	0.31
Distance to Airstrip	-0.002	0.001	-2.10	0.062				
Semipalmated Sandpiper								
Constant	5.989	1.515	3.95	0.003	2.52	1, 10	0.143	0.20
Distance to Airstrip	-0.001	0.001	-1.59	0.143				
Lapland Longspur								
Constant	4.753	0.902	5.27	<0.001	0.42	1, 10	0.532	0.04
Distance to Airstrip	>-0.001	0.001	-0.65	0.532				
Red-necked Phalarope								
Constant	2.113	0.593	3.56	0.005	1.86	1, 10	0.203	0.16
Distance to Airstrip	>-0.001	<0.001	-1.36	0.203				
All Avian Species Detected								
Constant	30.584	3.230	9.47	<0.001	12.70	1, 10	0.005	0.56
Distance to Airstrip	-0.007	0.002	-3.56	0.005				

within plot) effects of distance to the airstrip on the distribution of avian nests.

The number of Pectoral Sandpiper nests dropped precipitously from 61 ($\bar{x}$ = 50.8 nests/km^2, *n* = 12 plots) in 1998 (Johnson et al. 1999b) to 24 ($\bar{x}$ = 20.0 nests/km^2, *n* = 12 plots) in 1999 (Johnson et al. 2000a), then rebounded to 70 ($\bar{x}$ = 58.3 nests/km^2, *n* = 12 plots) in 2000. Pectoral Sandpiper nest densities appear to have been unusually high in the Alpine project area in 1998 and 2000 compared to densities observed elsewhere on the coastal plain. In the National Petroleum Reserve–Alaska, Pectoral Sandpipers had a mean of 30 nests/km^2 on 10 plots in drained lake basins during 1998 (Cotter and Andres 2000). In the Pt. McIntyre area, Pectoral Sandpiper densities varied from 1 to 33 nests/km^2 ($\bar{x}$ = 8.7 nests/km^2, *n* = 10 years; TERA 1993), and densities in the Kuparuk Oilfield varied over five years from 2.9 to 18.4 nests/km^2 ($\bar{x}$ = 7.9 nests/km^2) and 4.0 to 23.5 nests/km^2 ($\bar{x}$ = 12.7 nests/km^2) on two different plots (Moitoret et al. 1996). Pitelka (1959) documented dramatic variation in annual densities of territorial Pectoral Sandpipers, and it appears that similar variation is characteristic of nesting densities on our study plots.

HABITAT ASSOCIATIONS

We measured several habitat variables within quadrants on the 12 breeding bird plots (*n* = 160 quadrants/plot) during 1999 (Johnson 2000a). Although the plots were placed in locations that appeared to have similar habitat composition at the scale of our habitat map (i.e., primarily Wet Sedge–Willow Meadow; Figure 2), plots differed in habitat characteristics measured at finer scales (Johnson et al. 2000a). Surface relief, water depth, proportion of water, and proportions of vegetation cover by vegetation association differed among plots (Kruskal-Wallis tests, $424.1 \geq \chi^2 \geq 45.4$, 11 df, $P < 0.001$). However, averaged across plots, the treatment and reference areas exhibited few differences (Table 20). The wet sedge–willow vegetation type was common and composed a higher proportion of reference plots than

Table 20. Comparison of habitat characteristics between treatment and reference breeding-bird plots, Alpine project area, Colville River Delta, Alaska, 1999–2000.

	Treatment Plots (n = 240 grid cells)		Reference Plots (n = 240 grid cells)		Mann-Whitney Test Results	
Habitat Variable	$\bar{x}$	SD	$\bar{x}$	SD	Z	P
Surface relief (cm)	48.4	17.4	49.6	19.7	0.60	0.55
Water depth (cm)	24.6	22.0	25.8	22.4	1.02	0.31
Water cover (%)	13.0	13.4	12.9	12.3	0.03	0.98
Wet sedge meadow (%)	38.3	19.5	34.7	18.8	1.52	0.13
Wet sedge–willow (%)	17.6	14.2	21.9	14.4	4.50	<0.01
Moist sedge–shrub (%)	31.2	17.6	28.1	15.2	1.46	0.15
Sedge marsh (%)	<0.1	0.4	<0.1	0.5	0.005	0.99
Grass marsh (%)	<0.1	0.1	0.2	1.8	2.36	0.02
Partially vegetated mud (%)	<0.1	<0.1	0.1	1.0	2.01	0.05
Open low willow (%)	<0.1	0.3	1.7	7.5	3.08	<0.01
Dryas tundra (%)	<0.1	0.6	0.4	2.6	2.91	<0.01

treatments plots ($P < 0.001$). We also noted differences between treatment and reference plots in the proportions of grass marsh, partially vegetated mud, open low willow, and *Dryas* tundra ($P \leq 0.05$), although all of these types were rare ($\bar{x} \leq 1.7\%$ cover).

The occurrence of polygons, disjunct polygons, nonpatterned ground, and dunes did not differ between treatment plots and reference plots ($\chi^2 = 5.78$, 3 df, $P = 0.12$). Polygon density (i.e., high, low, or none) was also similar between plot types ($\chi^2 = 3.41$, 2 df, $P = 0.18$). Relative to reference plots, however, grids within treatment plots included high-centered polygons more frequently, and low-centered polygons or nonpatterned ground less frequently ($\chi^2 = 9.88$, 2 df, $P = 0.007$).

We used logistic regression to test for associations between the occurrence of bird nests and habitat features, including the continuous and categorical variables we measured on grids and quadrants within plots (see Johnson et al. 2000a). Because the number of quadrants was large (n = 1,920) compared to the number of nests (n = 248 in 2000), we averaged the quadrant measurements within each grid (n = 4 quadrants/grid) and constructed explanatory models for nest occurrence using habitat characteristics at the scale of the grid (n = 480 grids on 12 plots). Distance of nests to Pad 1 was eliminated from the pool of potential explanatory variables because it was highly correlated with distance of nests to the airstrip (r = 0.98). In previous modeling efforts, polygon centers were dropped from three models (1999 waterfowl and 1999 and 1998 White-fronted Goose nests) in which the no-center category (dunes, nonpatterned meadow, and disjunct polygons) contained no nests and in one model (1998 shorebird nests) in which polygon density entered earlier; these relationships between independent variables and among categories produced excessively high (i.e., unreliable) coefficients and standard errors (Hosmer and Lemeshow 1989). For the same reasons, surface form was dropped from the 1999 Lapland Longspur model. Neither surface form nor polygon centers were significant explanatory variables in any of the final models in 2000.

Our logistic regression models for 2000 demonstrated some common tendencies for bird–habitat associations on the breeding-bird plots (Appendix H). Open low willow was the most common habitat variable, entering 3 of 7 models with odds ratio >1.0. Sedge marsh and surface relief were significant explanatory variables in two models each, and also had odds ratios >1.0. Distance to the airstrip was included in three final models, with the general pattern that the probability of nest occurrence was greater in the three distance categories closest to the airstrip versus the category farthest away.

In 2000, our models suggested that the probability of occurrence for nests of both White-fronted Geese and all waterfowl increased with increasing cover of sedge marsh within grids (odds ratio = 1.82 and 1.99, for all waterfowl and White-fronted Geese, respectively; Appendix H). Although our model for all waterfowl was significant ($P = 0.04$) and correctly predicted group membership for 100% of grids with no waterfowl nests, it correctly predicted group membership for only 7% of grids where a nest occurred. Similarly, our Greater White-fronted Goose model was significant ($P = 0.02$) and correctly predicted group membership for 100% of grids with no waterfowl nests but only 10% of grids where a nest occurred. This limitation probably arose because of low statistical power associated with the rarity of nests relative to the large number of grids that we intensively searched, and unstable regression-coefficient estimates associated with the small number of nests relative to the large pool of potential explanatory variables. It is also possible that waterfowl selected habitats at spatial scales other than that of our study design (i.e., habitat characteristics of 50–x–50-m grids), or that variables other than those we measured were important determinants of nest-site selection. The latter might include stochastic events such as weather and intraspecific or interspecific interactions, which could confound the observed habitat associations. We hope to refine our conclusions further by pooling nest-occurrence data across multiple years and testing for habitat associations after the final year of data collection, thereby enhancing statistical power and reducing the potential influence of confounding variables. Consistent with our results for 1998 and 1999, most nests during 2000 (i.e., 14 of 15 nests for all waterfowl, and 9 of 10 White-fronted Goose nests) occurred within grids characterized by high- or low-centered polygons; only one White-fronted Goose nest occurred in an area of disjunct polygons. The weight of evidence, therefore, suggests that the presence of high- and low-centered polygons has a positive influence on nest-site selection by waterfowl.

All of our models for the occurrence of shorebird nests during 2000 included distance to the airstrip as a significant explanatory variable (Appendix H). Consistent with results from 1998 and 1999, all (9 of 9) of the odds ratios for distance categories closest to the airstrip (i.e., 0–780 m, 781–1,430 m, and 1,431–2,412 m) were >1.0, suggesting that the probability of nest occurrence for all shorebirds, Pectoral Sandpipers, and Semipalmated Sandpipers was higher in the distance categories closest to the strip versus the category farthest away (i.e., >2,412 m). The estimated probability of nest occurrence was greatest between 1,431 m and 2,412 m from the airstrip for all shorebirds and for the most common species, Pectoral Sandpipers. For Semipalmated Sandpipers, the area ≤780 m from the airstrip had the highest estimated probability of nest occurrence. Based on the data from 1998–2000, we conclude that shorebirds did not appear to be deterred from nesting near the airstrip, at least at the scale of these analyses. Other habitat relationships observed among shorebirds include a higher probability of nest occurrence in areas of greater surface relief for both Pectoral Sandpipers and shorebirds in general, and a positive association between Semipalmated Sandpiper nests and the percentage of open low willow. We caution that, although our models for shorebird nest occurrence were significant ($P < 0.01$ for all shorebirds, Pectoral Sandpipers, and Semipalmated Sandpipers) and correct classification rates for grids without nests were high (≥99%), the models performed poorly for predicting where nests would occur. The same limitations and explanations given above for the waterfowl models apply here. Results for the associations of nest occurrence and vegetation type have varied annually for 1998–2000 (see Johnson 2000a); we will defer final conclusions in this regard until we conduct multi-year analyses following 2001 field season.

The probability of occurrence for passerine nests had a positive association with areas having high polygon density and, to a lesser extent, low polygon density; only 3 of 59 grids with disjunct polygons or nonpatterned ground included passerine nests. Nests of both Lapland Longspurs and all passerines also were predicted to be more common in areas with greater availability of the open low willow vegetation type. Again we observed some differences between the 2000 results and those for 1998–1999. Further, although the logistic regression models were significant ($P = 0.001$) and had 100% predictive success for grids lacking nests, predictive capability for grids with nests was low. As for other species and species groups, we will defer final conclusions regarding passerine nesting preferences until the 2001 data are available.

SEASONAL USE OF LAKES

Twenty-three species of waterbirds were recorded during 10 aerial surveys of lakes in the Alpine project area (Table 21). Shorebirds, raptors, and other birds were noted; however, the primary focus of these surveys was large waterbirds. Ducks were the most numerous birds observed (45% of the total, Appendix I). The most commonly occurring ducks were Northern Pintail (66% of all ducks), scaup (17%), and American Wigeon (4%). Northern Pintails, scaup, and less abundant species—Northern Shoveler, Green-winged Teal, and Long-tailed Duck—were found nesting in the Alpine project area (Appendix D2). Loons (Pacific, Red-throated, and Yellow-billed), geese (Greater White-fronted, Canada, and Brant), and Tundra Swans also nested in the area and were well represented throughout the surveys.

Waterbirds using the lakes in the Alpine project area were most numerous in late June and mid-August and least numerous in late July-early August (Table 21). The high counts of birds in

Table 21. Numbers of waterbirds observed during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 2000.

	Survey Dates										
	June			July				August			
	22[a]	24	30	7	15	21	29	6	17	25	Total
Pacific Loon	57	50	58	60	39	41	30	41	60	36	472
Red-throated Loon	3	0	9	8	1	1	1	1	8	2	34
Yellow-billed Loon	12	6	9	9	2	5	9	0	5	7	64
Red-necked Grebe	7	1	7	3	0	0	1	1	2	2	24
Horned Grebe	2	2	0	0	0	0	0	0	0	0	4
Greater White-fronted Goose	143	196	94	108	105	287	255	104	356	95	1,743
Brant	14	3	1	3	2	0	0	0	18	0	41
Canada Goose	17	7	12	4	7	9	0	6	235	311	608
Tundra Swan	25	36	23	35	52	52	54	45	66	78	466
American Wigeon	32	17	2	13	10	7	3	0	115	77	276
Northern Shoveler	4	24	23	9	5	8	0	0	0	0	73
Northern Pintail	299	332	454	194	206	149	126	79	238	89	2,166
Green-winged Teal	3	0	0	0	4	21	13	0	8	0	49
Greater Scaup	126	73	116	66	46	7	17	56	0	0	507
Unidentified scaup	0	0	0	0	0	0	0	0	20	29	49
Unidentified eider	0	0	15	0	0	0	4	0	0	0	19
Long-tailed Duck	13	39	25	1	0	11	6	9	4	11	119
Red-breasted Merganser	20	10	1	2	0	0	0	0	9	2	44
Unidentified duck	0	0	0	0	0	2	0	0	0	0	2
Sandhill Crane	2	10	4	0	0	2	2	0	2	0	22
Glaucous Gull	44	74	35	9	11	8	8	8	11	9	217
Sabine's Gull	2	3	5	0	0	1	0	0	0	0	11
Arctic Tern	28	27	85	44	112	69	36	12	0	0	413
Total birds	853	910	978	568	602	680	565	362	1,157	748	7,423
Total species	20	18	19	16	14	17	15	12	16	13	23

[a] Survey incomplete, Lakes S6.6, S6.2, T5.2, T5.5, T5.6, T6.1, and T6.2 were not surveyed. Maps of lakes found in Figure 4.

early summer (Table 22) occurred when aggregations of ducks and geese occupied tapped basins (Tapped Lake with Low-water Connection and the constituent lakes in basins that have drained; Figure 2). In August, molting and brood-rearing waterfowl foraged in large numbers in tapped basins.

In 2000, we recorded 7,423 waterbirds in the survey area (10 surveys combined). In the nine surveys we flew in both 1999 and 1998, we counted 6,348 and 11,015 waterbirds respectively. The number of species observed, the distributions of those species, and the patterns of use of the lakes surveyed were similar among years. In all three years, the greatest number of waterbirds were seen in mid-to-late June and again in mid-to-late August, with the least number of birds counted in the middle of July. In 1998, 59% of all waterbirds were ducks, compared with 46% in 1999 and 45% in 2000. The composition of duck species was similar between years: Northern Pintails represented 53% and 60% of all ducks in 1998 and 1999, respectively, and 66% in 2000. Scaup (greater and lesser) accounted for 21% of all ducks in both 1998 and 1999; and 17% in 2000.

Most of the lakes we surveyed probably are used primarily by locally nesting and brood-rearing waterbirds. Exceptions to this general observation were tapped basins, which attracted large assemblages of waterbirds. We found few nests on

Table 22. Mean number of waterbirds in tapped basins and other types of lakes recorded during 10 aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 2000. Sample size equals number of surveys.

	June (*n* = 3)		July (*n* = 4)		August (*n* = 3)	
Species	Basin	Other	Basin	Other	Basin	Other
Pacific Loon	10.0	45.0	7.3	35.3	16.3	29.3
Red-throated Loon	1.7	2.3	1.3	1.5	1.7	2.0
Yellow-billed Loon	0.3	8.7	0.0	6.3	0.0	4.0
Red-necked Grebe	0.0	5.0	0.0	1.0	0.0	1.7
Horned Grebe	0.0	1.3	0.0	0.0	0.0	0.0
Gr. White-fronted Goose	109.3	35.0	178.8	10.0	139.0	46.0
Brant	4.3	1.7	0.5	0.8	6.0	0.0
Canada Goose	4.7	7.3	5.0	0.0	176.7	7.3
Tundra Swan	16.0	12.0	26.3	22.0	46.7	16.3
American Wigeon	15.0	2.0	6.5	1.8	64.0	0.0
Northern Shoveler	12.0	5.0	5.3	0.3	0.0	0.0
Northern Pintail	285.3	76.3	114.3	54.5	127.7	7.7
Green-winged Teal	0.7	0.3	6.5	3.0	2.7	0.0
Greater Scaup	40.0	65.0	29.5	4.5	18.7	0.0
Unidentified scaup	0.0	0.0	0.0	0.0	8.3	8.0
Unidentified eider	5.0	0.0	1.0	0.0	0.0	0.0
Long-tailed Duck	13.0	12.7	2.3	2.3	1.7	6.3
Red-breasted Merganser	5.0	5.3	0.5	0.0	1.7	2.0
Unidentified duck	0.0	0.0	0.5	0.0	0.0	0.0
Sandhill Crane	1.0	4.3	0.0	1.0	0.0	0.7
Glaucous Gull	47.7	3.3	5.3	3.8	2.3	7.0
Sabine's Gull	0.0	3.3	0.0	0.3	0.0	0.0
Arctic Tern	5.0	41.7	32.3	33.0	0.0	4.0
Total birds	576.0	337.7	422.8	181.0	613.3	142.3
Total species	18	20	17	17	14	13

the shorelines of the basins that we searched (Figure 6); rather, they seem to be used primarily for resting and feeding by aggregations of pre-nesting birds, post-breeding males, failed and non-breeders, molting birds, and fall-staging groups. Four tapped basins were included in the area surveyed (Table 23, Figure 4). As in the previous two years, tapped basins were important to waterbirds throughout the summer; the percentage of birds found in these tapped basins ranged from 59% (of 602 waterbirds on 15 July) to 84% (of 748 waterbirds on 25 August). When the results of all 10 aerial surveys are pooled, 71% of all waterbirds were observed in tapped basins. Similarly, in 1998 and 1999, tapped basins accounted for 78% and 77%, respectively, of all birds recorded. The largest of the four basins (V5.1; Figure 4), accounted for 36%, 37%, and 33% of the total waterbirds counted in 2000, 1999, and 1998, respectively. This basin also is the most recently tapped of the four, having been drained sometime after 1955 (Jorgensen et al. 1996). Because the water levels in tapped basins are dependent on those of the channels that they are connected to, water levels fluctuate throughout the summer. Consequently, the availability of food sought by waterbirds also may fluctuate, which in turn could contribute to the wide variation in numbers of waterbirds observed in tapped basins.

As would be expected, the amount of use by waterbirds varied widely among lakes, ranging from only three sightings of birds on lake T4.4 (Figure 4) over all 10 surveys, to 406 birds on lake V5.1 on a single survey. The lakes receiving the greatest activity—S7.2, U4.1, U5.1, and V5.1—were each used by >700 birds over all surveys combined (Table 23). Of these lakes, the only one that was not a Tapped Lake with Low-water Connection was lake U5.1, classified as a Deep Open Lake without Islands. The margins of this lake are composed of extensive areas of Aquatic Grass Marsh (Figures 2 and 4). In many years, lake U5.1 is almost totally inundated by snow melt early in spring, and is one of the first of the non-tapped lakes to lose its ice cover. In 2000, U5.1 was inundated by the flood waters of spring river breakup.

Of the non-tapped lakes, lake U5.1 was the most heavily-used. Over all 10 aerial surveys, 36% of the total waterbirds (2,167) in non-tapped basins occurred in U5.1. In 1998 and 1999 U5.1 contributed 35% and 52%, respectively, of all non-tapped basin waterbird sightings. Lake U5.1 seems to be used for foraging by various species of waterfowl during the month of June. Throughout the rest of the summer this lake probably was used by locally nesting and brood-rearing species (e.g., Red-necked Grebes, Pacific Loons, Tundra Swans, Greater Scaup).

Lakes U5.1 and T5.1 were used by both nesting and brood-rearing Red-necked Grebes (Figure 4). In 2000, two nests were found in lake T5.1 by ground searchers, and one more nest was found on lake U5.1 during aerial surveys. From 1997–2000, Red-necked Grebe nests were found on lakes T5.1 and U5.1. Although we did not find any nests in 1996, we did observe a brood of Red-necked Grebes in T5.1 and a brood in U5.1 (Johnson et al. 1998, 1997). A pair of Horned Grebes was seen on U5.1 on 21 June 1999; our first record of this species on the Colville delta. On two occasions (22 and 24 June) in 2000, a pair was again seen on U5.1.

The T7.2 lake complex (Figure 4) lies east of the facility and airstrip footprint, across the Sakoonang Channel of the Colville River. Approximately 15% (315 of 2145) of the cumulative waterbird count from non-tapped lakes was recorded from this group of lakes. Many waterbird nests and a diversity of species were found close to the T7.2 complex (Figure 6). Most nests were clumped in two areas of emergent vegetation along the south and southwestern margins. The most common nesting species were Pacific Loon, Arctic Tern, and scaup. Nests of Yellow-billed Loon, Tundra Swan, Canada Goose, Brant, Spectacled Eider, and Bar-tailed Godwit also have been found on the margins of the T7.2 lake complex. This area is important to loons in the Alpine project area, accounting for 18% of all Pacific Loon sightings and 64% of all Yellow-billed Loon sightings. Additionally, 12% of all Arctic Tern sightings were from this system. Throughout the summer, the T7.2 lake complex was used by fewer birds and species than were the tapped basins, but among the other types of lakes it was second only to lake U5.1 in total numbers and species richness (Table 23).

Table 23. Number of waterbirds seen during 10 aerial surveys of lakes (by lake number) in the Alpine project area, Colville River Delta, Alaska, 2000. See Figure 4 for lake identification and locations.

Species	R6.1	R7.1	S7.1	S7.2	S7.3	S7.4	T4.2	T4.3	T4.4	T4.5	T4.6	T5.1	T5.3	T5.4	T6.3	T7.1	T7.2	T7.3	T7.4	T7.5	T8.1	U4.1
Pacific Loon	18	11	12	9	5	3	19	10	1	1	12	55	6	6	0	13	47	5	4	15	0	18
Red-throated Loon	0	1	0	5	0	0	3	0	0	0	0	5	0	1	0	0	0	0	0	0	0	2
Yellow-billed Loon	0	0	0	1	2	0	0	0	0	0	0	2	0	0	0	0	26	0	2	0	13	0
Red-necked Grebe	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0
Horned Grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gr. White-fronted Goose	7	2	0	95	2	8	43	9	9	2	1	12	12	17	0	6	14	1	1	7	4	192
Brant	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	3	0	1
Canada Goose	29	0	0	231	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	83
Tundra Swan	8	2	2	60	2	0	7	12	0	0	0	23	0	3	0	4	21	6	3	2	4	37
American Wigeon	0	0	0	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77
Northern Shoveler	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0	0	13
Northern Pintail	4	1	8	202	0	2	15	1	2	0	0	40	0	4	1	0	3	0	0	0	1	466
Green-winged Teal	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Greater Scaup	0	0	0	11	0	0	2	0	0	0	2	11	0	2	7	0	8	2	0	0	0	78
Unidentified scaup	0	0	0	1	0	3	0	0	0	0	0	2	0	0	0	0	6	0	0	0	0	3
Unidentified eider	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long-tailed Duck	1	6	6	2	5	3	5	0	0	0	0	0	0	0	0	3	5	0	0	0	0	11
Red-breasted Merganser	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0
Unidentified duck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sandhill Crane	2	1	2	0	0	0	1	0	0	0	5	0	0	0	0	0	6	0	0	0	2	3
Glaucous Gull	0	0	0	1	0	0	22	15	0	0	0	0	0	0	0	0	1	1	0	2	1	33
Sabine's Gull	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	2	0
Arctic Tern	9	0	2	3	10	0	3	2	0	0	4	3	0	9	0	3	27	6	1	10	1	3
Total birds	78	24	32	700	26	19	120	51	12	3	24	171	18	42	8	29	173	22	11	51	28	1,022
Total species	8	7	6	15	6	5	10	7	3	2	5	13	2	7	2	5	13	7	5	8	8	16

Table 23. (Continued).

Species	U4.2	U5.1	U5.2	U5.3	U6.1	U6.2	U6.3	U6.4	V5.1	S6.1	S6.2	T5.2	T5.5	T5.6	T6.1	T6.2	T4.1	U4.1	U4.2	Total
Pacific Loon	3	36	7	14	3	0	1	12	53	8	10	13	11	9	1	8	11	0	2	472
Red-throated Loon	0	1	0	0	5	0	0	0	5	2	0	0	0	0	0	0	3	1	0	34
Yellow-billed Loon	0	0	0	0	3	5	5	0	0	0	0	0	0	0	5	0	0	0	0	64
Red-necked Grebe	0	10	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Horned Grebe	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Gr. White-fronted Goose	0	46	0	0	4	2	14	1	968	188	12	14	17	0	0	1	32	0	0	1,743
Brant	0	0	0	0	0	0	0	0	10	20	0	0	0	0	0	0	0	0	0	41
Canada Goose	0	0	0	0	0	0	3	0	10	218	0	0	13	9	0	0	8	0	0	608
Tundra Swan	4	38	7	0	4	3	5	0	125	25	4	2	26	10	6	0	1	10	0	466
American Wigeon	0	13	0	0	0	0	0	0	89	0	0	0	21	14	0	0	0	0	0	276
Northern Shoveler	0	8	0	2	0	0	0	0	33	6	0	0	5	0	0	0	0	0	0	73
Northern Pintail	0	354	10	4	7	0	0	0	851	60	0	0	66	32	0	5	8	19	0	2,166
Green-winged Teal	0	12	0	0	0	0	0	0	28	0	0	0	8	0	0	0	0	0	0	49
Greater Scaup	2	140	13	0	12	0	0	2	155	0	0	0	0	20	10	0	0	30	0	507
Unidentified scaup	0	6	0	0	1	0	0	0	21	0	0	0	0	0	6	0	0	0	0	49
Unidentified eider	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	19
Long-tailed Duck	0	14	0	0	4	3	2	5	35	0	2	0	1	0	0	2	0	4	0	119
Red-breasted Merganser	0	1	0	0	10	4	2	0	22	0	0	0	0	0	0	0	0	0	0	44
Unidentified duck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sandhill Crane	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22
Glaucous Gull	0	2	1	0	1	0	0	0	132	5	0	0	0	0	0	0	0	0	0	217
Sabine's Gull	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11
Arctic Tern	0	97	0	10	41	0	0	0	134	0	2	3	2	2	0	16	10	0	0	413
Total birds	9	782	38	31	96	17	32	20	2675	532	30	32	170	96	28	32	73	64	2	7,423
Total species	3	16	5	5	13	5	7	4	17	9	5	4	10	7	5	5	7	5	2	23

PREDATORS

NEST PREDATION

Monitoring predators and nest predation is important to an evaluation of development impacts, because nest predation can depress the productivity of tundra nesting birds and some of the most effective nest predators on the coastal plain (foxes, Glaucous Gulls, and Common Ravens) are suspected to be attracted to human development. Since 1998, 194 nests have failed, of which 31 were known or suspected to be preyed on by birds and 35 were known or suspected to be preyed on by foxes. Predation likely contributed to the failure of 128 nests, but no signs of predators were found for identification. Identification of nest predators was more accurate for a small sample of nests monitored by video. From 1998 to 2000, video cameras at 14 nests that were observed through hatch or failure recorded egg predation by foxes at three nests and by avian predators at seven nests.

Video cameras repeatedly recorded foxes near nests in 1998–2000. In 2000, foxes (arctic and red) were observed within camera view on 23 occasions (17 at 3 White-fronted Goose nests and 6 at 2 Tundra Swan nests). Foxes were <50 m from the White-fronted Goose nests 8 times, >50 m from the nests 9 times, and most often (15 times) only in the camera view for 1 recording interval. We also saw foxes in view >25 m from swan nests two times and on the nest mound four times. Two pairs of geese defended their nests a total of three times and swans at one nest also defended their nest three times. During four of these six events, a fox was <5 m from the nest, and the incubating bird reacted by standing over the nest for 1–2 min, and in some intervals, rising up and flapping its wings.

In 2000, we documented on video one case of predation by a fox, which involved a red fox at a Tundra Swan nest (see TUNDRA SWAN section in NESTING BEHAVIOR AND DISTURBANCE MONITORING). This nest was visited by a Parasitic Jaeger five hours before the fox and some eggs may have been taken at that time. Both of these events occurred while the swan was on two different disturbance recesses. We also observed a fox carrying a goose egg, but we do not know which nest it came from. We found fox sign (scent or scat) at three nests (one Long-tailed Duck, two White-fronted Geese) when we checked their fate. However, fox sign is weak evidence for the type of nest predator because foxes can visit nests after they fail from other causes.

Based on video records, foxes were more active in the Alpine project area in 1999 and 2000 than in 1998, and based on observations, fox activity in 1998 was similar to 1997. The frequency of fox occurrence (determined by the number of detections on video) was 4× higher in 1999 (0.29 foxes/d of video recording, or 33 foxes) and 2000 (0.28 foxes/d, or 23 foxes) than in 1998 (0.07 foxes/d, or 3 foxes). The level of nest failure for White-fronted Geese in 2000 (62%) and in 1999 (65%) was unprecedented among the years we have checked nest fate in the project area, and foxes probably are one cause of the rise in nest losses, but unfavorable weather conditions those years also could have contributed to nest failures. Although we have observed arctic foxes almost daily every year we have worked in the Alpine project area, 1999 was the first year we saw red foxes on a regular basis.

Avian predators appeared to be more active in 1998 than 1999 or 2000. Of seven video recordings of nest predation, five were in 1998. The rate of occurrence of avian predators (jaegers, Glaucous Gulls, Common Raven) on video also was highest in 1998 (0.91 birds/d of video recording, or 38 birds) compared to 1999 (0.15 birds/d, or 17 birds) and 2000 (0.07 birds/d, or 6 birds). Parasitic Jaegers were the most frequently identified bird preying on nests. The number of nests and species composition of avian predators (Parasitic and Long-tailed Jaeger, and Glaucous Gull) seen in the Alpine project area was similar (2–4 nests of all species combined) among years with the exception of Common Ravens (Appendix D2). Ravens were first observed regularly in 1998, but were not known to nest in the Alpine project area until 2000. On a few occasions in 2000, we saw ravens carrying eggs in their bills and flying toward Pad 1, where a pair nested on a drill-rig tower (S. Donnelly, pers. comm.). We saw ravens hunting in the project area more often in 2000 than in previous years and observed one picking up an egg (the size of a duck or large shorebird egg) from the tundra. On video, we captured a raven standing <1 m from a White-fronted Goose nest for 1 recording interval.

The raven was lunging towards the incubating female, who stayed on the nest and appeared to be hissing at the raven. Also on video, we observed a Parasitic Jaeger attempting to take eggs at a swan nest. We directly observed two different occurrences of Parasitic Jaegers attempting to take eggs from White-fronted Goose nests. These two instances occurred after we had flushed the geese and covered the eggs with nesting material. We flushed the jaegers off the nests before any eggs were damaged. We returned to one nest the next day to install an egg thermistor and found one broken egg in the nest; the other four eggs were undamaged and the nest was still active. Both of these nests later failed, but not until 7 and 16 d after our visits. We found signs of probable predation by an avian predator (broken egg shells) at 13 nests (one each of Yellow-billed Loon, Brant, Northern Pintail, scaup, Long-tailed Duck, Common Snipe, and seven White-fronted Geese).

FOX DEN MONITORING

The presence of permafrost in arctic tundra forces foxes to dig dens in locations that have relatively deep seasonal thaw layers. Foxes locate dens on raised landforms with well-drained soil; typical locations on the Arctic Coastal Plain include ridges, dunes, lake and stream shorelines, pingos, and low mounds (Chesemore 1969, Eberhardt et al. 1983, Burgess et al. 1993). Both arctic and red foxes occur in the study area, and have similar denning requirements, sometimes using the same den sites in different years. In the Delta and Alpine Transportation Corridor survey areas, respectively, foxes prefer two habitat types—Riverine or Upland Shrub and Moist Sedge–Shrub Meadow—for denning (Johnson et al. 2000b; ABR, Inc., unpublished data). In those areas, the landforms used most are banks of streams and lakes (including drained-lake basins), dunes, ridges, and pingos (Garrott 1980, Eberhardt et al. 1983, Johnson et al. 1997). These observations all confirm that the primary requirement for denning habitat is well-drained soil with a texture conducive to burrowing, conditions that occur on elevated microsites within a variety of larger habitat types.

In 8 years of surveys and contacts with other observers, we have located 62 fox dens between the western edge of the Colville Delta and the western edge of the Kuparuk Oilfield, including areas both north and south of the Alpine pipeline (Figure 11). In 2000, 53 (85%) of these dens were classified as arctic fox dens and the remaining 9 dens (15%) were occupied by red foxes; 3 of the dens used by red foxes were former arctic fox dens. Our sample of confirmed dens has increased in each year of study, from 6 dens in 1992 to 62 dens in 2000. We added one red fox den on the Colville Delta to the database in 2000 and three arctic fox dens in the Meltwater project area, south of the Alpine Transportation Corridor. We expect that a few additional dens are present in the outermost portion of the delta, which we have not yet searched thoroughly.

Of the 53 arctic fox dens, 14 dens were on the Colville Delta, 20 dens were in the Alpine Transportation Corridor (extending from the delta to the Kuparuk Oilfield), and the other 19 dens were north or south of the corridor (Table 24). The overall density of arctic fox dens (active and inactive) in the combined Delta (551 km²) and Alpine Transportation Corridor (343 km²) survey areas was 1 den/26 km². The density of arctic fox dens was more than twice as high in the Alpine Transportation Corridor (1 den/17 km²) as on the Delta (1 den/39 km²), probably due to the more limited availability of suitable denning habitat on the outer delta and our lower search effort there. The overall density is higher than the 1 den/34 km² reported by Eberhardt et al. (1983) for their 1,700-km² Colville study area (which extended farther east and west than ours, but not as far inland). The overall density we report for arctic foxes is lower than those reported for the 805-km² developed area of the Prudhoe Bay Oilfield (1 den/12–15 km²; Eberhardt et al. 1983, Burgess et al. 1993, Rodrigues et al. 1994, Ballard et al. 2000), but was within the range reported for undeveloped areas near the Prudhoe field (1 den/28–72 km²; Burgess et al. 1993, Rodrigues et al. 1994, Ballard et al. 2000). The overall density we recorded was slightly higher than the mean densities reported for large areas of tundra in the Northwest Territories (1 den/36 km²; Macpherson 1969) and Siberia (1 den/32 km²; Boitzov 1937, as cited in MacPherson 1969).

All but one of the nine red fox dens were on the Colville Delta; the exception was a pingo den near the Kachemach River that was occupied by

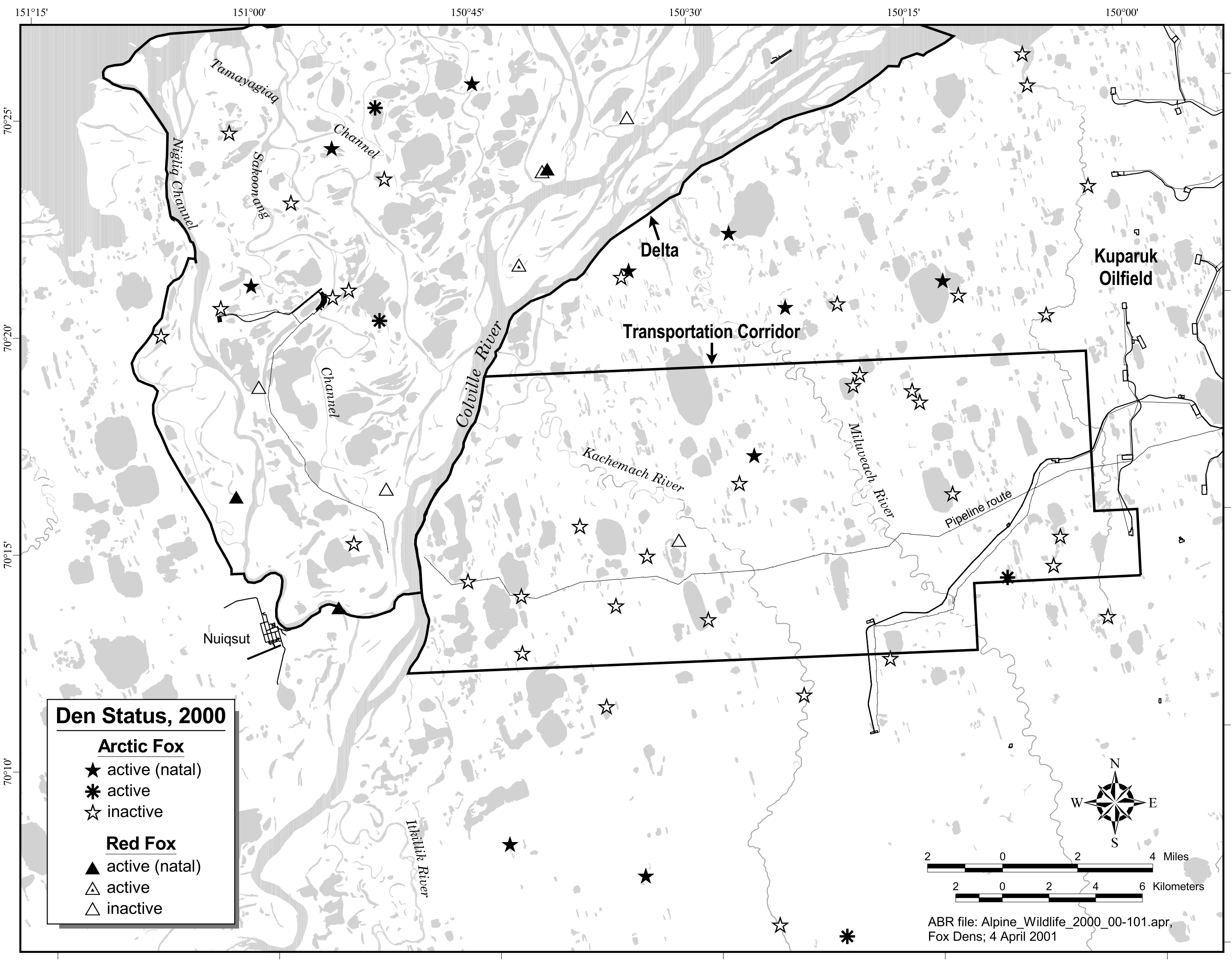

Figure 11. Distribution of arctic and red fox dens found during aerial and ground surveys on the Colville River Delta and adjacent areas, Alaska in 1992, 1993, and 1995–2000. Survey coverage was not uniform over the entire area portrayed. Two arctic fox dens occur south of the area portrayed.

Table 24. Landforms, activity status, and number of pups at arctic and red fox dens during the 1996–2000 seasons on the Colville River Delta and adjacent coastal plain, Alaska (3 perennially inactive sites excluded).

		No. of Pups	Den Status[b]			
Location/Species/Landform	2000 Status [a]	(2000)	1999	1998	1997	1996
DELTA						
Arctic Fox						
old dune	inactive?	–	natal	natal	inactive	natal
old dune	active	0	inactive?	inactive	inactive?	inactive
dune/lake bank	inactive	–	inactive	inactive	inactive?	natal
lake bank	natal	3	inactive	natal?	natal?	natal
dune/lake bank	inactive?	–	inactive	inactive	inactive	natal
dune/lake bank	natal?	0	active	active	natal	natal
dune ridge	natal	5	natal	natal	inactive?	natal
dune mound	inactive	–	inactive	inactive	inactive?	inactive
dune/riverbank	inactive	–	inactive	natal	natal	natal
low ridge	inactive	–	secondary	natal	active	secondary?
low dune ridge	natal	5	natal	inactive	natal	secondary
low mound	inactive	–	inactive	natal?	inactive	–
Red Fox						
dune/lake bank	inactive?	–	inactive?	active	inactive?	inactive
sand dune	active?	0	inactive?	active	inactive	inactive
sand dune	inactive	0	natal	natal	active	natal
dune/riverbank	natal	4	natal?	natal?	inactive	natal
sand dune	natal	1	natal	natal	active?	natal
sand dune	inactive	–	inactive?	inactive	inactive	*not checked*
sand dune	secondary	2	inactive	inactive	–	–
sand dune	natal	0	–	–	–	–
ALPINE TRANSPORTATION CORRIDOR						
Arctic Fox						
pingo	inactive	0	natal	inactive	inactive	natal
drained-lake bank	inactive?	–	inactive	inactive	inactive	inactive
pingo	inactive	–	inactive	inactive	inactive	inactive
lake bank	inactive?	–	inactive	inactive	inactive?	natal
lake bank	inactive	–	inactive	inactive	inactive	natal
drained-lake bank	inactive	–	inactive	inactive	active	inactive
lake bank	inactive	–	secondary?	inactive	inactive?	natal
terrace bank	inactive?	–	inactive	inactive	active	secondary
low mound	active?	0	active	inactive	active	natal
terrace bank	inactive	–	inactive	inactive	inactive	natal
lake bank	inactive	–	inactive	inactive	inactive	natal
drained-lake bank	inactive	–	inactive	inactive	inactive?	active
low mound	inactive	–	inactive	inactive	active	–
drained-lake island	inactive?	–	inactive	inactive	inactive	–
pingo ridge	inactive?	–	natal	inactive	–	–
drained-lake bank	inactive?	–	natal	inactive	–	–
creek bank	natal	5	natal	–	–	–
Red Fox						
pingo	inactive?	–	natal	inactive	inactive	natal (arctic fox)
NORTH OR SOUTH OF ALPINE TRANSPORTATION CORRIDOR						
Arctic Fox						
pingo	inactive	–	inactive	inactive	natal	inactive
pingo	natal	6	inactive?	natal	inactive	natal
pingo	natal	3	inactive?	inactive	natal	inactive
stream bank	inactive	–	inactive	inactive	natal	inactive
drained-lake bank	inactive	–	inactive	inactive	inactive	inactive
drained-lake bank	natal	1	natal	natal	natal	inactive?
lake bank	active	5	natal	natal	natal?	inactive?
stream bank	inactive	–	inactive?	inactive	inactive	natal
stream bank	inactive	–	inactive?	active	natal	inactive
drained-lake bank	natal	1	natal	inactive	natal	natal
drained-lake bank	inactive	–	natal	inactive	natal?	–
drained-lake bank	inactive	–	inactive	inactive	secondary	–
terrace bank	inactive	0	natal	–	–	–
old lake shore	natal	3	natal	–	–	–
peat road	inactive	–	secondary	–	–	–
stream bank	inactive	–				
pingo	natal?	0				
pingo	natal?	0		–	–	–

[a] Based on observations during 28 June–2 July and 10–13 July; question mark indicates some uncertainty regarding the status listed ("active" means natal vs. secondary status could not be determined).

[b] Sources: 1999—Johnson et al. (2000a); 1998—Johnson et al. (1999a); 1997—Johnson et al. (1998); 1996—Johnson et al. (1997).

arctic foxes until 1999. In 2000, the density of red fox dens in the Delta area was 1 den/79 km² (treating two nearby dens used by one breeding pair of foxes as a single site). Comparative data on den density are unavailable for this species from other arctic tundra areas, but it appears that the density of red fox dens on the Colville Delta is relatively high for the Arctic Coastal Plain.

Based on brief visits at 50 arctic fox dens during 28 June–2 July 2000 and longer observations at 17 of those dens during 10–13 July, we concluded that pups were present at a minimum of 10 natal dens and suspected that pups were present at 5 other active dens (Table 25). Thus, the number of active dens (occupied at some point by pups) was estimated to be 15 (30%) of the 50 arctic fox dens checked; the remaining 35 dens (70%) showed signs of occasional use by adults only or were completely inactive. This 30% den occupancy rate by litters (natal and active categories combined) in 2000 was below the 7-year average we have observed since 1993 ($\bar{x}$ = 39%, range = 24–67%). Of the 14 arctic fox dens we checked on the Colville Delta, 5 were active (including 3 natal dens), for an occupancy rate of 36%. In their Colville study area, Eberhardt et al. (1983) reported that the percentage of dens containing pups ranged from 6% to 55% in a 5-year period, whereas 56–67% showed signs of activity by adults alone. Burgess et al. (1993) estimated that 45–58% of the dens in their study area in the Prudhoe Bay Oilfield produced litters in 1992, although only 21% still were occupied by families at the time of ground visits in late July–early August. In 1993, the occupancy rate by arctic foxes at 53 natural den sites in the Prudhoe Bay Oilfield and surrounding area was 71%, and 49% of the sites were classified as natal dens (Ballard et al. 2000). The occupancy rate for the nine red fox dens in our sample in 2000 was 44%, including three natal dens and one secondary den.

During 10–13 July 2000, we observed 23 dens (17 arctic fox dens and 6 red fox dens) classified as active on our initial check at the end of June, counting 37 arctic fox pups at 10 dens and 7 red fox pups at 3 dens. The mean litter size for arctic foxes was 4.4 pups (SD = 1.2, n = 8), disregarding two dens at which only a single pup was seen and the observers doubted they had obtained a complete count. The mean litter size for two red fox dens was 3 pups, disregarding a third den at which only a single pup was seen briefly. Estimates of pup production are minimal figures because pups often remain underground for extended periods, making it difficult to reliably obtain complete counts. In general, our observations at dens were most successful in obtaining pup counts during early morning and evening, when foxes tend to be most active; litters occasionally can be counted successfully even in midday, however. Red fox dens are more difficult to observe than arctic fox dens because they tend to be located in sand dunes having high topographic relief and tall shrubs that obscure the den entrances and activity areas.

Estimates of pup production can be confounded by the use of secondary dens, which may result in splitting of litters among several dens by one family (Garrott 1980, Eberhardt et al. 1983). Garrott (1980) noted that movements of arctic foxes from natal dens to secondary dens typically occurred after early to mid-July when the young were 5–7 weeks old, and that interchange of young between dens occurred after the initial move. We found no indication of any such moves by arctic foxes in 2000, but one red fox litter of two pups was moved between alternate den sites in 2000.

Litter size of arctic foxes in 2000 ($\bar{x}$ = 4.4 pups; n = 8 litters) was near the midpoint of the annual range observed since 1995 ($\bar{x}$ = 3.0–6.1 pups). These figures were virtually identical to those reported by Garrott (1980) for low and high years of pup production in his Colville study area. In 1978, when small mammals (the principal prey of arctic foxes) were abundant, Garrott (1980) closely observed 7 litters from a total of 23 active dens, which averaged 6.1 pups (range = 2–8). In contrast, he observed only one litter the year before (from two active dens), when small mammals were scarce, and was unable to obtain a complete litter count. The occupancy rate and litter sizes at arctic fox dens in 2000 led us to infer that the density of small mammals in our study area was relatively low, although we have no population sampling data on which to base this conclusion. These same measures of fox productivity do not provide clear evidence on how construction of the Alpine development (1998–2000) has affected the local fox population. However, the increased activity of

Table 25. Occupancy and activity status of arctic fox dens during the 1993 and 1995–2000 denning seasons on the Colville River Delta and adjacent coastal plain, Alaska.

	2000		1999		1998		1997		1996		1995		1993	
Den Status	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Natal	10	18	14	28	7	15	4	9	22	51	9	26	5	22
Secondary	–	–	3	6	–	–	–	–	3	7	2	6	7	30
Active [a]	5	12	2	4	4	9	7	17	4	9	2	6	–	–
Inactive [b]	35	70	31	62	35	76	33	74	14	33	21	62	11	48
TOTAL	50		50		46		44		43		34		23	

[a] Dens showing heavy use, but for which natal vs. secondary status, or presence of pups, could not be confirmed.
[b] Dens showing either no signs of activity or limited use by adults, but not pups.

foxes at nests (see NEST PREDATION section above) in 1999 and 2000 was coincident with increased construction activity, suggesting factors other than increased numbers of foxes (e.g., attraction to facilities, increased vulnerability of nests, fluctuations in prey populations), yet to be identified, have influenced the annual variation observed in fox predation.

SUMMARY AND CONCLUSIONS

The breeding season in 2000 stood out among all years we have worked in the Alpine project area for its cold spring and extensive flooding, which delayed the initiation of nests by waterfowl and some other ground nesting birds in the study area. At the same time, construction, aircraft, and other oilfield activities were the highest ever, about twice the levels of 1999 and many times greater than in 1998. Disturbance effects on breeding birds, if expressed in the parameters examined in this report, should reflect the temporal increase in activity in the Alpine project area, and also should be most noticeable among those nests and birds closest to the Alpine airstrip and Pad 1.

Several lines of evidence may suggest a disturbance effect during the construction phase (beginning at a low level in 1998 and accelerating to a peak in 2000) of the Alpine project, but may be explained or countered by other findings. Numbers of large waterbird nests (standardized for search effort) in the common ground-search area were lower in 2000 than in all previous years, but weather conditions in 2000 undoubtedly delayed nesting, and flooding may have prevented many birds from nesting in the study area. Numbers of shorebird and passerine nests, which were sampled on plots primarily outside the area that flooded and, therefore, had unrestricted access to breeding habitat, actually were higher in 2000 than in 1998 and 1999. Nest success for White-fronted Geese was lower in 1999 and 2000, than in 1997 and 1998. However, nest predation and weather may also account for differences in nest success among years. Foxes were seen more frequently in the area in 1999 and 2000 than before construction, and Commons Ravens were first known to nest at Alpine in 2000. Increased predator populations could be a secondary effect of development. Ravens probably were attracted to the area because of potential nest sites on buildings and structures; before the first buildings were erected in 1998, they were seen only passing through the project area. The effect of development on foxes is unclear. Den occupancy has been low since a peak in 1996, and litter sizes have been similar to levels in pre-construction years with the exception of 1996, when productivity was unusually high, presumably because small mammals were abundant.

Contrary to expectations that the density of water bird and goose nests would be lowest in the area adjacent to the Alpine airstrip, where noise, dust, and activity were the greatest, densities of nests were lowest in the zone from 500 to 1,000 m. Although densities of large waterbird nests were lower within 1,000 m of the airstrip than beyond 1,000 m, densities in the closest (0–500 m) and farthest (1,500–2,000 m) zones around the airstrip were both intermediate, indicating that the response, if any, did not decrease with increasing distance. Similarly, density (as indicated by nearest-neighbor distances) of White-fronted Goose nests was not linearly related with distance to the airstrip, and the density of nests found on breeding bird plots actually increased on plots that were closer to the airstrip. The distance of the airstrip from nests did not affect clutch sizes nor did it differ between successful and failed nests. Nor did the distance from the airstrip of White-fronted Goose nests, Tundra Swan nests, or all nests combined differ significantly among years (including pre-construction years [1996 and 1997] and years of different construction intensities [1998–2000]), indicating the distribution of nests did not substantially vary with construction activity. Habitat use by nesting White-fronted Geese varied slightly among years, but the same three primary habitats were used every year. However, the interaction of habitat and distance of nests from the airstrip has not been thoroughly evaluated, so the possibility of a more complex effect on nest distribution cannot be ruled out until further analysis is completed.

Behaviorally, nesting geese reacted (by concealing on the nest) to aircraft more often than to any other source of disturbance, but aircraft also were the most frequent disturbance source. Nesting geese appeared to be most sensitive to pedestrians (i.e., elicited the highest rate of concealment) relative to aircraft and vehicles, and stayed concealed for the longest periods when other birds (particularly other geese) were near their nests. Although none of the video-monitored nesting birds in 2000 were observed to take recesses from nests when aircraft were landing or taking off, incubation constancy from a larger sample of nests containing temperature-sensing eggs declined with increasing frequency of landings and takeoffs of fixed-wing aircraft, increased wind speed, and decreased durations of vehicles on the airstrip. However, the relationship of these dependent variables explained a small amount of the variation (≤26%) in incubation constancy, indicating that other factors probably were important.

Overall, most of the evidence collected to date does not indicate the airstrip and its air traffic are having major impacts on nesting birds in the Alpine project area. Secondary effects, such as attraction of predators, increases in pedestrians, and activity on pads may be affecting the behavior of some nesting birds and contribute to failure of some nests. In addition, variation in responses among individuals and species, annual variation in weather and availability of nesting habitat, and variation in predation pressure confound the evaluation of airstrip and aircraft disturbance, making it crucial to consider the range of possible variation when making conclusions. Causal relationships and annual changes will be comprehensively analyzed in the final report after the 2001 field season.

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Appendix A. Common and scientific names of birds and mammals seen during wildlife surveys on the Colville River Delta, 1992–2000 (Johnson et al. 2000 and this study).

BIRDS

COMMON NAME	SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME
Red-throated Loon	*Gavia stellata*	Lesser Yellowlegs	*Tringa Flavipes*
Pacific Loon	*Gavia pacifica*	Upland Sandpiper	*Bartramia longicauda*
Yellow-billed Loon	*Gavia adamsii*	Whimbrel	*Numenius phaeopus*
Horned Grebe	*Podiceps auritus*	Bar-tailed Godwit	*Limosa lapponica*
Red-necked Grebe	*Podiceps grisegena*	Ruddy Turnstone	*Arenaria interpres*
Greater White-fronted Goose	*Anser albifrons*	Semipalmated Sandpiper	*Calidris pusilla*
Snow Goose	*Chen caerulescens*	Least Sandpiper	*Calidris minutilla*
Canada Goose	*Branta canadensis*	White-rumped Sandpiper	*Calidris fuscicollis*
Brant	*Branta bernicla*	Baird's Sandpiper	*Calidris bairdii*
Tundra Swan	*Cygnus columbianus*	Pectoral Sandpiper	*Calidris melanotos*
American Wigeon	*Anas americana*	Dunlin	*Calidris alpina*
Mallard	*Anas platyrhynchos*	Stilt Sandpiper	*Calidris himantopus*
Northern Shoveler	*Anas clypeata*	Buff-breasted Sandpiper	*Tryngites subrficollis*
Northern Pintail	*Anas acuta*	Long-billed Dowitcher	*Limnodromus scolopaceus*
Green-winged Teal	*Anas crecca*	Common Snipe	*Gallinago gallinago*
Greater Scaup	*Aythya marila*	Red-necked Phalarope	*Phalaropus lobatus*
Lesser Scaup	*Aythya affinis*	Red Phalarope	*Phalaropus fulicaria*
Steller's Eider	*Polysticta stelleri*	Pomarine Jaeger	*Stercorarius pomarinus*
Spectacled Eider	*Somateria fischeri*	Parasitic Jaeger	*Stercorarius parasiticus*
King Eider	*Somateria spectabilis*	Long-tailed Jaeger	*Stercorarius longicaudus*
Common Eider	*Somateria mollissima*	Ring-billed Gull	*Larus delawarensis*
Surf Scoter	*Melanitta perspicillata*	Glaucous Gull	*Larus hyperboreus*
White-winged Scoter	*Melanitta fusca*	Sabine's Gull	*Xema sabini*
Black Scoter	*Melanitta nigra*	Arctic Tern	*Sterna paradisaea*
Oldsquaw	*Clangula hyemalis*	Snowy Owl	*Nyctea scandiaca*
Red-breasted Merganser	*Mergus serrator*	Short-eared Owl	*Asio flammeus*
Bald Eagle	*Haliaeetus leucocephalus*	Common Raven	*Corvus corax*
Northern Harrier	*Circus cyaneus*	Horned Lark	*Eremophila alpestris*
Rough-legged Hawk	*Buteo lagopus*	Violet-green Swallow	*Tachycineta bicolor*
Golden Eagle	*Aquila chrysaetos*	American Robin	*Turdus migratorius*
Merlin	*Falco columbarius*	Varied Thrush	*Ixoreus naevius*
Peregrine Falcon	*Falco peregrinus*	Bluethroat	*Luscinia svecica*
Willow Ptarmigan	*Lagopus lagopus*	Yellow Wagtail	*Motacilla flava*
Rock Ptarmigan	*Lagopus mutus*	Wilson's Warbler	*Wilsonia pusilla*
Sandhill Crane	*Grus canadensis*	American Tree Sparrow	*Spizella arborea*
Black-bellied Plover	*Pluvialis squatarola*	Savannah Sparrow	*Passerculus sandwichensis*
American Golden-Plover	*Pluvialis dominica*	Lapland Longspur	*Calcarius lapponicus*
Semipalmated Plover	*Charadrius semipalmatus*	Snow Bunting	*Plectrophenax nivalis*
		Common Redpoll	*Carduelis flammea*

MAMMALS

COMMON NAME	SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME
Snowshoe Hare	*Lepus americanus*	Grizzly Bear	*Ursus arctos*
Arctic Ground Squirrel	*Spermophilus parryii*	Ermine	*Mustela erminea*
Brown Lemming	*Lemmus sibiricus*	Wolverine	*Gulo gulo*
Collared Lemming	*Dicrostonyx rubricatus*	Spotted Seal	*Phoca largha*
Gray Wolf	*Canis lupus*	Moose	*Alces alces*
Arctic Fox	*Alopex lagopus*	Caribou	*Rangifer tarandus*
Red Fox	*Vulpes vulpes*	Muskox	*Ovibos moschatus*

Appendix B. Classification of incubation behavior of Greater White-fronted Geese monitored with time-lapse cameras and egg thermistors in the Alpine project area, Colville River Delta, Alaska, 2000.

In 2000, we used the same decision rules that we developed in 1998 for interpretation of the egg thermistor data. In 1998, we simultaneously monitored two White-fronted Goose nests with both an egg thermistor and a time-lapse camera. We collected 867 temperature records (recorded at 5-min intervals) and 4,335 video pictures (1-sec recordings at 1-min intervals) from the two nests combined. (Camera malfunctions interrupted video recording while nests were monitored with the egg thermistors, so that video coverage was incomplete.) We identified the occurrence of incubation, breaks, and recesses on the video recordings and compared those behaviors to temperature changes in thermistors recorded during the same time period. From the video recording, we determined that breaks, when the female turned the eggs or repositioned herself on the nest, occurred in ≤3 consecutive recordings (hereafter, we represent 1 video recording as 1 min, recognizing that the behavior recorded could last from >0 min to <2 min) and that recesses, when the female was off the nest, either standing beside it or out of the video picture, occurred in ≥4 consecutive recordings (4 min). We observed the female, at times, repositioning herself on the nest before and/or after a recess, and therefore, a break could precede or follow a recess. The female was considered incubating during a video recording when she was sitting on the nest and her body position had not changed relative to her position in the previous recording.

After matching the video-recorded behaviors with concurrent temperature records, we observed that incubation could be distinguished from breaks or recesses by the magnitude of change in temperature during a 5-min recording interval. (Mean temperature difference between consecutive records was +0.3° C for incubation [*n* = 804], −1.9° C for breaks [*n* = 65], and −4.4° C for recesses [*n* = 13].) Because the temperature of nests was lower during recesses ($\bar{x}$ = 24.3° C, *n* = 13) than during breaks ($\bar{x}$ = 32.2° C, *n* = 13), we used nest temperature to distinguish a break from a recess. To establish numeric cutpoints for classifying each behavior type, we calculated the 5th and 95th percentiles of the observed frequency distribution of temperature difference and nest temperature. The 5th and 95th percentiles for temperature difference were −0.4 and +1.6° C for incubation (*n* = 804), −5.08 and +0.4° C for breaks (*n* = 65), and −7.4 and −1.1° C for recesses (*n* = 13). The 5th and 95th percentiles for nest temperature were 30.3 and 37° C for incubation, 28.3 and 35.7° C for breaks, and 18.9 and 30.3° C for recesses.

In the thermistor data, we distinguished the occurrence of a break or recess from incubation by a temperature difference of ≥1° C during a 5-min recording interval. A record was classified as a break if the temperature decreased by ≥1° C and the nest temperature of that record was ≥28.3° C, the 5th percentile value of breaks. Breaks occurred in consecutive temperature records, but we considered them separate discontinuous events, because video records of breaks were ≤3 min. Each break was counted as lasting 5 min (hereafter, we represent each temperature record as 5 min). A record was classified as a recess if the temperature decreased by ≥1° C and the nest temperature of that record was <28.3° C. A recess was considered to continue into succeeding intervals, regardless of the temperature difference, as long as the nest temperature remained <28.3° C. When a temperature record classified as a recess was preceded by a record classified as a break, the break was reassigned and included as part of the recess. A recess was defined to be over when a rise of ≥1° C indicated the female's return to the nest. Recesses often were events continuous across multiple temperature records, and recess length was calculated as the number of consecutive temperature records that the bird was absent multiplied by 5 min.

The onset of hatch was evident in the temperature data as the end of long periods of incubation and an increase in the frequency of breaks 24–36 h before the female and brood left the nest. After brood departure the temperature values from the thermistor were similar to ambient temperature.

Appendix C. Elapsed time (min) from engine startup to takeoff and landings to shutdown estimated from visual and audio video recordings of aircraft at the Alpine airstrip, Colville River Delta, Alaska, 2000.

Aircraft	Minimum	Maximum	Value Used for Noise Assignments
DC6 departure	1	10	10
DC6 arrival	3	8	8
C130 departure	5	8	8
C130 arrival	2	7	7
Otter departure	1	6	6
Otter arrival	1	4	4
Caravan departure			4
Caravan arrival			2
CASA departure	1	5	5
CASA arrival	1	4	4
Small planes arrival	<1	1	1
Small planes departure	<1	1	1
Helicopter departure[a]	<1	1	3
Helicopter arrival[b]	<1	1	3

[a] Helicopter not always in camera view; subtracted 3 min for warmup.
[b] Helicopter not always in camera view; added 3 for warmdown.

Appendix D1. Numbers and densities (unadjusted for search effort) of nests of selected species found during ground searches within the common ground-search area in 1996–2000 in the Alpine project area, Colville River Delta, Alaska. The search area boundary is displayed in Figure 6.

	Common Ground-search Area (10.6 km²)									
	Number of Nests					Density (nests/km²)				
Species	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Red-throated Loon	1	5	1	0	0	0.1	0.5	0.1	0	0.0
Pacific Loon	2	4	0	5	1	0.2	0.4	0.1	0.5	0.1
Yellow-billed Loon	1	1	0	0	0	0.1	0.1	0	0	0.0
Red-necked Grebe	0	3	2	2	1	0	0.3	0.2	0.2	0.1
Greater White-fronted Goose	25	35	32	53	39[b]	2.4	3.3	2.9	5.0	3.7[b]
Brant	1	4	1	2[a]	0	0.1	0.4	0.1	0.2[a]	0.0
Tundra Swan	5	4	5	4	4	0.5	0.4	0.5	0.4	0.4
Northern Shoveler	0	0	5[b]	0	0	0	0	0.5[b]	0	0.0
Northern Pintail	2	4	7[b]	8[b]	5[b]	0.2	0.4	0.7[b]	0.8[b]	0.5[b]
Green-winged Teal	1	0	1	2[b]	2[b]	0.1	0	0.1	0.2[b]	0.2[b]
Greater Scaup	0	1	1	0	0	0	0.1	0.1	0	0.0
Lesser Scaup	0	0	1	0	0	0	0	0.1	0	0.0
Unidentified scaup	0	0	0	1[b]	0	0	0	0	0.1[b]	0.0
Long-tailed Duck	6	9	5[b]	5[b]	4[b]	0.6	0.8	0.5[b]	0.4[b]	0.4[b]
Unidentified duck	0	0	3	2	1	0	0	0.2	0.2	0.1
Willow Ptarmigan	1	11	nd	16	7	0.1	1.0	nd	1.5	0.7
Rock Ptarmigan	0	0	nd	0	1	0	0	nd	0	0.1
Unidentified Ptarmigan	0	0	nd	3	1	0	0	nd	0.3	0.1
Sandhill Crane	0	0	0	1	0	0	0	0	0.1	0.0
Bar-tailed Godwit	0	0	2	2	0	0	0	0.2	0.2	0.0
Common Snipe	0	1	0	0	1	0	0.1	0	0	0.1
Parasitic Jaeger	1	1	2	2	2	0.1	0.1	0.2	0.2	0.2
Long-tailed Jaeger	1	0	1	1	1	0.1	0	0.1	0.1	0.1
Glaucous Gull	0	1	0	0	0	0	0.1	0	0	0.0
Sabine's Gull	1	0	0	0	0	0.1	0	0	0	0.0
Arctic Tern	0	5	3	6	2	0	0.5	0.3	0.5	0.2
Total nests or densities[c]	47	78	72	96	63	4.4	7.4	6.8	9.1	5.9
Total species[d]	12	14	15	14	11					

[a] Includes nest identified from down and nest characteristics.
[b] Includes nests identified from feather and down samples.
[c] Total does not include ptarmigan.
[d] Total does not include ptarmigan or unidentified ducks.
nd = no data

Appendix D2. Numbers and densities of nests of selected species found during ground searches in 1996–2000, in the Alpine project area, Colville River Delta, Alaska. Search area boundaries are displayed in Figure 6 and in Johnson et al. (1999: Figure 5; 1998: Figure 10). For 1998, only the results of the first nest search are presented.

	Number of Nests					Density (nests/km^2)				
Species	1996	1997	1998	1999	2000	1996	1997	1998	1999	2000
Red-throated Loon	2	7	1	0	0	0.1	0.5	0.1	0	0
Pacific Loon	3	8	1	8	1	0.2	0.6	0.1	0.5	0.1
Yellow-billed Loon	1	1	0	1	0	0.1	0.1	0	0.1	0
Red-necked Grebe	0	3	2	2	1	0	0.2	0.1	0.1	0.1
Greater White-fronted Goose	35	45	48	79	51[b]	2.0	3.1	3.2	5.0	3.8[b]
Canada Goose	0	0	2	1	1	0	0	0.1	0.1	0.1
Brant	3	7	1	4[a]	3	0.2	0.5	0.1	0.3[a]	0.2
Tundra Swan	7	6	5	6	5	0.4	0.4	0.3	0.4	0.4
Northern Shoveler	1	0	5[b]	0	0	0.1	0	0.3[b]	0	0
Northern Pintail	2[b]	5	9[b]	9[b]	8[b]	0.1[b]	0.3	0.6[b]	0.6[b]	0.6[b]
Green-winged Teal	1	0	1	4[b]	2[b]	0.1	0	0.1	0.3[b]	0.2[b]
Greater Scaup	0	2	1	6	1	0	0.1	0.1	0.4	0.1
Lesser Scaup	0	0	1	0	0	0	0	0.1	0	0
Unidentified scaup	0	0	2	2[b]	1	0	0	0.1	0.1[b]	0.1
Spectacled Eider	0	0	1	1	0	0	0	0.1	0.1	0
King Eider	1	0	0	0	0	0.1	0	0	0	0
Long-tailed Duck	7[b]	9	6[b]	5[b]	5[b]	0.4[b]	0.6	0.4[b]	0.2[b]	0.4[b]
Unidentified duck	0	0	4	2	1	0	0	0.3	0.1	0.1
Willow Ptarmigan	1	12	nd	21	12	0.1	0.8	nd	1.3	0.9
Rock Ptarmigan	0	1	nd	0	1	0	0.1	nd	0	0.1
Unidentified ptarmigan	0	0	nd	3	1	0	0	nd	0.2	0.1
Sandhill Crane	0	0	0	1	0	0	0	0	0.1	0
Bar-tailed Godwit	1	0	2	3	0	0.1	0	0.1	0.2	0
Common Snipe	0	1	0	0	1	0	0.1	0	0	0.1
Parasitic Jaeger	1	1	2	2	2	0.1	0.1	0.1	0.1	0.2
Long-tailed Jaeger	1	0	1	1	1	0.1	0	0.1	0.1	0.1
Glaucous Gull	0	2	0	1	1	0	0.1	0	0.1	0.1
Sabine's Gull	1	0	0	0	1	0.1	0	0	0	0.1
Arctic Tern	0	5	4	15	4	0	0.3	0.3	1.0	0.3
Short-eared Owl	1	0	0	0	0	0.1	0	0	0	0
Area (km^2)	17.2	14.3	14.8	15.7	13.3					
Total nests or densities[c]	68	102	99	153	90	4.0	7.1	6.7	9.7	6.8
Total species[d]	16	14	18	18	16					

[a] Includes one nest identified by down and nest site location.

[b] Includes nests identified from feather and down samples.

[c] Total does not include ptarmigan.

[d] Total does not include ptarmigan or unidentified ducks.

Appendix D3. Habitat selection by Greater White-fronted Geese during nesting in the common ground search area in the Alpine project area, Colville River Delta, Alaska, 1996, 1997, 1998, and 1999.

Year/Habitat	Area (km²)	No. of Nests	Use (%)	Availability (%)	Monte Carlo Results[a]
1996					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.6	ns
Tapped Lake w/ High-water Connection	0.80	0	0	7.6	ns
Salt Marsh	0.62	0	0	5.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.90	0	0	8.5	ns
Deep Open Water w/ Islands or Polygonized Margins	0.10	0	0	0.9	ns
Shallow Open Water w/o Islands	<0.01	0	0	<0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.01	0	0	0.1	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0.08	0	0	0.8	ns
Aquatic Sedge w/ Deep Polygons	0.12	2	8.0	1.1	prefer
Aquatic Grass Marsh	0.10	0	0	1.0	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	0.97	0	0	9.1	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.57	18	72.0	42.9	prefer
Moist Sedge-Shrub Meadow	1.27	5	20.0	12.0	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.64	0	0	6.0	ns
Barrens (riverine, eolian, lacustrine)	0.18	0	0	1.7	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.64	25	100	100	
1997					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.6	ns
Tapped Lake w/ High-water Connection	0.80	0	0	7.6	ns
Salt Marsh	0.62	0	0	5.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.90	0	0	8.5	ns
Deep Open Water w/ Islands or Polygonized Margins	0.10	1	2.9	0.9	ns
Shallow Open Water w/o Islands	<0.01	0	0	<0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.01	0	0	0.1	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0.08	0	0	0.8	ns
Aquatic Sedge w/ Deep Polygons	0.12	1	2.9	1.1	ns
Aquatic Grass Marsh	0.10	0	0	1.0	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	0.97	0	0	9.1	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.57	29	82.9	42.9	prefer
Moist Sedge-Shrub Meadow	1.27	3	8.6	12.0	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.64	1	2.9	6.0	ns
Barrens (riverine, eolian, lacustrine)	0.18	0	0	1.7	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.64	35	100	100	

Appendix D3. (Continued).

Year/Habitat	Area (km²)	No. of Nests	Use (%)	Availability (%)	Monte Carlo Results[a]
1998					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.6	ns
Tapped Lake w/ High-water Connection	0.80	0	0	7.6	ns
Salt Marsh	0.62	0	0	5.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.90	0	0	8.5	ns
Deep Open Water w/ Islands or Polygonized Margins	0.10	0	0	0.9	ns
Shallow Open Water w/o Islands	<0.01	0	0	<0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.01	0	0	0.1	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0.08	-	-	0.8	ns
Aquatic Sedge w/ Deep Polygons	0.12	2	6.3	1.1	ns
Aquatic Grass Marsh	0.10	0	0	1.0	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	0.97	1	3.1	9.1	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.46	25	78.1	41.9	prefer
Moist Sedge-Shrub Meadow	1.17	4	12.5	11.0	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.63	0	0	5.9	ns
Barrens (riverine, eolian, lacustrine)	0.18	0	0	1.7	ns
Artificial (water, fill, peat road)	0.22	0	0	2.1	ns
Total	10.64	32	100	100	
1999					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.6	ns
Tapped Lake w/ High-water Connection	0.80	0	0	7.6	avoid
Salt Marsh	0.62	1	1.9	5.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.90	0	0	8.5	avoid
Deep Open Water w/ Islands or Polygonized Margins	0.10	0	0	0.9	ns
Shallow Open Water w/o Islands	<0.01	-	-	<0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.01	0	0	0.1	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0.08	0	0	0.8	ns
Aquatic Sedge w/ Deep Polygons	0.12	4	7.5	1.1	prefer
Aquatic Grass Marsh	0.10	0	0	1.0	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	0.96	3	5.7	9.0	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.39	34	64.2	41.2	prefer
Moist Sedge-Shrub Meadow	1.16	9	17.0	10.9	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.63	2	3.8	5.9	ns
Barrens (riverine, eolian, lacustrine)	0.18	0	0	1.7	ns
Artificial (water, fill, peat road)	0.31	0	0	2.9	ns
Total	10.64	53	100	100	

[a] Significance calculated from 1,000 simulations at $\alpha = 0.05$; ns = not significant, prefer = significantly greater use than availability, avoid = significantly less use than availability.

Appendix E1. Frequency and duration of nesting activities of Greater White-fronted Goose 002 monitored at 1-min intervals by video camera at the Alpine project area, Colville River Delta, Alaska, 2000.

		On-Nest Activities[a]							Recesses		
		Normal Incubation	Breaks		Defense		Total	Incubation		Total	
Date	Day Before Failure	Min	No.	Min	No.	Min	Min on Nest	Constancy (%)	No.	Min off Nest	Total Min Monitored[b]
16 June[c]	9	457	11	18	0	0	475	–	2	48	523
17 June	8	1,393	32	47	0	0	1,440	100.0	0	0	1,440
18 June	7	1,401	23	27	0	0	1,428	99.2	2	12	1,440
19 June	6	1,411	18	23	0	0	1,434	99.6	1	6	1,440
20 June	5	1,337	28	32	0	0	1,369	95.1	3	71	1,440
21 June	4	427	5	6	0	0	433	–	1	35	468
22 June[d]	3	–	–	–	–	–	–	–	–	–	–
23 June[d]	2	–	–	–	–	–	–	–	–	–	–
24 June[d]	1	–	–	–	–	–	–	–	–	–	–
25 June[d]	Failure	–	–	–	–	–	–	–	–	–	–
Total[e]	8	5,542	101	129	0	0	5,671	–	6	89	5,760
Average[e]		1,386	25	32	0	0	1,418	98.5	2	22	1,440

[a] On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts, because nest was attended.

[b] Total min monitored excludes disturbance min.

[c] Day camera deployed, data not included in summary.

[d] Partial or missing video coverage, data not included in summary.

[e] Includes days 5–8 before failure.

Appendix E2. Frequency and duration of nesting activities of Greater White-fronted Goose 914 monitored at 1-min intervals by video camera at the Alpine project area, Colville River Delta, Alaska, 2000.

		On-Nest Activities[a]							Recesses		
			Breaks		Defense						
Date	Day Before Hatch	Normal Incubation Min	No.	Min	No	Min	Total Min on Nest	Incubation Constancy (%)	No.	Total Min off Nest	Total Min Monitored[b]
21 June[c]	22	390	13	13	0	0	403	–	0	0	403
22 June	21	1,391	39	43	0	0	1,434	99.7	1	4	1,438
23 June	20	1,380	32	33	0	0	1,413	98.2	2	26	1,439
24 June	19	1,392	27	29	0	0	1,421	98.7	1	19	1,440
25 June	18	1,406	27	29	0	0	1,435	100.0	0	0	1,435
26 June	17	1,347	16	18	0	0	1,365	100.0	0	0	1,365
27 June	16	1,399	20	20	0	0	1,419	98.7	1	19	1,438
28 June	15	1,420	16	17	1	1	1,438	100.0	0	0	1,438
29 June	14	1,380	35	35	0	0	1,415	98.3	5	25	1,440
30 June	13	1,409	27	29	0	0	1,438	100.0	0	0	1,438
1 July	12	1,345	12	15	0	0	1,360	100.0	0	0	1,360
2 July	11	1,395	22	25	0	0	1,420	99.0	1	14	1,434
3 July	10	1,404	18	20	0	0	1,424	98.9	1	16	1,440
4 July	9	1,409	10	10	1	1	1,420	98.7	1	18	1,438
5 July	8	1,397	12	15	0	0	1,412	98.1	2	28	1,440
6 July[d]	7	1,025	18	18	1	1	1,044	96.2	2	41	1,085
7 July[d]	6	832	20	26	0	0	858	92.2	3	73	931
8 July	5	1,310	18	20	0	0	1,330	92.4	4	110	1,440
9 July	4	1,362	19	21	0	0	1,383	96.0	3	57	1,440
10 July	3	1,323	25	26	0	0	1,349	93.7	5	91	1,440
11 July	2	1,269	22	28	0	0	1,297	90.2	6	141	1,438
12 July	1	1,241	29	39	0	0	1,280	93.8	5	84	1,364
13 July	Hatch	–	–	–	–	–	–	–	–	–	–
Total[e]	19	25,979	426	472	2	2	26,453	–	38	652	27,105
Average[e]		1,367	22	25	<1	<1	1,392	97.6	2	34	1,427

[a] On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts, because nest was attended.
[b] Total min monitored excludes disturbance min.
[c] Day camera deployed, data not included in summary.
[d] Partial or missing video coverage, data not included in summary.
[e] Includes days 1–5, and 8–21 before hatching.

Appendix E3. Frequency and duration of nesting activities of Greater White-fronted Goose 917 monitored at 1-min intervals by video camera at the Alpine project area, Colville River Delta, Alaska, 2000.

		On-Nest Activities[a]							Recesses		
			Breaks		Defense						
Date	Day Before Hatch	Normal Incubation Min	No.	Min	No.	Min	Total Min on Nest	Incubation Constancy (%)	No.	Total Min off Nest	Total Min Monitored[b]
26 June[c]	16	486	9	9	0	0	495	–	0	0	495
27 June	15	1,402	27	33	0	0	1,435	99.7	1	5	1,440
28 June	14	1,413	25	26	1	1	1,440	100.0	0	0	1,440
29 June	13	1,404	32	36	0	0	1,440	100.0	0	0	1,440
30 June	12	1,414	25	26	0	0	1,440	100.0	0	0	1,440
1 July	11	1,342	18	22	1	1	1,365	95.2	0	0	1,365
2 July	10	1,418	19	21	1	1	1,440	100.0	0	0	1,440
3 July	9	1,416	24	24	0	0	1,440	100.0	0	0	1,440
4 July	8	1,424	16	16	0	0	1,440	100.0	0	0	1,440
5 July	7	1,416	16	19	1	5	1,440	100.0	0	0	1,440
6 July[d]	6	1,101	25	29	0	0	1,130	97.7	1	27	1,157
7 July[d]	5	820	25	26	0	0	846	91.3	1	49	895
8 July	4	1,398	29	30	0	0	1,428	99.2	1	12	1,440
9 July	3	1,415	23	24	1	1	1,440	100.0	0	0	1,440
10 July	2	1,401	15	17	0	0	1,418	98.5	1	22	1,440
11 July	1	1,392	20	23	0	0	1,415	98.3	1	25	1,440
12 July	Hatch	–	–	–	–	–	–	–	–	–	–
Total[e]	13	18,255	289	317	5	9	18,581	–	4	64	18,645
Average[e]		1,404	22	24	<1	<1	1,429	99.3	<1	5	1,434

[a] On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts, because nest was attended.

[b] Total min monitored excludes disturbance min.

[c] Day camera deployed, data not included in summary.

[d] Partial or missing video coverage, data not included in summary.

[e] Includes days 1–4, and 7-15 before hatching.

Appendix E4. A comparison of the frequency and length of nesting activities of a Greater White-fronted Goose at nest 001 monitored by a video camera at 1-min intervals and by a thermistored egg at 5-min intervals, in the Alpine project area, Colville River Delta, Alaska, 2000.

		Video Camera										Thermistored Egg						
		On Nest[a]							Recesses			On Nest[a]				Recesses		
		Normal Incubation	Breaks		Defense		Total	Incubation		Total		Normal		Total	Incubation		Total	
Date	Day Before Hatch	Min	No.	Min	No.	Min	Min. on Nest	Constancy (%)	No.	Min off Nest	Total Min. Monitored[b]	Incubation Min	No. of Breaks	Min on Nest	Constancy (%)	No.	Min off Nest	Total Min Monitored[b]
15 June[c]	25	–	–	–	–	–	–	–	–	–	–	555	10	605	–	3	50	655
16 June[d]	24	388	13	15	0	0	403	–	1	15	778	1,285	4	1,305	98.1	2	25	1,330
17 June	23	1,404	25	30	0	0	1,434	100.0	0	0	1,434	1,430	2	1,440	100.0	0	0	1,440
18 June	22	1,395	23	26	0	0	1,421	98.7	2	19	1,440	1,415	3	1,430	99.3	1	10	1,440
19 June	21	1,413	27	27	0	0	1,440	100.0	0	0	1,440	1,420	4	1,440	100.0	0	0	1,440
20 June[e]	20	805	8	9	0	0	814	100.0	0	0	814	815	2	825	100.0	0	0	825
21 June	19	1,276	28	29	0	0	1,305	99.5	1	7	1,312	1,290	2	1,300	99.2	1	10	1,310
22 June	18	1,381	35	42	0	0	1,423	98.8	1	17	1,440	1,380	8	1,420	98.6	1	20	1,440
23 June	17	1,368	36	41	0	0	1,409	97.8	2	31	1,440	1,405	4	1,425	99.0	1	15	1,440
24 June	16	1,390	32	41	0	0	1,431	99.4	1	9	1,440	1,420	1	1,425	99.0	1	15	1,440
25 June	15	1,392	29	31	0	0	1,423	98.8	1	17	1,440	1,425	3	1,440	100.0	0	0	1,440
26 June	14	1,277	23	23	0	0	1,300	100.0	0	0	1,300	1,340	4	1,355	100.0	0	0	1,355
27 June	13	1,420	18	20	0	0	1,440	100.0	0	0	1,440	1,380	12	1,440	100.0	0	0	1,440
28 June	12	1,413	16	20	0	0	1,433	99.5	1	7	1,440	1,400	6	1,430	99.3	1	10	1,440
29 June	11	1,363	36	45	0	0	1,408	97.8	3	32	1,440	1,385	7	1,420	98.6	2	20	1,440
30 June	10	1,390	34	37	1	1	1,428	99.2	1	12	1,440	1,390	6	1,420	98.6	1	20	1,440
01 July	9	1,312	16	17	1	1	1,330	100.0	0	0	1,330	1,315	3	1,325	100.0	0	0	1,325
02 July	8	1,393	26	29	0	0	1,422	98.8	2	18	1,440	1,405	2	1,415	98.3	2	25	1,440
03 July[f]	7	942	22	22	0	0	964	98.4	1	16	980	1,405	1	1,410	97.9	2	30	1,440
04 July[f]	6	–	–	–	–	–	–	–	–	–	–	1,420	4	1,440	100.0	0	0	1,440
05 July[f]	5	–	–	–	–	–	–	–	–	–	–	1,370	5	1,395	96.9	3	45	1,440
06 July[f]	4	–	–	–	–	–	–	–	–	–	–	1,350	7	1,385	96.2	4	55	1,440
07 July[f]	3	–	–	–	–	–	–	–	–	–	–	1,275	5	1,300	95.2	3	65	1,365
08 July[f]	2	–	–	–	–	–	–	–	–	–	–	1,395	5	1,420	98.6	2	20	1,440
09 July[f]	1	–	–	–	–	–	–	–	–	–	–	1,390	7	1,425	99.0	1	15	1,440
10 July	Hatch	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[g]	15	20,587	404	458	2	2	21,047	–	15	169	21,216	20,800	65	21,125	–	11	145	21,270
Average[g]		1,373	27	31	<1	<1	1,403	99.2	1	11	1,414	1,387	4	1,408	99.3	<1	10	1,418

[a] On-nest activities include normal incubation, breaks (nest maintenance activities) and defense bouts, because nest was attended.
[b] Total min monitored excludes disturbance min.
[c] Day thermistored egg was deployed, data not included in summary.
[d] Day camera was deployed, data not included in summary.
[e] Disturbance by ground crews near nest for >150 min, data not included in summary
[f] Partal or missing video coverage, data not included in summary.
[g] Includes days 8-19 and 21-23 before hatching.

Appendix E5. Frequency and duration of nesting activites of Tundra Swans at nest 701 monitored at 1-min intervals by video camera at the Alpine project area, Colville River Delta, Alaska, 2000.

		On-Nest Activities[a]							Off-Nest Activities					
			Breaks		Defense				Exchanges		Recesses			
Date	Day Before Hatch	Normal Incubation Min	No.	Min	No.	Min	Total Min on Nest	Incubation Constancy (%)	No.	Min	No.	Min	Total Min off Nest[b]	Total Min Monitored[c]
17 June[d]	25	86	1	1	0	0	87	–	1	3	0	0	3	90
18 June	24	1,383	31	39	0	0	1,422	98.8	5	18	0	0	18	1,440
19 June	23	1,400	22	22	1	3	1,425	99.0	4	8	1	7	15	1,440
20 June	22	1,413	16	18	0	0	1,431	99.4	4	9	0	0	9	1,440
21 June	21	1,404	21	26	0	0	1,430	99.3	3	7	1	3	10	1,440
22 June[e]	20	386	13	16	0	0	402	99.0	2	4	0	0	4	406
23 June[e]	19	–	–	–	–	–	–	–	–	–	–	–	–	–
24 June[e]	18	–	–	–	–	–	–	–	–	–	–	–	–	–
25 June[e]	17	–	–	–	–	–	–	–	–	–	–	–	–	–
26 June[e]	16	918	11	12	0	0	930	96.9	1	2	1	28	30	960
27 June	15	1,389	19	20	0	0	1,409	99.6	3	6	0	0	6	1,415
28 June	14	1,411	16	17	0	0	1,428	99.2	3	5	1	7	12	1,440
29 June	13	1,388	30	34	0	0	1,422	98.8	4	12	1	6	18	1,440
30 June	12	1,403	29	30	0	0	1,433	99.5	4	7	0	0	7	1,440
01 July	11	1,340	19	20	1	2	1,362	99.8	1	3	0	0	3	1,365
02 July	10	1,403	30	31	0	0	1,434	99.6	3	6	0	0	6	1,440
03 July	9	1,410	23	27	0	0	1,437	99.8	2	3	0	0	3	1,440
04 July	8	1,408	17	18	0	0	1,426	99.0	5	9	1	5	14	1,440
05 July	7	1,410	18	24	0	0	1,434	99.6	4	6	0	0	6	1,440
06 July[e]	6	1,050	17	20	0	0	1,070	97.5	6	27	0	0	27	1,097
07 July[e]	5	873	14	15	0	0	888	94.8	3	7	3	42	49	937
08 July	4	1,404	21	22	0	0	1,426	99.0	6	14	0	0	14	1,440
09 July	3	1,407	16	16	1	1	1,424	98.9	4	11	1	5	16	1,440
10 July	2	1,391	18	19	1	1	1,410	98.0	3	7	3	22	29	1,439
11 July	1	1,401	22	23	1	2	1,425	99.0	3	7	2	8	15	1,440
12-July	Hatch	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[f]	17	23,763	368	406	5	9	24,178	–	61	138	11	63	201	24,379
Average[f]		1,398	22	24	<1	<1	1,422	99.2	4	8	<1	4	12	1,434

[a] On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts, because nest was attended.
[b] Total min off nest includes exchange min. and recess min.
[c] Total min. monitored excludes disturbance min.
[d] Day camera deployed, data not included in summary.
[e] Partial or missing video coverage, data not included in summary.
[f] Includes days 1–4, 7-15, and 21-24 before hatching.

Appendix F1. The incidence of concealment postures and normal incubation occurring during aircraft, airstrip vehicle, and airstrip pedestrian events at four Greater White-fronted Goose nests monitored with time-lapse video cameras in the Alpine project area, 2000. Nests 001, 914, and 917 were successful and nest 002 failed.

Nest No.	Distance from Airstrip (m)	Total Days Monitored	Behavior	Aircraft Landings & Takeoffs No.	Aircraft Landings & Takeoffs %	Airstrip Vehicles No.	Airstrip Vehicles %	Airstrip Pedestrians No.	Airstrip Pedestrians %
002	32	4.7	Concealment Posture[a]	78	30	38	19	13	65
			Normal Incubation	186	70	161	81	7	35
			Total	264	100	199	100	20	100
917	77	16.3	Concealment Posture[a]	159	26	54	12	46	58
			Normal Incubation	453	74	382	88	34	42
			Total	612	100	436	100	80	100
001	130	17.0	Concealment Posture[a]	126	16	51	10	15	26
			Normal Incubation	657	84	475	90	43	74
			Total	783	100	526	100	58	100
914	194	22.7	Concealment Posture[a]	209	24	54	9	17	18
			Normal Incubation	665	76	554	91	75	82
			Total	874	100	608	100	92	100
All Nests Pooled		60.7	Concealment Posture[a]	572	23	197	11	91	36
			Normal Incubation	1,961	77	1,572	89	159	64
			Total	2,533	100	1,769	100	250	100

[a] One concealment posture may occur during >1 aircraft, vehicle, or pedestrian event.

Appendix F2. The number, duration, and type of vehicles observed on the airstrip during the nesting period at the Alpine project area, Colville River Delta, Alaska, 2000. Data were recorded by Alpine air traffic control personnel and by video cameras at Greater White-fronted Goose nests.

	Small Truck			Large Truck			Machinery			All Vehicles			
Date	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	Total Min Monitored
11 June	4	8	8	2	5	5	4	20	39	10	33	52	448
12 June	2	3	3	0	0	0	2	9	9	4	12	12	1,440
13 June	4	8	8	0	0	0	0	0	0	4	8	8	1,440
14 June	8	19	19	0	0	0	6	8	11	14	27	30	1,440
15 June	4	5	5	4	19	19	8	13	13	16	37	37	1,440
16 June	12	78	78	12	36	36	6	240	459	30	354	573	1,433
17 June	22	43	45	18	28	28	20	160	250	60	231	323	1,440
18 June	44	49	49	14	80	80	20	146	146	78	275	275	1,440
19 June	40	139	139	30	41	41	36	82	82	106	262	262	1,440
20 June	32	77	77	42	77	77	46	250	455	120	404	609	1,440
21 June	20	87	87	4	13	13	12	139	143	36	239	243	1,440
22 June	16	177	177	4	5	5	4	8	8	24	190	190	1,440
23 June	20	237	237	10	59	59	9	144	158	39	440	454	1,440
24 June	25	431	493	34	123	123	38	370	612	97	924	1228	1,440
25 June	26	444	444	20	97	99	24	265	325	70	806	868	1,440
26 June	26	239	239	14	48	48	18	146	146	58	433	433	1,440
27 June	20	101	101	18	44	44	26	286	308	64	431	453	1,440
28 June	24	159	159	16	19	19	30	313	369	70	491	547	1,440
29 June	14	99	103	16	11	11	19	148	189	49	258	303	1,440
30 June	18	35	35	24	66	66	26	87	87	68	188	188	1,440
1 July	28	28	28	4	64	64	6	133	191	38	225	283	1,440
2 July	12	13	18	0	0	0	6	192	192	18	205	210	1,440
3 July	18	48	48	12	19	19	6	10	10	36	77	77	1,440
4 July	22	82	82	20	23	23	8	97	97	50	202	202	1,440
5 July	16	23	23	10	7	7	6	81	81	32	111	111	1,440
6 July	20	40	40	10	8	8	12	27	27	42	75	75	1,085
7 July	4	5	5	12	10	10	14	108	108	30	123	123	965
8 July	38	105	105	14	25	25	12	146	146	64	276	276	1,440
9 July	14	26	26	10	14	14	6	15	15	30	55	55	1,440
10 July	32	42	42	30	97	97	24	46	46	86	185	185	1,400
11 July	32	89	89	30	32	32	20	114	114	82	235	235	1,440
12 July	26	108	108	22	52	52	10	32	32	58	192	192	1,440
13 July	24	40	41	24	35	35	22	48	48	70	123	124	1,440
14 July	40	94	99	26	65	65	18	110	153	84	269	317	1,440
15 July	20	39	42	10	40	42	6	47	47	36	126	131	1,118
Total	727	3,220	3,302	516	1,262	1,266	530	4,040	5,116	1,773	8,522	9,684	48,209
Average[c]	21.7	96.2	98.6	15.4	37.7	37.8	15.8	120.7	152.8	52.9	254.5	289.3	1,377

[a] Duration = number of min ≥1 vehicle was on airstrip.

[b] Veh. min = sum of min each vehicle was on airstrip.

[c] Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored = sum of total min monitored/no. of days monitored.

Appendix F3. The number, duration, and type of vehicles observed on the infield road during the nesting period at the Alpine project area, Colville River Delta, Alaska, 2000. Data were recorded by a video camera at Tundra Swan nest 701.

	Small Truck			Large Truck			Machinery			All Vehicles			
Date	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	No.	Duration (min)[a]	Veh. Min[b]	Total Min Monitored
17 June	0	0	0	0	0	0	0	0	0	0	0	0	129
18 June	2	2	2	0	0	0	1	1	1	3	3	3	1,440
19 June	1	1	1	0	0	0	1	1	1	2	2	2	1,440
20 June	0	0	0	0	0	0	1	1	1	1	1	1	1,440
21 June	1	1	1	0	0	0	1	1	1	2	2	2	1,440
22 June	0	0	0	0	0	0	0	0	0	0	0	0	439
23 June[c]	–	–	–	–	–	–	–	–	–	–	–	–	–
24 June[c]	–	–	–	–	–	–	–	–	–	–	–	–	–
25 June[c]	–	–	–	–	–	–	–	–	–	–	–	–	–
26 June	1	1	1	0	0	0	0	0	0	1	1	1	992
27 June	0	0	0	0	0	0	10	27	27	10	27	27	1,415
28 June	2	3	3	0	0	0	33	115	120	35	118	123	1,440
29 June	2	23	23	0	0	0	9	27	32	11	50	55	1,440
30 June	1	1	1	2	1	1	8	53	53	11	55	55	1,440
1 July	1	1	1	0	0	0	0	0	0	1	1	1	1,428
2 July	1	1	1	0	0	0	1	1	1	2	2	2	1,440
3 July	2	2	2	0	0	0	2	4	4	4	6	6	1,440
4 July	1	1	1	0	0	0	0	0	0	1	1	1	1,440
5 July	1	1	1	0	0	0	0	0	0	1	1	1	1,440
6 July	0	0	0	0	0	0	0	0	0	0	0	0	1,057
7 July	0	0	0	0	0	0	2	2	2	2	2	2	967
8 July	5	5	6	1	10	10	4	7	7	10	22	23	1,440
9 July	1	1	1	0	0	0	1	2	2	2	3	3	1,365
10 July	1	1	1	0	0	0	0	0	0	1	1	1	1,439
11 July	5	5	6	0	0	0	0	0	0	5	5	6	1,440
12 July	1	1	1	0	0	0	0	0	0	1	1	1	1,433
13 July	2	5	5	0	0	0	1	1	1	3	6	6	1,440
Total	31	56	58	3	11	11	75	243	253	109	310	322	30,824
Average[d]	1.4	2.6	2.7	0.1	0.5	0.5	3.5	11.4	11.8	5.1	14.5	15.0	1,284

[a] Duration = number of min ≥1 vehicle was on airstrip.

[b] Veh. min = sum of min each vehicle was on airstrip.

[c] Missing video coverage.

[d] Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored = sum of total min monitored/no. of days monitored.

Appendix F4. The number, group size, and duration of pedestrians observed on the airstrip, infield road, and on tundra adjacent to the airstrip during the nesting period in the Alpine project area, Colville River Delta, Alaska, 2000. Data were recorded by video cameras at three White-fronted Goose nests and one Tundra Swan nest.

	Airstrip					Infield Road					Tundra Travel				
Date	No. of Groups	Max. Size	Duration (Min)[a]	Person Min[b]	Total Min Monitored	No. of Groups	Max. Size	Duration (Min)[a]	Person Min[b]	Total Min Monitored	No. of Groups	Max. Size	Duration (Min)[a]	Person Min[b]	Total Min Monitored
16 June	6	6	30	107	563	–	–	–	–	–	2	1	205	205	460
17 June	10	4	65	189	1,440	0	0	0	0	129	2	1	75	75	1,440
18 June	4	3	2	4	1,440	0	0	0	0	1,440	0	0	0	0	1,440
19 June	6	5	14	45	1,440	0	0	0	0	1,440	0	0	0	0	1,440
20 June	14	9	41	157	1,440	0	0	0	0	1,440	4	9	601	1,987	1,440
21 June	0	0	0	0	941	0	0	0	0	1,440	6	6	570	1,715	1,440
22 June	4	6	3	8	1,438	0	0	0	0	439	15	8	484	1,772	1,440
23 June[c]	10	1	11	11	1,439	–	–	–	–	–	6	6	105	630	1,440
24 June[c]	4	5	3	11	1,440	–	–	–	–	–	0	0	0	0	1,440
25 June[c]	6	3	70	128	1,435	–	–	–	–	–	0	0	0	0	1,440
26 June	14	2	79	138	1,430	2	1	1	1	992	2	1	177	177	1,440
27 June	4	1	3	3	1,438	0	0	0	0	1,415	0	0	0	0	1,440
28 June	6	2	3	5	1,438	0	0	0	0	1,440	0	0	0	0	1,440
29 June	10	2	26	27	1,440	4	2	3	6	1,440	0	0	0	0	1,440
30 June	10	3	98	182	1,438	8	3	9	19	1,440	0	0	0	0	1,440
1 July	6	2	3	4	1,436	2	2	1	2	1,428	2	2	145	290	1,440
2 July	2	1	1	1	1,434	2	1	23	23	1,440	0	0	0	0	1,420
3 July	6	1	26	26	1,440	0	0	0	0	1,440	0	0	0	0	1,440
4 July	12	3	25	42	1,438	4	3	18	34	1,440	0	0	0	0	1,440
5 July	2	1	15	15	1,440	0	0	0	0	1,440	0	0	0	0	1,440
6 July	6	1	3	3	1,085	0	0	0	0	1,057	0	0	0	0	1,440
7 July	28	2	66	115	965	8	2	5	7	967	1	1	118	118	1,085
8 July	16	2	36	61	1,440	2	2	19	38	1,440	0	0	0	0	965
9 July	8	2	13	27	1,440	0	0	0	0	1,465	0	0	0	0	1,440
10 July	6	2	10	20	1,440	0	0	0	0	1,439	0	0	0	0	1,440
11 July	8	1	32	37	1,438	2	1	2	2	1,440	1	1	1	1	1,440
12 July	14	4	35	65	1,435	2	1	12	12	1,433	2	1	168	168	1,440
13 July	2	1	2	2	1,438	0	0	0	0	1,440	0	0	0	0	1,440
14 July	2	1	1	1	1,440	0	0	0	0	1,440	0	0	0	0	1,440
15 July	0	0	0	0	600	–	–	–	–	–	0	0	0	0	600
Total	226	76	716	1,434	40,109	36	18	93	144	32,264	43	37	2,649	7,138	40,530
Average[d]	8.1	2.7	25.7	51.5	1,337	1.6	0.8	4.2	6.4	1,291	1.5	1.3	94.1	253.6	1,351

[a] Duration = number of min ≥1 person was present in camera view.

[b] Person min = sum of min each person was at location.

[c] Missing video coverage from the camera positioned near the infield road.

[d] Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored = sum of total min monitored/no. of days monitored.

Appendix F5. The type and frequency of aircraft using the Alpine airstrip after the waterfowl nesting period in the Alpine project area, Colville River Delta, Alaska, 2000. Frequency for aircraft includes takeoffs and landings. Data are from Alpine air traffic control personnel.

	Aircraft Type						
Date	C-130 Hercules	DC-6	CASA[a]	Twin Otter/ Conquest[a]	Small Planes[b]	Helicopter	Total
16 July	0	0	10	10	0	24	44
17 July	0	0	8	28	0	16	52
18 July	0	4	8	24	0	12	48
19 July	0	4	0	18	0	12	34
20 July	0	2	2	18	0	10	32
21 July	0	0	6	10	0	22	38
22 July	0	4	6	10	0	16	36
23 July	2	0	6	8	0	14	30
24 July	0	0	6	36	0	16	58
25 July	0	0	2	26	0	22	50
26 July	0	2	2	22	4	14	44
27 July	0	0	1	13	0	24	40
28 July	0	2	0	17	2	8	28
29 July	0	4	0	8	0	28	40
30 July	0	0	4	4	0	12	20
31 July	0	0	6	28	0	12	46
1 August	0	4	7	26	0	8	44
2 August	0	2	6	18	0	18	44
3 August	0	4	2	16	0	8	30
4 August	0	0	6	14	0	22	42
5 August	0	4	6	6	0	0	16
6 August	0	0	8	8	0	6	22
7 August	0	0	10	30	0	14	54
8 August	0	2	4	18	2	30	56
9 August	2	2	4	20	0	14	42
10 August	0	2	4	18	0	14	38
11 August	0	0	0	0	0	0	2
12 August	0	2	8	12	0	14	36
13 August	0	0	8	6	0	12	26
14 August	0	2	6	32	0	6	46
15 August	0	0	6	26	0	16	48
16 August	0	4	8	22	0	14	48
17 August	0	0	10	26	2	18	56
18 August	0	0	6	18	0	6	30
19 August	0	4	4	14	0	8	30
20 August	0	0	4	12	2	8	26
21 August	0	0	8	34	0	8	50
22 August	0	4	2	30	0	8	44
23 August	0	4	0	26	0	18	48
24 August	0	2	4	26	0	18	50
25 August	0	0	6	14	0	20	40
26 August	0	0	6	10	0	24	40
Daily Mean	0.1	1.5	5.0	18.1	0.3	14.1	39.2
Total	4	64	210	762	12	594	1,648

[a] Takeoffs did not always equal landings because aircraft periodically stayed overnight at Alpine.

[b] Includes Cessna 207 and Cessna 185.

Appendix G1. Matrix of pairwise Pearson correlation coefficients of nest-attendance parameters for 24 Greater White-fronted Goose nests monitored with egg thermistors and/or video cameras in the Alpine project area, Colville River Delta, Alaska, 2000. $n = 411$ nest · days.

	Incubation Constancy	Number of Recesses	Total Time Off Nest	Number of Breaks
Incubation Constancy (arcsin transformation)	1.00			
Number of Recesses (square root transformation)	-0.91**	1.00		
Total Time off Nest (square root transformation)	-0.99**	0.93**	1.00	
Number of Breaks (logarithmic transformation)	-0.04	0.02**	-0.04	1.00

** Correlation is significant at the 0.01 level (2-tailed).

Appendix G2. Matrix of pairwise Pearson correlation coefficients for environmental and potential disturbance variables monitored during the Greater White-fronted Goose nesting season in the Alpine project area, Colville River Delta, Alaska, 2000. Pedestrians were monitored with video cameras and aircraft and vehicles were monitored by Alpine air traffic control and video cameras.

	DC-6	C-130	Otter	CASA	Small Plane	All Planes	Helicopter	All Aircraft	Vehicles	Airstrip Pedestrian	Tundra Pedestrian	Wind Speed (mph)
Landings/Takeoffs												
DC-6	1.00											
C-130	< -0.01	1.00										
Otter	-0.13**	-0.35**	1.00									
Casa	-0.19**	-0.08	0.01	1.00								
Small Plane	-0.11*	-0.11*	-0.10*	-0.10*	1.00							
All Planes	0.36**	-0.22**	0.94**	0.15**	-0.10*	1.00						
Helicopter	0.35**	0.21**	< 0.01	-0.19**	-0.12*	0.08	1.00					
All Aircraft	0.48**	-0.02	0.66**	-0.02	-0.15**	0.75**	0.72**	1.00				
Cumulative Time												
Vehicles	0.64**	0.64**	-0.09	-0.20**	-0.04	0.14*	0.45**	0.39**	1.00			
Airstrip Pedestrians	-0.02	0.25**	0.23**	-0.08	-0.22**	0.22**	0.16**	0.26**	0.11*	1.00		
Tundra Pedestrians	0.23**	-0.15**	0.36**	-0.13**	-0.01	0.36**	0.44**	0.54**	-0.02	< -0.01	1.00	
Mean Wind Speed	-0.04	-0.22**	0.04	0.56**	-0.04	-0.14**	-0.30**	-0.29**	-0.28**	-0.33**	-0.11*	1.00
Mean Temperature	0.31**	0.32**	-0.07	-0.36**	0.12*	0.01	0.35**	0.24**	0.41**	0.21**	0.35**	-0.56**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Appendix G3. Daily air temperature (degrees C) and wind speed (mph) data were obtained from weather records at the Alpine airport, Colville River Delta, Alaska, 2000.

	Temperature (degrees C)			Wind Speed (mph)			
Date	Mean	Max.	Min.	Mean	Max.	Min.	Direction (deg.)
1 June	1.8	3	1	12.0	22	8	246
2 June	-0.9	1	-2	11.0	18	6	303
3 June	-2.6	-2	-3	3.8	7	0	59
4 June	-4.6	-2	-9	6.1	12	2	113
5 June	-2.7	1	-6	5.2	6	4	132
6 June	0.8	4	-3	7.5	10	4	118
7 June	3.7	6	1	8.2	14	4	127
8 June	5.4	8	2	5.4	9	3	299
9 June	1.7	3	1	9.9	16	4	62
10 June	0.2	2	-1	9.1	14	4	109
11 June	0.6	3	-1	4.9	8	0	77
12 June	1.7	4	-2	8.1	10	5	90
13 June	1.0	4	-1	13.4	89	6	82
14 June	6.3	9	3	3.9	8	0	350
15 June	10.6	17	5	3.3	10	0	64
16 June	12.9	18	7	5.8	10	3	114
17 June	11.8	16	5	5.0	10	0	56
18 June	12.9	18	7	7.1	14	5	158
19 June	11.3	15	7	5.9	12	2	102
20 June	10.1	16	7	7.2	18	3	7
21 June	9.4	14	6	9.9	14	4	83
22 June	16.3	19	10	6.9	12	2	277
23 June	16.8	22	11	6.4	10	0	271
24 June	17.0	24	8	6.5	10	0	270
25 June	13.4	21	9	6.3	12	2	32
26 June	12.0	17	8	7.0	16	0	236
27 June	5.6	7	5	10.5	14	6	273
28 June	3.2	5	2	9.2	14	8	290
29 June	4.5	9	1	5.6	10	3	4
30 June	9.1	13	4	5.4	12	3	75
1 July	9.8	12	8	9.7	12	4	280
2 July	3.8	7	1	11.4	14	7	325
3 July	7.7	14	2	4.8	8	3	296
4 July	9.1	15	4	8.6	16	0	240
5 July	3.9	5	3	14.5	28	5	304
6 July	9.4	16	4	5.9	8	3	156
7 July	15.4	18	11	9.0	12	6	277
8 July	8.8	13	5	11.9	16	1	56
9 July	4.6	5	4	13.3	16	10	71
10 July	3.8	6	2	13.4	17	10	84
11 July	3.5	5	2	16.1	18	12	70
12 July	2.3	5	-1	12.3	16	8	63
13 July	1.6	4	0	16.7	19	12	84
14 July	4.0	10	-1	15.6	23	12	96
15 July	14.2	22	4	7.2	10	3	192

Appendix G4. Multiple regression model for incubation constancy (arcsine transformed) at 24 Greater White-fronted Goose nests monitored with egg thermistors and/or video cameras, as a function of daily environmental and potential disturbance variables, Alpine project area, Colville River Delta, Alaska, 2000. Stepwise regression was used, with alpha-to-enter = 0.10 and alpha-to-remove = 0.15.

	Regression Coefficients				Model Statistics				
Independent Variables	ß	SE	*t*	*P*	*F*	*df*	*P*	R^2	Adj.R^2
Constant	1.540	0.025	61.25	<0.001	18.51	4, 406	<0.001	0.04	0.04
Mean Wind Speed	-0.011	0.002	5.54	<0.001					
Cumulative Time of Vehicles on Airstrip	<0.001	<0.001	4.15	<0.001					
Cumulative Time of Pedestrians on Tundra	<0.001	<0.001	2.99	0.003					
No. of Airplanes	0.001	0.001	2.19	0.029					

Appendix G5. Test of equality of slopes of the relationships between incubation constancy and potential disturbance or environmental factors for Greater White-fronted Goose nests with different fates in the Alpine project area, Colville River Delta, Alaska, 2000. Results of a general linear modeling procedure run on nest constancy data from successful ($n = 12$) and failed ($n = 12$) nests. Independent variables were selected by stepwise multiple regression analysis of incubation constancy on disturbance and environmental variables.

Source	Type III Sum of Squares	df	Mean Square	*F*	*P*	R^2	Adj. R^2
Corrected Model	1.61	9	0.18	17.58	<0.001	0.283	0.267
Intercept	43.46	1	43.46	4,275.49	<0.001		
Fate	0.01	1	0.01	0.55	0.460		
Cumulative Time of Vehicles on Airstrip	0.26	1	0.26	25.78	<0.001		
Cumulative Time of Pedestrians on Tundra	0.14	1	0.14	13.95	<0.001		
No. of Airplanes	0.07	1	0.07	6.87	0.009		
Mean Wind Speed	0.51	1	0.51	50.54	<0.001		
Fate * Vehicles on Airstrip	0.07	1	0.07	6.79	0.009		
Fate * Pedestrians on Tundra	0.07	1	0.07	6.53	0.011		
Fate * No. of Airplanes	<0.01	1	<0.01	0.25	0.620		
Fate * Mean Windspeed	0.05	1	0.05	5.21	0.023		
Error	4.08	401	0.01				
Total	874.32	411					
Corrected Total	5.68	410					

Appendix H. Logistic regression models for predicting the occurrence of nest sites of the most common nesting birds on 480 50-m x 50-m grids within 12 200-m x 500-m plots, Alpine project area, Colville River Delta, Alaska, 1998-2000. Explanatory variables included characteristics of vegetation and physiography. Variables were chosen with forward-backward stepwise procedures (see text).

Variable Type	Variable	*β*	S.E.	Wald	df	*P*-value	Odds Ratio (Exp[*β*])
2000 Waterfowl Nests, *n* = 480 grids (15 with ≥ 1 nest). [*LR*[a] = 4.314, 1 df, *P* = 0.038]							
Vegetation Cover	Sedge Marsh (%)	0.597	0.245	5.909	1	0.015	1.816
Constant		-3.517	0.273	165.722	1	<0.001	0.030
1999 Waterfowl Nests, *n* = 480 grids (14 nests).							
No variables entered this model.[b]							
1998 Waterfowl Nests, *n* = 480 grids (24 nests).							
Polygon	Center			4.713	2	0.095	
	Low	1.028	1.037	0.981	1	0.322	2.794
	High	-.460	1.238	0.138	1	0.710	0.631
Constant		-3.663	1.013	13.088	1	<0.001	0.026
2000 Greater White-fronted Goose Nests, *n* = 480 grids (10 with ≥ 1 nest).[*LR* = 5.332, 1 df, *P* = 0.021]							
Vegetation Cover	Sedge Marsh (%)	0.689	0.252	7.492	1	0.006	1.992
Constant		-3.977	0.340	137.014	1	<0.001	0.019
1999 Greater White-fronted Goose Nests, *n* = 480 grids (9 nests).							
Vegetation Cover	Moist Sedge–Shrub (%)	0.033	0.018	3.269	1	0.071	1.033
Constant		-5.076	0.785	41.756	1	<0.001	0.006
1998 Greater White-fronted Goose Nests, *n* = 480 grids (16 nests).							
No variables entered this model.[b]							
2000 Shorebird Nests, *n* = 480 grids (130 with ≥ 1 nest). [*LR* = 25.530, 4 df, *P* < 0.001]							
Distance	Airstrip (m)			16.666	3	0.001	
	0–780	1.166	0.330	12.505	1	<0.001	3.210
	781–1,430	0.927	0.346	7.178	1	0.007	2.528
	1,431–2,412	1.279	0.334	14.669	1	<0.001	3.595
Topography	Surface Relief (cm)	0.016	0.006	7.788	1	0.005	1.016
Constant		-2.703	0.427	40.018	1	<0.001	0.067
1999 Shorebird Nests, *n* = 487 grids (85 nests).							
Distance	Airstrip (m)			5.435	3	0.143	
	0–780	0.485	0.387	1.577	1	0.209	1.625
	781–1,430	0.824	0.377	4.779	1	0.029	2.280
	1,431–2,412	0.294	0.402	0.536	1	0.464	1.342
Water	Depth (cm)	-0.011	0.006	3.360	1	0.067	0.989
Vegetation Cover	Moist Sedge–Shrub (%)	0.028	0.008	13.108	1	<0.001	1.029
	Open Low Willow (%)	-0.068	0.057	1.426	1	0.323	0.934
Constant		-2.580	.381	45.900	1	.000	.076
1998 Shorebird Nests, *n* = 491 grids (116 nests).							
Distance	Airstrip (m)			5.985	3	0.112	
	0–780	0.677	0.351	3.725	1	0.054	1.967
	781–1,430	0.803	0.343	5.463	1	0.019	2.231
	1,431–2,412	0.673	0.352	3.657	1	0.056	1.961
Polygon	Density			5.259	2	0.072	
	Low	0.852	0.504	2.861	1	0.091	2.344
	High	1.258	0.557	5.097	1	0.024	3.520

Appendix H. (Continued).

Variable Type	Variable	β	S.E.	Wald	df	P-value	Odds Ratio (Exp[β])
Vegetation Cover	Wet Sedge–Willow (%)	0.016	0.008	4.197	1	0.040	1.016
	Dryas Tundra (%)	0.095	0.044	4.607	1	0.032	1.100
Constant		-2.948	0.603	23.916	1	0.000	0.052
2000 Pectoral Sandpiper Nests, *n* = 480 grids (62 with ≥ 1 nest). [*LR* = 18.595, 4 df, *P* = 0.001]							
Distance	Airstrip (m)			8.583	3	0.035	
	0–780	0.601	0.458	1.721	1	0.190	1.823
	781–1,430	1.061	0.462	5.269	1	0.022	2.889
	1,431–2,412	1.223	0.444	7.584	1	0.006	3.397
Topography	Surface Relief (cm)	0.026	0.008	11.323	1	0.001	1.027
Constant		-4.042	0.598	48.753	1	<0.001	0.018
1999 Pectoral Sandpiper Nests, *n* = 480 grids (24 nests).							
Distance	Airstrip (m)			4.635	3	0.201	
	0–780	0.372	0.750	0.246	1	0.620	1.450
	781–1,430	1.259	0.673	3.495	1	0.062	3.522
	1,431–2,412	0.698	0.721	0.936	1	0.333	2.009
Vegetation Cover	Moist Sedge–Shrub (%)	0.021	0.012	2.816	1	0.093	1.021
Constant		-4.287	0.716	35.830	1	<0.001	0.014
1998 Pectoral Sandpiper Nests, *n* = 483 grids (61 nests).							
Polygon	Density			4.038	2	0.133	
	Low	1.788	1.025	3.043	1	0.081	5.979
	High	2.099	1.062	3.906	1	0.048	8.156
Vegetation Cover	*Dryas* Tundra	0.069	0.052	1.763	1	0.184	1.071
Constant		-3.715	1.014	13.425	1	0.000	0.024
2000 Semipalmated Sandpiper Nests, *n* = 480 grids (47 with ≥ 1 nest). [*LR* = 16.319, 4 df, *P* = 0.003]							
Distance	Airstrip (m)			10.093	3	0.018	
	0–780	1.791	0.601	8.893	1	0.003	5.998
	781–1,430	1.198	0.634	3.571	1	0.059	3.313
	1,431–2,412	1.632	0.596	7.503	1	0.006	5.115
Vegetation Cover	Open Low Willow (%)	0.051	0.023	4.896	1	0.027	1.052
Constant		-3.596	0.541	44.163	1	<0.001	0.027
1999 Semipalmated Sandpiper Nests, *n* = 480 grids (37 nests).							
Water	Depth	-.021	.010	4.517	1	.034	.979
Vegetation Cover	Moist Sedge–Shrub	.031	.010	8.922	1	.003	1.031
	Open Low Willow	-0.126	.117	1.161	1	.281	.882
Constant		-2.949	.400	54.449	1	.000	.052
1998 Semipalmated Sandpiper Nests, *n* = 480 grids (21 nests).							
Distance	Airstrip (m)			6.223	3	0.101	
	0–780	2.037	0.900	5.120	1	0.024	7.667
	781–1,430	2.383	0.980	5.912	1	0.015	10.838
	1,431–2,412	1.809	0.942	9.689	1	0.055	6.106
Vegetation Cover	Wet Sedge–Willow (%)	0.050	0.018	7.997	1	0.005	1.051
	Moist Sedge–Shrub (%)	0.059	0.016	12.797	1	0.000	1.061
	Open Low Willow (%)	0.072	0.026	7.788	1	0.005	1.075
Constant		-8.095	1.455	30.972	1	<0.001	<0.001
2000 Passerine Nests, *n* = 480 grids (59 with ≥ 1 nest). [*LR* = 15.697, 3 df, *P* = 0.001]							
Polygon	Density			11.426	2	0.003	
	Low	0.494	0.637	0.601	1	0.438	1.639
	High	1.521	0.672	5.130	1	0.024	4.578
Vegetation Cover	Open Low Willow (%)	0.042	0.020	4.367	1	0.037	1.043
Constant		-2.689	0.617	18.974	1	<0.001	0.068

Appendix H. (Continued).

Variable Type	Variable	β	S.E.	Wald	df	*P*-value	Odds Ratio (Exp[β])
1999 Passerine Nests, *n* = 481 grids (64 nests).							
Topography	Surface Relief (cm)	0.010	0.007	2.202	1	0.138	1.011
Water	Depth (cm)	0.011	0.006	3.606	1	0.058	1.011
Vegetation Cover	Wet Sedge–Willow (%)	0.020	0.010	3.970	1	0.046	1.020
	Moist Sedge–Shrub (%)	0.015	0.010	2.522	1	0.112	1.015
Constant		-3.562	0.527	45.630	1	<0.001	0.028
1998 Passerine Nests, *n* = 482 grids (54 nests).							
Topography	Surface Relief (cm)	0.016	0.007	5.143	1	0.023	1.016
Constant		-2.809	0.369	57.970	1	<0.001	0.060
2000 Lapland Longspur Nests, *n* =480 grids (48 with ≥ 1 nest). [*LR* = 6.521, 1 df, *P* = 0.011]							
Vegetation Cover	Open Low Willow (%)	0.050	0.018	7.358	1	0.007	1.051
Constant		-2.272	0.158	206.021	1	<0.001	0.103
1999 Lapland Longspur Nests, *n* =481 grids (62 nests).							
Topography	Surface Relief (cm)	0.017	0.008	4.284	1	0.038	1.017
Water	Depth (cm)	0.009	0.006	2.195	1	0.138	1.009
Vegetation Cover	Wet Sedge–Willow (%)	0.024	0.010	5.407	1	0.020	1.024
	Moist Sedge–Shrub (%)	0.016	0.010	2.631	1	0.105	1.016
	Open Low Willow (%)	-0.082	0.064	1.618	1	0.203	0.922
Constant		-3.947	0.565	48.881	1	<0.001	0.019
1998 Lapland Longspur Nests, *n* = 480 grids (49 nests).							
Topography	Surface Relief (cm)	0.014	0.007	4.223	1	0.040	1.015
Constant		-2.855	0.377	57.435	1	<0.001	0.058

[a] *LR* = likelihood ratio statistic, tests the null hypothesis that all coefficients in the final model except the constant are 0.

[b] Polygon center was a significant variable, but no nests were found on grids without polygon centers; therefore, the coefficients could not be estimated correctly. Nonetheless, low- and high-center polygons should have high odds of having nests.

Appendix I. Counts of waterbirds during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 2000.

	June			July				August			
	22[a]	24	30	7	15	21	29	6	17	25	Total
Loons, grebes	81	59	83	80	42	47	41	43	75	47	598
Geese	174	206	107	115	114	296	255	110	609	406	2392
Swans	25	36	23	35	52	52	54	45	66	78	466
Ducks	497	495	636	919	271	203	169	144	394	208	3936
Cranes	2	10	4	0	0	2	2	0	2	0	22
Gulls, terns	74	104	127	54	123	78	44	20	11	9	641
Total birds	853	910	980	569	602	680	565	362	1157	748	7423

[a] Survey incomplete; Lakes S6.6, S6.2, T5.2, T5.5, T5.6, T6.1 and T6.2 were not surveyed. Map of lakes found in Figure 4.