SECOND ANNUAL REPORT

ALPINE AVIAN MONITORING PROGRAM, 1999

CHARLES B. JOHNSON
BRIAN E. LAWHEAD
JOHN R. ROSE
JOANNA E. ROTH
SHARON F. SCHLENTNER
ALICE A. STICKNEY
ANN M. WILDMAN

PREPARED FOR

PHILLIPS ALASKA, INC.
AND
ANADARKO PETROLEUM CORPORATION

PREPARED BY

ABR, INC.
P. O. BOX 80410
FAIRBANKS, AK 99708-0410

ABR, INC. ALPINE AVIAN MONITORING PROGRAM, 1999 SECOND ANNUAL REPORT

ALPINE AVIAN MONITORING PROGRAM, 1999

SECOND ANNUAL REPORT

Prepared for

PHILLIPS Alaska, Inc.
(formerly ARCO Alaska, Inc.)
P. O. Box 100360
Anchorage, AK 99510

and

Anadarko Petroleum Corporation

Prepared by

Charles B. Johnson
Brian E. Lawhead
John R. Rose
Joanna E. Roth
Sharon F. Schlentner
Alice A. Stickney
Ann M. Wildman

ABR, Inc.
P. O. Box 80410
Fairbanks, AK 99708

August 2000

EXECUTIVE SUMMARY

- The Alpine Avian Monitoring Program was initiated in 1998 with the issuance of construction permits for the Alpine Development, which stipulated that ARCO and Anadarko conduct a three-year monitoring program on the effects of airplane disturbance on waterfowl. The Alpine airstrip was in place by spring 1998 and in operation by spring 1999. In 1999, the ice road to Alpine was closed 15 May, after which aircraft, primarily a DC-6 and Twin Otter, took over transportation. A Bell 206 LR was based at Alpine from 24 May through 7 October, and transported people within and beyond the project area. By June 1999, all gravel was in place for Pad 1, Pad 2, and the airstrip. In 1999, Pad 1 was under full construction and contained a main camp, drill rig, rig camp, and other miscellaneous buildings. During summer, Pad 2 was used as a staging area for spill containment supplies, but was not under construction. The Alpine airstrip was in use by summer 1999, but the packed surface was extended and maintained by heavy equipment during the breeding season.

- Noise events were monitored at three sites (35, 148, and 330 m from the airstrip) during June and three different sites (25, 85, and 130 m from the airstrip) during July–August. Noise events (sound exposure levels [SEL]for noise exceeding 85 dBA for ≥2sec in June and ≥10 sec in July–August) were attributed to aircraft and vehicle sources based on time of occurrence. Most noise events (4,773) could not be assigned to a source and were presumed to be caused by wind. The most noise events associated with sources in June were attributed to vehicles on the airstrip (752 events), but the highest SEL and longest event duration were from helicopters (131 dBA and 521 sec, respectively). SELs generally diminished with distance from the airstrip, and helicopters generally had higher SELs and event durations than did airplanes or vehicles.

- Nest densities (standardized for search effort) of all species of large waterbirds in the area common to search areas in 1996–1999 were intermediate in 1999 (4.5 nests/km^2), highest in 1997 (5.9 nests/km^2), and lowest in 1996 (4.2 nests/km^2). Greater White-fronted Geese were the most abundant nesting birds in the area, followed by several species of ducks. Twenty-two species of large birds were found nesting in the common search area during 1996–1999, of which 14 species nested in 1999. Nest densities in 1999 were lowest between 500 and 1,000 m of the airstrip (6.4 nests/km^2), and greatest between 1,000 and 1,500 m (12.1 nests/km^2). This spatial distribution could not be explained by the distribution of the most used habitats (based on our habitat map) among the distance zones; within Wet Sedge–Willow Meadow, Moist Sedge–shrub Meadow, and Nonpatterned Wet Meadow, the relative distribution of nests was similar to that of all habitats combined. The distance of nests to the airstrip location did not differ significantly ($P = 0.34$) among the years (1996–1999), despite differing levels of human activity.

- The density of Greater White-fronted Goose nests (standardized for search effort) in the common search area was intermediate in 1999 (2.5 nests/km^2) compared to 1997 (2.7 nests/km^2) and 1996 (2.4 nests/km^2). In 1999, Greater White-fronted Geese nested in 5 of 15 habitats in the project area in 1999; they preferred Wet Sedge–Willow Meadow and Aquatic Sedge with Deep Polygons and avoided two lake habitats. The density of nests increased within the preferred habitats from 0–500 m of the airstrip to 1,000–1,500 m of the airstrip. The mean distance of goose nests from the airstrip in 1999 (1,094 m) did not differ ($P = 0.82$) from those in the other years (1996–1998). Nearest neighbor distances of White-fronted Goose nests were clumped in all years, but nearest neighbor distance was not linearly related to distance of nests from the airstrip in any year ($r^2 < 0.01$, $P > 0.18$).

- Similar numbers of Tundra Swan nests were found in the common ground-search area in all four years (3–5 nests). The distance of nests to the airstrip did not differ significantly among the four years of study ($P = 0.77$). In 1999, the closest nest to the airstrip was 449 m from the western end of the strip, and this nest hatched successfully. The closest nest during four years of study was 159 m away in 1998, and this nest also hatched successfully.

- Nest attendance by Greater White-fronted Geese was monitored with temperature recording eggs at 29 nests. At 12 nests that hatched successfully, geese spent 99% of their time incubating. Recess frequency averaged 0.9/d, recess length averaged 15.9 min, and time off nest averaged 13.9 min/d. At failed nests, geese averaged 98.0 % of their time incubating, recess frequency averaged 1.7/d, recess length averaged 18.1 min, and time off nest averaged 31 min/d. The distance from the airstrip of monitored nests was about the same for nests that hatched ($\bar{x}$ = 1,122 m) and nests that failed ($\bar{x}$ = 1,223 m; $P = 0.98$)

- Two Tundra Swan nests were monitored by video cameras. The swans closest to the airstrip (449 m) incubated 99% of the time, took 0.6 recesses/d averaging 10.4 min/recess, and spent 12.1 min/d off the nest. The swans farther from the airstrip (1,281 m) incubated 97% of the time, took 2.5 recesses/d averaging 14.7 min/recess, and spent 43 min/d off the nest. Both pairs of swans successfully defended their nests from foxes two times. Both nests hatched successfully.

- Time-lapse video cameras monitored behavior, predation, and responses to aircraft at three White-fronted Goose nests. A Parasitic Jaeger was observed at one nest and may have caused one egg to not hatch. We observed arctic and red foxes in the camera views on 17 occasions and ≤50 m from nests on 11 occasions. Geese defended two nests a total of three times successfully against arctic foxes. At one of these nests, a red fox managed to take all four eggs on possibly the last day of incubation. Five recesses ($\bar{x}$ = 45.6 min/recess) occurred at one of the monitored nests when aircraft landed and took off, and the mean length of these recesses was more than twice the length of other recesses ($\bar{x}$ = 19.2 min, n = 84) at this nest. Recesses were not observed at the other two nests while aircraft used the airstrip.

- Stepwise regression analysis was conducted to select factors from environmental variables (wind speed and ambient temperature) and potential disturbance variables (number of airplanes and helicopters, duration of vehicles, duration of pedestrians on the airstrip and on the tundra, and duration of noise events from airplanes, helicopters, and vehicles) having the greatest effect on incubation constancy and number of incubation breaks. Mean temperature, mean wind speed, and number of airplanes entered the regression of incubation constancy. The duration of vehicle noise events and the duration of pedestrians on the tundra entered the regression of incubation breaks. The final analysis of covariance model of incubation constancy showed a weak negative affect of ambient temperature at failed nests, no effect of temperature at hatched nests, and no significant effects from wind speed or number of airplanes. The final analysis of covariance model of incubation breaks showed a significant effect for nest fate, significant positive effect from duration of vehicle noise, and a marginal effect from tundra pedestrians; however, the model explained only 8% of the variation in incubation breaks. Thus, neither analysis demonstrated a strong relationship between disturbance or environmental variables and nesting behavior, but further analyses are required to investigate effects at different distances from the airstrip.

- Few duck nests (8 of 33 nests, 24%) were successful at hatching in 1999. The distance to the airstrip of failed ducks nests ($\bar{x}$ = 1,336 m, n = 25) was less than the distance for hatched nests ($\bar{x}$ = 1,670, n = 8), but not significantly less ($P = 0.22$). Of 82 Greater White-fronted Goose nests that were checked for fate, 35% hatched successfully in 1999. The distance from the airstrip of successful and failed nests was essentially identical ($\bar{x}$ = 1,359 and 1,339 m, respectively; $P = 0.89$). Clutch sizes of goose nests were positively but insignificantly related to distance from the airstrip, and the regression explained only 2% of the variation. Six of seven Tundra Swan nests (86%) hatched in 1999, and the failed nest was 2,417 m from the airstrip, farther than the mean distance for all nests (1,383 m).

- In 1999, we found 169 nests of 19 species on 12 breeding-bird plots (10 ha each), a decline from the 196 nests found in 1998. The predominant nesting species in 1999 were Lapland Longspurs (62 nests, 37% of all nests), Semipalmated Sandpipers (37 nests, 22%), Pectoral Sandpipers (24 nests, 14%), and White-fronted Geese (9 nests, 5%). More nests were found on treatment plots ($\bar{x}$ = 17.0 nests, n = 6) than on reference plots ($\bar{x}$ = 11.2 nests, n = 6) in 1999. Simple linear regressions of nest densities for the same four species (1998 and 1999 tested separately) with the distance of plots to the airstrip were insignificant and explained little of the variance ($P \geq 0.2$, $r^2 \leq 0.15$), except for Semipalmated Sandpipers in 1999 ($P = 0.06$, $r^2 = 0.30$). All the relationships between distance and density were negative, with the exception of weak positive relationships for Lapland Longspurs in 1999 ($P = 0.87$, $r^2 = 0.003$) and White-fronted Geese in 1998 ($P = 0.56$, $r^2 = 0.03$), indicating that nest densities decreased slightly or not at all with increasing distance to the airstrip. Logistic regression models of habitat features in the plots showed moist sedge–shrub cover (7 of 14 models) and surface relief, distance to airstrip, wet sedge–willow cover, and open low willow cover (each entered 4 of 14 models) to be the most consistent predictors of nest density.

- Twenty-three species of waterbirds were recorded on 9 aerial surveys of lakes in the Alpine project area in 1999. Ducks were the most numerous species, making up 46% of the 6,354 birds recorded on all surveys combined. The most commonly occurring ducks were Northern Pintail (60% of all ducks), scaup (21%), and American Wigeon (8%). The highest numbers of birds were recorded on surveys in early June and early August. Tapped basins were used by 77% of all waterbirds recorded.

- The number of avian predators seen in the Alpine project area appeared to be similar to previous years. In 1999, avian predators nesting within the Alpine project area included Glaucous Gulls (5 nests), Long-tailed Jaegers (1 nest) and Parasitic Jaegers (2 nests). In 1999, 38% of 50 arctic fox dens were active throughout the delta and area between the Colville River and Kuparuk Oilfield. Den occupancy was intermediate and pup production (5.4 pups/litter) was the second highest since 1993. However, from direct observation of nest predation, sign at failed nests, and video records of predators at nests, we concluded that arctic and red foxes were more active in the project area and took more nests in 1999 than in any of the previous three years of nest searches.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

The Alpine monitoring program was a team effort requiring participation by many people. The authors thank the other biologists who spent long, arduous hours wading the tundra for this project: Bob Burgess, Robin Corcoran, Aaron Helmericks, Brian Lawhead, Tara Livingston, Lonnie Rossow, and John Shook. Will Lentz and Allison Zusi-Cobb managed GIS data and crafted figures. Sarah McGowan and Devonee Harshburger assiduously managed the document production. Sue Bishop improved this document with a careful review. Doris Armijo provided logistic support. Jim Dell, Howard Reed and Dick Elder of Maritime Helicopters, flew our surveys and transported our crews safely and with outstanding skill. Mike Joyce, ARCO Alaska, Inc., was instrumental in initiating, designing, and continuing the biological studies on the Colville River Delta. To all these contributors, the authors are grateful for their help bringing this year's study and report to a successful conclusion. In 1999, ARCO was purchased by BP, but the western holdings of ARCO Alaska, Inc. were sold to PHILLIPS Petroleum Company. Because the second year of the Alpine Avian Monitoring Program was conducted for ARCO Alaska, Inc., we have chosen to use that name in text rather than PHILLIPS Alaska, Inc., the current owner of the Alpine project. We thank all the employees of ARCO Alaska, Inc. that we have worked with over the last eight years on the Colville River Delta, and we look forward to working with the staff of PHILLIPS Alaska, Inc. in the future. Without the encouragement and support of the management and employees of these companies, studies such as this one could not be conducted successfully.

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, 1999) and fish resources (Moulton 1996, 1998). The physical, biological, and human resources of the delta were summarized in an environmental evaluation of the Alpine development (ARCO 1997).

ARCO 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 relies 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, ARCO and Anadarko agreed to a three-year monitoring program to study disturbance of waterfowl by aircraft in the area of the oilfield. The intention 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 airstrip operation in 2000. Portions of the gravel footprint were in place by spring 1998, however, thereby substituting an additional construction year for 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 three-year program are

1. to monitor sources of potential disturbance in the Alpine project area including aircraft, vehicles, pedestrians, and noise;
2. to investigate nest abundance, distribution, and fate for large waterbirds and evaluate the relationships of these variables with distance from the airstrip;
3. to monitor a sample of nests for changes in nesting 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 second of three data-collection seasons. 1999 was the primary construction year for the Alpine Development, with major mobilization of materials and workers beginning in late winter. 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 1998 and previous years where appropriate and within-year analyses of potential disturbance effects. We have refrained from conducting comprehensive among-year comparisons of nesting data, because these analyses cannot be completed until all three years' data have been collected. 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 Nechelik and 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 of the 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. (1999).

The completed oilfield development will include 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 projected to be covered with gravel fill is ~39 ha. A sales-quality pipeline to the Kuparuk Oilfield will connect 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, we need to isolate aircraft from other forms of disturbance and compare birds exposed to aircraft 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 in the absence of aircraft; and

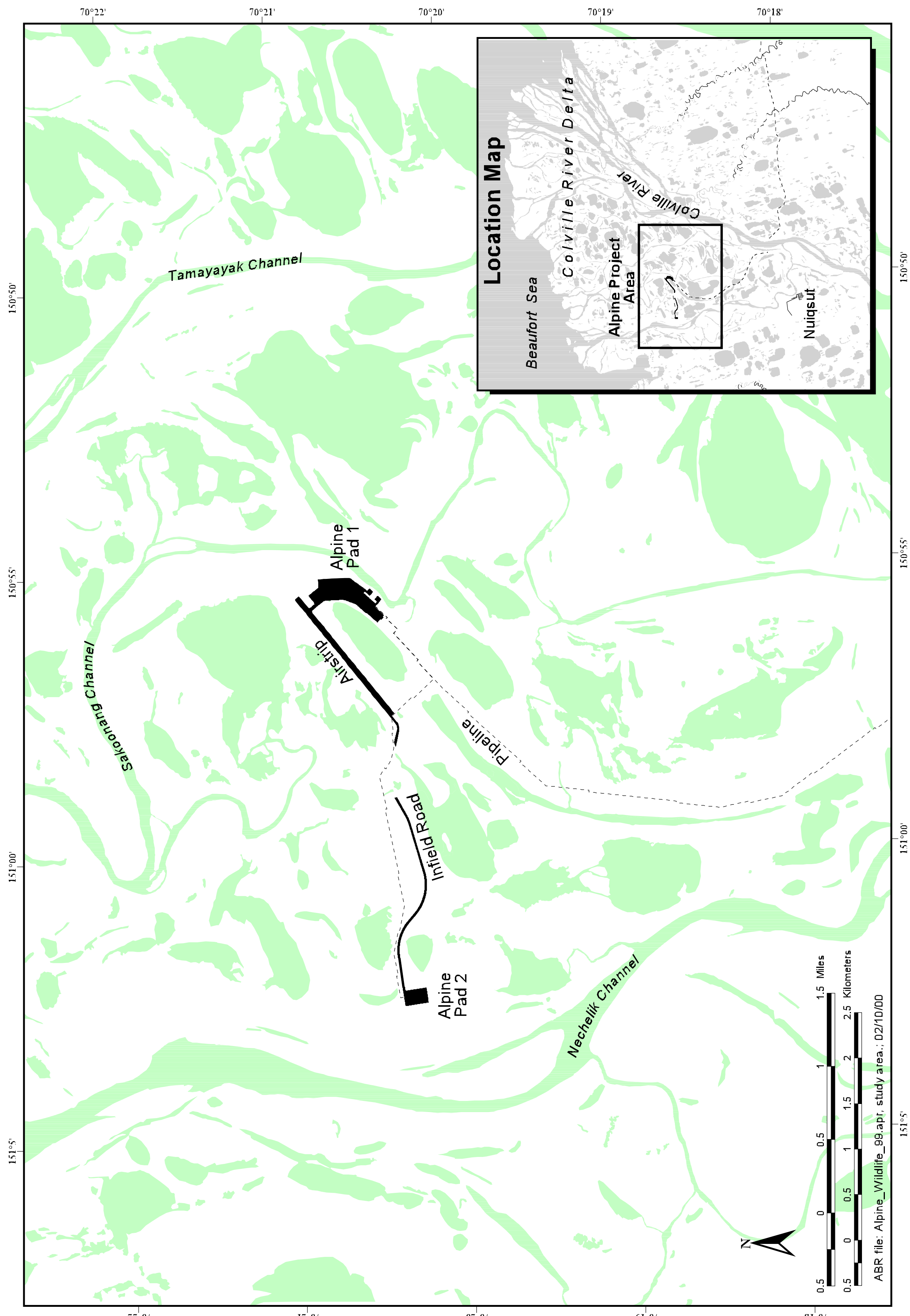

Figure 1. Study area map showing the Alpine project area, Colville River Delta, Alaska, 1999.

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 first year of construction, we will compare data from 1996 and 1997 (Johnson et al. 1997, 1998) with data from the current field study, when appropriate. The gradient design requires sampling over some continuous measure from a point source, in this case, we used distance from the airstrip and levels of activity (e.g., number of landings and takeoffs) as gradients of potential disturbance. In this report we present gradient and other analyses on nesting data from individual years, but BACI style analyses will be delayed until the operational year data (2000) 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 nests (in evaluations of nesting behavior). Because we are evaluating the responses of several species of birds and numerous parameters, our 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

We recorded conditions in the study area 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 aerial lake surveys. Several factors were used to gauge the phenological stage of the season: 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* sp.) 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. Prior to 1999, human activity in the Alpine project area was not monitored directly, but was assessed from records of activities kept by the contractors and others working in the area. In 1999, we used time-lapse video cameras that were focussed on nests and facilities to document helicopter landings and vehicle and pedestrian traffic. Landings and takeoffs of fixed-wing aircraft were recorded by Alpine security staff and also were documented on videotape. 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]).

NOISE MONITORING

Noise conditions were monitored in the Alpine project area with three Larsen-Davis Model 870 Sound Level Meters. The sound monitors recorded noise levels from 11 to 29 June on the north side of the airstrip near the point of liftoff during takeoffs and maximum braking for landings of a DC-6 encountering the prevailing northeast wind (Figure 2). The three monitors were placed at 35, 148, and 330 m perpendicularly to the airstrip. From 12 July to 25 August, the monitors were moved to 25, 85, and 130 m from the south side of the airstrip. All sound measurements were recorded in A-weighted decibels (dBA). During June, the monitors recorded time, date, and SELs (sound equivalent levels) for noise that exceeded 85 dBA for durations ≥2 sec (noise event), as well as other sound metrics. SELs are logarithmic measurements of sound energy over periods of time when the noise exceeds a prescribed level. During July and August, the monitors recorded SELs that exceeded 85 dBA for ≥10 sec. We removed noise measurements from analysis when average daily wind speed was ≥20 mph, assuming that noise levels on these days were influenced by wind-generated noise. We gathered records of daily

Table 1. Current, past, and projected (Year 2000) 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, production equipment and buildings 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	helicopters, 2 Twin Otters, C-207, 3 DC-6s, C-130

average and maximum 2-min average wind speeds from an automated National Weather Service station in Nuiqsut. We also removed noise measurements made during noise events ≥10 min in duration, under the assumption that these events were generated by wind or some unknown source (none could be assigned to aircraft, vehicles, or other activities monitored by video cameras). All averages of SELs were logarithmic. We assigned a source (DC-6, Twin Otter, C-207, C-185, helicopter, machinery, large truck, small truck) 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 and vehicles did not correspond exactly to the time these noise sources were closest to the noise monitors and there were activities such as engine starts, taxiing, and approaches before and after the time of the events, we placed "buffers" around the times of landings, takeoffs, and the appearances and disappearances of vehicles from the field of view of the video cameras. We subtracted 5 min from the landings of all airplanes and added 5 min to all takeoffs (i.e., a 10-min buffer). We treated helicopters similarly, except we subtracted and added 3 min because their approaches and takeoffs were more rapid. If an aircraft was on the ground for

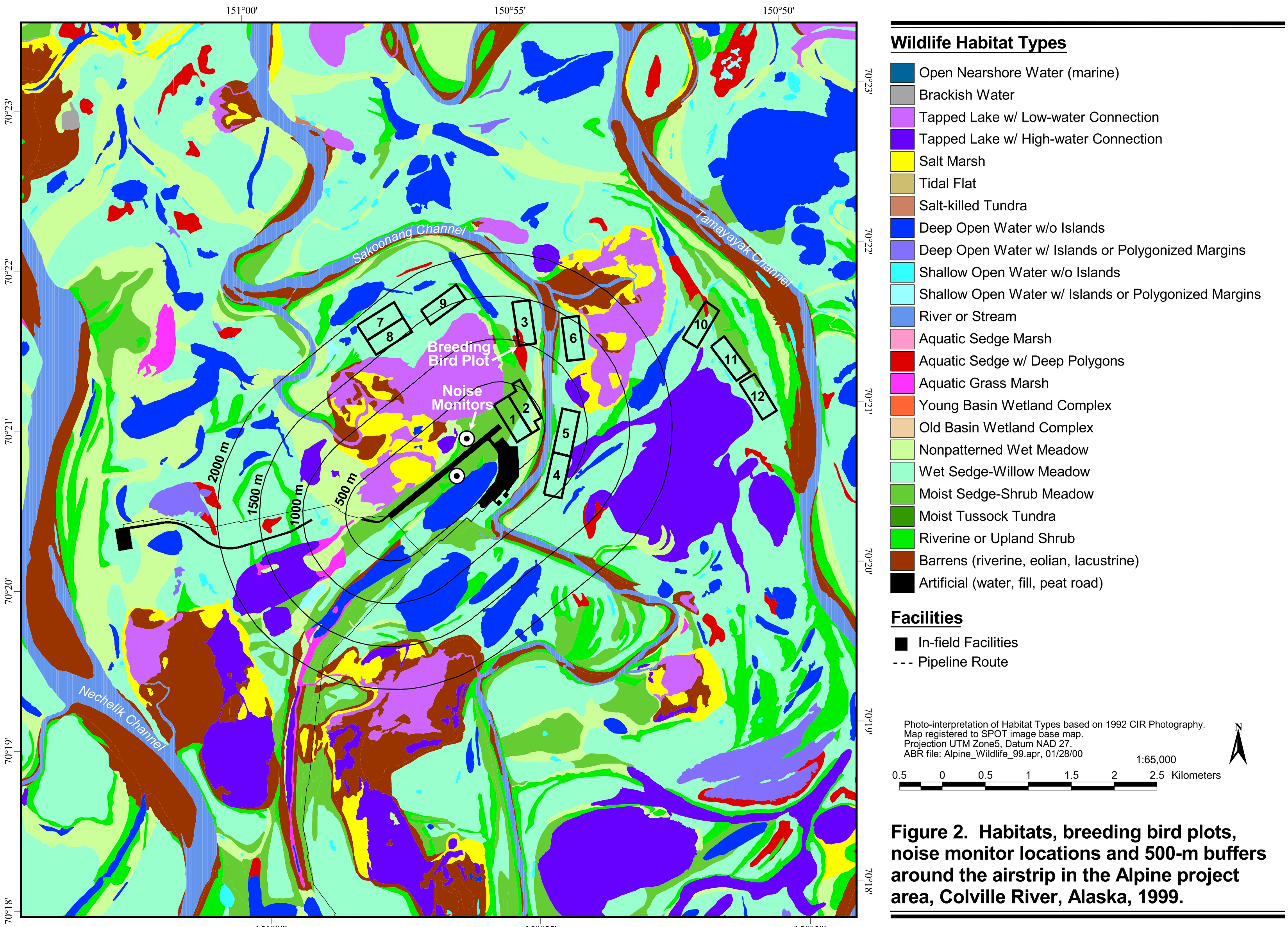

Figure 2. Habitats, breeding bird plots, noise monitor locations, and 500-m buffers around the airstrip in the Alpine project area, Colville River Delta, Alaska, 1999.

≥15 min, we placed the buffers around each takeoff and landing separately (i.e., two separate periods of time). If an aircraft was on the ground for <15 min, we assumed there was continuous activity (helicopters often kept their turbines running) and placed the buffer around the time it was on the ground (i.e., one period of time). Vehicles generally were active throughout the period of their recording, so we subtracted 3 min from each appearance and added 3 min to each disappearance from camera view to account for approach and departure time. If an noise event occurred outside the buffers placed on aircraft and vehicles, the source was unknown; we were unable to determine whether wind or some unrecorded aircraft, vehicle, or activity on the airstrip or Pad 1 produced these noise records. Noise events were summarized by day for evaluation of disturbance effects on nesting behavior described below. We summarized average SEL (logarithmic), duration (sum of all events), and number of events.

NEST DENSITIES AND NESTING SUCCESS

We conducted nest searches on the ground using the same techniques as were used in the Colville wildlife studies in 1996–1998 (Johnson et al. 1997, 1998, 1999). The survey area in 1999 was restricted to the Alpine project area adjacent to the airstrip and Pad 1 (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. Using five to eight observers, we 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, we recorded the species, distance to nearest waterbody, waterbody class, habitat type, and, if the bird flushed, the number of eggs in the nest. In 1999, we conducted our nest search between 11–22 and 25–26 June. Some waterbird nests were located during the surveys of the breeding-bird plots, aerial lake surveys, and video-camera maintenance. For the purposes of annual comparisons, we used only nests found during the nest search and breeding-bird plot surveys, 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.

We mapped all nest locations on 1:18,000-scale color aerial photographs and added the locations found in 1999 to the existing GIS database containing locations found in 1992–1998. For the majority of nests of waterbirds within 1,000 m of the airstrip, we recorded their exact locations using a GPS with differential correction. We also collected GPS locations on nests within 200 m of the pipeline transportation system south of Pad 1 and within 200 m of the proposed in-field pipeline and road to Pad 2. Down and feather samples were taken from all waterfowl nests found during the regular nest searches. For those nests that were unattended and could not be identified to species, the down and feather samples were used to make preliminary identifications. Eight 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.

We revisited nest sites of waterbirds in the ground-search area after hatch (on 12–15 July for waterfowl, and 24–26 August for loons) to determine their fate. Nests were classified as successful if we found egg membranes that had thickened and were detached from the eggshells, 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 our revisits to nests, we opportunistically recorded broods in the area on 1:18,000-scale color aerial photographs.

To facilitate comparisons of the distribution and density of nests among years, we delineated the common area that had been searched in 1996–1999 and then calculated with GIS the number of nests by species that occurred in what we henceforth refer to as the "common ground-search area". Also, we identified the nests occurring within four distance buffers (500, 1,000, 1,500, and 2,000 m) of the airstrip. The search effort was less intensive in 1995 (focusing on Spectacled Eiders, Johnson et al. 1996) than in subsequent years, so we will not discuss the results of that year's nest survey 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, we calculated nest-search effort for annual comparison. We calculated nest-search effort for each year by summing the number of hours spent searching in the common ground-search area. For 1996–1998, we estimated this sum as a proportion by multiplying the total number of hours searched by the ratio of the common ground-search area (10.6 km^2) to the total area searched in each year (17.2 km^2, 14.3 km^2, and 14.8 km^2, in 1996, 1997, and 1998, respectively). In 1999, we recorded the hours spent in the common ground-search area directly. We used the search effort to adjust the number and density of nests found each year to a common standard. We calculated the standardized numbers and densities of nests 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:

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

Therefore, numbers of nests and nest densities for 1997–1999 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. We used parametric two-sample t-tests and one-way ANOVAs or their nonparametric equivalents (Mann-Whitney U or Kruskal-Wallis tests, respectively) depending on whether the data satisfied assumptions of normality and homogeneity of variance that are required for traditional parametric tests. We measured nearest-neighbor distances between White-fronted Goose nests with ArcView (ESRI v1.8, Redlands, CA) and analyzed the distances for distributional patterns with a nearest-neighbor program (Clark and Evans 1954 cited in 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).

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, we combined dissimilar vegetation types with similar surface forms 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. 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). In our study, we concentrated on breeding waterbirds that use waterbodies and wet and moist tundra.

HABITAT SELECTION

Because the Greater White-fronted Goose (henceforth, White-fronted Goose) was a focal species in our disturbance analyses, we investigated habitat selection as one factor that could affect its nest distribution. We based the quantitative analyses of habitat selection on the locations of nests found during ground surveys each year from 1996 to 1999. We calculated use 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.

We tested for significant habitat selection (i.e., use $\neq$ availability) by conducting Monte Carlo simulations (Haefner 1996, Manly 1997). 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. We conducted 1,000 simulations and summarized the frequency distribution of use for each habitat by percentiles. We defined habitat preference (i.e., use > availability) to occur when the observed use was greater than the 97.5 percentile of simulated random use. Conversely, we defined habitat avoidance (i.e., use < availability) to occur when the observed use was less than the 2.5 percentile of simulated random use. These percentiles were chosen 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

We used egg thermistors and time-lapse video cameras to monitor nest attendance for a sample of focal species nesting in the Alpine project area in 1999. Egg thermistors were placed only in 42 White-fronted Goose nests, whereas cameras were placed at three White-fronted Goose and two Tundra Swan nests. We deployed egg thermistors 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. We selected White-fronted Goose and Tundra Swan nests nearest to the airstrip to monitor with cameras, so that we could monitor reactions to aircraft in the area with the highest potential for disturbance impact. We positioned the cameras to include the nest and the airstrip or Alpine Pad 1 in the camera view, so that we could monitor aircraft, vehicle, and pedestrian traffic.

We implanted thermistors in domestic goose eggs that had the contents removed and a coating of epoxy added to the interior of the shell to strengthen the egg. Into each egg, we glued a temperature probe with a 6-ft lead (TMC6-HA) and connected it to a data-logger (HOBO[â] H8 temperature logger, Onset Computer Corp., Pocasset, MA). We attached a large nail 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.

We deployed the egg thermistors on the day the nest was found or shortly thereafter. After installing an egg thermistor, we buried the cable and data-logger under vegetation and organic soil to conceal them from predators. We covered the egg thermistor and the rest of the clutch with the 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 a storage capacity large enough to record the entire incubation period. After hatch (or failure), we checked each nest to judge its fate and retrieved the egg thermistor. We placed one data-logger in a shaded location and programmed it to record ambient temperature at 10-min intervals.

We used Sony CCD-TR 516 video camera recorders each 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, we strapped the case to an aluminum sawhorse stand and secured the stand with guy lines to the surrounding tundra to stabilize the camera during windy conditions. We staked the solar battery charger to the ground near the unit. We placed the video camera a minimum of 65 m from the nest and used the zoom lens to center the nest in a field of view approximately 5 m across at the nest site. During setup, we connected a 2.2-in video monitor (Citizen ST055) to the video camera to act as a viewfinder for reviewing camera control features. We attempted to program each camera identically, but nevertheless, one camera recorded 1 sec of videotape (Sony P6-150HGD) and four cameras recorded 2 sec of videotape 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 5–10 d, depending on the duration of each recording interval, before it required replacing.

We distinguished three types of behavior 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 on the nest incubating, and breaks, when the female stands above the nest and rearranges the eggs, nesting material, or changes position. 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, we used the same decision rules developed in 1998 from two White-fronted Goose nests monitored with both an egg thermistor and a time-lapse camera (see Appendix B for details of behavior classification from temperature records). We matched nesting behavior seen on videotape with patterns of egg temperatures recorded by thermistors.

In addition to recording nest attendance, cameras were used to record nesting behaviors, occurrences of predation, and other disturbances at nests. We recorded the time and duration of any periods that predators were observed near or at the nest. 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 sources of direct disturbance at the nest included humans, caribou, and non-predatory bird species (e.g., swans, geese, and ducks). At Tundra Swan nests monitored by video cameras, we identified alert and concealment behavior and incubation exchanges 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, the length of recesses, and total time off the nest. The length of incubation breaks could not be measured with egg thermistors because they were shorter than the 5-min interval between recordings. We eliminated any days of partial monitoring, which included the day the egg thermistor and/or camera was installed and the day of hatch. We also eliminated 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. 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 our objective with this nest monitoring was to identify the effects of aircraft and the airstrip on nesting behavior, we identified unrelated human disturbance that could confound our evaluation. We subtracted 30 min from the beginning and added 30 min to the end (i.e, increased the duration by 60 min) of the period human activity within 200 m of a nest to account for any change of the bird's behavior as the pedestrians approached or departed; we defined this time period as "disturbed", whether we detected a response to the pedestrians 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. We also subtracted from the total time of video monitoring 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. 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.

We tested for differences in nesting behavior between successful and failed White-fronted goose nests using data from egg thermistors. We ranked the incubation data because they violated assumptions of equality of variances and normality, and used a nested ANOVA (SPSS) of individual nests within nest fate to evaluate variation among nests and between successful and failed nests.

DISTURBANCE MONITORING

We included the airstrip in the view of four of the video cameras and the helipad, located on Alpine Pad 1, in the view of one camera. We recorded the time that people, aircraft, and vehicles entered and exited each camera view. For the days before and after video coverage, we used aircraft landing and takeoff times recorded by the Alpine security office. We calculated the frequency of occurrence of each activity by day for the period that we monitored nesting (June 11–July 12). In addition, for people and each type of vehicle, we calculated the amount of time they were active on the airstrip and the cumulative number of person or vehicle minutes (the number of people or vehicle type multiplied by the time present). We did not include the time when vehicles were parked and immobile. We recorded activity for the airstrip and the helipad separately because they had distinctly different activities and traffic patterns.

We analyzed the effects of disturbance variables on the nesting behavior of geese monitored with egg thermistors in several steps. All data were summarized by nest and day. Our measures of nesting behavior from egg thermistors included incubation constancy, time off nest, time on nest, number of recesses, and number of incubation breaks. We considered an array of variables that might affect nesting behavior: frequency of landings and takeoffs of DC-6s, Twin Otters, small planes (C-207 and smaller), and helicopters; total time that road machinery, large trucks, small trucks, or pedestrians were on the airstrip; total time that pedestrians were on the tundra; mean SEL, total duration, and number of noise events for each of three sources—airplanes, helicopters, and traffic; mean temperature; and mean wind speed. We used a correlation matrix to select a set of behavior variables and a separate matrix to select disturbance variables by eliminating variables that had correlations (Pearson r) > 0.5. We used this reduced set of variables—airplane and helicopter frequencies, vehicle and pedestrian cumulative durations (total min), noise event durations (total sec) from three sources (airplanes, helicopters, and vehicles), wind speed (mean mph), and air temperature (mean degrees C)—summarized for each day as independent variables in forward stepping multiple regression analyses of White-fronted Goose nesting behavior to select independent variables for analysis of covariance (ANCOVA). Those variables that remained in the stepwise regression with a probability to enter of 0.1 and probability to remove of 0.2, were used in an ANCOVA to evaluate whether their effect on nesting behavior differed between hatched and failed nests.

BREEDING-BIRD PLOTS

Twelve plots for sampling nesting birds were established in 1998. Plots measured 200 x 500 m (10 ha) and were marked by two rows of surveyor's lath that demarked 50 x 50 m grids (Figure 3). We placed six 10-ha plots ("treatment" plots) in locations that were expected to be exposed to loud noise during aircraft landings and take-offs from the airstrip; that is, locations near (within 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). We used the habitat classification map 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). We replaced missing and broken plot markers and recorded locations of nests we encountered opportunistically on 8–10 June 1999. We sampled each plot once between 16 and 22 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 between the ends 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).

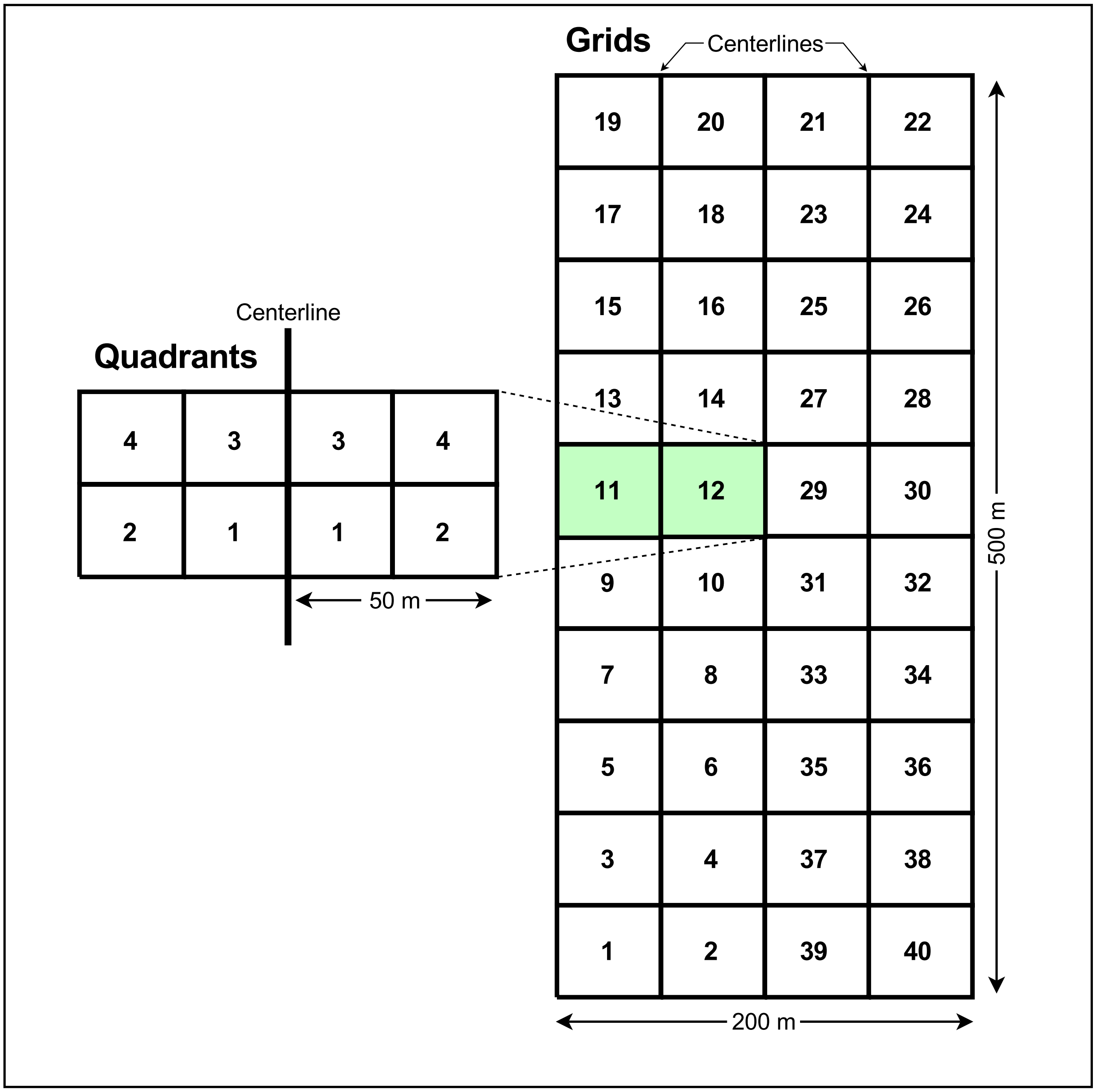

Figure 3. Diagram of layout for breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 1999.

HABITAT ASSOCIATIONS

During July and August 1999, we measured habitat variables on the breeding-bird plots to describe nesting habitat. We described habitat variables at two scales: grids (50 x 50 m) and quadrants (25 x 25 m). We classified grids 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). We measured the distance of the plots (centroid of each plot) to the closest point on the airstrip using GIS. We used

Kruskal-Wallis, Mann-Whitney, and chi-square tests to evaluate differences among plots and plot location (treatment vs. reference).

Habitat use was analyzed with forward stepwise logistic regression (Hosmer and Lemeshow 1989) on 480 grids (40 grids/plot). We ran separate regressions on 1998 and 1999 data for nests of the seven most numerous taxa: all waterfowl, White-fronted Goose, all shorebirds, Pectoral Sandpiper, Semipalmated Sandpiper, all passerines, and Lapland Longspur. Logistic regression identifies variables that significantly affect the probability of an event occurring, in this case a nest occurring in a particular grid. Logistic regressions can include both continuous and categorical independent variables. Continuous variables included surface relief, water cover, water depth, and cover of vegetation types: wet sedge meadow, wet sedge willow, moist sedge shrub, sedge marsh, grass marsh, open low willow, *Dryas* tundra, and partially vegetated mud. Distance to airstrip was transformed into a categorical variable based on quartiles, because we did not have measures of distance to each grid, which was the sample unit for this analysis. We screened the continuous variables for high correlations ($r > 0.7$) and categorical variables for zero cells and potential interactions, and removed variables with these problems from the set of independent variables. We set the probabilities to enter and to remove at 0.2 and 0.4, respectively and tested for model goodness-of-fit with the Hosmer-Lemeshow test or, when expected values were less than 1, the log-likelihood test (Hosmer and Lemeshow 1989, Norusis 1999).

SEASONAL USE OF LAKES

We conducted nine surveys of lakes in the Alpine project area to assess seasonal use of lakes by large waterbirds (Figure 4). A pre-arranged flight path was flown from lake to lake, with each survey following the same sequence of lake visits. Numbers from the Emergency Response Grid (Moulton 1998; Moulton, pers. comm.) were used to identify the lakes covered in these aerial surveys. Helicopters (a Bell 206L Long Ranger or Bell 206B mounted on floats) were used to fly surveys during June (3 surveys), July (3), 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 onto data forms soon after the completion of the aerial survey.

FOX DEN MONITORING

We used aerial and ground-based surveys to evaluate the distribution and status of arctic and red fox dens on the Colville Delta and in the Alpine Transportation Corridor in 1999, continuing the annual monitoring effort begun in 1993 for the Colville wildlife studies. We assessed den status and pup presence at known dens on helicopter-supported ground visits during 29 June–2 July, and then returned to active dens during 12–15 July to count pups; additional observations were made at several dens on 14 and 24 July. Most survey effort focused on checking dens found in previous years, although we also searched opportunistically for undiscovered dens in suitable habitats while travelling 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). Green-up occurs earlier on these traditionally used den sites than on surrounding tundra, a difference that is helpful in locating dens as early as the third week of June.

During ground visits, we evaluated evidence of use by foxes and confirmed the species using the den. Following Garrott (1980), we examined the following fox sign to assess den status: presence or absence of adults and pups; presence and appearance of droppings, diggings, and tracks; trampled vegetation in play areas or beds; shed fur; prey remains; and signs of predation (e.g., pup remains). We classified dens into four categories (following Burgess et al. 1993), the first three of which are considered to be “occupied” dens:

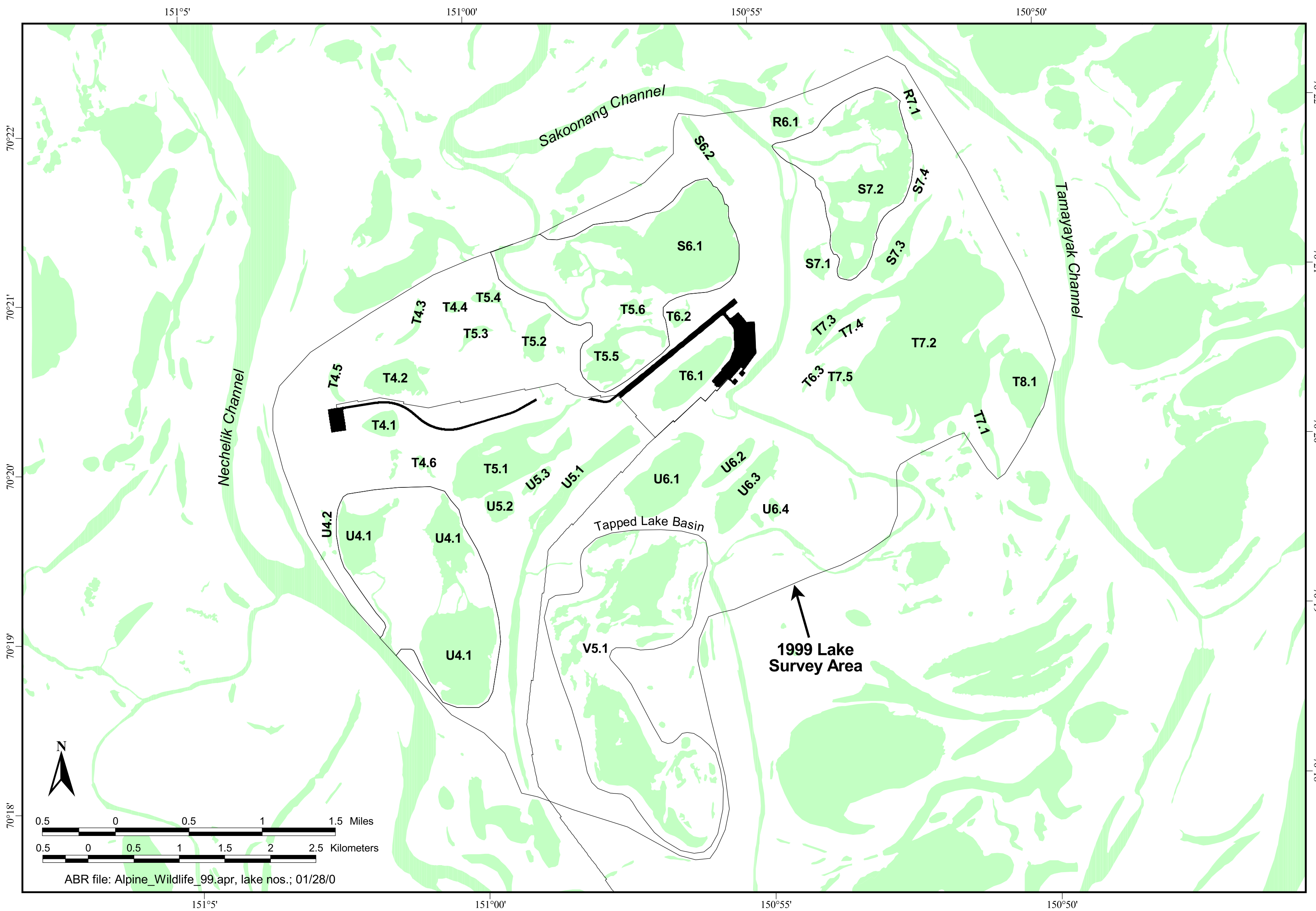

Figure 4. Lake numbers and boundary for lake surveys conducted in the Alpine project area, Colville River Delta, Alaska, 1999. Groups of lakes outlined within the boundary represent basins containing Tapped Lakes (both High- and Low-water Connections).

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 during our visits; 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 during the denning season are needed to classify den status with confidence. Based on our initial assessment of den activity, our observations during 12–15 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 spotting scopes over periods of 2.5–4 h. 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. In 1999, snow and ice cover were relatively persistent. On 7 June, snow cover was approximately 20% at the Alpine Development, but closer to 70% between the Colville River and the Kuparuk Oilfield. By 9 June, snow cover in the Alpine Development had diminished to 5%. On our first aerial lake survey, 10 June, Tapped Lakes with Low Water Connections (henceforth, tapped basins) had been flooded by river discharge, hastening ice melt in the shallowest portions; however, deeper sections of the basins remained frozen. All other lakes were solidly frozen, with the exception of lake U5.1 (see Figure 4) which was almost completely thawed and inundated by snow melt. Some lakes had open water restricted to narrow shore leads, and low-lying polygon fields bordering some lakes were flooded by snow melt. By 16 June, the deeper portions of tapped basins had noticeably diminished ice cover and more extensive open water (2–3 m) along shorelines. Little change was evident in the extent of ice cover of other lakes, although open water shore leads had widened. Shallow (< ~1.5m deep), restricted embayments of the larger lakes were thawing more rapidly than main bodies of lakes. By 22 June, the ice cover of almost all of the lakes in the survey area was restricted to their deeper portions, and was able to shift about in response to wind. All lakes had open water leads along shore. In some of the mid-sized lakes, ice was overriding the downwind lake shores in response to wind. All ice cover in the Alpine area had melted by 6 July. The first emergence of midges was recorded on 17 June, but the primary hatch appeared to be interrupted by cool temperatures until 26 June. Mosquitos briefly emerged on the tundra on 28 and 29 June, but winds ≥16 kph (10 mph) delayed severe mosquito activity until sometime after 30 June. The dates that hatchlings were first observed were 19 June for Lapland Longspur (1 chick), 25 June for Common Redpoll, 2 July for White-fronted Goose ($\bar{x}$ = 5 July, n = 16 nests monitored with temperature sensors), and 6 July for Greater Scaup. These dates of first hatch were 2 to 9 days later than the dates for the same species in 1998 (Johnson et al. 1999b). Compared with the timing of 1996–1998, the snow melt, development of open water on lakes, hatch of midges, and onset of mosquito harassment in 1999 generally were similar to 1997, which was about a week later than in 1996 and 1998.

HUMAN ACTIVITY

The Alpine project area was under full construction in 1999 (Table 1). During late winter and early spring 1999, ice roads and pads were completed and equipment and materials were transported to Pad 1. Ice roads were closed to traffic on 15 May, after which all materials and personnel were transported by aircraft, primarily a DC-6 and Twin Otter. A Bell 206 LR helicopter was stationed on the northwest corner of Pad 1, making flights from 24 May to 7 October. By June 1999, all gravel was in place for Pad 1, Pad 2, and the airstrip with the exception of one section of the connecting road and bridge (Figure 1). Pad 1 contained a 300-man camp, drill rig and separate rig camp, water and waste treatment systems, power generation and communication systems, bulk materials, heavy equipment, and personnel vehicles. During summer, Pad 2 was used as a staging area for spill containment supplies, but was not under construction. Although the gravel footprint of the Alpine airstrip was in place by summer 1999, the packed surface was extended and maintained by heavy equipment during the breeding season. The camp population varied between approximately 100 and 300 people during the breeding season. Nuiqsut Constructors, the primary labor and construction contractor at Alpine, had seven types of heavy equipment for road, airstrip, and pad maintenance, five large trucks, five pickups, and one ATV at Alpine. Several other contractors maintained small numbers of small vehicles (pickups, "Suburbans", and ATVs) on site.

NOISE MONITORING

From 12 through 29 June 1999 we recorded 1,005 noise events (59 events/d) that could be assigned to a known source (Table 2). Noise events were recorded at three monitor locations (35, 148, and 330 m from the airstrip), but we have summarized the highest SEL for each event regardless of recording location. Most noise events attributed to identifiable sources were recorded while vehicles were on the airstrip (752 events), with helicopters (166 events) and fixed-wing aircraft (87 events) accounting for the remainder of the events. The highest SEL was recorded for a helicopter (131 dBA). Although a higher SEL was recorded for a fixed-wing aircraft on 21 June, wind speeds that day averaged 23 mph, so we eliminated that day from our analyses. The longest noise event (521 sec) was recorded for a helicopter, but the longest cumulative durations (3,386 sec) for any day were produced by vehicles, which were operating on the airstrip for extended periods. Another 4,773 events (280 events/d) occurred when aircraft or vehicles were not known to be present. We assume that a large proportion of these unknown events were generated by gusts or high winds; however, we do not have detailed wind data to confirm this assumption. For unknown events, mean daily wind speed was not significantly correlated with number of events ($r = 0.06$, $P = 0.8$, $n = 17$ d) or mean duration of events ($r = 0.11$, $P = 0.67$), but had a weak relationship with mean SEL ($r = 0.46$, $P = 0.06$). Unknown noise events 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 on the tundra, but we did not have a way to record aircraft activity that did not occur in the view of our video cameras. Similarly, some of the noise events to which we assigned a source based on the timing coinciding with other records may have been produced by wind or activities on Pad1 (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.

The mean SEL generally diminished with distance from the airstrip, although the three sound monitors did not record all the same events (Table 3). Noise events in Table 3 were ≥10 sec long, and therefore fewer events were recorded than in Table 2, where noise events ≥2 sec long are reported. The monitor 35 m from the airstrip malfunctioned initially, and was not operational until 20 June; therefore, it recorded fewer noise events than the other monitors. The helicopter generally had higher SELs and durations than fixed-wing aircraft or vehicles in June. The helicopter also produced the largest number of noise events at two different locations in June, probably because it passed over or near the monitors while in transit. The largest number of noise events at one location in June was attributed to machinery, which operated for extended periods of time maintaining the airstrip. Large and small trucks produced fewer and shorter noise events with lower SELs than did helicopters and machinery. Due to the malfunction in the monitor at 35 m during June, July–August provided the best comparative data for types of fixed-wing aircraft. In July–August, helicopters and vehicles were active, but because we were no longer monitoring the airstrip with video cameras, noise events could not be attributed to them. The DC-6 produced the most numerous (116) and longest (maximum = 580 sec) noise events at 25 m from the airstrip. The mean SEL was high (131 dBA), but all SELs in July–August (Appendix C) were high relative to June readings, because in July we recorded

Table 2. Mean (logarithmic) sound exposure levels (SEL) in A-weighted decibels (dBA) and the duration (sec) of noise events exceeding 85 dBA for ≥2 secs recorded at noise monitors from three locations around the Alpine airstrip, Colville Delta, Alaska, 1999. Events were averaged separately at each monitor and the highest mean is reported.

	Fixed-Wing Aircraft						Helicopter						Vehicle Traffic						Unknown Source					
	SEL		Duration (sec)				SEL		Duration (sec)				SEL		Duration (sec)				SEL		Duration (sec)			
Date	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*
12 June						0	111.8	114.6	8.4	15	126.3	15	111.9	128.8	8.3	173.6	3,386.0	410	113.5	130.5	11.0	288.8	8,629.80	784
13 June	111.8	118.1	8.3	24.4	375.0	45	109.8	112.8	6.5	12.4	417.5	64	110.6	121.7	7.2	48.6	1,354.8	187	111.1	125.1	7.6	109.9	13,423.90	1,778
14 June	93.7	94.1	4.4	4.5	8.8	2						0	82.5	82.7	2.4	2.5	4.7	2	91.5	94.1	6.4	11.1	45.0	7
15 June						0						0						0	104.9	109.8	55.5	303.9	499.1	9
16 June	95.5	95.5	5.3	5.3	5.3	1	96.1	96.1	6.4	6.4	6.4	1	95.8	99.0	12.0	21.4	72.1	6	93.7	102.5	9.0	64.5	108.2	12
17 June						0	96.1	100.9	9.8	30.4	107.7	11	84.4	90.8	3.6	6.1	221.7	62	92.4	113.8	5.1	87.1	1,774.1	348
18 June						0	102.7	114.4	32.7	520.8	817.7	25	90.2	99.4	3.8	10.4	98.5	26	102.4	120.1	16.1	538.8	2,270.9	141
19 June	98.9	112.6	4.3	32.1	123.5	29	89.9	97.9	3.9	17.5	65.5	17	88.9	91.3	2.5	3.5	40.5	16	94.2	110.0	5.4	224.2	1,634.8	305
20 June	93.6	93.6	3.4	3.4	3.4	1	90.8	92.1	2.7	3.6	8.2	3	93.5	96.0	4.0	5.6	24.0	6						0
21 June[a]	130.9	133.9	355.1	703.7	710.1	2	94.0	103.2	4.5	16.2	93.7	21	76.0	77.4	2.5	2.8	4.9	2	117.0	134.1	8.0	252.4	2,767.6	344
22 June						0	116.0	131.4	14.0	275.8	911.8	65	109.2	109.6	6.1	6.3	98.1	16	111.8	126.1	9.0	114.2	10,631.2	1,180
23 June	96.7	98.8	5.0	5.0	9.9	2						0						0	92.5	99.2	2.9	4.9	37.6	13
24 June	96.8	98.7	5.2	5.2	10.4	2						0						0	87.6	89.5	2.5	2.9	12.4	5
25 June	100.1	100.3	5.3	5.3	10.5	2	98.7	98.7	5.2	5.2	5.2	1	74.9	75.5	2.6	3.0	5.2	2	81.7	90.2	2.6	5.6	109.7	43
26 June	112.1	115.1	7.4	12.4	14.8	2	75.6	77.5	2.3	2.9	13.9	6	75.7	77.2	2.4	2.7	16.6	7	93.2	114.5	2.4	8.7	332.4	139
27 June						0						0						0	107.4	113.4	4.6	8.7	18.5	4
28 June	90.8	90.8	4.1	4.1	4.1	1	91.4	91.4	3.2	3.2	3.2	1	92.9	98.1	3.1	5.2	34.4	11	75.9	75.9	2.0	2.0	2.0	1
29 June							101.9	101.9	6.1	6.1	6.1	1	96.7	96.7	4.9	4.9	4.9	1	94.5	98.6	3.4	5.3	13.7	4

[a]Wind speed >20mph; day was excluded from summaries and analyses.

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 10 secs recorded at noise monitors from six locations around the Alpine airstrip, Colville Delta, Alaska, 1999. *n* = number of noise events. Video cameras were not operational during July, so no data is available for occurrence of helicopter and vehicle traffic.

	Distance of Monitor from Airstrip (Dates Active)																	
	35 m (20 June-29 June)						148 m (12 June-22 June)						330 m (12 June-19 June)					
North of Airstrip	SEL			Duration			SEL			Duration			SEL			Duration		
	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*
DC-6	115	115	115	12	12	1	-	-	-	-	-	0	113	113	113	32	32	1
C-207	-	-	-	-	-	0	115	112	118	15	24	10	-	-	-	-	-	0
Twin Otter	-	-	-	-	-	0	-	-	-	-	-	0	-	-	-	-	-	0
Helicopter	-	-	-	-	-	0	120	112	131	29	276	24	106	95	114	65	521	13
Large Truck	-	-	-	-	-	0	118	113	127	25	174	22	-	-	-	-	-	0
Machinery	-	-	-	-	-	0	117	111	129	21	113	43	-	-	-	-	-	0
Small Truck	-	-	-	-	-	0	116	112	122	19	49	19	98	96	99	17	21	6
Unknown	-	-	-	-	-	0	117	109	131	21	289	645	107	90	120	62	539	66
	Distance of Monitor from Airstrip (Dates Active)																	
	25 m (14 July-24 August)						85 m (13 July-23 August)						130 m (13 July-24 August)					
South of Airstrip	SEL			Duration			SEL			Duration			SEL			Duration		
	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*	$\bar{x}$	Min	Max	$\bar{x}$	Max	*n*
DC-6	131	87	148	39	580	116	109	103	114	11	14	7	104	104	104	11	11	1
C-207	120	103	124	28	40	4	-	-	-	-	-	0	-	-	-	-	-	0
Twin Otter	137	83	155	23	109	55	128	98	132	18	22	5	-	-	-	-	-	0
Helicopter	-	-	-	-	-	nd	-	-	-	-	-	nd	-	-	-	-	-	nd
Large Truck	-	-	-	-	-	nd	-	-	-	-	-	nd	-	-	-	-	-	nd
Machinery	-	-	-	-	-	nd	-	-	-	-	-	nd	-	-	-	-	-	nd
Small Truck	-	-	-	-	-	nd	-	-	-	-	-	nd	-	-	-	-	-	nd
Unknown	132	80	158	32	580	2,316	126	66	137	29	375	299	125	78	129	13	14	17

noise events ≥10 sec in duration compared with ≥2 sec in June–August, and SEL is a function of duration as well as sound intensity. The high SEL values for the Twin Otter were not expected, and might be due to anomalous measurements (e.g., wind-affected recordings).

NEST DENSITIES AND DISTRIBUTION

ALL SPECIES

In 1999, we searched an area of 15.7 km^2 around the Alpine airstrip (Figure 5). This area overlapped extensively with the areas searched in previous years; the area that was searched in common in all years comprised 10.6 km^2 (henceforth referred to as the common ground-search area; for the 1998 search area boundaries, see Johnson et al. 1999b: Figure 5; for 1996 and 1997 boundaries, see Johnson et al. 1998: Figure 10). Search effort varied among years; the number of hours spent in the common ground-search area each year was highest in 1999 (429 h) and lowest in 1996 (218) (Table 4). Adjusting for the annual levels of search effort, the number of nests found was highest in 1997 (63 nests) and lowest in 1996 (44 nests).

In the common ground-search area, we found the nests of 22 species between 1996 and 1999, but only six of these species had nests in all four years. The largest number of species found was in 1998 (16). 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) (Table 4). Ducks were the second most abundant group with Northern Pintails and Oldsquaws usually the most common nesting ducks. Tundra Swans produced 2–4 nests each year within the common ground-search area. Nests of Pacific Loons (1–3 nests) were found in each year, those of Red-throated Loons (1–4 nests) were found in 3 of 4 years, but nests of Yellow-billed Loons (1 nest) were found during the ground search in 1996 and 1997 (two nests were found after nest searching in 1998). In 1999, we recorded the first nest of a Sandhill Crane and the first Horned Grebes (no nests were found) within the common ground-search area. We have found 2–3 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 are 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 1999 (429 h), we found the highest number of nests (94 nests or 8.9 nests/km^2, not standardized for effort; Appendix D1). The previous high was in 1997 (78 nests, 271 h of searching). Within the total area searched in 1999 (15.7 km^2), we found 154 nests (9.8 nests/km^2) belonging to 18 species, producing the highest nest density found in all years of surveys (Figure 5, Appendix D2). The lowest density occurred in 1996 (3.7 nests/km^2) and the lowest species richness occurred in 1997 (14 species).

By far, the most abundant large waterbird nesting in 1999 in the total area searched in the Alpine project area (15.7 km^2, Figure 5) was the White-fronted Goose (79 nests, not standardized for effort; Appendix D2). Ducks were the second most abundant group, led by Northern Pintails (9 nests), Greater Scaup (6), Oldsquaws (5), and Green-winged Teal (4). Seven Tundra Swan nests were found in the 1999 search area. One Spectacled Eider nest and one Canada Goose nest were found in 1999; the first record of these birds nesting in the Alpine project area was in 1998, although a Spectacled Eider brood was observed there in 1993 (Smith et al. 1994). Both these species nest in other areas of the Colville Delta, although Canada Geese appear to have begun nesting on the delta only recently (Johnson et al. 1999b). We also located 21 Willow Ptarmigan nests in the nest search area, which was the highest number ever recorded. These nests were not included in the total because ptarmigan nests have been recorded inconsistently in previous years. In 1999, we found two Red-necked Grebe nests on a lake within 1,000 m of the Alpine airstrip (Figure 5), and two additional nests were found in the surrounding area during aerial lake surveys.

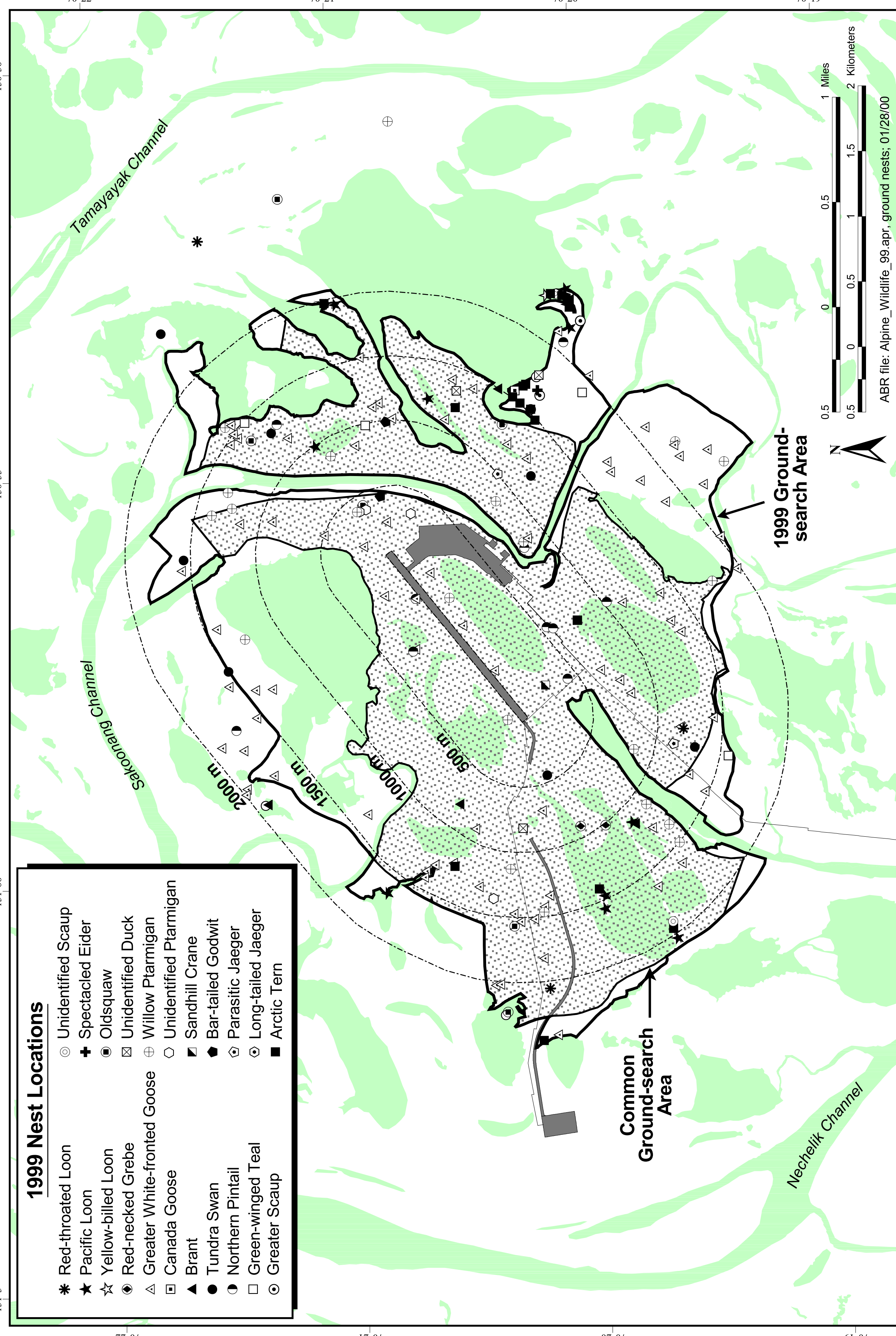

Figure 5. Locations of nests found during nest searches in the Alpine project area, Colville River Delta, Alaska, 1999.

Table 4. Numbers and densities, standardized by search effort, of nests of selected species found within the common ground-search area in 1996–1999, in the Alpine project area, Colville River Delta, Alaska. Search area boundary is displayed in Figure 5. 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	1996	1997	1998	1999
Red-throated Loon	1	4.0	0.7	0	0.1	0.4	0.1	0
Pacific Loon	2	3.2	0.7	2.5	0.2	0.3	0.1	0.2
Yellow-billed Loon	1	0.8	0	0	0.1	0.1	0	0
Red-necked Grebe	0	2.4	1.5	1.0	0	0.2	0.1	0.1
Greater White-fronted Goose	25	28.1	22.5	26.9	2.4	2.7	2.1	2.5
Canada Goose	0	0	0	0	0	0	0	0
Brant	0	3.2	0.7	1.0[a]	0	0.3	0.1	0.1[a]
Tundra Swan	3	3.2	3.6	2.0	0.3	0.3	0.3	0.2
Northern Shoveler	0	0	3.6[b]	0	0	0	0.3[b]	0
Northern Pintail	2	3.2	5.1[b]	4.1[b]	0.2	0.3	0.5[b]	0.4[b]
Green-winged Teal	1	0	0.7	1.0[b]	0.1	0	0.1	0.1[b]
Greater Scaup	0	0.8	0.7	0	0	0.1	0.1	0
Lesser Scaup	0	0	0.7	0	0	0	0.1	0
Unidentified scaup	0	0	0	0.5[b]	0	0	0	<0.1[b]
Spectacled Eider	0	0	0	0	0	0	0	0
King Eider	0	0	0	0	0	0	0	0
Oldsquaw	6	7.2	3.6[b]	2.0[b]	0.6	0.7	0.3[b]	0.2[b]
Unidentified duck	0	0	1.5	1.0	0	0	0.1	0.1
Willow Ptarmigan	1	8.8	nd	8.1	0.1	0.8	nd	0.8
Unidentified ptarmigan	0	0	nd	1.5	0	0	nd	0.1
Sandhill Crane	0	0	0	0.5	0	0	0	0
Bar-tailed Godwit	0	0	1.5	1.0	0	0	0.1	0.1
Common Snipe	0	0.8	0	0	0	0.1	0	0
Parasitic Jaeger	1	0.8	1.5	1.0	0.1	0.1	0.1	0.1
Long-tailed Jaeger	1	0	0.7	0.5	0.1	0	0.1	0.0
Glaucous Gull	0	0.8	0	0	0	0.1	0	0.0
Sabine's Gull	1	0	0	0	0.1	0	0	0.0
Arctic Tern	0	4.0	2.2	2.5	0	0.4	0.2	0.2
Short-eared Owl	0	0	0	0	0	0	0	0
Search hours	218	271	300	429				
Adjusting ratio[c]	1.0	0.8	0.7	0.5	1.0	0.8	0.7	0.5
Standardized total[de]	44	62.7	51.5	47.8	4.2	5.9	4.9	4.5
Total number of species[e]	11	13	16	14				

[a] Includes nest identified from down and nest characteristics.
[b] Includes nests identified from feather and down samples.
[c] $Ratio_{year}$ = search $hours_{1996}$/ search $hours_{year}$
[d] Standardized $total_{year}$ = adjusting $ratio_{year}$ • total $nests_{year}$.
[e] Does not include Willow or unidentified ptarmigan.

During the nest search in 1999, we found 146 nests of waterbirds within 2,000 m of the airstrip; 68 were nests of White-fronted Geese and 78 were nests of other species (Table 5, Figure 5). The density of nests in 1999 was lowest between 500 and 1,000 m of the airstrip (6.4 nests/km^2) and greatest between 1,000 and 1,500 m (12.1 nests/km^2). Habitat distribution, as defined by our map of the project area (Figure 2), did not explain the densities of nests observed around the airstrip. Most of the nests found in the search area were in three habitats: Wet Sedge-Willow Meadow (91 of 146 nests, 62%), Moist Sedge-Shrub Meadow(22 nests, 15%,), and Nonpatterned Wet Meadow, (15 nests, 10%). The density of nests by distance category within these three habitats combined followed the same pattern as density in all habitats: the 500–1,000-m buffer had the lowest density (9.6 nests/km^2), whereas the 1,000–1,500-m buffer had the highest density (19.6 nests/km^2). The density in the nearest (≤500 m) and farthest buffers (1,500–2,000 m) around the airstrip were similar (15.8 nests/km^2 and 16.8 nests/km^2, respectively).

To further evaluate the effects of activity around the airstrip we compared the mean distance of nests from the airstrip in 1999 with the distance of nests from the airstrip's current location in years prior to its construction (1996 and 1997) and during early construction (1998). Despite varying levels of human activity in the project area from 1996 to 1999 (Table 1), the distance of nests from the airstrip did not differ significantly among the years (using data from only the common ground-search area, one-way ANOVA, P = 0.34). The mean distance from the airstrip was highest in 1996 ($\bar{x}$ = 1,134, n = 44) and lowest in 1998 ($\bar{x}$ = 1,029, n = 72), the first year the airstrip was actually in place, although it was used during nesting for landings only by a helicopter (Table 6).

GREATER WHITE-FRONTED GEESE

White-fronted Geese are the most numerous waterfowl species nesting in the Alpine project area. Within the common ground-search area in 1999, 27 White-fronted Goose nests (standardized for effort) were found (Table 4, Figure 6); the lowest number of nests was found in 1998 (23 nests) and the highest in 1997 (28 nests). The actual number of nests in 1999 (not standardized for effort) found within the common ground-search area (53 nests, 5.0 nests/km^2) and in the total area searched (79 nests or 5.0 nests/km^2) were higher than in any previous year (Appendices D1, D2), but our search effort also was greater. The densities of White-fronted Goose nests in the Alpine project area are high compared with other 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 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.

White-fronted Geese nested in 6 of 16 available habitats in the common ground-search area in 1999 (Table 7). 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) Tapped Lake with High-water Connection and Deep Open Water without Islands. Most nests (34 of 53, 64%) found in 1999 were in Wet Sedge–Willow Meadow, but other habitats were used as well: Moist Sedge–Shrub Meadow (9 nests, 17%), Aquatic Sedge with Deep Polygons (4 nests, 8%), Nonpatterned Wet Meadow (3 nests, 6%), Riverine or Upland Shrub (2 nests, 4%) and Salt Marsh (1 nest, 2%). 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 ($\bar{x}$ = 125.7 m, n = 79) from the nearest permanent waterbody. In 1996, 1997, and 1998, White-fronted Geese also preferred Wet Sedge–Willow Meadow, but none of the habitats were avoided (Appendix D3).

During the nest search in 1999, we found 68 nests ≤2,000 m from the airstrip ($\bar{x}$ = 1,204 m, range 28–1,995 m; Table 5). Fifty-one nests (75%, 6.1 nests/km^2) were >1,000 m from the airstrip, compared to 17 nests (2.8 nests/km^2) within 1,000 m of the airstrip. The higher densities at greater distances from airstrip cannot be explained by the distribution of habitats around the airstrip (Figure 2). The preferred nesting habitats for White-fronted Geese, Wet Sedge–Willow Meadow and Aquatic Sedge with Deep Polygons (Table 7), occurred in increasing proportions (14%, 32%, 47%, and 51%) in the successive distance buffers around the airstrip. However, the density of

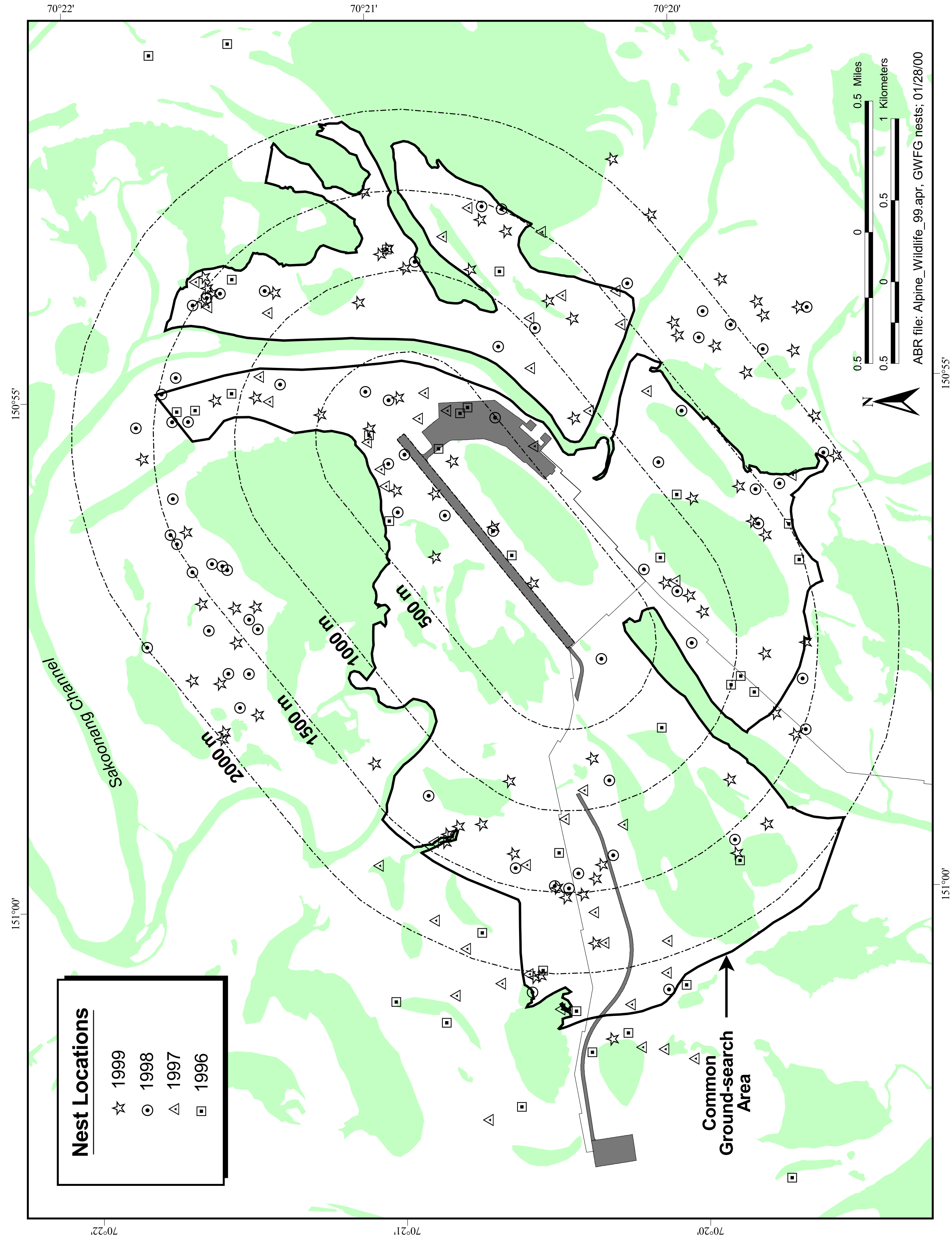

Figure 6. Locations of Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 1996–1999.

Table 5. 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 1999.

Species	Density (nests/km^2) by Distance Buffer				Total Nests	Distance (m) from Airstrip	
	0–500 m	500–1,000 m	1,000–1,500 m	1,500–2,000 m		$\bar{x}$	Range
Red-throated Loon	0	0	0	0	0		
Pacific Loon	0	0.3	0.4	0.3	2	1,289.0	988–1,564
Yellow-billed Loon	0	0	0	0	0		
Red-necked Grebe	0	0.3	0.2	0	2	963.2	913–1,014
Greater White-fronted Goose	3.6	2.2	6.8	5.1	68	1,203.9	28–1,995
Canada Goose	0	0	0	0.3	1	1,550.9	
Brant[a]	0	0.3	0.2	0.3	3	1,515.8	790–1,484
Tundra Swan	0.4	0	0.6	0.6	6	1,210.8	449–1,548
Northern Pintail[b]	1.2	0.8	0.4	0	8	628.0	32–1,301
Green-winged Teal[c]	0	0.3	0.2	0.6	4	1,481.0	981–1,899
Greater Scaup	0	0	0	0.9	3	1,635	1,522–1,736
Unidentified scaup	0	0	0	0.3	1	1,914.8	
Spectacled Eider	0	0	0	0.3	1	1,663.0	
Oldsquaw[d]	0.4	0	0.4	0.3	4	1,368.7	409–1,568
Unidentified duck	0	0.3	0.2	0	2	1,069.3	815–1,324
Willow Ptarmigan	1.2	1.1	1.6	0.9	18	1,057.5	75–1,755
Unidentified ptarmigan	0.8	0	0.2	0	3	687.2	323–1,371
Sandhill Crane	0.4	0	0	0	1	262.1	
Bar-tailed Godwit	0.4	0.3	0	0	2	707.4	425–989
Parasitic Jaeger	0	0.3	0.2	0	2	1,065.3	1,000–1,131
Long-tailed Jaeger	0.4	0	0	0	1	382.3	
Arctic Tern	0	0.3	0.8	2.1	12	1,482.1	764–1,964
Area (km^2) searched	2.5	3.6	5.0	3.4	14.3		
Total density	8.8	6.4	12.1	11.9	10.2		
Total nests	22	23	61	40	146	1,167.5	28–1,995

[a] Includes a probable Brant nest determined from down and nest characteristics.
[b] Includes probable Northern Pintails nests (3) determined from feather and down samples.
[c] Includes a probable Green-winged Teal nest determined from feather and down samples.
[d] Includes a probable Oldsquaw nest determined from feather and down samples.

White-fronted Goose nests in these preferred habitats also increased from the 0–500-m to 1,000–1,500-m buffers (2.9, 5.2, and 11.9 nests/km^2, respectively), then declined in the 1,500–2,000-m buffer (8.7 nests/km^2). The lower nest densities of the preferred habitats in the two distance buffers nearest to the airstrip may be an indication of geese avoiding nest sites near the airstrip.

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 ($0.38 \leq R \leq 0.52$, $-6.70 \leq Z \leq -5.70$, $P < 0.0001$, where a random pattern has $R = 1.0$). The distance of nests to the airstrip in 1998 and 1999, or to its current location in 1996 and 1997, did not explain the variation in nearest-neighbor distances ($r^2 < 0.01$; $P > 0.18$); that is, distances between nests were not linearly related to distance from the airstrip.

As for all nests combined, comparison among years (1996–1999) found no annual pattern in the distribution of White-fronted Goose nests relative to the airstrip. The distance of nests from the airstrip did not differ significantly among years (one-way ANOVA, $P = 0.82$). The mean distance of nests in 1997 (1,172 m, $n = 35$) was only slightly greater than

Table 6. Mean distances of nests from the airstrip in the common ground-search area of the Alpine project area, Colville River Delta, Alaska, 1996–1999.

Year	Distance (m) $\bar{x}$	SE	*n*	Test	F	*P*-value
All Species						
1996	1,134	338.6	44			
1997	1,147	68.2	89			
1998	1,029	64.0	72			
1999	1,051	46.6	113			
All Years	1,112	55.0	318	ANOVA	1.112	0.34
Greater White-fronted Goose						
1996	1,040	113.6	25			
1997	1,172	101.6	35			
1998	1,085	102.8	31			
1999	1,094	69.8	53			
All Years	1,102	46.0	144	ANOVA	0.305	0.82

the mean distances in 1996 (1,040 m, $n = 25$), 1998 (1,085 m, $n = 31$), and 1999 (1,094 m, $n = 53$) (Table 6). The lack of relationship between nearest-neighbor measurements and distance to the airstrip and the similarity of distances of nests (White-fronted Geese and all species combined) to the airstrip among years suggests that the addition of construction activities in 1998 and aircraft flights in 1999 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 birds nesting near the site of the present airstrip. One caution we advise in interpreting this result is that we have not taken into account the possible interactions of habitat and the variety of scales over which a response might be detected. After collection of nesting data in 2000, 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 diversity of the project area.

TUNDRA SWANS

Similar numbers and densities of Tundra Swan nests were found in the common ground-search area during all four years (range = 3–5 nests) (Appendix D1). In 1999, seven swan nests (0.4 nests/km^2) were found in the total area searched (Appendix D2); four of these were in the common ground-search area (0.4 nests/km^2) (Appendix D1). Five nests (0.5 nests/km^2) were found in the common ground-search area in 1998, four were found in 1997, and three were found in 1996 (plus two found on an aerial survey). The sample sizes of nests were too small to test for annual habitat selection, but in 1999 six of seven nests occurred in habitats that were significantly preferred during five years of study on the Colville Delta (Johnson et al. 1999a): four nests were found in Wet Sedge–Willow Meadow and two nests were found in Moist Sedge–Shrub Meadow. One nest was found in Salt Marsh, a habitat used in proportion to its availability over the entire delta.

The distance of nests from the airstrip did not differ significantly between 1999 ($\bar{x}$ = 1,055 m, $n = 4$), 1998 ($\bar{x}$ = 914 m, $n = 5$), 1997 ($\bar{x}$ = 1,212 m, $n = 4$), or 1996 ($\bar{x}$ = 1,309 m, $n = 5$) (ANOVA, $P = 0.77$). In 1999, the closest nest to the airstrip was 449 m from the western end of the strip (Figure 5); this site was also occupied annually in 1995–1998. Despite the nest's proximity to the airstrip

Table 7. Habitat selection by Greater White-fronted Geese during nesting in the Alpine project area, Colville River Delta, Alaska, 1999. Only nests found in 1999 within the common area searched in all four years (1996–1999) are included.

Habitat	Area (km^2)	No. of Nests	Use (%)	Availability (%)	Monte Carlo Results[a]
Open Nearshore Water (marine)	0	0	0	0	-
Brackish Water	0	0	0	0	-
Tapped Lake w/Low-water Connection	0.28	0	0	2.7	ns
Tapped Lake w/High-water Connection	0.79	0	0	7.4	avoid
Salt Marsh	0.60	1	1.9	5.7	ns
Tidal Flat	0	0	0	0	-
Salt-killed Tundra	0	0	0	0	-
Deep Open Water w/o Islands	0.93	0	0	8.7	avoid
Deep Open Water w/Islands or Polygonized Margins	<01	0	0	<0.1	ns
Shallow Open Water w/o Islands	01	0	0	0.1	ns
Shallow Open Water w/Islands or Polygonized Margins	04	0	0	0.4	ns
River or Stream	<01	0	0	<0.1	ns
Aquatic Sedge Marsh	0	0	0	0	-
Aquatic Sedge w/Deep Polygons	0.12	4	7.5	1.1	prefer
Aquatic Grass Marsh	0.10	0	0	0.9	ns
Young Basin Wetland Complex	0	0	0	0	-
Old Basin Wetland Complex	0	0	0	0	-
Nonpatterned Wet Meadow	1.01	3	5.7	9.5	ns
Wet Sedge–Willow Meadow	4.44	34	64.2	41.7	prefer
Moist Sedge–Shrub Meadow	1.29	9	17.0	12.1	ns
Moist Tussock Tundra	0	0	0	0	-
Riverine or Upland Shrub	0.49	2	3.8	4.6	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0	2.2	ns
Artificial (water, fill, peat road)	0.30	0	0	2.9	ns
Total	10.63	53	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.

and its location under the takeoff and landing patterns of aircraft, four eggs hatched successfully in this nest. 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 cone 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 two days of nest searching, resulting in prolonged concealment on the nest and incubation recesses off the nest. Although this nest also hatched successfully in 1998, the nest site was not reused in 1999.

NESTING BEHAVIOR AND DISTURBANCE MONITORING

GREATER WHITE-FRONTED GEESE

In 1999, we deployed one egg thermistor in each of 42 White-fronted Goose nests (Figure 7). Three nests with egg thermistors also were monitored simultaneously with time-lapse video cameras. The mean distance from nests monitored with egg thermistors to the airstrip was 1,303 m (range = 28–2,360 m, $n = 42$) and the mean distance of nests monitored with video cameras was 60 m (range = 28–118 m, $n = 3$). Of the 42 egg thermistors that we deployed in White-fronted Goose nests, we obtained temperature data for 29 nests from the time of deployment to the time of brood departure or nest failure. In the remaining 13 nests, 5 nest failed within 48 h after we deployed the egg thermistor, and the rest produced erroneous readings because the thermistors were expelled from the nests or repositioned where they were not consistently incubated.

Nest Attendance

Incubation constancy was measured using the temperature data at 12 White-fronted Goose nests that hatched successfully and at 17 nests that failed. Successful female White-fronted Geese spent 99.0% of their time incubating (Table 8). Each bird maintained a high nest-attendance rate during the monitoring period, sometimes incubating 1–2 d without a recess. Mean number of recesses for the successful nests remained relatively constant during the 24 d before hatch and averaged 0.9 recesses/d (Figure 8, Table 9). Mean recess length was 15.9 min/recess, and mean time off the nest was 13.9 min/d. A higher than average number of recesses (2) was taken two days before hatch, resulting in more time spent off the nest on that day compared to other days; however, mean recess length did not deviate from the overall average on that day. One recess by a goose six days before hatch was 8 h long, which resulted in a daily mean recess length that was 3.5× longer than that of other days. We have no records of aircraft or other sources of disturbance when this recess was initiated. Despite the unusually long recess, this nest hatched. Except for the day with the 8-h recess, mean recess length remained relatively constant during the 24 d before hatch. In 1998, successful geese (n = 16) spent a similar amount of time incubating (98.9%) and took a slightly higher number of recesses per day (1.3 recesses/d, n = 116 nest·d) (Johnson et al. 1999b). Mean recess length and mean time off nest in 1998 (13 min/recess and 16 min/d, respectively) were similar in 1999.

Most of the nesting parameters we measured with egg thermistors in 1999 differed between successful and failed nests and among nests within both categories of nest fate (Table 9). White-fronted Geese at failed nests spent significantly less time incubating ($\bar{x}$ = 97.8%, nested ANOVA, P = 0.03) than geese at successful nests ($\bar{x}$ = 99.0%), although the difference was slight and there was significant variation among nests within both categories of fate (P <0.001, Table 9, Figure 8). Mean recess length at failed nests ($\bar{x}$ = 18.1 min/recess) was longer than at successful nests ($\bar{x}$ = 15.9 min/recess), but the difference was not significant (nested ANOVA, P = 0.36). Mean recess length varied significantly among nests within each fate (P < 0.001) and appeared to vary more at failed nests (Figure 8). Mean number of recesses (1.7 recesses/d, P = 0.02) and mean time off the nest (31.4 min/d, P = 0.03) for failed nests were about twice the corresponding values for successful nests (Table 9), but as for the other parameters, variation was significant among nests (P < 0.001). As the nests approached the day of failure, there were increasing trends in the number of recesses and time off nest (Figure 8). Failed nests were about the same distance from the airstrip ($\bar{x}$ = 1,223 m, SD = 651, n = 17; Mann-Whitney U test, Z = –0.04, P = 0.98) as successful nests ($\bar{x}$ = 1,122 m, SD = 879, n = 12). Likewise, the mean distance of failed nests to Pad 1 (1,182 m, SD = 445, n = 17; Mann-Whitney U test, Z = –0.04, P = 0.98) was similar to that of successful nests (1,158 m, SD = 797, n = 12), suggesting that airstrip and pad associated activities were not major factors in the failure of nests monitored with thermistors. In 1998, only one goose nest with an egg thermistor failed, and that female also spent less time incubating (94.9%) than did geese of successful nests on average in 1999. Recess frequency, recess length, and time off the nest (3.8 recesses/d, 21 min/recess, and 80 min/d, respectively) all were higher at the failed nest in 1998 compared to failed nests in 1999.

Three White-fronted Goose nests with egg thermistors also were monitored with time-lapse video cameras. 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 (Appendices E1–E3). A comparison of daily incubation behavior recorded by video and thermistor monitoring showed no significant differences in total recess time, number of recesses, or incubation constancy (Wilcoxon signed ranks test of 64 nest·d, $-0.55 \leq Z \leq -0.04$, $P \geq 0.58$ for all three tests). However, we counted significantly more breaks with video camera monitoring ($\bar{x}$ = 15.1 breaks/d, SD = 7.69, n = 64 nest·d) than we did at the same nests monitored with thermistors

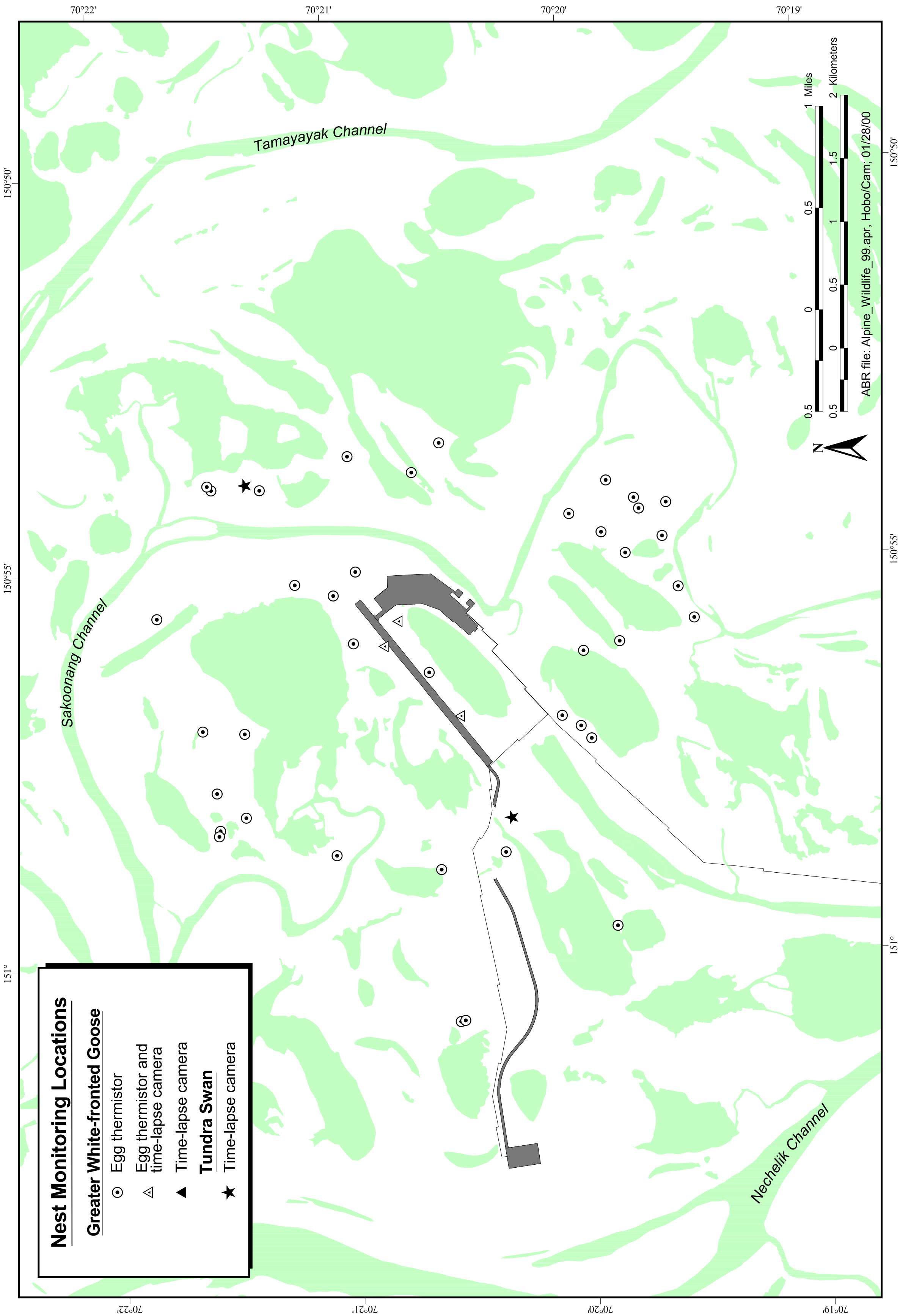

Figure 7. Locations of thermistor eggs and time-lapse cameras in the Alpine project area, Colville River Delta, 1999.

Table 8. Mean incubation constancy (% of time) of Greater White-fronted Geese at successful and failed nests, as determined by egg thermistors (1 recording interval/5 min) in the Alpine project area, Colville River Delta, Alaska, 1999.

Day Before Hatch	Successful		Day Before Failure	Failed	
	%	*n*		%	*n*
24	98.6	1	26	97.9	1
23	98.8	2	25	99.7	2
22	99.3	4	24	97.6	2
21	99.1	8	23	99.4	3
20	99.4	9	22	99.4	4
19	99.0	9	21	99.1	4
18	99.5	9	20	99.1	5
17	98.9	9	19	99.1	5
16	99.2	9	18	99.2	5
15	99.4	10	17	98.7	3
14	99.5	12	16	99.5	4
13	99.1	12	15	99.5	6
12	99.2	12	14	98.1	7
11	99.0	12	13	98.9	6
10	99.2	12	12	98.9	8
9	99.0	11	11	97.7	9
8	99.0	11	10	98.1	10
7	99.4	10	9	98.1	11
6	97.7	11	8	98.8	11
5	98.1	11	7	97.1	12
4	99.3	11	6	97.7	14
3	99.3	11	5	97.8	15
2	98.2	11	4	98.0	15
1	99.7	11	3	97.5	15
Hatch			2	96.9	17
			1	94.1	17
			Failure		
Overall Mean	99.0	228	Overall Mean	97.8	211

n = number of nests monitored each day

($\bar{x}$ = 11.2 breaks/d, SD = 3.8, n = 64 nest·d) (Wilcoxon signed ranks test, $Z = -4.5$, $P < 0.001$), 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 provide good estimation of incubation constancy and recesses, but underestimate incubation breaks.

Effects of Disturbance

Predators, people, and aircraft were easily identifiable disturbance sources during nesting. From the video recordings, we were able to identify defense breaks and defense recesses, which occurred during visits by predators or human disturbance. We recorded a total of three defense breaks for two of the nests. In each case an arctic fox was within 5 m of the nest, and the incubating bird reacted by standing over the nest for 1–7 min.

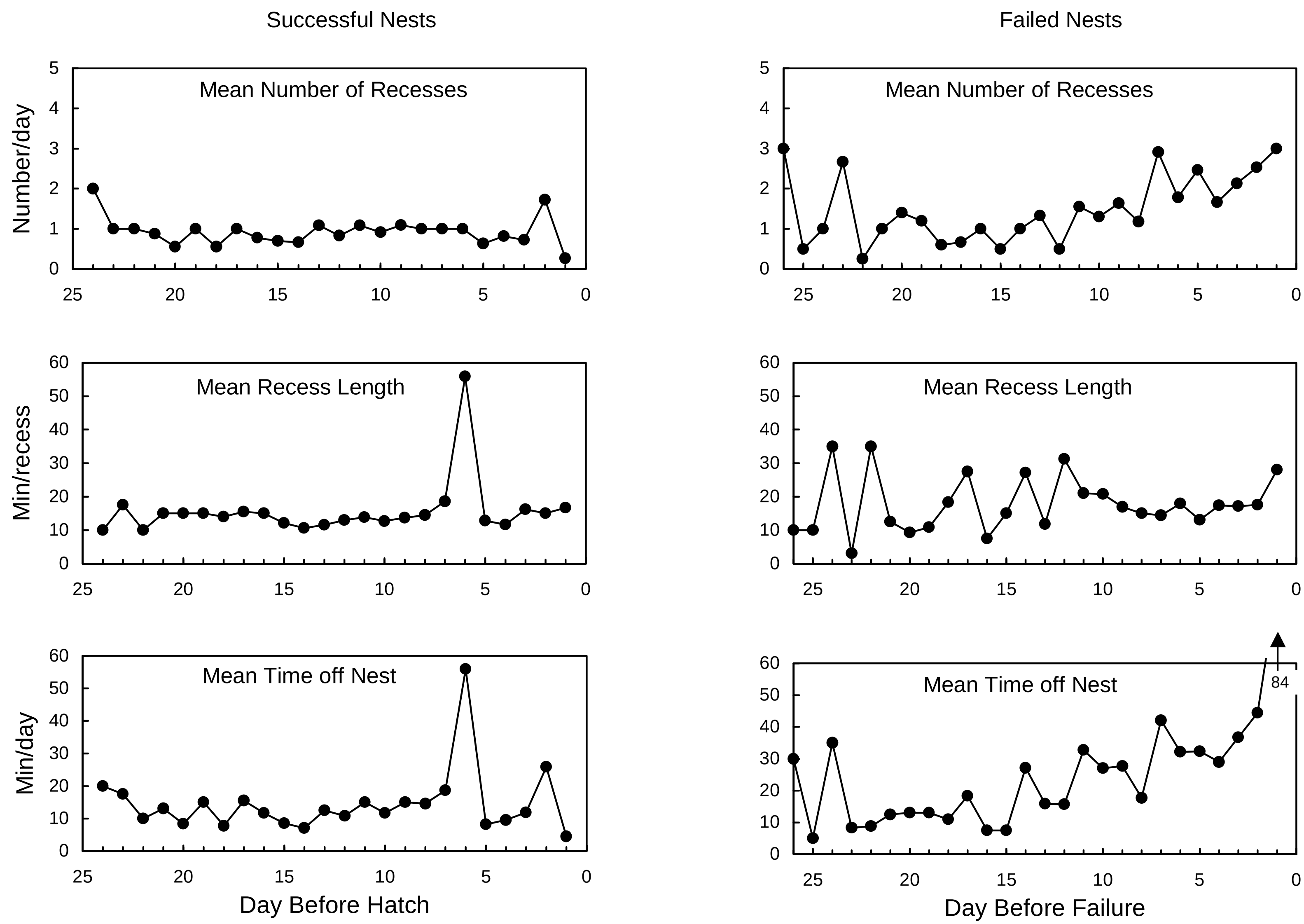

Figure 8. Mean frequency, length, and total time of incubation recesses for 12 successful nests and 17 failed nests of Greater White-fronted Geese monitored by egg thermistors (1 temperature recording/5-min interval) in the Alpine project area, Colville River Delta, Alaska, 1999.

Table 9. Comparison of nesting activities at 12 nests that successfully hatched and 17 that failed of Greater White-fronted Geese monitored by egg thermistors at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 1999. Tests conducted with a nested ANOVA, with nest fate the main effect and individual nests within nest fate the random effect.

							Model Effects							
	Successful			Failed			Fate				Nest w/in Fate			
	$\bar{x}$	SD	*n*	$\bar{x}$	SD	*n*	*df*	MSE	*F*	*P*	*df*	MSE	*F*	*P*
Incubation Constancy (%/d)	99.0	1.8	228	97.8	4.0	211	1	278,992	5.15	0.031	27	65,947	5.80	<0.001
Recess Frequency (no./d)	0.9	0.9	228	1.7	2.0	211	1	278,001	6.58	0.015	27	50,669	4.43	<0.001
Recess Length (min/recess)	15.9	33.8	200	18.1	19.5	366	1	83,108	0.85	0.365	27	152,023	8.24	<0.001
Time Off Nest (min/d)	13.9	25.8	228	31.4	57.3	211	1	279,975	5.23	0.030	27	65,103	5.71	<0.001
Break Frequency (no./d)	10.3	3.2	228	12.5	4.9	211	1	495,815	6.89	0.014	27	88,836	8.72	<0.001
Time Disturbed[a] (min/d)	2.4	11.7	228	0.6	9.0	211	1	87	0.03	0.867	27	3,641	4.08	<0.001

[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.

Each of the three White-fronted Goose nests monitored by video camera provided descriptive information on reactions to disturbance. Five recesses taken by the female at nest 401 (on days 9, 10, 13, 17, and 24 before nest failure) occurred when aircraft (DC-6 during 4 recesses; Twin Otter during 1 recess) were landing or taking off from the airstrip. Mean recess length for the five recesses ($\bar{x}$ = 45.6 min/recess, SD = 54.61) was more than twice as long as the mean for all other recesses for that goose ($\bar{x}$ = 19.2 min/recess, SD = 8.17, n = 84), but the difference was not statistically significantly (Mann-Whitney U test, Z = -1.62, P = 0.10). One prolonged recess (143 min) occurred 1.5 h after the video camera was installed (24 d before failure), which may have been on or before the day incubation commenced (average incubation period of 24 d); this day was not included in our summaries (Appendix E3) because the nest was disturbed by the camera installation and was monitored only part of the day. During this long recess, the goose left the nest from the time the DC-6 landed until 23 min after take-off. This nest was located 28 m from the airstrip and was adjacent to the southwest end of the airstrip, which was most often used for landings and takeoffs into prevailing winds (from the northeast). During the period we monitored this nest, 57 aircraft landed and took off at the airstrip (8 DC-6s, 39 Twin Otters, and 10 small airplanes) (Table 10). No other recesses were initiated during landings or takeoffs. Predation by a red fox caused this nest to fail on or close to the day of hatch. No aircraft were recorded in the area at the time of predation. The other two geese monitored with cameras were 34 and 118 m from the airstrip, but we detected no recesses after the first day of incubation that occurred during aircraft landings or takeoffs (see nest 201 discussion below).

Although we observed jaegers hunting and taking eggs from several nests in the Alpine project area, we observed only one Parasitic Jaeger at a White-fronted Goose nest (nest 006) that was monitored with a video camera. The goose was incubating normally when a DC-6 landed, taxied, and parked. Thirteen minutes later, the goose covered its eggs and left on a recess. Nineteen minutes into the recess, a jaeger appeared at the nest for 3 min then left the field of view followed 2 min later by the return of a goose. The goose stood by the nest and a jaeger returned <2 m from the nest for another 2 min then left. Two minutes later, while the goose still was standing by the nest, the DC-6 taxied for 4 min before takeoff. The goose concealed three times for 1 min each, twice during taxi and takeoff and again 3 min after takeoff. The goose remained off the nest for 70 min after the DC-6 departed. The goose returned to incubate the nest, when one of our biologists (with no knowledge of the previous sequence of events) walked to the camera (105 m from the nest), to change the videotape. The goose stayed on the nest during the tape change. The entire recess lasted 98 min, but was not included in our behavior analysis because it occurred on a day when video coverage was incomplete (thus, number of recesses and recess length could not be calculated). The nest hatched successfully, but one unhatched egg was found in the nest after the brood departed.

The other White-fronted Goose nest monitored with a video camera and an egg thermistor (nest 201) was repeatedly exposed to low altitude helicopter flights. Because of the direction of prevailing winds, nest 201 often was directly under the helicopter's flight path during landing. The nest was adjacent to both the helipad on Pad 1 (111 m) and the portion of the airstrip where planes stopped for loading (118 m). On 11 June, the day the egg thermistor was installed, the female goose initiated four recesses near the time (<5 min) that aircraft were taking off or landing (2 recesses each for a DC-6 and helicopter). Times for the aircraft and recesses on 11 June could not be aligned more precisely because the video camera was not installed until the following day; therefore, the aircraft times were from direct observation and recesses were recorded by egg thermistor. We observed the goose flush from its nest and fly during one of these recesses as we landed in the helicopter. Mean recess length for the four recesses ($\bar{x}$ = 25.0 min/recess, SD = 9.13) was similar to the mean of all other recesses for that goose ($\bar{x}$ = 22.8 min/recess, SD = 14.29, n = 34). The goose may have been less attentive to its nest on June 11 because that was the nest's first day of incubation (Appendix E2); we detected no other recesses that were initiated during aircraft landings or takeoffs. However, we did observe on the video recordings a pattern of alert and concealment postures by the incubating goose on this nest immediately prior to a helicopter landing. Despite high levels of helicopter (Table 10), vehicle, and pedestrian activity nearby (Appendix F2, F3), the nest hatched two eggs.

Table 10. The type and frequency of aircraft using the airstrip during nest monitoring in the Alpine project area, Colville River Delta, Alaska, 1999. Frequency for fixed-wing aircraft includes take-offs and landings.

	Aircraft Type					
		Twin		Helicopter[b]		
Date	DC-6	Otter/ Caravan	Small Planes[a]	Takeoffs[c]	Landings[c]	Total
June 11	4	4	2	nd	nd	10
June 12	2	0	0	nd	nd	2
June 13	0	0	2	5	4	11
June 14	0	4	0	4	5	13
June 15	0	0	4	7	7	18
June 16	0	6	0	9	9	24
June 17	0	0	0	8	8	16
June 18	0	8	0	12	12	32
June 19	4	0	4	12	11	31
June 20	0	0	2	10	11	23
June 21	0	4	0	12	12	28
June 22	0	4	0	10	10	24
June 23	0	6	0	4	4	14
June 24	0	4	0	4	3	11
June 25	0	8	0	7	8	23
June 26	4	0	2	10	10	26
June 27	2	0	0	11	11	24
June 28	0	6	0	12	12	30
June 29	0	4	2	13	13	32
June 30	2	6	0	10	10	28
July 1	0	4	0	4	3	11
July 2	0	4	0	4	5	13
July 3	0	0	0	3	3	6
July 4	0	0	2	6	6	14
July 5	2	4	0	6	6	18
July 6	0	6	2	6	5	19
July 7	2	6	0	nd	nd	8
July 8	6	4	0	nd	nd	10
July 9	0	6	0	nd	nd	6
July 10	2	4	0	nd	nd	6
July 11	6	0	0	nd	nd	6
July 12	0	6	0	nd	nd	6
Total	36	108	22	189	188	543

[a] Includes C-207, C-185 (1 occurrence), PA-18 (1 occurrence) aircraft.
[b] Helicopter activity recorded by a video camera at a White-fronted Goose nest which was active only to 8 July 1999.
[c] Takeoffs did not always equal landings because the helicopter periodically stayed overnight in the Kuparuk Oilfield for maintenance.

When we deployed the egg thermistors in White-fronted Goose nests, we flushed the incubating females from the nests. The interval from the time we flushed a female to install the egg thermistor to the time the female returned to incubate averaged 143 min (range = 23–475 min, $n = 41$). The length of time that we were at the nest ($\bar{x}$ = 20 min, range = 5–85 min) and in the vicinity after the egg thermistor was installed probably affected the amount of time that the female was away. Generally we were nest searching in the area, so it could take several hours before we were no longer visible from the nest site. During nest searching, we flushed two 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 after the bird was flushed. These females were off the nest for 70 and 130 min after these two disturbances. While nest searching in the breeding bird plots, we flushed five different geese off nests eight times (three geese were flushed twice), and our presence in the area (range 240–525 min) resulted in some prolonged recesses ($\bar{x}$ = 251 min, range = 45–800 min). 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 ≥9 d before failure occurred.

We used nesting behavior data from thermistor-monitored White-fronted Goose nests to quantitatively evaluate the effects of different potential disturbance factors. Vehicle traffic was monitored on the airstrip and on the airstrip access road from Pad 1 by video camera (Appendices F1, F2). Traffic on the access road was confined to a small area and probably was not a factor for any of the nests except nest 201, which was closer to Pad 1 and the access road (111 m) than to the airstrip (118 m). 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 was monitored on the airstrip, access road, and tundra (Appendix F3), but we used the pedestrian data from only the airstrip and tundra. Aircraft were recorded during the nesting season (Table 10) by video, but after nests hatched video monitoring was suspended. After hatch, we gathered data on aircraft use of the airstrip from Alpine security records (Appendix F4). However, we have no data on the amount of helicopter, vehicle, or pedestrian traffic after cameras were shut down.

Because all the incubation variables we measured with thermistored eggs differed between hatched and failed nests and therefore could be indicators of disturbance, we chose two variables that were uncorrelated to each other (Appendix G1). Incubation constancy was significantly correlated with time on nest ($r = 0.96$, $P < 0.01$) and time in normal incubation ($r = 0.88$, $P < 0.01$), and negatively correlated to number of recesses ($r = -0.74$, $P \leq 0.01$) and time off nest ($r = 1.0$, $P < 0.01$), but not with number of incubation breaks ($r = -0.07$, $P > 0.05$). We chose incubation constancy because of its relationship to time on and time off the nest, and number of incubation breaks because it was independent of the other variables. We used a similar process to select the independent variables for disturbance (Appendix G2). 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 airplane landings and takeoffs, cumulative time that vehicles and pedestrians were on the airstrip, cumulative time that pedestrians were on tundra, separate noise event durations from each of three sources (airplanes, helicopters, and vehicles), wind speed (mean mph), and air temperature (mean degrees C)—were summarized for each day. Two variables were correlated with mean daily temperature—number of helicopter landings and takeoffs ($r = -0.52$, $P \leq 0.01$) and cumulative vehicle time ($r = 0.64$, $P \leq 0.01$)—but we kept them in the analysis because they all potentially affect incubation constancy. Stepwise regression selected mean daily temperature ($P = 0.02$), mean wind speed ($P = 0.02$), and number of airplane takeoffs and landings ($P = 0.06$) as significant variables in a model of incubation constancy (Appendix G3). Similarly, duration of vehicle noise events ($P < 0.001$) and cumulative time of pedestrians on tundra ($P = 0.076$) were selected as significant variables by a stepwise regression for incubation breaks (Appendix G3).

We used analysis of covariance (ANCOVA) to test the effects of the temperature, wind, and airplanes on incubation constancy of hatched and failed nests. We tested for equality of slopes of the independent variables between hatched and failed nests (Appendix

G4) before running a final model. The slopes for number of airplane takeoffs and landings (P = 0.5) and mean wind speed (P = 0.13) were the same for both nest fates. However, mean temperature differed between nest fates (P < 0.001), therefore requiring the final model to have separate estimators for the effect of temperature on hatched and failed nests (Table 11). Temperature had a weak negative relationship on incubation constancy at failed nests (β = -0.01, P <0.001), and no relationship at hatched nests (β < 0.001, P = 0.98). We suspect the negative correlation of temperature and incubation constancy was spurious; incubation constancy declined as nests approached the date of failure (Table 8), which occurred in late June and early July when temperatures were warming (Appendix G5). Neither wind speed nor airplane landings and takeoffs had significant effects on incubation constancy in the final model.

Similar ANCOVA tests were applied to number of incubation breaks with the dependent variables cumulative time for tundra pedestrians and duration of vehicle noise events. The slopes of tundra pedestrians and vehicle noise did not differ (P > 0.18 for both) among nest fates (Appendix G4). Therefore, the final model contained only the main factors—tundra pedestrians (P = 0.09), vehicle noise (P = 0.001), and nest fate (P = 0.001)—explaining only 8% of the variance in incubation breaks (Table 11). Although neither ANCOVA for incubation constancy or incubation breaks demonstrated any strong relationships with disturbance or environmental variables, further analysis is needed to fully evaluate the effects of these variables. All nests were pooled in this analysis and the response to potential disturbance may vary as a function of distance. We plan to investigate the relationships of vehicles, aircraft, pedestrians, and noise at different distances after the final season of data collection.

Table 11. Final analysis of covariance models of incubation constancy and incubation breaks for 29 Greater White-fronted Goose nests monitored by egg thermistors in the Alpine project area, Colville River Delta, Alaska, 1999. Independent variables were selected by stepwise regression of disturbance and environmental variables on incubation constancy and incubation breaks.

	β	SE	t	P	df	Mean Square	F	R^2	Adj. R^2
Dependent Variable: Incubation Constancy (arcsine transformed)									
Model					6	150.92	23,000.62	0.997	0.997
Fate = failed	1.515	0.02	62.96	0.000	2	15.01	2,287.83		
Fate = hatched	1.476	0.02	62.79	0.000					
Wind Speed	0.002	0.00	1.46	0.145	1	0.01	2.13		
No. of Airplanes	0.000	0.00	-0.13	0.897	1	0.00	0.02		
Failed * Mean Temp.	-0.011	0.00	-6.84	0.000	2	0.15	23.45		
Hatched * Mean Temp.	0.000	0.00	-0.02	0.985					
Error					409	0.01			
Total					415				
Dependent Variable: Number of Incubation Breaks (logarithm transformed)									
Corrected Model					3	0.19	9.75	0.083	0.074
Intercept	1.032	0.01	89.71	0.000	1	288.81	14,870.47		
Tundra Pedestrian Time	0.000	0.00	1.70	0.091	1	0.06	2.88		
Vehicle Noise Duration	0.000	0.00	3.32	0.001	1	0.21	11.02		
Fate	0.054	0.02	3.48	0.001	1	0.24	12.11		
Error					324	0.02			
Total					328				
Corrected Total					327				

TUNDRA SWAN

We monitored two Tundra Swan nests with time-lapse cameras: nest 301 was 449 m from the airstrip and was monitored for 30 d, and nest 008 was 1,281 m from the airstrip and was monitored for 21 d (Figure 7; Appendices E4, E5). Swan nest 301 also was near (154 m) the infield road. Both nests were successful. Mean daily incubation constancy was high for both nests, but nest 301 ($\bar{x}$ = 99.1%) had a higher constancy than nest 008 ($\bar{x}$ = 97.0%) (Table 12). Mean recess length was similar for the two nests (10.4 min/recess and 14.7 min/recess, P = 0.70), but mean recess frequency and mean time off the nest was significantly different. The swans closest to the airstrip (nest 301) took fewer recesses ($\bar{x}$ = 0.6 recesses/d) and spent less time off the nest each day ($\bar{x}$ = 12.1 min/d) than the swans farther from the airstrip (nest 008) ($\bar{x}$ = 2.5 recesses/d and $\bar{x}$ =43.0 min/d, $P \leq 0.003$ for both tests). We observed 50 incubation exchanges between the male and female birds at both nests. Mean number of exchanges for both nests (2.3 and 2.6 exchanges/d, P = 0.82), and mean time off the nest for exchanges was similar (5.6 and 6.7 min/d, P = 0.83).

In 1998, time spent incubating by swans at a successful nest (82.1%, n = 9 d) and a failed nest (83.9%, n = 4 d) that we monitored with video cameras were similar but lower than either swan

Table 12. Comparison of nesting activities at two Tundra Swan nests monitored by video cameras at 1-min intervals in the Alpine project area, Colville River Delta, Alaska, 1999. Nest 301 was 449 m and nest 008 was 1,281 m from the Alpine airstrip.

	Nest 301			Nest 008			Mann-Whitney U Test		
	$\bar{x}$	*SD*	*n*	$\bar{x}$	*SD*	*n*	*U*	*Z*	*P*
Incubation Constancy (%/d)	99.1	0.8	22	97.0	2.8	19	95.5	-2.97	0.003
Recess Frequency (no./d)	0.6	0.9	22	2.5	2.1	19	93.5	-3.15	0.002
Recess Length (min/recess)	10.4	7.1	14	14.7	20.3	47	307.0	-0.38	0.705
Time Off Nest (min/d)	12.1	11.0	22	43.0	39.8	19	95.5	-2.97	0.003
Break Frequency (no./d)	9.2	7.0	22	13.2	4.0	19	122.0	-2.28	0.023
Break Length (min/break)	14.7	12.3	22	15.4	5.3	19	160.0	-1.28	0.200
Exchange Frequency (no./d)	2.3	1.5	22	2.6	2.0	19	200.5	-0.23	0.820
Exchange Length (min./exchange)	5.6	3.8	22	6.7	6.9	19	201.0	-0.21	0.833
Defense Frequency (no./d)	0.1	0.4	22	0.1	0.3	19	202.5	-0.30	0.764
Time Disturbed[a] (min/d)	28.9	55.7	22	31.1	49.1	19	104.0	-2.83	0.005

[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.

monitored in 1999 (Johnson et al. 1999b). Mean recess frequency of the successful nest in 1998 was 2.4 recesses/d, and mean recess length and time off the nest were 101 min/recess and 246 min/d, respectively. At both the failed and successful swan nests monitored in 1998, nest mates were rarely observed and incubation exchanges were uncommon.

On the videotapes we observed two defensive breaks at each swan nest when foxes approached the nests. On all four occasions, a fox was on the nest mound and the incubating swan reared up and flapped its wings. The encounters lasted from 1–7 min, and each time the swans successfully deterred the fox. On one occasion, we observed a defensive reaction by the incubating swan to another swan flying over.

Off-airstrip human activities occurred in the vicinity of both swan nests; duration of the activity and distance of the activity to the nest varied. The swans responded to these activities by leaving the nest (and camera view), "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, or concealing on the nest. At the swan nest closest to the airstrip (nest 301), off-airstrip human activities occurred on 14 of the 31 days that the camera was recording. Some activities, such as servicing the camera, were short in duration ($\bar{x}$ = 23 min, n = 3), while other activities, such as work by surveyors and researchers conducting vegetation experiments, kept people in the vicinity for ≤600 min. We do not know the exact duration of all activities because the people were not continuously in the camera view, nor do we know the exact distance of all these activities to the swan nest. The swan was directly approached (probably within a few meters judging from the video) and flushed from the nest by a person on only one occasion. After the person (a research technician from Boise State University, unaffiliated with this study) left the area, the swan returned to the nest 60 min later. For the remaining 14 events of off-airstrip human activity that occurred during incubation, the people were >100 m from the nest when in the camera view. During seven events the swan sneaked-off the nest and stood beside it for an average of 86 min (range = 14–239 min). During the other seven events, the swan concealed and remained on the nest.

Our own research activities were the only human activities we detected on video tape at the nest farthest from the airstrip (nest 008), and they occurred on 8 of the 26 days of monitoring. This swan nest was in one of the breeding bird plots and nest searching for extended periods in the plot caused the birds to be off the nest for 389 and 330 min on two consecutive days. Other prolonged recesses occurred when the video camera was installed (315 min [camera installation required 65 min]), when a caribou approached within 5 m of the nest (83 min), and once when nothing unusual was in the field of view (105-min recess). The monitoring camera was serviced five times during incubation; on three of those visits the incubating swan sneaked-off the nest and was out of the camera view and on the other visits the swan incubated the nest in both alert and normal postures. Mean time off the nest was 36 min (range = 22–51 min) and mean return time to the nest after the person left the area was 21 min (range = 18–25 min). The person servicing the camera was at the camera for a mean time of 16 min and in the vicinity (in view of the nest) for approximately 30 min.

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. Mean clutch sizes of loons were 1.8 eggs (n = 12 nests), of Parasitic Jaegers, 2.0 eggs (n = 2 nests), and of Arctic Terns, 2.2 eggs (n = 12 nests), whereas mean clutch sizes for various duck species varied from 4 to 7 eggs (n = 1 to n = 6 nests) (Table 13). Mean clutch sizes were intermediate for Red-necked Grebes (4.0 eggs, n = 1 nest), geese (2.0–4 eggs, n = 1 to n = 65 nests), Tundra Swans (2.5 eggs, n = 4 nests), and the Sandhill Crane (2.0 eggs, n = 1 nest). 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 1999 (after the hatch) to determine the fate of nests in the ground-search area (Table 14). Nests were determined to be successful if we found egg membranes that were detached from the eggshells. Using this technique, we could determine nest fate for most waterfowl species, but not for species such as loons, gulls, or Arctic Terns, whose eggshells and membranes rarely are found after hatch. Loon nests were considered successful if a brood was associated with a nest site. We did not determine the fate of nests on inaccessible islands, as was the case for two Red-necked Grebe nests and one Brant nest. Of the 33 duck nests found in the project area (including nests found during activities other than the nest search), only 8 (24%) were successful: one each of Spectacled Eider, Northern Pintail, Green-winged Teal, unidentified duck, unidentified scaup, Oldsquaw, and two of Greater Scaup. The fate of duck nests in 1999 did not appear to be influenced by their distance from the airstrip (Table 15). Although successful nests were farther ($\bar{x}$ = 1,670 m, n = 8) from the airstrip than were failed nests ($\bar{x}$ = 1,336 m, n = 25), the difference was not statistically significant (Mann-Whitney Z, P = 0.22).

GREATER WHITE-FRONTED GEESE

The mean clutch size of White-fronted Geese in 1999 was 3.7 eggs (n = 65 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 1995–1998 ranged from 3.7 to 4.1 eggs (Johnson et al. 1996, 1997, 1998, 1999). In 1999, proximity to the Alpine airstrip did not have a detectable effect on clutch size. Clutch size increased slightly with increasing distance from the airstrip, but distance explained only 2% of the variance (y = 0.0005x + 2.53, r^2 = 0.019, P = 0.22).

Table 13. Clutch sizes of nests found during ground nest searches in the Alpine project area, Colville River Delta, Alaska, 1999.

	Clutch size		
Species	$\bar{x}$	SE	n
Red-throated Loon	1.5	0.50	2
Pacific Loon	1.9	0.11	9
Yellow-billed Loon	2.0	-	1
Red-necked Grebe	4.0	-	1
Greater White-fronted Goose	3.7	0.19	65
Canada Goose	4.0	-	1
Brant	2.0	0	2
Tundra Swan	2.5	0.29	4
Northern Pintail	5.2	0.20	5
Green-winged Teal[a]	4.8	0.86	4
Greater Scaup	6.8	0.60	6
Unidentified scaup	4.5	0.50	2
Spectacled Eider	5.0	-	1
Oldsquaw	5.3	1.11	4
Unidentified duck	2.0	-	1
Willow Ptarmigan	8.0	0.64	18
Sandhill Crane	2.0	-	1
Bar-tailed Godwit	1.5	0.50	2
Parasitic Jaeger	2.0	0	2
Arctic Tern	2.3	0.11	12

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

Of 82 White-fronted Goose nests found throughout the project area in 1999 (including nests found during activities other than the nest search), 29 (35%) hatched successfully, and 53 (65%) failed (Table 15). Because we started looking for White-fronted Goose nests earlier in their nesting season (to install egg thermistors) than in previous years, all of the nests we located prior to the start of the regular nest search (11 June) were active. The success rate for those nests we found early (31%) was slightly lower than for the nests located later (36%), but the overall success rate was half that recorded during our surveys in 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,). We observed more cases of fox (both red and arctic) predation of nests in 1999 than in previous years, but avian predators, particularly Parasitic Jaegers, also caused nest and egg losses (see PREDATION section below). The proximity of White-fronted Goose nests to the airstrip had little effect on their fate in 1999; the distance of successful ($\bar{x}$ = 1,359 m, n = 29) and failed nests ($\bar{x}$ = 1,339 m, n = 53) was virtually the same (two sample t-test, P = 0.89, Table 15).

Table 14. The number, fate, and mean distance from the airstrip of nests of selected species found during nest searches in Alpine project area, Colville River Delta, Alaska, 1999. Only nests with known fates were included.

	Successful Nests				Failed Nests			
			Distance (m)				Distance (m)	
Species	No.	%	$\bar{x}$	SE	No.	%	$\bar{x}$	SE
Red-throated Loon	2	100.0	1,996	801	–	–	–	–
Pacific Loon	3	100.0	1,385	328	–	–	–	–
Yellow-billed Loon	1	100.0	2,285	–	–	–	–	–
Greater White-fronted Goose	29	43.3	1,359	124	38	56.7	1,330	85
Canada Goose	1	100.0	1,551	–	–	–	–	–
Brant	2	66.7	1,922	438	1	33.3	790	–
Tundra Swan	6	85.7	1,223	162	1	14.3	2,417	–
Northern Pintail	1	25.0	1,301	–	3	75.0	885	612
Green-winged Teal[a]	1	33.3	1,564	–	2	66.7	1,690	209
Greater Scaup	2	40.0	1,692	44	3	60.0	2,029	254
Unidentified Scaup	1	50.0	2,336	–	1	50.0	1,915	–
Spectacled Eider	1	100.0	1,663	–	–	–	–	–
Oldsquaw	1	25.0	1,353	–	3	75.0	1,895	475
Unidentified duck	1	33.3	1,758	0	–	–	–	–
All ducks	8	27.6	1,670	112	12	60.0	1,643	222
Sandhill Crane	1	100.0	262	–	–	–	–	–
Bar-tailed Godwit	–	–	–	–	2	100.0	1,392	966
Parasitic Jaeger	2	100.0	1,065	66	–	–	–	–
Glaucous Gull	1	100.0	1,926	–	–	–	–	–
Arctic Tern	3	100.0	2,101	301	–	–	–	–
Total nests	59	52.2	1,466	81	54	48.2	1,412	86

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

TUNDRA SWANS

Clutch sizes of Tundra Swans averaged 2.5 eggs in 1999 ($n = 4$ nests). In 1996, 1997 and 1998, the mean clutch sizes were 4, 3, and 3 eggs, respectively ($n = 4$ to $n = 6$ 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 1999 was lower than those recorded in other studies on the Colville Delta; average clutch size was 3.6 eggs ($n = 28$) in 1981 (Rothe et al. 1983) and 3.4 eggs ($n = 43$) in 1982 (Simpson et al. 1982).

In 1999, six of seven (86%) Tundra Swan nests succeeded in hatching. The failed nest was 2,417 m from the airstrip, farther than the mean distance for all nests, 1,383 m. In 1998, three of five nests (60%) were successful, in 1997 all four nests (100%) were successful, and in 1996 we did not check the fate of nests. Success rates from 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).

Table 15. Mean distances of nests of ducks and Greater White-fronted Geese from the airstrip and their fate in the Alpine project area, Colville River, Alaska, 1999. Nests were found during 11–22 and 25–26 June and includes nests found during activities other than the nest search..

	Distance (m)					
Nest Fate	$\bar{x}$	SE	*n*	Test	Statistic (*Z* or *t*)	*P*-value
All Ducks						
Successful	1,670	152	8			
Failed	1,336	112	25	Mann-Whitney	-1.26	0.22
Greater White-fronted Goose						
Successful	1,359	124	29			
Failed	1,339	70	53	two sample *t* test	1.41	0.89

BROOD-REARING

We did not conduct a specific survey for broods of large waterbirds in the Alpine project area during 1999. Broods were recorded during nest fate checks in early July and during a ground search for loon broods in August. We recorded 69 broods belonging to 16 species in the ground-search area (Figure 9). We saw broods of Pacific, Red-throated and Yellow-billed loons, Red-necked Grebe, White-fronted and Canada geese, Brant, Tundra Swan, Northern Pintail, scaup, Oldsquaw, Willow Ptarmigan, Pectoral Sandpiper, Parasitic Jaeger, Glaucous Gull, and Arctic Tern.

BREEDING-BIRD PLOTS

We found 169 nests belonging to 19 species of birds on the 12 breeding-bird plots we sampled in 1999 (Table 16). The predominant nesting species were Lapland Longspurs (62 nests, 37% of all nests), Semipalmated Sandpipers (37 nests, 22%), Pectoral Sandpipers (24 nests, 14%), and White-fronted Geese (9 nests, 5%). The total number of nests per plot ranged from 8 to 28 (80–280 nests/km^2) and averaged 14.1 nests (140.8 nests/km^2). In 1998, we found more nests (196) of about the same number of species (20). Although the same four species were numerically dominant both years, in 1998 Pectoral Sandpiper nests (61 nests, 31% of the total) and White-fronted Goose nests (16 nests, 8%) were markedly more numerous than in 1999, whereas Lapland Longspur nests (49 nests, 25%), and Semipalmated Sandpipers nests (21 nests, 11%), were much less abundant than in 1999. The number of shorebird nests declined from 116 to 85 from 1998 to 1999 and the number of waterfowl nests fell from 24 to 14.

More nests were found on treatment plots ($\bar{x}$ = 17.0 nests, SD = 6.45, n = 6) than on reference plots ($\bar{x}$ = 11.2 nests, SD = 1.17, n = 6) in 1999, although the difference was marginally significant (two-sample t-test, P = 0.054). Among the four most numerous nesting species, all had more nests on treatment than on reference plots (Table 17), but only Semipalmated Sandpipers nested significantly more often on treatment ($\bar{x}$ = 4.0 nests, SD = 1.67, n = 6) plots ($\bar{x}$ = 2.17 nests, SD = 0.98, n = 6) (two-sample t-test, P = 0.04). In 1998, the number of nests of all species did not differ significantly (P = 0.38) between treatment ($\bar{x}$ = 17.7 nests, SD = 2.80, n = 6) and reference plots ($\bar{x}$ = 15.0 nests, SD = 6.51, n = 6), nor did the numbers of nests of the four most common species (Table 17). Simple linear regressions of nest densities for the same four species (each year tested separately) with the distance of plots to the airstrip showed no significant relationships and explained little of the variance in nest densities ($P \geq 0.2$, $r^2 \leq 0.15$), except for Semipalmated Sandpipers in 1999 (P = 0.06, r^2 = 0.30). All the relationships between distance and density were negative, with the exception of weak positive relationships for Lapland Longspurs in 1999 (P = 0.87, r^2 = 0.003) and White-fronted Geese in 1998 (P = 0.56, r^2 = 0.03), indicating that nest densities decreased slightly or not at all with increasing distance to the airstrip. The relationship of distance

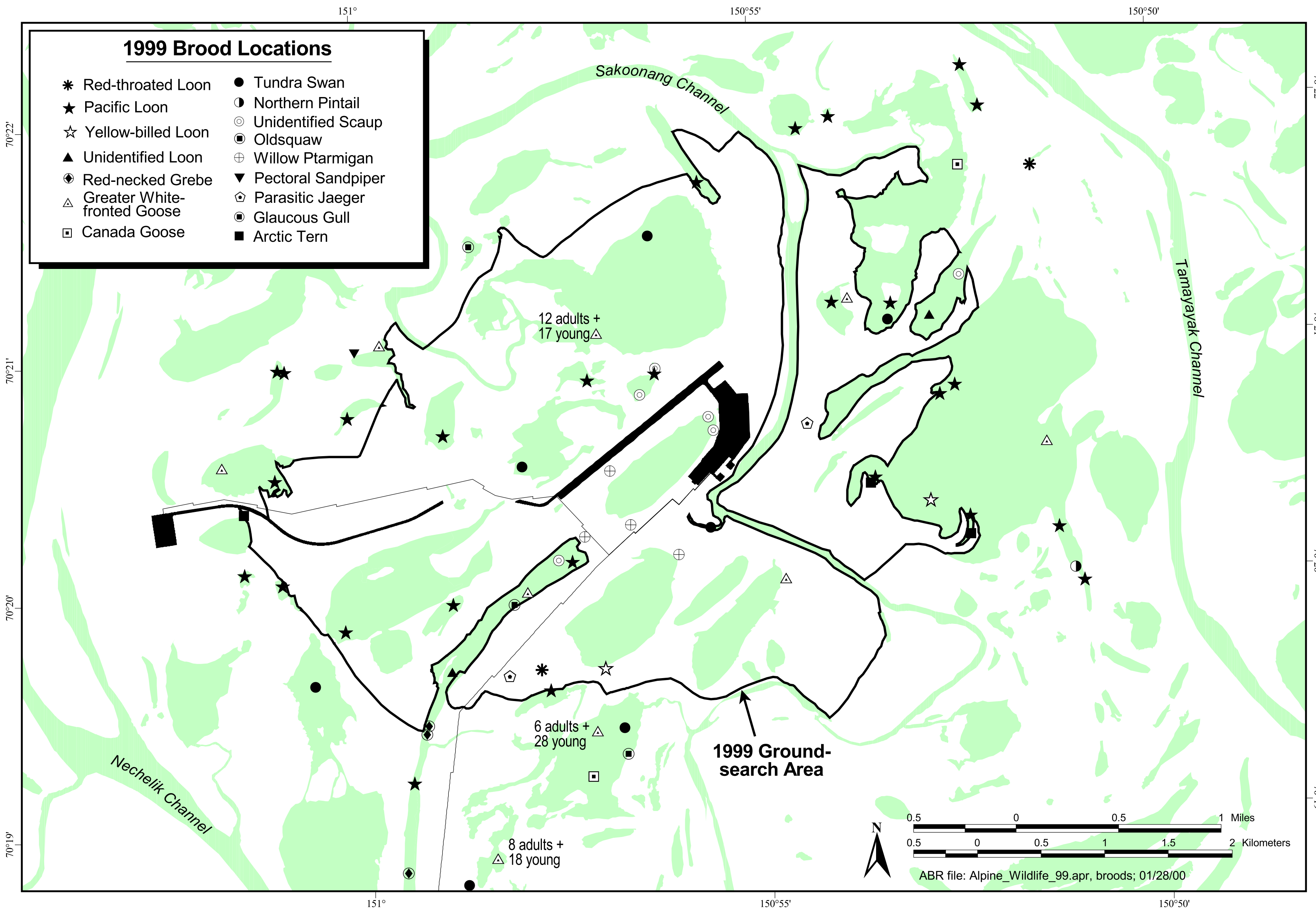

Figure 9. Locations of broods found incidentally during nest-fate checks in the Alpine project area, Colville River Delta, Alaska, 1999.

Table 16. Numbers and densities of nests found on 10-ha plots in the Alpine project area, Colville River Delta, Alaska, 1999. 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							Mean
													Total	Density
Species	1	2	3	4	5	6	7	8	9	10	11	12	Nests	(nests/km^2)
Red-throated Loon	0	0	0	0	0	0	0	0	0	1	0	0	1	0.8
Greater White-fronted Goose	2	0	0	0	0	4	1	2	0	0	0	0	9	7.5
Tundra Swan	0	0	0	0	0	1	0	0	0	0	0	0	1	0.8
Oldsquaw	0	1	0	0	0	1	0	0	0	0	1	0	3	2.5
Unidentified Duck	0		0	0	0	0	1	0	0	0	0	0	1	0.8
Willow Ptarmigan	0	1	2	0	0	0	0	0	0	0	0	0	3	2.5
Unidentified Ptarmigan	0	1	0	0	0	0	0	0	0	0	0	0	1	0.8
Black-bellied Plover	0		0	0	0	0	1	0	0	1	0	0	2	1.7
American Golden Plover	1		0	0	0	0	0	0	0	1	0	1	3	2.5
Bar-tailed Godwit	0	1	0	0	0	0	0	0	0	0	0	0	1	0.8
Semipalmated Sandpiper	4	3	3	2	6	6	2	4	2	2	2	1	37	30.8
Pectoral Sandpiper	0	3	4	0	2	6	1	0	5	1	1	1	24	20.0
Dunlin	1		0	1	0	0	0	0	0	1	0	0	3	2.5
Stilt Sandpiper	1	1	0	1	0	1	0	0	0	0	0	0	4	3.3
Long-billed Dowitcher	0		0	1	0	0	0	0	0	0	0	0	1	0.8
Red-necked Phalarope	1		0	0	0	1	1	0	0	0	0	0	3	2.5
Red Phalarope	0		1	0	2	1	1	1	0	0	0	1	7	5.8
Long-tailed Jaeger	0	1	0	0	0	0	0	0	0	0	0	0	1	0.8
Yellow Wagtail	1		0	0	0	0	0	0	0	0	0	0	1	0.8
Savannah Sparrow	0		0	0	0	0	0	1	0	0	0	0	1	0.8
Lapland Longspur	4	6	6	3	7	7	4	5	4	4	6	6	62	51.7
	0		0	0	0	0	0	0	0	0	0	0		
Total Nests	15	18	16	8	17	28	12	13	11	11	10	10	169	140.8
Density (nests/km2)	150	180	160	80	170	280	120	130	110	110	100	100	140.8	
Total Species	8	8	5	5	4	9	8	5	3	7	4	5	19	

Table 17. 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.

	Treatment		Reference			
Species/Year	$\bar{x}$	SD	$\bar{x}$	SD	*t*	*P*-value
Greater White-fronted Goose						
1998	1.0	1.10	1.7	1.51	-0.88	0.40
1999	1.0	1.67	0.5	0.84	0.66	0.53
Pectoral Sandpiper						
1998	5.7	2.42	4.5	2.51	0.82	0.43
1999	2.5	2.35	1.5	1.76	0.84	0.42
Semipalmated Sandpiper						
1998	2.3	1.37	1.2	1.94	1.20	0.26
1999	4.0	1.67	2.2	0.98	2.31	0.04
Lapland Longspur						
1998	4.3	1.37	3.8	1.72	0.56	0.59
1999	5.5	1.64	4.8	0.98	0.85	0.41
Total Nests						
1998	17.7	2.80	15.0	6.51	0.92	0.38
1999	17.0	6.45	11.2	1.17	2.18	0.05

meadow, and disjunct polygons). The lower odds for high-center polygons was due to the occurrence of one Northern Shoveler nest in disjunct polygons. The difference between the two years' waterfowl models in the contribution of polygon centers illustrates the sensitivity of these models to sample size; waterfowl nests were less numerous than the number of independent variables and will not produce reliable models until sample sizes increase to approximately $n \geq 30$. This limitation suggests pooling years together would be appropriate, and we plan to pool three years of data after the 2000 field year. Nonetheless, the weight of evidence from the waterfowl and White-fronted Goose models is that high and low polygon centers are important to waterfowl nest site selection.

Models for shorebird nests in 1999 and 1998, Pectoral Sandpiper nests in 1999, and Semipalmated Sandpiper nests in 1998 all had distance to airstrip as a significant variable (Appendix H). As discussed above, all three distance categories from 0–2,412 m had higher odds of having nests than the farthest category (≥ 2,412 m), and the second distance category (731–1,430 m) had the highest odds of having nests, suggesting that nest density was not linear in its relationship to the proximity of the airstrip. Distance to the airstrip was not a significant variable in the remaining shorebird models; therefore, shorebirds did not appear to be strongly deterred from nesting near the airstrip, at least at this scale of analysis. We shall investigate other distance scales for analysis after the third year's field data have been collected. Pectoral Sandpiper nests and shorebird nests in 1999 had increasing odds of occurring with higher coverages of moist sedge–shrub. In 1998, Pectoral Sandpiper nests and shorebird nests had increased odds of occurrence in areas with higher coverage of *Dryas* tundra and on high and low density polygons compared to areas without polygons. Semipalmated Sandpipers in both 1999 and 1998 had increased odds of nesting to nest density was curvilinear (see results of logistic regressions below) indicating that linear regression at the scale of plot measurements is inappropriate; we will investigate the relationship at different scales (e.g., distance to individual quadrants) after the 2000 data are collected. Therefore, the proximity of plots to the Alpine airstrip (both distance of plots and location [treatment plots versus reference plots]), did not result in lower nest densities in 1998 or 1999, but we cannot rule out the possibility of distance effects at finer scales of measurement.

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. Pectoral Sandpiper nest densities appear to have been unusually high in the Alpine project area in 1998 compared to densities in other studies on the coastal plain. 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 in the Kuparuk Oilfield densities varied 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 over five years (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

In 1999, we measured habitat variables on the breeding bird plots to investigate whether habitat features could explain differences in nest densities among the plots. Although the plots were placed in locations that appeared to have similar habitat composition at the scale of our habitat map (Figure 2), some differences were apparent (Tables 18 and 19). All continuous habitat variables except coverage of *Dryas* tundra (one-way ANOVA, $F_{11, 468}$ = 1.64, P = 0.08) differed significantly among plots (one-way ANOVA, $F_{11, 468} \geq 2.01$, $P \leq 0.03$), but not between treatment and reference locations. Wet sedge meadow (t = 2.03, P = 0.04), and moist sedge–shrub (t = 2.03, P = 0.04) were significantly greater on treatment than on reference plots (Table 20). Wet sedge–willow (t = -3.32, P = 0.001), open low willow (t = -3.38, P = 0.001), and *Dryas* tundra (t = -2.02, P = 0.04) all were significantly greater on reference than on treatment plots. Surface relief, water cover, water depth, sedge and grass marsh, and partially vegetated mud did not differ among treatment and reference locations ($t \leq 1.79$, $P \geq 0.07$). The distribution of surface forms and polygon density was not significantly different among treatment and reference plots (χ^2 = 5.78, 3 df, P = 0.12 and χ^2 = 3.41, 2 df, P = 0.18, respectively), whereas high-center polygons occurred more often than expected on treatment plots, and low-center polygons and non-polygonal surface forms (disjunct polygons, dunes, or nonpatterned meadow) occurred more often than expected on reference plots (χ^2 = 9.88, 2 df, P = 0.007).

We tested for significant associations between bird nests and habitat features with logistic regression models using the continuous and categorical variables measured on plot grids and quadrants (Tables 17 and 18). Because the number of quadrants was large (1,920) compared to the number of nests (169 in 1999), we averaged the quadrant measurements on each grid (n = 4 quadrants/grid) and tested only at the grid scale (n = 480 grids on 12 plots). Distance of nests to Pad 1 was eliminated from the model because it was highly correlated with distance of nests to the airstrip (r = 0.98). 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.

Logistic regression models of habitat features demonstrated several common tendencies for bird habitat associations on the bird plots (Appendix H). Moist sedge–shrub cover was the most common habitat variable, entering half of the 14 models. Surface relief entered in four of the models, as did wet sedge–willow and open low willow cover. The distance to the airstrip entered 4 of 14 models, but the β coefficients were positive for all three distance categories closest to the strip (0–780 m, 781–1,430 m, and 1,431–2,412 m) compared to the farthest

Table 18. Distance to Pad 1 and the Alpine airstrip, surface relief, water, and vegetation cover measurements on breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 1999. n = 160 quadrants/plot.

	Treatment												Reference Plot Number													
	1		2		3		4		5		6		7		8		9		10		11		12		All Plots	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Distance to Pad 1 (m)[a]	248		446		1361		442		591		1,413		1,858		1,658		1,636		2,564		2,682		2,859		1,480	914
Distance to Airstrip (m)[a]	169		370		1,223		848		758		1,325		1,798		1,597		1,537		2,617		2,788		3,011		1,503	925
Surface Relief (cm)	49.6	26.4	42.3	20.5	38.4	14.3	34.4	6.9	62.8	16.4	47.5	9.2	39.7	12.9	37.1	20	39.1	13.7	43.6	40.4	61.8	18.3	46.3	22.1	45.2	22.0
Water																										
Water Depth (cm)	18.3	22.6	23.6	26.4	14.5	18.9	13.8	17.9	26.1	25.9	51.3	24.2	38.5	20.8	28.0	18.7	13.5	7.5	17.9	27.5	34.7	43.3	22.1	35.6	25.2	27.8
Water Cover (%)	13.2	21.2	8.7	13.8	12.3	21.1	12.2	19.1	10	12.2	21.5	16.3	20.3	16.0	11.4	9.8	17.1	13.1	13.4	20.9	11.1	18.8	4.2	9.6	12.9	17.1
Vegetation Cover (%)																										
Wet Sedge Meadow	40.1	25.2	37.4	25.2	50.1	25.6	46.3	21.1	30.6	18.2	25.0	18.7	33.4	18.2	35.9	21.1	35.4	17.8	32.4	25.4	44.0	22.6	27.1	26.1	36.5	23.4
Wet Sedge Willow	14.8	14.2	28.3	24.6	15.3	15.6	23.7	16.4	14.5	8.4	8.7	5.0	12.8	8.2	24.8	13.8	17.9	9.9	22.7	20.2	17.6	12.0	35.4	23.6	19.7	17.0
Moist Sedge Shrub	32.1	24.0	25.6	19.8	22.4	13.1	17.7	8.5	44.5	17.0	44.7	16.3	33.6	18.8	24.7	18.2	28.9	11.5	27.7	23.0	25.8	15.3	28.1	16.4	29.6	19.0
Sedge Marsh	<0.1	0.4	0	0	0	0	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0.3	0.3	0	0	0	0	<0.1	0.6
Grass Marsh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	6.3	0.1	0.9	0	0	0.1	1.9
Open Low Willow	0	0	<0.1	0.4	0	0	0	0	0.1	1.6	0	0	0	0	3.1	14.9	0	0	2.3	9.1	0.8	4.6	3.9	12.8	0.8	6.5
Dryas Tundra	0	0	0	0	0	0	0	0	0.2	2.8	0	0	0	0	0.2	1.4	0	0	0.2	1.1	0.8	6.2	1.2	4.5	0.2	2.4
Partially Vegetated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	3.5	0	0	0	0	0	0	0.1	1.0

[a] Distance to Pad 1 and Alpine airstrip (n = 1) measured from centroid of plot to closest point on pad and airstrip with GIS.

Table 19. Relative frequencies (%) of surface features on breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 1999. $n = 40$ grids/plot.

	Plot Number and Treatment Classification														
	Treatment							Reference							Overall
	1	2	3	4	5	6	Total	7	8	9	10	11	12	Total	Total
Surface Form															
Polygons	92.5	92.5	100	82.5	92.5	97.5	92.9	72.5	100	100	87.5	97.5	85.0	90.4	91.7
Disjunct Polygons	7.5	5.0	0	17.5	7.5	2.5	6.7	27.5	0	0	0	2.5	7.5	6.3	6.5
Nonpatterned	0	2.5	0	0	0	0	0.4	0	0	0	5.6	0	7.5	2.1	1.3
Dune	0	0	0	0	0	0	0	0	0	0	6.9	0	0	1.3	0.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Polygon Centers															
High	37.5	40	5.0	15.0	72.5	25.0	32.5	25.0	42.5	17.5	10	5.0	20	20	26.3
Low	55.0	52.5	95.0	67.5	20	72.5	60.4	47.5	57.5	82.5	77.5	92.5	65.0	70.4	65.4
None	7.5	7.5	0	17.5	7.5	2.5	7.1	27.5	0	0	12.5	2.5	15.0	9.6	8.3
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Polygon Density															
High	15.0	10	0	0	65.0	15.0	17.5	5.0	47.5	20	0	0	0	12.1	14.8
Low	77.5	82.5	100	82.5	27.5	82.5	75.4	67.5	52.5	80	87.5	97.5	85.0	78.3	76.9
None	7.5	7.5	0	17.5	7.5	2.5	7.1	27.5	0	0	12.5	2.5	15.0	9.6	8.3
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 20. Comparison of habitat measurements between treatment and reference breeding bird plots near the Alpine project area, Colville River Delta, 1999.

	Treatment Quadrants (n = 240)		Reference Quadrants (n = 240)			
Habitat Variable	$\bar{x}$	SD	$\bar{x}$	SD	t	P
Surface relief (cm)	45.8	17.3	44.6	20.1	0.73	0.47
Water depth (cm)	24.6	22.0	25.8	22.4	-0.60	0.55
Water cover (%)	13.0	13.4	12.9	12.3	0.07	0.95
Wet sedge meadow (%)	38.3	19.5	34.7	18.8	2.03	0.04
Wet sedge–willow (%)	17.6	14.2	21.9	14.4	-3.32	0.001
Moist sedge–shrub (%)	31.1	17.6	28.1	15.2	2.03	0.04
Sedge marsh (%)	<0.1	0.4	<0.1	0.5	-0.27	0.79
Grass marsh (%)	<0.1	<0.1	0.2	1.8	-1.78	0.08
Partially vegetated mud (%)	<0.1	<0.1	0.1	1.0	-1.79	0.07
Open low willow (%)	<0.1	0.3	1.7	7.5	-3.38	0.001
Dryas tundra (%)	<0.1	0.6	0.4	2.6	-2.02	0.04

category (> 2,412 m), indicating the odds of nests occurring were higher in the distance categories close to the strip than the one farthest away. β coefficients (Appendix H) are natural logarithm odds ratios (odds of a nest occurring divided by the odds of a nest not occurring); to provide a more intuitive scale, β is transformed to Exp (β), the odds ratio that gives the change in odds with a one-unit change in the variable (e.g., 1 cm for relief, 1 % for vegetation cover, or one category for categorical variables). If $\beta = 0$, then Exp (β) = 1, and the odds ratio of occurrence to none-occurrence are equal (i.e., 1:1). Therefore, positive β coefficients and Exp (β) >1.0 indicate increasing odds of occurrence with increasing values of continuous variables. Likewise with categorical variables, a positive β indicates increasing odds of occurrence relative to a reference category (one category of the original variable is selected to be the reference to which the other categories are compared). Decreasing odds are indicated by a negative β and Exp(β) < 1.0.

White-fronted Goose nests in 1999 occurred with increasing odds with increasing moist sedge–shrub cover (Appendix H). No variables entered the models for 1999 waterfowl nests or 1998 White-fronted Goose nests after polygon centers were deleted from the independent variables. We conclude that despite the problem with coefficient estimation in the model (see discussion above), low and high polygons were important to waterfowl (1999) and White-fronted Goose nest sites (both years), because nests occurred only in areas with low or high polygon centers. In 1998, waterfowl nests had greater odds of occurring in low-center polygons and lower odds (i.e., negative β coefficient) of occurring in high center polygons than in areas without centers (dunes, nonpatterned with higher coverage of moist sedge–shrub, but the two years differed in response to open low willow cover. Interestingly, the distance to airstrip was a significant factor for Semipalmated nests in 1998 when the airstrip was being constructed, but not in 1999 when the airstrip was used for aircraft landings and vehicle traffic. However, as with nests of the other commonly occurring taxa, the relationship to distance category was such that the farthest zone had the lowest odds of containing nests.

Passerine nests consistently had increasing odds of occurrence in areas of higher surface relief. Surface relief was the only significant variable in the 1998 passerine and Lapland Longspur models. For passerine nests in 1999, in addition to surface relief, significant variables were water depth, wet sedge–willow, and moist sedge–shrub, all of which had positive coefficients. Lapland Longspur nests in 1999 had the same predictor variables, with the addition of open low willow, which had a negative coefficient.

The general patterns observed from the logistic regression analysis are those of increasing occurrence of nests with 1) the presence of polygons (with low or high centers or with low or high density), 2) high cover of moist sedge–shrub and wet sedge–willow, and 3) increasing surface relief. The differences in habitat we measured between treatment and reference plots may account for differences in nest numbers between plot types, but not all patterns in the variables were consistent with higher nest densities on treatment plots. Wet sedge–willow had lower coverage and low-center polygons occurred less frequently than expected on treatment plots. Two of the most common predictors in the models did help explain the higher densities of nests on treatment plots—surface relief and moist sedge–shrub cover were higher on treatment plots—and high-center polygons occurred more frequently than expected on treatment plots.

SEASONAL USE OF LAKES

Twenty-three species of waterbirds were recorded during nine aerial surveys of lakes in the Alpine project area (Table 21). Ducks were the most numerous birds observed (46% of the total, Appendix I). The most commonly occurring ducks were Northern Pintail (60% of all ducks), scaup (21%), and American Wigeon (8%). Northern Pintails, scaup, and less abundant species—Northern Shoveler, Green-winged Teal, and Oldsquaw—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. Shorebirds, raptors, and other birds were noted; however, the primary focus of these surveys was large waterbirds. Waterbirds using the lakes in the Alpine project area were most numerous in early June and early August and least numerous in July (Table 21). The high counts of birds in early summer (Table 22) occurred when aggregations of ducks and geese used 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 also foraged in large numbers in tapped basins.

In 1999, we recorded about half as many waterbirds (6,354) in the survey area as we had in 1998. In nine surveys we flew in 1998, we counted 11,015 waterbirds (20 species). However, the number of species observed, the distributions of those species, and the patterns of use of the lakes surveyed were very similar between years. In 1998 and 1999, 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. The composition of duck species was similar between years: Northern Pintails represented 53% and 60% of all ducks in 1998 and 1999, respectively and unidentified scaup accounted for 21% in both years.

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 the shorelines of these basins (Figure 5); 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). Tapped basins were important to waterbirds throughout the summer; the percentage of birds found in these tapped basins ranged from 52% (of 413 waterbirds on 15 July) to 91% (of 1,092 waterbirds on 17 August). When the results of all aerial surveys are pooled, 77% of all waterbirds

Table 21. Numbers of waterbirds observed during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1999.

	Survey Date									
	June			July			August			
Species	10	16	22[a]	6	15	26	5	17	26	Total
Pacific Loon	45	59	24	38	48	29	52	58	53	406
Red-throated Loon	4	2	3	3	0	4	2	1	0	19
Yellow-billed Loon	5	6	9	9	13	7	8	13	5	75
Unidentified loon	0	0	0	0	0	0	0	0	4	4
Red-necked Grebe	2	0	0	2	3	1	2	7	1	18
Unidentified grebe	0	0	0	1	0	0	0	0	0	1
Greater White-fronted Goose	193	65	39	33	46	39	622	153	183	1,373
Brant	154	7	5	6	0	0	76	33	26	307
Canada Goose	0	11	55	8	5	6	42	96	78	301
Tundra Swan	18	25	14	39	58	54	67	71	122	468
American Wigeon	58	13	42	22	0	0	0	38	60	233
Mallard	5	0	2	0	0	0	0	0	0	7
Northern Shoveler	20	8	10	0	0	0	0	0	0	38
Northern Pintail	92	106	235	127	111	38	286	518	264	1,777
Green-winged Teal	2	0	0	0	0	0	2	6	1	11
Unidentified scaup	112	30	20	124	5	0	13	18	292	614
Spectacled Eider	2	0	0	0	0	0	0	0	0	2
King Eider	2	0	0	0	0	0	0	0	0	2
Oldsquaw	72	46	15	1	12	0	0	0	0	146
Red-breasted Merganser	0	0	4	0	0	0	0	0	0	4
Unidentified duck	0	0	0	4	4	2	19	72	12	113
Sandhill Crane	0	1	0	0	0	0	2	0	3	6
Long-tailed Jaeger	0	0	0	0	1	0	0	0	0	1
Glaucous Gull	7	17	7	18	9	13	9	8	10	98
Sabine's Gull	3	1	1	15	0	0	0	0	0	20
Arctic Tern	11	43	21	91	98	25	21	0	0	310
Total birds	807	440	506	541	413	218	1,223	1,092	1,114	6,354
Total species	19	16	17	15	12	10	14	13	13	23

[a] Incomplete coverage.

recorded were observed in tapped basins. Similarly, in 1998, tapped basins accounted for 78% of all birds recorded. The largest of the four basins, V5.1, accounted for 37% of the total waterbirds counted in 1999, and 36% of those counted in 1998. 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 probably fluctuates in response, which may 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 no sightings of any birds on lake T4.4 over all surveys, to 560 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 >500 birds over all surveys combined (Table 23). Of these lakes, the only one that was not a Tapped Lake with Low-

Table 22. Mean number of waterbirds in tapped basins and other types of lakes recorded during nine aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1999.

	June surveys (n = 3)		July surveys (n = 3)		August surveys (n = 3)	
Species	basin[a]	other	basin	other	basin	other
Pacific Loon	13.0	29.0	5.7	32.7	12.7	41.7
Red-throated Loon	2.7	0.3	1.7	0.7	1.0	0.0
Yellow-billed Loon	1.3	5.3	2.0	7.7	2.7	6.0
Unidentified loon	0.0	0.0	0.0	0.0	0.0	1.3
Red-necked Grebe	0.0	0.7	0.0	2.0	0.0	3.3
Unidentified grebe	0.0	0.0	0.0	0.3	0.0	0.0
Greater White-fronted Goose	88.7	10.3	36.7	2.7	253.3	66.0
Brant	52.3	3.0	1.3	0.7	45.0	0.0
Canada Goose	21.0	1.0	6.0	0.3	66.0	6.0
Tundra Swan	12.0	7.0	22.7	27.7	39.7	47.0
American Wigeon	35.7	2.0	7.3	0.0	23.0	9.7
Mallard	2.3	0.0	0.0	0.0	0.0	0.0
Northern Shoveler	11.3	1.3	0.0	0.0	0.0	0.0
Northern Pintail	123.3	21.0	67.3	24.7	338.3	17.7
Green-winged Teal	0.7	0.0	0.0	0.0	3.0	0.0
Unidentified scaup	41.3	12.7	42.0	1.0	88.3	19.3
Spectacled Eider	0.0	0.7	0.0	0.0	0.0	0.0
King Eider	0.0	0.7	0.0	0.0	0.0	0.0
Oldsquaw	32.7	11.7	2.7	1.7	0.0	0.0
Red-breasted Merganser	1.3	0.0	0.0	0.0	0.0	0.0
Unidentified duck	0.0	0.0	1.3	2.0	34.3	0.0
Sandhill Crane	0.0	0.3	0.0	0.0	0.0	1.7
Long-tailed Jaeger	0.0	0.0	0.3	0.0	0.0	0.0
Glaucous Gull	6.3	4.0	8.7	4.7	8.0	1.0
Sabine's Gull	1.3	0.3	0.0	5.0	0.0	0.0
Arctic Tern	8.7	16.3	39.7	31.7	5.3	1.7
Total birds	456.7	127.7	245.3	145.3	920.7	222.3
Species total	18	19	14	15	13	13

[a] Tapped basin or Tapped Lake with Low-water Connection.

water Connection was lake U5.1, which is a Deep Open Lake without Islands. 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. This lake also contains extensive areas of Aquatic Grass Marsh (Figures 2 and 4). Of the non-tapped lakes, lake U5.1 was the most heavily-used; over all surveys, 35% of the total waterbirds (1,486) in non-tapped basins occurred in U5.1. Lake U5.1 was heavily used, apparently 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). In late August we saw an abrupt increase in the number of waterfowl using U5.1. Lake U5.1 was important to waterbirds in 1998 also, contributing 52% of the count of waterbirds in non-tapped basins.

Lakes U5.1 and T5.1 were both used by nesting and brood-rearing Red-necked Grebes (Figure 4). In 1999, two nests were found in lake T5.1 by ground searchers, and one more nest was found on lake U5.1 during aerial surveys. In 1997 and 1998, 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

Table 23. Number of waterbirds seen during nine aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1999. See Figure 4 for lake identification.

	Lake Number																	
Species	R6.1	R7.1	S6.1[a]	S6.2	S7.1	S7.2[a]	S7.3	S7.4	T4.1	T4.2	T4.3	T4.4	T4.5	T4.6	T5.1	T5.2	T5.3	T5.4
Pacific Loon	15	8	9	13	14	14	2	2	11	18	7	0	5	14	34	14	2	2
Red-throated Loon	0	0	7	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0
Yellow-billed Loon	0	0	14	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0
Unidentified loon	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Red-necked Grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Unidentified grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Greater White-fronted Goose	0	0	124	5	5	175	0	0	11	25	0	0	3	0	6	1	16	29
Brant	3	0	18	0	2	9	0	0	0	0	2	0	0	0	0	0	0	0
Canada Goose	0	0	54	0	1	12	0	0	1	0	0	0	0	0	0	0	0	0
Tundra Swan	9	4	45	1	0	4	6	2	2	12	1	0	1	0	12	12	0	7
American Wigeon	0	0	0	0	2	57	0	0	0	0	0	0	0	0	0	0	0	0
Mallard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern Shoveler	0	0	0	0	2	16	0	0	0	0	0	0	0	0	0	0	0	0
Northern Pintail	1	0	12	0	0	422	0	19	0	0	1	0	0	2	5	2	0	0
Green-winged Teal	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified scaup	0	0	8	0	0	58	8	0	0	0	0	0	0	0	2	0	0	0
Spectacled Eider	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
King Eider	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Oldsquaw	5	2	11	3	8	26	0	0	0	0	0	0	0	0	0	0	0	0
Red-breasted Merganser	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified duck	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
Sandhill Crane	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Long-tailed Jaeger	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Glaucous Gull	0	0	3	0	0	4	0	0	0	4	4	0	0	0	0	0	0	0
Sabine's Gull	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctic Tern	2	0	4	2	11	3	7	0	1	13	0	0	0	0	6	7	0	0
Total birds	36	14	417	34	49	1,044	25	25	26	72	24	0	9	16	69	36	20	38
Total species	7	3	12	6	10	16	4	4	5	5	5	0	3	2	9	5	3	3

Table 23, continued.

Species	T5.5[a]	T5.6[a]	T6.1	T6.2	T6.3	T7.2 complex[b]	U4.1[a]	U4.2	U5.1	U5.2	U5.3	U6.1	U6.2	U6.3	U6.4	V5.1[a]	Total
	Lake Number																
Pacific Loon	16	5	2	6	2	70	12	6	41	2	10	2	0	2	6	40	406
Red-throated Loon	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	1	19
Yellow-billed Loon	0	0	2	0	0	32	0	0	0	0	0	9	2	8	0	4	75
Unidentified loon	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	4
Red-necked Grebe	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	18
Unidentified grebe	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Greater White-fronted Goose	1	0	0	0	0	86	74	0	47	0	0	0	0	0	3	762	1,373
Brant	12	0	0	0	0	4	48	0	0	0	0	0	0	0	0	128	307
Canada Goose	0	0	0	18	0	0	26	0	0	0	2	0	0	0	0	79	301
Tundra Swan	24	11	2	0	1	34	38	0	97	2	2	7	3	9	1	65	468
American Wigeon	22	12	0	0	0	0	20	0	33	0	0	0	0	0	0	87	233
Mallard	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	5	7
Northern Shoveler	0	0	0	0	0	0	8	0	2	0	0	0	0	0	0	10	38
Northern Pintail	52	24	1	0	0	8	410	0	131	2	5	1	2	0	10	559	1,777
Green-winged Teal	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	11
Scaup	2	0	0	8	0	2	126	0	77	0	0	2	0	0	0	321	614
Spectacled Eider	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
King Eider	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Oldsquaw	18	0	0	4	1	4	12	0	11	0	0	0	2	0	0	39	146
Red-breasted Merganser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Unidentified duck	2	0	0	0	0	0	12	0	6	0	0	0	0	0	0	87	113
Sandhill Crane	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	6
Long-tailed Jaeger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glaucous Gull	0	1	1	0	0	11	16	0	9	0	0	0	0	0	0	45	98
Sabine's Gull	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	4	20
Arctic Tern	43	0	2	0	0	56	9	0	35	0	0	4	2	1	0	102	310
Total birds	193	53	25	36	4	308	815	6	513	6	19	25	11	20	20	2,346	6,354
Total species	10	5	7	4	3	11	15	1	14	3	4	6	5	5	4	17	23

[a] Tapped basins.

[b] Includes Lakes T7.1, T7.2, T7.3, T7.4, T7.5, and T8.

of Horned Grebes was seen on U5.1 on 21 June 1999; our first record of this species on the Colville delta.

The T7.2 lake complex (Figure 4; Table 23) lies east of the facility and airstrip footprint, across the Sakoonang Channel of the Colville River. The T7.2 complex supported high numbers of waterbird nests and a diversity of species (Figure 5). Approximately 21% (308 of 1,486) of the cumulative waterbird count from non-tapped lakes was recorded from this complex. The T7.2 complex is very important to loons in the Alpine project area, accounting for 23% of all Pacific Loon sightings and 56% of all Yellow-billed Loon sightings. Additionally, 38% of all Arctic Tern sightings were taken 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).

Most nests (Figure 5) at lake T7.2 were clumped in two areas of emergent vegetation along the south and southwestern margins. The most common nesting species were Pacific Loons, Arctic Terns, and scaup. Nests of Yellow-billed Loon, Tundra Swan, Brant, Spectacled Eider, and Bar-tailed Godwit also were found on the margins of the T7.2 lake complex.

PREDATORS

NEST PREDATION

We directly observed seven instances of nest predation by arctic fox and three instances by jaegers (Long-tailed, Pomarine, and Parasitic) during our research activities in the Alpine project area in 1999. We watched foxes attack nests of Long-tailed Jaegers (1 nest), Oldsquaws (2 nests), White-fronted Geese (2 nests), and Willow Ptarmigans (2 nests), and we saw jaegers attack three nests of White-fronted Geese. Additionally, we documented on video predation by foxes at two nests (arctic fox predation of a Northern Pintail nest recorded by the camera monitoring White-fronted Goose nest 006 and red fox predation of White-fronted Goose nest 401) and partial predation by a Parasitic Jaeger of White-fronted Goose nest 006. An Alpine staff member saw a fox (species unknown) at a White-fronted Goose nest from a building on Alpine Pad 1 (D. Niver, pers. comm.). Two weeks later when we checked the fate of this nest, we verified that the nest had been preyed on by a fox and found a carcass of an adult goose within 5 m of the nest. We also found carcasses of adult geese at two other White-fronted Goose nests in the project area, indicating predation by foxes.

Evidence from the temperature records of 8 of 17 failed White-fronted Goose nests monitored with egg thermistors strongly suggested that fox predation was the cause of nest failure. The temperature readings at the time of failure and after were exceedingly high and erratic compared to temperatures readings when the goose was incubating or off the nest (egg temperature approaches ambient), indicating that the temperature cord was partially severed. We found fox sign (scent, scat, or teeth marks in egg thermistor) at an additional nine nests (one Brant, one Oldsquaw, seven White-fronted Geese) when we checked their nest fate. Fox sign is weak evidence of cause of predation because foxes can visit the nests after failure from other causes. We found signs of probable predation by an avian predator (broken egg shells) at nine nests (one each of Green-winged Teal, Northern Pintail, and Oldsquaw, and six White-fronted Geese).

Video cameras repeatedly recorded foxes near nests. We observed foxes (arctic and red) within camera view on 30 occasions (17 at three White-fronted Goose nests and 13 at two Tundra Swan nests). Foxes were <50 m from the White-fronted Goose nests 11 times, >50 m from the nests 6 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 nine times and on the nest mound four times. Two pairs of geese defended their nests a total of four times and swans at two nests also defended their nests four times. In each case but one, a fox was ≤5 m of the nest, and the incubating bird reacted by standing over the nest for 1–7 min, and in some intervals, rising up and flapping its wings. The exception occurred when a red fox took a White-fronted Goose nest; the pair had previously defended their nest against an arctic fox, but they were apparently unable to deter the red fox and were seen near and beside the nest while the fox made four trips to the nest for eggs.

The number of avian predators seen in the Alpine project area appeared to be similar to previous years. On video tapes, we observed only one avian predator (Parasitic Jaeger) at a goose nest attempting to take eggs. One egg was left in the nest after hatch and may have been damaged by the jaeger. We directly observed a Pomarine Jaeger take one of two eggs from a White-fronted Goose nest, which later failed. We also observed a Parasitic Jaeger take one egg and a Long-tailed Jaeger destroy two eggs in different White-fronted Goose nests that failed. In 1999, avian predators nesting within the Alpine project area included Glaucous Gulls (5 nests), Long-tailed Jaegers (1 nest) and Parasitic Jaegers (2 nests). In 1998, the number of nesting jaegers was the same and the number of nesting Glaucous Gulls was similar (4 nests). Common Ravens, Short-eared Owls, Rough-legged Hawks, Peregrine Falcons, and Pomarine Jaegers were also observed in the project area, but we did not find nests of these predators in 1999.

Although the number of active fox dens in the vicinity was similar to previous years (see below), the level of fox activity in the area appeared high. From observations made during daily surveys in the project area and circumstantial evidence at nests, we concluded that arctic and red foxes were more active in the project area and took more nests in 1999 than in the previous three years. 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. Clearly, the level of nest failure for White-fronted Geese in 1999 (65%) was unprecedented in the years we have checked nest fate in the project area, and foxes probably are the cause of the rise in nest predation.

FOX DEN MONITORING

In 7 years of surveys and contacts with other observers, we have located 58 fox dens between the western edge of the Colville Delta and the western edge of the Kuparuk Oilfield (Figure 10). In 1999, 51 of these dens were classified as arctic fox dens and 7 were occupied by red foxes; two of the dens used by red foxes in 1999 were former arctic fox dens. We have been unsuccessful in locating four other dens on the Colville Delta reported to us by other researchers (M. North, unpubl. data; S. Earnst, pers. comm.). Our sample of confirmed dens has increased in each year of study, from 6 dens in 1992 to 58 dens in 1999. We added four arctic fox dens to the database in 1999—one in the Alpine Transportation Corridor and three north of it—but found no new sites on the Colville Delta. We expect that additional dens are present in portions of the outer delta we have not yet searched thoroughly, particularly because the abundance of arctic ground squirrel burrows in dune habitats there make it difficult to distinguish fox dens.

Of the 51 arctic fox dens, 14 dens were on the Colville Delta, 20 dens were in the Transportation Corridor, and the other 17 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 km^2) and Transportation Corridor (343 km^2) survey areas was 1 den/26 km^2. The density of arctic fox dens was more than twice as high in the Transportation Corridor (1 den/17 km^2) as on the Delta (1 den/39 km^2), probably due to the more limited availability of suitable denning habitat on the Outer Delta, as well as to our lower survey effort there. The overall density was higher than the 1 den/34 km^2 reported by Eberhardt et al. (1983) for their 1,700-km^2 Colville study area (which extended farther east–west than ours, but not as far inland). The overall density we report for arctic fox dens was lower than those reported for the 805-km^2 developed area of the Prudhoe Bay Oilfield (1 den/12–15 km^2; Eberhardt et al. 1983, Burgess et al. 1993, Roderigues et al. 1994), but was within the range reported for undeveloped areas near the Prudhoe field (1 den/28–72 km^2; Burgess et al. 1993, Roderigues et al. 1994). 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 km^2; Macpherson 1969) and Siberia (1 den/32 km^2; Boitzov 1937, as cited in MacPherson 1969).

All but one of the seven red fox dens were on the Colville Delta; the exception was a den on a pingo near the Kachemach River that was occupied by arctic foxes in former years. The density of red fox dens in the Delta area was 1 den/92 km^2; comparative data are unavailable for this species from other arctic tundra areas.

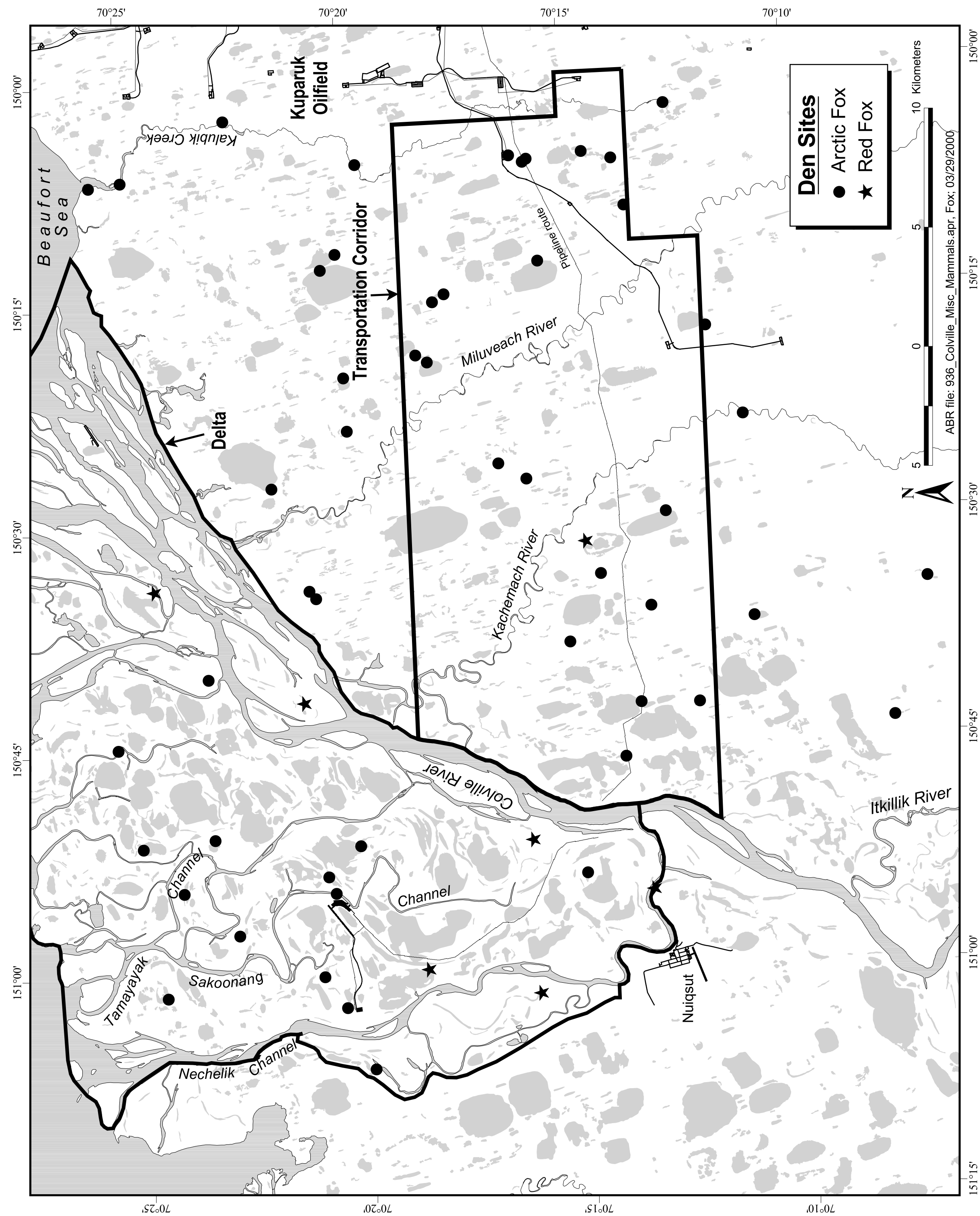

Figure 10. Distribution of arctic and red fox dens found during aerial and ground surveys on the Colville River Delta and adjacent areas, Alaska in 1992, 1993, and 1995–1999. Survey coverage was not uniform over the entire area portrayed.

Table 24. Landforms, activity status, and number of pups at arctic and red fox dens during the 1996–1999 seasons on the Colville River Delta and adjacent coastal plain, Alaska (4 perennially inactive sites excluded).

Location/Species/Landform	1999 Status [a]	No. of Pups [b] (1999)	1998 Status [c]	1997 Status [c]	1996 Status [c]
DELTA					
Arctic Fox					
old dune	natal	8	natal	inactive	natal
old dune	inactive?	–	inactive	inactive?	inactive
dune/lake bank	inactive	–	inactive	inactive?	natal
lake bank	inactive	–	natal?	natal?	natal
dune/lake bank	inactive	–	inactive	inactive	natal
dune/lake bank	active	0?	active	natal	natal
dune ridge	natal	(0)	natal	inactive?	natal
dune mound	inactive	–	inactive	inactive?	inactive
dune/riverbank	inactive	–	natal	natal	natal
dune/lake bank	inactive	–	*not checked*	*not checked*	inactive
low ridge	secondary	(4)	natal	active	secondary?
low dune ridge	natal	2	inactive	natal	secondary
low mound	inactive	–	natal?	inactive	–
sand dune	inactive	–	inactive	–	–
Red Fox					
dune/lake bank	inactive?	0	active	inactive?	inactive
sand dune	inactive?	0	active	inactive	inactive
sand dune	natal	2	natal	active	natal
dune/riverbank	natal?	0?	natal?	inactive	natal
sand dune	natal	2	natal	active?	natal
sand dune	inactive?	0	inactive	inactive	*not checked*
ALPINE TRANSPORTATION CORRIDOR					
Arctic Fox					
pingo	natal	8	inactive	inactive	natal
stream bank	natal	4	inactive?	inactive?	natal
drained-lake bank	inactive	–	inactive	inactive	inactive
pingo	inactive	–	inactive	inactive	inactive
lake bank	inactive	–	inactive	inactive?	natal
lake bank	inactive	–	inactive	inactive	natal
drained-lake bank	inactive	–	inactive	active	inactive
lake bank	secondary?	0?	inactive	inactive?	natal
terrace bank	inactive	–	inactive	active	secondary
low mound	active	0?	inactive	active	natal
terrace bank	inactive	–	inactive	inactive	natal
lake bank	inactive	–	inactive	inactive	natal
drained-lake bank	inactive	–	inactive	inactive?	active
low mound	inactive	–	inactive	active	–
drained-lake island	inactive	–	inactive	inactive	–
pingo ridge	natal	5	inactive	–	–
drained-lake bank	natal	5	inactive	–	–
creek bank	natal	7	–	–	–
Red Fox					
pingo	natal	5	inactive	inactive	natal (arctic fox)
NORTH OR SOUTH OF ALPINE TRANSPORTATION CORRIDOR					
Arctic Fox					
pingo	inactive	–	inactive	natal	inactive
pingo	inactive?	0	natal	inactive	natal
pingo	inactive?	0	inactive	natal	inactive
stream bank	inactive	–	inactive	natal	inactive
drained-lake bank	inactive	–	inactive	inactive	inactive
drained-lake bank	natal	7	natal	natal	inactive?
lake bank	natal	(1)	natal	natal?	inactive?
stream bank	inactive?	0	inactive	inactive	natal
stream bank	inactive?	–	active	natal	inactive
drained-lake bank	natal	1	inactive	natal	natal
drained-lake bank	natal	6	inactive	natal?	–
drained-lake bank	inactive	–	inactive	secondary	–
terrace bank	natal	7	–	–	–
old lake shore	natal	3	–	–	–
peat road	secondary	(3)	–	–	–

[a] Based on observations between 28 June and 15 July (29 June–2 July and 12–15 July for most dens); question mark indicates uncertainty regarding status ("active" means natal vs. secondary status could not be determined).

[b] Number of different pups counted; question mark indicates count suspected to be incomplete; parentheses indicate litters moved or split between natal and secondary dens.

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

Based on brief visits at 50 arctic fox dens during 28 June–2 July and longer observations at 22 of those dens during 12–15 July, we concluded that pups were present at a minimum of 14 natal dens and 3 secondary dens, and suspected that pups were present at two other active dens (Table 25). Thus, the number of active dens (occupied at some point by pups) was estimated to be 19 (38%) of the 50 arctic fox dens checked; the remaining 31 dens (62%) showed signs of occasional use by adults only or were completely inactive (Table 25).

The 38% den occupancy rate by litters (natal, secondary, and active categories combined) in 1999 was intermediate between the lowest and highest values we have recorded since 1993, and was identical to that observed in 1995. The lowest occupancy rates we have observed in the study area were 23% in 1998 and 26% in 1997; in contrast, the 67% occupancy rate in 1996 was the highest on record for the Colville area (Table 25). 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 49 natural den sites in the Prudhoe Bay Oilfield and surrounding area was 69%, and 53% of the sites were classified as natal dens (Rodrigues et al. 1994). Despite a high density of dens on Herschel Island in the northern Yukon (Smith et al. 1992), only 3–19% of a sample of 32 dens examined over 5 years were used as natal dens in any one year (Smits and Slough 1993).

Estimates of pup production are minimal figures because pups often remain underground for extended periods, making it difficult to reliably obtain complete counts. During 12–15 July 1999, we expended 74 person-h observing 29 dens (22 arctic fox dens and all 7 red fox dens) classified as active on our initial check at the end of June, and were successful in counting 71 arctic fox pups at 15 den sites. After the second visit, we revised our classification of site activity. To calculate mean litter size, we disregarded one count thought to be incomplete and combined a litter split between a natal and secondary den nearby, resulting in a total of 70 arctic fox pups at 13 natal dens and a mean litter size of 5.4 pups.

Pup production by arctic foxes in 1999 represented the second highest pup production we have observed in the study area, although it was still well below the 119 pups (6.1 pups/litter) counted in 1996 (Johnson et al. 1997). The mean litter size for arctic foxes in 1999 was similar to the mean of 5.0 pups in 1997, well above the mean litter sizes in 1995 and 1998 (3.0 and 3.1 pups, respectively) (Johnson et al. 1996, 1999). The range of mean litter sizes was virtually identical to that reported by Garrott (1980) for low and high years of pup production in his Colville study area. In 1978, when small mammals were abundant on the delta, Garrott (1980) closely observed 7 litters (from a total of 23 active dens), which averaged 6.1 pups. In contrast, he observed only one litter the year before (from two

Table 25. Occupancy and activity status of arctic fox dens during the 1993 and 1995–1999 denning seasons on the Colville River Delta and adjacent coastal plain, Alaska.

	1999		1998		1997		1996		1995		1993	
Den Status	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Natal	14	28	7	15	4	9	22	51	9	26	5	22
Secondary	3	6	–	–	–	–	3	7	2	6	7	30
Active [a]	2	4	4	8	7	17	4	9	2	6	–	–
Inactive [b]	31	62	35	76	33	74	14	33	21	62	11	48
Total	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.

active dens), when small mammals were scarce, and was unable to obtain a complete litter count. The number of pups produced and the mean litter size we recorded in 1999 suggested that prey populations were moderately high in the study area.

We counted 9 red fox pups at 3 dens, resulting in a mean litter size of 3.0 pups for that species. A fourth site was strongly suspected to be a natal den, but we did not observe pups during our visit. 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 view of the den.

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 concluded that two arctic fox litters, each containing four pups, were moved between alternate den sites in 1999. In one case, we concluded that a litter of four pups was whelped at a den in the vegetated dunes north of the Alpine Pad 2 access road; those pups evidently were moved in early July to the den just north of Alpine Pad 2. These two dens were the nearest occupied den sites to the Alpine facilities. The three dens immediately east of Alpine—between the Sakoonang and Tamayayak channels—were not occupied by litters in 1999. The other pair of dens inhabited by a split litter was located north of the Alpine Transportation Corridor.

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 Transportation Corridor survey areas, respectively, foxes preferred two habitat types—Riverine or Upland Shrub and Moist Sedge–Shrub Meadow—for denning (Johnson et al. 1999; 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. 1999). 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.

LITERATURE CITED

ARCO. 1997. Alpine development project environmental evaluation document. Prepared for U.S. Army Corps of Engineers, Anchorage, AK, by ARCO Alaska, Inc., Anadarko Petroleum Corp., and Union Texas Petroleum Alaska, Corp., Anchorage, AK.

Anderson, B. A., R. J. Ritchie, A. A. Stickney, and A. M. Wildman. 1999. Avian studies in the Kuparuk Oilfield, 1998. Final report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 100 pp.

Anderson, B. A., R. J. Ritchie, A. A. Stickney, and A. M. Wildman. 1998. Avian studies in the Kuparuk Oilfield, 1997. Final report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 69 pp.

Andres, B. A. 1989. Littoral zone use by post-breeding shorebirds on the Colville River Delta, Alaska. M.S. thesis, Ohio State Univ., Columbus, OH. 116 pp.

Baicich, P. J., and C. J. O. Harrison. 1997. A guide to the nests, eggs, and nestlings of North American Birds. 2nd Edition. Academic Press. San Diego, CA. 347 pp.

Brackney, A. W., and R. J. King. 1994. Aerial breeding pair survey of the Arctic Coastal Plain of Alaska, 1993. U.S. Fish and Wildlife Service, Fairbanks, AK. 13 pp.

Burgess, R. M., J. R. Rose, P. W. Banyas, and B. E. Lawhead. 1993. Arctic fox studies in the Prudhoe Bay Unit and adjacent undeveloped area, 1992. Final report prepared for BP Exploration (Alaska) Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 16 pp.

Chesemore, D. L. 1969. Den ecology of the arctic fox in northern Alaska. Canadian Journal of Zoology 47: 121–129.

Cooper, J. A. 1978. The history and breeding biology of the Canada geese of Marshy Point, Manitoba. Wildlife Monograph 61:1–87.

Eberhardt, L. E., R. A. Garrott, and W. C. Hanson. 1983. Den use by arctic foxes in northern Alaska. Journal of Mammalogy 64: 97–102.

Ellis, J. I. and D. C. Schneider. 1997. Evaluation of a gradient sampling design for environmental impact assessment. Environmental Monitoring and Assessment 48:157–172.

Ely, C. R., and D. G. Raveling. 1984. Breeding biology of Pacific White-fronted Geese. J. Wildlife Manage. 48: 823–837.

Garrott, R. A. 1980. Den characteristics, productivity, food habits and behavior of arctic foxes in northern Alaska. M. S. thesis, Penn. State Univ., State College. 95 pp.

Gerhardt, F., R. Field, and J. Parker. 1988. Bird–habitat associations on the North Slope, Alaska: Chronological species summaries, 1987. U.S. Fish and Wildlife Service, Anchorage, AK. 55 pp.

Haefner, J. W. 1996. Modeling biological systems: principles and applications. Chapman and Hall, New York, NY. 473 pp.

Hosmer, D. W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley & Sons, New York, NY.

Johnson, C. B. 1995. Abundance and distribution of eiders on the Colville River Delta, Alaska, 1994. Final report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 12 pp.

Johnson, C. B., M. T. Jorgenson, R. M. Burgess, B. E. Lawhead, J. R. Rose, and A. A. Stickney. 1996. Wildlife studies on the Colville River Delta, Alaska, 1995. Fourth annual report prepared for ARCO Alaska, Inc., Anchorage, and Kuukpik Unit Owners by ABR, Inc., Fairbanks, AK. 154 pp.

Johnson, C. B., B. E. Lawhead, J. R. Rose, A. A. Stickney, and A. M. Wildman. 1997. Wildlife studies on the Colville River Delta, Alaska, 1996. Fifth annual report prepared for ARCO Alaska, Inc., Anchorage, and Kuukpik Unit Owners by ABR, Inc., Fairbanks, AK. 139 pp.

Johnson, C. B., B. E. Lawhead, J. R. Rose, M. D. Smith, A. A. Stickney, and A. M. Wildman. 1998. Wildlife studies on the Colville River Delta, Alaska, 1997. Sixth annual report prepared for ARCO Alaska, Inc., Anchorage, and Kuukpik Unit Owners by ABR, Inc., Fairbanks, AK. 144 pp.

Johnson, C. B., B. E. Lawhead, J. R. Rose, M. D. Smith, A. A. Stickney, and A. M. Wildman. 1999a. Wildlife studies on the Colville River Delta, 1998. Seventh annual report prepared for ARCO Alaska, Inc., Anchorage, and Kuukpik Unit Owners by ABR, Inc., Fairbanks, AK. 102 pp.

Johnson, C. B., W. Lentz, J. R. Rose, A. A. Stickney, and A. M. Wildman. 1999b. Alpine Avian Monitoring Program, 1998. Annual report prepared for ARCO Alaska, Inc., Anchorage, and Kuukpik Unit Owners by ABR, Inc., Fairbanks, AK. 46 pp.

Jorgenson, M. T., J. E. Roth, E. R. Pullman, R M. Burgess, M. Raynolds, A. A. Stickney, M. D. Smith, and T. Zimmer. 1997. An ecological land survey for the Colville River Delta, Alaska, 1996. Final report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 160 pp.

Krebs, C. 1989. Ecological methodology. Harper Collins, New York. 654 pp

Lawhead, B.E. 1999. Caribou distribution, abundance, and movements in the Kuparuk Oilfield and vicinity during the 1998 calving and insect seasons. Draft report prepared for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks. 21 pp.

Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. 2nd Edition. Chapman & Hall, London. 399 pp.

Markon, C. J., L. L. Hawkins, and T. C. Rothe. 1982. Waterbird populations and habitat analysis of the Colville River Delta, Alaska. U.S. Fish and Wildlife Service, Anchorage, AK. 93 pp.

Macpherson, A. H. 1969. The dynamics of Canadian arctic fox populations. Canadian Wildlife Service Report Series, No. 8. 52 pp.

Meehan, R. 1986. Colville River Delta: overview of bird use. U.S. Fish and Wildlife Service, Anchorage, AK. 30 pp.

Meehan, R., and T. W. Jennings. 1988. Characterization and value ranking of waterbird habitat on the Colville River Delta, Alaska. U.S. Fish and Wildlife Service, Anchorage, AK. 105 pp.

Moitoret, C. S., T. R. Walker, and P. D. Martin. 1996. Predevelopment surveys of nesting birds at two sites in the Kuparuk Oilfield, Alaska, 1988–1992. U.S. Fish and Wildlife Service, Northern Alaska Ecological Services, Fairbanks, AK, Technical Report NAES-TR-96-02. 104 pp.

Moulton, L. L., 1996. Colville delta fish habitat study. Report prepared for ARCO Alaska, Inc., Anchorage by MJM Research, Bainbridge Island, WA. 41 pp. and appendices.

Moulton, L.L. 1998. Lakes sampled for fish within and near the Colville River Delta, Alaska 1979-1998. Report for ARCO Alaska, Inc., Anchorage, by MJM Research Lopez Island, WA.. 477p.

Murphy, S. M., and B. A. Anderson. 1993. Lisburne Terrestrial Monitoring Program: The effects of the Lisburne Development Project on geese and swans, 1985–1989. Final synthesis report prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 202 pp.

Nelson, U. C. 1953. Northern record of nesting of Rednecked Grebe. Condor 55: 220.

North, M. R. 1986. Breeding biology of Yellow-billed Loons on the Colville River Delta, arctic Alaska. M. S. thesis, North Dakota St. Univ., Fargo. 109 pp.

North, M. R., J. L. Schwerin, and G. A. Hiemenz. 1984b. Waterbird studies on the Colville River Delta, Alaska: 1984 summary report. U.S. Fish and Wildlife Service, Anchorage, AK. 18 pp.

Norusis,M. 1999. SPSS regression models 10.0. SPSS Inc., Chicago, IL.

Pitelka, F. A. 1959. Numbers, breeding schedule, and territoriality in Pectoral Sandpipers of northern Alaska. Condor 61: 233–264.

Rodrigues, R., R. O. Skoog, and R. H. Pollard. 1994. Inventory of arctic fox dens in the Prudhoe Bay Oilfield, Alaska. Report prepared for BP Exploration (Alaska) Inc., Anchorage, by LGL Alaska Research Associates, Anchorage. 25 pp. + appendix.

Rothe, T. C., C. J. Markon, L. L. Hawkins, and P. S. Koehl. 1983. Waterbird populations and habitat analysis of the Colville River Delta, Alaska: 1981 summary report U.S. Fish and Wildlife Service, Anchorage, AK. 131 pp.

Seaman, G. A., G. F. Tande, D. L. Clausen, and L. L. Trasky. 1981. Mid-Beaufort coastal habitat evaluation study: Colville River to Kuparuk River. Report prepared for North Slope Borough, Barrow, by Alaska Dep. Fish and Game, Habitat Division, Anchorage. 199 pp.

Simpson, S. G. 1983. White-fronted Geese on the Colville River Delta, Alaska: 1983 Progress report U.S. Fish and Wildlife Service, Anchorage, AK. 3 pp.

Simpson, S. G., J. Barzen, L. Hawkins, and T. Pogson. 1982. Waterbird stidies on the Colville River Delta, Alaska, 1982 summary report. U.S. Fish and Wildlife Service, Anchorage, AK.

Smith, C. A. S., C. M. M. Smits, and B. G. Slough. 1992. Landform selection and soil modifications associated with arctic fox (*Alopex lagopus*) den sites in Yukon Territory, Canada. Arctic Alpine Research 24: 324–328.

Smith, L. N., L. C. Byrne, C. B. Johnson, and A. A. Stickney. 1994. Wildlife studies on the Colville River Delta, Alaska, 1993. Final report prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 95 pp.

Smith, L. N., L. C. Byrne, and R. J. Ritchie. 1993. Wildlife studies on the Colville River Delta, Alaska, 1992. Final report prepared for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks. 69 pp.

Smits, C. M. M., and B. G. Slough. 1993. Abundance and summer occupancy of arctic fox, *Alopex lagopus*, and red fox, *Vulpes vulpes*, dens in the northern Yukon Territory, 1984–1990. Canadian Field-Naturalist 107: 13–18.

Stewart-Oaten, A., W. W. Murdoch, and K. A. Parker. 1986. Environmental impact assessment: "psuedoreplication" in time? Ecology 67:929–940.

TERA. 1993. Population dynamics of birds in the Pt. McIntyre Reference Area 1981–1992. Final Report prepared for BP Exploration (Alaska) Inc., Anchorage, by Troy Ecological Research Associates, Anchorage. 30 pp.

U.S. Air Force (USAF). 1995. Final Environmental Impact Statement: Alaska Military Operations Areas, Vol. II. Elmendorf Air Force Base, Anchorage, AK.

Walker, H. J. 1978. Lake tapping in the Colville River Delta, Alaska. Pages 233–238 *in* Proc. 3rd Intl. Conference on Permafrost, Vol. 1. Nat. Res. Council Canada, Edmonton, AB.

Walker, H. J. 1983. Guidebook to permafrost and related features of the Colville River Delta, Alaska. Guidebook 2. Alaska Division Geological and Geophysical Survey, Anchorage. 34 pp.

Walker, H. J., and H. H. Morgan. 1964. Unusual weather and river bank erosion in the delta of the Colville River, Alaska. Arctic 17: 41–47.

Appendix A. Common and scientific names of birds and mammals seen during wildlife surveys on the Colville River Delta, 1992–1999 (Johnson et al. 1999 and this study).

BIRDS

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

MAMMALS

COMMON NAME	SCIENTIFIC NAME
Snowshoe Hare	*Lepus americanus*
Arctic Ground Squirrel	*Spermophilus parryii*
Brown Lemming	*Lemmus sibiricus*
Collared Lemming	*Dicrostonyx rubricatus*
Gray Wolf	*Canis lupus*
Arctic Fox	*Alopex lagopus*
Red Fox	*Vulpes vulpes*
Grizzly Bear	*Ursus arctos*
Ermine	*Mustela erminea*
Wolverine	*Gulo gulo*
Spotted Seal	*Phoca largha*
Moose	*Alces alces*
Caribou	*Rangifer tarandus*
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, 1999.

In 1999, 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. Mean (logarithmic) sound exposure levels (SEL) in A-weighted decibels (dBA) and the duration (sec) of noise events exceeding 85 dBA for ≥10 secs recorded from mid-July to late August at noise monitors from three locations around the Alpine project area, Colville River Delta, Alaska, 1999. Events were averaged separately at each monitor and the highest mean is reported. Vehicles and helicopters were not monitored during this period, and probably account for a portion of the unknown source events.

	Fixed-Wing Aircraft						Unknown Sources					
	SEL		Duration				SEL		Duration			
Date	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*	$\bar{x}$	Max	$\bar{x}$	Max	Sum	*n*
16 July						0	101	103	16	21	32	2
17 July	122	122	12	12	12	1	141	153	16	42	284	18
21 July						0	128	131	15	17	31	2
22 July						0	125	128	15	15	29	2
23 July						0	117	120	18	20	35	2
24 July	104	104	11	11	11	1	106	106	13	13	13	1
25 July						0	126	129	14	14	28	2
26 July						0	128	131	17	18	33	2
28 July						0	125	129	14	14	28	2
29 July						0	131	131	11	11	11	1
30 July	144	155	31	85	377	12	133	148	22	98	1,891	86
31 July	141	148	43	81	260	6	131	148	20	68	2,924	148
1 August	129	132	24	31	47	2	132	149	23	307	3,350	146
2 August	138	147	27	56	320	12	132	148	23	132	3,220	140
3 August	111	116	12	14	36	3	133	148	22	44	2,226	103
4 August	102	104	12	12	24	2	130	147	28	70	3,410	124
5 August	127	134	21	32	126	6	136	155	27	369	4,700	172
6 August	130	134	16	24	48	3	141	158	29	150	3,502	121
7 August	109	124	42	121	3,864	93	127	146	32	185	8,537	269
8 August						0	131	152	30	76	3,619	121
9 August	111	114	31	42	92	3	128	146	33	212	2,113	64
10 August						0	112	129	43	559	6,168	143
11 August	126	132	16	17	65	4	129	147	46	457	3,016	66
12 August	114	117	14	17	27	2	111	125	42	274	3,635	87
13 August	125	131	21	42	85	4	111	124	44	544	4,365	99
14 August	124	127	23	23	46	2	120	132	33	238	1,472	45
15 August	129	132	17	23	34	2	129	146	41	217	2,754	67
16 August	110	115	24	109	191	8	130	149	65	424	4,467	69
17 August	113	116	30	85	120	4	123	134	30	173	1,789	59
18 August	112	118	11	13	45	4	123	134	44	580	2,087	47
19 August[a]						0	122	132	51	126	1,130	22
20 August[a]						0	125	132	42	164	418	10
21 August						0	121	135	34	147	1,643	48
22 August	108	108	28	28	28	1	122	133	24	59	824	35
23 August						0	124	131	27	60	429	16
24 August	114	118	15	20	46	3	121	132	26	58	546	21

[a] Windspeed >20 mph.

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 1996–1999 in the Alpine project area, Colville River Delta, Alaska. The search area boundary is displayed in Figure 5.

	Common Ground-search Area (10.6 km^2)							
	Number of Nests				Density (nests/km^2)			
Species	1996	1997	1998	1999	1996	1997	1998	1999
Red-throated Loon	1	5	1	0	0.1	0.5	0.1	0
Pacific Loon	2	4	1	5	0.2	0.4	0.1	0.5
Yellow-billed Loon	1	1	0	0	0.1	0.1	0	0
Red-necked Grebe	0	3	2	2	0	0.3	0.2	0.2
Greater White-fronted Goose	25	35	31	53	2.4	3.3	2.9	5.0
Canada Goose	0	0	0	0	0	0	0	0
Brant	0	4	1	2[a]	0	0.4	0.1	0.2[a]
Tundra Swan	3	4	5	4	0.3	0.4	0.5	0.4
Northern Shoveler	0	0	5[b]	0	0	0	0.5[b]	0
Northern Pintail	2	4	7[b]	8[b]	0.2	0.4	0.7[b]	0.8[b]
Green-winged Teal	1	0	1	2[b]	0.1	0	0.1	0.2[b]
Greater Scaup	0	1	1	0	0	0.1	0.1	0
Lesser Scaup	0	0	1	0	0	0	0.1	0
Unidentified scaup	0	0	0	1[b]	0	0	0	0.1[b]
Spectacled Eider	0	0	0	0	0	0	0	0
King Eider	0	0	0	0	0	0	0	0
Oldsquaw	6	9	5[b]	4[b]	0.6	0.8	0.5[b]	0.4[b]
Unidentified duck	0	0	2	2	0	0	0.2	0.2
Willow Ptarmigan	1	11	nd	16	0.1	1.0	nd	1.5
Unidentified Ptarmigan	0	0	0	3	0	0	0	0.3
Sandhill Crane	0	0	0	1	0	0	0	0.1
Bar-tailed Godwit	0	0	2	2	0	0	0.2	0.2
Common Snipe	0	1	0	0	0	0.1	0	0
Parasitic Jaeger	1	1	2	2	0.1	0.1	0.2	0.2
Long-tailed Jaeger	1	0	1	1	0.1	0	0.1	0.1
Glaucous Gull	0	1	0	0	0	0.1	0	0
Sabine's Gull	1	0	0	0	0.1	0	0	0
Arctic Tern	0	5	3	5	0	0.5	0.3	0.5
Short-eared Owl	0	0	0	0	0	0	0	0
Total nests or densities[c]	44	78	71	94	4.2	7.4	6.8	8.9
Total species[c]	11	13	16	14				

[a] Includes nest identified from down and nest characteristics.
[b] Includes nests identified from feather and down samples.
[c] Does not include Willow or unidentified ptarmigan.

Appendix D2. Numbers and densities of nests of selected species found during ground searches in 1996–1999, in the Alpine project area, Colville River Delta, Alaska. Search area boundaries are displayed in Figure 5 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	1996	1997	1998	1999
Red-throated Loon	2	7	1	0	0.1	0.5	0.1	0
Pacific Loon	3	8	1	8	0.2	0.6	0.1	0.5
Yellow-billed Loon	1	1	0	1	0.1	0.1	0	0.1
Red-necked Grebe	0	3	2	2	0	0.2	0.1	0.1
Greater White-fronted Goose	35	45	48	79	2.0	3.1	3.2	5.0
Canada Goose	0	0	2	1	0	0	0.1	0.1
Brant	2	7	1	4[a]	0.1	0.5	0.1	0.3[a]
Tundra Swan	3	6	5	7	0.2	0.4	0.3	0.4
Northern Shoveler	1	0	5[b]	0	0.1	0	0.3[b]	0
Northern Pintail	2[b]	5	9[b]	9[b]	0.1[b]	0.3	0.6[b]	0.6[b]
Green-winged Teal	1	0	1	4[b]	0.1	0	0.1	0.3[b]
Greater Scaup	0	2	1	6	0	0.1	0.1	0.4
Lesser Scaup	0	0	1	0	0	0	0.1	0
Unidentified scaup	0	0	2	2[b]	0	0	0.1	0.1[b]
Spectacled Eider	0	0	1	1	0	0	0.1	0.1
King Eider	1	0	0	0	0.1	0	0	0
Oldsquaw	7[b]	9	6[b]	5[b]	0.4[b]	0.6	0.4[b]	0.2[b]
Unidentified duck	0	0	4	2	0	0	0.3	0.1
Willow Ptarmigan	1	12	nd	21	0.1	0.8	nd	1.3
Rock Ptarmigan	0	1	0	0	0	0.1	0	0
Unidentified ptarmigan	0	0	nd	3	0	0	0	0.2
Sandhill Crane	0	0	0	1	0	0	0	0.1
Bar-tailed Godwit	1	0	2	3	0.1	0	0.1	0.2
Common Snipe	0	1	0	0	0	0.1	0	0
Parasitic Jaeger	1	1	2	2	0.1	0.1	0.1	0.1
Long-tailed Jaeger	1	0	1	1	0.1	0	0.1	0.1
Glaucous Gull	0	2	0	1	0	0.1	0	0.1
Sabine's Gull	1	0	0	0	0.1	0	0	0
Arctic Tern	0	5	4	15	0	0.3	0.3	1.0
Short-eared Owl	1	0	0	0	0.1	0	0	0
Area (km^2)	17.2	14.3	14.8	15.7				
Total nests or densities[c]	63	102	99	154	3.7	7.1	6.7	9.8
Total species[c]	16	14	18	18				

[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.

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, and 1998.

Habitat	Area (km2)	No. of Groups	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	2.7	ns
Tapped Lake w/ High-water Connection	0.79	0	0	7.4	ns
Salt Marsh	0.60	0	0	5.7	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.93	0	0	8.7	ns
Deep Open Water w/ Islands or Polygonized Margins	<0.01	0	0	<0.1	ns
Shallow Open Water w/o Islands	0.01	0	0	0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.04	0	0	0.4	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0	-	-	0	-
Aquatic Sedge w/ Deep Polygons	0.12	1	4.5	1.1	ns
Aquatic Grass Marsh	0.10	0	0	0.9	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	1.01	0	0	9.5	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.61	16	72.7	43.4	prefer
Moist Sedge-Shrub Meadow	1.40	5	22.7	13.2	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.50	0	0	4.7	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0	2.2	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.63	22	100	100	
1997					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.7	ns
Tapped Lake w/ High-water Connection	0.79	0	0	7.4	ns
Salt Marsh	0.60	0	0	5.7	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.93	0	0	8.7	ns
Deep Open Water w/ Islands or Polygonized Margins	<0.01	0	0	<0.1	ns
Shallow Open Water w/o Islands	0.01	0	0	0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.04	0	0	0.4	ns
River or Stream	<0.01	0	0	<0.1	ns
Aquatic Sedge Marsh	0	-	-	0	-
Aquatic Sedge w/ Deep Polygons	0.12	1	4.3	1.1	ns
Aquatic Grass Marsh	0.10	0	0	0.9	ns
Young Basin Wetland Complex	0	-	-	0	-
Old Basin Wetland Complex	0	-	-	0	-
Nonpatterned Wet Meadow	1.01	0	0	9.5	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.61	18	78.3	43.4	prefer
Moist Sedge-Shrub Meadow	1.40	3	13.0	13.2	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.50	1	4.3	4.7	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0	2.2	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.63	23	100	100	

Appendix D3 cont.

Habitat	Area (km2)	No. of Groups	Use (%)	Availability (%)	Monte Carlo Results[a]
1998					
Open Nearshore Water (marine)	0	-	-	0.0	-
Brackish Water	0	-	-	0.0	-
Tapped Lake w/ Low-water Connection	0.28	0	0.0	2.6	ns
Tapped Lake w/ High-water Connection	0.79	0	0.0	7.4	ns
Salt Marsh	0.60	0	0.0	5.6	ns
Tidal Flat	0	-	-	0.0	-
Salt-killed Tundra	0	-	-	0.0	-
Deep Open Water w/o Islands	0.93	0	0.0	8.7	ns
Deep Open Water w/ Islands or Polygonized Margins	<0.01	0	0.0	<0.1	ns
Shallow Open Water w/o Islands	0.01	0	0.0	0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.04	0	0.0	0.4	ns
River or Stream	<0.01	0	0.0	<0.1	ns
Aquatic Sedge Marsh	0	-	-	0.0	-
Aquatic Sedge w/ Deep Polygons	0.12	2	6.5	1.1	ns
Aquatic Grass Marsh	0.10	0	0.0	0.9	na
Young Basin Wetland Complex	0	-	-	0.0	-
Old Basin Wetland Complex	0	-	-	0.0	-
Nonpatterned Wet Meadow	1.01	1	3.2	9.5	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.51	24	77.4	42.4	prefer
Moist Sedge-Shrub Meadow	1.29	4	12.9	12.1	ns
Moist Tussock Tundra	0	-	-	0.0	-
Riverine or Upland Shrub	0.49	0	0.0	4.6	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0.0	2.2	ns
Artificial (water, fill, peat road)	0.22	0	0.0	2.1	ns
Total	10.63	31	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. A comparison of the frequency and length of nesting behavior of a White-fronted Goose at nest 006 monitored by a video camera at 1-min intervals and by a thermistored egg at 5-min intervals, near the Alpine project area, Colville River Delta, Alaska, 1999.

		Video Camera										Thermistored Egg						
		On Nest[a]							Recesses			On Nest[a]				Recesses		
			Breaks		Defense													
Date	Day Before Hatching	Normal Incubation Min.	No.	Min.	No.	Min.	Total Min. On Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]	Normal Incubation Min.	No. of Breaks	Total Min. on Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]
10 June[c]	23	–	–	–	–	–	–	–	–	–	–	735	14	805	–	0	0	805
11 June[d]	22	681	13	19	1	7	707	–	2	13	720	1,155	16	1,235	98.4	2	20	1,255
12 June	21	1,413	14	18	0	0	1,431	99.4	1	9	1,440	1,370	12	1,430	99.3	1	10	1,440
13 June	20	1,298	12	15	0	0	1,313	98.7	1	17	1,330	1,375	10	1,425	99.0	1	15	1,440
14 June	19	1,400	8	9	0	0	1,409	97.8	1	31	1,440	1,390	4	1,410	97.9	1	30	1,440
15 June	18	1,433	7	7	0	0	1,440	100.0	0	0	1,440	1,410	6	1,440	100.0	0	0	1,440
16 June	17	1,337	9	11	0	0	1,348	100.0	0	0	1,348	1,330	10	1,380	100.0	0	0	1,380
17 June	16	1,395	11	14	1	1	1,410	97.9	2	30	1,440	1,335	15	1,410	97.9	2	30	1,440
18 June	15	1,427	11	13	0	0	1,440	100.0	0	0	1,440	1,385	11	1,440	100.0	0	0	1,440
19 June	14	1,410	11	14	0	0	1,424	98.9	1	16	1,440	1,385	8	1,425	99.0	1	15	1,440
20 June	13	1,403	12	19	0	0	1,422	98.8	1	18	1,440	1,375	10	1,425	99.0	1	15	1,440
21 June	12	1,345	5	5	0	0	1,350	100.0	0	0	1,350	1,320	12	1,380	100.0	0	0	1,380
22 June	11	1,264	6	6	0	0	1,270	98.8	1	16	1,286	1,360	12	1,420	98.6	1	20	1,440
23 June	10	1,390	11	11	0	0	1,401	97.3	2	39	1,440	1,330	12	1,390	96.5	3	50	1,440
24 June	9	1,399	7	7	0	0	1,406	97.6	2	34	1,440	1,365	8	1,405	97.6	2	35	1,440
25 June	8	1,373	9	10	0	0	1,383	96.0	3	57	1,440	1,335	10	1,385	96.2	3	55	1,440
26 June[e]	7	981	8	8	0	0	989	89.9	3	111	1,100	1,240	9	1,285	93.1	3	95	1,380
27 June[e]	6	–	–	–	–	–	–	–	–	–	–	1,365	12	1,425	99.0	1	15	1,440
28 June[e]	5	862	2	2	0	0	864	96.0	2	36	900	1,285	11	1,340	97.1	2	40	1,380
29 June	4	1,392	6	7	0	0	1,399	97.2	2	41	1,440	1,365	8	1,405	97.6	2	35	1,440
30 June	3	1,313	8	8	0	0	1,321	97.4	2	35	1,356	1,285	11	1,340	97.1	2	40	1,380
01 July	2	1,299	9	9	0	0	1,308	90.8	6	132	1,440	1,280	10	1,330	92.4	5	110	1,440
02 July	1	1,391	6	6	0	0	1,397	97.0	2	43	1,440	1,370	6	1,400	97.2	2	40	1,440
03 July	Hatching	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[f]	18	24,682	162	189	1	1	24,872		27	518	25,390	24,365	175	25,240		27	500	25,740
Average[f]		1,371	9	11	0	0	1,382	98.0	2	29	1,410	1,354	10	1,402	98.1	2	28	1,430

[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] Partial or missing video coverage, data not included in summary.
[f] Includes days 1–4, 8–21 before hatching.

Appendix E2. A comparison of the frequency and length of nesting behavior of a White-fronted Goose at nest 201 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, 1999.

		Video Camera								Thermistored Egg						
		On Nest[a]					Recesses			On Nest[a]				Recesses		
			Break													
Date	Day Before Hatching	Normal Incubation Min.	No.	Min.	Total Min. on Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]	Normal Incubation Min.	No. of Breaks	Total Min. on Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]
11 June[c]	25	–	–	–	–	–	–	–	–	335	8	375	–	5	130	505
12 June[d]	24	276	3	4	280	–	0	0	280	1,175	11	1,230	95.0	7	65	1,295
13 June	23	1,402	16	17	1,419	98.5	2	21	1,440	1,390	6	1,420	98.6	1	20	1,440
14 June	22	1,410	12	13	1,423	98.8	1	17	1,440	1,385	8	1,425	99.0	1	15	1,440
15 June	21	1,363	17	33	1,396	96.9	2	44	1,440	1,355	7	1,390	96.5	2	50	1,440
16 June	20	1,396	8	14	1,410	97.9	2	30	1,440	1,340	12	1,400	97.2	2	40	1,440
17 June	19	1,308	14	17	1,325	97.9	2	29	1,354	1,295	10	1,345	97.5	2	35	1,380
18 June	18	1,401	15	20	1,421	98.7	1	19	1,440	1,365	12	1,425	99.0	1	15	1,440
19 June	17	1,377	12	15	1,392	96.7	4	48	1,440	1,325	13	1,390	96.5	3	50	1,440
20 June	16	1,278	9	14	1,292	97.7	2	31	1,323	1,360	10	1,410	97.9	2	30	1,440
21 June	15	1,402	14	23	1,425	99.0	1	15	1,440	1,355	13	1,420	98.6	1	20	1,440
22 June	14	1,298	10	28	1,326	98.4	1	22	1,348	1,295	13	1,360	98.6	1	20	1,380
23 June	13	1,376	19	45	1,421	98.7	2	19	1,440	1,365	14	1,435	99.7	1	5	1,440
24 June	12	1,368	12	27	1,395	97.3	2	38	1,433	1,350	11	1,405	97.6	2	35	1,440
25 June	11	1,421	7	9	1,430	99.3	1	10	1,440	1,375	8	1,415	98.3	1	25	1,440
26 June	10	1,109	11	17	1,126	100.0	0	0	1,126	1,405	7	1,440	100.0	0	0	1,440
27 June	9	1,320	4	4	1,324	98.9	1	15	1,339	1,320	9	1,365	98.9	1	15	1,380
28 June	8	1,390	4	7	1,397	97.0	3	43	1,440	1,365	12	1,425	99.0	2	15	1,440
29 June	7	1,291	7	8	1,299	98.9	1	15	1,314	1,395	7	1,430	99.3	1	10	1,440
30 June	6	1,317	12	14	1,331	98.6	2	19	1,350	1,320	8	1,360	98.6	2	20	1,380
1 July	5	1,406	19	22	1,428	99.2	1	12	1,440	1,370	11	1,425	99.0	1	15	1,440
2 July	4	1,389	17	27	1,416	98.3	2	24	1,440	1,370	9	1,415	98.3	2	25	1,440
3 July	3	1,391	15	17	1,408	97.8	2	32	1,440	1,375	9	1,420	98.6	1	20	1,440
4 July	2	1,392	9	9	1,401	97.3	3	39	1,440	1,380	3	1,395	96.9	4	45	1,440
5 July	1	1,352	9	10	1,362	100.0	0	0	1,362	1,350	6	1,380	100.0	0	0	1,380
6 July	Hatching	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[e]	23	31,157	272	410	31,567		38	542	32,109	31,205	218	32,295		34	525	32,820
Average		1,355	12	18	1,373	98.3	2	24	1,396	1,357	10	1,404	98.4	2	23	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 thermistored egg was deployed, data not included in summary.
[d] Day camera was deployed, data not included in summary.
[e] Includes days 1–23 before hatching.

Appendix E3. A comparison of the frequency and length of nesting behavior of a White-fronted Goose at nest 401 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, 1999.

		Video Camera										Thermistored Egg						
		On Nest[a]							Recesses			On Nest[a]				Recesses		
			Breaks		Defense													
Date	Day Before Failure	Normal Incubation Min.	No.	Min.	No.	Min.	Total Min. on Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]	Normal Incubation Min.	No. of Breaks	Total Min. on Nest	Incubation Constancy (%)	No.	Total Min. off Nest	Total Min. Monitored[b]
11 June[c]	25	–	–	–	–	–	–	–	–	–	–	180	2	190		6	260	450
12 June[d]	24	275	2	2	0	0	277		1	143	420	1,010	26	1,140	87.4	7	165	1,305
13 June	23	1,368	40	61	0	0	1,429	99.2	2	11	1,440	1,300	27	1,435	99.7	1	5	1,440
14 June	22	1,360	32	46	0	0	1,406	97.6	2	34	1,440	1,315	18	1,405	97.6	2	35	1,440
15 June	21	1,371	25	44	1	3	1,418	98.5	1	22	1,440	1,340	16	1,420	98.6	1	20	1,440
16 June	20	1,394	20	32	0	0	1,426	99.0	1	14	1,440	1,345	16	1,425	99.0	1	15	1,440
17 June	19	1,293	25	38	0	0	1,331	97.9	1	28	1,359	1,280	16	1,360	98.6	1	20	1,380
18 June	18	1,246	21	33	0	0	1,279	98.7	2	17	1,296	1,195	14	1,265	98.1	2	25	1,290
19 June	17	1,338	22	41	0	0	1,379	95.8	3	61	1,440	1,305	16	1,385	96.2	3	55	1,440
20 June	16	1,201	16	26	0	0	1,227	98.2	1	23	1,250	1,365	10	1,415	98.3	1	25	1,440
21 June	15	1,392	16	20	0	0	1,412	98.1	1	28	1,440	1,350	13	1,415	98.3	1	25	1,440
22 June	14	1,201	15	22	0	0	1,223	91.3	4	117	1,340	1,195	12	1,255	90.9	3	125	1,380
23 June	13	1,362	25	32	0	0	1,394	96.8	2	46	1,440	1,315	16	1,395	96.9	2	45	1,440
24 June	12	1,338	20	21	0	0	1,359	94.4	3	81	1,440	1,305	9	1,350	93.8	3	90	1,440
25 June	11	1,289	25	25	0	0	1,314	91.3	5	126	1,440	1,275	9	1,320	91.7	5	120	1,440
26 June	10	1,198	27	29	0	0	1,227	89.9	6	138	1,365	1,190	13	1,255	90.9	6	125	1,380
27 June	9	1,277	28	31	0	0	1,308	90.8	7	132	1,440	1,235	14	1,305	90.6	7	135	1,440
28 June	8	1,306	25	30	0	0	1,336	92.8	5	104	1,440	1,260	13	1,325	92.0	5	115	1,440
29 June	7	1,321	23	27	0	0	1,348	93.6	6	92	1,440	1,280	13	1,345	93.4	6	95	1,440
30 June	6	1,220	27	28	0	0	1,248	92.0	8	109	1,357	1,175	18	1,265	91.7	8	115	1,380
01 July	5	1,290	20	21	0	0	1,311	91.0	7	129	1,440	1,290	10	1,340	93.1	6	100	1,440
02 July	4	1,305	23	23	0	0	1,328	92.2	6	112	1,440	1,270	11	1,325	92.0	6	115	1,440
03 July	3	1,284	27	28	0	0	1,312	91.1	7	128	1,440	1,240	13	1,305	90.6	8	135	1,440
04 July	2	1,329	19	19	0	0	1,348	93.6	6	92	1,440	1,290	12	1,350	93.8	6	90	1,440
05 July	1	1,283	15	16	0	0	1,299	95.4	4	62	1,361	1,245	14	1,315	95.3	4	65	1,380
06 July	Failure	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[e]	23	29,966	536	693	1	3	30,662		90	1,706	32,368	29,360	323	30,975		88	1,695	32,670
Average		1,303	23	30	<0	<0	1,333	94.7	4	74	1,407	1,277	14	1,347	94.8	4	74	1,420

[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] Includes days 1–23 before failure.

Appendix E4. Frequency and duration of nesting behavior of Tundra Swans at nest 301 monitored at 1-min intervals by video camera in the Alpine project area, Colville River Delta, Alaska, 1999.

		On-Nest Activities[a]						Incubation Constancy (%)	Off-Nest Activities					
			Breaks		Defense				Exchange		Recesses			
Date	Day Before Hatching	Normal Incubation Min.	No.	Min.	No.	Min.	Total Min. on Nest		No.	Min.	No.	Min.	Total Min. off Nest[b]	Total Min. Monitored[c]
10 June[d]	29	392	3	6	0	0	398	–	0	0	0	0	0	398
11 June[e]	28	665	3	7	0	0	672	99.4	2	4	0	0	4	676
12 June	27	1,409	7	13	1	2	1,424	98.9	1	1	2	15	16	1,440
13 June	26	1,433	3	3	0	0	1,436	99.7	3	4	0	0	4	1,440
14 June	25	1,282	2	2	1	7	1,291	100.0	0	0	0	0	0	1,291
15 June	24	1,393	7	8	0	0	1,401	97.3	1	3	2	36	39	1,440
16 June	23	1,423	4	10	0	0	1,433	99.5	2	7	0	0	7	1,440
17 June[e]	22	1,136	3	4	0	0	1,140	99.8	1	2	0	0	2	1,142
18 June	21	1,432	2	3	0	0	1,435	99.7	2	5	0	0	5	1,440
19 June	20	1,266	3	8	0	0	1,274	99.8	1	3	0	0	3	1,277
20 June	19	1,146	5	5	0	0	1,151	99.1	1	2	2	8	10	1,161
21 June	18	1,436	4	4	0	0	1,440	100.0	0	0	0	0	0	1,440
22 June[e]	17	1,181	5	5	0	0	1,186	99.4	4	7	0	0	7	1,193
23 June[e]	16	1,217	5	7	0	0	1,224	99.0	4	6	1	6	12	1,236
24 June	15	1,310	4	6	1	4	1,320	99.1	5	12	0	0	12	1,332
25 June	14	1,397	11	15	0	0	1,412	98.1	4	10	1	18	28	1,440
26 June	13	1,398	11	18	0	0	1,416	99.7	2	4	0	0	4	1,420
27 June	12	1,258	1	1	0	0	1,259	98.0	3	6	1	20	26	1,285
28 June	11	1,420	8	12	0	0	1,432	99.4	3	8	0	0	8	1,440
29 June	10	1,293	6	11	0	0	1,304	98.6	2	11	1	8	19	1,323
30 June[e]	9	796	6	8	0	0	804	99.0	3	8	0	0	8	812
01 July	8	1,254	27	43	0	0	1,297	99.4	3	6	1	2	8	1,305
02 July	7	1,350	18	31	0	0	1,381	99.6	3	5	0	0	5	1,386
03 July	6	1,290	18	24	0	0	1,314	97.5	2	8	2	26	34	1,348
04 July	5	1,400	16	26	0	0	1,426	99.0	6	14	0	0	14	1,440
05 July	4	1,385	19	40	0	0	1,425	99.0	2	4	2	11	15	1,440
06 July	3	1,421	11	12	0	0	1,433	99.5	3	7	0	0	7	1,440
07 July	2	1,323	15	28	0	0	1,351	99.9	1	2	0	0	2	1,353
08 July[e]	1	857	12	24	0	0	881	99.9	1	1	0	0	1	882
09 July	Hatching	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[f]	22	29,719	202	323	3	13	30,055		50	122	14	144	266	30,321
Average[f]		1,351	9.2	14.7	0.1	0.6	1,366	99.1	2.3	5.5	0.6	6.5	12.1	

[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] Disturbance by ground crews near nest for >150 min, data not included in summary.
[f] Includes days 2–8, 10–15, 18–21, and 23–27 before hatching.

Appendix E5. Frequency and duration of nesting behavior of Tundra Swans at nest 008 monitored at 1-min intervals by video camera at the Alpine project area, Colville River Delta, Alaska, 1999.

Date	Day Before Hatching	On-Nest Activities[a] Normal Incubation Min.	Breaks No.	Breaks Min.	Defense No.	Defense Min.	Total Min. on Nest	Incubation Constancy (%)	Off-Nest Activities Exchange No.	Exchange Min.	Recess No.	Recess Min.	Total Min. off Nest[b]	Total Min. Monitored[c]
12 June[d]	29	–	–	–	–	–	–	–	–	–	–	–	–	–
13 June[e]	28	1,264	17	22	0	0	1,286	99.5	1	2	1	5	7	1,293
14 June	27	1,375	10	12	0	0	1,387	96.3	4	6	4	47	53	1,440
15 June	26	1,424	10	12	0	0	1,436	99.7	2	4	0	0	4	1,440
16 June	25	1,420	9	10	1	1	1,431	99.4	4	5	1	4	9	1,440
17 June[e]	24	1,328	11	14	0	0	1,342	99.3	3	7	1	3	10	1,352
18 June	23	1,413	12	14	0	0	1,427	99.1	2	3	2	10	13	1,440
19 June[f]	22	897	10	13	0	0	910	99.8	1	2	0	0	2	912
20 June[f]	21	1,015	8	9	0	0	1,024	99.4	1	1	1	5	6	1,030
21 June	20	1,409	11	11	0	0	1,420	98.6	7	20	0	0	20	1,440
22 June[e]	19	1,318	10	11	0	0	1,329	97.8	6	27	1	3[e]	30	1,359
23 June	18	1,387	13	15	0	0	1,402	97.4	1	5	4	33	38	1,440
24 June[g]	17	400	3	3	0	0	403	97.8	1	2	1	7	9	412
25 June[g]	16	–	–	–	–	–	–	–	–	–	–	–	–	–
26 June[g]	15	–	–	–	–	–	–	–	–	–	–	–	–	–
27 June[g]	14	–	–	–	–	–	–	–	–	–	–	–	–	–
28 June[g]	13	–	–	–	–	–	–	–	–	–	–	–	–	–
29 June[g]	12	–	–	–	–	–	–	–	–	–	–	–	–	–
30 June[g]	11	221	3	3	0	0	224	99.6	1	1	0	0	1	225
01 July	10	1,338	14	18	0	0	1,356	94.2	1	3	4	81	84	1,440
02 July	9	1,316	13	16	0	0	1,332	92.5	1	3	6	105	108	1,440
03 July	8	1,299	18	21	0	0	1,320	91.7	2	3	5	117	120	1,440
04 July	7	1,364	10	11	0	0	1,375	95.5	2	4	7	61	65	1,440
05 July[e]	6	1,212	14	14	0	0	1,226	92.4	0	0	3	101[e]	101	1,327
06 July[e]	5	1,258	13	15	0	0	1,273	98.8	4	13	1	3	16	1,289
07 July	4	1,328	14	16	1	1	1,345	93.4	1	3	2	92	95	1,440
08 July	3	1,425	9	9	0	0	1,434	99.6	2	4	1	2	6	1,440
09 July[e]	2	1,279	25	31	0	0	1,310	98.2	1	2	4	22	24	1,334
10 July	1	1,371	18	20	0	0	1,391	99.0	6	14	0	0	14	1,405
11 July	Hatching	–	–	–	–	–	–	–	–	–	–	–	–	–
Total[h]	19	25,528	251	292	2	2	25,822		50	128	47	689	817	26,639
Average[h]		1,343.6	13.2	15.4	0.1	0.1	1,359.1	97.0	2.6	6.7	2.5	36.3[e]	43	

[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, no times calculated.
[e] Disturbance by ground crews near nest for <150 min; these periods were not included in table, but overlapped partially on June 22, and completely on July 5, with the time that the swan was on recess. Inclusion of these recess periods results in a total recess duration of 9 min on June 22 and 126 min on July 5, and a mean recess duration of 37.9 min.
[f] Disturbance by ground crews near nest for >150 min, data not included in summary.
[g] Partial or missing video coverage, data not included in summary.
[h] Includes days 1–10, 18–20, and 23–28 before hatching.

Appendix F1. The number, duration, and type of vehicles observed on the airstrip during the nesting period at the Alpine project area, Colville River Delta, Alaska, 1999. Data were recorded at White-fronted Goose nests by video cameras at 1-min intervals.

	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	5	44	44	1	4	4	5	212	212	11	244	260	820
12 June	1	1	1	2	35	35	4	192	249	7	211	285	1,440
13 June	8	66	66	1	15	15	4	86	116	13	164	197	1,440
14 June	2	12	12	2	10	10	4	24	24	8	36	46	1,440
15 June	11	54	54	3	10	10	5	158	158	19	199	222	1,440
16 June	7	27	30	0	0	0	1	49	49	8	76	79	1,440
17 June	5	93	95	0	0	0	1	8	8	6	101	103	1,433
18 June	10	60	67	6	88	88	4	172	172	20	234	327	1,440
19 June	8	81	81	1	10	10	2	129	190	11	210	281	1,440
20 June	6	74	74	7	118	118	6	277	335	19	404	527	1,440
21 June	3	27	27	2	12	12	3	99	99	8	111	138	1,440
22 June	4	41	41	3	39	39	4	295	547	11	360	627	1,433
23 June	8	28	28	4	28	28	4	54	54	16	64	110	1,440
24 June	2	9	9	2	21	21	4	43	43	8	54	73	1,440
25 June	7	39	39	2	20	20	6	126	134	15	162	193	1,440
26 June	2	20	20	7	136	136	1	19	19	10	175	175	1,436
27 June	2	2	2	1	6	6	5	269	381	8	275	389	1,440
28 June	8	64	64	5	87	98	12	698	1,680	25	701	1,842	1,440
29 June	7	43	43	8	114	114	12	691	1,707	27	691	1,864	1,440
30 June	13	74	74	4	40	40	9	569	833	26	603	947	1,431
1 July	3	35	35	8	147	158	8	730	1,380	19	790	1,573	1,440
2 July	9	94	94	8	90	90	11	797	1,307	28	804	1,491	1,440
3 July	5	22	22	11	252	280	15	771	1,729	31	814	2,031	1,440
4 July	7	43	43	14	335	401	6	880	1,430	27	913	1,874	1,440
5 July	9	52	52	8	101	104	11	681	1,174	28	726	1,330	1,433
6 July	10	80	80	7	52	63	9	801	908	26	830	1,051	1,370
7 July	8	143	143	4	82	82	11	380	433	23	483	658	1,440
8 July	12	87	87	7	78	78	9	498	572	28	563	737	1,440
9 July	14	117	136	8	38	38	10	117	149	32	250	323	1,435
10 July	13	81	81	9	63	63	9	278	343	31	355	487	1,405
11 July	19	207	210	3	29	29	14	905	1,120	36	1,007	1,359	1,440
12 July	10	140	153	6	50	50	12	295	494	28	358	697	982
Total	238	1,960	2,007	154	2,110	2,240	221	11,303	18,049	613	12,968	22,296	44,858
Average	7	61	63	5	66	70	7	353	564	19	405	697	1,402

[a] Duration = number of minutes ≥1 vehicle was on airstrip.
[b] Veh. min = sum of min each vehicle was on airstrip

Appendix F2. The number, type and duration of traffic during the nesting period on the airstrip access road at the Alpine project area, Colville River Delta, Alaska, 1999. Data were recorded at nest 201 by video camera at 1-min intervals.

	Small Truck			Large Truck			Machinery			All Vehicles			
Date	No.	Duration (Min.)[a]	Vehicle Min.[b]	No.	Duration (Min.)[a]	Vehicle Min.[b]	No.	Duration (Min.)[a]	Vehicle Min.[b]	No.	Duration (Min.)[a]	Vehicle Min.[b]	Total Min. Monitored
12 June	4	5	5	1	1	1	2	3	3	7	9	9	353
13 June	11	15	15	3	3	3	10	12	12	24	29	30	1,440
14 June	9	14	14	5	5	5	19	21	22	33	40	41	1,440
15 June	8	11	11	4	6	6	17	63	65	29	80	82	1,440
16 June	7	8	8	2	2	2	3	3	3	12	13	13	1,440
17 June	5	6	6	0	0	0	2	5	5	7	11	11	1,431
18 June	8	11	11	3	3	3	4	4	4	13	18	18	1,440
19 June	13	30	31	5	5	5	3	7	7	20	41	43	1,440
20 June	17	42	42	3	3	3	13	19	19	33	64	64	1,323
21 June	16	56	91	1	1	1	4	4	4	23	68	96	1,440
22 June	7	9	9	1	1	1	4	13	13	12	23	23	1,432
23 June	11	21	24	0	0	0	6	12	12	17	33	36	1,440
24 June	8	49	51	0	0	0	4	25	25	12	74	76	1,433
25 June	8	68	68	0	0	0	10	11	11	18	78	79	1,440
26 June	12	14	15	8	8	8	24	31	31	44	53	54	1,126
27 June	8	16	16	3	3	3	29	86	89	40	93	108	1,403
28 June	3	3	3	7	8	8	12	35	35	22	46	46	1,440
29 June	10	13	13	2	2	2	16	66	66	26	77	81	1,314
30 June	12	31	33	5	8	8	8	8	9	25	47	50	1,420
1 July	7	31	31	6	18	18	7	7	7	20	56	56	1,440
2 July	5	7	7	7	13	13	14	17	17	26	37	37	1,440
3 July	6	7	7	9	16	16	12	34	34	27	57	57	1,440
4 July	20	34	34	13	22	22	17	81	96	47	135	152	1,440
5 July	18	38	38	1	1	5	17	45	46	36	88	89	1,431
6 July	6	12	12	2	2	2	9	17	17	17	30	31	792
Total	239	551	595	91	131	135	266	629	652	590	1,300	1,382	33,618
Average	9.6	22.0	23.8	3.6	5.2	5.4	10.6	25.2	26.1	23.6	52.0	55.3	1,344.7

[a] Duration = number of minutes ≥1 vehicle was on airstrip.
[b] Veh. min = sum of min each vehicle was on airstrip

Appendix F3. The number of people and groups observed during the nesting period on the airstrip, airstrip access road, and on tundra adjacent to the airstrip in the Alpine project area, Colville River Delta, Alaska, 1999. Data were recorded at three White-fronted Goose nests and one Tundra Swan nest by video cameras at 1-min intervals.

	Airstrip					Airstrip Access 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
10 June	–	–	–	–	–	–	–	–	–	–	1	3	89	267	554
11 June	3	2	29	56	525	–	–	–	–	–	2	4	168	402	995
12 June	0	0	0	0	1,440	4	3	23	30	353	0	0	0	0	1,440
13 June	1	1	16	16	1,440	10	4	26	51	1,440	0	0	0	0	1,440
14 June	2	1	50	50	1,440	11	8	96	474	1,440	1	1	33	33	1,440
15 June	1	1	62	62	1,440	22	5	60	117	1,440	0	0	0	0	1,440
16 June	1	1	42	42	1,440	18	5	92	138	1,440	0	0	0	0	1,440
17 June	6	2	113	175	1,427	17	5	48	70	1,431	1	6	157	942	1,440
18 June	2	1	14	14	1,440	30	5	104	169	1,440	0	0	0	0	1,440
19 June	6	12	72	209	1,440	29	5	111	179	1,440	2	1	37	37	1,425
20 June	1	2	48	96	1,250	25	5	111	198	1,323	0	0	0	0	1,161
21 June	2	1	75	75	1,440	21	5	230	875	1,440	0	0	0	0	1,440
22 June	0	0	0	0	1,427	22	5	93	161	1,432	1	6	182	1,092	1,440
23 June	0	0	0	0	1,440	20	3	44	70	1,440	2	2	18	23	1,440
24 June	1	1	4	4	1,440	12	3	58	80	1,433	0	0	0	0	1,332
25 June	0	0	0	0	1,440	24	4	75	140	1,440	0	0	0	0	1,440
26 June	3	4	19	31	1,436	30	5	224	425	1,126	0	0	0	0	1,420
27 June	1	1	2	2	1,440	26	4	48	71	1,403	0	0	0	0	1,285
28 June	1	1	1	1	1,440	14	10	99	438	1,440	0	0	0	0	1,440
29 June	0	0	0	0	1,440	18	4	100	195	1,314	1	4	21	84	1,440
30 June	3	2	8	9	1,431	19	5	147	266	1,420	3	3	408	937	1,425
01 July	2	4	23	82	1,440	20	4	115	222	1,440	1	3	63	189	1,440
02 July	1	1	4	4	1,440	14	4	24	42	1,440	0	0	0	0	1,386
03 July	1	1	1	1	1,440	15	4	40	48	1,440	0	0	0	0	1,348
04 July	0	0	0	0	1,440	14	6	59	119	1,440	0	0	0	0	1,440
05 July	2	1	4	4	1,428	13	4	134	198	1,431	0	0	0	0	1,440
06 July	0	0	0	0	1,440	8	7	53	120	792	0	0	0	0	1,440
07 July	0	0	0	0	1,440	–	–	–	–	–	1	4	17	68	1,440
08 July	4	3	13	31	1,440	–	–	–	–	–	1	4	498	1,992	1,440
09 July	1	1	1	1	1,256	–	–	–	–	–	2	4	377	1,505	1,440
10 July	–	–	–	–	–	–	–	–	–	–	1	2	258	516	1,440
11 July	–	–	–	–	–	–	–	–	–	–	0	0	0	0	1,434
Total	45	–	601	965	40,420	456	–	2,214	4,896	33,618	20		2,326	8,087	44,005
Average	1.6	1.5	20.7	33.3	1393.8	18.2	4.9	88.6	195.8	1,344.7	0.6	1.5	72.7	252.7	1,375.2

[a] Duration = number of min 1 person was present in camera view.
[b] Person min = sum of min for all people by location.

Appendix F4. The number of aircraft by type landing after the waterfowl nesting period at the Alpine airstrip, Colville River Delta, Alaska, 13 July–24 August, 1999. Data from Alpine Security records and this study.

	Aircraft			
Date	DC-6	Twin Otter	C-207	Total
13 July	0	0	0	0
14 July	0	3	0	3
15 July	0	2	1	3
16 July	3	3	0	6
17 July	1	2	1	4
18 July	0	0	1	1
19 July	0	2	1	3
20 July	0	2	0	2
21 July	0	3	4	7
22 July	0	2	0	2
23 July	0	2	0	2
24 July	4	0	0	4
25 July	3	2	0	5
26 July	0	2	0	2
27 July	1	2	0	3
28 July	0	2	1	3
29 July	0	2	1	3
30 July	0	3	0	3
31 July	2	0	0	2
1 August	1	0	0	1
2 August	1	4	0	5
3 August	0	2	0	2
4 August	0	3	0	3
5 August	1	1	0	2
6 August	1	2	0	3
7 August	2	0	1	3
8 August	0	0	0	0
9 August	0	3	1	4
10 August	0	1	0	1
11 August	1	4	0	5
12 August	0	1	0	1
13 August	1	1	0	2
14 August	1	0	0	1
15 August	1	0	0	1
16 August	0	2	0	2
17 August	0	2	0	2
18 August	0	3	1	4
19 August	0	1	0	1
20 August	0	3	0	3
21 August	0	0	0	0
22 August	0	0	1	1
23 August	0	0	0	0
24 August	0	3	0	3
Daily Mean	0.6	1.6	0.3	2.5
Total	24	70	14	108

Appendix G1. Correlations of nesting parameters for 29 Greater White-fronted Goose nests measured with egg thermistors in the Alpine project area, Colville River Delta, Alaska, 1999. n = 439 nest·days.

	Incubation Constancy	Number of Recesses	Total Time Off Nest	Total Time On Nest	Normal Incubation	Number of Breaks
Incubation Constancy	1.00					
Number of Recesses	-0.74**	1.00				
Total Time off Nest	-1.00**	0.74**	1.00			
Total Time On Nest	0.96**	-0.71**	-0.96**	1.00		
Normal Incubation	0.88**	-0.69**	-0.87**	0.92**	1.00	
Number of Breaks	-0.07	0.15**	0.06	-0.09	-0.47**	1.00

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

Appendix G2. Correlation coefficients (r) for environmental and potential disturbance factors monitored during nesting in the Alpine project area, Colville River Delta, Alaska, 1999. Vehicles, helicopters, and pedestrians were monitored with video cameras. Noise events (SEL exceeded 85 dBA for ≥2 sec) were recorded at one of three locations (33m, 148 m, and 330 m from the airstrip). Mean SELs are logarithmic. $n = 158–415$.

	Number of Landings and Takeoffs					Cumulative Time (min)[a]				Airplane Noise Events			Vehicle Noise Events			Helicopter Noise Events			Unknown Noise Events			
	DC-6	Otter	Small Plane	All Planes	Helicopter	All Aircraft	Vehicles	Airstrip Pedestrian	Tundra Pedestrian	Mean SEL	Duration (sec)	No. of Events	Mean SEL	Duration (sec)	No. of Events	Mean SEL	Duration (sec)	No. of Events	Mean SEL	Duration (sec)	No. of Events	Wind Speed (mph)
Landings/Takeoffs																						
DC-6	1.00																					
Otter	-0.37**	1.00																				
Small Plane	0.42**	-0.57**	1.00																			
All Planes	0.35**	0.64**	0.12*	1.00																		
Helicopter	0.30**	0.07	0.26**	0.40**	1.00																	
All Aircraft	0.35**	0.26**	0.25**	0.64**	0.96**	1.00																
Cumulative Time																						
Vehicles	-0.18**	0.03	-0.09	-0.12*	0.05	0.01	1.00															
Airstrip Ped.	0.35**	-0.46**	0.50**	-0.07	0.21**	0.15*	-0.28**	1.00														
Tundra Ped.	-0.03	0.01	-0.23**	-0.13**	0.17**	0.09	-0.03	0.17**	1.00													
Airplane Noise																						
Mean SEL	0.51**	-0.46**	0.39**	0.02	-0.07	-0.06	-0.38**	-0.05	-0.19**	1.00												
Duration	0.19**	-0.30**	0.36**	-0.05	-0.15**	-0.14*	-0.13**	0.19**	-0.14*	0.56**	1.00											
No. of Events	0.37**	-0.34**	0.49**	0.09	-0.05	-0.02	-0.14**	0.39**	-0.15**	0.47**	0.95**	1.00										
Vehicle Noise																						
Mean SEL	-0.26**	-0.14*	-0.03	-0.34**	-0.11	-0.20*	0.26**	-0.23**	0.27**	-0.08	0.33**	0.24**	1.00									
Duration	0.09	-0.25**	-0.07	-0.31**	-0.44**	-0.48*	-0.08	-0.11	-0.03	0.54**	0.33**	0.25**	0.53**	1.00								
No. of Events	0.09	-0.28**	-0.06	-0.35**	-0.42**	-0.47*	-0.09	-0.04	0.03	0.55**	0.37**	0.29**	0.51**	0.99**	1.00							
Helicopter Noise																						
Mean SEL	-0.58**	0.28**	-0.43**	-0.21**	-0.34**	-0.34*	0.07	-0.38**	0.44**	-0.12	0.15*	0.03	0.74**	0.41**	0.41**	1.00						
Duration	-0.18**	0.25**	-0.21**	0.09	0.23**	0.22*	0.01	-0.18**	0.51**	0.57**	0.12*	0.06	0.49**	0.11*	0.15**	0.67**	1.00					
No. of Events	-0.03	-0.07	0.00	-0.11*	0.07	0.02	-0.01	-0.04	0.56**	0.61**	0.53**	0.45**	0.66**	0.30**	0.34**	0.68**	0.84**	1.00				
Unknown Noise																						
Mean SEL	0.08	-0.43**	0.19**	-0.39**	-0.04	-0.15*	-0.22**	-0.06	0.27**	0.60**	0.24**	0.17**	0.71**	0.43**	0.43**	0.64**	0.55**	0.61**	1.00			
Duration	-0.06	-0.17**	-0.03	-0.27**	-0.17**	-0.23*	-0.04	-0.12*	0.48**	0.58**	0.57**	0.46**	0.76**	0.58**	0.61**	0.74**	0.69**	0.93**	0.67*	1.00		
No. of Events	0.03	-0.24**	0.03	-0.29**	-0.16**	-0.23*	-0.06	-0.02	0.48**	0.62**	0.67**	0.57**	0.69**	0.53**	0.57**	0.64**	0.61**	0.93**	0.60*	0.98**	1.00	
Mean Wind Speed	-0.19**	0.04	0.00	-0.06	0.08	0.05	-0.18**	-0.12*	0.10*	-0.23**	-0.17**	-0.22**	0.40**	-0.03	-0.08	0.23**	-0.03	0.03	0.25*	0.08	0.03	1.00
Mean Temperature	-0.02	-0.07	-0.09	-0.14**	-0.52**	-0.48*	0.64**	-0.21**	-0.16**	0.60**	0.04	0.00	-0.35**	0.28**	0.26**	-0.34**	-0.49**	-0.35**	-0.30*	-0.16**	-0.12*	-0.27**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Appendix G3. Regression models (stepwise method) and coefficients of disturbance variables for incubation constancy (arcsine transformed) and number of incubation breaks (logarithm transformed), summarized by day for 29 nests of Greater White-fronted Geese monitored with egg thermistors at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 1999. *P* to enter was 0.1 and to remove was 0.2.

		Standardized				Model Statistics				
Dependent/Independent Variables	β	SD	Beta	*t*	*P*	*F*	*P*	*R*	R^2	Adj.R^2
Incubation Constancy										
Constant	1.467	0.023		62.45	0.000	5.02	0.002	0.21	0.04	0.04
Mean Temperature	-0.005	0.002	-0.13	-2.35	0.019					
Mean Wind Speed	0.003	0.001	0.13	2.27	0.024					
No. of Airplanes	0.003	0.002	0.11	1.89	0.060					
No. of Incubation Breaks										
Constant	1.058	0.009		119.86	<0.001	8.29	0.00	0.22	0.05	0.04
Duration of Vehicle Noise Events	<0.001	<0.001	0.20	3.71	<0.001					
Cumulative Time of Pedestrians on Tundra	<0.001	<0.001	0.10	1.78	0.076					

Appendix G4. Analysis of covariance tests for equality of slopes for incubation constancy and number of incubation breaks for 29 Greater White-fronted Goose nests monitored by egg thermistors in the Alpine project area, Colville River Delta, Alaska, 1999. Independent variables were selected by stepwise regression of disturbance and environmental variables on incubation constancy and incubation breaks.

Source	Type III Sum of Squares	df	Mean Square	*F*	*P*	R^2	Adj. R^2
Dependent Variable: Incubation Constancy (arcsine transformed)							
Corrected Model	0.56	7	0.08	12.11	0.000	0.172	0.158
Intercept	29.44	1	29.44	4,493.27	0.000		
Fate	0.04	1	0.04	5.45	0.020		
Mean Temperature	0.18	1	0.18	27.42	0.000		
No. of Airplanes	0.00	1	0.00	0.00	0.965		
Windspeed	0.02	1	0.02	2.69	0.102		
Fate * Mean Temperature	0.22	1	0.22	33.16	0.000		
Fate * No. of Airplanes	0.00	1	0.00	0.46	0.500		
Fate * Windspeed	0.02	1	0.02	2.30	0.130		
Error	2.67	407	0.01				
Total	908.21	415					
Corrected Total	3.22	414					
Dependent Variable: Number of Incubation Breaks (logarithm transformed)							
Corrected Model	0.63	5	0.13	6.51	0.000	0.092	0.078
Intercept	288.84	1	288.84	14,925.74	0.000		
Fate	0.20	1	0.20	10.28	0.001		
Tundra Pedestrian Time	0.07	1	0.07	3.36	0.068		
Traffic Noise Duration	0.09	1	0.09	4.73	0.030		
Fate * Tundra Pedestrian Time	0.03	1	0.03	1.38	0.241		
Fate * Traffic Noise Duration	0.03	1	0.03	1.76	0.185		
Error	6.23	322	0.02				
Total	384.67	328					
Corrected Total	6.86	327					

Appendix G5. Daily air temperature (deg. C) and wind speed (mph) recorded on the Colville River delta, 1999. Air temperature was recorded at 10-min intervals in a shaded location with a temperature probe and a Hobo data-logger in the Alpine project area. Wind speed records were obtained from the automated National Weather Service station in Nuiqsut (U.S. Dept of Commerce, National Oceanic and Atmospheric Admin., unpubl. data).

	Temperature (C)			Wind Speed (mph)			
Date	Mean	Maximum	Minimum	Mean	Maximum 5-sec Average	Maximum 2-min Average	Direction (deg.)
11 June	6.1	14	0	10.6	18	17	70
12 June	9.7	18	2	10.5	22	20	60
13 June	6.8	13	2	9.5	16	14	320
14 June	6.1	11	2	9.0	17	15	350
15 June	8.2	15	3	11.8	23	21	40
16 June	5.6	10	2	18.2	33	28	70
17 June	5.9	17	2	8.1	16	15	20
18 June	3.9	8	1	7.0	16	13	320
19 June	5.3	12	0	7.8	16	13	340
20 June	3.0	8	-1	14.3	28	24	50
21 June	2.2	7	-1	23.1	34	30	70
22 June	3.2	7	0	13.9	24	22	80
23 June	7.1	12	2	8.0	17	15	40
24 June	5.8	10	1	11.5	21	18	70
25 June	8.0	13	2	9.8	17	15	50
26 June	9.7	16	3	8.4	22	18	20
27 June	4.1	9	-1	10.4	17	15	20
28 June	6.9	17	1	7.3	20	16	30
29 June	7.6	13	1	11.2	21	18	60
30 June	10.1	16	3	10.4	18	16	60
1 July	17.3	26	6	8.5	15	13	90
2 July	17.1	22	12	8.1	21	17	330
3 July	16.4	22	9	8.1	18	16	40
4 July	16.1	26	10	9.0	18	16	190
5 July	14.8	20	10	12.7	29	25	240
6 July	10.2	14	6	13.7	28	24	280
7 July	9.5	12	7	8.4	21	17	340
8 July	14.5	22	7	7.6	15	14	90
9 July	15.4	22	10	6.8	15	14	100
10 July	10.4	14	7	9.3	17	15	360
11 July	9.4	14	4	9.2	17	15	50
12 July	10.4	18	5	9.8	20	16	70
13 July	12.8	20	5	13.0	23	20	90
14 July	13.7	22	5	13.7	25	22	80

Appendix H. Logistic regression models of habitat for predicting nest sites of the most common nesting birds on 12 breeding-bird plots in the Alpine project area, Colville River, Alaska, 1998 and 1999. Variables were chosen with forward stepwise procedures using a probability to enter of 0.2 and probability to remove of 0.4. All models fit the data according to the Hosmer-Lemeshow or log-likelihood goodness-of-fit tests ($P > 0.05$).

Variable Type	Variable	β	S.E.	Wald	df	*P*-value	Exp (β)
1999 Waterfowl Nests, *n* = 480 grids, 14 nests.							
No variables entered this model.[a]							
1998 Waterfowl Nests, *n* = 480 grids, 24 nests.							
Polygon	Center			4.713	2	.095	
	Low	1.028	1.037	.981	1	.322	2.794
	High	-.460	1.238	.138	1	.710	.631
Constant		-3.663	1.013	13.088	1	.000	.026
1999 Greater White-fronted Goose Nests, *n* = 480 grids, 9 nests.							
Vegetation Cover	Moist Sedge–Shrub	.033	.018	3.269	1	.071	1.033
Constant		-5.076	.785	41.756	1	.000	.006
1998 Greater White-fronted Goose Nests, *n* = 480 grids, 16 nests							
No variables entered this model.[a]							
1999 Shorebird Nests, *n* = 487 grids, 85 nests							
Distance	Airstrip (m)			5.435	3	.143	
	0–780	.485	.387	1.577	1	.209	1.625
	781–1,430	.824	.377	4.779	1	.029	2.280
	1,431–2,412	.294	.402	.536	1	.464	1.342
Water	Depth	-.011	.006	3.360	1	.067	.989
Vegetation Cover	Moist Sedge–Scrub	.028	.008	13.108	1	.000	1.029
	Open Low Willow	-.068	.057	1.426	1	.323	.934
Constant		-2.580	.381	45.900	1	.000	.076
1998 Shorebird Nests, *n* = 491 grids, 116 nests.							
Distance	Airstrip (m)			5.985	3	.112	
	0–780	.677	.351	3.725	1	.054	1.967
	781–1,430	.803	.343	5.463	1	.019	2.231
	1,431–2,412	.673	.352	3.657	1	.056	1.961
Polygon	Density			5.259	2	.072	
	Low	.852	.504	2.861	1	.091	2.344
	High	1.258	.557	50.97	1	.024	3.520
Vegetation Cover	Wet Sedge–Willow	.016	0.008	4.197	1	.040	1.016
	Dryas Tundra	.095	.044	4.607	1	.032	1.100
Constant		-2.948	.603	23.916	1	.000	.052

Appendix H cont.

Variable Type	Variable	β	S.E.	Wald	df	*P*-value	Exp (β)
1999 Pectoral Sandpiper Nests, *n* = 480 grids, 24 nests.							
Distance	Airstrip (m)			4.635	3	.201	
	0–780	.372	.750	.246	1	.620	1.450
	781–1,430	1.259	.673	3.495	1	.062	3.522
	1,431–2,412	.698	.721	.936	1	.333	2.009
Vegetation Cover	Moist Sedge–Shrub	.021	.012	2.816	1	.093	1.021
Constant		-4.287	.716	35.830	1	.000	.014
1998 Pectoral Sandpiper Nests, *n* = 483 grids, 61 nests.							
Polygon	Density			4.038	2	.133	
	Low	1.788	1.025	3.043	1	.081	5.979
	High	2.099	1.062	3.906	1	.048	8.156
Vegetation Cover	*Dryas* Tundra	.069	.052	1.763	1	.184	1.071
Constant		-3.715	1.014	13.425	1	.000	.024
1999 Semipalmated Sandpiper Nests, *n* = 480 grids, 37 nest.							
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	.101	
	0–780	2.037	.900	5.120	1	.024	7.667
	781-1,430	2.383	980	5.912	1	.015	10.838
	1,431-2,412	1.809	.942	9.689	1	.055	6.106
Vegetation Cover	Wet Sedge–Willow	.050	.018	7.997	1	.005	1.051
	Moist Sedge Shrub	.059	.016	12.797	1	.000	1.061
	Open Low–Willow	.072	.026	7.788	1	.005	1.075
Constant		-8.095	1.455	30.972	1	.000	.000

Appendix H cont.

Variable Type	Variable	β	S.E.	Wald	df	*P*-value	Exp (β)
1999 Passerine Nests, *n* = 481 grids, 64 nests.							
Topography	Surface Relief	.010	.007	2.202	1	.138	1.011
Water	Depth	.011	.006	3.606	1	.058	1.011
Vegetation Cover	Wet Sedge–Willow	.020	.010	3.970	1	.046	1.020
	Moist Sedge–Shrub	.015	.010	2.522	1	.112	1.015
Constant		–3.562	.527	45.630	1	.000	.028
1998 Passerine Nests, *n* = 482 grids, 54 nests.							
Topography	Surface Relief	.016	.007	5.143	1	.023	1.016
Constant		–2.809	.369	57.970	1	.000	.060
1999 Lapland Longspur Nests, *n* = 481 grids, 62 nests.							
Topography	Surface Relief	.017	.008	4.284	1	.038	1.017
Water	Depth	.009	.006	2.195	1	.138	1.009
Vegetation Cover	Wet Sedge–Willow	.024	.010	5.407	1	.020	1.024
	Moist Sedge–Shrub	.016	.010	2.631	1	.105	1.016
	Open Low Willow	–.082	.064	1.618	1	.203	.922
Constant		–3.947	.565	48.881	1	.000	.019
1998 Lapland Longspur Nests, *n* = 480 grids, 49 nests.							
Topography	Surface Relief	.014	.007	4.223	1	.040	1.015
Constant		–2.855	.377	57.435	1	.000	.058

[a] Polygon center was significant variable, but no nests were found on grids without polygon centers; therefore, the coefficients cannot 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, 1999.

	Survey Date									
	June			July			August			
Waterbird groups	10	16	22[a]	6	15	26	5	17	26	Total
Loons and grebes	56	67	36	53	64	41	64	79	63	523
Geese	347	83	99	47	51	45	740	282	287	1,981
Tundra Swans	18	25	14	39	58	54	67	71	122	468
Diving ducks	184	76	39	125	17	0	13	18	292	764
Dabbling ducks	177	127	289	149	111	38	288	562	325	2,066
Total ducks[b]	365	203	328	278	132	40	320	652	629	2,947
Sandhill Crane	0	1	0	0	0	0	2	0	3	6
Gulls and terns	21	61	29	124	108	38	30	8	10	429
Total birds	807	440	506	541	413	218	1,223	1,092	1,114	6,354

[a] Incomplete survey.
[b] Includes unidentified ducks