

# **ALPINE AVIAN MONITORING PROGRAM, 2001**

## **FOURTH ANNUAL AND SYNTHESIS REPORT**

Prepared for

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## EXECUTIVE SUMMARY

The Alpine Development Project is the first North Slope 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 2 isolated communities. The delta is a regionally important nesting area for Yellow-billed Loons, Tundra Swans, Brant, and Spectacled Eiders, and provides breeding habitat for a wide array of other waterfowl, as well as passerines, shorebirds, gulls, jaegers, and owls.

ConocoPhillips Alaska, Inc. and its partner Anadarko Petroleum Corporation (Anadarko) were granted permits for construction of the Alpine Development Project on the central portion of the Colville Delta in 1998. That year, construction began on a central processing facility and well pad with an airstrip connected by ~3 km of road to a second well pad; this construction continued through 2001. The final gravel footprint occupied ~37 ha (91 acres) by 2000. Alpine was the first oilfield developed on the North Slope without an all-season connection to the Prudhoe-Kuparuk road system, and was designed to be dependent on ice roads and aircraft for support.

The Alpine avian monitoring 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 on large waterbirds during the brood-rearing season, when disturbance likely would have the greatest impacts on productivity. Disturbance, in the forms of aircraft, vehicles, pedestrians, noise, predators, and other birds, was monitored and related to bird and nest abundance, distribution, habitat use, nesting success, and nesting behavior. This report includes an annual synopsis of conditions in 2001 and a synthesis of multi-year data and analyses that evaluate the effects of aircraft and other sources of disturbance on the avian community during the breeding season.

The monitoring program began in 1998 but incorporated data on nest densities and distribution from baseline data collected in 1996 and 1997. Conditions in the study area varied annually. Generally, 1996 and 1998 had warm temperatures

and were phenologically advanced, whereas 1999–2001 were cold and delayed, and 1997 was intermediate. Widespread flooding of the Alpine project area occurred during the second week of June in 2000 and a smaller flood occurred in 2001. As a result of those conditions, nesting was delayed in 1999–2001 relative to 1998 by 8–14 days. Human activity in the study area grew slightly from low levels in 1996 and 1997, before gravel was spread, to light construction activity in 1998, when gravel was spread and compacted by several pieces of heavy equipment. From 1999 to 2001, heavy construction ensued with high numbers of people, vehicles, and aircraft. Aircraft and associated noise peaked during the 2000 breeding season, whereas vehicle and pedestrian traffic peaked in 2001.

The abundance of nests of all species studied in the Alpine project area varied among the years, but other than White-fronted Geese and all ducks as a group, no taxa exhibited trends clearly suggesting a decline from the pre-construction to construction periods. The numbers of White-fronted Goose and duck nests declined from a peak in 1997 to a low in 2001 and were correlated with both weather conditions and levels of disturbance. Because the heavy-construction years coincided with cool temperatures and late spring phenologies, which could have affected nest abundance, we were unable to directly link declines in numbers of nests with levels of disturbance.

Most species of nesting birds did not have detectable differences in distribution relative to the airstrip during years of varying levels of human activity. Nest densities of shorebirds and passerines were higher close to the airstrip than farther away, a trend contrary to what would be expected under a disturbance hypothesis. The distribution of all waterbird nests combined in the study area did not differ during 1996–2001 with respect to the airstrip or flight path, but did differ with respect to the gravel footprint. As might be expected, some nest sites in 1997 that occurred in the future gravel footprint were eliminated after deposition of gravel pads. The distribution of Tundra Swan nests did not change among years. White-fronted Geese, however, did shift nests from areas close to the airstrip to areas farther away during the heavy-construction years; that is,

nesting was reduced within 1,000 m of the airstrip and increased 1,000–1,500 m from the airstrip relative to nest distributions in pre- and light-construction years. Although we did not mark nesting geese to investigate nest relocation, the increases in nest densities in the 1,000–1,500-m zone around the airstrip during heavy-construction activity appeared to be the result of redistribution of nesting pairs.

Although White-fronted Geese modified their nest distribution relative to the Alpine airstrip, their selection and use of habitats did not vary. Consistent habitat use despite the redistribution of nests during heavy-construction years implied preferred nesting habitats were not saturated with nests in the Alpine project area. White-fronted Geese in the Alpine area experienced frequent human disturbance in the heavy-construction years, and apparently were able to choose nest locations that reduced their exposure without having to choose different nesting habitat.

The proximate causes for the changing distribution of White-fronted Goose nests may have been incubating birds experiencing increased levels of stress from multiple sources of disturbance in the areas of the airstrip and gravel pads. Behaviorally, incubating geese and swans reacted to sources of disturbance with concealment and alert postures, which demonstrated variation in sensitivity to different types of human disturbance, but did not indicate negative impacts to nest attendance. In the Alpine project area, airplanes, helicopters, vehicular traffic, and proximity to the airstrip were implicated in longer or more frequent incubation recesses, but nest site (or individual geese), the proximity of hatch date, and nest fate accounted for more variation than did any other explanatory variables. Concealment and alert postures are considered normal incubation activity because the incubating bird does not leave the nest during these responses, so the impacts of increased concealment and alert frequencies to nest incubation probably are minimal. Increases in recess length and recess frequency may be more important to the eventual outcome of the nest, because of the indirect effects that increased time off the nest may have on the risk of egg predation. Evidence linking increased recess length and frequency with reduced nest success was weak. Nonetheless, our observations of nest predation

during this study lead us to suspect that any increase in the time spent off nests by incubating geese increases the risk of predation.

Evidence did not clearly indicate whether predation rates changed during our study. Predator numbers, however, appeared to be stable from pre-construction to construction periods. The number of occupied fox dens and overall pup production did not increase during construction of the Alpine project, nor did the density of occupied dens or pup production in the zone nearest the development increase during the construction period. Similarly, nests of avian predators (Glaucous Gull and Parasitic and Long-tailed jaegers) did not increase during construction of Alpine. The one exception was Common Ravens which were first attracted to buildings in the Alpine project area in 1998. Ravens nested at Alpine in 2000 and 2001 and possibly in 1999. The primary avian predator observed preying on nests in the Alpine project area was the Parasitic Jaeger, which is unlikely to increase in developed areas because it generally does not feed on human foods nor is it attracted to artificial nesting structures.

Little evidence was found indicating that productivity of nesting birds was negatively affected by the Alpine project. Clutch sizes were relatively consistent among years for all waterbirds and for White-fronted Geese, and did not differ with proximity to the airstrip. The daily survival rate of White-fronted Goose nests in only one heavy-construction year (1999) was significantly lower than in a light-construction year (1998). However, failed nests of White-fronted Geese were farther from the airstrip than were successful nests in all heavy-construction years, which was contrary to a disturbance effect; therefore, we interpreted the reduced survival rate in 1999 to be unrelated to disturbance from the airstrip. Although trends in the location of successful and failed waterbird nests (primarily ducks) suggested possible effects of disturbance on waterbird productivity, those relationships were not significant, and therefore, were interpreted as weak evidence of a disturbance effect.

The effects of the Alpine project on non-nesting birds using lakes appeared to be minor and less obvious than the annual variation in the abundance of birds in the project area. The abundance of waterbirds using lakes in the project



area declined from 1998 to 2001, and the decline was primarily among ducks, with other birds remaining at relatively stable numbers. Numbers and densities of all waterbirds differed significantly among months and between tapped lakes and non-tapped lakes. Densities of waterbirds did not decline in the distance zones nearest the airstrip in the heavy-construction years and generally were highest in the nearest zone. We concluded that the annual trend in waterfowl use of lakes was not evidence of a decline related to construction activity, because the distribution of birds did not fit the declining trend expected along the disturbance gradient.

We were unable to directly compare the relative effects of the different sources of disturbance on nesting geese or swans. Our data clearly show individual variation in the responses of geese and swans to potential disturbance, and a reduction in response with increasing distance to the source, consistent with a gradient of exposure. Of all the human-caused disturbance types, helicopters were the least predictable because they were not restricted to any flight pattern. Neither incubating White-fronted Geese nor Tundra Swans reacted to helicopters more often than airplanes. However, monitored nests were closer to the airstrip than they were to the helipad. Therefore, results of comparisons among disturbance types should not be generalized to nests in other locations. For the sample of nesting geese at Alpine, airplanes and pedestrians elicited the highest, and vehicles the lowest, rates of response. The highest rate of response by swans also was to pedestrians. We observed the most severe responses to disturbance—incubating geese flushing from nests—in response to pedestrians, airplanes, helicopters, and foxes, but these responses were not frequent and occurred only at nests that were near the source of disturbance.

We did not evaluate noise independently from visual stimuli of the sources of noise (e.g., airplanes, helicopters, vehicles, and pad activities). Evaluation of changes in behavior and changes in nest distribution found aircraft noise was not a significant explanatory variable. Noise exposure at nests increased with aircraft traffic levels, but did not have a significant effect on observed changes in waterbird or White-fronted Goose nest distributions among years. The results suggested

that geese and other waterbirds did not move nests between years to reduce noise exposure.

Overall, we conclude that the greatest observable impact to birds from the construction of the Alpine project was the change in nest distribution for a few species, primarily White-fronted Geese, around the gravel pads and airstrip. Although nesting birds did exhibit behavioral responses to aircraft and other sources of disturbance, none clearly affected nest outcomes. The Alpine project was designed to minimize gravel coverage and to avoid some of the nesting areas in its vicinity. The design of Alpine may be partially credited for the low number of negative effects on the bird community. We recommend that oilfield developments, particularly airstrips, be located in areas with low densities of nesting birds, avoid areas containing species that are vulnerable to small losses of nests, and avoid habitats that may be limiting for a particular species. We also recommend that off-pad pedestrian activity during the nesting period, and predator access to food and artificial nesting structures, be limited. Project design incorporating knowledge of local avian ecology can effectively reduce potential impacts during the short breeding season of tundra nesting birds, which often face a harsh and unpredictable environment.

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## INTRODUCTION

Oil exploration has occurred on the Colville River Delta (hereafter, the Colville Delta or the delta) intermittently over the last several decades. The Alpine Development Project is the first North Slope 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 2 isolated communities: the native village of Nuiqsut and the Helmericks' family homesite. The delta is a regionally important nesting area for Yellow-billed Loons, Tundra Swans, Brant, and Spectacled Eiders (Rothe et al. 1983, North et al. 1984, Meehan and Jennings 1988; see Appendix A for scientific names). The delta also provides breeding habitat for a wide array of other waterfowl, as well as passerines, shorebirds, gulls, jaegers, and owls. Baseline wildlife studies were conducted on the delta in the 1970s and 1980s by the U.S. Fish and Wildlife Service (e.g., Markon et al. 1982, Simpson et al. 1982, Simpson 1983, Rothe et al. 1983, Meehan 1986). In the 1990s, ARCO Alaska, Inc. (ARCO) began collecting pre-development data on wildlife (Smith et al. 1993, 1994; Johnson 1995; Johnson et al. 1996, 1997, 1998, 1999a) and fish resources (Moulton 1996, 1998). Similar baseline wildlife studies were conducted in 2000–2002, both north (Johnson et al. 2000a, 2002, 2003) and south (Burgess et al. 2000, 2002, 2003) of the Alpine project area. The physical, biological, and human resources of the delta were summarized in an environmental evaluations of the Alpine development (ARCO 1997) and Colville satellites (PHILLIPS and Anadarko 2002).

ARCO Alaska, Inc., (which became PHILLIPS Alaska, Inc. in 2000, and is now ConocoPhillips Alaska, Inc. [CPAI]) 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.). Construction of a portion of the gravel footprint began that spring. The development of the Alpine project relied on ice roads for winter transport of

materials and aircraft for year-round delivery of personnel and supplies. Alpine was the first oilfield developed on the North Slope without an all-season connection to the road system and was designed to be dependent on aircraft support.

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 an airstrip, are poorly understood. As a stipulation of the construction permits, CPAI and Anadarko agreed to a multi-year monitoring program to study disturbance of birds by aircraft in the area of the oilfield. 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 specific objectives of the monitoring program were

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

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 on large waterbirds during the brood-rearing season, when disturbance likely

would have the greatest impacts on productivity. The intent was to collect data during 3 phases of development: prior to construction (1998) (for use as a baseline), during construction in (1999), and during normal airstrip operation (2000). However, the construction schedule for Alpine changed during the course of the study. Portions of the gravel footprint were in place by spring 1998 and were reworked by several pieces of large equipment during that summer, thereby compromising the baseline pre-construction year in the original study design. Full-scale construction occurred during 1999 and 2000, with oil production beginning in November 2000. During the breeding season in 2001, additional construction and drilling occurred at the western well pad (CD-2), while construction (e.g., modification of existing structures) and support activities continued at the main camp and processing facility on the eastern pad (CD-1; Figure 1). So, although Alpine was in an operation phase and producing oil at CD-1 in 2001, activity levels (aircraft and vehicle traffic) were more consistent with the construction phase of development. Consequently, some comparisons of the pre-construction vs. construction vs. post-construction conditions for nesting birds could not be evaluated. For documentation of pre-construction conditions of some parameters of nesting waterfowl and loons, the study relied on data collected in the Alpine project area during 1996 and 1997 as part of the Colville wildlife studies (Johnson et al. 1997, 1998).

In the first part of this report (Part I) on the avian monitoring program at the Alpine Development Project, we present the results of the 4th year of data collection. In Part I, we describe the conditions in the development area and factors that influenced use of the area by birds during the 2001 breeding season. In the second part of this report (Part II), the 2001 results are combined with those from previous years (1996–2000; Johnson et al. 1997, 1998, 1999b, 2000b, 2001). We present a comprehensive among-year synthesis of the changes observed in the abundance, distribution, productivity, behavior, and habitat use of the avian community in the Alpine project area and evaluate which changes were related to the construction and development of Alpine. Finally, we assess whether any of those changes associated with the Alpine

Development Project had negative consequences for avian populations in the area.

## STUDY AREA

The Alpine project area is located on the central Colville Delta, between the Nigliq (Nechelik) and Tamayagiaq (Tamayayak) channels, and can be described approximately as the area within 5 km of the Alpine airstrip (Figure 1). Lakes and ponds are dominant physical features of the Colville Delta. Most waterbodies are shallow (e.g., polygon ponds  $\leq 2$  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).

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 river 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  $\sim 8$  months and are cold and windy. Spring is brief, lasting only  $\sim 3$  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 between mid-May and mid-June (PHILLIPS and Anadarko 2002). Water levels subsequently decrease in the delta

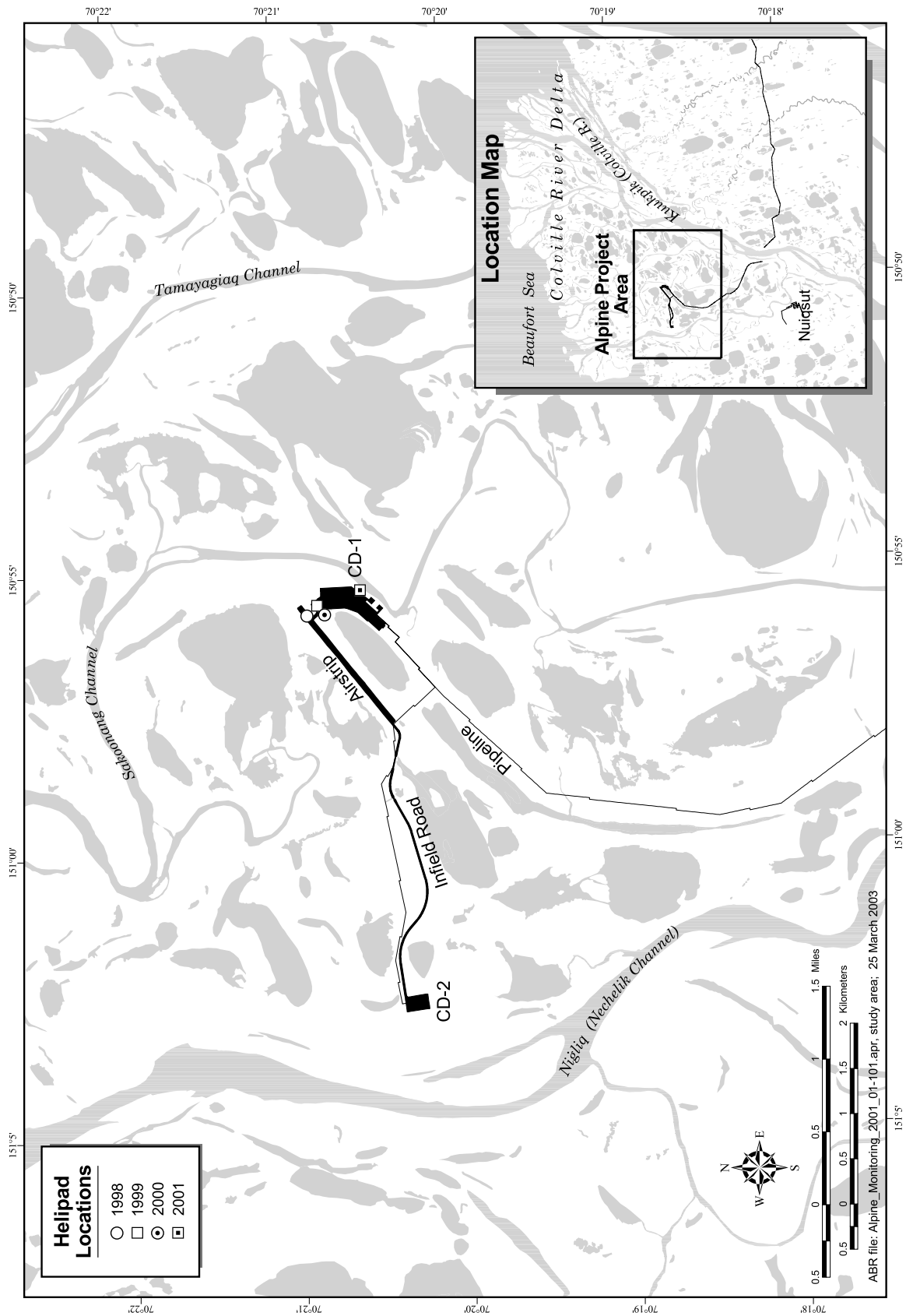


Figure 1. Study area map showing the Alpine project area, Colville River Delta, Alaska, 1998–2001.

throughout the summer, with the lowest levels occurring in winter (Walker 1983). Summers are cool, with temperatures ranging from  $-10^{\circ}$  C in mid-May to  $+15^{\circ}$  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 more rare westerly winds usually bring storms that often are accompanied by high, wind-driven tides and rain (Walker and Morgan 1964). The Colville Delta is described in more detail by Johnson et al. (1999a).

The Alpine development includes a gravel airstrip (~1.8 km long) and 2 gravel pads (CD-1, which includes a drill site, camp, and processing facility, and CD-2, a drill site), all connected by ~3 km of gravel road (Figure 1). In an effort to reduce the amount of wildlife habitat lost to gravel placement, the footprint was designed to minimize gravel coverage. Therefore, the airstrip was designed to serve as a road when there was no air traffic using it. Also, the original road route between the airstrip and CD-2 was altered from a straight line to avoid areas where Tundra Swans and Brant nested. The total area estimated to be covered with gravel fill is ~37 ha (91 acres). A sales-quality pipeline connects this development to infrastructure in the Kuparuk Oilfield. No all-season road connects the Alpine facilities with the Kuparuk Oilfield; materials, equipment, and personnel 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, other forms of disturbance should be accounted for, so that the effects of aircraft on birds can be assessed without the complicating influences of other factors. Although on the surface this process would seem simple, in practice, many confounding factors unrelated to aircraft occur at an active airstrip: predators; weather; noise from construction and drilling; and vehicles, machinery, and people working on the airstrip and in research or 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 involves sampling before and after an impact in control and impacted areas; replicating the samples in the before and after periods increases the ability to detect differences. To evaluate annual variation and evaluate potential effects of changing levels of construction, data from 1996–2000 (Johnson et al. 1997, 1998, 1999b, 2000b, 2001) were combined with data collected in 2001 (presented in Part I). The gradient design requires sampling over some continuous measure from a point source; in this case, distance from the airstrip, flight path, and any gravel pad where human activity occurred, and levels of activity (e.g., number of landings and takeoffs, numbers of vehicles) were used as gradients of potential disturbance. In this report, gradient and other analyses on nesting data from individual and all years are presented, along with BACI-style analyses that compare among all years, or compare among pre-construction (1996 and 1997), light construction (1998), and full construction (1999–2001) (see Conditions in the Study Area for descriptions). The analyses were conducted on 1) all large avian species nesting in the project area; 2) a single species, the Greater White-fronted Goose (because their nests are relatively abundant and well distributed in the project area); 3) bird species nesting on breeding-bird plots; 4) on individual nesting pairs (in evaluations of nesting behavior); 5) birds using lakes in the project area; and 6) indices of fox productivity. Because the responses of numerous species and parameters were evaluated, conclusions necessarily were based on the “weight of evidence”, with more weight placed on analyses that provided evidence of possible population responses to disturbance.

Various analytical techniques were used to test hypotheses. In general, distributions were checked for normality, residual distributions were evaluated, and variances were checked for homogeneity with analytical programs and, when the assumptions of tests relying on normal distribution theory were not met, data were either transformed to approximate normality or tested with non-parametric statistical techniques. Most parametric and non-parametric statistical tests were conducted with SPSS 11.0 for Windows (Chicago, IL). Some simple linear regressions, correlations, chi-square, and Monte Carlo tests were conducted



with Microsoft® Excel. Generalized linear models were constructed using R (The R Development Core Team, Version 1.5.1, 2002). Data collection methods and statistical analyses are described in more detail for each study aspect in the following sections.

## CONDITIONS IN THE STUDY AREA

Conditions in the study area were recorded to assess factors such as weather, timing of snowmelt, river breakup, and human activity that could affect avian use of the Alpine project area.

## WEATHER AND PHENOLOGY

Snow and ice conditions in the Alpine project area were monitored during lake surveys. Dates of peak levels and discharge on the Colville River were gathered from data reported in the Colville EED (PHILLIPS and Anadarko 2002). Daily mean temperatures were summarized into thawing degree-days (calculated by summing the number of degrees that the daily mean temperature was above freezing [ $0^{\circ}\text{C}$ ] for each day during a particular period) from 19 years of weather records kept at the Kuparuk Oilfield. The first date the tundra was free of snow was recorded at the Kuparuk airport. We used Kuparuk weather data because it was recorded in all the years that were used in the analyses, and we judged it to be a good index to weather in the Alpine project area. Weather data on the delta was collected at Colville Village (National Oceanographic and Atmospheric Administration, <http://lwf.ncdc.noaa.gov>) since 1997 and at the Alpine airstrip since 2000. Data collected at Colville Village were highly correlated with those of Kuparuk (for both June temperatures and total thawing degree-days,  $r > 0.9$ ,  $P \leq 0.03$ ), but temperatures at Colville Village tended to be  $1\text{--}2^{\circ}\text{C}$  cooler and snow-free dates were 1–5 d later, because of its coastal location on the outer delta. The Alpine project area is farther from the coast than is Colville Village, and its mean June temperatures, for the 2 years available, were similar ( $\leq 0.1\text{--}0.4^{\circ}\text{C}$  difference) to those reported for Kuparuk. Therefore, Kuparuk weather data were used instead of data from Colville Village as the best estimate for conditions at Alpine.

Several factors were used to gauge the relative phenology of each year: the number of thawing degree-days in the last half of May (during arrival

of birds) and the first half of June (during nest initiation for waterfowl), the first date of snow-free tundra, the first date of midge (Chironomidae) emergence, the first date of mosquito (*Aedes* spp.) harassment, and first and mean dates of egg hatch for nesting birds. The relationships of annual weather conditions, various nesting parameters (e.g., numbers of nests, nesting success), measured levels of potential disturbance (e.g., numbers of aircraft, average noise levels), and levels of predator activity (e.g., numbers of occupied fox dens) were evaluated with bivariate Spearman's rank correlations.

## HUMAN ACTIVITY

Because human activity in the Alpine project area has varied among the years of study, it was necessary to document the timing and extent of the activity each year for the investigation of human-related disturbance effects. Prior to 1998, surveyors, hydrologists, botanists, and wildlife biologists conducted pre-development evaluations in the project area (Table 1). Local residents probably hunted in the project area prior to construction. Complete records of helicopter traffic and people in the Alpine project area were not available prior to 1998. For 1997, we estimated (for the purposes of correlation analysis only) that an average of one helicopter landed every day (approximately half that recorded in 1998) in the Alpine project area during the nesting season. In 1996, helicopter traffic was less frequent than in 1997, so we estimated that one helicopter landed every other day. Initial construction of the Alpine facilities (primarily gravel-pad construction of the airstrip and CD-1) began during winter 1998. In 1998, construction activity was recorded during our sampling visits and gathered from contractors working at the site, so daily summaries (not hourly) of the amounts of helicopter traffic, vehicle activity, and pedestrian activity were available for analysis. From 1999 through 2001, hourly summaries of those potential sources of disturbance were recorded. In 1999, time-lapse video cameras that were focused on nests and included views of facilities in the background were used to document helicopter landings and vehicle and pedestrian traffic. That year Alpine security staff also began recording landings and takeoffs of fixed-wing aircraft. In

Table 1. Summer construction status of the Alpine development project, Colville River Delta, Alaska, 1996–2001.

| 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 | Pad 1 and airstrip under construction; drilling on Pad 1, airstrip maintenance | vehicles, road equipment, drill rig                         | surveyors, hydrologists, biologists, equipment operators, construction workers | facility in place, airstrip and camp operational, Pad 2 gravel and pipeline in place, in-field road partially complete   | helicopter, Twin Otter, Caravan, C-207, DC-6                                  |
| 2000 | drilling on Pad 1, construction, pad and road maintenance                      | vehicles, road equipment, construction equipment, drill rig | surveyors, hydrologists, biologists, equipment operators, construction workers | airstrip, camp, and drilling operational; oil production equipment and modules being installed; additional housing and modules in place; in-field road and bridges in place but requiring surface improvements; Pad 2 storage and fuel depot for helicopters | helicopter, C-207, C-185, Twin Otter, CASA, Conquest 3, DC-6, C-130           |
| 2001 | Pad 1 maintenance and construction, Pad 2 drilling and construction            | vehicles, road equipment, construction equipment, drill rig | surveyors, hydrologists, biologists, equipment operators, construction workers | airstrip, camp, and drilling operational; in-field road and bridges completed  | helicopter, C-207, C-185, Twin Otter, CASA, Navajo & Beech twins, DC-6, C-130 |

2000 and 2001, records were kept by Alpine security of all aircraft and vehicles on the airstrip during work hours, and their records were supplemented by our video recordings for periods when vehicle traffic was not recorded. Aircraft were classified as 4-engine (Douglas DC-6 or Lockheed C-130 Hercules), twin-engine (deHavilland Twin Otter, CASA Aviocar, or Cessna 441 Conquest), single-engine (Cessna 207 and Cessna 185), or helicopter (Bell 206 Long

Ranger and Bell 206 Jet Ranger). Aircraft events were counted for each landing and each takeoff so that 2 events were recorded for each aircraft. Vehicles were classified from video recordings as machinery (graders, bulldozers, compactors, cranes, and loaders), large trucks ( $\geq 1$ -ton axle rating), and small trucks (pickups, “Suburbans”, and single-person all-terrain vehicles). Vehicles were not classified to type in Alpine security records.

## NOISE MONITORING

Noise conditions were monitored during 1998–2000 in the Alpine project area with 2–3 sound level meters (Larsen-Davis Model 870) placed at fixed locations around the airstrip (Johnson et al. 1997, 1998, 1999b, 2000b, 2001). The sound monitors were placed 300 m away from the airstrip in 1998 to record background noise levels. In 1999 and 2000, the monitors recorded noise levels 35–40 m from the airstrip to measure worst-case noise levels. Because the number of sample locations was small, noise levels could not be described for more than a few nest locations. In 2001, Michael Minor and Associates (Portland, OR) was contracted to model the distribution of noise throughout the project area for the aircraft that use the Alpine airstrip. Noise levels were monitored during 24–28 August 2001 at 20 locations where Greater White-fronted Geese (henceforth White-fronted Geese) had nested once between 1998 to 2001 (Figure 2). Nest sites were relocated with handheld GPS units using coordinates recorded at the time of nest discovery. The noise measurements for each type of aircraft (not all aircraft flew into the airstrip while monitoring was taking place at each location) were used to calibrate the model (INM ver 6.0, Federal Aviation Administration). After calibration, the model was run for each aircraft type (single-engine, twin-engine, and 4-engine airplanes) for 2 arrival and 2 departure directions (30° and 210°). The model used assumptions (when data on each flight were unavailable) about each aircraft type (flight paths, ascent and descent angles, weight, and throttle settings) and weather conditions (temperature, humidity, and wind) that could affect the noise produced by individual aircraft. Details of modeling assumptions are provided in Appendix B.

Each nest location was assigned an  $L_{\max}$  (maximal sound level) and SEL (sound exposure level, or the integral of the sound energy during the period it was above 85 dBA, standardized for 1 sec) based on aircraft type and direction of arrival or departure. Helicopters used a different helipad almost every year, so annual noise contours were calculated from each location, assuming vertical landings and takeoffs, because no records were available for flight directions. Helicopter noise

contours were circular and estimated from an assumed level of 111.9 dBA at 15 m (50 ft) for a Bell 206 Long Ranger (calculated from data provided in Bell Helicopter Information Letter GEN-01-78, 26 April 2001) and estimated for each nest location by the distance function:

$$L_{\max} = 111.9 - [20 \times \log (\text{distance} / 15 \text{ m})].$$

Based on records of aircraft flights (complete records available for time period 0600–1759 hr summarized for each hour (available only for 1999–2001) and for each day (same 12-hr period, records available for 1998–2001), multiple noise events were predicted for all nest locations (not just the monitored nest sites). Noise events were summarized for the  $L_{\max}$  and  $L_{\text{eq}}$  (equivalent sound level, in this report termed the hourly noise level when integrated over 1 hr and termed the daily noise level when integrated over 12 hr). Annual noise levels for each nest were calculated from the logarithmic average of daily  $L_{\text{eq}}$  during 1 June–15 July (the general nesting period). As mentioned above, flights were recorded by Alpine security personnel, but flight directions were not recorded. Arrival and departure directions were taken from video recordings when available. When arrival and departure directions were unknown, we assumed that aircraft landed and departed into the wind until wind speeds dropped below 5 mph for the single- and twin-engine aircraft. At lower wind speeds, we assumed that the planes landed to the northeast and departed to the southwest to reduce taxiing on the airstrip. We also assumed that 4-engine aircraft always landed into the wind regardless of wind speed because they generally carried heavy loads and needed more airspeed for lift. Video recordings of landings and takeoffs confirmed the above assumptions. Ambient  $L_{\text{eq}}$  levels were assumed to be 25 dBA regardless of location prior to construction activity and 65 dBA at the edge of pads (diminishing with distance from pads) during construction and drilling (estimated from measurements taken in 2001). Detailed methods and results of the noise monitoring and modeling are reported in Appendix B.

The effects of noise levels on birds were evaluated by determining responses of bird behavior and distribution. Nesting behavior and

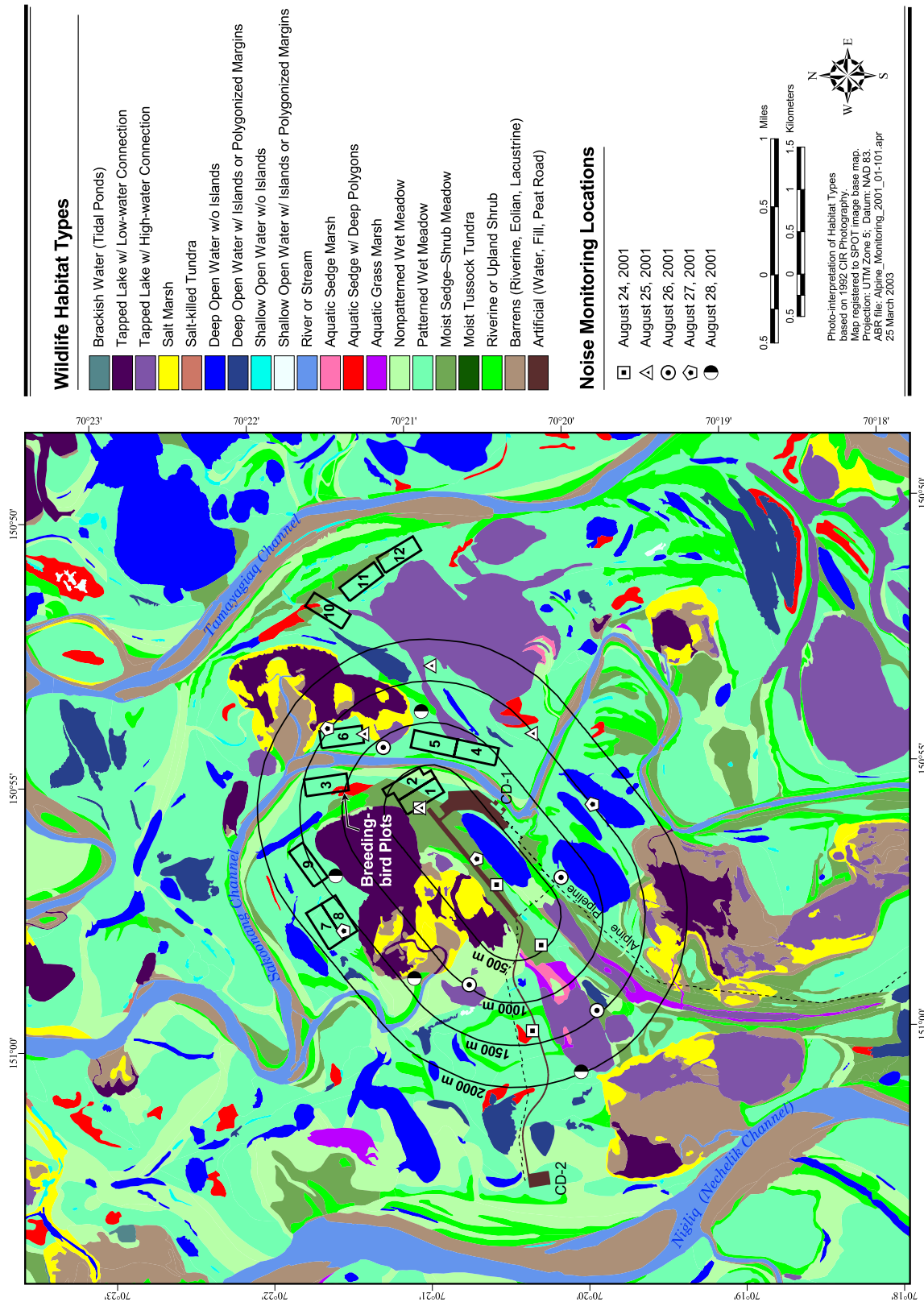


Figure 2. Habitats, breeding-bird plots (1998–2001), noise monitoring locations (2001), and 500-m buffers around the airstrip in the Alpine project area, Colville River Delta, Alaska.

activity budgets were analyzed with noise as one of the covariates (see Nest Attendance and Disturbance Monitoring). Annual differences in noise levels in the study area were estimated by modeling a set of 200 randomly selected nest locations with the noise conditions from each year of study and comparing among years with ANOVA and Bonferroni multiple comparisons. To test whether noise levels at nests changed with differences in annual distributions of nests, a single year's noise conditions were modeled based on each year's nest distribution and the summary noise values compared among years in 2-sample *t* tests and ANOVA.

### NEST SEARCHES, NEST DENSITIES, AND NESTING SUCCESS

Ground-based nest searches were conducted using the same techniques each year from 1996 to 2001, although the area covered and the search effort varied annually (Johnson et al. 1997, 1998, 1999b, 2000b, 2001). The extent of the search areas varied among years (Figure 3), because of changing expectations of pad locations prior to construction and the availability of nest searchers in later years. To standardize comparisons of the distribution and density of nests among years, the area that had been searched in common in 1996–2001 (henceforth, “common search area”) was delineated. Each year the area within 10 m of the shorelines of all waterbodies was searched, and all intervening habitat was searched by observers walking zig-zag paths at ~10-m spacing between observers. Five to 11 observers searched for nests of all ducks, geese, Tundra Swans, loons, gulls, terns, and other large birds (including ptarmigan, Common Snipe, and Bar-tailed Godwit). For each nest, the species, distance to nearest waterbody, waterbody class, habitat type, and, if the bird flushed, the number of eggs in the nest were recorded. The nest searches were conducted for 8–10 d between 11–30 June each year, and the area was searched once completely except in 1998. In 1998, 2 ground searches were conducted, and although the second search yielded a few more nests, the disturbance to known nests appeared to increase rates of predation, so this approach was abandoned. Some waterbird nests were located during the surveys of the breeding-bird plots, lake

surveys, and video-camera maintenance. For the purposes of annual comparisons of numbers or densities, only nests found during the nest search (1<sup>st</sup> search only in 1998) and in the breeding-bird plots (where effort was standardized) that were within the common search area were used, unless specifically stated otherwise. Breeding-bird plots were searched only one time by dragging ropes (see methods for breeding-bird plots, below), and although the method of locating nests differs from our foot searches, we believe the 2 techniques produce similar results for large nesting birds such as swans, ducks, and geese.

All nest locations were mapped on 1:18,000-scale color aerial photographs and the locations were added to a GIS database. The exact locations of nests of waterbirds were recorded using a GPS in 1997–1999 at nests near (within ~500 m) the airstrip, and at all locations in 2000–2001. Down and feather samples were collected from all waterfowl nests after hatch or failure. For those nests that were unattended and could not be identified to species, the down and feather samples were used to make preliminary identifications. Seven to 11 researchers experienced with nesting tundra birds each year compared these unknown feather samples with samples from known nests and identified them to species when possible. The assessments were compiled and nest samples receiving  $\geq 75\%$  of the assignments to one species were so identified; all others were recorded as unidentified.

Nest sites of waterbirds in the ground-search area were revisited after hatch to determine their fate. Fate checks took place between 10 and 18 July. Nests were classified as successful if the egg membranes 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 revisits to nests, broods in the area were recorded opportunistically on 1:18,000-scale color aerial photographs. Ground-searches that were designed to locate loon broods were conducted in August year. These surveys were conducted for a few days between 14 and 26 August, and all waterbodies  $\geq 25$  m long were searched. Any broods observed during these surveys were recorded on aerial photographs. Because broods

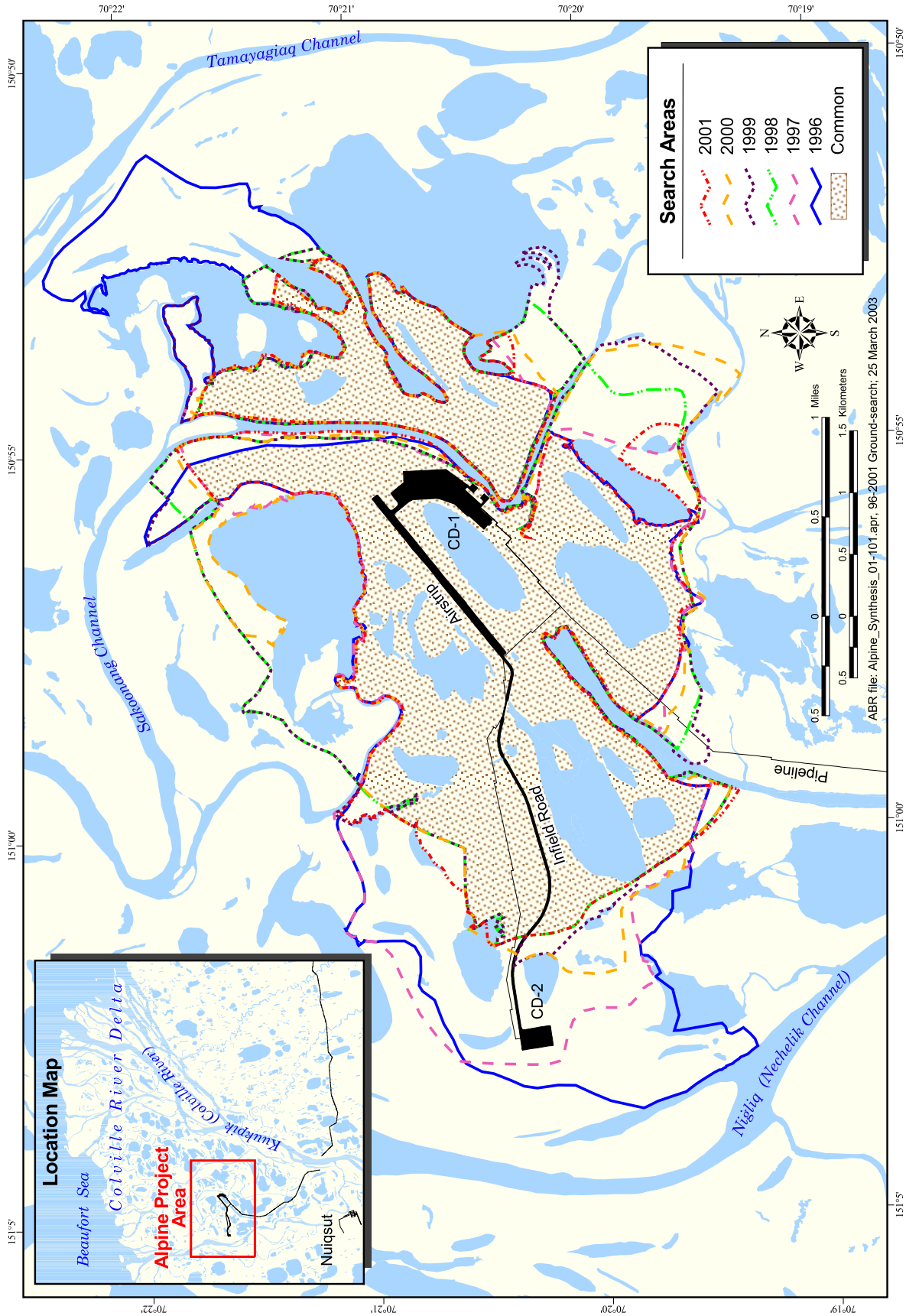


Figure 3. Study area map showing the ground-search areas, Alpine project area, Colville River Delta, Alaska, 1996–2001.



were recorded opportunistically, annual comparisons of brood numbers were not made in Part II of this report.

The number of nests of each species within the common search area was calculated using GIS. Because the amount of effort (number of personnel and hours) spent searching for nests, as well as the total area searched, varied among years, nest-search effort was calculated for annual comparison. Nest-search effort was calculated for each year by summing the number of hours spent searching in the common search area. Because records were not kept specifically for the common search area in 1996–1998, the effort was estimated by multiplying the total number of hours searched by the ratio of the common search area (10.6 km<sup>2</sup>) to the total area searched in each year (17.2 km<sup>2</sup>, 14.3 km<sup>2</sup>, and 14.8 km<sup>2</sup>, in 1996, 1997, and 1998, respectively). In 1999–2001, the hours spent in the common search area were recorded directly. The search effort was used to adjust the number and density of nests found each year to a common standard for annual comparisons. The standardized numbers and densities of nests were calculated by multiplying each by the ratio of the search effort in 1996 (our lowest number of hours) divided by the search effort for each year:

$$\text{standardized nests}_{\text{year}} = \text{nests}_{\text{year}} \times \left( \frac{\text{search effort}_{1996}}{\text{search effort}_{\text{year}}} \right).$$

Therefore, numbers of nests and nest densities for 1997–2001 were adjusted downward to the levels that would have been found using the same effort as in 1996. Standardized numbers of nests were used only in comparisons of numbers and densities among years and not for analyses of nest distribution.

For assessment of nest distribution and analysis of potential disturbance from the Alpine airstrip, nests (unadjusted for search effort) were assigned to 100-m and 500-m distance buffers around the airstrip. In addition, the distance to the airstrip, the nearest gravel infrastructure, and distance to aircraft approach and takeoff flight paths (hereafter, flight paths) extending through the midline of the airstrip were calculated for each nest.

Various approaches were used to look for responses by nesting birds within the common search area to the potential disturbance factors of the Alpine airstrip, the project infrastructure, and the typical flight path used by fixed-wing aircraft. Noise levels at nest sites (estimated with the noise model) were compared among different annual nest distributions to evaluate whether nest distributions were affected by overall noise exposure. Distribution (distance from development features [airstrip, nearest gravel pad, and flight path] and distance between nests [nearest-neighbor distance]) were evaluated for differences among years and between successful and failed nests. Daily survival rates of White-fronted Goose nests were calculated among years and between 2 distance zones ( $\leq 1,000$  m and  $>1,000$  m from the airstrip) using the Mayfield Method (Mayfield 1961, 1975; Johnson 1979) from a sample of nests monitored with egg thermistors (see Nest Attendance and Disturbance Monitoring methods below). For each year and for each combination of distance zone and year, the number of failed nests and the number of exposure days (the number of days each nest was observed summed over all nests) was calculated. Comparisons among groups were conducted as described by Johnson (1979). Each year between 1999 and 2001 was compared to 1998 and for each year the daily survival rate was compared between distance zones. All significance levels were adjusted for multiple comparisons using the Bonferroni method.

Parametric tests were used when data satisfied assumptions of normality, and non-parametric techniques were used in cases where parametric tests were inappropriate. Nearest-neighbor distances between White-fronted Goose nests were measured with ArcView (ESRI v3.0a, Redlands, CA) and the distances analyzed for distributional patterns with a nearest-neighbor analysis (Clark and Evans 1954, modified by Krebs 1989). Depending on the attributes of the data and the null hypothesis to be tested, we used the appropriate statistical test, including Pearson and Spearman's rank correlation, Mann-Whitney U or *t* tests, Kruskal-Wallis or analysis of variance (ANOVA), analysis of covariance (ANCOVA), and chi-square tests.

## HABITAT CLASSIFICATION AND MAPPING

The Alpine project area was classified and mapped for wildlife habitats (Figure 2) as part of the Colville wildlife studies (Johnson et al. 1999a). Detailed methods for the mapping and classification were presented by Johnson et al. (1996), and the accuracy of the habitat map was assessed by Jorgenson et al. (1997). In 2000, the habitat map was reviewed and some revisions and refinements were made to the classifications.

The habitat classification was based on those landscape properties that were considered to be most important to wildlife: shelter, security (or escape), and food. Our study concentrated on breeding waterbirds that use waterbodies and wet and moist tundra. A comparison of habitat classifications previously used in this region illustrated some of the differences among various systems (Johnson et al. 1996: Appendix Table A8).

## HABITAT SELECTION

Because the White-fronted Goose was a focal species in our disturbance analyses, habitat selection was investigated as one factor that could affect its nest distribution. Quantitative analyses of habitat selection were based on the locations of nests found during ground surveys each year from 1996 to 2001. Use was calculated as the percentage of the total number of nests that was observed in each habitat. The availability of each habitat was the percent of that habitat in the survey area common among the 6 years.

Habitat selection (i.e., use  $\neq$  availability) was evaluated by conducting Monte Carlo simulations (Haefner 1996, Manly 1997) in Microsoft® Excel. Each simulation used random numbers (range 0–100) to choose a habitat from the cumulative relative frequency distribution of habitat availability (0–100%). The number of “random choices” used in each simulation was equal to the number of nests from which percent use was calculated. One thousand simulations were conducted and the frequency distribution of use for each habitat was summarized by percentiles. Habitat preference (i.e., use  $>$  availability) was defined to occur when the observed use was greater than the 97.5 percentile of simulated random use. Conversely, habitat avoidance (i.e., use  $<$  availability) was defined to

occur when the observed use was less than the 2.5 percentile of simulated random use. These percentiles were chosen together to achieve an alpha level (Type I error) of 5% for a 2-tailed test. Habitats with non-significant selection (i.e., observed use  $\geq 2.5$  and  $\leq 97.5$  percentiles) were deemed to have been used approximately in proportion to their availability. Analyses were conducted for each year separately and for all years combined.

## NEST ATTENDANCE AND DISTURBANCE MONITORING

### NEST ATTENDANCE

Egg thermistors and/or time-lapse video cameras were used to monitor nest attendance for a sample of White-fronted Geese, Tundra Swans (cameras only), and Yellow-billed Loons (cameras only) nesting in the Alpine project area from 1998 to 2001. Thermistors were implanted in domestic goose and duck eggs that had their contents removed and an internal coating of epoxy added to strengthen the shell. A temperature probe with a 6-ft lead (TMC6-HA) was glued into each egg, and the lead connected to a data-logger (HOBO® H8 temperature logger, Onset Computer Corp., Pocasset, MA). A large nail was attached to the bottom of each egg using layers of canvas cloth coated with epoxy. The nail was pushed into the ground under the nest so that the egg could not be removed by a predator or rolled out of the nest by the incubating female.

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

Five Samsung SCF-32 video cameras were used to monitor nests in 1998 and 5 Sony CCD-TR 516 video camera recorders were used in 1999–2001. Cameras were controlled by a



programmable electronic board (LJ&L Products, Ringgold, LA) and powered by one 12V, 33 amp-h battery (Power Sonic PS-12330) connected to a solar battery charger (Uni-Solar MBC-262). Each unit, including the battery, was housed in a weatherized plastic case with a plastic window (LJ&L Products, Ringgold, LA). For deployment at the nest, the case was strapped to an aluminum sawhorse stand and secured with guy lines to stakes. The video camera was placed a minimum of 45 m from the nest and the zoom lens was used to center the nest in a field of view approximately 2–5 m across at the nest site. Each camera 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. Each videotape lasted approximately 5.5 d before it required replacing.

Three types of nest attendance activity were distinguished from the videotapes based on definitions used by Cooper (1978): incubation, breaks, and recesses. Time on the nest is composed of incubation (also known as sitting spells), when the bird is sitting on the nest, and breaks, when the incubating bird changes position or stands above the nest and rearranges the eggs and nesting material. Periods off the nest, when the incubating bird 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 White-fronted Goose nests monitored with egg thermistors, the same decision rules developed in 1998 from 2 White-fronted Goose nests monitored with both an egg thermistor and a time-lapse camera were used (see Appendix C). Incubation activity seen on videotape was compared with incubation activity determined from patterns of egg temperatures recorded by thermistors at each of 7 White-fronted Goose nests monitored by both cameras and thermistors (3 nests from 1999, 1 nest from 2000, and 3 nests from 2001). Differences between incubation variables measured using a video camera and using an egg thermistor were tested using the Wilcoxon signed ranks test.

In addition to recording nest attendance and incubation activity, cameras were used to record occurrences of predation and disturbances at White-fronted Goose, Tundra Swan, and

Yellow-billed Loon nests. The time and duration of any periods that predators were observed near or at the nest were recorded. Potential nest predators in the Alpine project area include Glaucous Gulls, jaegers, Snowy Owls, Common Ravens, and arctic and red foxes. If the incubating bird reacted to the predator by standing over the nest, the event was identified as a defense break (Hawkins 1986) and included in time on the nest. If the incubating bird reacted to the predator by leaving the nest, the event was identified as a defense recess and included in time off the nest. Other potential sources of disturbance at the nest included humans, aircraft, vehicles, caribou, and non-predatory birds (e.g., swans, geese, and ducks). Alert and concealment postures were identified at White-fronted Goose nests monitored in 2000–2001, and at the Tundra Swan nests monitored in 1999–2001. Incubation exchanges between male and female Tundra Swans were recorded and included in time off the nest.

In 1998, 20 egg thermistors were placed in White-fronted Goose nests. In 1999, 2000, and 2001, egg thermistors were placed in 42, 37, and 34 nests, respectively. Egg thermistors were deployed in 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. In 1998, video cameras were focused at 3 White-fronted Goose, 2 Tundra Swan, and 2 Yellow-billed Loon nests, with the intention of collecting baseline data before aircraft used the airstrip. White-fronted Goose and Tundra Swan nests found closest to the airstrip were selected to be monitored with cameras in 1999–2001, so that reactions to aircraft could be monitored in the area with the highest potential for disturbance. Two Tundra Swan nests were video-taped in both 1999 and 2000, and one nest was monitored in 2001. Three White-fronted Goose nests were video-taped in 1999, and 4 nests were monitored in both 2000 and 2001. Each goose monitored with a camera was simultaneously monitored with an egg thermistor, except for one goose in 1998, which was only monitored with a camera.

For all White-fronted Goose, Tundra Swan, and Yellow-billed Loon nests monitored with egg thermistors and/or time-lapse cameras in 1998–2001, we calculated incubation constancy

(the percentage of time that a female bird spends on the nest per day), the frequency of incubation breaks, frequency of recesses, and time off nest. The frequency and time spent in exchanges of incubation responsibilities between mates was calculated for Tundra Swan nests. For summaries of Greater White-fronted Geese incubation activity, the data were pooled by year for all nests active on each day before hatch or day before failure (sample unit = nest-d [1 nest monitored for 1 d]). Mean recess length for each year was calculated by pooling all recesses from all active nests each day. The length of incubation breaks could not be measured with egg thermistors because breaks were shorter than the 5-min interval between recordings.

Any days of partial monitoring, which included the day the egg thermistor and/or camera was installed, the day of hatching, and any days when data were not collected due to equipment malfunction, operator error, or logistical constraints, were eliminated from the dataset. 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 also were eliminated. Off-airstrip human activity was exclusively pedestrian traffic on the tundra (biologists, surveyors, and cleanup personnel), and was not related to normal operations of the aircraft, the airstrip, or its maintenance. Because the objective of this nest monitoring was to identify the effects of aircraft and other airstrip activities on nesting behavior, unrelated human disturbance that could confound the evaluation was identified. Thirty minutes was subtracted from the beginning and added to the end (i.e., the duration was increased by 60 min) of the period human activity occurred within 200 m of a nest to account for any change of the bird's activity as the pedestrians approached or departed; this time period was defined as "disturbed", whether a response to the pedestrians was detected or not. If the incubating bird was flushed from the nest because of off-airstrip human activity, the bird was considered disturbed until 30 min after it resumed normal incubation. If the total amount of disturbed time in a day was greater than 150 min (the approximate interval between recesses or breaks plus 60 min), the day was eliminated from the analysis, under the assumption that the normal schedule of recesses

and breaks probably was affected. If the total amount of disturbed time was less than 150 min, that time period was subtracted from the daily total time of egg thermistor or video monitoring, and the remaining portion of the day was used for calculations. The time that poor viewing conditions (e.g., heavy fog, moisture on the lens, or too little light) prevented us from judging whether the incubating bird was on or off the nest also was subtracted from the total time of video monitoring. In such cases, incubation constancy was calculated as the percentage of time the bird was observed incubating out of the total time the nest was visible.

Nest attendance variables were used as response variables in different analyses to evaluate the potential effects of disturbance, environmental variables, and intrinsic variables such as nest fate and nest location on nest incubation. A comparison of nest attendance variables among years was conducted using nested ANOVAs with nest site (nest site was a nominal variable included to account for lack of independence in incubation values for a specific nest) as a nested variable. Year was used as a factor and nest site was nested within fate and used as a random factor. In addition, for each year separately, differences in nest attendance variables between successful and failed White-fronted Goose nests were tested using nested ANOVAs with nest site as a nested variable. Fate was used as a factor and the nest site variable was nested within fate and used as a random factor. To better meet the assumptions of normality, dependent variables were modified with the appropriate transformation: square root (number of recesses, number of breaks, and time off nest), natural log (recess length), and arcsine (incubation constancy). Tests were run with data from all days of monitoring and with data from days prior to the last 5 d before hatch or failure. Values of failed nests were erratic within 5 d of failure and this pattern may have been symptomatic of nests prior to failure or a result of a female still attempting to incubate after nest failure. The presence of the thermistored egg, whether intact or damaged, may have kept geese on nests longer after failure. Because some portions of days were eliminated because of researcher-caused disturbances or equipment failure, the values of the dependent variables (incubation constancy, number of recesses, number of breaks, and time off nest) were

adjusted to a complete day using the formula,  $(\text{value}/\text{min monitored}) \times 1440 = \text{value}/\text{day}$ . In addition, Mann-Whitney tests were used to test for differences in distance to airstrip, distance to flight path, and distance to nearest gravel between successful and failed White-fronted Goose nests within each year.

#### DISTURBANCE MONITORING

Disturbance reactions of White-fronted Geese and Tundra Swans were recorded with video cameras. The occurrence and duration of concealment postures for 7 geese (4 in 2000 and 3 in 2001) and alert postures for 4 swans (2 in 1999 and 1 each in 2000 and 2001) were summarized for periods when aircraft, traffic, and pedestrians were on the airstrip and the infield road and occasions when predators or large birds were in the video view. The occurrence of concealment or alert postures during disturbance events was summarized by bird (on nest), year, and disturbance type. If a concealment or alert postures occurred during multiple disturbance events, the source that occurred closest in time to the onset of behavior was assigned. If a concealment or alert posture occurred outside the time bracketing the disturbance events, the source was unknown. To examine the relative sensitivity of nesting geese to aircraft, vehicles, and pedestrians on the airstrip, the rate of concealment (i.e., the percentage of all events of one source that elicited concealment or alert postures) was calculated for each disturbance source.

Data from field notes, video recordings, and Alpine security records were used to summarize sources and occurrences of disturbance. In 1998, the airstrip was not used by airplanes because the gravel was being compacted and leveled. Records of heavy equipment operations and helicopter flights were gathered from contractors and field notes. In 1999–2001, the airstrip was included in the view of the video cameras when possible. One camera was set up to monitor airstrip activity exclusively for 10 d (11–21 June) in 2000 and 28 d (18 June–16 July) in 2001. The infield road also was included in some camera views in 2000 and 2001. The times that aircraft, vehicles, and pedestrians entered and exited each camera view were recorded. In 1999–2001, aircraft arrival and departure times also were recorded by Alpine

security, and airstrip activities were summarized using these arrival and departure times. In 2000, arrival and departure times of vehicles driving on the airstrip were recorded by Alpine security between 0600 and 1800 ADT for 19 June–15 July. In 2001, the number of vehicles driving between CD-1 and CD-2 via the airstrip between 0600 and 1800 ADT were counted by Alpine security stationed at a checkpoint on the infield road during 18–30 June (Appendix D1). The occurrence of vehicles on the infield road and pedestrians on the airstrip, the infield road, and the tundra were obtained from the videotapes only (Appendices D2 and D3). The frequencies of occurrence of aircraft and vehicles were calculated by hour, by 12-h day (0600–1800 ADT), and by 24-h day during the nesting period, depending on what variables were being summarized and tested. In addition, the amount of time vehicles and pedestrians were on the airstrip and infield road and the cumulative number of person-minutes (the sum of minutes each person was present) at each location were calculated (Appendices D3 and D4). Temperature (°C), wind speed (mph), and wind direction were collected at the airstrip by Alpine security (Appendix E1).

Tests of the effects of potential disturbance sources on nest attendance patterns of White-fronted Geese monitored with egg thermistors and video cameras used both hour and day as sample units (both for the period 0600–1800 ADT). In 2001, chi-square analyses were used to estimate whether the proportion of hours with recesses differed when each type of disturbance (airplanes, helicopters, and pedestrians, each tested separately) was present or absent on the airstrip. A similar test was conducted to determine the frequency of occurrence of recesses during hours with and without potential disturbances (airplanes, helicopters, and/or pedestrians combined). Vehicles were not included in this analysis because they occurred at high levels during all hours. Logistic regression analysis was used to simultaneously investigate the influence of environmental and potential sources of disturbance in 2001 on the probability that a recess would occur during an hour. The explanatory variables (i.e., independent) were maximal noise level ( $L_{\text{max}}$ ) at the nest, day before hatch or failure, temperature (°C), wind speed (mph), time of day

(0600–1000, 1000–1400, 1400–1800), airplanes (presence or absence), helicopters (presence or absence), pedestrians (presence or absence), number of vehicles, and distance from airstrip (0–1,000 m, 1,000–2,000 m, >2,000 m). To reduce the likelihood of multicollinearity, hourly weather variables and potential disturbance variables were examined with Pearson correlation. No strong correlations ( $r > 0.5$ ) were found among continuous explanatory variables. The model was run with individual nest site as a categorical variable to evaluate the effect of variation among incubating females, and without nest site as a variable, which pooled all nests together and ignored individual variation. The model also was run with maximal noise level and average noise level separately, and the results compared to select the more informative of the 2 variables. A backward stepwise procedure (using Likelihood ratio,  $P < 0.10$  to enter,  $P < 0.15$  to remove) was used to choose a final model. The 5 d prior to hatch or failure were excluded from all tests using hours as sample units.

Generalized linear models were used to analyze the effects of environmental and potential disturbance sources on recess frequency, time off nest, and average recess length (using 12-hr days as sample units) for each year (1999, 2000, 2001) and all 3 years pooled. The explanatory variables were daily noise level ( $L_{eq}$ ) at the nest, day before hatch or failure, wind speed (mph), number of airplanes, number of helicopters, natural logarithm of the number of minutes (duration) pedestrians were on the airstrip, and distance from airstrip (0–1000 m, 1000–2000 m, >2000 m). The duration of pedestrians was transformed using the formula  $\ln(\text{groups} + 1/6)$  (Mosteller and Tukey 1977) because of a highly skewed distribution. Recess frequency and time off nest were initially modeled as poisson variables; however, time off nest was overdispersed and better fit a negative binomial model (Venables and Ripley 2002). To best meet the assumptions of the model, time off nest was divided by 5 (i.e., converted to number of thermistor intervals). Models were run with and without nest site as a variable; when nest site was included, distance to airstrip was removed. The full models were run and a stepwise procedure was used to choose the model with the lowest Akaike's Information Criterion (AIC) value (stepAIC;

Venables and Ripley 2002). A general linear model assuming normally distributed error terms was used to model the effect of explanatory variables on average recess length (min). After the first model was fit, variables with the highest  $P$ -values sequentially were removed until all remaining variables had  $P$ -values  $< 0.15$ . The model was run with all days of monitoring.

Sources of disturbance were not always visible on video recordings and were not recorded with temperature records from thermistor eggs, so recordings of bird behavior had to be matched with potential disturbance events by time records. To incorporate the duration of disturbance events in their time records for the purpose of matching with the reactions of White-fronted Geese and Tundra Swans, time buffers were placed around the instantaneous time of arrivals and departures of aircraft, vehicles, pedestrians, predators, and other birds. Because the recorded time of an aircraft event (time of landing or takeoff from Alpine security) might not have corresponded exactly with the time recordings on the camera (time-record difference), 2 min was subtracted from and added to disturbance-event times (i.e., a 4-min "buffer" centered around each event). An additional time buffer was added to aircraft times because their recorded times likely were not the times these sources were closest to the nests being monitored (because nests were in different locations relative to the airstrip), and associated activities, such as engine starts, taxiing, and approaches, occurred before and after liftoff and touchdown times. These additional time buffers were specific to each aircraft type and were based on time records on videotape of the period before and after arrival and takeoff that engines were operating and producing noise. The maximal times observed during the videotaped sample were applied to the buffers (Appendix F). For example, for a DC-6, 8 min were added to arrival times (i.e., a DC-6 took  $\leq 8$  min from touchdown to taxi, park, and shut its engines off) and 10 min subtracted from takeoff times. An additional 1 min was subtracted from all aircraft arrival times and added to all aircraft takeoff times to include disturbance that might have been occurred just before touchdown (on approach) or just after takeoff.

For vehicles, the arrival and departure times on the airstrip and the infield road were recorded as

the time each vehicle entered and exited the camera view. The views of the cameras monitoring the airstrip and the infield road did not include the entire length of the airstrip or the infield road. Because vehicles were actually on the airstrip or the infield road before being detected on the videotape and vehicles remained on the airstrip after last seen on the videotape, 2 min were subtracted from all arrival times and added to all departure times (i.e., a 4-min buffer). For pedestrians on the airstrip, the infield road, and the tundra, 30 min were subtracted from their time of first appearance and added to their first and last time of appearance to represent probable time spent in the area. For predators, 2 min were subtracted from the time of the first appearance of the predator in the camera view, and 2 min were added to the time of the last appearance because incubating birds often react to the presence of predators before and after the time that they are nearest to the nest. No time adjustments were made to the arrival and departure times of large birds, because the length of time they were in the vicinity of the nest was unknown.

For White-fronted Geese, ANCOVA was used to evaluate whether the proportion of concealment postures that occurred during disturbance events differed among disturbance types (airplanes, helicopters, vehicles, and pedestrians) and differed with distance from the source of the disturbance. Disturbance type was a factor and distance from disturbance was a covariate. For Tundra Swans, a Chi-square analysis was used to test whether the proportion of alert postures differed among disturbance types for 2 nests monitored in 1999 and for 1 nest that was monitored in 1999, 2000, and 2001. Because reactions to each disturbance type were recorded at each nest, an ANOVA was used to test if time spent concealed or alert varied by disturbance type.

### BREEDING-BIRD PLOTS

Breeding-bird plots were established primarily to evaluate nest densities of shorebirds and passerines. Twelve plots were established in 1998 and were sampled for nesting birds with the same methods from 1998 to 2001 (Johnson et al. 2000b). Plots measured 200 × 500 m (10 ha) and were marked by 2 rows of surveyor's lath that

delineated 50-×-50-m grids (Figure 4). Six plots ("treatment" plots) were placed in locations that were expected to be exposed to noise or disturbance during aircraft landings and takeoffs from the airstrip; that is, locations near ( $\leq 1,000$  m) the airstrip (plots 1, 2, 4, and 5) or directly under the flight path (plots 3 and 6; Figure 2). The remaining 6 plots ("reference" plots) were located farther away from the airstrip ( $> 1,500$  m). The habitat classification map was used to choose locations for the plots in an attempt to match the habitat composition between the treatment and reference plots. Three treatment and 3 reference plots were placed in areas of the Patterned Wet Meadow habitat class (plots 4–9) and the remaining plots were placed in areas of mixed habitat, predominantly Patterned Wet Meadow with varying proportions of Moist Sedge–Shrub Meadow and Aquatic Sedge with Deep Polygons (Figure 2). In the week prior to sampling, plots were established (1998) or maintained (1999–2001), and nests that were encountered opportunistically were recorded. Each plot was sampled once during a 7-day period between 15 and 24 June each year. A rope 53-m long was dragged between 2 people (one walking the centerline while the other walked the outer border of the grid) followed by an observer walking behind the middle of the rope. When a bird was flushed, all 3 people stopped and observed, and 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, 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 type at the nest were recorded, along with its location by grid number and quadrant within the grid (Figure 4).

During July and August 1999, habitat variables were measured on the breeding-bird plots to describe nesting habitat (Johnson et al. 2000b). Habitat variables were described at 2 scales: grids (50 × 50 m) and quadrants (25 × 25 m). Grids were classified by vegetation type and surface features including surface form (polygon, disjunct polygon, dune, nonpatterned), relief (low, high, none), polygon centers (low, high, none), and polygon density (low, high, none) (see Jorgenson et al. 1997 for definitions). For each quadrant, estimates of coverage were made for water and

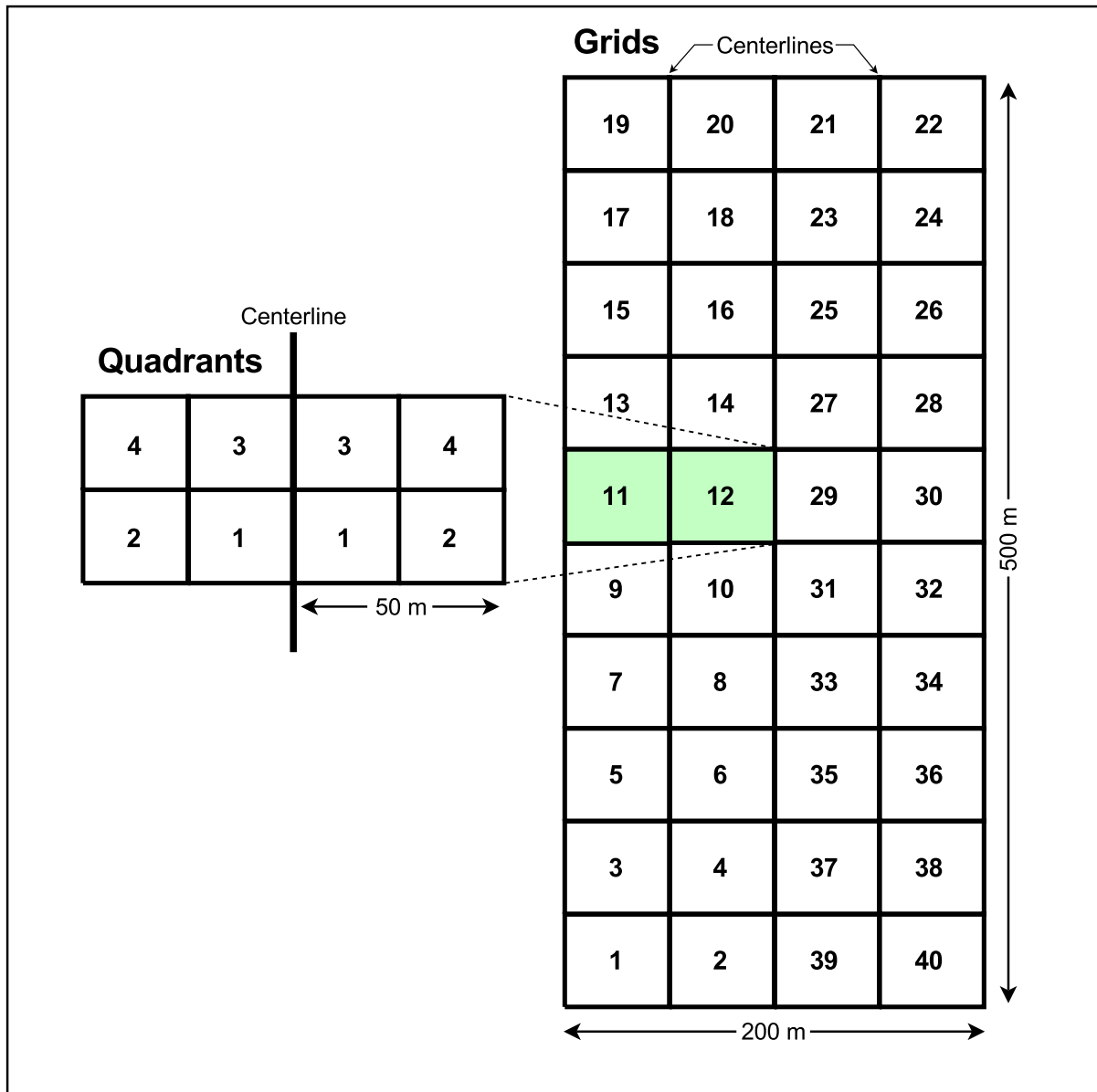


Figure 4. Diagram of a breeding-bird plot in the Alpine project area, Colville River Delta, Alaska, 1998–2001.

vegetation types and estimates were made of the modal relief (from water level to highest point) and modal water depth in centimeters. Water containing  $\geq 15\%$  vegetation cover was classified as a vegetation type (e.g., Aquatic Grass Marsh, Aquatic Sedge Marsh). The distances of plots and grids (centroid of each plot or grid) were measured to the closest point on the airstrip using GIS.

To compare the number of nests between treatment and reference plots for all birds combined and for each of the 5 most common species individually, *t* tests were used for

individual years and 2-way ANOVAs were used to test differences among years and between plots. To examine the relationship between frequency of nests and distance from the airstrip among years, ANCOVAs were conducted for the number of nests on plots with distance as a covariate for each of the 5 most common species and for all species combined. All data and residuals were inspected for normality and homoscedasticity. Log or reciprocal transformations were applied to meet assumptions of normality. Stepwise logistic regression was used (Hosmer and Lemeshow

1989) to analyze the relationship between habitat characteristics and the occurrence (presence/absence) of bird nests within the 480 study grids (40 grids/plot). Presence/absence data were analyzed using similar stepwise logistic regression techniques for each year (1998–2001) and with all years pooled. Separate regressions were run for the following species or species groups: all waterfowl, White-fronted Goose, all shorebirds, Pectoral Sandpiper, Semipalmated Sandpiper, Red-necked Phalarope, Red Phalarope, all passerines, and Lapland Longspur. The pool of potential explanatory variables included both continuous and categorical habitat characteristics. Continuous variables were surface relief (cm), water cover (%), water depth (cm), and cover (%) of 8 vegetation types (i.e., wet sedge meadow, wet sedge willow, moist sedge shrub, sedge marsh, grass marsh, open low willow, *Dryas* tundra, and partially vegetated). Distance to the airstrip of each grid was transformed into a categorical variable with 4 levels ( $\leq 780$  m, 781–1,430 m, 1,431–2,412 m, and  $> 2,412$  m). Other categorical habitat variables included surface form, the nature of polygon centers, and polygon density.

Explanatory models to predict nest occurrence were built using a subset of habitat characteristics in forward stepwise logistic regressions with probability to enter = 0.15 and probability to remove = 0.2. The 95% confidence intervals (CIs) then were examined for the odds ratios of selected parameters. The odds ratio derives from the estimated regression coefficient (specifically, odds ratio =  $\text{Exp}[\beta]$ ), and describes the change in probability of response corresponding to a unit change in the explanatory variable. For example, in a model that describes nest occurrence of Semipalmated Sandpipers, if the odds ratio for open low willow (% vegetation cover) is 1.044, there is a predicted 4.4% increased probability that at least one Semipalmated Sandpiper nest will occur per grid for each 1% increase in open low willow cover. As a further illustration, if the odds ratio for water depth (cm) in the same model is 0.977, there is a predicted 2.3% decreased probability (i.e.,  $1.000 - 0.977$ ) that at least one Semipalmated Sandpiper nest will occur per grid for each 1.0 cm increase in water depth. An odds ratio of 1.0 suggests that a potential explanatory variable has no effect on the response (in this

example, the occurrence of  $\geq 1$  nest). The inclusion of 1.0 in the 95% CI for a logistic regression odds ratio suggests that the associated habitat characteristic may not be useful for predicting nest occurrence. The significance of each final model was tested with a likelihood-ratio statistic, and classification performance assessed with a 2-way classification table for observed versus predicted outcomes.

## SEASONAL USE OF LAKES

Aerial surveys of lakes in the Alpine project area were conducted from 1998 to 2001 to assess seasonal use by waterbirds (Figure 5). Lake designations from the Emergency Response Grid (Moulton 1998; L. Moulton, MJM Research, pers. comm.) were used to identify the lakes covered in these aerial surveys. Bell 206 Long Ranger or 206B Jet Ranger helicopters were used to fly 3 or 4 surveys per month during June, July, and August (Table 2). In general, altitude was 45–90 m above ground level, and speed was  $\sim 123$  km/h but was reduced when necessary to count or identify groups of birds. A single observer sat in the front left seat of the helicopter. Observations were recorded with a hand-held tape recorder and/or on a schematic map of the study area. In addition to numbers and species of waterbirds using the lakes and lake margins, any nests or broods of waterbirds also were noted. All tape-recorded information was transcribed to data forms soon after the completion of the aerial survey.

Eight surveys from each year (1998–2001) were selected for statistical analyses (Table 2): 2 surveys during June and 3 surveys each in July and August. The number of surveys included for each month was determined by the minimum number of surveys in that month in any year. Incomplete surveys also were excluded (2 incomplete surveys occurred during June 1999 and 2000, due to deteriorating weather). Individual lakes were excluded from statistical comparisons if they were not sampled during every survey.

Counts of birds from each lake were converted to densities calculated from lake areas, which were determined from digital maps. Bird densities were examined for evidence of the effects of air-traffic related disturbance with a repeated-measures ANOVA design that modeled

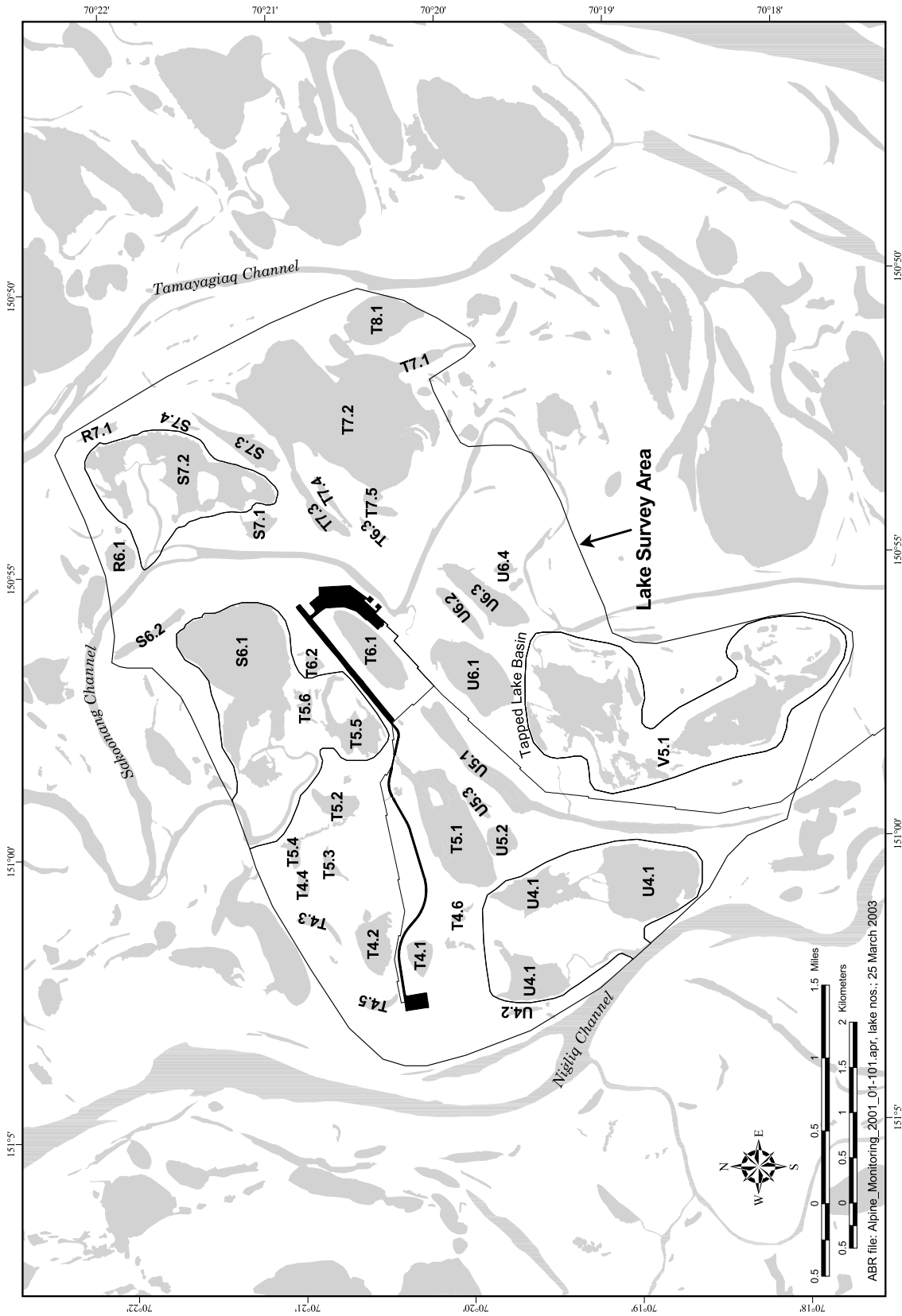


Figure 5. Lake numbers and boundary for lake surveys conducted in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Groups of lakes outlined within the boundary represent tapped lake basins (associated Tapped Lakes with Low-water Connections).



Table 2. Dates of aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Asterisks indicate surveys not included in comparative annual summaries.

| Year | June |     |     | July |   |    | August |     |    |    |    |
|------|------|-----|-----|------|---|----|--------|-----|----|----|----|
| 1998 | 16*  | 17  | 21* | 29   | 8 | 14 | 27     | 13  | 24 | 27 |    |
| 1999 | 10   | 16  | 22* |      | 6 | 15 | 26     | 5   | 17 | 26 |    |
| 2000 | 22*  | 24  | 30  |      | 7 | 15 | 21     | 29* | 6  | 17 | 25 |
| 2001 | 14   | 21* | 30  |      | 9 | 16 | 26     | 5   | 20 | 26 |    |

the relationship between bird density and distance from air-traffic facilities (SPSS GLM procedure). Because bird numbers vary substantially over the summer in relation to different aspects of the breeding cycle, months were tested separately (June, July, and August). Density data were transformed (both square-root and rank transformations were used) to correct deviations from normality and results with both transformations were compared for all statistical tests. Results were similar for square-root and rank transformed densities, but the rank transformation was selected for final models largely because of its ability to reduce the effect of outlying data points. Potential factors affecting bird densities also were evaluated for inclusion in ANOVA models: lake size, lake type (tapped lake basins and all other lakes), year, and 3 distance measures (distance from the Alpine airstrip, distance from nearest gravel, and distance from the flight path). The 3 distance measures were known a priori to be highly correlated, so correlations with bird density were computed and the single distance measure with the highest  $r^2$  was selected for use in ANOVA models. Because sample sizes were limited ( $n = 31$  lakes), each of these potential factors was examined for a relationship with bird density and unimportant factors were eliminated from consideration prior to creation of the ANOVA models.

### FOX DEN MONITORING

Aerial and ground-based surveys were used to evaluate the distribution and status of arctic and red fox dens on the Colville River Delta and adjacent coastal plain in 2001, continuing the annual monitoring effort begun in 1992. Den status and pup presence were assessed on ground visits during 28 June–1 July 2001, followed by return visits

during 9–15 July to count pups at sites judged to be active. Most survey effort focused on checking dens found in previous years (Smith et al. 1993, 1994; Johnson et al. 1996, 1997, 1998, 1999a, 2000), although opportunistic searches for dens in suitable habitats also were conducted while transiting between known dens. In 2001, a concerted effort was made to locate dens in an intensive helicopter search of the area proposed for construction of DS-3S, a new drill site east of the Colville Delta and west of DS-3G in the northwestern Kuparuk Oilfield, thereby adding to the sample of dens north of the Alpine pipeline corridor.

During ground visits, evidence of use by foxes was evaluated and the species using the den was confirmed. Den status was assessed by carefully examining fox sign at the site (following Garrott 1980): presence of adult or pup foxes; presence and appearance of droppings, digging, tracks, trampled vegetation, shed fur, and prey remains; and signs of predation (e.g., pup remains). Dens were classified into 4 categories (following Burgess et al. 1993), the first 3 of which are considered to be “occupied” dens:

1. *natal*—dens at which young were whelped, characterized by abundant adult and pup sign early in the current season;
2. *secondary*—dens not used for whelping, but used by litters moved from natal dens later in the season (determination made from sequential visits or from amount and age of pup sign);
3. *active*—dens showing evidence of consistent, heavy use, and suspected to be natal or secondary dens, but at which pups were not confirmed; 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.

Our emphasis on pup production led us to adopt a more restrictive definition of active dens than has been used by some other researchers who considered any den with current fox sign to be active (e.g., Ballard et al. 2000). We focused on the presence of pups and attempted to separate natal and secondary dens from those used only by adult foxes. Most dens examined each year showed some evidence of current-year visitation by adults. Dens that showed only limited signs of use by adults were presumed to be used for resting or loafing, and thus were considered to be inactive for our analyses.

Because foxes commonly move pups from natal dens to secondary dens, repeated observations usually are needed to classify den status with confidence. Litters may be moved or split between natal and secondary sites, especially more than 5–7 weeks after whelping (Garrott 1980, Eberhardt et al. 1983, Anthony 1996), which occurs from early May to early June (Garrott et al. 1984). Because the date of observation can influence conclusions about den status, we standardized our sampling methods with respect to date and time by 1996. Observations were timed to detect pups when they were becoming more active above ground but before litters were moved or split. Visits in previous years (1993, 1995) tended to occur later in July or early August, when it was more likely that litters had been moved from natal dens.

Den-search effort in 1992 and 1993 was low and incomplete. Search effort was increased in 1995, and substantially more dens were found in the study area. Since 1996, a consistent effort was made annually to confirm den occupancy and to count pups. Based on our initial assessment of den activity at the end of June, the observations during early–mid-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 or spotting scopes over periods of several hours

(mean = 2.5 hr, range 1.8–3.1 hr). Observations usually were conducted in the morning or evening, when foxes tend to be more active.

Annual variation in fox den occupancy and production of pups were evaluated statistically to identify potential effects of construction on the fox population. Fox den activity and pup production in the pre- to light construction phase (1996–1998) were compared with values from the heavy construction phase (1999–2001). Fox productivity in 3 distance zones (<5 km, 5–10 km, and >10 km) centered on CD-1 were compared. Data collection methods and seasonal timing of den observations were standardized by 1996, so we excluded data collected before 1996 from these particular analyses. No distinction was made between arctic and red fox dens in this analysis.

A total of 38 fox dens were checked in all 6 years (1996–2001). The numbers of those “index” dens in 2 status categories (natal, secondary, and active dens were lumped as ‘active’, all others were ‘inactive’) were used as response variables in a loglinear model to test for differences among years, construction phases, and distance zones.

Pup production was compared among years, construction phases, and distance zones using ANOVA models. We used all index dens checked between 1996 and 2001 for which we obtained a good count or estimate of the total litter size. A square-root transformation was applied to the litter sizes to meet the assumptions of ANOVA. The litter-size model used distance zone, year nested within construction phase, and an interaction term of construction phase and distance zone as explanatory factors. Separate models were conducted for dens in all 3 distance zones and for just the dens within 10 km of CD-1.

## **PART I: 2001 ANNUAL REPORT RESULTS AND DISCUSSION**

### **CONDITIONS IN THE STUDY AREA**

#### **PHENOLOGY**

The 2001 breeding season was similar to 2000, but both were unusual compared with previous years, because weather and flooding river conditions may have delayed the onset of nesting for birds on much of the Colville River Delta. Spring temperatures were colder and river breakup

was later in 2001 and 2000 relative to all previous years since 1996 (Table 3), the first year that comprehensive nest searches were conducted in the Alpine project area.

During winter 2000–2001, cumulative snow deposition in Prudhoe Bay was one of the highest on record, with much of the snow falling in May (National Resources Conservation Service, unpubl. data). Snow was recorded in Colville Village on all but 7 d in May 2001. However, snowmelt was rapid in June, with the first snow-free day recorded at Colville Village (Helmericks) on 7 June. In comparison, the first snow-free day recorded in the Kuparuk Oilfield (the airport weather station) was on 3 June (Table 3), although tundra farther away from major infrastructure and gravel still retained 30–40% snow cover on 9 June. Late snowmelt was coupled with late, but rapid river breakup in early June, with peak surface elevation on the Colville River at the head of the delta on 10 June (PHILLIPS and Anadarko 2002), resulting in some flooding of low-lying and coastal areas. However, flooding in 2001 was not as extensive or as persistent as in 2000, which was estimated to be a 25-yr flood (Baker 2000). Localized temporary (2–3 d) flooding occurred in the Alpine project area southwest of the airstrip, as a result of ice jamming at the easternmost bridge.

Temperatures in May 2001 were below average on the Colville Delta with mean daily temperatures rising above freezing only on 31 May. Late May (15–31 May), when birds typically start to arrive, was the second coldest recorded in the adjacent Kuparuk Oilfield (mean =  $-8.3^{\circ}\text{C}$ , Table 3). However, temperatures rose rapidly in early June, accumulating 54 thawing degree-days between 15 May and 15 June 2001 (usual end of nest initiation for most geese and swans), with almost all of the accumulation in June (Figure 6). In comparison, only 37 thawing degree-days accumulated during the same period in 2000 and all accumulated in June.

Shallow lakes typically are the earliest to melt out, and in 2001, shallow lakes around the Alpine project area were ice-free by mid-June. In contrast, deep lakes tend to retain ice longer, but these are often more critical for bird nesting habitat, especially for species such as Yellow-billed Loons. In 2001, moderately sized ( $\sim 0.2\text{ km}^2$ ) deep lakes were 90–95% ice-covered at the time of the first

lake survey on 14 June, 65% ice-covered on 30 June, and free of ice by 9 July. Larger lakes, such as Lake T7.2 (see Figure 5; area =  $2.8\text{ km}^2$ ) still retained 20% ice cover on 9 July, only becoming ice-free sometime before 16 July. Cold temperatures, and late snow and ice melt, affect nesting birds by delaying the onset of nesting and increasing energy expenditure, often exerting strong impacts on breeding success.

The emergence of Chironomid midges occurred around 26–27 June, 2–3 d later than in 2000. Light mosquito activity in 2001 was noted by researchers working in NPRA between 28 and 30 June and moderate-to-severe mosquito activity was recorded on the delta by 2 July. The mosquito season was somewhat delayed from that in 2000, when moderate mosquito activity was noted by 22 June. However, the nesting season was slightly earlier than in 2000. The first hatchling of a Lapland Longspur in 2001 was observed on 20 June, about 3 d earlier than in 2000. The mean hatch date for White-fronted Geese in 2001 was 7 July (range 3–10 July,  $n = 19$  nests), which also was 3 d earlier than in 2000. Another index to the late nesting season in 2001 compared to most previous years was the delayed development of Tundra Swan young, which take longer than many other species to become flight-capable. During the aerial survey for brood-rearing swans in August, young swans were still small, and in mid-September, biologists in Prudhoe Bay observed broods with young that were still incapable of flight. No young were observed at that time in flocks, which usually form in mid-September prior to migration and freeze-up. Most geese and smaller birds probably had enough time even with the cool spring and delayed breakup to complete their nesting cycle, but for birds such as Tundra Swans and loons, some young may not have been able to fledge before freeze-up occurred in 2001.

#### HUMAN ACTIVITY

The Alpine project area was under construction in 2001 (Table 1). During late winter and early spring 2001, ice roads and pads were completed and equipment and materials were transported to CD-1 (Figure 1). Ice roads were closed to general traffic on 17 May, after which all materials and personnel were transported by

Table 3. Weather, disturbance, and biological parameters in the Alpine project area, Colville River Delta, Alaska, 1996–2001.

| Variables   | 1996    | 1997    | 1998    | 1999    | 2000    | 2001     |
|---|---------|---------|---------|---------|---------|----------|
| <b>Weather Conditions</b>                             |         |         |         |         |         |          |
| Peak Breakup: Colville River <sup>a</sup>             | 26 May  | 29 May  | 29 May  | 30 May  | 11 June | 10 June  |
| Peak Discharge (cfs): Colville River <sup>a</sup>     | 160,000 | 177,000 | 213,000 | 203,000 | 580,000 | 300,000  |
| Extent of Flooding at Alpine                          | low     | low     | low     | low     | high    | moderate |
| First Snow-free Date: Kuparuk <sup>b</sup>            | 23 May  | 11 June | 25 May  | 11 June | 10 June | 3 June   |
| Mean Temp (°C): 15–31 May (arrival) <sup>b</sup>      | 1.1     | -1.0    | 2.1     | -3.6    | -8.8    | -8.3     |
| Mean Temp (°C): 1–15 June (initiation) <sup>b</sup>   | 5.7     | 1.7     | 4.9     | 1.8     | 1.9     | 3.3      |
| Thawing degree-days: 15–31 May (arrival) <sup>b</sup> | 41.7    | 20.8    | 45.8    | 1.4     | 0       | 1.1      |
| Thawing degree-days: 15 May–15 June <sup>b</sup>      | 128     | 60      | 120     | 32      | 37      | 54       |
| <b>Human Activity<sup>c</sup></b>                     |         |         |         |         |         |          |
| Airplanes (no./d, 1 June–15 July)                     | 0       | 0       | 0       | 2.6     | 12.0    | 7.7      |
| Helicopters (no./d, 1 June–15 July) <sup>d</sup>      | <1      | 1       | 1.8     | 7.9     | 10.1    | 8.6      |
| Vehicles (no./d, 1 June–15 July)                      | 0       | 0       | 2.5     | 13.0    | 25.3    | 313.2    |
| Pedestrians (no./d, 1 June–15 July)                   | –       | –       | 1       | 4.7     | 9.0     | 16.5     |
| Camp Population (mean daily residents)                | 0       | 0       | 0       | 160     | 550     | 455      |
| <b>Biological Data</b>                                |         |         |         |         |         |          |
| Midge Emergence Date <sup>e</sup>                     | –       | 20 June | 19 June | 17 June | 24 June | 26 June  |
| First Moderate Mosquito Activity <sup>e</sup>         | 18 June | 28 June | 20 June | ~1 July | 22 June | 2 July   |
| No. White-fronted Goose Nests <sup>f</sup>            | 25      | 28.1    | 23.2    | 26.9    | 22.0    | 21.9     |
| White-fronted Goose Nest Success (%)                  | –       | 89      | 81      | 35      | 38      | 63       |
| Mean White-fronted Goose Hatch Date <sup>g</sup>      | –       | –       | 27 June | 5 July  | 10 July | 7 July   |
| No. Duck Nests <sup>f</sup>                           | 9       | 11.2    | 16.6    | 9.1     | 6.8     | 6.1      |
| No. Shorebird Nests <sup>h</sup>                      | –       | –       | 116     | 112     | 161     | 109      |
| No. Passerine Nests <sup>h</sup>                      | –       | –       | 54      | 64      | 66      | 46       |
| First Hatchling Date: Lapland Longspur <sup>c</sup>   | –       | –       | 10 June | 19 June | 23 June | 20 June  |
| Number of Fox Dens ≤5 km from Airstrip <sup>i</sup>   | 4       | 2       | 3       | 2       | 2       | 2        |
| Number of Fox Pups ≤5 km from Airstrip                | 15      | 4       | 6       | 4       | 5       | 4        |

<sup>a</sup> Data from ConocoPhillips and Anadarko (2001) and Michael Baker Inc. (2001).

<sup>b</sup> Data from the Kuparuk Airport and the National Weather Service.

<sup>c</sup> Activity on airstrip or at airstrip location (prior to completion); camp population is based on housing records.

<sup>d</sup> Helicopter frequency estimated for 1996 and 1997, relative to level in 1998—based on number of field crew visits.

<sup>e</sup> Data from unpublished field notes, ABR, Inc.

<sup>f</sup> Nest numbers from the common search area and adjusted for search effort.

<sup>g</sup> Data from nests monitored with thermistored eggs.

<sup>h</sup> Data from breeding-bird plots.

<sup>i</sup> Occupied dens known or suspected to contain pups.

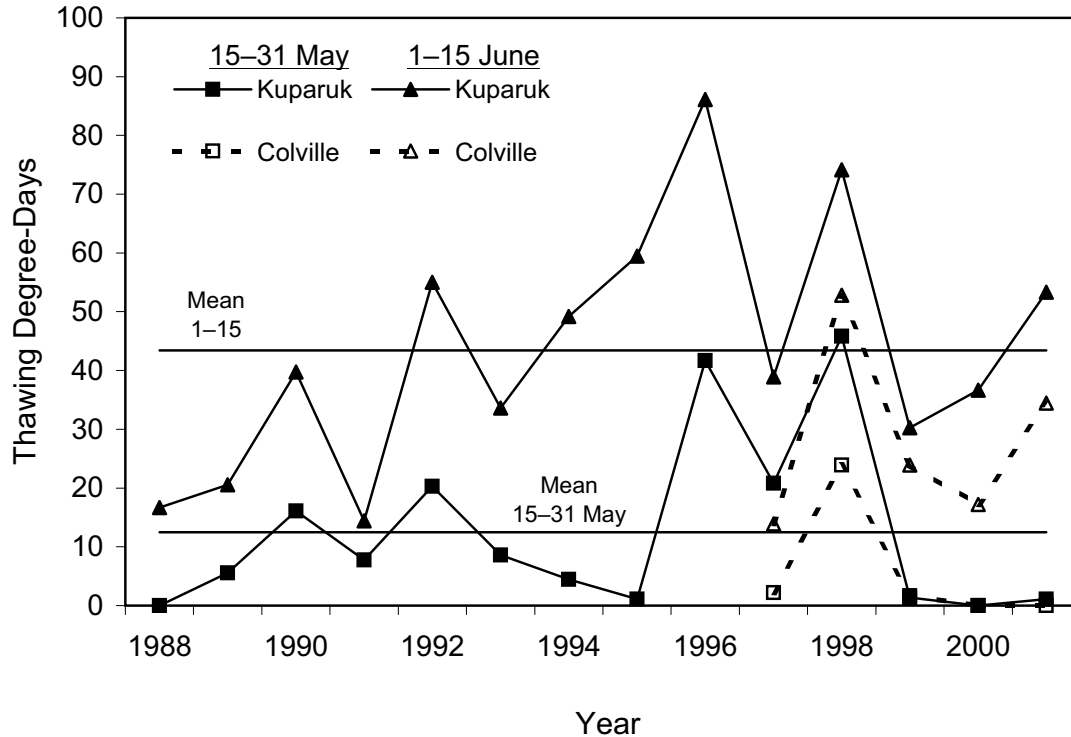


Figure 6. Number of thawing degree-days recorded for 15 May–15 June in the Kuparuk Oilfield, 1988–2001 and Colville Village, 1997–2001, Alaska. Thawing degree-days are calculated by summing the number of degrees above 0° C for daily mean temperature.

aircraft, primarily DC-6s, Twin Otters, and CASAs. Two Bell 206 Long Ranger and one Bell 206 Jet Ranger helicopters were flown in the project area (but were stationed in Kuparuk) from late May to early October, primarily landing on the boatramp on the southeast side of CD-1, but occasionally landing to refuel on the apron adjacent to the airstrip (Figure 1). CD-2 was undergoing construction and drilling during summer 2001, and high levels of vehicle traffic traveled between CD-1 and CD-2. Most major construction of buildings and modules was complete at CD-1 in 2001, but heavy equipment still was operating to spread and dry wet gravel on CD-1 and the infield road from CD-2, and also was used in small construction projects elsewhere on the pads.

The average daily camp population in 2001 varied between 447 and 468 people each month during the summer season. Exact counts of vehicles and mobile equipment were not available, but the number of vehicles passes on the Alpine airstrip averaged 313/d ( $n = 13$  d, 18–30 June 2001, 0600–1759 each day), which was the highest ever recorded. The number of pedestrians on the

airstrip also peaked in 2001 (mean = 16.5/d,  $n = 13$  d). The number of aircraft (fixed-wing and helicopter) events during the nesting season were slightly lower than during 2000. In 2001, the mean daily rate of aircraft events (each representing 1 landing or 1 takeoff) from 1 June to 15 July was 32.8/d ( $n = 45$  d; Table 4), similar to the rate from 16 July to 31 August (mean = 34.6/d,  $n = 47$  d; Appendix D5). Helicopter events in 2001 (mean = 17/d) slightly outnumbered twin-engine airplane events (mean = 13/d), and 4-engine planes, primarily DC-6s, averaged 2 events each day (Table 4).

#### NOISE MONITORING

During 1998–2000, sound monitoring was conducted at several fixed locations around the airstrip (Johnson et al. 1999b, 2000b, 2001). Although data were collected for each flight that occurred during monitoring periods, the recorded levels were valid only for the sampling locations and under the conditions measured and could not be extrapolated to other sites or times. Monitoring noise levels at 68–153 nest locations simultaneously each year was clearly impractical

Table 4. The number of landings or takeoffs of aircraft using the airstrip during nest monitoring in the Alpine project area, Colville River Delta, Alaska, 2001. Numbers are sums of takeoffs plus landings. Data are from Alpine air-traffic control records.

| Date       | Aircraft Type     |      |      |                             |                              |            | Total |
|------------|-------------------|------|------|-----------------------------|------------------------------|------------|-------|
|            | C-130<br>Hercules | DC-6 | CASA | Twin Otter/<br>Navajo/Beech | Small<br>Planes <sup>a</sup> | Helicopter |       |
| 1 June     | 0                 | 2    | 6    | 6                           | 0                            | 6          | 20    |
| 2 June     | 0                 | 0    | 2    | 0                           | 0                            | 0          | 2     |
| 3 June     | 0                 | 0    | 4    | 1 <sup>b</sup>              | 2                            | 4          | 11    |
| 4 June     | 0                 | 2    | 12   | 18                          | 4                            | 6          | 42    |
| 5 June     | 0                 | 4    | 8    | 8                           | 0                            | 8          | 28    |
| 6 June     | 0                 | 2    | 8    | 6                           | 0                            | 6          | 22    |
| 7 June     | 0                 | 2    | 8    | 4                           | 0                            | 4          | 18    |
| 8 June     | 0                 | 0    | 8    | 6                           | 4                            | 4          | 22    |
| 9 June     | 0                 | 2    | 8    | 0                           | 0                            | 22         | 32    |
| 10 June    | 0                 | 2    | 8    | 0                           | 2                            | 18         | 30    |
| 11 June    | 0                 | 0    | 4    | 14                          | 6                            | 12         | 36    |
| 12 June    | 0                 | 4    | 10   | 6                           | 0                            | 14         | 34    |
| 13 June    | 0                 | 6    | 6    | 10                          | 2                            | 16         | 40    |
| 14 June    | 0                 | 4    | 8    | 4                           | 2                            | 14         | 32    |
| 15 June    | 0                 | 8    | 4    | 8                           | 0                            | 20         | 40    |
| 16 June    | 0                 | 2    | 4    | 0                           | 0                            | 14         | 20    |
| 17 June    | 0                 | 0    | 4    | 0                           | 0                            | 10         | 14    |
| 18 June    | 0                 | 0    | 8    | 12                          | 0                            | 20         | 40    |
| 19 June    | 0                 | 4    | 4    | 10                          | 0                            | 30         | 48    |
| 20 June    | 0                 | 2    | 8    | 6                           | 0                            | 16         | 32    |
| 21 June    | 0                 | 4    | 8    | 4                           | 0                            | 24         | 40    |
| 22 June    | 0                 | 0    | 8    | 12                          | 0                            | 26         | 46    |
| 23 June    | 0                 | 4    | 2    | 0                           | 0                            | 36         | 42    |
| 24 June    | 0                 | 0    | 2    | 4                           | 2                            | 32         | 40    |
| 25 June    | 0                 | 0    | 12   | 14                          | 0                            | 32         | 58    |
| 26 June    | 0                 | 4    | 8    | 8                           | 0                            | 20         | 40    |
| 27 June    | 0                 | 2    | 6    | 6                           | 0                            | 28         | 42    |
| 28 June    | 0                 | 0    | 8    | 6                           | 0                            | 34         | 48    |
| 29 June    | 0                 | 4    | 8    | 4                           | 0                            | 26         | 42    |
| 30 June    | 0                 | 0    | 4    | 0                           | 0                            | 26         | 30    |
| 1 July     | 0                 | 0    | 6    | 0                           | 0                            | 30         | 36    |
| 2 July     | 0                 | 0    | 12   | 12                          | 0                            | 16         | 40    |
| 3 July     | 0                 | 0    | 10   | 6                           | 0                            | 16         | 32    |
| 4 July     | 0                 | 6    | 2    | 12                          | 0                            | 4          | 24    |
| 5 July     | 0                 | 0    | 6    | 4                           | 0                            | 8          | 18    |
| 6 July     | 0                 | 2    | 6    | 6                           | 0                            | 12         | 26    |
| 7 July     | 0                 | 0    | 4    | 0                           | 0                            | 0          | 4     |
| 8 July     | 2                 | 0    | 4    | 0                           | 0                            | 6          | 12    |
| 9 July     | 0                 | 0    | 10   | 16                          | 2                            | 10         | 38    |
| 10 July    | 0                 | 2    | 10   | 14                          | 0                            | 14         | 40    |
| 11 July    | 0                 | 4    | 6    | 6                           | 0                            | 16         | 32    |
| 12 July    | 0                 | 2    | 10   | 4                           | 0                            | 28         | 44    |
| 13 July    | 0                 | 4    | 8    | 12                          | 0                            | 24         | 48    |
| 14 July    | 0                 | 0    | 4    | 10                          | 0                            | 28         | 42    |
| 15 July    | 0                 | 0    | 4    | 6                           | 0                            | 36         | 46    |
| Daily Mean | <0.1              | 1.9  | 6.7  | 6.4                         | 0.6                          | 17.2       | 32.8  |
| Total      | 2                 | 84   | 300  | 286                         | 26                           | 776        | 1,474 |

<sup>a</sup> Includes Cessna 207 and Cessna 185.

<sup>b</sup> Missed approach landing by Beech 1900.

because of the high cost of monitors and maintaining monitors (requiring daily to weekly visits) at nest sites would potentially disrupt nesting behavior and confound any responses of birds to aircraft, thereby compromising an important aspect of the study. Noise modeling for airstrips, based on empirical measurements of aircraft, allowed the estimation of noise levels at any location at any time for which information on flights was available.

Noise monitoring was conducted during 24–28 August 2001 at 20 sites where White-fronted Geese had nested from 1998–2001 (Figure 2). Sites were selected to sample a variety of directions and distances from the airstrip to facilitate calibration of the noise model. Detailed methods and results of the noise measurements and noise modeling are provided in Appendix B. Here we present a summary of results from the noise modeling that describes the noise environment in the Alpine project area and provides some explanation of how the results will be used in analyses of distribution of nests and analyses of nesting behavior.

The noise model produced different contours of  $L_{\max}$  (maximal noise levels) for each aircraft depending on whether they were arriving or departing and their direction of travel (Figure 7). The louder aircraft generally produce larger contours (Table 5), but the altitude of the aircraft also affects the noise level and contour size. Departing aircraft usually are louder than arriving aircraft at the same distance, because they require more power for takeoff. However, arriving aircraft usually approach at lower angles and lower altitudes than departing aircraft, which climb more steeply. Therefore, single-engine and twin-engine airplanes, which have relatively short takeoffs, have longer arrival contours than departure contours (Table 5). However, the width or perpendicular distance for each contour is usually wider for departures, resulting from higher noise levels on departure. The DC-6, the loudest aircraft that used the Alpine airstrip, has departure contours that are both longer and wider than on arrival, because its landing and takeoff angles are similar.

Noise levels at 3 nest sites (not all active in the same years, but noise levels were estimated for each year at all nest sites) around the airstrip are

presented as examples to illustrate how noise levels differ among aircraft, between takeoffs and landings, between flight directions, and among nest locations (Figure 7, Table 5). The example nests are 3 of the closest to the airstrip and in the loudest noise zone; these nests are used as examples because estimated noise levels vary more dramatically among flight conditions. The loudest aircraft to use the Alpine airstrip during the avian studies was the DC-6, a 4-engine piston-propeller airplane. The highest maximal noise level for a departing DC-6 estimated at these 3 example nests was 109 dBA at nest 002, which was a White-fronted Goose nest (active in 2000) located near the center point of the airstrip, 32 m from the airstrip perimeter and 58 m from the centerline. The noise levels for nests located midway along the length of the airstrip (e.g., nest 002) did not vary with flight direction ( $030^\circ$  and  $210^\circ$ ) for a departing DC-6, but a nest at either end of the runway (e.g., nests 001 or 105) had vastly different noise levels with different departure directions. Likewise, nests at one end of the airstrip had vastly different noise levels between arriving and departing aircraft using the same flight direction. The 85-dBA contour of a departing DC-6 was the largest for the aircraft using the Alpine airstrip, having a maximal width from the airstrip centerline of 500 m and length from center of airstrip of 5,100 m (Figure 7, Table 5). Although the 4-engine C-130 occasionally used the airstrip (3% of all 4-engine aircraft in 2001), it was not as loud as a DC-6 (Johnson et al. 2001) and was not included separately in the modeling.

The second loudest aircraft was the Bell 206 LR helicopter, but only if compared with aircraft at the same distances. At nest 002, the maximal noise from the helicopter was 80 dBA, less than any departing airplane, but nest 002 was 575 m from the helipad, approximately 10 times farther than from departing airplanes. However, the 85-dBA contour for helicopters was 335 m wide, second in width to the DC-6. Thus, the relative noise levels of different types of aircraft will vary among nest sites, depending on the distance of nests to the aircraft.

The second loudest airplanes were twin-engine turbo-propeller aircraft (Twin Otter or CASA) used for passengers and freight. At nest 002, the  $L_{\max}$  on the runway at  $210^\circ$  was 93 dBA

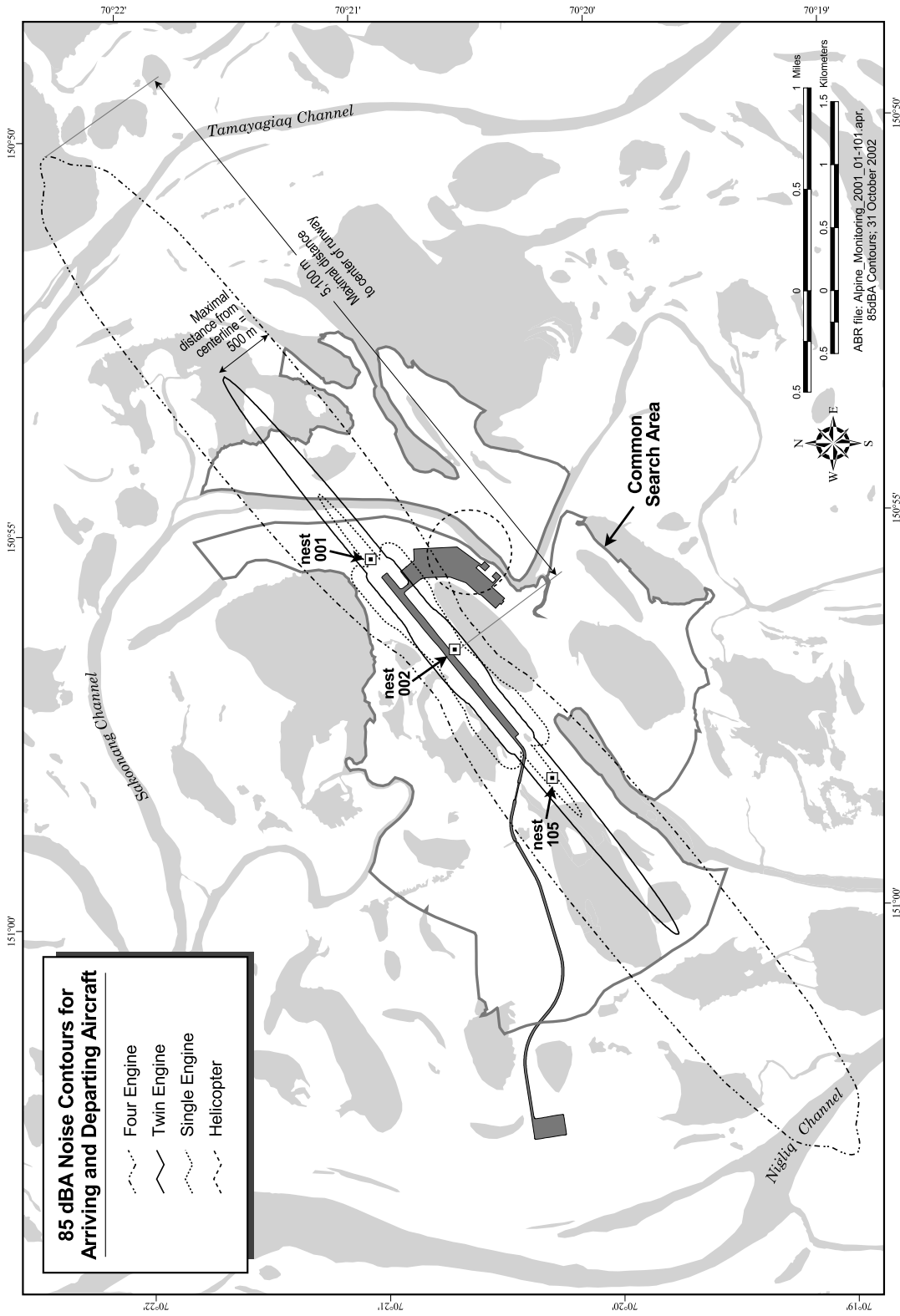


Figure 7. Noise contours of 85 dBA ( $L_{max}$ ) levels for 4 types of aircraft as estimated by noise modeling (INM ver. 6.0, FAA) in the Alpine project area, Colville River Delta, Alaska, 2001. Separate contours for arrival and departure and 2 flight directions have been merged for illustration. Measurements illustrate how length and width of contours were measured in Table 5. Nests locations are of Greater White-fronted Geese and a Tundra Swan used as examples for noise level calculations.



Table 5. Maximal length and width distances (m) from center of runway to noise contours and maximal noise levels ( $L_{max}$  in dBA) at 3 nest sites for types of aircraft using the Alpine airstrip, Colville River Delta, Alaska. Distances for airplanes were measured from the center of the airstrip along its length (contour length) and perpendicular to the long axis of the airstrip (contour width; see Figure 7). Distance for helicopters was measured as the radius from the helipad. Noise contours were modeled with INM ver. 6.0, Federal Aviation Administration (see Appendix B).

| Aircraft Type            | Contour Length (m) |        |                | Contour Width (m) |        |        | Max. Noise Level ( $L_{max}$ , dBA) |          |          | Max. Noise Level ( $L_{max}$ , dBA) |          |          |
|--------------------------|--------------------|--------|----------------|-------------------|--------|--------|-------------------------------------|----------|----------|-------------------------------------|----------|----------|
|                          | 75 dBA             | 85 dBA | 95 dBA         | 75 dBA            | 85 dBA | 95 dBA | Nest 001                            | Nest 002 | Nest 105 | Nest 001                            | Nest 002 | Nest 105 |
| Single Engine            |                    |        |                |                   |        |        |                                     |          |          |                                     |          |          |
| Arriving                 | 3,230              | 1,647  | 867            | 118               | 54     | 18     | 37.1                                | 50.0     | 87.2     | 88.3                                | 50.8     | 35.2     |
| Departing                | 2,536              | 1,025  | 920            | 456               | 235    | 111    | 83.4                                | 92.2     | 68.5     | 76.2                                | 92.8     | 81.8     |
| Twin Engine              |                    |        |                |                   |        |        |                                     |          |          |                                     |          |          |
| Arriving                 | 7,102              | 2,858  | 1,273          | 274               | 106    | 37     | 46.0                                | 60.9     | 94.2     | 94.9                                | 61.9     | 44.0     |
| Departing                | 2,564              | 934    | — <sup>a</sup> | 425               | 163    | 60     | 82.4                                | 92.3     | 57.1     | 67.3                                | 92.7     | 80.7     |
| DC-6                     |                    |        |                |                   |        |        |                                     |          |          |                                     |          |          |
| Arriving                 | 9,255              | 4,557  | 1,925          | 411               | 170    | 65     | 50.0                                | 93.1     | 99.7     | 100.3                               | 93.9     | 47.8     |
| Departing                | 15,331             | 5,100  | 2,310          | 1,195             | 500    | 200    | 103.7                               | 108.7    | 63.3     | 79.3                                | 108.7    | 101.3    |
| Bell 206 LR <sup>b</sup> | 1,067              | 335    | 107            | 1,067             | 335    | 107    | 86.1                                | 80.4     | 69.9     |                                     |          |          |

<sup>a</sup> 95-dBA contour did not extend to center of airstrip, producing a negative length.

<sup>b</sup> Helicopter landings and takeoffs assumed to be vertical, so runway direction is not relevant.

and 62 dBA for departing and arriving twin-engine airplanes, respectively. Several other similar twin-engine aircraft used the airstrip, but the noise model did not have noise profiles for each, so they were assumed to be similar to the Twin Otter. Likewise, several single-engine aircraft used the airstrip (primarily Cessna 207, Cessna 185, and Piper Supercub), but only the Cessna 207 was used in the model. The  $L_{\max}$  on the runway at  $210^\circ$  for a departing Cessna 207 at nest 002 was 93 dBA, about the same as for twin-engine aircraft, but on arrival the 207 was quieter at 51 dBA. The departure contours of the single-engine aircraft were larger than those for the twin-engine aircraft, probably because the single-engine aircraft are louder under full power, (Table 5), but the arrival contours were larger for twin-engine aircraft.

The daily noise level ( $L_{\text{eq}}$  estimated for 0600–1759 hr each day from 1 June to 15 July) at nest 002 in 2001 varied from 51 dBA, when only a twin-engine airplane landed and departed, to 84 dBA resulting from 49 events of all types of aircraft. The ambient level from the activity on the pads was estimated to be 38 dBA at the nest site, and any estimated noise levels above ambient were the result of aircraft. The annual noise level (logarithmic average of daily values for 1 June–15 July) for nest 002 was 78 dBA. At nest 001 the annual noise level in 2001 was 80 dBA (44 dBA ambient), and at nest 105 it was 72 dBA (29 dBA ambient). The lowest annual noise level estimated for a nest in 2001 was 57 dBA at a Pacific Loon nest that was 2,499 m from the airstrip. We were unable to determine if that nest hatched. The highest annual noise level was 80 dBA estimated for a Willow Ptarmigan nest. That nest was not the closest to the airstrip (831 m), but it was the closest nest to the helipad (227 m away) and managed to hatch  $\geq 9$  eggs.

## NEST DENSITIES AND DISTRIBUTION

### ALL SPECIES

In 2001, 11.4 km<sup>2</sup> were searched for nests around the Alpine airstrip (Figure 8), which was smaller than any area searched between 1996 and 2000. The 2001 nest-search area overlapped extensively with the areas searched in previous years (Figure 3). Ninety nests of 17 species (excluding ptarmigan) were located during the nest

searches, resulting in a density of 7.9 nests/km<sup>2</sup> (Table 6). Although the number of nests was one of the lowest recorded, the area searched was the smallest, which resulted in the second highest density of nests. Species diversity was nearly the same as the mean diversity for 1996–2000.

As in previous years, the most abundant large waterbird nesting in the Alpine project area was the White-fronted Goose. In 2001, 37 White-fronted Goose nests were located during the nest search, a density of 3.3 nests/km<sup>2</sup> (Table 6; Appendix G1). The number of White-fronted Goose nests was the second lowest found during any nest search, but the density was similar to the mean for 1996–2000 (3.5 nests/km<sup>2</sup>). Only 2 nests each were found of Brant and Canada Geese in 2001, but their densities were similar to the previous 3 years. The number and density of Tundra Swan nests in the Alpine project area in 2001 (5 nests, 0.4 nests/km<sup>2</sup>) were similar to the mean of the previous 5 years (5.8 nests, 0.4 nests/km<sup>2</sup>).

In 2001, Northern Pintails and Long-tailed Ducks were the most common nesting ducks in the Alpine project area (Table 6). In 2001, the number of nests and nest density for Northern Pintails were similar to previous years, whereas the number and density of Long-tailed Duck nests were lower. The number and density of Greater Scaup nests in 2001 were consistent with other years, but Green-winged Teal nests, which occur in most years in the Alpine project area, were not found. Other duck species are uncommon breeders in the Alpine project area. Only one Spectacled Eider nest was found during the nest search in 2001, although an unidentified eider nest (probably a Spectacled Eider, based on coloration of contour feathers) was found during the nest-fate check. Prior to 2001, a Spectacled Eider nest was found in 1998 and 1999 (Appendix G1). King Eider and Northern Shoveler nests were found in some previous years, but no nests were found in 2001.

Nests of 3 loon species and 1 grebe were found in the Alpine project area during nest searches in 2001 (Table 6). Pacific Loon nested at a slightly higher density (6 nests, 0.5 nests/km<sup>2</sup>) than the mean density of the previous 5 years. In 2001, nest numbers of Red-throated Loons (3 nests) and Yellow-billed Loons (1 nest) were similar to the means for each species during the previous 5 years. One to 3 Red-necked Grebe

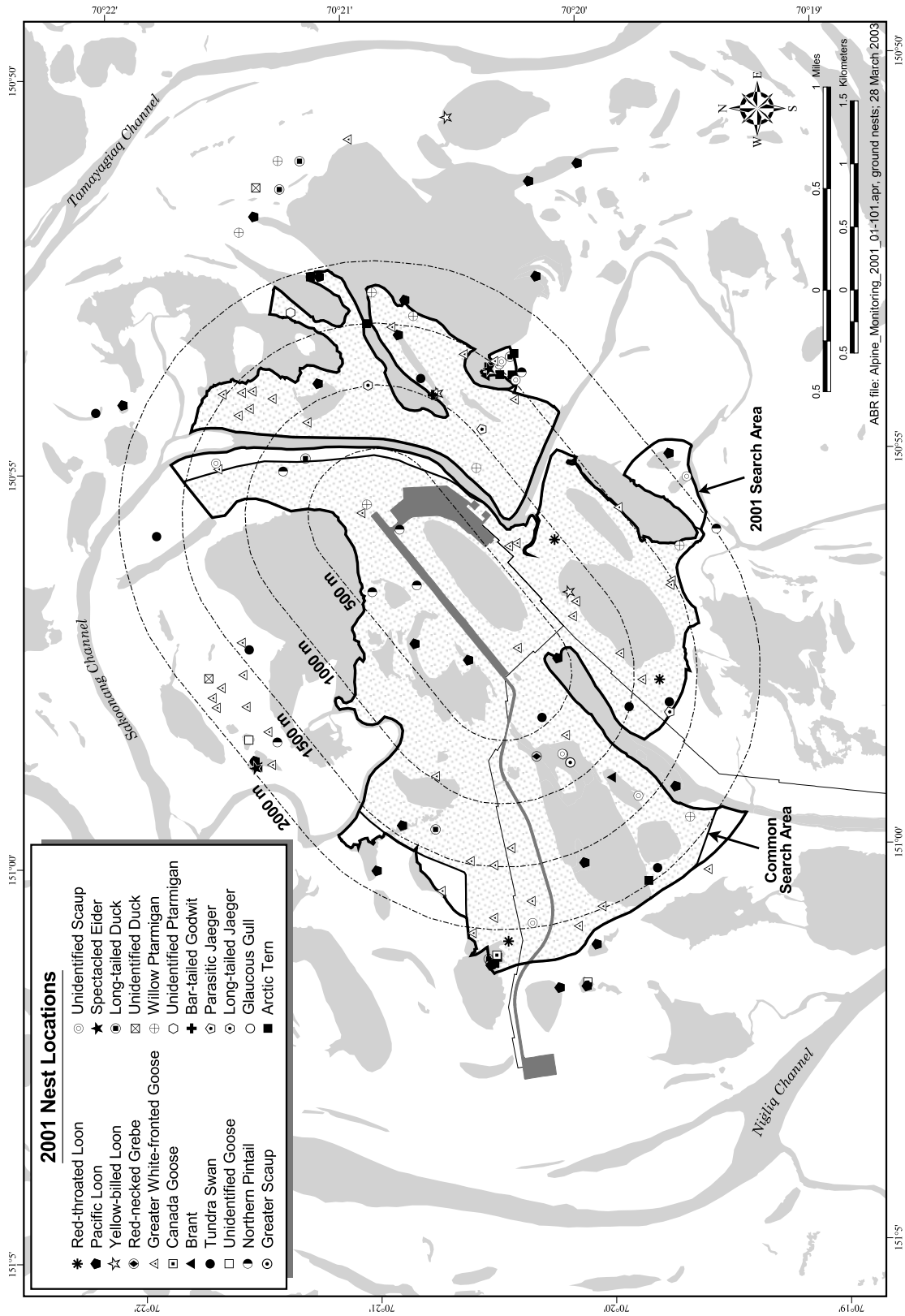


Figure 8. Locations of nests in the Alpine project area, Colville River Delta, Alaska, 2001. Stippled area is the common search area. Nests found during ground searches, except Tundra Swans, which also were found during aerial surveys.

Table 6. Numbers and densities of nests of selected species found in the Alpine ground-search area, Colville River Delta, Alaska, in 2001 compared to 1996–2000. Search area boundary is displayed in Figure 8. Annual values are presented in Appendix G1.

| Species                                  | Number of Nests |           |         |           | Density (nests/km <sup>2</sup> ) |           |         |           |
|--|-----------------|-----------|---------|-----------|----------------------------------|-----------|---------|-----------|
|  | 2001            | 1996–2000 |         |           | 2001                             | 1996–2000 |         |           |
|  |                 | Minimum   | Maximum | $\bar{x}$ |                                  | Minimum   | Maximum | $\bar{x}$ |
| Red-throated Loon                        | 3               | 0         | 7       | 2.8       | 0.3                              | 0         | 0.5     | 0.2       |
| Pacific Loon                             | 6               | 3         | 11      | 6.8       | 0.5                              | 0.2       | 0.7     | 0.5       |
| Yellow-billed Loon                       | 1               | 1         | 2       | 1.2       | 0.1                              | 0.1       | 0.2     | 0.1       |
| Red-necked Grebe                         | 2               | 0         | 3       | 1.6       | 0.2                              | 0         | 0.2     | 0.1       |
| Greater White-fronted Goose <sup>a</sup> | 37              | 35        | 79      | 51.8      | 3.3                              | 2.0       | 5.0     | 3.5       |
| Canada Goose                             | 2               | 0         | 2       | 0.8       | 0.2                              | 0         | 0.1     | 0.1       |
| Brant                                    | 2               | 1         | 4       | 3.6       | 0.2                              | 0.2       | 0.5     | 0.2       |
| Tundra Swan                              | 5               | 5         | 7       | 5.8       | 0.4                              | 0.2       | 0.4     | 0.4       |
| Northern Shoveler <sup>a</sup>           | 0               | 0         | 5       | 1.2       | 0                                | 0         | 0.3     | 0.1       |
| Northern Pintail <sup>a</sup>            | 7               | 2         | 9       | 6.6       | 0.6                              | 0.1       | 0.6     | 0.4       |
| Green-winged Teal <sup>a</sup>           | 0               | 0         | 4       | 1.6       | 0                                | 0         | 0.3     | 0.1       |
| Greater Scaup                            | 1               | 0         | 6       | 2.0       | 0.1                              | 0         | 0.4     | 0.1       |
| Lesser Scaup                             | 0               | 0         | 1       | 0.2       | 0                                | 0         | 0.1     | <0.0      |
| Unidentified scaup <sup>a</sup>          | 6               | 0         | 2       | 1.0       | 0.5                              | 0         | 0.1     | 0.1       |
| Spectacled Eider                         | 1               | 0         | 1       | 0.4       | 0.1                              | 0         | 0.1     | <0.1      |
| King Eider                               | 0               | 0         | 1       | 0.2       | 0                                | 0         | 0.1     | <0.1      |
| Long-tailed Duck <sup>a</sup>            | 3               | 5         | 9       | 6.2       | 0.3                              | 0.2       | 0.6     | 0.4       |
| Unidentified duck                        | 0               | 0         | 4       | 1.4       | 0                                | 0         | 0.3     | 0.1       |
| Willow Ptarmigan                         | 6               | 1         | 21      | 11.3      | 0.5                              | 0.1       | 1.3     | 0.8       |
| Rock Ptarmigan                           | 0               | 0         | 1       | 0.5       | 0                                | 0         | 0.1     | <0.1      |
| Unidentified ptarmigan                   | 1               | 0         | 3       | 1.0       | 0.1                              | 0         | 0.2     | 0.1       |
| Sandhill Crane                           | 0               | 0         | 1       | 0.2       | 0                                | 0         | 0.1     | <0.1      |
| Bar-tailed Godwit                        | 1               | 0         | 3       | 1.2       | 0.1                              | 0         | 0.2     | 0.1       |
| Common Snipe                             | 0               | 0         | 1       | 0.4       | 0                                | 0         | 0.1     | <0.1      |
| Parasitic Jaeger                         | 2               | 1         | 2       | 1.6       | 0.2                              | 0.1       | 0.2     | 0.1       |
| Long-tailed Jaeger                       | 1               | 0         | 1       | 0.8       | 0.1                              | 0         | 0.1     | 0.1       |
| Glaucous Gull                            | 1               | 0         | 2       | 0.8       | 0.1                              | 0         | 0.1     | 0.1       |
| Sabine's Gull                            | 0               | 0         | 1       | 0.4       | 0                                | 0         | 0.1     | <0.1      |
| Arctic Tern                              | 9               | 0         | 15      | 5.6       | 0.8                              | 0         | 0.3     | 0.4       |
| Short-eared Owl                          | 0               | 0         | 1       | 0.2       | 0                                | 0         | 0.1     | <0.1      |
| Area (km <sup>2</sup> )                  | 11.4            | 13.3      | 17.2    | 15.0      |                                  |           |         |           |
| Total Nests or Densities <sup>b</sup>    | 90              | 68        | 158     | 106.4     | 7.9                              | 4.0       | 10.1    | 7.1       |
| Total Number of Species <sup>c</sup>     | 17              | 14        | 18      | 16.4      |                                  |           |         |           |

<sup>a</sup> Includes nests identified from feather and down samples.

<sup>b</sup> Total does not include ptarmigan.

<sup>c</sup> Total does not include ptarmigan or unidentified ducks.

nests were found in the Alpine project area every year since 1997, and 2 were found in 2001 (Appendix G1).

Additional species found nesting during the nest search in 2001 included Parasitic Jaeger (2 nests), Long-tailed Jaeger (1 nest), Glaucous Gull (1 nest), and Arctic Tern (9 nests) (Table 6). Six Willow Ptarmigan nests and one nest of a Bar-tailed Godwit also were found. Shorebird and passerine nests were numerous in the Alpine project area and their occurrence is reported in the section on Breeding-Bird Plots.

In comparison with nest densities found elsewhere on the delta in 2001, the density of nests in the Alpine project area (8.5 nests/km<sup>2</sup>, including ptarmigan) was more similar to that found in the adjacent CD South area (8.6 nests/km<sup>2</sup>) than in the CD North area (16.7 nests/km<sup>2</sup>) (Table 7). However, the relative densities in the 3 areas varied by species. In general, nest densities of individual species at Alpine were more similar with those in CD South, which offered a comparable array of wildlife habitats, than with nest densities in the more coastal CD North area (Burgess et al. 2003, Johnson et al. 2003).

In the Alpine project area in 2001, 87 nests were found within 2,000 m of the airstrip (Table 8, Figure 8). The overall density of nests increased as the distance from the airstrip increased such that the density was lowest (4.4 nests/km<sup>2</sup>) within 500 m of the airstrip and highest (14.4 nests/km<sup>2</sup>) between 1,500 and 2,000 m of the airstrip. Habitat distribution, as defined by our map of the project area (Figure 2), had a small influence on the variation in densities of nests among the distance buffers around the airstrip in 2001. Most of the nests found in the search area were in 3 polygonized habitats: Patterned Wet Meadow (48 of 85 nests, 56%), Aquatic Sedge with Deep Polygons (10 nests, 12%), and Moist Sedge-Shrub Meadow (6 nests, 7%). Within these 3 habitats combined, the density of nests remained lowest in the ≤500-m buffer (6.3 nests/km<sup>2</sup>), and highest in the 1,500–2,000-m buffer (18.3 nests/km<sup>2</sup>). Thus, there appeared to be reduced nesting near the airstrip, which might reflect a disturbance effect. However, such a conclusion would be unsupported without information on the distribution of nests in pre-construction years. We evaluated the distribution of nests around the

airstrip with all years of data and other factors in Part II of this report.

#### GREATER WHITE-FRONTED GOOSE

As noted previously, 37 nests of White-fronted Geese were found during the nest search around the Alpine project area, which was 41% of all nests found (Table 6). The density of White-fronted Goose nests was 3.3 nests/km<sup>2</sup>, which was similar to the mean density for the previous 5 years.

White-fronted Geese nested in 4 of 17 available habitats in the Alpine project area in 2001 (Table 9). One habitat, Patterned Wet Meadow, was preferred (use significantly greater than availability). The other habitats used by nesting White-fronted Geese each contained 1–2 nests. Most nests (89%) 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 (mean = 76.8 m, *n* = 37) from the nearest permanent waterbody.

During the nest search in 2001, 34 White-fronted Goose nests were found ≤2,000 m from the airstrip (mean = 1,198 m, range 85–1,977 m; Figure 9, Table 8). Twenty-three nests (68%, 4.2 nests/km<sup>2</sup>) were >1,000 m from the airstrip, compared with 11 nests (32%, 2.1 nests/km<sup>2</sup>) ≤1,000 m from the airstrip. The lowest density of nests occurred ≤500 m from the airstrip (0.9 nests/km<sup>2</sup>), and the highest density was found between 1,000–1,500 m (4.4 nests/km<sup>2</sup>). The higher densities in the 2 buffers farthest from the airstrip did not appear to be related to the amount of a particular habitat in those buffers. The most frequently used nesting habitats for White-fronted Geese were Patterned Wet Meadow, Moist Sedge-Shrub Meadow, and Aquatic Sedge with Deep Polygons (Table 9). The pattern of nest densities among the distance buffers in only these combined habitats (1.6, 5.5, 7.4, and 6.1 nests/km<sup>2</sup> in the nearest to farthest buffers, respectively) was the same as the pattern among distance buffers with all habitats included (Table 8).

The lower density of Greater White-fronted Goose nests found near the airstrip suggests an effect on the distribution of nesting geese, which was possibly a negative response to the Alpine airstrip in 2001. The increasing amount of air, vehicular, and pedestrian traffic in 2001 (see

Table 7. Densities of nests (nests/km<sup>2</sup>) in the Alpine project area, CD South, and CD North ground-search areas, Colville River Delta, Alaska, 2001. CD South data and CD North data are from Burgess et al. (2003) and Johnson et al. (2003), respectively.

| Species                             | Alpine | CD North         | CD South |
|-------------------------------------|--------|------------------|----------|
| Red-throated Loon                   | 0.3    | 0.5 <sup>a</sup> | 0.1      |
| Pacific Loon                        | 0.5    | 0.6              | 0.2      |
| Yellow-billed Loon                  | 0.1    | 0.2 <sup>b</sup> | 0        |
| Red-necked Grebe                    | 0.2    | 0                | 0.2      |
| Greater White-fronted Goose         | 3.3    | 9.9 <sup>c</sup> | 4.1      |
| Canada Goose                        | 0.2    | 0                | 0        |
| Brant                               | 0.2    | 1.3              | 0        |
| Tundra Swan                         | 0.4    | 0.2              | 0.2      |
| Mallard                             | 0      | 0                | 0.1      |
| Northern Shoveler                   | 0      | 0                | 0        |
| Northern Pintail                    | 0.6    | 0.1 <sup>c</sup> | 0.7      |
| Green-winged Teal                   | 0      | 0                | 0        |
| Greater Scaup                       | 0.1    | 0                | 0.1      |
| Lesser Scaup                        | 0      | 0                | 0        |
| Unidentified scaup                  | 0.5    | 0                | 0.1      |
| Spectacled Eider                    | 0.1    | 0.4 <sup>c</sup> | 0.1      |
| King Eider                          | 0      | 0                | 0        |
| Long-tailed Duck                    | 0.3    | 1.2 <sup>c</sup> | 0.2      |
| Unidentified duck                   | 0      | 0.1              | 0.1      |
| Willow Ptarmigan                    | 0.5    | 0.4              | 1.1      |
| Rock Ptarmigan                      | 0      | 0                | 0        |
| Unidentified ptarmigan              | 0.1    | 0.1              | 0        |
| Sandhill Crane                      | 0      | 0                | 0        |
| Whimbrel                            | 0      | 0                | 0        |
| Bar-tailed Godwit                   | 0.1    | 0                | 0.2      |
| Common Snipe                        | 0      | 0                | 0        |
| Parasitic Jaeger                    | 0.2    | 0.1              | 0        |
| Long-tailed Jaeger                  | 0.1    | 0                | 0.1      |
| Glaucous Gull                       | 0.1    | 0.2              | 0        |
| Sabine's Gull                       | 0      | 0.5              | 0        |
| Arctic Tern                         | 0.8    | 0.9              | 0.4      |
| Short-eared Owl                     | 0      | 0                | 0.3      |
| Area Searched (km <sup>2</sup> )    | 11.4   | 17.9             | 9.7      |
| Waterbird <sup>d</sup> Nest Density | 7.9    | 16.2             | 7.0      |
| Total Nest Density                  | 8.5    | 16.7             | 8.6      |
| Total Number of Nests               | 97     | 299              | 83       |
| Number of Species                   | 18     | 14               | 18       |

<sup>a</sup> Includes nests that were presumed present from the presence of broods during the nest fate check.

<sup>b</sup> Includes Yellow-billed Loon nest or nests sighted on aerial survey.

<sup>c</sup> Includes nests identified to species from feather and down samples.

<sup>d</sup> Waterbirds include all species except ptarmigan and Short-eared Owl.

Table 8. Nest densities of selected species found within distance buffers around the Alpine airstrip, and the mean distance of nests from the airstrip, Alpine project area, Colville River Delta, Alaska, 2001.

| Species                          | Density (nests/km <sup>2</sup> ) by Distance Buffer |             |               |               |             | Distance (m) from Airstrip |             |
|----------------------------------|---|-------------|---------------|---------------|-------------|----------------------------|-------------|
|                                  | 0–500 m   | 500–1,000 m | 1,000–1,500 m | 1,500–2,000 m | Total Nests | $\bar{x}$                  | Range       |
|                                  | Red-throated Loon                                   | 0.0         | 0.3           | 0.3           | 0           | 2                          | 1,076       |
| Pacific Loon                     | 1.3   | 0           | 0             | 0.7           | 6           | 1061                       | 125–1,942   |
| Yellow-billed Loon               | 0   | 0           | 0.3           | 0             | 1           | 1,052                      | 1,052       |
| Red-necked Grebe                 | 0   | 0.7         | 0             | 0             | 2           | 728                        | 681–775     |
| Greater White-fronted Goose      | 0.9   | 3.0         | 4.4           | 3.9           | 34          | 1,198                      | 85–1,977    |
| Brant                            | 0   | 0           | 0.5           | 0             | 2           | 1,271                      | 1,163–1,379 |
| Tundra Swan                      | 0.4   | 0.3         | 0.5           | 0.6           | 4           | 1,160                      | 442–1,944   |
| Northern Pintail <sup>a</sup>    | 1.3   | 0.3         | 0             | 1.1           | 7           | 731                        | 51–1,595    |
| Greater Scaup                    | 0   | 0.3         | 0             | 0             | 1           | 861                        | 861         |
| Unidentified scaup <sup>b</sup>  | 0   | 0.3         | 0.5           | 1.7           | 6           | 1,419                      | 770–1,962   |
| Spectacled Eider                 | 0   | 0.0         | 0.3           | 0             | 1           | 1,438                      | 1,438       |
| Long-tailed Duck <sup>c</sup>    | 0   | 0.3         | 0.3           | 0.6           | 3           | 1,210                      | 690–1,620   |
| Willow Ptarmigan                 | 0.4   | 0.3         | 0             | 2.2           | 6           | 1,295                      | 90–1,838    |
| Unidentified ptarmigan           | 0   | 0           | 0             | 0.6           | 1           | 1,717                      | 1,717       |
| Bar-tailed Godwit                | 0   | 0           | 0.3           | 0             | 1           | 1,028                      | 1,028       |
| Parasitic Jaeger                 | 0   | 0           | 0.5           | 0             | 2           | 1,187                      | 1,058–1,315 |
| Long-tailed Jaeger               | 0   | 0           | 0.3           | 0             | 1           | 1,004                      | 1,004       |
| Arctic Tern                      | 0   | 0           | 0.8           | 2.2           | 6           | 1,644                      | 1,453–1,984 |
| Area (km <sup>2</sup> ) Searched | 2.3   | 3.0         | 3.7           | 1.8           | 10.7        |                            |             |
| Total Density                    | 4.4   | 6.1         | 9.0           | 14.4          | 8.1         |                            |             |
| Total Nests                      | 10  | 18          | 33            | 24            | 87          | 1,199                      | 51–1,984    |

<sup>a</sup> Includes probable Northern Pintail nests (4) determined from feather and down samples.

<sup>b</sup> Includes probable scaup nests (6) determined from feather and down samples.

<sup>c</sup> Includes a probable Long-tailed Duck nest determined from feather and down samples.

Human Activity section) may have influenced the amount of nesting, at least within the area nearest the airstrip. The relationships of nest density, disturbance, and habitat use will be investigated with data from all available years in Part II of this report.

#### TUNDRA SWAN

In 2001, 5 Tundra Swan nests (0.4 nests/km<sup>2</sup>) were found during the nest search in the Alpine project area (Figure 8; Table 6). Similar numbers

of swan nests were found in the area during the previous 5 years (range 5–7 nests) (Appendix G1).

The mean distance of nests from the airstrip in 2001 was 1,160 m (range 442–1,944 m; Table 8), which was similar to means in previous years (Johnson et al. 2001). The closest nest to the airstrip in 2001 was 442 m from the western end of the airstrip, 243 m from the nearest road, and 28 m from the flight path (Figure 8). The sample size of swan nests in the Alpine project area was too small to test for annual habitat selection, but all 5 nests in

Table 9. Habitat selection by Greater White-fronted Geese during nesting in the Alpine project area, Colville River Delta, Alaska, 2001. Only nests found in 2001 within the common area searched in all 6 years (1996–2001) are included.

| Habitat  | Area (km <sup>2</sup> ) | No. of Nests | Use (%) | Availability (%) | Monte Carlo Results <sup>a</sup> |
|--|-------------------------|--------------|---------|------------------|----------------------------------|
| Tapped Lake with Low-water Connection                  | 0.28                    | 0            | 0       | 2.6              | ns                               |
| Tapped Lake with High-water Connection                 | 0.80                    | 0            | 0       | 7.6              | ns                               |
| Salt Marsh   | 0.62                    | 0            | 0       | 5.8              | ns                               |
| Deep Open Water without Islands                        | 0.90                    | 0            | 0       | 8.5              | ns                               |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                    | 0            | 0       | 0.9              | ns                               |
| Shallow Open Water without Islands                     | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                    | 0            | 0       | 0.1              | ns                               |
| River or Stream  | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Aquatic Sedge Marsh                                    | 0.08                    | 0            | 0       | 0.8              | ns                               |
| Aquatic Sedge w/ Deep Polygons                         | 0.12                    | 2            | 6.0     | 1.1              | ns                               |
| Aquatic Grass Marsh                                    | 0.10                    | 0            | 0       | 1.0              | ns                               |
| Nonpatterned Wet Meadow                                | 0.96                    | 2            | 6.0     | 9.0              | ns                               |
| Patterned Wet Meadow                                   | 4.39                    | 28           | 85.0    | 41.2             | prefer                           |
| Moist Sedge–Shrub Meadow                               | 1.16                    | 1            | 3.0     | 10.9             | ns                               |
| Riverine or Upland Shrub                               | 0.63                    | 0            | 0       | 5.9              | ns                               |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                    | 0            | 0       | 1.7              | ns                               |
| Artificial (water, fill, peat road)                    | 0.31                    | 0            | 0       | 2.9              | ns                               |
| Total  | 10.64                   | 33           | 100     | 100              |                                  |

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

2001 occurred in habitats that were significantly preferred over an 9-year period on the Colville Delta (Johnson et al. 2003). Two nests occurred in Patterned Wet Meadow and 3 nests in Moist Sedge–Shrub Meadow.

## NESTING BEHAVIOR AND DISTURBANCE MONITORING

### GREATER WHITE-FRONTED GOOSE

#### Nest Attendance

Temperature sensing eggs and video cameras were used to collect information on nest attendance of White-fronted Geese for evaluations of development-related effects on nest activities. In 2001, egg thermistors were deployed at 34 White-fronted Goose nests (Figure 10). Of these 34 egg thermistors, temperature data were obtained for 27 nests from the time of deployment to the time of brood departure or nest failure. Of the

remaining 7 nests, 3 nests failed within 24 hr after the egg thermistor was deployed, and at 4 nests no data were collected because of equipment failure or installation error. Three nests with egg thermistors also were monitored simultaneously with time-lapse video cameras for  $\geq 14$  d; a fourth nest was monitored for 2.5 d but was not included in the analysis of the video data (Appendices H1–H4). The mean distance to the airstrip for the 27 nests monitored with egg thermistors was 1,336 m (range 85–2,218 m), and the mean distance of the 3 nests monitored with video cameras was 847 m (range 85–1,788 m).

To evaluate the relationship of nest fate and incubation activities in 2001, measures of nest attendance were compared between 19 White-fronted Goose nests that were successful and at 8 nests that subsequently failed. Each bird maintained high nest-attendance during the monitoring period, sometimes incubating 1–2 d



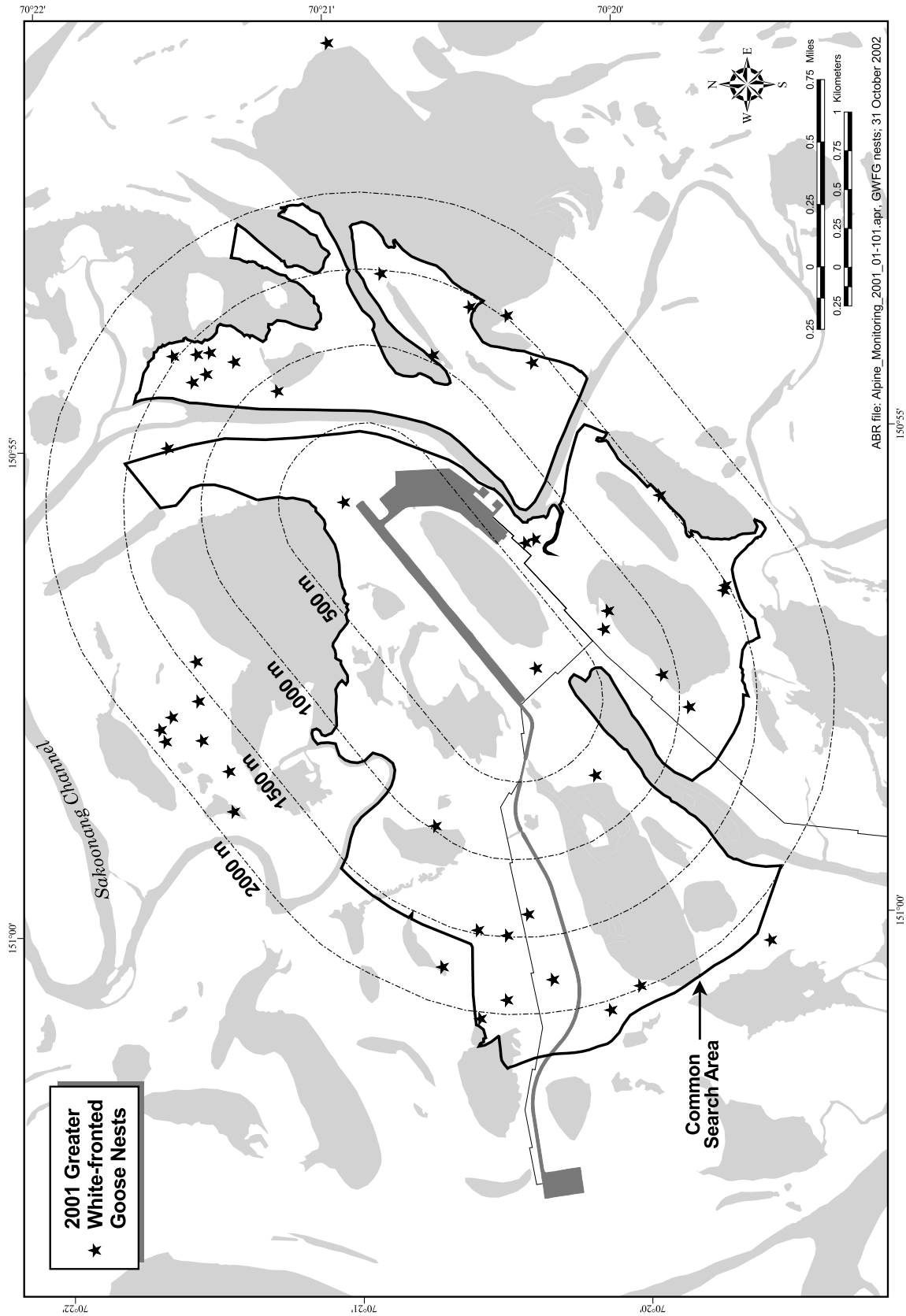


Figure 9. Locations of Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 2001.

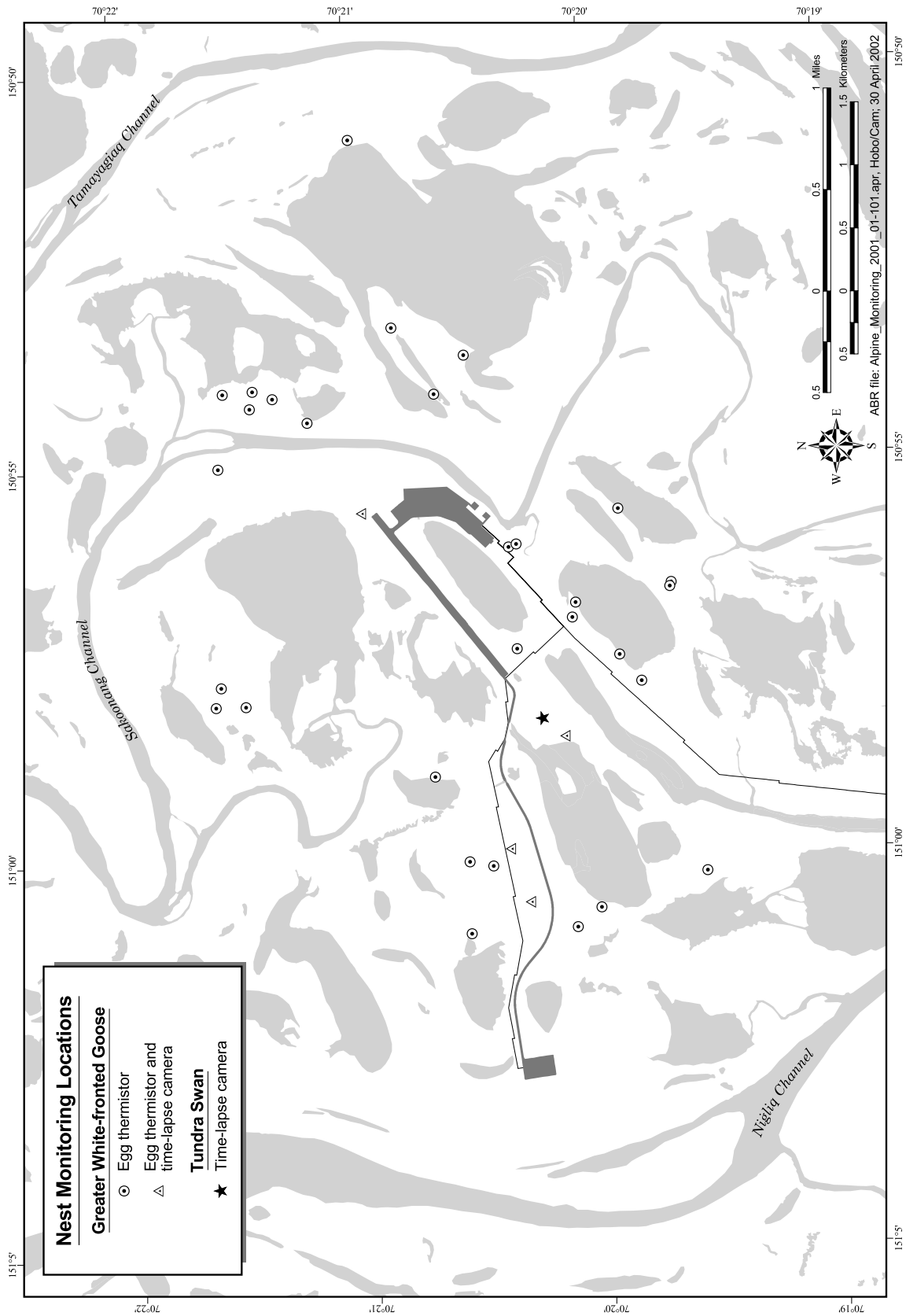


Figure 10. Locations of thermistor eggs and time-lapse cameras in the Alpine project area, Colville River Delta, 2001.

without a recess. The amount of time spent incubating in 2001 did not differ between White-fronted Geese at successful and failed nests (mean = 98.4% and 96.2%, respectively;  $P = 0.19$ ) (Tables 10 and 11). Mean recess length was longer at failed nests than at successful nests (mean = 23.8 min/recess and 16.5 min/recess, respectively), but the difference was not significant ( $P = 0.12$ ). Similarly, total time off the nest was longer at failed nests than at successful nests (mean = 54.0 min/d and 22.2 min/d, respectively), but the difference was not significant ( $P = 0.22$ ). Mean numbers of recesses and breaks did not differ between failed and successful nests. The daily number of recesses, mean recess length, and mean time off nest for geese at successful nests gradually increased from the start of incubation to the day before hatch (Figure 11). The pattern was similar for geese at failed nests, except for the 3 d before failure, when the number of recesses, mean recess length, and mean time off nest sharply increased. Thus, although geese at failed nests tended to have lower nest attendance, the difference between failed and successful nests was not significant and probably not large enough a factor to affect nest fates.

We evaluated the sample of monitored White-fronted Goose nests in 2001 for relationships between nest fate and distance to sources of potential disturbance, to see if proximity to disturbance might be a factor in nesting outcomes. Distance from the airstrip did not significantly differ ( $t = 1.44$ ,  $df = 18.2$ ,  $P = 0.17$ ) between failed nests (mean = 1,540 m,  $SD = 422$ ,  $n = 8$ ) and successful nests (mean = 1,251 m,  $SD = 582$ ,  $n = 19$ ). Similarly, distance to the flight path of airplanes did not differ ( $t = 1.27$ ,  $df = 17.8$ ,  $P = 0.22$ ) between failed nests (mean = 1,033 m,  $SD = 439$ ,  $n = 8$ ) and successful nests (mean = 770 m,  $SD = 592$ ,  $n = 19$ ). Also, distance to the nearest gravel did not differ ( $t = 0.30$ ,  $df = 14.1$ ,  $P = 0.77$ ) between failed nests (mean = 811 m,  $SD = 563$ ,  $n = 8$ ) and successful nests (mean = 885 m,  $SD = 601$ ,  $n = 19$ ), suggesting that airplane-, pad-, or road-associated activities were not major factors in the failure of nests monitored with thermistors and video cameras in 2001.

#### Effects of Disturbance on Nest Attendance

The effects of disturbance on White-fronted Goose incubation activities were evaluated by comparing the occurrence of recesses between hours when disturbances were present and absent. If human-related disturbance caused geese to take recesses, then recesses should occur more frequently in hours with disturbance events. White-fronted Geese monitored in 2001 took recesses during 199 of 3,311 hr (6.0%) of monitoring between 0600 and 1800 ADT. Separate tests were conducted with each type of potential disturbance to evaluate whether their presence affected the occurrence of recesses. Vehicles were present on the airstrip during all hours (range 5–46 vehicles/hr), and therefore were not included in this presence-vs.-absence test of disturbance factors affecting nest attendance. Geese took slightly more recesses when airplanes were present (6.5% of 1,880 hr) than when they were absent (5.3% of 1,431 hr, Fisher's exact test,  $P = 0.16$ ) and when helicopters were present (6.4% of 2,200 hr) than when they were absent (5.1% of 1,111 hr, Fisher's exact test,  $P = 0.19$ ), but those differences were not significant. Recess frequency did not differ when pedestrians were present (5.5% of 289 hr) or absent (6.1% of 3,022 hr, Fisher's exact test,  $P = 0.80$ ).

To further investigate the effect of disturbance on recess frequency, we considered the presence of any of 3 types of disturbance (airplanes, helicopters, or pedestrian events) as an event in a similar test that included the time of day. Disturbance events occurred during 2,710 of 3,311 hr (81.8%) of monitoring. The frequency of recesses during hours with disturbance events (6.2%) did not differ from the frequency during hours with no events (5.2%, Fisher's exact test,  $P = 0.39$ ). However, during midday (1000–1400), recesses were more likely to occur in hours with disturbance events than in hours without (6.8% vs. 2.1%; Fisher's exact test,  $P = 0.02$ ), and during the afternoon (1400–1800), recesses were less likely to occur in hours with disturbance events than in hours without (7.9% vs. 14.3%; Fisher's exact test,  $P = 0.02$ ). During the morning (0600–1000), the frequency of recesses between hours with and without disturbance events was similar (3.4% vs. 2.8%; Fisher's exact test,  $P = 0.71$ ). These results

Table 10. Mean incubation constancy (% of time) of Greater White-fronted Geese at successful and failed nests, as determined from egg thermistors (1 recording interval/5 min) in the Alpine project area, Colville River Delta, Alaska, 2001.

| Day Before Hatch        | Successful Nests |          | Day Before Failure      | Failed Nests |                       |
|-------------------------|------------------|----------|-------------------------|--------------|-----------------------|
|                         | %                | <i>n</i> |                         | %            | <i>n</i> <sup>a</sup> |
|                         |                  |          | 25                      | 100.0        | 1                     |
| 24                      | 99.3             | 2        | 24                      | 100.0        | 1                     |
| 23                      | 99.1             | 3        | 23                      | 99.5         | 2                     |
| 22                      | 98.3             | 8        | 22                      | 99.1         | 2                     |
| 21                      | 99.5             | 8        | 21                      | 99.1         | 2                     |
| 20                      | 99.1             | 10       | 20                      | 99.5         | 3                     |
| 19                      | 99.2             | 9        | 19                      | 99.1         | 4                     |
| 18                      | 98.3             | 8        | 18                      | 99.9         | 5                     |
| 17                      | 99.3             | 12       | 17                      | 99.4         | 5                     |
| 16                      | 99.5             | 16       | 16                      | 99.2         | 6                     |
| 15                      | 98.3             | 16       | 15                      | 99.0         | 6                     |
| 14                      | 98.7             | 17       | 14                      | 99.4         | 6                     |
| 13                      | 98.5             | 15       | 13                      | 99.4         | 6                     |
| 12                      | 98.8             | 18       | 12                      | 99.0         | 6                     |
| 11                      | 98.5             | 18       | 11                      | 99.1         | 6                     |
| 10                      | 98.6             | 19       | 10                      | 99.0         | 6                     |
| 9                       | 98.2             | 19       | 9                       | 98.3         | 6                     |
| 8                       | 98.0             | 19       | 8                       | 97.8         | 7                     |
| 7                       | 98.1             | 18       | 7                       | 97.7         | 7                     |
| 6                       | 98.3             | 18       | 6                       | 98.5         | 8                     |
| 5                       | 98.0             | 18       | 5                       | 98.0         | 8                     |
| 4                       | 98.4             | 18       | 4                       | 98.4         | 8                     |
| 3                       | 97.8             | 18       | 3                       | 93.9         | 8                     |
| 2                       | 97.5             | 18       | 2                       | 92.5         | 8                     |
| 1                       | 97.9             | 18       | 1                       | 86.4         | 8                     |
| Daily Mean <sup>b</sup> | 98.4             |          | Daily Mean <sup>c</sup> | 97.4         |                       |

<sup>a</sup> *n* = number of nests monitored each day.

<sup>b</sup> Based on 343 cumulative nest-days.

<sup>c</sup> Based on 135 cumulative nest-days.

Table 11. Comparison of nesting activities at Greater White-fronted Goose nests that hatched (*n* = 19) and failed (*n* = 8) in the Alpine project area, Colville River Delta, Alaska, 2001. Nests were monitored with egg thermistors.

|                            | Successful |      | Failed    |       | Nested ANOVA <sup>a</sup> |         |          |
|----------------------------|------------|------|-----------|-------|---------------------------|---------|----------|
|                            | $\bar{x}$  | SE   | $\bar{x}$ | SE    | <i>F</i>                  | df      | <i>P</i> |
| Incubation Constancy (%)   | 98.5       | 0.34 | 96.2      | 2.00  | 1.78                      | 1, 26.1 | 0.19     |
| Recess Frequency (no./d)   | 1.2        | 0.20 | 1.6       | 0.52  | 0.39                      | 1, 26.2 | 0.54     |
| Recess Length (min/recess) | 16.5       | 0.93 | 23.8      | 4.84  | 2.54                      | 1, 31.7 | 0.12     |
| Time off Nest (min/d)      | 22.2       | 4.92 | 54.0      | 28.79 | 1.58                      | 1, 26.0 | 0.22     |
| Break Frequency (no./d)    | 10.0       | 0.71 | 10.2      | 0.78  | 0.12                      | 1, 25.9 | 0.73     |

<sup>a</sup> For the ANOVA, the arcsine transformation was applied to incubation constancy, logarithmic transformation to recess length, and square-root transformation to recess frequency, break frequency, and time off nest.

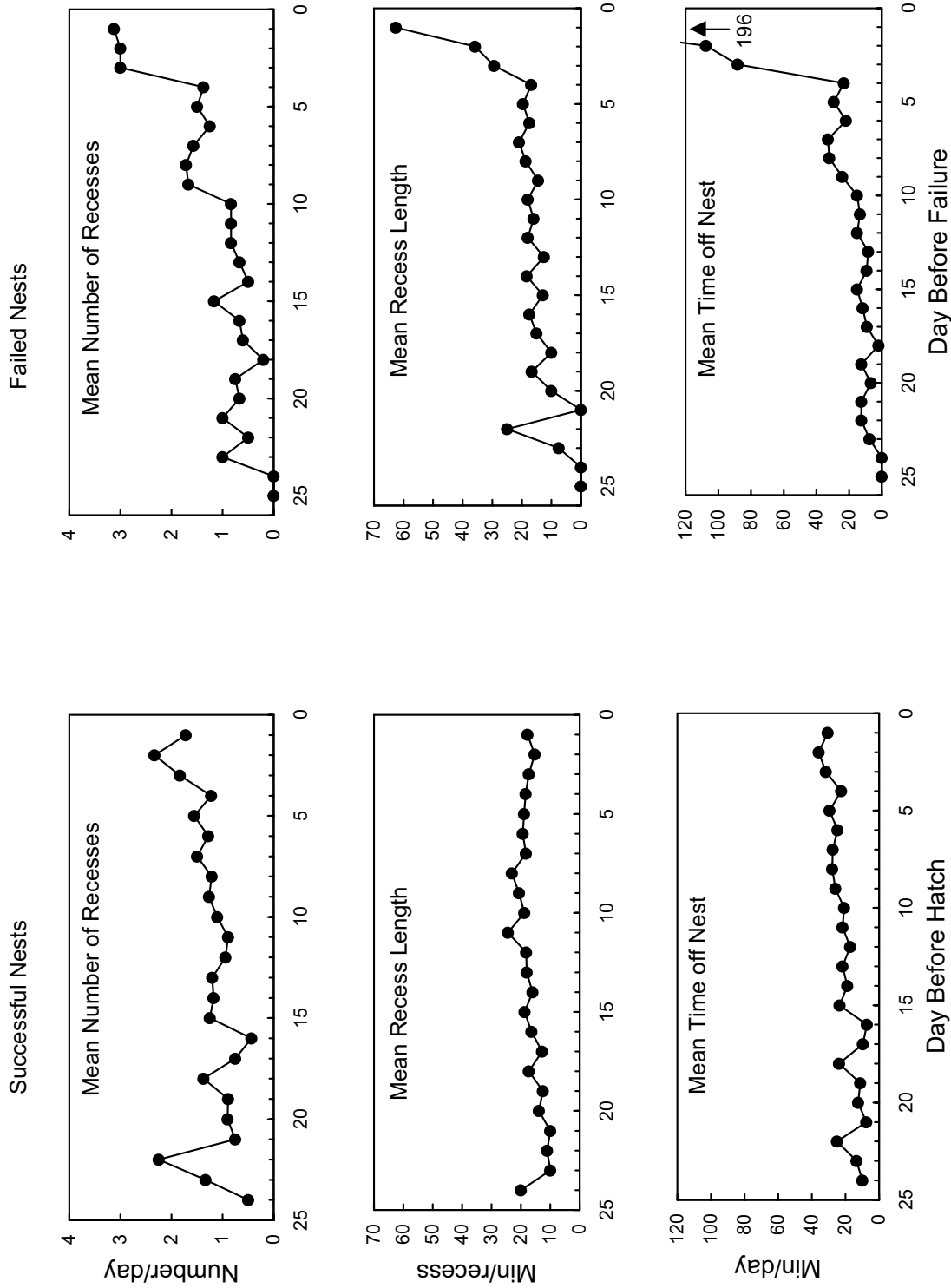


Figure 11. Mean frequency, length, and total time of incubation recesses for 19 successful and 8 failed nests of Greater White-fronted Geese monitored by egg thermistors (1 recording interval/5 min) in the Alpine project area, Colville River Delta, Alaska, 2001.

suggest that the occurrence of a recess as a response to an airplane, helicopter, and/or pedestrian event varied with time of day.

The effects of different sources of disturbance and environmental variables on the probability of a White-fronted Goose taking a recess during each hour (0600–1759 ADT) were tested using stepwise logistic regression analysis. To reduce the likelihood of multicollinearity, hourly weather variables and potential disturbance variables were examined using Pearson correlation coefficients. No strong correlations ( $r > 0.5$ ) were found among continuous explanatory variables. Maximal noise levels ( $L_{\max}$ ) and hourly noise levels ( $L_{\text{eq}}$ ) were strongly correlated with each other ( $r = 0.9$ ), but neither variable was significant in the initial model. When the nest site variable (a categorical variable to account for variation among individual nests) was included in the initial model, 3 other variables were retained: wind speed ( $P = 0.01$ ), time of day ( $P < 0.01$ ), and nest site ( $P < 0.01$ , Table 12). The probability of taking a recess during an hour increased with increasing wind speed and was higher in the afternoon than in the morning ( $P < 0.01$ ) or during midday ( $P = 0.05$ ). The inclusion of nest site ( $P < 0.01$ ) indicated significant variation existed among incubating birds and/or among nest locations. No other variables entered the model. When nest site was removed from the initial model, 4 variables were retained in the model: wind speed ( $P = 0.02$ ), time of day ( $P < 0.01$ ), day before hatch or failure ( $P = 0.14$ ), and distance from airstrip ( $P = 0.15$ ). As in the previous model, the probability of taking a recess during an hour increased with increasing wind speed and was higher in the afternoon than in the morning ( $P < 0.01$ ) or midday ( $P = 0.04$ ). As the day before hatch or failure approached, the probability of recesses increased. Geese nesting <1,000 m ( $P = 0.05$ ) and 1,000–2,000 m ( $P = 0.08$ ) from the airstrip had a higher probability of taking a recess than geese nesting >2,000 m from the airstrip.

Days were used as sample units to evaluate the effects of disturbance on incubation activities over a longer time scale and to evaluate incubation variables that could not be calculated for individual hours. Relationships of recess frequency, time off nest, and recess length with sources of potential disturbance and environmental conditions were

analyzed using generalized linear models (Table 13). Temperature and number of vehicles showed strong correlations ( $r > 0.6$ ) with other explanatory variables and were not included in the models (Appendix E2). Based on Akaike's Information Criterion (AIC), models with daily noise level (12-h  $L_{\text{eq}}$ ) were superior to models with maximal noise level ( $L_{\max}$ ) and therefore, daily noise level was used in the analyses. When nest site was included in the final models for recess frequency, time off nest, and average recess length, the same 3 variables were retained in each model—day before hatch or failure, duration of pedestrians on the airstrip, and nest site—and number of airplanes was retained in the model of recess frequency. Geese took more recesses, took longer recesses, and spent more time off the nest as the time pedestrians were on the airstrip increased ( $P \leq 0.03$ ). Recess frequency, recess length, and time off nest also increased as the day before hatch or failure approached ( $P \leq 0.15$ ). Nesting geese took fewer recesses on days when the number of airplanes was high ( $P = 0.03$ ). Nest site was significant ( $P < 0.01$ ) in models for each response variable, indicating that variability among nests was high.

When nest site was excluded in the final models for recess frequency, recess length, and time off nest, the same 4 variables were retained in each model: daily noise level, day before hatch or failure, number of helicopters, and distance to airstrip (Table 13). As daily noise levels and numbers of helicopters increased, the number of recesses, recess length, and time off nest decreased ( $P \leq 0.03$  and  $P \leq 0.04$ , for noise and helicopters, respectively). Geese also took more and longer recesses and spent more time off the nest as day before hatch or failure approached ( $P \leq 0.05$ ). Geese nesting <1,000 m took more recesses and spent more time off the nest than geese nesting >1,000 m from the airstrip (both models  $P \leq 0.01$ ). Recess length was longer for geese nesting  $\leq 2,000$  m from the airstrip than for geese nesting >2,000 m from the airstrip ( $P = 0.03$ ).

To summarize, the most consistent variables affecting nest attendance were day before hatch or failure, nest site (variation among individual locations or birds), and pedestrians (Table 13). When nest site was not included in the models, noise levels, helicopters, and distance to the airstrip

Table 12. Logistic regressions of the effects of disturbance and environmental variables on the probability of a recess during an hour at 27 Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 2001. Nests were monitored by egg thermistors between 0600 and 1800 ADT. Models were run with and without nest site as a categorical variable, and the 5 days prior to hatch or failure were excluded. Nagelkerke  $R^2 = 0.10$  with nest site in model and Nagelkerke  $R^2 = 0.03$  without nest site.  $n = 3,311$  hr.

| Model                       | $\beta$ | SE   | Wald  | df | $P$   | Odds Ratio<br>(Exp[ $\beta$ ]) |
|-----------------------------|---------|------|-------|----|-------|--------------------------------|
| <b>With Nest Site</b>       |         |      |       |    |       |                                |
| Intercept                   | -3.593  | 0.66 | 30.01 | 1  | <0.01 |                                |
| Wind Speed                  | 0.067   | 0.03 | 6.78  | 1  | 0.01  | 1.07                           |
| Time of Day                 |         |      | 18.27 | 2  | <0.01 |                                |
| 0600–1000                   | -0.914  | 0.21 | 18.07 | 1  | <0.01 | 0.40                           |
| 1000–1400                   | -0.332  | 0.17 | 3.86  | 1  | 0.05  | 0.72                           |
| 1400–1800                   | 0       |      |       |    |       |                                |
| Nest Site                   |         |      | 78.88 | 26 | <0.01 |                                |
| <b>Without Nest Site</b>    |         |      |       |    |       |                                |
| Intercept                   | -3.249  | 0.51 | 40.48 | 1  | <0.01 |                                |
| Day Before Hatch or Failure | -0.030  | 0.02 | 2.19  | 1  | 0.14  | 0.97                           |
| Wind Speed                  | 0.060   | 0.03 | 5.58  | 1  | 0.02  | 1.06                           |
| Time of Day                 |         |      | 18.68 | 2  | <0.01 |                                |
| 0600–1000                   | -0.912  | 0.21 | 18.43 | 1  | <0.01 | 0.40                           |
| 1000–1400                   | -0.333  | 0.17 | 4.02  | 1  | 0.04  | 0.72                           |
| 1400–1800                   | 0       |      |       |    |       |                                |
| Distance to Airstrip        |         |      | 3.73  | 2  | 0.15  |                                |
| 0–1,000 m                   | 0.750   | 0.39 | 3.73  | 1  | 0.05  | 2.12                           |
| 1,000–2,000 m               | 0.658   | 0.37 | 3.10  | 1  | 0.08  | 1.93                           |
| >2,000 m                    | 0       |      |       |    |       |                                |

became important. Airplanes and noise levels both affected a decrease in recess frequency and time (negative coefficients) and, therefore, probably were not a negative influence on nesting geese. Helicopters, pedestrians, and proximity to the airstrip, however, all increased recess frequency and time, which suggests these factors negatively affect nesting geese to spend less time incubating. Because these same nest attendance variables did not differ significantly between failed and successful White-fronted Goose nests, we cannot attribute reproductive effects to the changes in nest attendance related to human disturbance in 2001 with any certainty.

#### *Effects of Disturbance on Concealment Responses*

We evaluated the frequency, duration, and rate of concealment postures by White-fronted Geese

as indicators of the responsiveness of geese to different types of disturbance. Concealment postures were considered a part of normal incubation activities and were not considered a negative effect on the incubation behavior of geese. However, geese conceal when a threat is perceived and these concealments indicate what kinds of disturbance geese are sensitive to. At the 3 White-fronted Goose nests monitored by video in 2001, concealment postures were recorded in response to airplanes, helicopters, vehicles, pedestrians, predators, and other large birds (swans, geese, or ducks) (Tables 14 and 15). For 2 of the incubating geese, concealment postures occurred most often (~40% of all concealments) when airplanes were taxiing, landing, or taking off (Table 14). One of those nests (no. 007) was 85 m from the northeast end of the airstrip and 76 m

Table 13. The effects of potential disturbance and environmental variables on daily values for recess frequency, time off nest, and recess length for Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 2001. Generalized linear models were run with and without nest site as a categorical variable for 27 nests monitored by egg thermistors between 0600 and 1800 ADT. The 5 days prior to hatch or failure were excluded

| Model  | $\beta$ | SE   | Z     | t                 | df      | P     |
|--|---------|------|-------|-------------------|---------|-------|
| <b>Recess Frequency (no./d)<sup>a</sup></b>      |         |      |       |                   |         |       |
| With Nest Site                                   |         |      |       |                   |         |       |
| Intercept  | 0.59    | 0.44 | 1.33  |                   |         | 0.19  |
| Day Before Hatch or Failure                      | -0.03   | 0.02 | -1.44 |                   |         | 0.15  |
| Number of Airplanes                              | -0.03   | 0.02 | -2.10 |                   |         | 0.04  |
| Min Pedestrians on Airstrip (ln)                 | 0.11    | 0.04 | 2.55  |                   |         | 0.01  |
| Nest Site  |         |      |       |                   |         | <0.01 |
| Without Nest Site                                |         |      |       |                   |         |       |
| Intercept  | 2.41    | 1.29 | 1.86  |                   |         | 0.06  |
| Daily Noise Level (L <sub>eq</sub> )             | -0.05   | 0.02 | -2.29 |                   |         | 0.02  |
| Day Before Hatch or Failure                      | -0.04   | 0.02 | -1.95 |                   |         | 0.05  |
| Number of Helicopters                            | 0.05    | 0.02 | 2.79  |                   |         | <0.01 |
| Distance to Airstrip                             |         |      |       |                   |         | 0.01  |
| 0–1,000 m  | 0       |      |       |                   |         |       |
| 1,000–2,000 m                                    | -0.27   | 0.18 | -1.53 |                   |         | 0.13  |
| >2,000 m   | -1.11   | 0.41 | -2.68 |                   |         | <0.01 |
| <b>Time off Nest (min/d)<sup>b</sup></b>         |         |      |       |                   |         |       |
| With Nest Site                                   |         |      |       |                   |         |       |
| Intercept  | 1.61    | 0.47 | 3.44  |                   |         | <0.01 |
| Day Before Hatch or Failure                      | -0.04   | 0.03 | -1.75 |                   |         | 0.08  |
| Min Pedestrians on Airstrip (ln)                 | 0.13    | 0.04 | 2.83  |                   |         | <0.01 |
| Nest Site  |         |      |       |                   |         | <0.01 |
| Without Nest Site                                |         |      |       |                   |         |       |
| Intercept  | 4.59    | 1.74 | 2.63  |                   |         | <0.01 |
| Daily Noise Level (L <sub>eq</sub> )             | -0.06   | 0.03 | -2.12 |                   |         | 0.03  |
| Day Before Hatch or Failure                      | -0.07   | 0.03 | -2.54 |                   |         | 0.01  |
| Number of Helicopters                            | 0.05    | 0.02 | 2.07  |                   |         | 0.04  |
| Distance to Airstrip                             |         |      |       |                   |         | 0.05  |
| 0–1,000 m  | 0       |      |       |                   |         |       |
| 1,000–2,000 m                                    | -0.16   | 0.25 | -0.63 |                   |         | 0.53  |
| >2,000 m   | -1.28   | 0.50 | -2.56 |                   |         | 0.01  |
| <b>Average Recess Length (min/d)<sup>c</sup></b> |         |      |       |                   |         |       |
| With Nest Site                                   |         |      |       |                   |         |       |
| Intercept  | 10.45   | 3.77 |       | 48.25             | 1       | <0.01 |
| Day Before Hatch or Failure                      | -0.43   | 0.16 |       | 4.53              | 1       | <0.01 |
| Min Pedestrians on Airstrip (ln)                 | 0.64    | 0.30 |       | 6.90              | 1       | 0.03  |
| Nest Site  |         |      |       | 4.50 <sup>d</sup> | 26, 243 | <0.01 |
| Without Nest Site                                |         |      |       |                   |         |       |
| Intercept  | 31.71   | 9.66 |       | 3.28              | 1       | <0.01 |
| Daily Noise Level (L <sub>eq</sub> )             | -0.45   | 0.17 |       | -2.72             | 1       | <0.01 |
| Day Before Hatch or Failure                      | -0.40   | 0.17 |       | -2.44             | 1       | 0.02  |
| Number of Helicopters                            | 0.32    | 0.15 |       | 2.14              | 1       | 0.03  |
| Distance to Airstrip                             |         |      |       | 2.29 <sup>d</sup> | 2, 266  | 0.03  |
| 0–1,000 m  | 6.32    | 2.95 |       | 2.14              | 1       | 0.07  |
| 1,000–2,000 m                                    | 4.59    | 2.54 |       | 1.80              | 1       | <0.01 |
| >2,000 m   | 0       |      |       |                   |         |       |

<sup>a</sup> Model assumes a poisson distribution.

<sup>b</sup> Model assumes a negative binomial distribution.

<sup>c</sup> Model assumes a normal distribution.

<sup>d</sup> F-statistic.



Table 14. The relative frequency and duration of all concealment postures during potential disturbance events at 3 Greater White-fronted Goose nests monitored with time-lapse video cameras in the Alpine project area, Colville River Delta, Alaska 2001. All nests were successful.

| Nest No. <sup>a</sup>   | Distance (m) From Nest |             |       | Disturbance             | Concealment Postures |     |                |                       |           |       |
|-------------------------|------------------------|-------------|-------|-------------------------|----------------------|-----|----------------|-----------------------|-----------|-------|
|                         | Airstrip               | Flight path | Road  |                         | No.                  | %   | Duration (min) |                       |           |       |
|                         |                        |             |       |                         |                      |     | Total          | %                     | $\bar{x}$ | SE    |
| 007                     | 85                     | 76          | 1,721 | Airplane <sup>b</sup>   | 58                   | 39  | 112            | 18                    | 1.9       | 0.35  |
|                         |                        |             |       | Helicopter <sup>b</sup> | 20                   | 14  | 29             | 5                     | 1.5       | 0.22  |
|                         |                        |             |       | Vehicle                 | 30                   | 20  | 82             | 13                    | 2.7       | 0.47  |
|                         |                        |             |       | Pedestrian              | 8                    | 5   | 113            | 19                    | 14.1      | 2.69  |
|                         |                        |             |       | Large Bird <sup>c</sup> | 19                   | 13  | 200            | 33                    | 10.5      | 1.86  |
|                         |                        |             |       | Unknown                 | 13                   | 9   | 74             | 12                    | 5.7       | 2.02  |
|                         |                        |             |       | Total                   | 148                  | 100 | 610            | 100                   | 4.1       | 0.48  |
|                         |                        |             |       | 1001                    | 669                  | 90  | 452            | Airplane <sup>b</sup> | 34        | 45    |
| Helicopter <sup>b</sup> | 4                      | 5           | 4     |                         |                      |     |                | 2                     | 1.0       | 0.00  |
| Vehicle                 | 9                      | 12          | 16    |                         |                      |     |                | 7                     | 1.8       | 0.53  |
| Pedestrian              | 2                      | 3           | 32    |                         |                      |     |                | 14                    | 16.0      | 11.03 |
| Large Bird <sup>c</sup> | 22                     | 29          | 135   |                         |                      |     |                | 57                    | 6.1       | 1.07  |
| Predator <sup>d</sup>   | 3                      | 4           | 4     |                         |                      |     |                | 2                     | 1.3       | 0.35  |
| Unknown                 | 1                      | 1           | 2     |                         |                      |     |                | 1                     | 2.0       | –     |
| Total                   | 75                     | 100         | 237   |                         |                      |     |                | 100                   | 3.2       | 0.52  |
| 1106                    | 1,789                  | 923         | 154   | Airplane <sup>b</sup>   | 23                   | 13  | 38             | 3                     | 1.7       | 0.27  |
|                         |                        |             |       | Helicopter <sup>b</sup> | 3                    | 2   | 4              | <1                    | 1.3       | 0.35  |
|                         |                        |             |       | Vehicle                 | 70                   | 40  | 231            | 20                    | 3.3       | 0.51  |
|                         |                        |             |       | Pedestrian              | 9                    | 5   | 156            | 14                    | 17.3      | 7.90  |
|                         |                        |             |       | Large Bird <sup>c</sup> | 38                   | 22  | 574            | 51                    | 15.1      | 2.37  |
|                         |                        |             |       | Predator <sup>d</sup>   | 1                    | 1   | 4              | <1                    | 4.0       | –     |
|                         |                        |             |       | Unknown                 | 32                   | 18  | 120            | 11                    | 3.8       | 0.88  |
|                         |                        |             |       | Total                   | 176                  | 100 | 1,127          | 100                   | 6.4       | 0.81  |
| All Nests Pooled        |                        |             |       | Airplane <sup>b</sup>   | 115                  | 29  | 194            | 10                    | 1.7       | 0.19  |
|                         |                        |             |       | Helicopter <sup>b</sup> | 27                   | 7   | 37             | 2                     | 1.4       | 0.17  |
|                         |                        |             |       | Vehicle                 | 109                  | 27  | 329            | 17                    | 3.0       | 0.35  |
|                         |                        |             |       | Pedestrian              | 19                   | 5   | 301            | 15                    | 15.8      | 3.88  |
|                         |                        |             |       | Large Bird <sup>c</sup> | 79                   | 20  | 909            | 46                    | 11.5      | 1.33  |
|                         |                        |             |       | Predator <sup>d</sup>   | 4                    | 1   | 8              | <1                    | 2.0       | 0.70  |
|                         |                        |             |       | Unknown                 | 46                   | 12  | 196            | 10                    | 4.3       | 0.84  |
|                         |                        |             |       | Total                   | 399                  | 100 | 1,974          | 100                   | 4.9       | 0.42  |

<sup>a</sup> Total days monitored was 23.3 d for nest 007, 15.5 d for nest 1001, 18.0 d for nest 1106, and 56.8 d for all nests pooled.

<sup>b</sup> Includes takeoffs and landings, not overflights.

<sup>c</sup> Includes swans, geese, and ducks.

<sup>d</sup> Includes foxes and jaegers; Glaucous Gulls and Common Ravens were not observed.

Table 15. The proportion of events during which incubating Greater White-fronted Geese at 3 nests concealed during each of 4 types of human disturbance events (airplane, helicopter, vehicle, and pedestrian) on the airstrip or infield road in the Alpine project area, Colville River Delta, Alaska, 2001. Nests were monitored with time-lapse video cameras. All nests were successful.

| Nest No. <sup>a</sup> | Distance (m) from Nest |      | Incubation Behavior/Events       | Airplane Landings or Takeoffs |     | Helicopter Landings or Takeoffs |     | Vehicles |     | Pedestrians |     | No. Potential Disturbance Events |
|-----------------------|------------------------|------|----------------------------------|-------------------------------|-----|---------------------------------|-----|----------|-----|-------------|-----|----------------------------------|
|                       | Airstrip               | Road |                                  | No.                           | %   | No.                             | %   | No.      | %   | No.         | %   |                                  |
|                       | Flight Path            | Road |                                  | No.                           | %   | No.                             | %   | No.      | %   | No.         | %   |                                  |
| 007                   | 85                     | 76   | 1,721                            | 71                            | 21  | 45                              | 9   | 214      | 3   | 41          | 18  | 7,280                            |
|                       |                        |      | Concealment Posture <sup>b</sup> | 265                           | 79  | 443                             | 91  | 6,013    | 97  | 188         | 82  |                                  |
|                       |                        |      | Normal Incubation                | 336                           | 100 | 488                             | 100 | 6,227    | 100 | 229         | 100 |                                  |
|                       |                        |      | Total                            |                               |     |                                 |     |          |     |             |     |                                  |
|                       |                        |      | Percent of Events                | 5                             |     | 7                               |     | 85       |     | 3           |     |                                  |
| 1001                  | 669                    | 90   | 452                              | 37                            | 16  | 21                              | 6   | 215      | 3   | 27          | 17  | 8,477                            |
|                       |                        |      | Concealment Posture <sup>b</sup> | 194                           | 84  | 332                             | 94  | 7,519    | 97  | 132         | 83  |                                  |
|                       |                        |      | Normal Incubation                | 231                           | 100 | 353                             | 100 | 7,734    | 100 | 159         | 100 |                                  |
|                       |                        |      | Total                            |                               |     |                                 |     |          |     |             |     |                                  |
|                       |                        |      | Percent of Events                | 3                             |     | 4                               |     | 91       |     | 2           |     |                                  |
| 1106                  | 1,789                  | 923  | 154                              | 49                            | 18  | 24                              | 6   | 238      | 7   | 5           | 16  | 4,181                            |
|                       |                        |      | Concealment Posture <sup>b</sup> | 221                           | 82  | 389                             | 94  | 3,228    | 93  | 27          | 84  |                                  |
|                       |                        |      | Normal Incubation                | 270                           | 100 | 413                             | 100 | 3,466    | 100 | 32          | 100 |                                  |
|                       |                        |      | Total                            |                               |     |                                 |     |          |     |             |     |                                  |
|                       |                        |      | Percent of Events                | 6                             |     | 10                              |     | 83       |     | 1           |     |                                  |
| Mean                  |                        |      | Concealment Posture <sup>b</sup> | 18                            |     | 7                               |     | 4        |     | 17          |     |                                  |
|                       |                        |      | Normal Incubation                | 82                            |     | 93                              |     | 96       |     | 83          |     |                                  |
|                       |                        |      | Total                            | 100                           |     | 100                             |     | 100      |     | 100         |     |                                  |
|                       |                        |      | Percent of Events                | 5                             |     | 7                               |     | 86       |     | 2           |     |                                  |

<sup>a</sup> Total days monitored was 23.3 d for nest 007, 15.5 d for nest 1001, 18.0 d for nest 1106, and 56.8 d for all nests pooled.

<sup>b</sup> One concealment posture may occur during multiple aircraft, vehicle, or pedestrian events.

from the flight path, and the other nest (no. 1001) was 669 m from the southwest end of the airstrip but only 90 m from the flight path. The third nest (no. 1106) monitored was closer to the infield road (154 m) than to the airstrip (1,789 m), and the incubating bird at this nest concealed most often (40%, 70 of 176 concealments) when vehicles were present on the infield road. Vehicles were the most common source of disturbance detected at each nest (83–91% of all human disturbance events), compared with helicopters (4–10%) and airplanes (3–6%; Table 15). The nest closest to the helipad (nest 007, 813 m) probably had the highest number of helicopter overflights and had the highest percentage of concealments to helicopters (14%) compared with the other nests (Table 14). The other 2 nests were farther from the helipad (nests 1001 and 1107 were 2,098 m and 3,292 m, respectively), and  $\leq 5\%$  of the concealment postures at those nests occurred in response to helicopters. At each nest, the number of concealment postures that occurred when pedestrians were on the airstrip or infield road was low (3–5% of all concealments). Pedestrians were the least frequent source of disturbance at each nest (1–3%). All 3 of the incubating birds, concealed when large birds (13–29% of all concealments)—most often other White-fronted Geese—were feeding or loafing near the nest, and 2 geese concealed when predators (1–4% of all concealments) were near the nest. In summary, the relative frequency of concealments among different types of disturbance is affected by the frequency of each type of disturbance event and the location of the nests relative to the disturbance sources. The relative sensitivity of geese to different types of disturbance is also a factor and is evaluated below.

The responsiveness of nesting geese to different types of potential human disturbance was calculated as the proportion of events of each type that were associated with concealment postures, here termed the concealment rate. Although vehicles on the airstrip or the infield road were the most common source of potential disturbance at each nest (83–91% of all disturbances), the rate of concealment to vehicles was low (3–7% of all vehicle events elicited concealment postures; Table 15). At all nests, the highest rates of concealments were either for airplanes (16–21% of all airplane

events) or pedestrians (16–18% of all pedestrian events), and the rates for these 2 disturbance sources were similar among nests. The rates of concealment for helicopters at the 2 nests (nos. 007 and 1001) closest to the airstrip and helicopter landing/departure areas were 2–3 times greater than for vehicles, while the incubating bird at the nest (no. 1106) near the infield road had a similar rate of concealment for helicopters (6%) and vehicles (7%).

The amount of time spent concealing in response to different sources of disturbance may reflect the type and/or duration of the disturbance. Mean time spent concealing by all 3 incubating birds monitored by video cameras during airplane events (mean = 1.7 min,  $n = 115$  events) and helicopter events (mean = 1.4 min,  $n = 27$ ) was less than the mean times for the other known disturbances (range 2.0–15.8 min) (Table 14). The longest mean time spent concealing by each incubating bird (mean = 15.8 min, range 14.1–17.3 min,  $n = 19$ ) for a particular disturbance type was in response to pedestrians on the airstrip, road, or adjacent tundra. Mean time spent concealing when other birds were present (mean = 11.5 min, range 6.1–15.1 min,  $n = 79$ ) was nearly as long as it was for pedestrians. Mean time spent concealing when vehicles were on the airstrip or infield road (mean = 3.0 min, range 1.8–3.3 min,  $n = 109$ ) was longer than for airplanes or helicopters, but shorter than for pedestrians. Two incubating birds responded to the presence of predators that were in the camera view by concealing, and the mean duration of these concealment postures was 2.0 min ( $n = 4$ ). Based on concealment durations of nesting geese, pedestrians and other birds caused the strongest responses and the length of time that pedestrians and other birds were present probably were longer than the duration of airplane, helicopter, and vehicle events, which are more transitory.

The response of the 3 monitored geese to potential sources of disturbance, as measured by the number, duration, and rate of concealment postures, varied with the type of disturbance, the proximity of the nest to the source of disturbance, and the length of the disturbance event. All 3 incubating geese appeared to be more responsive to airplanes and pedestrians than to helicopters or

vehicles, but the distance to each source was a factor in how each goose responded.

#### *Responses to Pedestrians*

Because geese were sensitive to pedestrians, we used data collected during nest searching and other observations to summarize responses other than concealment of nesting geese to pedestrian activity in the Alpine project area. When egg thermistors were deployed in White-fronted Goose nests, incubating birds were flushed from their nests. Thermistors were deployed during nest searching, and it could have taken several hours before researchers were no longer visible from the nest site. The interval from the time researchers left the nest after installing an egg thermistor to the time the incubating bird returned to incubate averaged 92 min (range 17–528 min,  $n = 26$ ). The length of time that the researchers were at the nest (mean = 18 min, range 9–41 min) and in the vicinity after the thermistor was installed probably affected the amount of time that the incubating bird was away. In 2001, 2 geese that spent the longest time away from their nests (356 and 528 min) were nesting in a breeding-bird plot, which usually required 1–1.5 d to search, and did not return to incubate until researchers had left the plot for the day. Excluding the contribution of those 2 nests, the mean time from when the researchers left the nest to the time the goose returned to incubate was 62 min ( $n = 24$ ).

During related research activities in 2001, incubating White-fronted Geese on nests previously equipped with egg thermistors sometimes were flushed. While nest searching in the breeding-bird plots, 5 different geese were flushed off nests 7 times (2 geese were flushed twice), and nest searching in the area after flushing the geese (range 20–415 min) resulted in some prolonged recesses (mean = 106 min, range 50–180 min). Two of these 5 geese returned to the nest while researchers were still working within 500 m. Of these 5 nests, 1 failed and 4 were successful. Temperature patterns from the egg thermistor indicated that the goose at the failed nest resumed normal incubation behavior after disturbance and incubated for 17 d before failure occurred. Disturbances to nesting White-fronted Geese by other people on the tundra also were recorded by video camera. At one goose nest 85 m

from the airstrip, the incubating bird was flushed by a man walking on the tundra and she remained off the nest for 40 min. Clean-up personnel flushed another goose (154 m from the infield road) 3 times from its nest. This incubating bird was off the nest for 38, 47, and 57 min after these 3 disturbances, 2 of which occurred on the same day within the same hour. Both nests were successful.

#### *Reactions to Predators*

Predators were another identifiable source of disturbance on the video recordings made during nesting. Geese responded to these sources of disturbance with concealment postures, defense breaks, disturbance recesses, and normal incubation. A total of 7 defense breaks, which were reactions to a fox near the nest, were recorded at 3 White-fronted Goose nests. Four breaks occurred when an arctic fox was <2 m from nests and the attending female and male geese reacted for 1–5 recording intervals (~1–5 min) by standing and flapping their wings. During the other 3 defense breaks, a fox was 5–10 m from a nest, and the incubating bird either stood over the nest in alert posture or remained sitting on the nest and hissed at the fox. On 4 other occasions at the same 3 nests, the attending female and male geese exhibited similar defensive postures (flapping of wings, hissing), but no predators were seen on the video image. On 3 occasions, a fox was >50 m from a nest and the incubating bird showed no reaction or responded for one recording interval (~1 min) with a concealment posture.

### TUNDRA SWAN

#### *Nest Attendance*

One Tundra Swan nest was monitored in 2001 with a time-lapse video camera. This nest (no. 105) was 442 m from the airstrip, 28 m from the flight path, and 243 m from the infield road. Nest 105 was monitored for 31 d (Appendix H5) from the start of incubation until 2 young hatched at the nest. Mean daily incubation constancy was high (99.2%,  $n = 29$  d) and recess frequency was low (mean = 0.4 recesses/d) (Table 16). Mean recess length was 8.1 min/recess, and mean time off nest was 11.6 min/d. Mean daily number of incubation exchanges between the male and female in 2001 was 3.5 exchanges/d, and mean time off nest for exchanges was 8.2 min/d.

Table 16. Summary of nesting activities at a Tundra Swan nest (no. 105) monitored with time-lapse video camera in the Alpine project area, Colville River Delta, Alaska, 2001. The nest was 442 m from the airstrip, 28 m from the flight path, 243 m from the infield road and 1,912 m from the helipad. The nest was successful.

|                                     | $\bar{x}$ | SE   | $n^a$ |
|-------------------------------------|-----------|------|-------|
| Incubation Constancy (%/d)          | 99.2      | 0.09 | 29    |
| Recess Frequency (no./d)            | 0.4       | 0.11 | 29    |
| Recess Length (min/recess)          | 8.1       | 2.40 | 12    |
| Time Off Nest (min/d)               | 11.6      | 1.21 | 29    |
| Break Frequency (no./d)             | 25.5      | 1.23 | 29    |
| Break Length (min/d)                | 28.3      | 1.65 | 29    |
| Exchange Frequency (no./d)          | 3.5       | 0.20 | 29    |
| Exchange Length (min/d)             | 8.2       | 0.56 | 29    |
| Defense Frequency (no./d)           | 0.9       | 0.19 | 29    |
| Time Disturbed <sup>b</sup> (min/d) | 24.2      | 8.00 | 29    |

<sup>a</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

<sup>b</sup> Time disturbed is the number of minutes people were on the tundra near the nest (as determined from video c and field notes) plus 30 minutes before and after to account for their approach to and departure from nest.

#### Effects of Disturbance on Alert Responses

Alert postures of incubating Tundra Swans occurred in response to perceived threats and were used as indicators of disturbance in this study the same way that concealment postures were used for White-fronted Geese. Alert postures occurred most often (55% of all alert postures) when vehicular traffic was present on the airstrip or the infield road (Table 17). The high percentage of alert postures occurring in response to vehicle events was largely because these events were the most common (89% of all disturbance events) source of potential disturbance and the nest was close to the road (243 m; Table 18). The second highest frequency of alert postures occurred when pedestrians (13% of all alert postures) were present on the airstrip, infield road, or the tundra adjacent to the airstrip. Alert postures occurred infrequently when airplanes (7% of all alerts) and helicopters (4% of all alerts) were taking off or landing. Eighteen percent of all alert postures could not be associated with a disturbance source. On 16 occasions (2% of all disturbance events), the swan was alert during predator events on the video. The mean time spent alert (mean = 2.2 min) was slightly longer when predators were in the area than during all other disturbances (range of means

1.0–1.7 min). The incubating swan had the highest rate of alert postures in response to pedestrians (59% of all pedestrian events elicited alert postures). The rate of alert postures to airplane events (20% of all aircraft events) was higher than for helicopters (17% of all helicopter events) and vehicles (12% of all vehicle events). The rate of alert postures indicates that swans at the monitored nest were more sensitive to pedestrians than aircraft, helicopters, or vehicles, despite the nest being closer to the flight path than to the airstrip or road.

One recess taken by the incubating swan may have been caused by a DC-6 when it was on approach for landing. The swan nest was 28 m from the flight path and planes flew low over the nest when landing to the northeast. (Approximately 72% of all airplane landings were to the northeast.) The incubating swan was alert for 4 recording intervals (~4 min) before it left the nest with no evidence of it having covered the eggs. Three recording intervals later (~3 min), a DC-6 appeared over the nest. The swan returned to the nest 4 recording intervals later (~4 min) and resumed incubating, for a disturbance duration of ~11 min. Another recess appeared to be caused by the presence of researchers working in the area.

Table 17. The relative frequency and duration of alert postures during potential disturbance events at a Tundra Swan nest (no. 105) monitored with time-lapse video camera in the Alpine project area, Colville River Delta, Alaska, 2001. The nest was 442 m from the airstrip, 28 m from the flight path, 243 m from the infield road and 1,912 m from the helipad. The nest was successful.

| Disturbance             | Alert Postures |     |                |     |           |      |
|-------------------------|----------------|-----|----------------|-----|-----------|------|
|                         | No.            | %   | Duration (min) |     |           |      |
|                         |                |     | Sum            | %   | $\bar{x}$ | SE   |
| Airplane                | 63             | 7   | 94             | 7   | 1.5       | 0.18 |
| Helicopter              | 34             | 4   | 57             | 4   | 1.7       | 0.26 |
| Vehicle                 | 469            | 55  | 751            | 57  | 1.6       | 0.06 |
| Pedestrian              | 106            | 13  | 168            | 13  | 1.6       | 0.19 |
| Large Bird <sup>a</sup> | 5              | 1   | 5              | <1  | 1.0       | 0.00 |
| Predator <sup>b</sup>   | 16             | 2   | 35             | 3   | 2.2       | 0.43 |
| Unknown                 | 154            | 18  | 205            | 16  | 1.3       | 0.06 |
| Total                   | 847            | 100 | 1,315          | 100 | 1.6       | 0.05 |

<sup>a</sup> Includes swans, geese, and ducks.

<sup>b</sup> Includes fox and jaegers; Glaucous Gulls and Common Ravens were not observed.

Table 18. The proportion of events during which an incubating Tundra Swan (nest no.105) was in alert posture during human disturbance events (airplane, helicopter, vehicle, and pedestrian) on the airstrip or infield road in the Alpine project area, Colville River Delta, Alaska, 2001. The nest was 442 m from the airstrip, 28 m from the flight path, 243 m from the infield road and 1,912 m from the helipad. The nest was successful.

| Behavior/Events            | Airplane Landings or Takeoffs |     | Helicopter Landings or Takeoffs |     | Vehicles |     | Pedestrians |     | No. Potential Disturbance Events |
|----------------------------|-------------------------------|-----|---------------------------------|-----|----------|-----|-------------|-----|----------------------------------|
|                            | No.                           | %   | No.                             | %   | No.      | %   | No.         | %   |                                  |
| Alert Posture <sup>a</sup> | 98                            | 20  | 111                             | 17  | 1,418    | 12  | 162         | 59  |                                  |
| Normal Incubation          | 382                           | 80  | 540                             | 83  | 9,947    | 88  | 113         | 41  |                                  |
| Total                      | 480                           | 100 | 651                             | 100 | 11,365   | 100 | 275         | 100 | 12,771                           |
| Percent of Events          |                               | 4   |                                 | 5   |          | 89  |             | 2   |                                  |

<sup>a</sup> One alert posture may occur during multiple aircraft, vehicle, or pedestrian events.

When 6 researchers searched for nests 200–500 m from the nest for 150 min, the incubating swan concealed for 26 min on the nest before sneaking off the nest and sitting beside it for 151 min. The swan resumed incubating 21 min after the researchers left the area, for a total disturbance duration of 198 min.

#### Reactions to Predators

Ten defensive breaks were recorded on the videos of the Tundra Swan nest that were reactions to an approaching fox. During all 10 encounters, a fox was on or <2 m from the nest mound and the incubating swan stood over the nest, sometimes with wings held open. Each encounter lasted 1–3 recording intervals (~1–3 min) and each time the swan successfully deterred the fox. During 3 of these encounters, the mate to the incubating swan also was on the mound defending the nest from the fox. On one additional occasion a fox was within 5 m of the incubating swan and the swan remained on the nest and hissed at the fox. On 7 other occasions a fox was recorded on the videotape >50 m from the nest and the incubating swan either was alert or showed no reaction.

Seventeen defensive breaks by an incubating swan were observed when no predator was visible on the video tape. During these breaks, the incubating swan and its mate (present during 14 of 17 occurrences) stood at the nest, raised their heads trumpeting in unison (recorded on audio) and performed vertical head bobbing and a quivering-wing display (wings are partially extended and held parallel to the ground and rapidly moved from the wrist). This type of display probably was a territorial response elicited when other swans were near the nest. In 2001, we did not see other swans on the videotape during this behavior, but the view of the sky was restricted in the video picture at this nest. In 1999, this behavior by nesting swans was observed when other geese or swans flew overhead. Other studies of swan nesting behavior also have noted this same territorial behavior when geese or other swans entered the nesting territory (Scott 1977, Cooper 1979). After one additional display, both swans left the nest for 4 recording intervals (~4 min) and this departure was counted as a defense recess.

## CLUTCH SIZE AND NEST FATE

### ALL SPECIES

Despite efforts to find nests without disturbing incubating birds, some were flushed from their nests. For those that were flushed, clutch sizes were recorded and then were covered with down and nest material (only for nests of ducks, geese, and swans) to conceal them from predators. Mean clutch sizes for various duck species ranged from 3 to 8 eggs (Table 19). Mean clutch sizes were average for geese (4 eggs), Tundra Swans (3 eggs), and Willow Ptarmigan (8 eggs). All clutch sizes were within the range of numbers that have been reported in the literature (Baicich and Harrison 1997).

Nest sites of waterfowl in the nest-search area were visited in mid-July 2001 (after hatch) to determine their fate (Table 20). Fates of nests on inaccessible islands were not determined. Of the 17 duck nests found in the project area (including nests found during activities other than the nest search), and for which fate was recorded, only one (6% of all duck nests), belonging to an unidentified scaup, was successful. Failed nests were closer on average to the airstrip (mean = 1,214 m) than was the successful nest (1,962 m). Although we cannot discount that the low productivity of duck nests in 2001 may have been influenced by the proximity of nests to the airstrip, conclusions are limited by the low sample size for successful nests (Table 21).

### GREATER WHITE-FRONTED GOOSE

The mean clutch size of White-fronted Geese in 2001 was 3.9 eggs (Table 19), similar to the values reported in other studies on the Colville Delta (Simpson et al. 1982; Simpson 1983; Smith et al. 1993, 1994; Johnson et al. 2001). In 2001, proximity of nests to the Alpine airstrip did not have a detectable effect on clutch size; distance of nests to the airstrip explained <2% of the variance ( $r^2 = 0.016$ ,  $P = 0.44$ ).

Of 40 White-fronted Goose nests with known fates found throughout the project area in 2001 (including nests found during activities other than the nest search), 25 (62%) hatched, and 15 (38%) failed (Table 20). The distance of successful and failed White-fronted Goose nests to the airstrip did not differ in 2001 ( $P = 0.15$ ; Table 21), although successful nests were slightly closer to the airstrip

Table 19. Mean clutch sizes of nests found during nest searches in the Alpine project area, Colville River Delta, Alaska, 2001.

| Species                     | Clutch size |      |          |
|-----------------------------|-------------|------|----------|
|                             | $\bar{x}$   | SE   | <i>n</i> |
| Red-throated Loon           | 1.5         | 0.41 | 2        |
| Pacific Loon                | 1.5         | 0.22 | 4        |
| Red-necked Grebe            | 1.5         | 1.50 | 2        |
| Greater White-fronted Goose | 3.9         | 0.19 | 40       |
| Brant                       | 3.0         | –    | 1        |
| Tundra Swan                 | 3.0         | 0.46 | 5        |
| Northern Pintail            | 5.0         | 0.58 | 6        |
| Greater Scaup               | 3.0         | –    | 1        |
| Unidentified scaup          | 7.0         | 1.00 | 2        |
| Long-tailed Duck            | 3.0         | 1.41 | 4        |
| Unidentified duck           | 3.0         | –    | 1        |
| Willow Ptarmigan            | 7.8         | 0.65 | 8        |
| Unidentified ptarmigan      | 11.0        | –    | 1        |
| Bar-tailed Godwit           | 4.0         | –    | 1        |
| Parasitic Jaeger            | 2.0         | 0.00 | 2        |
| Long-tailed Jaeger          | 1.0         | –    | 1        |
| Glaucous Gull               | 2.0         | –    | 1        |
| Arctic Tern                 | 1.8         | 0.17 | 6        |
| Total                       |             |      | 87       |

<sup>a</sup> Includes probable nests determined from feather and down samples.

Table 20. The mean distance from the airstrip, and fate of nests of selected species found during the nest search and in the breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 2001. Only nests with known fates were included.

| Species                       | Successful Nests |     |              |     | Failed Nests |     |              |     |
|-------------------------------|------------------|-----|--------------|-----|--------------|-----|--------------|-----|
|                               | No.              | %   | Distance (m) |     | No.          | %   | Distance (m) |     |
|                               |                  |     | $\bar{x}$    | SE  |              |     | $\bar{x}$    | SE  |
| Greater White-fronted Goose   | 25               | 62  | 1,251        | 108 | 15           | 38  | 1,480        | 111 |
| Canada Goose                  | 2                | 100 | 2,355        | 153 | 0            | –   | –            | –   |
| Brant                         | 2                | 100 | 1,271        | 108 | 0            | –   | –            | –   |
| Tundra Swan                   | 5                | 100 | 1,160        | 243 | 0            | –   | –            | –   |
| Northern Pintail <sup>a</sup> | 0                | –   | –            | –   | 7            | 100 | 913          | 301 |
| Greater Scaup                 | 0                | –   | –            | –   | 1            | 100 | 861          | –   |
| Unidentified Scaup            | 1                | 25  | 1,962        | –   | 3            | 75  | 1,455        | 79  |
| Spectacled Eider              | 0                | –   | –            | –   | 1            | 100 | 1,438        | –   |
| Long-tailed Duck <sup>a</sup> | 0                | –   | –            | –   | 3            | 100 | 1,210        | 274 |
| Unidentified duck             | 0                | –   | –            | –   | 1            | 100 | 2,739        | –   |
| All ducks                     | 1                | 6   | 1,962        | –   | 16           | 94  | 1,214        | 178 |
| Bar-tailed Godwit             | 1                | 100 | 1,028        | –   | 0            | –   | –            | –   |
| Glaucous Gull                 | 0                | –   | –            | –   | 1            | 100 | 2,265        | –   |
| Total Nests                   | 36               | 53  | 1,314        | 94  | 32           | 47  | 1,371        | 108 |

<sup>a</sup> Includes probable nests determined from feather and down samples.



Table 21. Comparison of mean distances from the airstrip between fates for duck and Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 2001. Nests were found between 12–29 June during the nest search and in the breeding-bird plots.

| Nest Fate                   | Distance (m) |     | <i>n</i> | Analysis Method          | Statistic<br>( <i>Z</i> or <i>t</i> ) | <i>P</i> -value |
|-----------------------------|--------------|-----|----------|--------------------------|---------------------------------------|-----------------|
|                             | $\bar{x}$    | SE  |          |                          |                                       |                 |
| All Ducks                   |              |     |          |                          |                                       |                 |
| Successful                  | 1,962        | –   | 1        |                          |                                       |                 |
| Failed                      | 1,214        | 177 | 16       | Mann-Whitney             | -1.23                                 | 0.35            |
| Greater White-fronted Goose |              |     |          |                          |                                       |                 |
| Successful                  | 1,251        | 108 | 25       |                          |                                       |                 |
| Failed                      | 1,480        | 111 | 15       | two-sample <i>t</i> test | -1.47                                 | 0.15            |

(mean = 1,251 m) than failed nests (1,480 m), suggesting that proximity to the airstrip did not affect nesting success negatively.

#### TUNDRA SWAN

Clutch sizes of Tundra Swan nests averaged 3.0 eggs ( $n = 5$  nests) in 2001 (Table 19), within the range of sizes found in previous years (Johnson et al. 2001). Because both sample size and the range of clutch sizes were small, relationships between clutch size and distance to the airstrip were not tested.

In 2001, all 5 Tundra Swan nests in Alpine project area were successful, and they averaged 1,160 m (range 442–1,944 m) from the airstrip (Table 20). Because all nests were successful in 2001, the effect of proximity to the airstrip on swan nesting success could not be tested. The closest nest to the airstrip was 243 m from the infield road and 28 m from the flight path, yet it still hatched successfully.

#### BROOD-REARING

A specific survey for broods of large waterbirds was not conducted in the Alpine project area during 2001. Broods were recorded opportunistically during nest-fate checks in early July and during a ground search for loon broods in August. Sixty-six broods belonging to 9 species were recorded around the Alpine project area (Figure 12). The broods seen included those of Red-throated Loon, Pacific Loon, White-fronted Goose, Brant, Tundra Swan, Northern Pintail, Green-winged Teal, Willow Ptarmigan, and

Glaucous Gull. The most numerous broods were those of White-fronted Geese (43 broods), although Brant and swans were also relatively abundant (8 and 7 broods, respectively).

#### BREEDING-BIRD PLOTS

The distribution and abundance of nests of all species were recorded on breeding-bird plots distributed along distance gradients from the Alpine airstrip. The plots were designed to estimate nest numbers primarily of shorebirds and passerines so that the effects of disturbance from the Alpine airstrip could be evaluated for these important members of the avian community. In 2001, 169 nests belonging to 15 species of birds were found on the 12 breeding-bird plots sampled since 1998 (Table 22). The predominant nesting species in 2001 were Pectoral Sandpiper (42 nests, 25% of all nests), Lapland Longspur (38 nests, 22%), Semipalmated Sandpiper (28 nests, 17%), Red-necked Phalarope (14 nests, 8%), and White-fronted Goose (9 nests, 5%). The total number of nests per plot ranged from 7 to 21 (70–210 nests/km<sup>2</sup>) and averaged 14.1 nests (140.8 nests/km<sup>2</sup>).

Comparisons between treatment ( $\leq 1,500$  m from the airstrip) and reference ( $> 1,500$  m from the airstrip) plots were conducted to evaluate whether proximity to the airstrip affected nest densities. More nests were found in 2001 on treatment plots (mean = 12.8 nests) near the airstrip than on reference plots (mean = 9.0 nests) away from the airstrip, although the difference was not significant

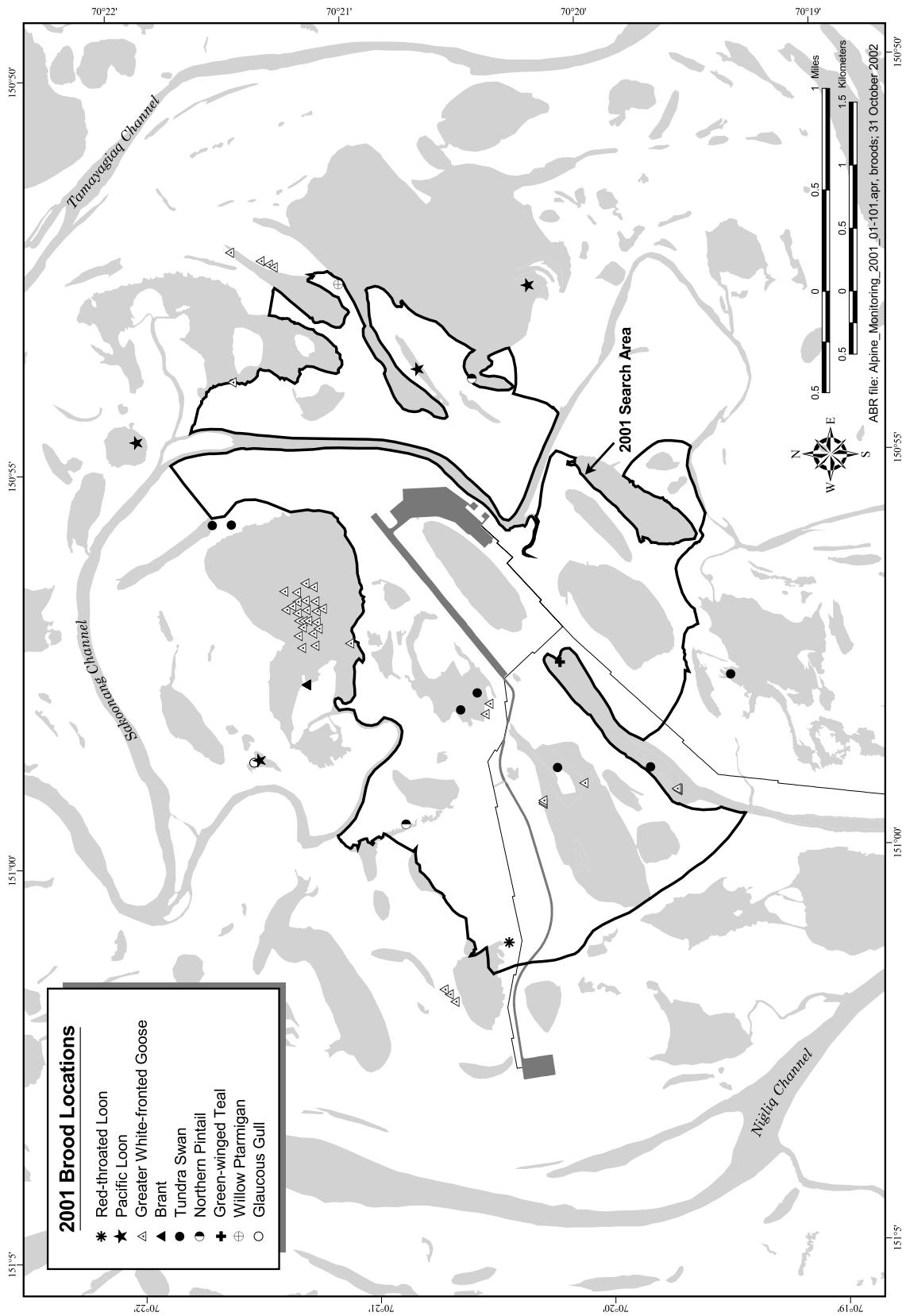


Figure 12. Locations of broods found incidentally during nest-fate checks in the Alpine project area, Colville River Delta, Alaska, 2001.

Table 22. Numbers and densities of nests found on 10-ha (0.1km<sup>2</sup>) breeding-bird plots in the Alpine project area, Colville River Delta, Alaska, 2001. Plots  $\leq 1,500$  m from the airstrip were classified as treatment plots and those  $> 1,500$  m were classified as reference plots.

| Species                          | Treatment Plot Number |     |    |     |     |     |     |     |    |     | Reference Plot Number |     |       |      | Total Nests | Mean Density (nests/km <sup>2</sup> ) |
|----------------------------------|-----------------------|-----|----|-----|-----|-----|-----|-----|----|-----|-----------------------|-----|-------|------|-------------|---------------------------------------|
|                                  | 1                     | 2   | 3  | 4   | 5   | 6   | 7   | 8   | 9  | 10  | 11                    | 12  |       |      |             |                                       |
| Greater White-fronted Goose      | 0                     | 0   | 1  | 0   | 0   | 3   | 3   | 2   | 0  | 0   | 0                     | 0   | 0     | 9    | 7.5         |                                       |
| Unidentified duck                | 0                     | 0   | 0  | 0   | 0   | 0   | 1   | 0   | 0  | 0   | 1                     | 0   | 0     | 2    | 1.7         |                                       |
| Willow Ptarmigan                 | 1                     | 0   | 0  | 0   | 0   | 0   | 0   | 0   | 0  | 1   | 1                     | 0   | 0     | 3    | 2.5         |                                       |
| American Golden Plover           | 1                     | 0   | 0  | 0   | 0   | 0   | 0   | 0   | 0  | 1   | 0                     | 0   | 0     | 2    | 1.7         |                                       |
| Bar-tailed Godwit                | 0                     | 0   | 0  | 0   | 1   | 0   | 0   | 0   | 0  | 0   | 0                     | 0   | 0     | 1    | 0.8         |                                       |
| Semipalmated Sandpiper           | 3                     | 6   | 2  | 2   | 5   | 3   | 1   | 2   | 0  | 1   | 1                     | 2   | 28    | 23.3 |             |                                       |
| Pectoral Sandpiper               | 3                     | 4   | 1  | 3   | 5   | 5   | 6   | 0   | 4  | 5   | 1                     | 5   | 42    | 35.0 |             |                                       |
| Dunlin                           | 1                     | 0   | 0  | 2   | 0   | 0   | 0   | 0   | 0  | 0   | 0                     | 0   | 3     | 2.5  |             |                                       |
| Stilt Sandpiper                  | 0                     | 0   | 0  | 1   | 0   | 0   | 1   | 0   | 0  | 0   | 0                     | 0   | 2     | 1.7  |             |                                       |
| Long-billed Dowitcher            | 0                     | 3   | 0  | 1   | 1   | 0   | 1   | 0   | 1  | 0   | 0                     | 1   | 8     | 6.7  |             |                                       |
| Red-necked Phalarope             | 1                     | 0   | 0  | 1   | 3   | 2   | 2   | 1   | 0  | 1   | 3                     | 0   | 14    | 11.7 |             |                                       |
| Red Phalarope                    | 1                     | 1   | 0  | 1   | 0   | 1   | 3   | 1   | 1  | 0   | 0                     | 0   | 9     | 7.5  |             |                                       |
| Yellow Wagtail                   | 3                     | 1   | 0  | 0   | 2   | 0   | 0   | 1   | 0  | 0   | 0                     | 0   | 7     | 5.8  |             |                                       |
| Savannah Sparrow                 | 0                     | 0   | 0  | 0   | 0   | 0   | 0   | 1   | 0  | 0   | 0                     | 0   | 1     | 0.8  |             |                                       |
| Lapland Longspur                 | 3                     | 3   | 4  | 4   | 4   | 6   | 3   | 3   | 1  | 1   | 2                     | 4   | 38    | 31.7 |             |                                       |
| Total Nests                      | 17                    | 18  | 8  | 15  | 21  | 20  | 21  | 11  | 7  | 10  | 9                     | 12  | 169   |      |             |                                       |
| Density (nests/km <sup>2</sup> ) | 170                   | 180 | 80 | 150 | 210 | 200 | 210 | 110 | 70 | 100 | 90                    | 120 | 140.8 |      |             |                                       |
| Number of Species                | 9                     | 6   | 4  | 8   | 7   | 6   | 9   | 7   | 4  | 6   | 6                     | 4   | 15    |      |             |                                       |

( $P = 0.12$ ; Table 23). Examination of the 5 most common species indicated no significant differences in number of nests between treatment and reference plots for White-fronted Goose, Pectoral Sandpiper and Red-necked Phalarope during 2001 ( $P \geq 0.8$ ). Only White-fronted Geese had more nests on reference plots (mean = 0.8 nests) than on treatment plots (mean = 0.7 nests). Significantly more Semipalmated Sandpiper and Lapland Longspur nests were found on treatment plots during 2001 ( $P \leq 0.03$ ). Among the 3 species groups (i.e., shorebirds, passerines, waterfowl), passerine nests also were significantly more abundant on treatment plots than reference plots during 2001 ( $P = 0.02$ ). Overall, comparisons between treatment and reference plots in 2001 indicated that higher densities of nests were found on plots close to the airstrip and did not suggest that disturbance from the airstrip had a negative effect on nest densities.

Similar relationships are inferred from regressions of the distance of plots from the airstrip on nest numbers. The number of Semipalmated Sandpiper nests in 2001 decreased with increasing distance of plots from the airstrip ( $P = 0.04$ ; Table 24). The number of nests per plot among the remaining 4 most common species—Pectoral Sandpiper, Red-necked Phalarope, Lapland Longspur, and White-fronted Goose—did not appear to be related to distance of plots from the airstrip ( $P \geq 0.2$ ). Among the species groups, only the number of waterfowl nests increased as a function of distance from the airstrip, although the relationship was not significant ( $P = 0.70$ ). The remaining groups all had declining nest numbers with increasing distance to the airstrip, but the relationship was significant only for passerines ( $P = 0.05$ ).

#### HABITAT ASSOCIATIONS

Habitat associations for nests on the breeding-bird plots were evaluated along with distance of nests to the airstrip to identify factors affecting nest distribution. Logistic regression models for 2001 demonstrated some common tendencies for bird-habitat associations on the breeding-bird plots (Table 25). Moist sedge shrub and water depth were the most common habitat variables, entering 4 of 9 models with odds ratios  $>1.0$ . Wet sedge willow and surface relief were

significant explanatory variables in 2 models each; wet sedge willow also had an odds ratio  $>1.0$ , but surface relief was  $<1.0$ . Distance to the airstrip was included in 2 final models, with the probability of nest occurrence being greater in the 3 distance categories closest to the airstrip versus the category farthest away, confirming the relationships presented above.

Models suggested that the probability of occurrence for nests of both White-fronted Geese and all waterfowl increased with increasing water depth within grids (odds ratio = 1.03 for both; Table 25). The occurrence of White-fronted Goose nests decreased with increasing surface relief (odds ratio = 0.965). Although both models were significant ( $P \leq 0.014$ ), low statistical power associated with the rarity of nests (9 goose nests and 11 waterfowl nests) relative to the large number of grids (480 grids) that were intensively searched probably explains the poor predictive ability of the models. For example, the waterfowl model correctly predicted 100% of the grids where no nests occurred but predicted none of the grids where nests did occur.

Logistic models for the occurrence of all shorebird and Semipalmated Sandpiper nests included distance to the airstrip as an explanatory variable (Table 25). Consistent with results from regression analyses above, all (6 of 6) of the odds ratios for distance categories closest to the airstrip (i.e., 0–780 m, 781–1,430 m, and 1,431–2,412 m) were  $>1.0$ , suggesting that the probabilities of nest occurrence for all shorebirds combined and for Semipalmated Sandpipers were higher in the distance categories closest to the airstrip versus the category farthest away (i.e.,  $>2,412$  m). The probability of nest occurrence was greatest between 0 and 780 m from the airstrip for all shorebirds combined and for Semipalmated Sandpipers. Distance did not enter the model for the occurrence of Pectoral Sandpiper nests. Pectoral Sandpiper and all shorebird nest occurrences were positively related to 2 vegetation types—wet sedge willow and moist sedge shrub. Surface relief entered into the model for all shorebird nests, but the odds ratio was  $<1.0$ , indicating that the probability of nests decreased with increasing relief. Semipalmated Sandpiper nests were the only nests associated with water cover; the odds ratio for percent water was  $<1.0$ ,

Table 23. Two-sample t tests of mean numbers of nests of the most prevalent species on treatment ( $\leq 1,500$  m of airstrip,  $n = 6$ ) and reference ( $> 1,500$  m of airstrip,  $n = 6$ ) breeding-bird plots in the Alpine project area, Colville River Delta, Alaska, 2001. Degrees of freedom for all tests were 10.

| Species/Species Group       | Treatment |     | Reference |     | <i>t</i> | <i>P</i> -value |
|-----------------------------|-----------|-----|-----------|-----|----------|-----------------|
|                             | $\bar{x}$ | SD  | $\bar{x}$ | SD  |          |                 |
| Greater White-fronted Goose | 0.7       | 1.2 | 0.8       | 1.3 | -0.23    | 0.82            |
| Pectoral Sandpiper          | 3.5       | 1.5 | 3.5       | 2.4 | <0.01    | >0.99           |
| Semipalmated Sandpiper      | 3.5       | 1.6 | 1.2       | 0.7 | 3.16     | 0.01            |
| Lapland Longspur            | 4.0       | 1.1 | 2.3       | 1.2 | 2.50     | 0.03            |
| Red-necked Phalarope        | 1.2       | 1.2 | 1.2       | 1.2 | <0.01    | >0.99           |
| Shorebirds                  | 10.7      | 4.2 | 7.5       | 3.6 | 1.09     | 0.30            |
| Passerines                  | 5.0       | 1.1 | 2.7       | 1.6 | 2.89     | 0.02            |
| Waterfowl                   | 0.7       | 1.2 | 1.2       | 1.6 | -0.61    | 0.56            |
| Total Nests                 | 12.8      | 4.4 | 9.0       | 3.5 | 1.68     | 0.12            |

suggesting that Semipalmated Sandpiper nests were less likely to be found in areas with increasing amounts of water. Water depth was a significant predictor of nest occurrence for both Red-necked and Red phalaropes with odds ratios  $> 1.0$  indicating increasing probabilities of nest occurrence with increasing water depths.

As with shorebirds, the probability of occurrence for all passerine nests and Lapland Longspur nests had a positive association with increased moist sedge shrub cover (odds ratio = 1.02 for both; Table 25). No other habitat variable entered into the models for these 2 taxa. Because the habitat models for each taxon have varied among years (Johnson et al. 2001b) and have had poor classification abilities due to imbalances in the number of nests to sample units, final results and interpretations will be made using the data collected over 4 years pooled together (see Part II).

### SEASONAL USE OF LAKES

Previous sections summarized information for nesting and brood-rearing birds in the Alpine project area. A large component of the avian community in the project area, however, use the area prior to and after breeding, or may have failed to nest altogether, but nonetheless use the lakes in the area for resting, feeding, molting, and

brood-rearing. In this section we present the results of repeated aerial surveys designed to quantify the use by non-nesting birds of lakes in the Alpine project area. Counts from these surveys are used in multi-year analyses of disturbance effects on the distribution and abundance of birds using lakes in Part II of this report.

In 2001, 21 species of large waterbirds were identified during 9 aerial surveys of lakes in the Alpine project area (Table 26). Geese were the most numerous birds observed (45% of the total) and ducks were second in number (29% of the total). The most abundant geese were White-fronted Geese, accounting for 92% of all goose sightings. The most commonly occurring ducks were Northern Pintail (65% of all ducks) and scaup (17%).

During 2001, 4,897 waterbirds were recorded in the survey area (9 surveys combined; Table 26). Waterbirds using the lakes in the Alpine project area were most numerous in late June and early and late August and least numerous in early to mid-June. The highest counts of birds occurred when aggregations of ducks and geese occupied tapped basins (Tapped Lake with Low-water Connection and associated lakes in basins that have drained; Figure 5, Table 27). In August, large numbers of molting and brood-rearing waterfowl foraged in tapped basins.

Table 24 Simple linear regression models of number of nests per breeding-bird plot on distance to the airstrip for the 5 most abundant species in the Alpine project area, Colville River Delta, Alaska, 2001.

| Species or Species Group/<br>model parameters | Regression Coefficients |        |       |        | Model Statistics |       |       |       |
|---|-------------------------|--------|-------|--------|------------------|-------|-------|-------|
|   | $\beta$                 | SE     | $t$   | $P$    | $F$              | df    | $P$   | $R^2$ |
| Greater White-fronted Goose (rank)            |                         |        |       |        |                  |       |       |       |
| Constant                                      | 6.526                   | 1.822  | 3.58  | 0.005  | 0.00             | 1, 10 | 0.987 | 0.00  |
| Distance to Airstrip                          | >-0.001                 | 0.001  | -0.02 | 0.987  |                  |       |       |       |
| Pectoral Sandpiper (log transform)            |                         |        |       |        |                  |       |       |       |
| Constant                                      | 2.587                   | 0.091  | 28.38 | <0.001 | 0.01             | 1, 10 | 0.944 | 0.00  |
| Distance to Airstrip                          | <0.001                  | <0.001 | 0.07  | 0.944  |                  |       |       |       |
| Semipalmated Sandpiper (reciprocal transform) |                         |        |       |        |                  |       |       |       |
| Constant                                      | 0.113                   | 0.015  | 7.67  | <0.001 | 5.43             | 1, 10 | 0.042 | 0.35  |
| Distance to Airstrip                          | <0.001                  | <0.001 | 2.33  | 0.042  |                  |       |       |       |
| Lapland Longspur                              |                         |        |       |        |                  |       |       |       |
| Constant                                      | 3.868                   | 0.806  | 4.80  | <0.001 | 1.01             | 1, 10 | 0.338 | 0.09  |
| Distance to Airstrip                          | >-0.001                 | <0.001 | -1.01 | 0.338  |                  |       |       |       |
| Red-necked Phalarope                          |                         |        |       |        |                  |       |       |       |
| Constant                                      | 0.996                   | 0.669  | 1.49  | 0.167  | 0.09             | 1, 10 | 0.775 | 0.01  |
| Distance to Airstrip                          | <0.001                  | <0.001 | 0.29  | 0.775  |                  |       |       |       |
| Waterfowl                                     |                         |        |       |        |                  |       |       |       |
| Constant                                      | 0.634                   | 0.825  | 0.77  | 0.460  | 0.16             | 1, 10 | 0.700 | 0.01  |
| Distance to Airstrip                          | <0.001                  | <0.001 | 0.40  | 0.700  |                  |       |       |       |
| Shorebirds (log transform)                    |                         |        |       |        |                  |       |       |       |
| Constant                                      | 2.400                   | 0.295  | 8.13  | <0.001 | 1.43             | 1, 10 | 0.259 | 0.12  |
| Distance to Airstrip                          | >-0.001                 | <0.001 | 0.29  | 0.259  |                  |       |       |       |
| Passerines (log transform)                    |                         |        |       |        |                  |       |       |       |
| Constant                                      | 2.747                   | 0.066  | 41.56 | <0.001 | 5.05             | 1, 10 | 0.048 | 0.34  |
| Distance to Airstrip                          | >-0.001                 | <0.001 | -2.25 | 0.048  |                  |       |       |       |
| All Avian Species Detected (log transform)    |                         |        |       |        |                  |       |       |       |
| Constant                                      | 2.899                   | 0.212  | 13.69 | <0.001 | 3.28             | 1, 10 | 0.100 | 0.25  |
| Distance to Airstrip                          | >-0.001                 | <0.001 | -1.81 | 0.100  |                  |       |       |       |

Most of the lakes 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 (Figure 5, Table 27). Relatively few nests were found on the shorelines of the basins that were searched (Figure 8); rather, they seem to be used primarily for loafing 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 28). As in the previous 3 years, tapped basins were important to waterbirds throughout summer 2001; the percentage of all birds found in these tapped basins ranged from 24% (84 of 352 waterbirds on 21 June) to 84% (603 of 720 waterbirds on 26 August). When the results of all 9 aerial surveys are pooled, 67% of all waterbirds were observed in tapped basins (Table 28).

As expected, the amount of use by waterbirds varied widely among lakes, ranging from only 4 birds on lake T6.3 over all 9 surveys, to 1,589 birds on lake V5.1 (Table 28). The lakes receiving the

Table 25. Logistic regression models for predicting the occurrence of nest sites of the most common nesting birds on 480 grids (50-m × 50-m) within 12 plots (10 ha each) in the Alpine project area, Colville River Delta, Alaska, 2001. Explanatory variables included characteristics of vegetation and physiography. Variables were chosen with forward stepwise procedures (see text).

| Variable Type   | Variable                | $\beta$ | SE    | Wald   | df | P-value | Odds Ratio<br>(Exp[ $\beta$ ]) |
|---|-------------------------|---------|-------|--------|----|---------|--------------------------------|
| <b>Greater White-fronted Goose, 9 grids with <math>\geq 1</math> nest. [<math>LR^a = 8.537, 2 \text{ df}, P = 0.014</math>]</b> |                         |         |       |        |    |         |                                |
| Topography  | Surface Relief (cm)     | -0.035  | 0.020 | 3.034  | 1  | 0.082   | 0.965                          |
| Water   | Depth (cm)              | 0.028   | 0.011 | 6.158  | 1  | 0.013   | 1.028                          |
| Constant  |                         | -4.894  | 0.594 | 67.838 | 1  | <0.001  |                                |
| <b>Pectoral Sandpiper, 41 grids with <math>\geq 1</math> nest. [<math>LR^a = 5.944, 2 \text{ df}, P = 0.051</math>]</b>         |                         |         |       |        |    |         |                                |
| Vegetation Cover  | Moist Sedge Shrub (%)   | 0.024   | 0.010 | 5.415  | 1  | 0.020   | 1.024                          |
|   | Wet Sedge Willow (%)    | 0.018   | 0.011 | 2.719  | 1  | 0.100   | 1.019                          |
| Constant  |                         | -3.498  | 0.519 | 45.501 | 1  | <0.001  |                                |
| <b>Semipalmated Sandpiper, 28 grids with <math>\geq 1</math> nest. [<math>LR^a = 14.526, 4 \text{ df}, P = 0.006</math>]</b>    |                         |         |       |        |    |         |                                |
| Distance  | Airstrip (m)            |         |       | 8.359  | 3  | 0.039   |                                |
|   | 0–780                   | 1.447   | 0.593 | 5.963  | 1  | 0.015   | 4.251                          |
|   | 781–1,430               | 0.757   | 0.648 | 1.363  | 1  | 0.243   | 2.132                          |
|   | 1,431–2,412             | 0.218   | 0.738 | 0.087  | 1  | 0.768   | 1.244                          |
|   | >2,412 <sup>b</sup>     | 0       |       |        |    |         |                                |
| Water   | Cover (%)               | -0.042  | 0.021 | 4.121  | 1  | 0.042   | 0.958                          |
| Constant  |                         | -3.069  | 0.520 | 34.894 | 1  | <0.001  |                                |
| <b>Red-necked Phalarope, 14 grids with <math>\geq 1</math> nest. [<math>LR^a = 8.047, 1 \text{ df}, P = 0.005</math>]</b>       |                         |         |       |        |    |         |                                |
| Water   | Depth (cm)              | 0.028   | 0.009 | 9.117  | 1  | 0.003   | 1.029                          |
| Constant  |                         | -4.440  | 0.481 | 85.322 | 1  | <0.001  |                                |
| <b>Red Phalarope, 9 grids with <math>\geq 1</math> nest. [<math>LR^a = 7.870, 2 \text{ df}, P = 0.020</math>]</b>               |                         |         |       |        |    |         |                                |
| Water   | Depth (cm)              | 0.021   | 0.013 | 2.691  | 1  | 0.101   | 1.021                          |
| Vegetation Cover  | Partially Vegetated (%) | 0.438   | 0.142 | 9.503  | 1  | 0.002   | 1.549                          |
| Constant  |                         | -4.731  | 0.599 | 62.477 | 1  | <0.001  |                                |
| <b>Lapland Longspur, 38 grids with <math>\geq 1</math> nest. [<math>LR^a = 2.383, 1 \text{ df}, P = 0.123</math>]</b>           |                         |         |       |        |    |         |                                |
| Vegetation Cover  | Moist Sedge Shrub (%)   | 0.015   | 0.010 | 2.463  |    | 0.116   | 1.015                          |
| Constant  |                         | -2.932  | 0.364 | 64.778 | 1  | <0.001  |                                |
| <b>Waterfowl, 11 grids with <math>\geq 1</math> nest. [<math>LR^a = 7.260, 1 \text{ df}, P = 0.007</math>]</b>                  |                         |         |       |        |    |         |                                |
| Water   | Depth (cm)              | 0.030   | 0.010 | 8.316  | 1  | 0.004   | 1.030                          |
| Constant  |                         | -4.756  | 0.547 | 75.621 | 1  | <0.001  |                                |
| <b>Shorebirds, 101 grids with <math>\geq 1</math> nest. [<math>LR^a = 13.369, 6 \text{ df}, P = 0.038</math>]</b>               |                         |         |       |        |    |         |                                |
| Distance  | Airstrip (m)            |         |       | 5.682  | 3  | 0.128   |                                |
|   | 0–780                   | 0.716   | 0.332 | 4.661  | 1  | 0.031   | 2.046                          |
|   | 781–1,430               | 0.224   | 0.350 | 0.410  | 1  | 0.522   | 1.251                          |
|   | 1,431–2,412             | 0.176   | 0.343 | 0.263  | 1  | 0.608   | 1.192                          |
|   | >2,412 <sup>b</sup>     | 0       |       |        |    |         |                                |
| Vegetation Cover  | Wet Sedge Willow (%)    | 0.012   | 0.008 | 2.307  | 1  | 0.129   | 1.013                          |
|   | Moist Sedge Shrub (%)   | 0.020   | 0.008 | 6.524  | 1  | 0.010   | 1.020                          |
| Topography  | Surface Relief (cm)     | -0.012  | 0.008 | 2.510  | 1  | 0.113   | 0.988                          |
| Constant  |                         | -1.886  | 0.522 | 13.069 | 1  | <0.001  |                                |
| <b>Passerines, 45 grids with <math>\geq 1</math> nest. [<math>LR^a = 5.856, 1 \text{ df}, P = 0.016</math>]</b>                 |                         |         |       |        |    |         |                                |
| Vegetation Cover  | Moist Sedge Shrub (%)   | 0.022   | 0.009 | 6.050  |    | 0.014   | 1.022                          |
| Constant  |                         | -2.972  | 0.346 | 73.622 | 1  | <0.001  | 0.051                          |

<sup>a</sup>  $LR$  = likelihood ratio statistic, tests the null hypothesis that all coefficients in the final model except the constant are 0.

<sup>b</sup> No coefficients calculated for the reference category; this is the category against which all other categories are compared with the indicator contrast method and, therefore, has an odds ratio of 1.0.

Table 26. Numbers of waterbirds and species groups observed during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 2001.

| Species/Species Group       | Survey Dates |     |     |      |     |     |        |     |     | Total |
|-----------------------------|--------------|-----|-----|------|-----|-----|--------|-----|-----|-------|
|                             | June         |     |     | July |     |     | August |     |     |       |
|                             | 14           | 21  | 30  | 9    | 16  | 26  | 5      | 20  | 26  |       |
| Pacific Loon                | 55           | 52  | 45  | 47   | 31  | 23  | 34     | 50  | 32  | 369   |
| Red-throated Loon           | 10           | 2   | 2   | 2    | 2   | 4   | 9      | 4   | 3   | 38    |
| Yellow-billed Loon          | 9            | 9   | 9   | 9    | 7   | 6   | 10     | 7   | 11  | 77    |
| Red-necked Grebe            | 1            | 2   | 6   | 6    | 5   | 1   | 7      | 5   | 0   | 33    |
| Greater White-fronted Goose | 14           | 32  | 110 | 107  | 194 | 428 | 590    | 250 | 319 | 2,044 |
| Brant                       | 2            | 3   | 0   | 20   | 0   | 0   | 0      | 0   | 9   | 34    |
| Canada Goose                | 2            | 4   | 4   | 2    | 77  | 0   | 0      | 40  | 18  | 147   |
| Tundra Swan                 | 13           | 22  | 28  | 25   | 52  | 35  | 44     | 48  | 54  | 321   |
| American Wigeon             | 0            | 8   | 4   | 27   | 2   | 0   | 0      | 7   | 11  | 59    |
| Northern Shoveler           | 0            | 2   | 4   | 1    | 0   | 0   | 0      | 0   | 0   | 7     |
| Northern Pintail            | 9            | 75  | 324 | 113  | 110 | 25  | 20     | 59  | 207 | 942   |
| Green-winged Teal           | 0            | 3   | 0   | 0    | 0   | 0   | 0      | 0   | 0   | 3     |
| Greater Scaup               | 0            | 53  | 30  | 0    | 16  | 0   | 0      | 0   | 21  | 120   |
| Unidentified scaup          | 36           | 0   | 0   | 33   | 0   | 8   | 13     | 39  | 0   | 129   |
| Surf Scoter                 | 0            | 0   | 0   | 0    | 0   | 0   | 0      | 0   | 1   | 1     |
| Long-tailed Duck            | 35           | 55  | 20  | 25   | 6   | 0   | 0      | 7   | 13  | 161   |
| Red-breasted Merganser      | 0            | 2   | 4   | 2    | 0   | 5   | 0      | 1   | 0   | 14    |
| Unidentified duck           | 0            | 0   | 0   | 0    | 0   | 0   | 0      | 0   | 3   | 3     |
| Sandhill Crane              | 0            | 0   | 3   | 0    | 2   | 3   | 0      | 0   | 4   | 12    |
| Parasitic Jaeger            | 0            | 3   | 0   | 0    | 0   | 0   | 0      | 0   | 0   | 3     |
| Glaucous Gull               | 20           | 1   | 5   | 8    | 5   | 4   | 3      | 6   | 14  | 66    |
| Sabine's Gull               | 1            | 1   | 6   | 0    | 0   | 0   | 0      | 0   | 0   | 8     |
| Arctic Tern                 | 9            | 23  | 127 | 40   | 107 | 0   | 0      | 0   | 0   | 306   |
| Loons, Grebes               | 75           | 65  | 62  | 64   | 45  | 34  | 60     | 66  | 46  | 517   |
| Geese                       | 18           | 39  | 114 | 129  | 271 | 428 | 590    | 290 | 346 | 2,225 |
| Swans                       | 13           | 22  | 28  | 25   | 52  | 35  | 44     | 48  | 54  | 321   |
| Ducks                       | 80           | 198 | 386 | 201  | 134 | 38  | 33     | 113 | 256 | 1,439 |
| Cranes                      | 0            | 0   | 3   | 0    | 2   | 3   | 0      | 0   | 4   | 12    |
| Gulls, Terns, Jaegers       | 30           | 28  | 138 | 48   | 112 | 4   | 3      | 6   | 14  | 383   |
| Total Birds                 | 216          | 352 | 731 | 467  | 616 | 542 | 730    | 523 | 720 | 4,897 |
| Total Species               | 14           | 19  | 17  | 16   | 14  | 11  | 9      | 13  | 14  | 21    |



Table 27. Mean number of waterbirds in tapped basins (tapped lakes and associated lakes in the same basin) and other types of lakes recorded during 9 aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 2001. Sample size equals number of surveys.

| Species                     | June (n = 3) |       | July (n = 3) |       | August (n = 3) |       |
|-----------------------------|--------------|-------|--------------|-------|----------------|-------|
|                             | Basin        | Other | Basin        | Other | Basin          | Other |
| Pacific Loon                | 15.3         | 35.3  | 5.3          | 28.3  | 12.3           | 26.3  |
| Red-throated Loon           | 3.3          | 1.3   | 2.3          | 0.3   | 4.3            | 1.0   |
| Yellow-billed Loon          | 1.0          | 8.0   | 0.3          | 7.0   | 0.7            | 8.7   |
| Red-necked Grebe            | 0            | 3.0   | 0            | 4.0   | 0              | 4.0   |
| Greater White-fronted Goose | 42.3         | 9.7   | 220.3        | 22.7  | 300.7          | 85.7  |
| Brant                       | 0            | 1.7   | 6.0          | 0.7   | 3.0            | 0     |
| Canada Goose                | 1.3          | 2.0   | 24.3         | 2.0   | 19.3           | 0     |
| Tundra Swan                 | 10.7         | 10.3  | 13.0         | 24.3  | 27.0           | 21.7  |
| American Wigeon             | 2.0          | 2.0   | 9.0          | 0.7   | 2.3            | 3.7   |
| Northern Shoveler           | 1.3          | 0.7   | 0            | 0.3   | 0              | 0     |
| Northern Pintail            | 100.7        | 35.3  | 64.0         | 18.7  | 89.3           | 6.0   |
| Green-winged Teal           | 0            | 1.0   | 0            | 0     | 0              | 0     |
| Greater Scaup               | 10.7         | 17.0  | 3.3          | 2.0   | 5.0            | 2.0   |
| Unidentified scaup          | 1.0          | 11.0  | 9.0          | 4.7   | 7.7            | 9.7   |
| Surf Scoter                 | 0            | 0     | 0            | 0     | 0              | 0.3   |
| Long-tailed Duck            | 9.3          | 27.3  | 4.7          | 5.7   | 2.7            | 4.0   |
| Red-breasted Merganser      | 0.7          | 1.3   | 2.0          | 0.3   | 0              | 0.3   |
| Unidentified duck           | 0            | 0     | 0            | 0     | 1.0            | 0     |
| Sandhill Crane              | 0            | 1.0   | 0            | 1.7   | 0              | 1.3   |
| Parasitic Jaeger            | 0            | 1.0   | 0            | 0     | 0              | 0     |
| Glaucous Gull               | 8.0          | 0.7   | 4.3          | 1.3   | 6.7            | 1.0   |
| Sabine's Gull               | 2.3          | 0.3   | 0            | 0     | 0              | 0     |
| Arctic Tern                 | 24.0         | 29.0  | 13.7         | 35.3  | 0              | 0     |
| Total Birds                 | 234.0        | 199.0 | 381.7        | 160   | 482.0          | 175.7 |
| Total Species               | 15           | 20    | 14           | 17    | 12             | 14    |

greatest activity—S6.1, S7.2, U4.1, U5.1, and V5.1—were each used by >400 birds over all surveys combined (Table 28). Of these lakes, the only one that is not a Tapped Lake with Low-water Connection is lake U5.1, which is classified as a Deep Open Lake without Islands. The margins of this lake are composed of extensive areas of Aquatic Grass Marsh (Figures 2 and 5). In many years, lake U5.1 was almost totally inundated by snow melt early in spring, and was one of the first of the non-tapped lakes to lose its ice cover. In 2000 and 2001, U5.1 was inundated by flood

waters from river breakup. Over all 9 aerial surveys, 32% of the total waterbirds in lakes other than tapped basins occurred in U5.1. Lake U5.1 appears to be used by various species of waterfowl foraging during June. Throughout the rest of the summer this lake probably is used by locally nesting and brood-rearing species (e.g., Red-necked Grebe, Pacific Loon, Tundra Swan, Greater Scaup).

A series of connected lakes, the T7.2 complex, accounted for a major proportion of the birds in the project area (Figure 5). Approximately

Table 28. Number of waterbirds recorded during 9 aerial surveys of lakes (by lake number) in the Alpine project area, Colville River Delta, Alaska, 2001. See Figure 5 for lake identification and location.

| Species                     | R6.1 | R7.1 | S6.1 <sup>a</sup> | S6.2 | S7.1 | S7.2 <sup>b</sup> | S7.3 | S7.4 | T4.1 | T4.2 | T4.3 | T4.4 | T4.5 | T4.6 | T5.1 | T5.2 | T5.3 | T5.4 | T5.5 <sup>a</sup> | T5.6 <sup>a</sup> |
|-----------------------------|------|------|-------------------|------|------|-------------------|------|------|------|------|------|------|------|------|------|------|------|------|-------------------|-------------------|
| Pacific Loon                | 10   | 9    | 5                 | 4    | 7    | 14                | 6    | 1    | 10   | 7    | 9    | 5    | 3    | 7    | 41   | 8    | 7    | 3    | 14                | 1                 |
| Red-throated Loon           | 0    | 0    | 8                 | 0    | 0    | 2                 | 0    | 0    | 0    | 3    | 0    | 0    | 0    | 0    | 2    | 0    | 0    | 0    | 0                 | 0                 |
| Yellow-billed Loon          | 0    | 0    | 1                 | 0    | 0    | 1                 | 0    | 0    | 0    | 4    | 0    | 1    | 1    | 0    | 0    | 0    | 1    | 0    | 0                 | 0                 |
| Red-necked Grebe            | 0    | 0    | 0                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 18   | 0    | 0    | 0    | 0                 | 0                 |
| Greater White-fronted Goose | 22   | 0    | 317               | 0    | 32   | 196               | 3    | 38   | 6    | 8    | 36   | 2    | 1    | 28   | 0    | 4    | 5    | 0    | 141               | 15                |
| Brant                       | 0    | 0    | 27                | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 3    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Canada Goose                | 0    | 0    | 132               | 0    | 0    | 0                 | 0    | 0    | 0    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Tundra Swan                 | 21   | 0    | 8                 | 15   | 8    | 26                | 0    | 0    | 4    | 2    | 4    | 0    | 3    | 0    | 21   | 2    | 4    | 2    | 19                | 0                 |
| American Wigeon             | 0    | 0    | 2                 | 0    | 0    | 1                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 20                | 0                 |
| Northern Shoveler           | 0    | 0    | 0                 | 0    | 0    | 4                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Northern Pintail            | 7    | 0    | 31                | 1    | 15   | 137               | 0    | 0    | 0    | 0    | 12   | 1    | 0    | 0    | 0    | 2    | 0    | 0    | 32                | 48                |
| Green-winged Teal           | 0    | 0    | 0                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0                 | 0                 |
| Greater Scaup               | 0    | 0    | 0                 | 0    | 0    | 2                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2    | 9    | 0    | 0    | 0    | 8                 | 2                 |
| Unidentified scaup          | 0    | 0    | 0                 | 0    | 0    | 6                 | 2    | 0    | 0    | 0    | 0    | 0    | 1    | 1    | 5    | 0    | 0    | 0    | 14                | 0                 |
| Surf Scoter                 | 0    | 0    | 0                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0    | 0                 | 0                 |
| Long-tailed Duck            | 12   | 0    | 6                 | 5    | 8    | 17                | 0    | 4    | 0    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2                 | 0                 |
| Red-breasted Merganser      | 0    | 0    | 0                 | 0    | 0    | 2                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Unidentified duck           | 0    | 0    | 1                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Sandhill Crane              | 0    | 0    | 0                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Parasitic Jaeger            | 0    | 0    | 0                 | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 0    | 0                 | 0                 |
| Glaucous Gull               | 1    | 0    | 24                | 0    | 0    | 1                 | 0    | 0    | 0    | 4    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 1                 | 0                 |
| Sabine's Gull               | 0    | 0    | 0                 | 0    | 1    | 5                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0                 |
| Arctic Tern                 | 7    | 0    | 0                 | 1    | 0    | 2                 | 3    | 0    | 0    | 2    | 3    | 0    | 0    | 0    | 2    | 1    | 1    | 0    | 0                 | 0                 |
| Total Birds                 | 80   | 9    | 562               | 26   | 71   | 416               | 14   | 43   | 20   | 32   | 68   | 9    | 9    | 38   | 99   | 18   | 18   | 5    | 251               | 66                |
| Total Species               | 7    | 1    | 11                | 5    | 6    | 14                | 4    | 3    | 3    | 9    | 7    | 4    | 5    | 4    | 7    | 6    | 5    | 2    | 9                 | 4                 |

Table 28. Continued.

| Species                     | T6.1 | T6.2 | T6.3 | T7.1 | T7.2 | T7.3 | T7.4 | T7.5 | T8.1 | U4.1 <sup>b</sup> | U4.2 | U5.1 | U5.2 | U5.3 | U6.1 | U6.2 | U6.3 | U6.4 | V5.1 <sup>b</sup> | Total |
|-----------------------------|------|------|------|------|------|------|------|------|------|-------------------|------|------|------|------|------|------|------|------|-------------------|-------|
| Pacific Loon                | 0    | 6    | 0    | 9    | 44   | 0    | 14   | 6    | 0    | 8                 | 2    | 32   | 0    | 9    | 0    | 0    | 0    | 11   | 57                | 369   |
| Red-throated Loon           | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2    | 0    | 6                 | 0    | 0    | 0    | 0    | 0    | 1    | 0    | 0    | 14                | 38    |
| Yellow-billed Loon          | 5    | 0    | 0    | 0    | 16   | 5    | 3    | 0    | 17   | 0                 | 0    | 0    | 0    | 0    | 11   | 4    | 3    | 0    | 4                 | 77    |
| Red-necked Grebe            | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0    | 15   | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 33    |
| Greater White-fronted Goose | 0    | 0    | 0    | 0    | 47   | 13   | 0    | 2    | 24   | 52                | 3    | 39   | 15   | 0    | 6    | 0    | 0    | 20   | 969               | 2,044 |
| Brant                       | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2    | 0    | 0                 | 0    | 0    | 0    | 2    | 0    | 0    | 0    | 0    | 0                 | 34    |
| Canada Goose                | 0    | 0    | 0    | 0    | 4    | 0    | 0    | 2    | 5    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 3                 | 147   |
| Tundra Swan                 | 4    | 11   | 0    | 6    | 17   | 6    | 2    | 0    | 0    | 26                | 1    | 27   | 2    | 5    | 1    | 0    | 1    | 0    | 73                | 321   |
| American Wigeon             | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 4                 | 0    | 19   | 0    | 0    | 0    | 0    | 0    | 0    | 13                | 59    |
| Northern Shoveler           | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0    | 3    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 7     |
| Northern Pintail            | 0    | 0    | 0    | 4    | 5    | 1    | 0    | 0    | 0    | 258               | 0    | 130  | 0    | 0    | 2    | 0    | 0    | 0    | 256               | 942   |
| Green-winged Teal           | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0    | 2    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 3     |
| Greater Scaup               | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 24                | 0    | 47   | 4    | 0    | 0    | 0    | 0    | 0    | 21                | 120   |
| Unidentified scaup          | 11   | 2    | 2    | 8    | 0    | 0    | 0    | 0    | 0    | 7                 | 0    | 33   | 11   | 0    | 0    | 0    | 0    | 0    | 26                | 129   |
| Surf Scoter                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 1     |
| Long-tailed Duck            | 3    | 2    | 0    | 2    | 15   | 4    | 0    | 0    | 0    | 6                 | 0    | 46   | 0    | 1    | 0    | 6    | 0    | 2    | 19                | 161   |
| Red-breasted Merganser      | 0    | 0    | 0    | 0    | 3    | 0    | 0    | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 1    | 2    | 0    | 6                 | 14    |
| Unidentified duck           | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 3     |
| Sandhill Crane              | 0    | 0    | 0    | 0    | 4    | 0    | 0    | 3    | 0    | 0                 | 0    | 4    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 12    |
| Parasitic Jaeger            | 0    | 0    | 0    | 0    | 2    | 0    | 0    | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 3     |
| Glaucous Gull               | 0    | 0    | 0    | 0    | 2    | 0    | 0    | 0    | 1    | 8                 | 0    | 1    | 0    | 0    | 0    | 0    | 0    | 0    | 23                | 66    |
| Sabine's Gull               | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0                 | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 2                 | 8     |
| Arctic Tern                 | 1    | 0    | 2    | 0    | 15   | 2    | 0    | 5    | 1    | 8                 | 0    | 117  | 0    | 2    | 4    | 1    | 0    | 23   | 103               | 306   |
| Total Birds                 | 25   | 21   | 4    | 29   | 174  | 31   | 19   | 22   | 48   | 409               | 6    | 516  | 32   | 19   | 24   | 13   | 6    | 56   | 1,589             | 4,897 |
| Total Species               | 5    | 4    | 2    | 5    | 12   | 6    | 3    | 7    | 5    | 10                | 3    | 14   | 4    | 5    | 5    | 5    | 3    | 4    | 15                | 21    |

<sup>a</sup> Lakes encompassed by a tapped-lake basin with low-water connection.<sup>b</sup> Tapped-lake basin with low-water connection.

20% of the waterbirds from non-tapped lakes were recorded from this group of lakes (Table 28). Many waterbird nests and a diversity of species were found close to the T7.2 complex (Figure 8). This area is important to loons in the Alpine project area, accounting for 20% of all Pacific Loons and 53% of all Yellow-billed Loons in 2001.

## PREDATORS

### NEST PREDATION

Predators were monitored as part of this study, because nest predation can depress the productivity of tundra-nesting birds, and predation contributes to the natural variability in the productivity of nesting birds. In addition, nest predation may be related to construction effects, because some of the most effective nest predators on the coastal plain (foxes, Glaucous Gulls, and Common Ravens) are suspected to be attracted to human development (see review by Day 1998).

Of all the large waterbird nests that were found and had their fate evaluated in the Alpine project area in 2001, 47 nests failed, of which 8 were known or suspected to have been preyed on by birds and 10 were known or suspected to have been preyed on by foxes. Predation likely contributed to the failure of the remaining 29 nests, but no signs of predators were found for identification. Identification of nest predators was more accurate for a small sample of nests monitored by video. In 2001, video cameras at 4 nests that were observed through hatch or failure recorded 2 incidences of egg predation by jaegers and none by foxes (although many attempts were recorded).

Arctic foxes were the most frequent predator recorded on video recordings near nests in 2001. We caution, however, that video cameras probably underestimate the number of avian visits to nests relative to mammalian predators. Birds fly through the camera view in less than 1 sec and likely are infrequently recorded because the recording intervals are 1 min. Predators on the ground move more slowly and, therefore, are more likely to be recorded. Arctic foxes were observed within camera view on 27 occasions (10 at 4 White-fronted Goose nests and 17 at 1 Tundra Swan nest). Foxes were <5 m from White-fronted Goose nests 9 times, >5 m from the nests 1 time,

and most often (9 times) only in the camera view for one recording interval (~1 min). Foxes were <5 m from the swan nest 11 times and >5 m from the nest 8 times, and in the camera view for a mean of 1.5 recording intervals (range 1–4 recording intervals; ~1–4 min). During 7 of the 11 times that a fox was <5 m from the swan nest, the swans defended the nest by standing and flapping their wings at the fox. The frequency of fox occurrence (determined by the number of detections on video) was 0.30 foxes/d or 28 fox events in 2001. No red foxes were observed on video in 2001, but they were observed in 1999 and 2000.

Parasitic Jaegers were the most frequently identified avian predator (54%, 7 of 13 avian predator events) recorded on video in 2001, and they were the only bird seen preying on nests. Glaucous Gulls and Common Ravens were recorded on video on 3 occasions each (23% of all avian predator events, each). Parasitic Jaegers visited one goose nest twice. Each time the goose was on recess and the jaeger took one egg. The remaining 4 eggs in the clutch hatched. The remaining 11 sightings of avian predators on video were of birds flying. On 3 of those 11 occasions, the predator flew <5 m from nests and the incubating birds responded with alert (2 times) and concealment (1 time) postures. Avian predators were flying >5 m from the nest on the remaining 8 occasions. The rate of occurrence of avian predators recorded on video <5 m from the nest was 0.05 birds/d or 5 bird events.

Nests of Parasitic Jaegers (2 nests), Long-tailed Jaegers (1), Glaucous Gulls (4), and Common Ravens (1) were found during aerial and ground surveys in the Alpine project area in 2001. All 4 species regularly were seen hunting in the area. We directly observed 6 different occurrences of Parasitic Jaegers taking eggs from Red-necked Grebe (1), White-fronted Goose (4), and Willow Ptarmigan (1) nests. Three of these instances occurred after the incubating birds (1 Red-necked Grebe and 2 White-fronted Geese) had flushed during nest-searching activities. At each nest the jaeger took or damaged one egg before researchers were able to drive the jaeger off the nest. The goose nests subsequently were covered with nesting material. One of these partially depredated goose nests was successful, the other goose nest failed, but 18 d after the predation event occurred,

and the fate of the grebe nest was unknown. Two Parasitic Jaegers were seen feeding on an egg within 1 m of another White-fronted Goose nest while the goose was incubating. A jaeger also was seen taking an egg from an unattended Willow Ptarmigan nest and another jaeger was seen eating the remains of a White-fronted Goose nest that had already been damaged by predators. Signs of probable predation by an avian predator (broken egg shells) were found at 8 nests (3 Long-tailed Duck, 2 White-fronted Geese, and one each of Yellow-billed Loon, Northern Pintail, Willow Ptarmigan).

On video recordings in 2001, arctic fox was the most common predator observed attempting to take eggs from geese and swan nests. The bird(s) attending the nest succeeded in deterring fox during all predation attempts seen on video. No direct observations of fox predation were made during other research activities. Parasitic Jaegers were the only avian predator seen preying on eggs at nests, either on video or by direct observation. Each nest was unattended at the time of predation, either because the incubating bird was on recess or because the bird had been flushed by researchers. The frequency of fox detections on video was higher than for avian predators, but the video probably under sampled avian predators because the view of the sky was restricted or absent in most of the camera views, and avian predators flew through the camera view in less time than the recording interval.

#### FOX DEN MONITORING

The presence of permafrost in arctic tundra forces foxes to dig dens in locations that have relatively deep, seasonal thaw layers. Foxes locate dens on raised landforms with well-drained soil; typical locations on the Arctic Coastal Plain include ridges, dunes, lake and stream shorelines, pingos, and low mounds (Chesemore 1969, Eberhardt et al. 1983, Burgess et al. 1993). Both arctic and red foxes occur in the region 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 2 habitat types for denning: Riverine or Upland Shrub and Moist Sedge–Shrub Meadow (Johnson et al. 2002; ABR, Inc., unpublished data). The landforms used most

commonly include the banks of streams and lakes (including drained-lake basins), dunes, ridges, and pingos (Garrott 1980, Eberhardt et al. 1983, this study). These observations demonstrate 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 habitat types.

Through a combination of our surveys and contacts with other observers over 9 years, 75 fox dens were located between the western edge of the Colville Delta and the western edge of the Kuparuk Oilfield, including areas both north and south of the Transportation Corridor (Figure 13). In 2001, 65 (87%) of these sites were classified as arctic fox dens and the remaining 10 sites (13%) were occupied by red foxes; 4 of the dens used by red foxes were former arctic fox dens. The 2001 total included 10 newly discovered dens in the vicinity of the proposed DS-3S drill site east of the Delta and north of the Transportation Corridor survey areas, in the northwestern corner of the Kuparuk Oilfield (Anderson et al. 2001), as well as 2 newly discovered dens on the Colville Delta (one of which was in the common search area) and one newly discovered den in the Transportation Corridor. We expect that a few more dens may be present in the northeastern portion of the delta, which has received lower search effort than the rest of the delta.

Of the 65 arctic fox dens, 15 dens were on the Colville Delta, 20 dens were in the Transportation Corridor, and the other 30 dens were north or south of the corridor (Appendix I1). The overall density of arctic fox dens (35 sites, both active and inactive) in the combined Delta (551 km<sup>2</sup>) and Transportation Corridor (343 km<sup>2</sup>) survey areas was 1 den/26 km<sup>2</sup>. The density of arctic fox dens was more than twice as high in the Transportation Corridor (1 den/17 km<sup>2</sup>) as on the Delta (1 den/37 km<sup>2</sup>), probably due to the more limited availability of suitable denning habitat on the outer delta and our lower search effort there. The overall density is higher than the 1 den/34 km<sup>2</sup> reported by Eberhardt et al. (1983) for their ~1,700-km<sup>2</sup> Colville study area (which extended farther east and west than ours, but not as far inland). The overall density we report for arctic fox dens is lower than those reported for the ~800-km<sup>2</sup> developed area of the Prudhoe Bay Oilfield

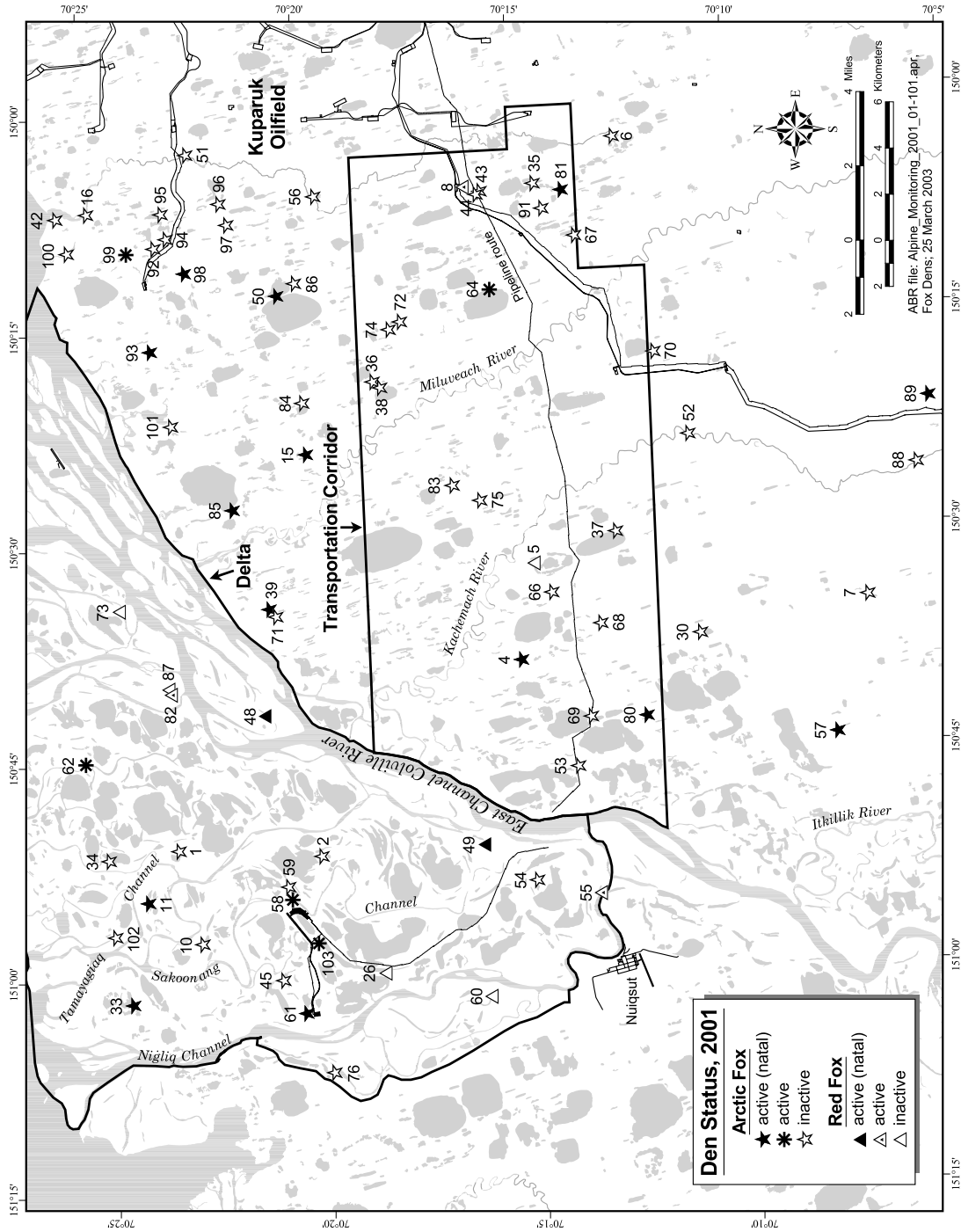


Figure 13. Distribution and status of arctic and red fox dens in the Colville River Delta and Alpine Transportation Corridor survey areas and adjacent coastal plain tundra, northern Alaska, 2001. Survey coverage was not uniform over the entire area portrayed. One arctic fox den occurred south of the area portrayed.

(1 den/12–15 km<sup>2</sup>; Eberhardt et al. 1983, Burgess et al. 1993, Rodrigues et al. 1994, Ballard et al. 2000), but was within the range reported for undeveloped areas near the Prudhoe field (1 den/28–72 km<sup>2</sup>; Burgess et al. 1993, Rodrigues et al. 1994, Ballard et al. 2000). The overall density we recorded was slightly higher than the mean densities reported for large areas of tundra in the Northwest Territories (1 den/36 km<sup>2</sup>; Macpherson 1969) and Siberia (1 den/32 km<sup>2</sup>; Boitzov 1937, as cited in MacPherson 1969).

Eight of the 10 red fox dens were located on the Colville Delta. The other 2, located in the Transportation Corridor, were a pingo den near the Kachemach River that was occupied by arctic foxes until 1999 and a well-developed den near DS-2M in the eastern end of the corridor that had been used by arctic foxes since at least 1984. In 2001, the density of red fox dens in the Delta survey area was 1 den/79 km<sup>2</sup> (treating 2 adjacent dens used by 1 breeding pair of foxes as a single site). Comparative data on den density are unavailable for this species from other arctic tundra areas, but it appears that the density of red fox dens on the Colville Delta is relatively high for the Arctic Coastal Plain.

During brief visits at 63 of the 65 arctic fox dens throughout the entire study area during late June and longer observations at 20 of those dens during mid-July, the presence of pups was confirmed at 13 natal dens, strongly suspected at 2 more dens, and considered probable at 3 other dens. Thus, the number of active dens (occupied at some point by pups) was estimated to be 18 (29%) of the 63 arctic fox dens checked; the remaining 45 dens (71%) showed signs of limited use by adults only or were completely inactive (Appendix I2). The estimated den occupancy rate by litters (natal, secondary, and active categories combined) in 2001 was below the 8-year mean for dens observed since 1993 (mean = 37%, range 24–67%).

Of 14 arctic fox dens checked on the Colville Delta, 5 were active (including 3 natal dens), for an occupancy rate of 36%. The 15<sup>th</sup> den on the delta appeared to be active when it was discovered during a loon brood survey in late August 2001, but it was excluded from the occupancy analysis because of the possibility that it was a secondary den. In their Colville study area, Eberhardt et al. (1983) reported that the percentage of dens

containing pups ranged from 6% to 55% in a 5-year period, whereas 56–67% showed signs of activity by adults alone. Burgess et al. (1993) estimated that 45–58% of the dens in their study area in the Prudhoe Bay Oilfield produced litters in 1992, although only 21% still were occupied by families at the time of ground visits in late July–early August. In 1993, the occupancy rate by arctic foxes at 53 natural den sites in the Prudhoe Bay Oilfield and surrounding area was 71%, and 49% of the sites were classified as natal dens (Ballard et al. 2000). The occupancy rate for the 10 red fox dens in our 2001 sample was 50%, including 2 natal dens and 3 other active dens at which pup presence could not be confirmed.

During 9–15 July 2001, ~102 hr were spent observing 20 arctic fox dens and 6 red fox dens identified as active sites on our first check in late June, and 37 pups were counted at 13 of the arctic fox dens and 5 pups at 2 of the red fox dens. The mean litter size for arctic foxes was 3.2 pups (SD = 0.87; range 2–5 pups) for the 11 dens at which observers were confident they obtained a complete count. The mean litter size was 2.5 pups for 2 red fox dens. Estimates of pup production are minimal figures because pups often remain underground for extended periods, making it difficult to reliably obtain complete counts. In general, observations at dens were more successful in obtaining pup counts during evening, when foxes tend to be most active, than in the morning; however, litters occasionally can be counted successfully even in midday. Red fox dens are more difficult to observe than arctic fox dens, because they tend to be located in sand dunes having high topographic relief and tall shrubs that obscure the den entrances and activity areas.

Estimates of pup production also can be confounded by the use of secondary dens, which can result in a litter being split 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 among dens occurred after the initial move. We found no indication of any such moves by arctic or red foxes in our study area in 2001.

The mean litter size of arctic foxes in 2001 (mean = 3.2 pups) was at the low end of the annual

range observed since 1993 (3.2–6.1 pups; Appendix I2). The maximal litter sizes in our study area occurred in 1996, a year of high lemming populations. These figures were virtually identical to those reported by Garrott (1980) for low and high years of pup production in his Colville study area. In 1978, when small mammals (the principal prey of arctic foxes) were abundant, Garrott (1980) closely observed 7 litters from a total of 23 active dens, which averaged 6.1 pups (range 2–8). In contrast, he observed only one litter (from 2 active dens) in 1977, when small mammals were scarce, and was unable to obtain a satisfactory litter count. The low occupancy rate and small litter sizes at arctic fox dens in 2001 led us to infer that the density of small mammals in our study area was relatively low, although we have no small mammal population data to support this conclusion. Further analyses of the relationship between fox population productivity and the presence of Alpine Project facilities are presented in Part II of this report.

#### **SUMMARY AND CONCLUSIONS FOR 2001 FIELD SEASON**

In 2001, spring and early summer conditions in the Alpine project area were cool and river break-up was late (10 June) relative to average conditions since 1996 (when comprehensive nest searches were initiated in the Alpine project area), producing a spring phenology similar to that observed in 1999 and 2000. Emergence of midges and mosquitoes was late and hatch of Lapland Longspurs and Greater White-fronted Geese was similarly delayed. The project area was flooded briefly (2–3 d) when ice-dams formed at the eastern bridge of the Alpine road. The camp population and human activity in the project area were high, supporting drilling on CD-2 and construction on CD-1 and CD-2. Vehicle and pedestrian traffic levels reached their highest levels in 2001, whereas aircraft traffic was slightly lower than the level in 2000. The most frequent aircraft using the Alpine airstrip were helicopters (17 events/d) and twin-engine CASAs and Twin Otters (13 events/d). Noise models that were calibrated in the study area in 2001 indicated that the highest noise levels (from aircraft) were produced by 4-engine airplanes (primarily DC-6) and

helicopters (Bell 206 Long Ranger). The models predicted noise levels for every nest sited each year based on flight records. Noise exposure at nests from individual aircraft depended on nest location, aircraft type, and direction of travel by aircraft (NE or SW), whereas noise exposure over time (hour, day, or season) depended additionally on the number of aircraft.

The density and number of species found in 2001 were similar to that found in previous years, but lower densities occurred near the airstrip than farther away, suggesting that the airstrip was affecting nest distribution. White-fronted Goose nests were the most abundant nests (40% of all nests) and, although they occurred at lower densities near the airstrip, the highest densities occurred not in the farthest buffer (1,500–2,000 m) from the airstrip, but in the third (1,000–1,500 m) of four buffers from the airstrip. White-fronted Geese were highly selective for nesting habitats, using 4 of 17 available habitats in 2001 and preferring only Patterned Wet Meadow. In contrast, shorebirds and passerines did not appear to be highly selective for nest habitats in the breeding-bird plots, which may be an artifact of the similarity among plots. Nor were shorebird and passerine nests affected by their proximity to the airstrip; more nests were found on plots near the airstrip than on plots farther away, but the differences were significant only for Semipalmated Sandpipers and Lapland Longspurs.

Incubation constancy was high at the 27 White-fronted Goose nests and the 1 Tundra Swan nest monitored in 2001. Incubation constancy, number of recesses, recess length, and time off nest for White-fronted Geese did not differ significantly between successful and failed goose nests. The probability of recesses occurring at goose nests in any hour did not change with the presence of airplanes, helicopters, or pedestrians. However, recess frequency, recess length, and total time off nest each day increased with numbers of helicopters, with the duration of pedestrians on the airstrip, with proximity of nests to the airstrip, and as day before hatch or failure approached.

The most common responses of nesting White-fronted Geese to sources of disturbance were concealment postures. Concealment postures occurred most frequently in 2001 in response to vehicles and aircraft, which also were the most



common sources of disturbance. The rates of concealment were highest for airplanes and pedestrians, but rates varied among incubating geese and appeared to be affected by distance of nests to disturbance sources. The helipad was farther from the monitored nests than was the airstrip and road, which undoubtedly reduced the rate of responses to helicopters. The swan nest monitored in 2001 was closer to the road than the airstrip, and the most frequent source of disturbance that elicited alert postures was vehicular traffic. However, swans were more sensitive (i.e., higher rate of reaction) to pedestrians than to vehicles or aircraft.

As in previous years, the location of nests relative to the airstrip did not appear to affect their productivity in 2001. Duck nests that failed to hatch were closer to the airstrip than was the one successful nest, but distances did not differ between fates of White-fronted Goose nests, and all swan nests hatched. Clutch sizes in White-fronted Goose nests did not vary with distance from the airstrip.

Large waterbirds used the same lakes in the study area throughout the summer in 2001 as in previous years. Tapped Lakes with Low-water Connections were used by far more birds than any other type of lake. In 2001, geese and ducks were the most numerous birds counted on lake surveys, and the highest numbers were recorded in late June and August.

Foxes appeared to be more active relative to avian predators in 2001 based on video recordings of goose and swan nests; however, avian predators were more successful at taking eggs. Foxes were not observed successfully taking eggs either on video recordings or during other research activities. Neither the number of occupied fox dens nor the size of fox litters increased in 2001. The number of jaeger and gull nests in 2001 was similar to previous years, but Common Ravens have nested in the project area only since development.

Potential effects of the airstrip and development were detected in the distribution of nests of large waterbirds and White-fronted Geese and in the number of fox and raven observations. No effects were detected on the distribution of shorebird or passerine nests on breeding-bird plots. Nest fate and clutch size of White-fronted Geese

and Tundra Swans did not appear to be affected by the activities at the airstrip in 2001. Both White-fronted Geese and Tundra Swans displayed reactions (concealment and alert postures) to disturbances related to the airstrip and construction, but the effects of noise, aircraft, traffic, and pedestrians on incubation activities were weak or inconsistent, and did not appear to affect the success or failure of nests. Consistent factors affecting incubation activities were individual variation among incubating birds or nest location, which cannot be evaluated simultaneously, time of day, and day before hatch or failure. Whether differences in incubation activities with distance from airstrip affected nesting success in 2001 was unclear, but that possibility will be examined with all years of data in Part II of this report.

## **PART II: MULTIYEAR SYNTHESIS RESULTS AND DISCUSSION**

### **CONDITIONS IN THE STUDY AREA**

#### **PHENOLOGY**

Because of the short nesting period available to birds in the Arctic, delayed melt of snow and ice affect the timing and potential number of nests initiated, as well as their subsequent success (Barry 1962, de Boer and Drent 1989). In years with persistent snow and ice, nesting habitat in some areas is limited (Boyd and Maltby 1979), and nesting occasionally prevented (McLaren and Alliston 1985). Nesting by birds in the Alpine project area also can be influenced by the timing and severity of the breakup of the Colville River, which can flood areas commonly used for nesting (Johnson et al. 2001). Because natural variation in nesting conditions could affect the same response variables for breeding birds (e.g., densities, distribution, and productivity) that were used as indicators of disturbance effects, we needed to account for background nesting conditions before we could evaluate the effects of the Alpine development.

Weather conditions during May and June varied greatly in the Alpine project area between 1996 and 2001. Generally, 1996 and 1998 were warm and phenologically advanced, whereas 1999–2001 were cold and delayed, and 1997 was

intermediate (Table 3). The long-term averages from the nearby Kuparuk Oilfield for the arrival (15–31 May) and nest initiation (1–15 June) periods for birds were  $-3.3^{\circ}\text{C}$  and  $2.2^{\circ}\text{C}$ , respectively. The same periods in 1996 and 1998 were  $\sim 3\text{--}5^{\circ}\text{C}$  warmer (Table 3). The number of thawing degree-days in 1996 and 1998 also was higher than the long-term mean, whereas the number was lower in 1999–2001, except during 1–15 June 2001 (Figure 6). Similarly, temperatures in 1999–2001 also were lower than the long-term mean, with the exception of 1–15 June 2001. Total thawing degree-days (15 May–15 June) was strongly correlated with mean temperatures during 1–15 June ( $r = 0.8$ ,  $P \leq 0.01$ ,  $n = 10$  years).

The date that the tundra was first free of snow ranged between 23 May and 11 June in the Kuparuk Oilfield (1996–2001) and was 1–5 days later at Colville Village on the outer Colville River Delta (1997–2001). Snow-free date was not correlated with dates of river breakup, but was earlier in years with higher thawing degree-days ( $r = -0.6$ ,  $P = 0.08$ ; Table 29). Peak breakup (surface elevation and discharge) at the head of the Colville River ranged between 26 May and 11 June during 1996–2001 (Table 3). Median date of breakup was 31 May based on records between 1992 and 2001 (PHILLIPS and Anadarko 2001). Peak breakup in 1996 was 5 days earlier than the median and 10–11 days later in 2000–2001, but about the same as the median in the other years. Peak discharges in 1996 and 1997 were well below average, but discharge in 2000 was more than twice the average, probably because only 3 days elapsed between when water first started to flow at the head of the delta and when it reached peak elevation (PHILLIPS and Anadarko 2001). Flooding in 2000 was the most extensive recorded in several years—estimated to be a 25-yr flood (Baker 2000)—extending from the Nigliq Channel northeast to the Sakoonang Channel, covering low areas and lakes between U4.1, U5.1, T4.2, and S6.1 (Figure 5). Therefore, a large portion of the study area was flooded from approximately 8 to 13 June, which is the time many geese, ducks, shorebirds, and passerines are nesting. Although river breakup also was late in 2001 relative to the median date, the flooding was not extensive and was similar to normal years. Localized flooding

occurred west–southwest of the Alpine airstrip as a result of ice jamming at the easternmost Alpine bridge, but lasted only 2–3 days. The amount and timing of flooding affects the amount of habitat available to nesting birds.

Nesting by birds appeared to be affected by the same environmental conditions discussed above, as well as other factors, such as conditions encountered while migrating. Most correlations of nesting with conditions were hampered by low sample sizes (4–6 years), but illustrate some trends despite lack of statistical significance. The number of White-fronted Goose nests was relatively consistent each year (Table 3), but was negatively correlated with the date of river breakup, as was the number of duck nests (both  $r = -0.6$ ,  $P = 0.23$ ; Table 29). The abundance of duck nests increased in years with more thawing degree-days during late May ( $r = 0.8$ ,  $P = 0.07$ ). The number of shorebird nests was not correlated with any weather variable analyzed ( $r \leq 0.2$ ). Passerine nests appeared to increase in numbers in years with cooler and later springs; abundance was negatively correlated with thawing degree-days ( $r = -0.6$ ,  $P = 0.40$ ) and increased with later snowmelt (snow-free date,  $r = 0.8$ ,  $P = 0.20$ ).

Hatch dates were the most strongly related to environmental conditions of all the nesting variables. The earliest mean hatch date for White-fronted Geese determined from 4 years of monitoring with thermistored eggs occurred on 27 June in 1998, a warm year, and the latest mean hatch date occurred on 10 July in 2000, a cold year with the most extensive flooding (Table 3). Both White-fronted Goose and Lapland Longspur hatch dates were strongly related to snow-free and river breakup dates (both species, both dates,  $r = 1.0$ ,  $P < 0.01$ ) and occurred earlier in years with high numbers of thawing degree-days in May (both species,  $r = -1.0$ ,  $P < 0.01$ ). The 2000 nesting season was approximately 8–14 days later than in 1998 and at least 3 days later than in 1999 or 2001 (Table 3).

Although environmental conditions during the study period obviously had an influence on avian nesting parameters, the strength of the relationships with specific conditions varied by species, and was limited by the sample size of years available. Correlations between nesting parameters and environmental conditions, many of

Table 29. Spearman rank correlation coefficients (*r*) of biological variables collected around the Alpine project area and environmental variables from the Colville River (peak breakup) and the adjacent Kuparuk Oilfield, Alaska, 1992–2001.

| Variables                        | Correlation Coefficient/<br>Sample Size | Arrival Thawing<br>Degree-days <sup>a</sup> | Total Thawing<br>Degree-days | First Snow-free<br>Date | Peak Breakup: <sup>b</sup><br>Colville River <sup>c</sup> | No. White-<br>fronted Goose<br>Nests | White-fronted<br>Goose Nest<br>Success | White-fronted<br>Goose Clutch<br>Size | No. Duck Nests | No. Shorebird<br>Nests | No. Passerine<br>Nests | Annual L <sub>eq</sub> <sup>c</sup> | Mean Daily<br>Aircraft Flights | Mean Daily No.<br>Vehicles | Mean Daily No.<br>Pedestrians | No. of Fox Dens <sup>d</sup> | No. Foxes Seen<br>on Video <sup>e</sup> |
|----------------------------------|---|---|------------------------------|-------------------------|---|--------------------------------------|--|---------------------------------------|----------------|------------------------|------------------------|-------------------------------------|--------------------------------|----------------------------|-------------------------------|------------------------------|---|
| Arrival Thawing Degree-days      | <i>r</i> 1.0<br><i>n</i> 10             |   |                              |                         |   |                                      |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| Total Thawing Degree-days        | <i>r</i> 0.7*<br><i>n</i> 10            | 1.0   |                              |                         |   |                                      |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| First Snow-free Date             | <i>r</i> -0.5<br><i>n</i> 10            | -0.6  | 1.0                          |                         |   |                                      |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| Peak Breakup: Colville River     | <i>r</i> -0.3<br><i>n</i> 10            | -0.4  | 0.3                          | 1.0                     |   |                                      |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| No. White-fronted Goose Nests    | <i>r</i> 0.4<br><i>n</i> 6              | -0.1  | 0.3                          | -0.6                    | 1.0   |                                      |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| White-fronted Goose Nest Success | <i>r</i> 0.6<br><i>n</i> 5              | 0.9*  | -0.3                         | -0.7                    | 0.3   | 1.0                                  |  |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| White-fronted Goose Clutch Size  | <i>r</i> -0.6<br><i>n</i> 7             | -0.4  | 0.7                          | 0.2                     | 0.1   | 0.3                                  | 1.0                                    |                                       |                |                        |                        |                                     |                                |                            |                               |                              |   |
| No. Duck Nests                   | <i>r</i> 0.8<br><i>n</i> 6              | 0.3   | -0.03                        | -0.6                    | 0.6   | 0.5                                  | -0.3                                   | 1.0                                   |                |                        |                        |                                     |                                |                            |                               |                              |   |
| No. Shorebird Nests              | <i>r</i> -0.2<br><i>n</i> 4             | 0.0   | 0.2                          | 0.2                     | 0.2   | 0.0                                  | 0.2                                    | 0.4                                   | 1.0            |                        |                        |                                     |                                |                            |                               |                              |   |
| No. Passerine Nests              | <i>r</i> -0.4<br><i>n</i> 4             | -0.6  | 0.8                          | 0.4                     | 0.4   | -0.6                                 | 0.4                                    | 0.2                                   | 0.8            | 1.0                    |                        |                                     |                                |                            |                               |                              |   |
| Annual L <sub>eq</sub>           | <i>r</i> -0.9*<br><i>n</i> 5            | -0.6  | -0.6                         | 1.0**                   | -0.8  | -0.7                                 | 0.0                                    | -0.8                                  | 0.2            | 0.4                    |                        | 1.0                                 |                                |                            |                               |                              |   |
| Mean Daily No. Aircraft Flights  | <i>r</i> -0.9*<br><i>n</i> 5            | -0.6  | 0.1                          | 1.0**                   | -0.8  | -0.7                                 | 0.0                                    | -0.8                                  | 0.2            | 0.4                    |                        | 1.0**                               | 1.0                            |                            |                               |                              |   |
| Mean Daily No. Vehicles          | <i>r</i> -0.8<br><i>n</i> 5             | -0.5  | -0.1                         | 0.9                     | -0.9*   | -0.6                                 | -0.1                                   | -0.9*                                 | 0.4            | 0.2                    |                        | 0.9*                                | 0.9*                           | 1.0                        |                               |                              |   |
| Mean Daily No. Pedestrians       | <i>r</i> -0.8<br><i>n</i> 5             | -0.5  | -0.1                         | 0.9                     | -0.9*   | -0.6                                 | -0.1                                   | -0.9*                                 | 0.4            | 0.2                    |                        | 0.9*                                | 0.9*                           | 1.0**                      | 1.0                           |                              |   |
| No. of Fox Dens                  | <i>r</i> 0.8<br><i>n</i> 6              | 0.8*  | -0.9*                        | -0.8                    | -0.03   | 0.4                                  | -0.8                                   | 0.3                                   | 0.3            | 0.3                    |                        | -0.4                                | -0.4                           | -0.4                       | -0.4                          | 1.0                          |   |
| No. of Foxes Recorded on Video   | <i>r</i> -0.4<br><i>n</i> 4             | -0.4  | 0.2                          | 0.4                     | -0.4  | -0.4                                 | 0.4                                    | 0.4                                   | -0.8           | -0.8                   |                        | 0.4                                 | 0.4                            | -0.4                       | -0.4                          | -0.8                         | 1.0                                     |

<sup>a</sup> Cumulative number of degrees above freezing for mean daily temperatures (°C). Arrival dates 15–30 May, total dates 15 May–15 June.

<sup>b</sup> Date (Julian) of peak flow in the Colville River.

<sup>c</sup> Logarithmic average of annual noise levels at all nest sites in the project area.

<sup>d</sup> Number of occupied fox dens within 5 km of the Alpine airstrip.

<sup>e</sup> Number of foxes detected on video recordings (standardized by length of recording) of goose and swan nests.

\* Correlation is significant at the  $\alpha = 0.05$  level (2-tailed).

\*\* Correlation is significant at the  $\alpha = 0.01$  level (2-tailed).

which are intercorrelated, are complex and not always indicative of causal relationships. Also, few analytical techniques can handle extraordinary events that occur one time or very rarely, such as the 25-year flood that occurred in the study area in 2000. If cooler, late springs can reduce nest abundance and nest success of geese and ducks, we would expect higher values for these measures of nesting in 1996 and 1998, intermediate values in 1997, and reduced values in 1999–2001. The flood in 2000 also could have reduced nest numbers and nest success, as floods did to White-fronted Geese on the Yukon-Kuskokwim Delta (Ely and Raveling 1984). Nesting and productivity of arctic breeding geese can be reduced in years with cold, late springs (Barry 1962, de Boer and Drent 1989) and may experience total failure during years with severe conditions (McLaren and Alliston 1985). The effects of weather must be considered when evaluating the results of further analyses involving environmental conditions and sources of disturbance.

#### HUMAN ACTIVITY

Human activity in the Alpine project area during the breeding season has varied from low-numbers of people (2–6 people) conducting civil engineering or field studies with occasional helicopter visits in 1996 and 1997 to full-scale construction with over 500 people and multiple aircraft flights each day in 2000. Residents of the delta (living in Nuiqsut and Colville Village) probably used the project area prior to this study. Hunting and fishing camps were present on the Nigliq Channel, but use of the project area by local residents was not observed during the study period. From here on, references to human activity will be used to describe non-resident people, who were in the area primarily to support oil development. Prior to 1998, the project area was not frequented by people, except for a temporary field camp for 6 people (nest searchers involved in this study) on the Nigliq Channel in 1996, and less than daily visits by biologists, hydrologists, and surveyors in 1996 and 1997 (Table 1). Helicopters landed in the project area at about the same frequency in 1996 and 1997 (based on observations made during nest searches; records are unavailable prior to 1998), and helicopters used multiple locations around the project area for landings and takeoffs, so

disturbance from flights was well dispersed. By May 1998, gravel was in place at the airstrip and CD-1 location, although the CD-1 footprint was not complete at that time (Figure 1). A crew of 3–5 people worked on drying and compacting the gravel with 3–5 pieces of heavy equipment from 23 June to 15 July (T. Carroll, Nuiqsut Constructors, pers. comm.). The helicopter landed daily at CD-1 while construction was in progress. In addition, nest searchers visited almost daily and hydrologists (J. Aldrich, Michael Baker Jr., Inc., pers. comm.) and surveyors (B. Mangold, Lounsbury & Associates, Inc., pers. comm.) visited sporadically in varied locations, all requiring helicopter flights to and from the project area (Figure 14). A portion of the helicopter landings were at the airstrip, but the helicopter also landed at locations close to work sites, which were often at various lakes or channels or along the road route. Although records of helicopters and pedestrians were not complete for 1998, it was clear that the levels of human activity that year were the lowest of all construction years at Alpine. Accordingly, 1998 was classified as a “light-construction” year relative to subsequent years (Table 3). By summer 1999, gravel had been deposited for the road and CD-2, but bridges (2) and their approaches had not been installed. Full construction and drilling on CD-1 began in 1999. The camp population that year averaged 160 people/d and 10 aircraft/d and 13 vehicles/d used the airstrip. Bridges were in place by summer 2000, but the road to CD-2 was soft, so vehicle traffic on the road during the nesting period was infrequent (0–3 vehicles/d) and primarily comprised large and track vehicles. CD-1 was the center of drilling and construction, which involved the installation of modules and other buildings. The camp population peaked in 2000 at 550 people/d (requiring additional temporary housing on CD-1 and commuting from the Kuparuk oilfield), as did aircraft at 22 flights/d. Vehicle traffic in 2000 averaged 25 vehicles/d. In 2001, oil was being produced from CD-1, but CD-2 was being drilled, and construction continued at both pads, which created the highest traffic levels recorded (313 vehicles/d [26 vehicles/hr in a 12-hr period]) in 1998–2001. The camp population declined slightly in 2001 to 455 people/d, and the number of flights declined to 16 aircraft/d. With the high levels of construction,

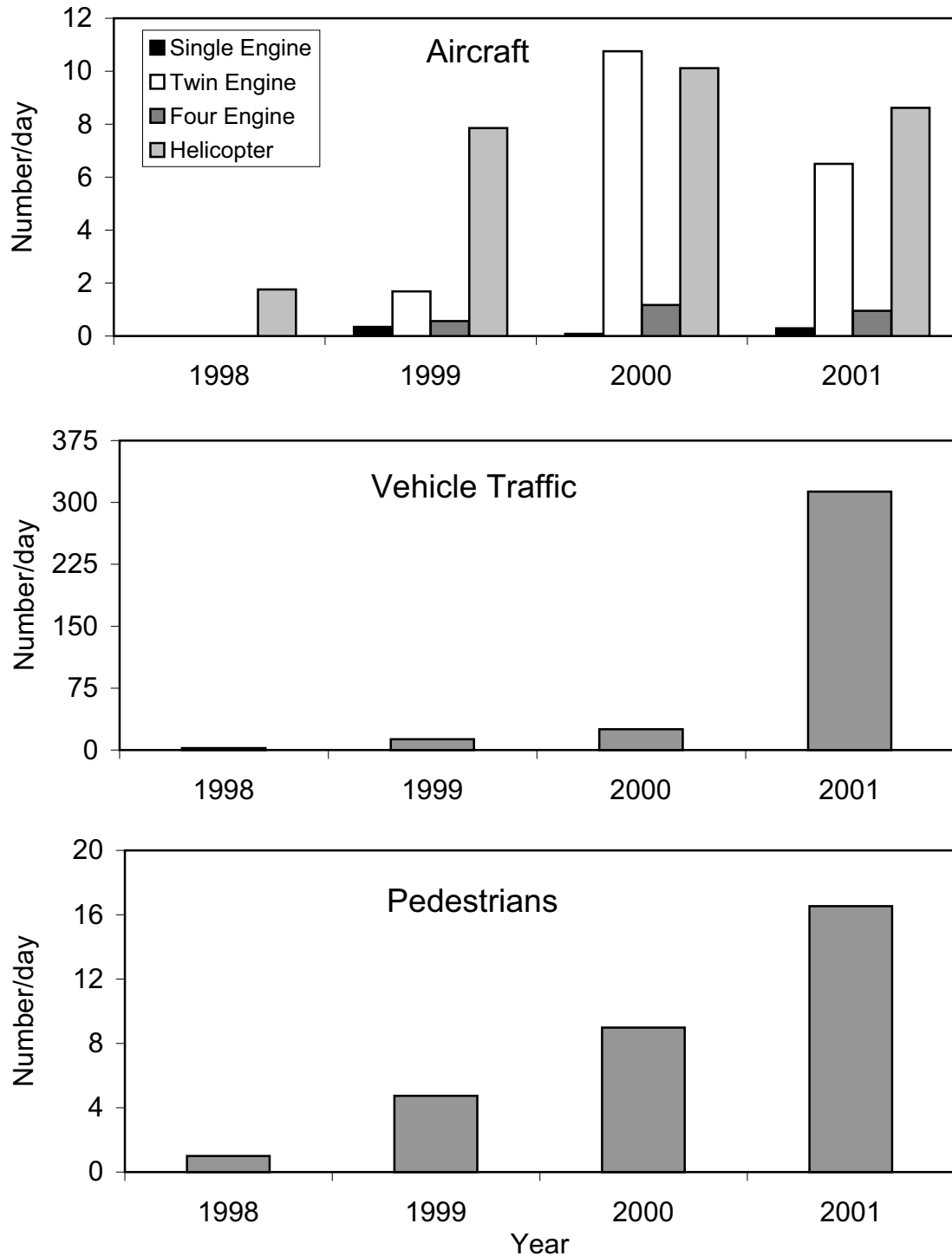


Figure 14. Mean daily number of aircraft, vehicles, and pedestrians using the Alpine airstrip, 1 June–15 July, Colville River Delta, Alaska, 1998–2001. Actual dates from which means were calculated vary by year and activity type, see text.

drilling, people, aircraft, and vehicles that existed at Alpine after 1998, we classified 1999–2001 as “heavy-construction” years. The heavy-construction years coincided with cold, late nesting seasons, whereas the “light-construction” year (1998) coincided with a warmer nesting season. The number of airplanes, vehicles, and pedestrians and resulting noise levels at the Alpine airstrip were intercorrelated (pairwise  $r \geq 0.9$ ,  $P \leq 0.05$  [uncorrected for multiple comparisons]) and increased with later breakup dates for the Colville River ( $r \geq 0.9$ ,  $P \leq 0.05$ ) and decreased with the number thawing degree-days in May ( $r \leq -0.8$ ,  $P \leq 0.10$ ; Table 29). Obviously, annual differences in weather did not cause increases in human activity, but the high correlations between weather and human activity confound analyses that evaluate differences among years in various biological parameters for nesting birds with respect to levels of aircraft, construction, and other potential disturbance activities. The warm temperatures and early phenologies of 1996 and 1998 coincided with no or low levels of human activity in the Alpine project area. Those weather conditions contrasted sharply with the cool conditions in 1999–2001 during the 3 years of heavy construction, when human activity and disturbance were most frequent. Because cool temperatures and late spring phenology can have a negative effect on nesting (Barry 1962, Mayfield 1983, McLaren and Alliston 1985, Troy 1996, Gratto-Trevor 1991), we should expect some declines in nest abundance and nesting success in 1999–2001, regardless of human activity levels. Therefore, we must consider those concurrent trends in weather when interpreting annual changes in nesting and non-nesting parameters of the avian community in relation to annual changes in disturbance.

#### NOISE FROM AIRCRAFT

Noise is an aspect of human activity that can have a wide variety of effects on wildlife, including several aspects of avian ecology investigated in this study: reproduction, behavior, and habitat use or distribution (Bowles 1995). We investigated noise levels around the Alpine airstrip as a possible explanatory factor for changes in the distribution of nests and incubation behavior of birds in the project area. Noise modeling was used to estimate

noise levels at each nest site found during 1998–2001 and to estimate changes in noise exposure among years. To illustrate some of the highest noise levels produced near the airstrip, we use as examples the same 3 nest sites that were examples in the Noise Monitoring section of Part I (Figure 7). Ambient noise levels in the absence of aircraft and human activity (i.e., absence of construction and pad activities) were estimated to be 25 dBA. The annual noise level (logarithmic average of daily  $L_{eq}$  [12 hr] for the period 1 June–15 July) at each nest increased from 1998 to 2000 and then decreased slightly in 2001 (Table 30). Nest 002 achieved its highest daily noise level on 24 June 2001 with 40 aircraft events (landings plus takeoffs: 6 four-engine, 14 twin-engine, and 20 helicopter). The highest daily noise values occurred at the other 2 nest sites on 2 June 2000, when 60 aircraft events (2 four-engine, 20 twin-engine, and 38 helicopter) occurred. Therefore, different nest locations were exposed to their highest levels of noise on different days with different arrays of aircraft. To characterize the change in noise levels among years in the project area, 200 nests were randomly selected as fixed sites for the noise model to estimate annual noise levels. The mean annual noise level of the random nest sites (Table 30) increased ~17 dBA from 1998 to 2000, and then decreased 1.7 dBA in 2001 (ANOVA,  $F = 404.8$ ,  $df = 3$ , 796,  $P < 0.01$ ). The mean noise level each year was significantly different from that in all other years (Bonferroni multiple comparisons,  $P \leq 0.01$ ), and was positively correlated with frequency of aircraft, vehicles, and pedestrians (all 3 correlations  $r \geq 0.9$ ,  $P \leq 0.05$ ; Table 29). Further analyses evaluating the effects of noise levels on nest distribution and on incubation behavior are presented in subsequent sections.

#### NEST DENSITIES AND DISTRIBUTION

Among the possible effects of disturbance from human activity related to the development of the Alpine project are changes to the abundance and distribution of bird nests. Changes in abundance, particularly of nests, could indicate population-level effects, whereas changes in distribution could affect the density of nests in the proximity of the airstrip that might or might not be

Table 30. Sound levels ( $L_{eq}$ , in dBA) for 3 nest sites near the airstrip, and at 200 randomly selected nest sites in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Sound levels were modeled with INM ver. 6.0, Federal Aviation Administration (see Appendix B).  $L_{eq}$  was calculated for 12 hr (0600–1759) and averaged (logarithmic) for days with aircraft records between 1 June and 15 July. Three nest locations are shown in Figure 7.

| Nest                         | 1998 <sup>a</sup> |      |      | 1999 <sup>b</sup> |      |      | 2000 <sup>c</sup> |      |      | 2001 <sup>c</sup> |      |      |
|------------------------------|-------------------|------|------|-------------------|------|------|-------------------|------|------|-------------------|------|------|
|                              | $\bar{x}$         | Min. | Max. | $\bar{x}$         | Min. | Max. | $\bar{x}$         | Min. | Max. | $\bar{x}$         | Min. | Max. |
| 001                          | 65                | 25   | 71   | 76                | 44   | 83   | 82                | 73   | 87   | 80                | 51   | 86   |
| 002                          | 59                | 25   | 66   | 74                | 54   | 79   | 80                | 70   | 84   | 78                | 51   | 84   |
| 105                          | 45                | 25   | 52   | 56                | 32   | 63   | 62                | 54   | 67   | 60                | 33   | 65   |
| Random<br>Nests <sup>d</sup> | 53                | 40   | 67   | 64                | 50   | 77   | 70                | 55   | 83   | 68                | 54   | 80   |

<sup>a</sup>  $n = 38$  days.

<sup>b</sup>  $n = 32$  days.

<sup>c</sup>  $n = 45$  days.

<sup>d</sup>  $n = 200$  nests randomly selected from all nest sites; noise modeling estimated levels at same nest sites each year using aircraft flight records from each year.

compensated for with corresponding changes in density in other locations. Changes in distribution might be reflected in modifications of habitat use; for example, preferred habitats in areas of severe disturbance might be abandoned for other habitats in low-disturbance settings. To investigate these and other changes to bird nesting locations in the Alpine project area, abundance and distribution of nests of large waterbirds were used in evaluations of differences among years and changes along gradients from potential disturbance sources to determine whether disturbance sources affected the location of nests. The nest searches in each year covered slightly different areas, but all included the same 10.6-km<sup>2</sup> area, hereafter referred to as the common search area. The search effort in the common search area varied among years; the number of search hours was highest in 1999 (429 hr) and lowest in 1996 (218 hr) (Table 31). After adjusting for the annual levels of search effort, the number of nests found was highest in 1997 (63 nests) and lowest in 2000 (37 nests) and fairly similar in 1996, 1999, and 2001 (46–58 nests) (unadjusted numbers presented in Appendix G2).

#### ALL SPECIES

In the common search area, the nests of 22 species (excluding ptarmigan, which were not recorded in 1998) were found between 1996 and 2001, but only 6 of these species nested in all 6

years (Table 31). The most species (17) were found in 1998 and the least were found in 1996 and 2000 (12). In each year, the most abundant large waterbird nesting in the common search area was the White-fronted Goose (22–28 nests, standardized for search effort; Figures 15–17). Other geese were less numerous in the area. One to 3 Brant nests were found annually in all but one year, and the first Canada Goose nest was recorded in the common search area in 2001 (Figure 18). A few Canada Goose nests had been recorded in the areas surrounding the common search area since 1998. Four to 5 pairs of Tundra Swans (numbers unadjusted for search effort, because they are relatively easy to detect and their numbers are not very sensitive to the amount of effort expended) nested within the common search area each year (Appendix G2).

The abundance of duck nests was highly variable during the study years (Table 31, Appendix G2). Northern Pintails and Long-tailed Ducks were the most common ducks found nesting within the common search area in all years (Figure 18, Table 31). Other species of duck nests were found in 1–4 of the 6 years. No nests of Spectacled or King eiders were found in the common search area, but just outside the common search area, Spectacled Eider nests were found in 3 of 6 years, and a King Eider nest was found in 1996. The number of duck nests increased in years with warm

Table 31. Numbers and densities, standardized by search effort, of nests of selected species found within the common search area in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Search area boundary is displayed in Figure 3. Unstandardized numbers and densities are presented in Appendix G2.

| Species                              | Common search Area (10.6 km <sup>2</sup> ) |      |                  |                  |                   |      |   |      |                  |                  |                  |      |
|--------------------------------------|--|------|------------------|------------------|-------------------|------|---|------|------------------|------------------|------------------|------|
|                                      | Standardized Number of Nests               |      |                  |                  |                   |      | Standardized Density (nests/km <sup>2</sup> ) |      |                  |                  |                  |      |
|                                      | 1996                                       | 1997 | 1998             | 1999             | 2000              | 2001 | 1996  | 1997 | 1998             | 1999             | 2000             | 2001 |
| Red-throated Loon                    | 1  | 4.0  | 1.5              | 1.0              | 0                 | 2.0  | 0.1   | 0.4  | 0.1              | 0.1              | 0                | 0.2  |
| Pacific Loon                         | 2  | 3.2  | 4.4              | 3.6              | 1.1               | 3.3  | 0.2   | 0.3  | 0.4              | 0.3              | 0.1              | 0.3  |
| Yellow-billed Loon                   | 1  | 0.8  | 0.7              | 0                | 0.6               | 0.7  | 0.1   | 0.1  | 0.1              | 0                | 0.1              | 0.1  |
| Red-necked Grebe                     | 0  | 2.4  | 1.5              | 1.0              | 0.6               | 1.3  | 0   | 0.2  | 0.1              | 0.1              | 0.1              | 0.1  |
| Greater White-fronted Goose          | 25   | 28.1 | 23.2             | 26.9             | 22.0 <sup>a</sup> | 21.9 | 2.4   | 2.7  | 2.2              | 2.5              | 2.1 <sup>a</sup> | 2.1  |
| Canada Goose                         | 0  | 0    | 0                | 0                | 0                 | 0.7  | 0   | 0    | 0                | 0                | 0                | 0.1  |
| Brant                                | 1  | 3.2  | 0.7              | 1.0 <sup>b</sup> | 0                 | 0.7  | 0.1   | 0.3  | 0.1              | 0.1 <sup>b</sup> | 0                | 0.1  |
| Tundra Swan                          | 5  | 3.2  | 3.6              | 2.0              | 2.3               | 3.3  | 0.5   | 0.3  | 0.3              | 0.2              | 0.2              | 0.3  |
| Northern Shoveler                    | 0  | 0    | 3.6 <sup>a</sup> | 0                | 0                 | 0.0  | 0   | 0    | 0.3 <sup>a</sup> | 0                | 0                | 0.0  |
| Northern Pintail                     | 2  | 3.2  | 5.1 <sup>a</sup> | 4.1 <sup>a</sup> | 2.8 <sup>a</sup>  | 2.7  | 0.2   | 0.3  | 0.5 <sup>a</sup> | 0.4 <sup>a</sup> | 0.3 <sup>a</sup> | 0.3  |
| Green-winged Teal                    | 1  | 0    | 0.7              | 1.0 <sup>a</sup> | 1.1 <sup>a</sup>  | 0.0  | 0.1   | 0    | 0.1              | 0.1 <sup>a</sup> | 0.1 <sup>a</sup> | 0.0  |
| Greater Scaup                        | 0  | 0.8  | 0.7              | 0                | 0                 | 0.7  | 0   | 0.1  | 0.1              | 0                | 0                | 0.1  |
| Lesser Scaup                         | 0  | 0    | 0.7              | 0                | 0                 | 0.0  | 0   | 0    | 0.1              | 0                | 0                | 0.0  |
| Unidentified scaup                   | 0  | 0    | 0                | 0.5 <sup>a</sup> | 0                 | 2.0  | 0   | 0    | 0                | <0.1             | 0                | 0.2  |
| Long-tailed Duck                     | 6  | 7.2  | 3.6 <sup>a</sup> | 2.5 <sup>a</sup> | 2.3 <sup>a</sup>  | 0.7  | 0.6   | 0.7  | 0.3 <sup>a</sup> | 0.2 <sup>a</sup> | 0.2 <sup>a</sup> | 0.1  |
| Unidentified duck                    | 0  | 0    | 2.2              | 1.0              | 0.6               | 0.0  | 0   | 0    | 0.2              | 0.1              | 0.1              | 0.0  |
| Willow Ptarmigan                     | 1  | 8.8  | nd               | 8.1              | 3.9               | 4.0  | 0.1   | 0.8  | nd               | 0.8              | 0.4              | 0.4  |
| Rock Ptarmigan                       | 0  | 0    | nd               | 0                | 0.6               | 0.7  | 0   | 0    | nd               | 0                | 0.1              | 0.1  |
| Unidentified ptarmigan               | 0  | 0    | nd               | 1.5              | 0.6               | 0.0  | 0   | 0    | nd               | 0.1              | 0.1              | 0.0  |
| Sandhill Crane                       | 0  | 0    | 0                | 0.5              | 0                 | 0.0  | 0   | 0    | 0                | 0                | 0                | 0.0  |
| Bar-tailed Godwit                    | 0  | 0    | 1.5              | 1.0              | 0                 | 0.7  | 0   | 0    | 0.1              | 0.1              | 0                | 0.1  |
| Common Snipe                         | 0  | 0.8  | 0                | 0                | 0.6               | 0.0  | 0   | 0.1  | 0                | 0                | 0.1              | 0.0  |
| Parasitic Jaeger                     | 1  | 0.8  | 1.5              | 1.0              | 1.1               | 1.3  | 0.1   | 0.1  | 0.1              | 0.1              | 0.1              | 0.1  |
| Long-tailed Jaeger                   | 1  | 0    | 0.7              | 0.5              | 0.6               | 0.7  | 0.1   | 0    | 0.1              | 0                | 0.1              | 0.1  |
| Glaucous Gull                        | 0  | 0.8  | 0                | 0                | 0                 | 0.7  | 0   | 0.1  | 0                | 0                | 0                | 0.1  |
| Sabine's Gull                        | 1  | 0    | 0                | 0                | 0                 | 0.0  | 0.1   | 0    | 0                | 0                | 0                | 0.0  |
| Arctic Tern                          | 0  | 4.0  | 2.2              | 3.0              | 1.1               | 2.7  | 0   | 0.4  | 0.2              | 0.3              | 0.1              | 0.3  |
| Search Hours                         | 218  | 271  | 300              | 429              | 387               | 329  |   |      |                  |                  |                  |      |
| Adjusting Ratio <sup>c</sup>         | 1.0  | 0.8  | 0.7              | 0.5              | 0.6               | 0.7  | 1.0   | 0.8  | 0.7              | 0.5              | 0.6              | 0.7  |
| Standardized Total <sup>de</sup>     | 47   | 62.7 | 58.1             | 50.8             | 36.7              | 45.7 | 4.4   | 5.9  | 5.5              | 4.8              | 3.5              | 4.3  |
| Total Number of Species <sup>e</sup> | 12   | 14   | 17               | 14               | 12                | 16   |   |      |                  |                  |                  |      |

<sup>a</sup> Includes nests identified from feather and down samples.

<sup>b</sup> Includes nest identified from down and nest characteristics.

<sup>c</sup> Ratio<sub>year</sub> = search hours<sub>1996</sub> / search hours<sub>year</sub>.

<sup>d</sup> Standardized total<sub>year</sub> = adjusting ratio<sub>year</sub> · total nests<sub>year</sub>.

<sup>e</sup> Does not include ptarmigan or unidentified ducks.



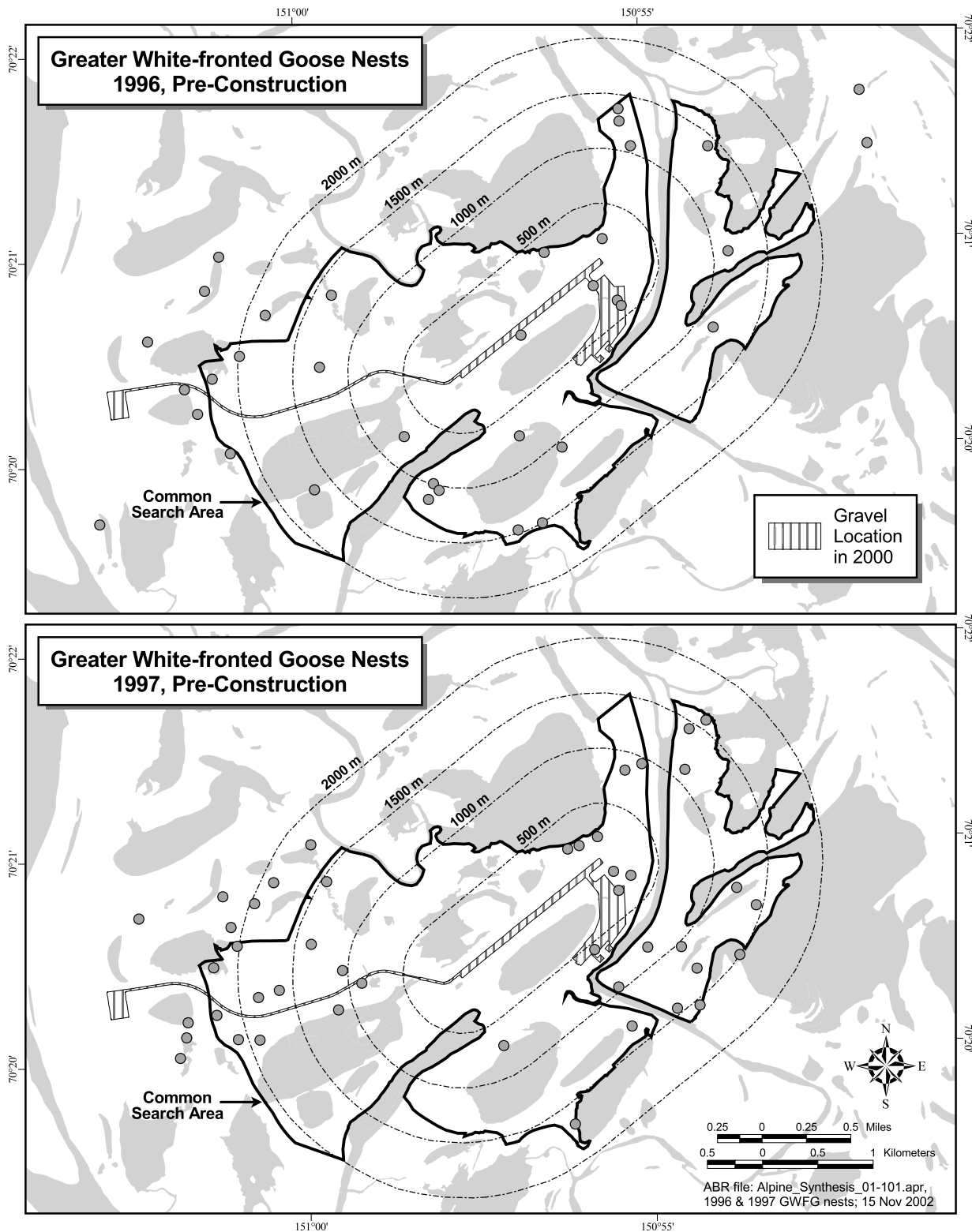


Figure 15. Locations of Greater White-fronted Goose nests during pre-construction years (1996 and 1997) in the Alpine project area, Colville River Delta, Alaska. The location of the future project area is striped.

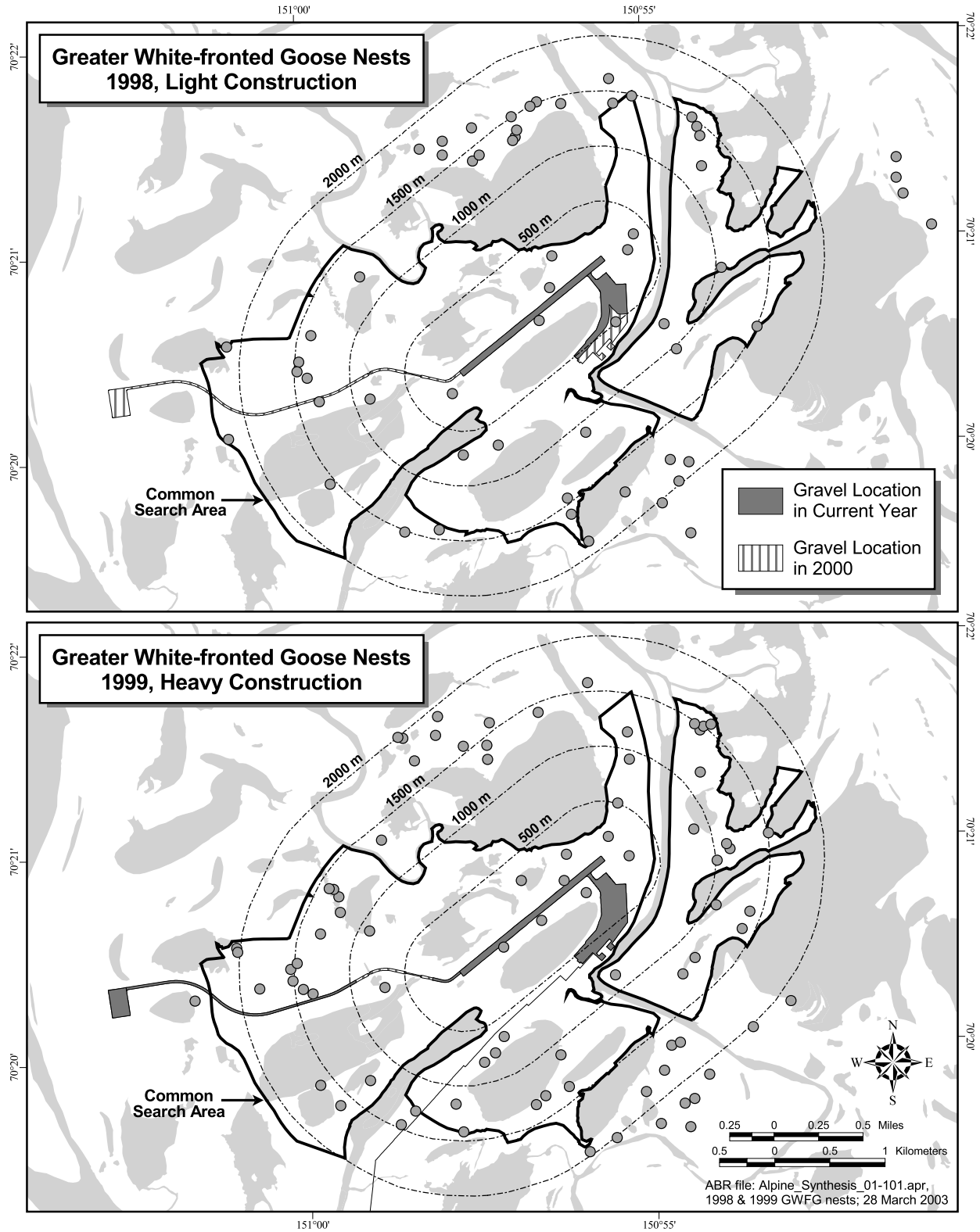


Figure 16. Locations of Greater White-fronted Goose nests during light construction (1998) and the first year of heavy construction (1999) in the Alpine project area, Colville River Delta, Alaska.

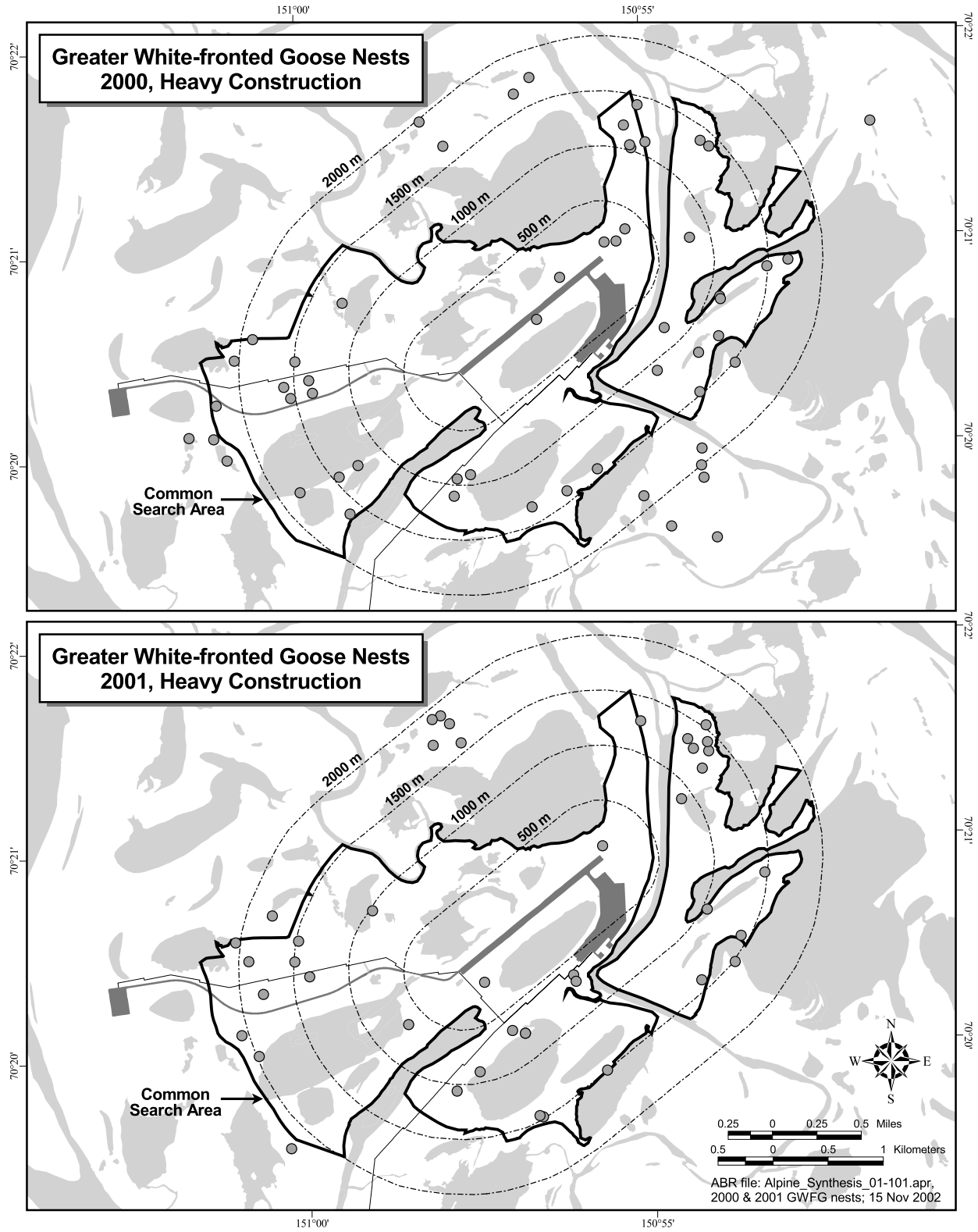


Figure 17. Locations of Greater White-fronted Goose nests during heavy-construction years (2000 and 2001) in the Alpine project area, Colville River Delta, Alaska.

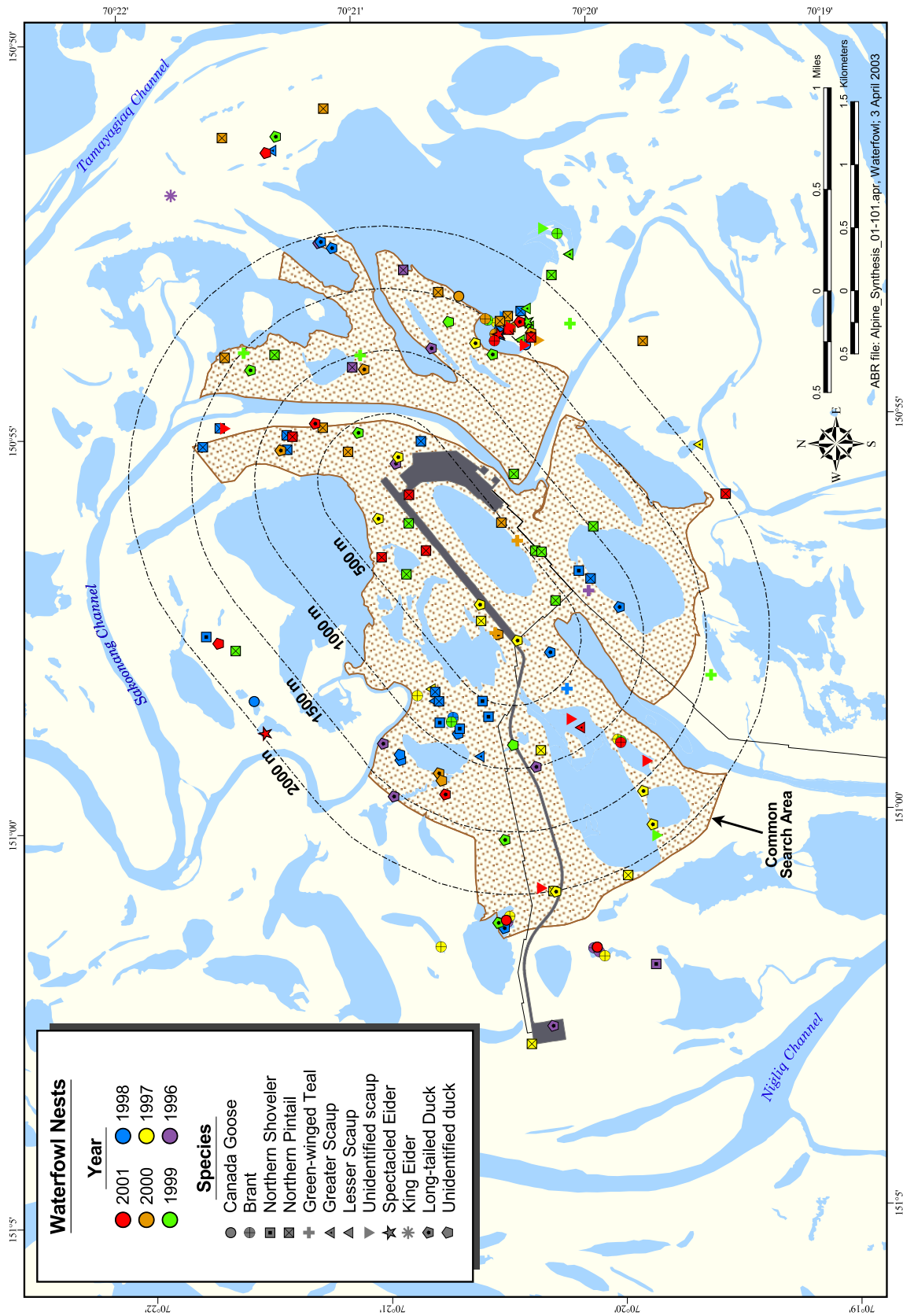


Figure 18. Locations of nests of geese and ducks in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Stippled area is the common search area. Nests found on ground searches.

May temperatures (arrival thawing degree-days,  $r = 0.8$ ,  $P = 0.07$ ) and earlier river breakup ( $r = -0.6$ ,  $P = 0.23$ ), but decreased with increases in noise, aircraft, vehicles, and pedestrians ( $r \leq -0.8$ ,  $P \leq 0.1$ ; Table 29). As mentioned earlier, levels of noise and human activity were intercorrelated with weather conditions. Large annual fluctuations in the numbers of ducks are common on the Arctic Coastal Plain (Derksen and Eldridge 1980, Malleck 2001). Given the inherent natural variation in the numbers of ducks and the likelihood that weather conditions on breeding grounds and migration paths affect their nesting effort, we did not interpret the correlation of human activity with abundance of duck nests to indicate a causal relationship.

Three species of loon and one species of grebe nested in low numbers in the common search area. Nests of Pacific Loons (2–7 nests, unadjusted for search effort) were found each year, Red-throated Loons nests (1–5 nests) were found in 5 of 6 years, and 1–2 nests of Yellow-billed Loons were found each year (Figures 19 and 20, Appendix G2), including Yellow-billed Loon nests found after nest searching in 1997–2000. In 1999, the first nest of a Sandhill Crane was recorded. One to 2 nests (adjusted for search effort) of Red-necked Grebes were found 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 discovery of a nest in the southern part of the delta in 1996 (Johnson et al. 1997), we were aware of only one other record of a Red-necked Grebe nesting in the region. In 1949, a nest was found south of the delta, at the junction of the Itkillik and Colville rivers (Nelson 1953).

Willow Ptarmigan were common in all years and had the second highest number (4–9) of nests in the common search area, whereas nests of Rock Ptarmigan were infrequent in the common search area. Ptarmigan nests were difficult to detect and recorded inconsistently in the early years of the study, however, so they were not included in any analyses.

The abundance of nests of avian predators was relatively constant among years (Table 31, Appendix G2), with the exception of Common

Raven nests. One to 2 Parasitic Jaeger nests (unadjusted for search effort) were found every year in the common search area along with a single Long-tailed Jaeger nest in most years (Figure 19). A Glaucous Gull nest was recorded in only 2 years (1997 and 2001). Common Ravens were first attracted to the Alpine project area in 1998, when they roosted in temporary buildings, but nesting was not confirmed. Ravens again were observed regularly in 1999, but were not known to nest in the Alpine project area until 2000. In 2000, a pair nested on a drill-rig tower on CD-1 (S. Donnelly, pers. comm.). In spring of 2001, the drill-rig was moved to CD-2, where a pair of ravens again built a nest. The nests in both years fledged young. Ravens were the only nest predators that increased with the construction of the Alpine project, although the effect of ravens on nesting birds in the the study area was not as substantial as other predators, based on evidence from video monitoring of nests and observations of predation events (see Nest Predation section).

For most species, Patterned Wet Meadow was the habitat used most frequently for nesting between 1996 and 2001 (57% of all nests; Appendix G3). In contrast, no other habitat was occupied by >10% of all nests. Moist Sedge–Shrub Willow and Nonpatterned Wet Meadow were the next most frequently used habitats with each containing 9–10% of all nests. Deep Open Water with Islands or Polygonized Margins and Tapped Lakes with High-water Connection were the most frequently used aquatic habitats (4–8% of all nests).

The effects of disturbance on the distribution of all nests (not including ptarmigan, passerines, or small shorebirds) were evaluated by analyzing changes among years in distance of nests to components of the Alpine facility and changes in noise exposure at nest sites. The distribution of nests was analyzed for relationships to 3 areas of potential disturbance: the airstrip, the nearest gravel (pad, road, or airstrip), and the airplane flight path. Mean distances of nests to either the airstrip or flight path did not differ significantly among years ( $P \geq 0.55$ ; Table 32). However, the distances of nests to gravel did differ significantly ( $P = 0.02$ ). Nests in 1997 (a pre-construction year) were located closer to gravel (in this case, the future footprint) than in any other year (Table 32).

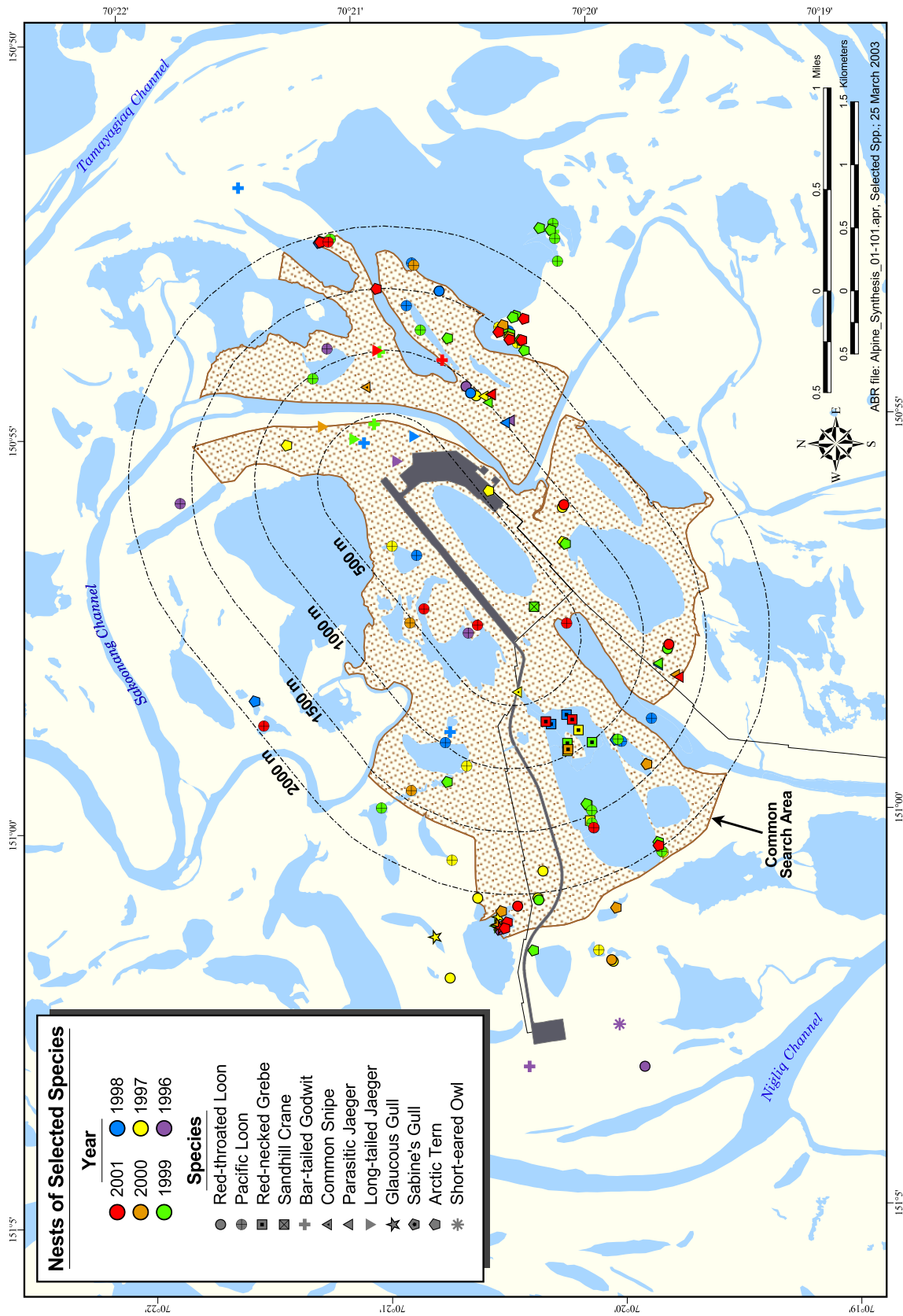


Figure 19. Locations of nests of loons and other birds in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Stippled area is the common search area.

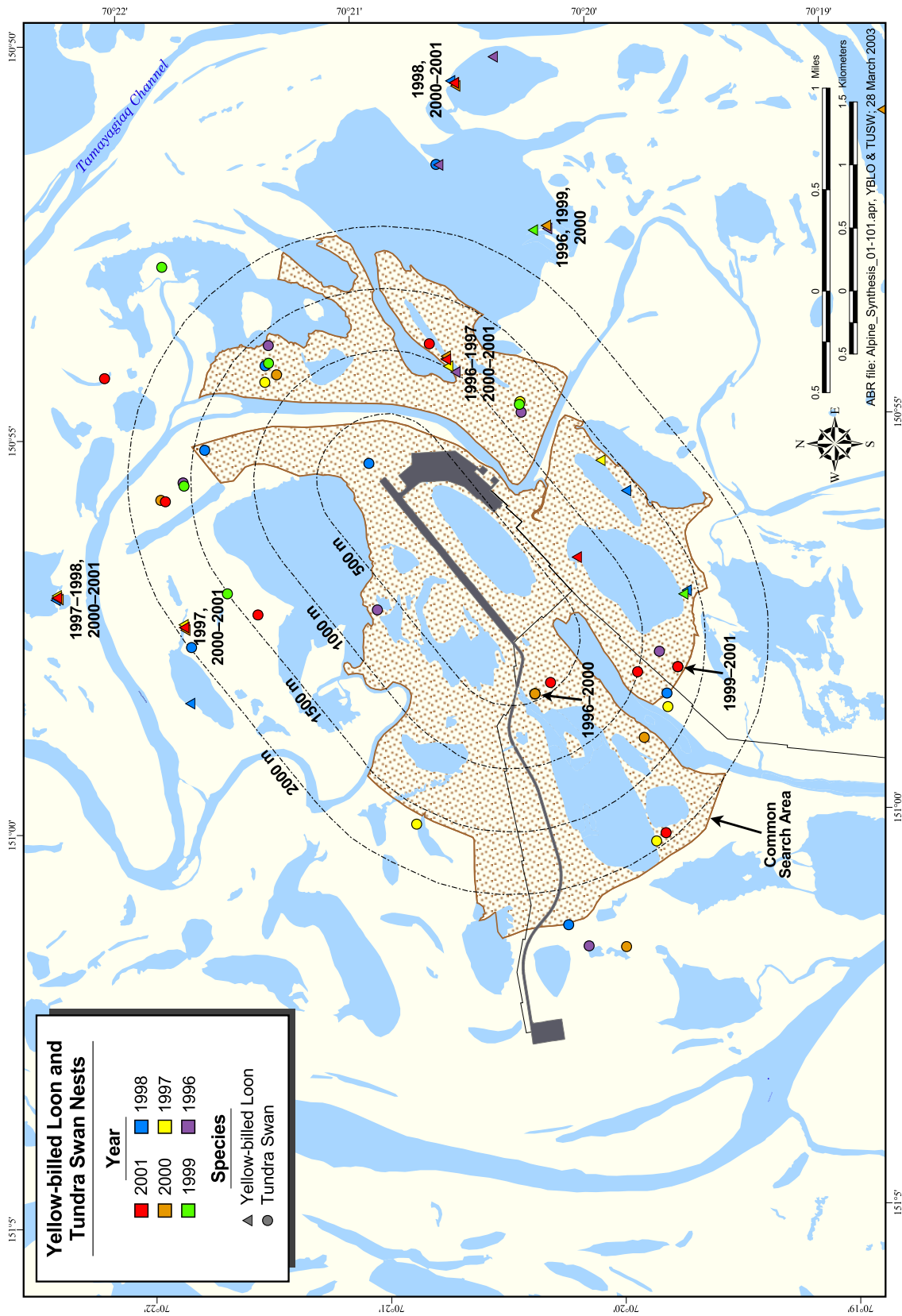


Figure 20. Locations of Tundra Swan and Yellow-billed Loon nests in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Nests were found on aerial and ground surveys. Stippled area is the common search area.

Table 32. Comparison among years of mean distances of all nests (excluding ptarmigan, shorebirds, and passerines) from facility features (airstrip, nearest gravel [pad, road or airstrip], and the flight path of planes) in the common search area of the Alpine project area, Colville River Delta, Alaska, 1996–2001.

| Feature/Year          | Distance (m) |      |          | ANOVA Statistics |          |                 |
|-----------------------|--------------|------|----------|------------------|----------|-----------------|
|                       | $\bar{x}$    | SE   | <i>n</i> | df               | <i>F</i> | <i>P</i> -value |
| <b>Airstrip</b>       |              |      |          |                  |          |                 |
| 1996                  | 1,064        | 84.0 | 47       |                  |          |                 |
| 1997                  | 1,173        | 71.9 | 78       |                  |          |                 |
| 1998                  | 1,055        | 61.1 | 80       |                  |          |                 |
| 1999                  | 1,107        | 51.5 | 100      |                  |          |                 |
| 2000                  | 1,100        | 64.3 | 65       |                  |          |                 |
| 2001                  | 1,207        | 70.6 | 69       |                  |          |                 |
| All Years             | 1,119        | 26.8 | 439      | 5                | 0.81     | 0.55            |
| <b>Nearest Gravel</b> |              |      |          |                  |          |                 |
| 1996                  | 699          | 70.7 | 47       |                  |          |                 |
| 1997                  | 478          | 43.2 | 78       |                  |          |                 |
| 1998                  | 687          | 56.5 | 80       |                  |          |                 |
| 1999                  | 691          | 43.9 | 100      |                  |          |                 |
| 2000                  | 686          | 52.7 | 65       |                  |          |                 |
| 2001                  | 683          | 54.8 | 69       |                  |          |                 |
| All Years             | 651          | 21.6 | 439      | 5                | 2.84     | 0.02            |
| <b>Flight Path</b>    |              |      |          |                  |          |                 |
| 1996                  | 740          | 67.5 | 47       |                  |          |                 |
| 1997                  | 694          | 54.2 | 78       |                  |          |                 |
| 1998                  | 696          | 49.6 | 80       |                  |          |                 |
| 1999                  | 643          | 43.6 | 100      |                  |          |                 |
| 2000                  | 682          | 57.3 | 65       |                  |          |                 |
| 2001                  | 694          | 57.1 | 69       |                  |          |                 |
| All Years             | 686          | 21.8 | 439      | 5                | 0.32     | 0.90            |

However, in 1996, the other pre-construction year, distance to gravel was similar to that in construction years ( $P = 1.00$ ). The lack of a significant difference or trend over time in distance from the airstrip or flight path suggests that nest distribution for all nests has not changed overall relative to these potential disturbance features in the Alpine project area. Distance of nests to gravel undoubtedly changed from pre-construction to construction as nest sites that occupied the final gravel footprint were eliminated (Figure 18). However, the lack of trend in distance of nests to gravel from the other pre-construction year (1996) to light construction (1998) to heavy construction

(1999–2001) indicates little or no change in distribution occurred after gravel was deposited, despite varying levels of human activity.

Noise exposure levels were evaluated for the effects of changing nest distributions among years. If nesting birds are sensitive to noise, one response might be to locate nests in areas with lower noise exposures. Noise levels were compared among adjacent pairs of years using each year's distribution of nests with the first of the 2 year's noise conditions, to test for a change in mean noise level for all nests. When 1998 noise levels ( $L_{eq}$ ) were applied by the noise model to the nest distributions in 1998 and 1999, the mean difference



in noise level was 0.18 dBA ( $t = 0.24$ ,  $df = 230$ ,  $P = 0.81$ ). That is, the distribution of nests in 1999 did not significantly lower the overall noise exposure from that calculated for the nest distribution in 1998. The mean difference in noise level between 1999 and 2000 nest locations using 1999 noise conditions was 0.40 dBA ( $t = 0.53$ ,  $df = 203$ ,  $P = 0.60$ ). Similarly, the mean difference in noise level between 2000 and 2001 nest locations under 2000 noise conditions (the year with the highest average noise levels) was 0.68 dBA ( $t = 0.85$ ,  $df = 163$ ,  $P = 0.40$ ). Thus, the changes in distribution of all nests from one year to the next did not reduce the mean noise exposure of nests a significant amount (less than 1 dBA in all cases) from the exposure experienced in each previous year.

Because the potential response of nesting pairs to noise (i.e., moving nests away from noise sources between years) may have taken more than one year to occur, all years were evaluated against each other, using the noise conditions from the year with the highest noise levels (2000, when aircraft traffic was most frequent) as the reference condition. If nesting birds in the common search area responded to the noise from aircraft by nesting in subsequent years in locations with lower noise levels, the nest locations in 2000 and 2001 should have the lowest overall estimated noise exposure, because those years had the greatest inducement for birds to avoid high-noise locations. Similarly, 1998 nest locations should have the highest overall estimated noise exposure when modeled with 2000 noise conditions, because in 1998 actual noise exposure was much lower than in 2000 (mean = 17 dBA lower, Table 30), which would have allowed birds to nest nearer the airstrip with less noise exposure. Comparisons among each year's distribution of nests in the common search area revealed no significant differences in maximal noise levels ( $L_{max}$ ) (ANOVA;  $F = 0.38$ ;  $df = 3$ , 393;  $P = 0.76$ ) or in annual noise level ( $L_{eq}$ ) (ANOVA;  $F = 0.48$ ;  $df = 3$ , 393;  $P = 0.48$ ). The highest annual noise levels were estimated for the distribution of nests in 1999 (mean = 68.2 dBA,  $SE = 0.49$ ,  $n = 123$  nests), and the lowest were in 2001 (mean = 67.1 dBA,  $SE = 0.57$ ,  $n = 83$  nests), a mean difference of 1.1 dBA. Therefore, the annual distribution of nests did not appear to change in response to estimated noise levels in the

project area, because average noise exposures at those nests did not significantly differ among years.

#### GREATER WHITE-FRONTED GOOSE

White-fronted Geese were the most common bird nesting both within the Alpine project area and the common search area every year, and their abundance and importance as a species used for subsistence are reasons we focused on this species in the analysis of disturbance effects. Numbers within the common search area ranged between 22 and 28 nests (adjusted for search effort; 25–53 actual nests) each year (Figures 15–17, Table 31, Appendix G2). The highest number of nests (adjusted for search effort) was found in 1997 and the lowest was in 2001 (Table 31). Slightly fewer nests were found in 1999 than in 1997. Similar numbers were found in 1998, 2000, and 2001. Thus, the differences among years did not clearly reflect a disturbance effect, because the first heavy-construction year (1999) had more nests than a pre-construction year (1996), and the light-construction year (1998) had similar numbers to the later heavy-construction years (2000 and 2001). The lower number of nests found in both 2000 and 2001 coincided with cooler spring temperatures in late May, late river breakup, and moderate-to-severe flooding, and high levels of human activity (see Conditions in the Study Area). The annual number of White-fronted Goose nests found during our study period was negatively correlated with the date of peak river breakup ( $r = -0.6$ ,  $P = 0.2$ ), with the number of aircraft and annual noise levels (both  $r = -0.8$ ,  $P = 0.1$ ), and with the number of vehicles and pedestrians (both  $r = -0.9$ ,  $P = 0.04$ ; Table 29). Thus, fewer nests were found in years with late breakups and high levels of aircraft, vehicle, and pedestrian traffic at the airstrip. Another probable negative influence was the extent of flooding in the Alpine area in 2000 and 2001, which certainly delayed nesting for White-fronted Geese and may have reduced the numbers that nested in the study area. Because the relationship of nest abundance with human activity was confounded by the possible effects of weather, and the pattern of nest abundance was not consistent in pre- and light-construction years, we interpreted the decline in White-fronted Goose nest

abundance during heavy-construction years as equivocal evidence of a disturbance effect.

One possible effect of disturbance from the airstrip on geese would be a change in the habitats used for nesting, if geese nested in different locations during the heavy-construction years and their preferred habitats were limited in availability. Over 6 years, White-fronted Geese nested in 7 of 17 available habitats in the common search area (Table 33). Two habitats, Patterned Wet Meadow and Aquatic Sedge with Deep Polygons, were preferred. Most nests (75% of 217 nests) in all years were found in Patterned Wet Meadow, but Moist Sedge–Shrub Meadow (14% of all nests) and Aquatic Sedge with Deep Polygons (7%) also were used frequently. Habitat use did not appear to vary between pre-construction and construction periods (Table 9, Appendix G4). Patterned Wet Meadow was preferred each year, and, although the lowest use (64%) of this habitat occurred in 1999 (a heavy-construction year), in subsequent years use of this habitat returned to  $\geq 72\%$ . Aquatic Sedge with Deep Polygons was preferred in 3 of 6 years, including both pre-construction and heavy-construction years. The proportion of nests in preferred and non-preferred habitats did not differ significantly among years ( $\chi^2 = 5.59$ ,  $df = 5$ ,  $P = 0.31$ ). The only year in which the proportion of nests in preferred habitats (72%) was less than expected (81%) was 1999, but in the following years use of preferred habitats returned to expected or higher than expected levels (Table 34). Therefore, use of preferred habitats did not vary substantially, and any effect on habitat use was transitory and not significant. Preference for nest microsites was not tested, but most nests (77% of all nests) occurred on elevated microsites (polygon rims, mounds, or small hummocks) similar to the nesting sites reported by Simpson et al. (1982). Nests ranged from  $<1$  to 500 m (mean = 83.4 m,  $n = 125$ ) from the nearest permanent waterbody.

To evaluate the effect of construction-related disturbance on nest distribution, we evaluated annual changes in the distance of nests to facility features. If nesting pairs of geese had strong aversions to human activity and noise, one possible response would be to nest in locations that reduced their exposure, presumably by nesting farther from areas of human activity. Annual patterns in the distance of White-fronted Goose nests from the

airstrip, nearest gravel (road, pad, or airstrip), or flight path (Table 35) did not clearly indicate whether these potential sources of disturbance affected the location of nests. The distances of nests from each of these 3 facility features did not differ significantly among years (all 3 tests,  $P \geq 0.43$ ). However, regressions of the distance of nests from the airstrip ( $r^2 = 0.006$ ,  $F = 1.26$ ,  $df = 1$ , 216,  $P = 0.26$ ) and from nearest gravel ( $r^2 = 0.008$ ,  $F = 1.80$ ,  $df = 1$ , 216,  $P = 0.18$ ) as a function of year showed that distance increased slightly from pre-construction to heavy-construction years, suggesting a weak trend, although none of the regressions were significant nor did they explain much of the variation. No annual trend was apparent in the regression of year and distance of nests to the flight path ( $r^2 < 0.001$ ,  $F = 0.00$ ,  $df = 1$ , 216,  $P = 0.99$ ), suggesting that aircraft overflights were less disturbing than activities on the pads. These analyses of nest distances evaluate changes in average locations within the common search area (10.6 km<sup>2</sup>), which extends beyond 2,000 m from the airstrip in some areas (Figure 17). Because White-fronted Geese may not be responding to activities at the airstrip and pads at that broad scale, we investigated potential distributional changes at finer scales.

As a preliminary assessment of potential shifts in the distribution of White-fronted Goose nests over 6 years, we analyzed the proportion of nests in 500-m zones around the airstrip, which were standardized for the amount of habitat available. The number of nests found within the most-used habitats (Patterned Wet Meadow, Aquatic Sedge with Deep Polygons, and Moist Sedge–Shrub Meadow) in 4 distance buffers (500 m each) around the airstrip were examined. The lowest density (0.6 nests/km<sup>2</sup>) occurred in 2001 in the 0–500-m buffer and the highest density (6.4 nests/km<sup>2</sup>) in 2000 in the 1,000–1,500-m buffer (Figure 21). Annual numbers of nests in the distance buffers did not significantly differ from expected numbers (expected numbers based on the proportion of area in the 3 combined habitats in each buffer) ( $P > 0.13$ ) in any year except for 2000 ( $P = 0.02$ ). The difference among buffers in number of nests in 1999 was marginally non-significant ( $P = 0.07$ ; Table 36). In both 1999 and 2000, the number of nests that occurred in the 1,000–1,500-m buffer was higher than expected

Table 33. Habitat selection by Greater White-fronted Geese during nesting in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Only nests found within the common search area are included.

| Habitat  | Area (km <sup>2</sup> ) | No. of Nests | Use (%) | Availability (%) | Monte Carlo Results <sup>a</sup> |
|--|-------------------------|--------------|---------|------------------|----------------------------------|
| Tapped Lake w/ Low-water Connection                  | 0.28                    | 0            | 0       | 2.6              | avoid                            |
| Tapped Lake w/ High-water Connection                 | 0.80                    | 0            | 0       | 7.6              | avoid                            |
| Salt Marsh   | 0.62                    | 1            | 0.5     | 5.8              | avoid                            |
| Deep Open Water w/o Islands                          | 0.90                    | 0            | 0       | 8.5              | avoid                            |
| Deep Open Water w/ Islands or Polygonized Margins    | 0.10                    | 1            | 0.5     | 0.9              | ns                               |
| Shallow Open Water w/o Islands                       | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Shallow Open Water w/ Islands or Polygonized Margins | 0.01                    | 0            | 0       | 0.1              | ns                               |
| River or Stream                                      | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Aquatic Sedge Marsh                                  | 0.08                    | 0            | 0       | 0.8              | ns                               |
| Aquatic Sedge w/ Deep Polygons                       | 0.12                    | 14           | 6.5     | 1.1              | prefer                           |
| Aquatic Grass Marsh                                  | 0.10                    | 0            | 0       | 1.0              | ns                               |
| Nonpatterned Wet Meadow                              | 0.96                    | 6            | 2.8     | 9.0              | avoid                            |
| Patterned Wet Meadow                                 | 4.39                    | 162          | 74.7    | 41.2             | prefer                           |
| Moist Sedge–Shrub Meadow                             | 1.16                    | 30           | 13.8    | 10.9             | ns                               |
| Riverine or Upland Shrub                             | 0.63                    | 3            | 1.4     | 5.9              | ns                               |
| Barrens (riverine, eolian, lacustrine)               | 0.18                    | 0            | 0       | 1.7              | ns                               |
| Artificial (water, fill, peat road)                  | 0.31                    | 0            | 0       | 2.9              | ns                               |
| Total  | 10.64                   | 217          | 100     | 100              |                                  |

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

Table 34. Comparison of annual frequency of use with availability of preferred habitats (Patterned Wet Meadow and Aquatic Sedge with Deep Polygons) used by nesting Greater White-fronted Geese in the common search area, Alpine project area, Colville River Delta, Alaska, 1996–2001. A goodness-of-fit test was conducted using expected frequencies calculated from the availability of each habitat category.

| Year      | Observed/<br>Expected | % Nests in each Habitat |               | Total<br>Nests | Goodness of Fit |    |          |
|-----------|-----------------------|-------------------------|---------------|----------------|-----------------|----|----------|
|           |                       | Preferred               | Non-preferred |                | $\chi^2$        | df | <i>P</i> |
| 1996      | Observed              | 80                      | 20            | 25             |                 |    |          |
| 1997      | Observed              | 86                      | 14            | 35             |                 |    |          |
| 1998      | Observed              | 84                      | 16            | 32             |                 |    |          |
| 1999      | Observed              | 72                      | 28            | 53             |                 |    |          |
| 2000      | Observed              | 80                      | 20            | 39             |                 |    |          |
| 2001      | Observed              | 91                      | 9             | 33             |                 |    |          |
| All Years | Expected              | 81                      | 19            | 217            | 5.59            | 5  | 0.31     |
|           | No. Nests             | 176                     | 41            | 217            |                 |    |          |

Table 35. Comparison among years of mean distances of Greater White-fronted Goose nests from the facility features (airstrip, nearest gravel [pad, road, airstrip], and the flight path of planes) in the common search area of the Alpine project area, Colville River Delta, Alaska.

| Feature/Year   | Distance (m) |       |          | ANOVA |          |                 |
|----------------|--------------|-------|----------|-------|----------|-----------------|
|                | $\bar{x}$    | SE    | <i>n</i> | df    | <i>F</i> | <i>P</i> -value |
| Airstrip       |              |       |          |       |          |                 |
| 1996           | 1,040        | 113.8 | 25       |       |          |                 |
| 1997           | 1,173        | 101.7 | 35       |       |          |                 |
| 1998           | 1,110        | 102.6 | 32       |       |          |                 |
| 1999           | 1,095        | 69.8  | 53       |       |          |                 |
| 2000           | 1,201        | 81.9  | 39       |       |          |                 |
| 2001           | 1,221        | 85.6  | 33       |       |          |                 |
| All Years      | 1,141        | 40.2  | 217      | 5     | 0.54     | 0.75            |
| Nearest Gravel |              |       |          |       |          |                 |
| 1996           | 714          | 97.2  | 25       |       |          |                 |
| 1997           | 534          | 77.2  | 35       |       |          |                 |
| 1998           | 664          | 91.0  | 32       |       |          |                 |
| 1999           | 697          | 60.7  | 53       |       |          |                 |
| 2000           | 701          | 70.8  | 39       |       |          |                 |
| 2001           | 764          | 80.6  | 33       |       |          |                 |
| All Years      | 678          | 31.5  | 217      | 5     | 0.97     | 0.43            |
| Flight Path    |              |       |          |       |          |                 |
| 1996           | 715          | 92.3  | 25       |       |          |                 |
| 1997           | 811          | 77.0  | 35       |       |          |                 |
| 1998           | 727          | 90.9  | 32       |       |          |                 |
| 1999           | 723          | 60.2  | 53       |       |          |                 |
| 2000           | 754          | 74.5  | 39       |       |          |                 |
| 2001           | 763          | 80.8  | 33       |       |          |                 |
| All Years      | 749          | 31.2  | 217      | 5     | 0.21     | 0.96            |

( $P < 0.05$ ), and in 2000, the number of nests in the 500–1,000-m buffer was lower than expected ( $P < 0.05$ ). The number of nests that occurred within the 0–500-m buffer in 2001 was lower than in any previous year, but the overall test was not significant ( $P = 0.13$ ), indicating that the differences among buffers were not substantial. This analysis suggests there was a shift in the distribution of White-fronted Goose nests from what was proportional to the area in most-used habitats among distance buffers during pre- and light-construction years (1996–1998) to a distribution away from the airstrip in heavy-construction years. Although the difference in proportions of nests among buffers was not

significant in 2001, the pattern among buffers was consistent with the pattern observed in 1999 and 2000.

To further investigate the scale of change in distribution of nests around the airstrip, the cumulative frequency (percent) of White-fronted Goose nests within 100-m bands of the airstrip in the pre-construction period (1996 and 1997 combined) was plotted and compared against the cumulative frequencies for 1998 and the years of heavy construction (1999–2001; Figure 22). The cumulative frequency distribution of nests around the airstrip illustrated that the percentage of nests between ~300 m and ~700 m of the airstrip was lower in the heavy-construction years than during

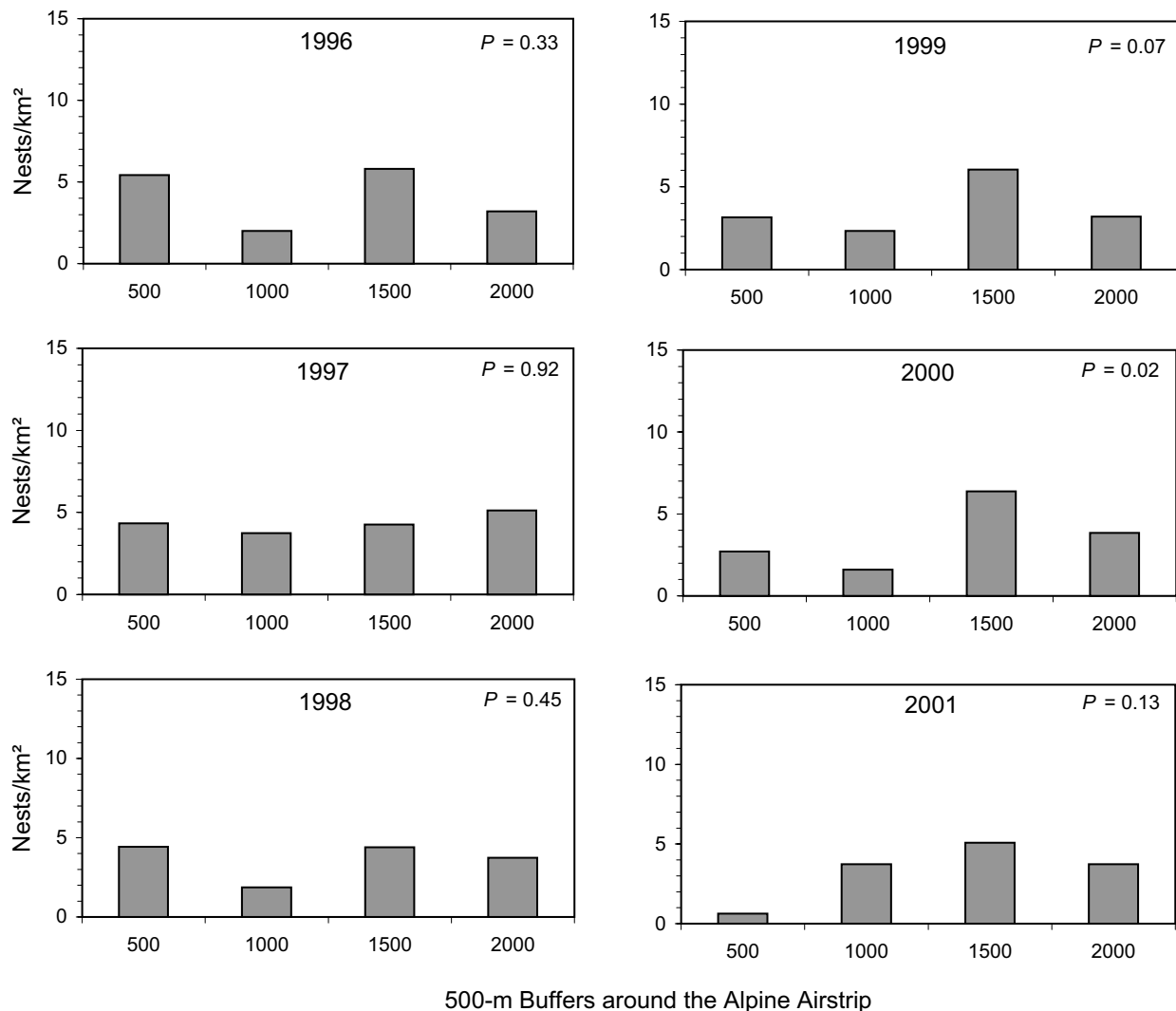


Figure 21. Densities (adjusted for search effort) of Greater White-fronted Goose nests in buffers around the airstrip in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Density was calculated for the area in the 3 most used habitats (Patterned Wet Meadow, Aquatic Sedge with Deep Polygons, and Moist Sedge–Shrub Meadow). P-values are for goodness-of-fit tests of the proportion of nests in the 3 habitats in each buffer with the proportion expected.

pre-construction years (Figure 22). The cumulative frequency distribution in 1998 appeared to match that of the pre-construction years. In each of the heavy-construction years, a lower cumulative percentage of nests occurred in the region  $\leq 600$  m of the airstrip than in the pre-construction period, but only in 2001 did the difference in distribution approach significance ( $\chi^2 = 4.07$ ,  $df = 3$ ,  $P = 0.07$ ).

To investigate whether differences among years, levels of disturbance within the study area, or habitat were affecting densities of White-fronted Goose nests, we calculated a measure of density

for each nest site. Nearest-neighbor distances between nests were calculated each year as continuous measures of distribution pattern and nest density (low nearest-neighbor distances are associated with high densities of nests). Nearest-neighbor measurements indicated that the distribution of nests each year was clumped, not random or uniform ( $R \leq 0.0001$ ,  $-13.93 \leq Z \leq -9.57$ ,  $P < 0.0001$ ; a random pattern would have  $R = 1.0$ ). Nearest-neighbor distances averaged 270 m for all nests  $\leq 2,000$  m from the airstrip ( $n = 204$  nests) and were lowest in 1999, when nest numbers (unadjusted for search effort) and search effort

Table 36. Comparison of the number of nests of Greater White-fronted Geese found in the most-used habitats among distance buffers around the airstrip, Alpine project area, Colville River Delta, Alaska. Only nests found within the common search area are included. The combined area of the 3 most-used habitats (Patterned Wet Meadow, Aquatic Sedge with Deep Polygons, and Moist Sedge–Shrub Meadow) was used to calculate expected values.

| Year/Nest Category               | Distance Buffers (m) |           |             |             | Goodness of Fit |          |
|----------------------------------|----------------------|-----------|-------------|-------------|-----------------|----------|
|                                  | 0–500                | 500–1,000 | 1,000–1,500 | 1,500–2,000 | $\chi^2$        | <i>P</i> |
| 1996                             |                      |           |             |             |                 |          |
| Observed Nests                   | 6                    | 3         | 12          | 3           |                 |          |
| Expected Nests                   | 4.8                  | 6.5       | 8.9         | 3.8         |                 |          |
| Pairwise Comparison <sup>a</sup> | ns                   | ns        | ns          | ns          | 3.45            | 0.33     |
| 1997                             |                      |           |             |             |                 |          |
| Observed Nests                   | 6                    | 7         | 11          | 6           |                 |          |
| Expected Nests                   | 6                    | 8.1       | 11.1        | 4.8         |                 |          |
| Pairwise Comparison <sup>a</sup> | ns                   | ns        | ns          | ns          | 0.45            | 0.92     |
| 1998                             |                      |           |             |             |                 |          |
| Observed Nests                   | 7                    | 4         | 13          | 5           |                 |          |
| Expected Nests                   | 5.8                  | 7.8       | 10.7        | 4.6         |                 |          |
| Pairwise Comparison <sup>a</sup> | ns                   | ns        | ns          | ns          | 2.63            | 0.45     |
| 1999                             |                      |           |             |             |                 |          |
| Observed Nests                   | 7                    | 7         | 25          | 6           |                 |          |
| Expected Nests                   | 9                    | 12.2      | 16.7        | 7.2         |                 |          |
| Pairwise Comparison <sup>a</sup> | ns                   | ns        | +           | ns          | 7.01            | 0.07     |
| 2000                             |                      |           |             |             |                 |          |
| Observed Nests                   | 5                    | 4         | 22          | 6           |                 |          |
| Expected Nests                   | 7.4                  | 1.0       | 13.7        | 5.9         |                 |          |
| Pairwise Comparison <sup>a</sup> | ns                   | –         | +           | ns          | 9.42            | 0.02     |
| 2001                             |                      |           |             |             |                 |          |
| Observed Nests                   | 1                    | 8         | 15          | 5           |                 |          |
| Expected Nests                   | 5.8                  | 7.8       | 10.7        | 4.6         |                 |          |
| Pairwise Comparison <sup>a</sup> | –                    | ns        | ns          | ns          | 5.7             | 0.13     |

<sup>a</sup> Pairwise comparison is the difference between the observed and expected nests. ns = not significant, “+” = observed nests > expected nests, “–” = observed nests < expected nests; significance at  $\alpha = 0.05$ ; Bonferroni adjusted.

were highest (Appendix G2). Analysis of variance was used to evaluate the effects of distance from the airstrip or nearest gravel (each used in separate models and collapsed into 500-m buffers), habitat (collapsed into 2 categories—the 3 most used habitats vs. all other habitats), and search effort (varied by year) on nearest-neighbor distance (Table 37). Because levels of search effort were thought to be related to the number of nests found and, therefore, nest density and nearest neighbor distances, we used the annual levels of search

effort as a covariate in these analyses rather than year as a factor. However, the analysis was conducted separately with year or effort as covariates, and the results were essentially the same for both. All two-way interactions were non-significant ( $P \geq 0.16$ ), but the interaction of airstrip distance and search effort approached significance ( $P = 0.16$ ) indicating the possibility that the relationship between airstrip distance and nearest-neighbor distances varied at different levels of search effort (Table 37). Final models

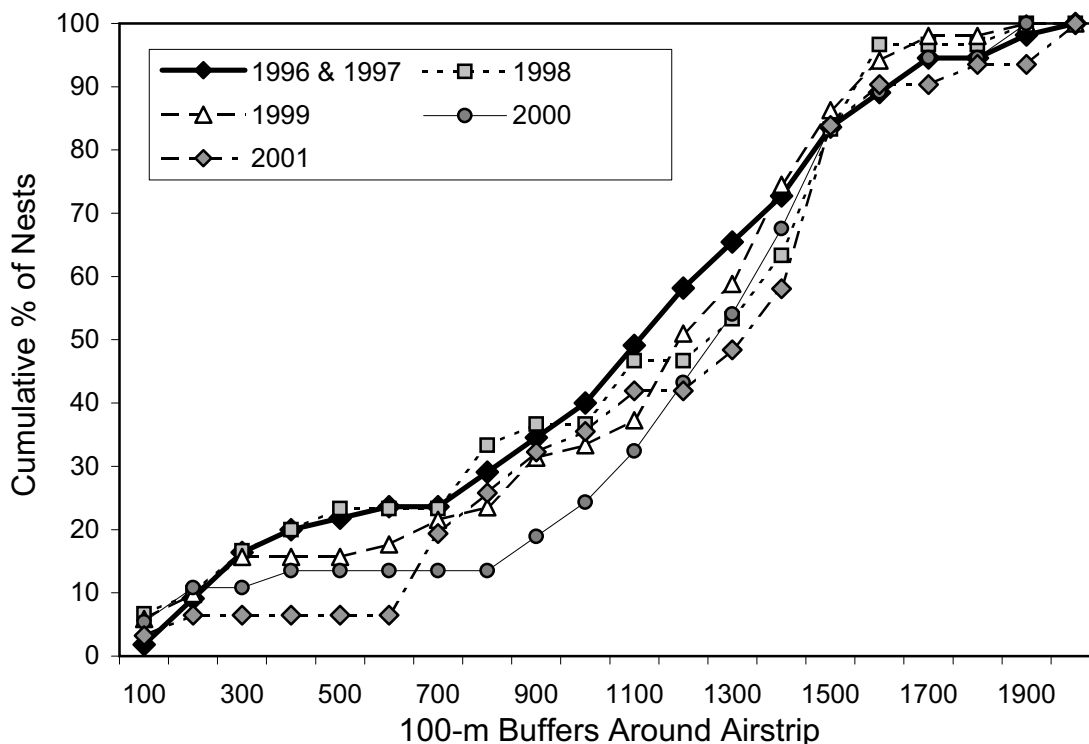


Figure 22. The cumulative percentage of Greater White-fronted Goose nests within 100-m buffers around the airstrip at the Alpine project area, Alaska, 1996–2001. Nests from 1996 and 1997 (pre-construction years) were combined to provide a baseline for comparison. Nests each year were assigned to buffers drawn around the final (2000–2001) airstrip footprint.

with only main effects showed that nearest-neighbor distances differed significantly with search effort ( $P < 0.01$ ) and between habitats ( $P < 0.01$ ), but not among distance buffers around the airstrip ( $P = 0.13$ ). The smallest nearest-neighbor distances (i.e., highest nest densities) were in the 3 most-used habitats combined (Patterned Wet Meadow, Aquatic Sedge with Deep Polygons, and Moist Sedge–Shrub Meadow) and in years with the highest search efforts (1999–2001).

Because the varying levels of disturbance during the construction years (essentially the effort or year effect above) may have affected not only the density of nests but also their distribution relative to the airstrip, we investigated the interaction of search effort and distance to airstrip identified in the analysis of variance model above. We compared regressions of pre-construction years (1996–1997) and heavy-construction years (1999–2001) to examine the relationship between nearest-neighbor distances and distance to airstrip and found a significant decline in nearest neighbor

distance (increased density) with increasing distance to the airstrip during the heavy-construction period ( $r^2 = 0.056$ ,  $F = 6.89$ ,  $P < 0.01$ ), but no relationship prior to construction ( $r^2 = 0.014$ ,  $F = 0.60$ ,  $P < 0.44$ ). Separate regressions for each year showed that the strongest negative relationship was in 1999 ( $P < 0.01$ , the other years were not significant), the first year the airstrip was used by airplanes, and that the negative slope in 1999 and 2001 contrasted with positive slopes in 1996–1998 (Figure 23). Thus, evaluations of nearest-neighbor distances confirmed the conclusions from the evaluations of distance buffers around the airstrip; the distribution of goose nests changed around the airstrip from pre- and light-construction years to heavy-construction years in a pattern suggesting avoidance (but not abandonment) of the airstrip area.

Noise was a potential source of disturbance at the airstrip that could affect the distribution of nesting White-fronted Geese. Because noise propagation from aircraft was not uniformly

Table 37. Tests of the effects of distance to airstrip, habitat, and search effort each year (covariate) on nearest-neighbor distance between Greater White-fronted Goose nests, Alpine project area, Colville River Delta, Alaska, 1998–2001. Fixed factors were 4 distance buffers (500 m intervals) around the airstrip and 2 habitat categories (most used habitats [Patterned Wet Meadow, Aquatic Sedge with Deep Polygons, and Moist Sedge–Shrub Meadow] and other habitats).

| Source               | Factor Statistics |          |          | ANCOVA Model Statistics |          |          |                       |
|----------------------|-------------------|----------|----------|-------------------------|----------|----------|-----------------------|
|                      | df                | <i>F</i> | <i>P</i> | df                      | <i>F</i> | <i>P</i> | <i>R</i> <sup>2</sup> |
| <b>Full Model</b>    |                   |          |          |                         |          |          |                       |
| Distance to Airstrip | 3                 | 0.92     | 0.43     | 12, 191                 | 3.19     | <0.01    | 0.31                  |
| Habitat              | 1                 | 0.85     | 0.36     |                         |          |          |                       |
| Search Effort        | 1                 | 2.36     | 0.13     |                         |          |          |                       |
| Distance * Effort    | 3                 | 1.75     | 0.16     |                         |          |          |                       |
| Habitat * Effort     | 1                 | 0.25     | 0.62     |                         |          |          |                       |
| Habitat * Distance   | 3                 | 0.30     | 0.83     |                         |          |          |                       |
| <b>Reduced Model</b> |                   |          |          |                         |          |          |                       |
| Distance to Airstrip | 3                 | 1.93     | 0.13     | 5, 198                  | 6.29     | <0.01    | 0.14                  |
| Habitat              | 1                 | 11.94    | <0.01    |                         |          |          |                       |
| Search Effort        | 1                 | 14.49    | <0.01    |                         |          |          |                       |

distributed about the airstrip nor were noise levels the same each year (see Noise Monitoring, Part II), noise could have a different effect on nest distribution than did the distance to airstrip evaluated above. Visual evaluation of nest locations with a noise contour (85 dBA) of the loudest aircraft (DC-6) did not suggest a substantial change in nest distribution relative to noise (Figure 24). Noise levels at White-fronted Goose nests, as estimated by noise modeling, were examined for differences among years that might indicate whether geese responded to aircraft noise by changing their nest locations. Pairwise comparisons of the annual noise levels ( $L_{eq}$ ) at nest locations between adjacent years (i.e., 1998 vs. 1999, 1999 vs. 2000, 2000 vs. 2001) using the earlier of the 2 year's noise conditions as a constant for both years found no significant differences between any of the 3 pairs of years. The mean noise levels decreased from 1998 to 1999 by 1.06 dBA ( $t = 0.78$ ,  $df = 92$ ,  $P = 0.43$ ) under 1998 noise conditions, indicating nests in 1999 were located in areas that reduced their noise exposure by only a small degree. The mean difference between 1999 and 2000 nest locations under 1999 noise conditions was even less (0.47 dBA) ( $t = 0.40$ ,  $df = 91$ ,  $P = 0.69$ ). Similarly, the mean difference between 2000 and 2001 noise levels was small

(0.50 dBA) and not significant ( $t = 0.42$ ,  $df = 70$ ,  $P = 0.68$ ). Because changes in nest distribution may take more than one year to have an effect on the overall noise exposure, we also examined all years for annual differences using the noise conditions from 2000 (the year with highest noise levels) as a constant so that differences among years would be related only to the distribution of nests. No difference in daily maximal noise levels ( $L_{max}$ ) at nests was found among the 4 years (ANOVA;  $F = 0.78$ ;  $df = 3, 162$ ;  $P = 0.98$ ). The highest daily maximal values occurred in 1998 (mean = 82.6 dBA,  $SE = 1.73$ ,  $n = 40$ ) and the lowest occurred in 2001 (mean = 81.6 dBA,  $SE = 1.56$ ,  $n = 33$ ), a mean difference of 1.0 dBA. The difference among annual noise levels ( $L_{eq}$ ) at all nest sites also was non-significant (ANOVA;  $F = 0.62$ ;  $df = 3, 162$ ;  $P = 0.60$ ). As with peak noise, 1998 had the highest values (mean = 68.7 dBA,  $SE = 1.16$ ,  $n = 40$ ) and 2001 had the lowest (mean = 66.9 dBA,  $SE = 1.73$ ,  $n = 40$ ), but the mean difference between these 2 years was small (1.8 dBA), which suggests that annually changing nest distributions did decrease mean noise exposure at nests, but not by a substantial degree. The proportions of White-fronted Goose nests in 4 noise-level contours (annual  $L_{eq}$  under 2000 noise conditions)



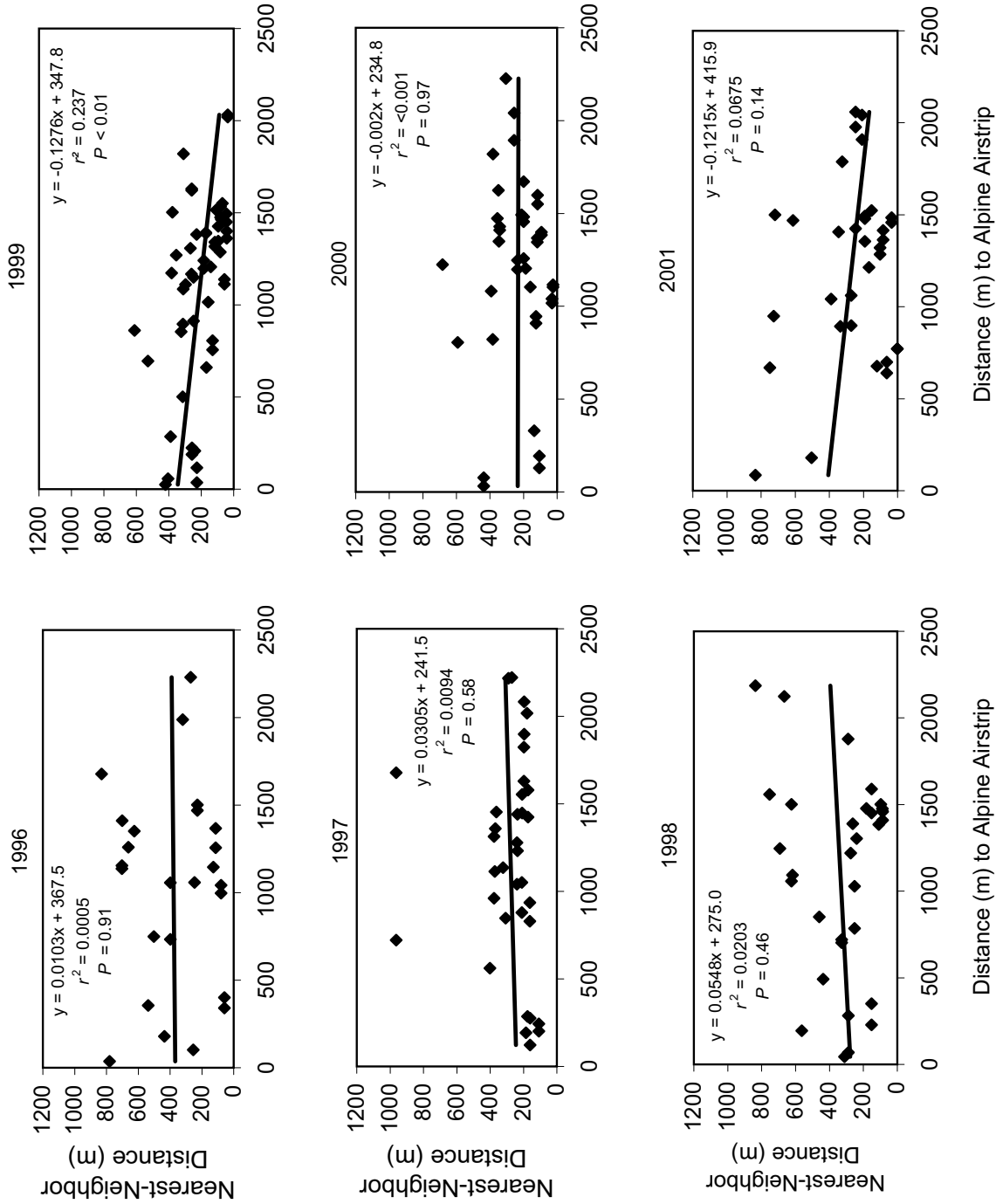


Figure 23. Simple linear regression of the relationship between nearest-neighbor distances of Greater White-fronted Goose nests and distance to the Alpine airstrip by year in the Alpine project area, 1996–2001.

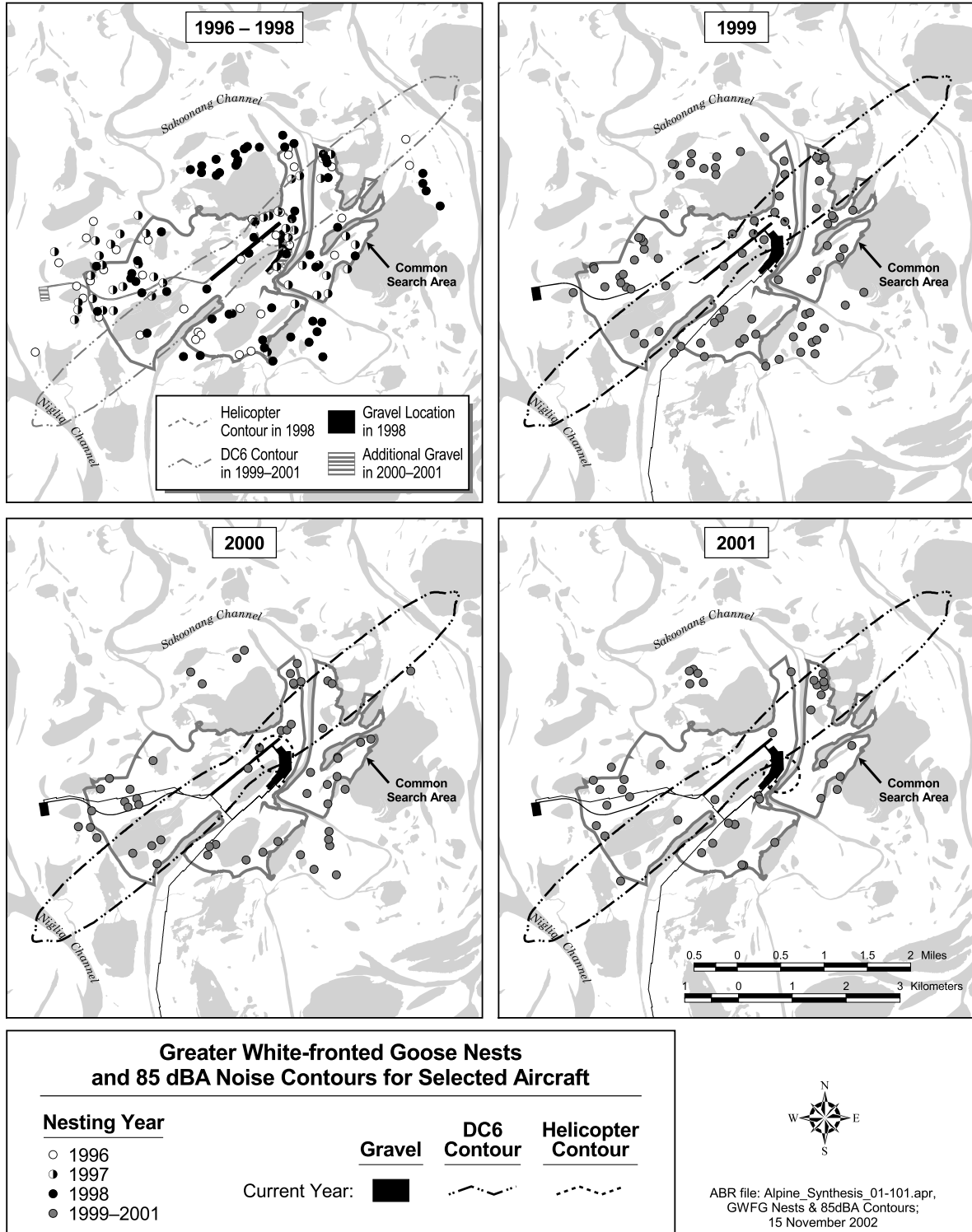


Figure 24. Greater White-fronted Goose nest locations and 85 dBA noise contour for departing four-engine aircraft (DC-6) at the Alpine airstrip, Colville River Delta, Alaska, 1996–2001. First use of the airstrip by airplanes during the avian breeding season was in 1999. First use by helicopters was in 1998.

also were evaluated for changes among years. Overall, the test of independence of year and noise levels was not significant ( $P = 0.30$ ; Table 38). However, the proportion of nests in the loudest contour declined from 20% in 1998 to 3% in 2001, while the proportion of nests in the quietest contour increased from 30% to 36% over the same time. Changes in the proportion of nests in the 2 intermediate noise contours were inconsistent among years. Thus, although annual changes in the distribution of White-fronted Goose nests did not have significant effects on the overall noise exposure at nests throughout the study area, trends in the data suggest that geese shifted nests away from areas of loudest noise exposure towards areas of less noise.

To summarize changes in the distribution and density of White-fronted Goose nests, the numbers of nests in the common search area declined in 2 of the 3 heavy-construction years and was negatively correlated with overall noise levels and frequency of aircraft, traffic, and pedestrians. However, late river breakup and extensive river flooding also occurred in those 2 years, making it difficult to identify the cause of low nest numbers among years with high annual variation. Generally, nesting White-fronted Geese exhibited statistically non-significant and weak distributional changes in relation to sources of disturbance, which suggest that geese moved their nests away from the airstrip, gravel footprints, and noisiest areas in the common search area but not enough to be detected at the scale of the study area (approximately 2,000 m around the airstrip). Habitat use was relatively consistent among years, with no substantial change in heavy-construction years. The distance of nests to the airstrip and gravel pads increased slightly from pre-construction to heavy construction and the noise exposure levels estimated for nests correspondingly declined from 1998 to 2001. Higher than expected proportions of nests occurred between 1,000 and 1,500 m of the airstrip in 1999 and 2000, and lower than expected proportions within 500 m of the airstrip in 2001 and 500–1,000 m of the airstrip in 2000, the only year with significant overall differences. The difference in distributions of nests between pre-construction and heavy-construction years appeared to occur within the first 700 m of the airstrip, and beyond that the densities generally converged. Nest

densities, as indicated by distance between nests, varied more with habitat and year (or search effort, because neither variable could be evaluated independently) than with distance from the airstrip. However, the trend in nest densities confirmed that White-fronted Geese in heavy-construction years tended to nest away from areas previously occupied around the airstrip in pre- and light-construction years.

#### TUNDRA SWAN

Tundra Swans nest in low densities relative to other species in the Alpine project area, but they are sensitive to some types of human activity (Hawkins 1986, Murphy and Anderson 1993, Limpert and Earnst 1994, Monda et al. 1994, Ritchie and King 2000) and, therefore, are a focal species in the evaluation of disturbance impacts. The number of Tundra Swan nests in the common search area—4 to 5 nests each year—varied little over 6 years (Figure 20, Appendix G2). The 3 years with the highest number of nests included one pre-construction year (1996), one light-construction year (1998) and one heavy-construction year (2001); thus, annual variation in nest numbers did not exhibit any trend suggesting construction-related effects.

The density of swans ranged between 0.4 and 0.5 nests/km<sup>2</sup> each year in the common search area. These densities were much higher than those recorded between 1996 and 2001 for the entire delta (0.05–0.08 nests/km<sup>2</sup>; Johnson et al. 2002) and in the Kuparuk Oilfield (0.03–0.05 nests/km<sup>2</sup>; Anderson et al. 2002). The mean nearest-neighbor distances between swan nests ranged from 877 to 1,363 m among years and the distribution of nests tended to be clumped ( $R < 1$ ).

The sample sizes of nests were too small to test for annual habitat selection, but in each year between 1996 and 2001 at least 75% of the nests found within the common search area occurred in 2 habitats that were significantly preferred over a 9-year period on the entire Colville Delta (Johnson et al. 2003): Patterned Wet Meadow and Moist Sedge–Shrub Meadow. In 3–6 years, at least 3 nests were located either on the same mounds used previously or within 25 m of previously used mounds.

As with goose nests, the distribution of swan nests was evaluated for changes among years that

Table 38. Test of independence of the annual nest distribution of Greater White-fronted Goose nests from annual noise levels ( $L_{eq}$ ) in the common search area at the Alpine project area, Colville River Delta, Alaska. Noise contours were modeled around the airstrip using with INM ver. 6.0, Federal Aviation Administration (see Appendix B) using aircraft traffic levels from 2000.

| dBA Levels  | Percent of Nests Observed |      |      |      | All Years  |     |          | df | P    |
|-------------|---------------------------|------|------|------|------------|-----|----------|----|------|
|             | 1998                      | 1999 | 2000 | 2001 | % Expected | n   | $\chi^2$ |    |      |
| <65         | 30.0                      | 33.3 | 38.5 | 36.4 | 34.3       | 57  | 10.7     | 9  | 0.30 |
| 65–70       | 40.0                      | 42.6 | 43.6 | 36.4 | 41.0       | 68  |          |    |      |
| 70–75       | 10.0                      | 11.1 | 5.1  | 24.2 | 12.0       | 20  |          |    |      |
| >75         | 20.0                      | 13.0 | 12.8 | 3.0  | 12.7       | 21  |          |    |      |
| Total Nests | 40                        | 54   | 39   | 33   |            | 166 |          |    |      |

might indicate a response to increased human activity at the Alpine facility. An examination of mean distance of Tundra Swan nests relative to the airstrip, nearest gravel, or flight path showed no differences among years (all 3 tests  $P \geq 0.94$ , Table 39), nor any trends suggestive of a disturbance effect. The closest swan nest to the airstrip that occurred during this study was 160 m northeast of the airstrip in 1998. Although airplanes were not a disturbance factor for that nest, helicopters, heavy equipment on the airstrip, and pedestrians used the northeast end of the airstrip that year. The swans nested successfully at that site despite daily helicopter landings at the near end of the airstrip in late June and early July and 2 prolonged recesses (~4 and ~8 hr) caused by nest searchers near the nest. Although the nest was not reused after 1998, it was not used in 1996–1997 either, and the nest bowl had only one year's accumulation of material, indicating 1998 was the first time that site had been used. From the information available, it is impossible to know whether the nest was not reused because of disturbance. Although Tundra Swans have high nest-site fidelity, about half the swan nests in an undeveloped area were on sites never before used (Monda et al. 1994), which indicates that swans regularly change nest mounds between years, even in the absence of aircraft and construction activity.

One swan nest site is noteworthy because of its proximity to the airstrip and its use for  $\geq 8$  years. Since 1995, what is assumed to be one pair of Tundra Swans has occupied and nested each year in a territory within 500 m of the Alpine airstrip. This nest was monitored by video cameras each year since 1999 and is labeled nest 105 in the

section on Nesting Behavior and Disturbance Monitoring. In 1995–2000, the pair nested on the same large mound 449 m southwest of the airstrip, 145 m from the infield road, and 124 m from the airstrip flight path (Figure 20). The original nest mound was unused in 2001, but a new mound 150 m away was occupied, and the new site was a similar distance (442 m) from the airstrip. This nest was the closest nest to the airstrip in 2001, but was farther from the infield road (243 m) and closer to the airstrip flightpath (28 m) than the previous mound. We speculate that the nest was moved in 2001 because of the large increase in vehicle traffic (from 6 to 178 vehicles/d) between 2000 and 2001, however, other factors could have contributed to the change in nest location. An ice dam at the easternmost bridge during breakup in 2001 caused flooding that approached the original nest site, and an ice road that passed within 5–10 m of the original nest site was present in May of 2001, when swans probably were choosing nest sites. A new pipeline was built between CD-1 and CD-2 in winter 2000–2001 and was located within 400 m of the former nest. It seems unlikely, however, that a stationary structure at that distance would affect nest-site selection. As mentioned before, swans may change nests sites annually even in undisturbed areas (Monda et al. 1994). In 2002, the original nest mound was used again, and what is assumed to be the alternate site was abandoned (unpubl. data, ABR). Despite the proximity of these nest sites to the airstrip and their location under the takeoff and approach patterns of aircraft, they hatched successfully every year they were checked (1997–2002).

Table 39. Comparison among years of mean distances of Tundra Swan nests from the facility features (airstrip, nearest gravel [pad, road, and airstrip], and the flight path of planes) in the common search area of the Alpine project area, Colville River Delta, Alaska.

| Feature/Year          | Distance (m) |       |          | ANOVA |          |                 |
|-----------------------|--------------|-------|----------|-------|----------|-----------------|
|                       | $\bar{x}$    | SE    | <i>n</i> | df    | <i>F</i> | <i>P</i> -value |
| <b>Airstrip</b>       |              |       |          |       |          |                 |
| 1996                  | 958          | 175.4 | 5        |       |          |                 |
| 1997                  | 1,212        | 297.0 | 4        |       |          |                 |
| 1998                  | 916          | 254.6 | 5        |       |          |                 |
| 1999                  | 1,055        | 203.4 | 4        |       |          |                 |
| 2000                  | 1,051        | 202.9 | 4        |       |          |                 |
| 2001                  | 1,160        | 242.7 | 5        |       |          |                 |
| All Years             | 1,053        | 88.1  | 27       | 5     | 0.24     | 0.94            |
| <b>Nearest Gravel</b> |              |       |          |       |          |                 |
| 1996                  | 754          | 219.9 | 5        |       |          |                 |
| 1997                  | 687          | 212.0 | 4        |       |          |                 |
| 1998                  | 834          | 280.3 | 5        |       |          |                 |
| 1999                  | 804          | 272.7 | 4        |       |          |                 |
| 2000                  | 867          | 248.8 | 4        |       |          |                 |
| 2001                  | 820          | 159.0 | 5        |       |          |                 |
| All Years             | 795          | 86.9  | 27       | 5     | 0.07     | 1.00            |
| <b>Flight Path</b>    |              |       |          |       |          |                 |
| 1996                  | 593          | 212.9 | 5        |       |          |                 |
| 1997                  | 424          | 274.2 | 4        |       |          |                 |
| 1998                  | 403          | 187.9 | 5        |       |          |                 |
| 1999                  | 602          | 273.7 | 4        |       |          |                 |
| 2000                  | 386          | 178.5 | 4        |       |          |                 |
| 2001                  | 511          | 202.3 | 5        |       |          |                 |
| All Years             | 488          | 82.9  | 27       | 5     | 0.19     | 0.97            |

The lack of any significant shift in the distribution of nests, in addition to most swan nests in the common search area recurring most years in the same vicinity as previous years, indicates that previously occupied nest sites were strong attractions to nesting swans. Similarly, disturbance effects of the various components of the Alpine project area apparently were not severe enough to cause major changes in nest site selection.

#### YELLOW-BILLED LOON

Yellow-billed Loons probably nest annually in the common search area but are not always found on nest searches that are timed for waterfowl. Although only one Yellow-billed Loon nest was

found in each year but 1999 during the ground searches in the common search area (Appendix G2), additional nests were found during other activities: 2 nests in 1998, and 1 nest in each of 1999–2001 (Figure 20). As with Tundra Swans, adjusting the number of nests of Yellow-billed Loons by search effort is unnecessary because these birds are large and their nests are readily detected if the searches are timed appropriately. Loons generally initiate nests later than geese and swans, so our nest searches were not conducted at the best time for finding loon nests, which was why some nests are found later during other surveys. The number and density of Yellow-billed Loon nests did not exhibit any trend that would suggest a

construction-related effect. The density of Yellow-billed Loons nests in the common search area at Alpine was lower than the density on the entire delta, and nest densities in both areas were annually variable (Johnson et al. 2002).

Yellow-billed Loons nests usually were located >1 km from the airstrip, except in 2001, when one nest was found 775 m from the airstrip. Of the 8 nests found within the common search area between 1996 and 2001 by all survey methods, 6 nests were located in Patterned Wet Meadow, which was significantly preferred over an 8-year period on the entire Colville Delta (Johnson et al. 2003). The remaining 2 nests were found in Nonpatterned Wet Meadow. All Yellow-billed Loon nests were less than 1 m from water and along the shores of Deep Open Water without Islands or Polygonized Margins. In summary, no evidence was found for disturbance effects on the annual abundance or distribution of Yellow-billed Loon nests. However, sample sizes were low and nest sites were always located over 700 m from the airstrip, which probably limited the detectability of potential disturbance effects.

## NESTING BEHAVIOR AND DISTURBANCE MONITORING

### GREATER WHITE-FRONTED GOOSE

#### Nest Attendance

We chose White-fronted Geese as the focus of our study of nesting behavior because they consistently had more than 30 nests (i.e., met sample size requirements) in the project area, their nests were relatively easy to locate, and their nests occurred over a wide range of distances relative the Alpine facilities (i.e., a range of potential disturbance exposure levels). To investigate the effects of construction activities on nest attendance we looked for differences among years that might reflect changing levels of human-related disturbance and differences among locations that might reflect varying levels of exposure. Nest attendance data was collected from artificial eggs implanted with thermistors that were inserted into nests early in the incubation period. In 1998–2001, egg thermistors were deployed at 133 White-fronted Goose nests (Figure 25). Useful temperature data were obtained for 94 nests from the time of deployment to the time of brood

departure or nest failure; 11 nests failed within 48 hr after deployment, and no data or erroneous readings were collected at 28 nests because of equipment failure or installation error. Ten nests were monitored successfully by time-lapse cameras, and 7 of those nests were monitored simultaneously with egg thermistors. Nest attendance data was analyzed from 94 nests with thermistors and 3 nests monitored only by video cameras. The mean distance of those 97 nests to the airstrip was 1,231 m (range 25–2,597 m), which was comparable to the mean distance to the airstrip of all White-fronted Goose nests found in the common search area in 1998–2001 (1,138 m,  $n = 165$ ). The mean distance of nests to the airstrip monitored with video cameras was 647 m (range 25–1,789 m,  $n = 14$ ). Video cameras were intended to monitor nests that were close to sources of disturbance.

Because nest attendance data collected from thermistored eggs were derived from temperature records, we verified those data with nest attendance summaries from the video cameras at nests monitored by both methods. Comparisons of nesting activities at 7 White-fronted Goose nests monitored simultaneously by video cameras and egg thermistors found no significant differences between methods for measures of incubation constancy, time off nest, or recess length ( $P \geq 0.54$  for all 3 tests;). However, significantly more breaks ( $P < 0.01$ ) and more recesses ( $P < 0.01$ ) were recorded with video monitoring than with thermistors. The number of breaks recorded from video monitoring (mean = 20.6 breaks/d) was greater than that recorded with thermistors (mean = 9.6 breaks/d) because the mean length of breaks (mean = 1.3 min, SE = 0.02,  $n = 2,604$  breaks, determined from video monitoring) was shorter than the interval between records on thermistor data loggers (5-min intervals). For similar reasons, the number of recesses counted from the video monitoring (mean = 2.2 recesses/d) was slightly greater than that recorded on thermistors (mean = 2.0 recesses/d). Successive recesses on the video that occurred <5 min apart were recorded as one recess by the thermistors, because the time the incubating bird was sitting on the nest between recesses was shorter than the interval between records on egg thermistors. During these successive recesses females were

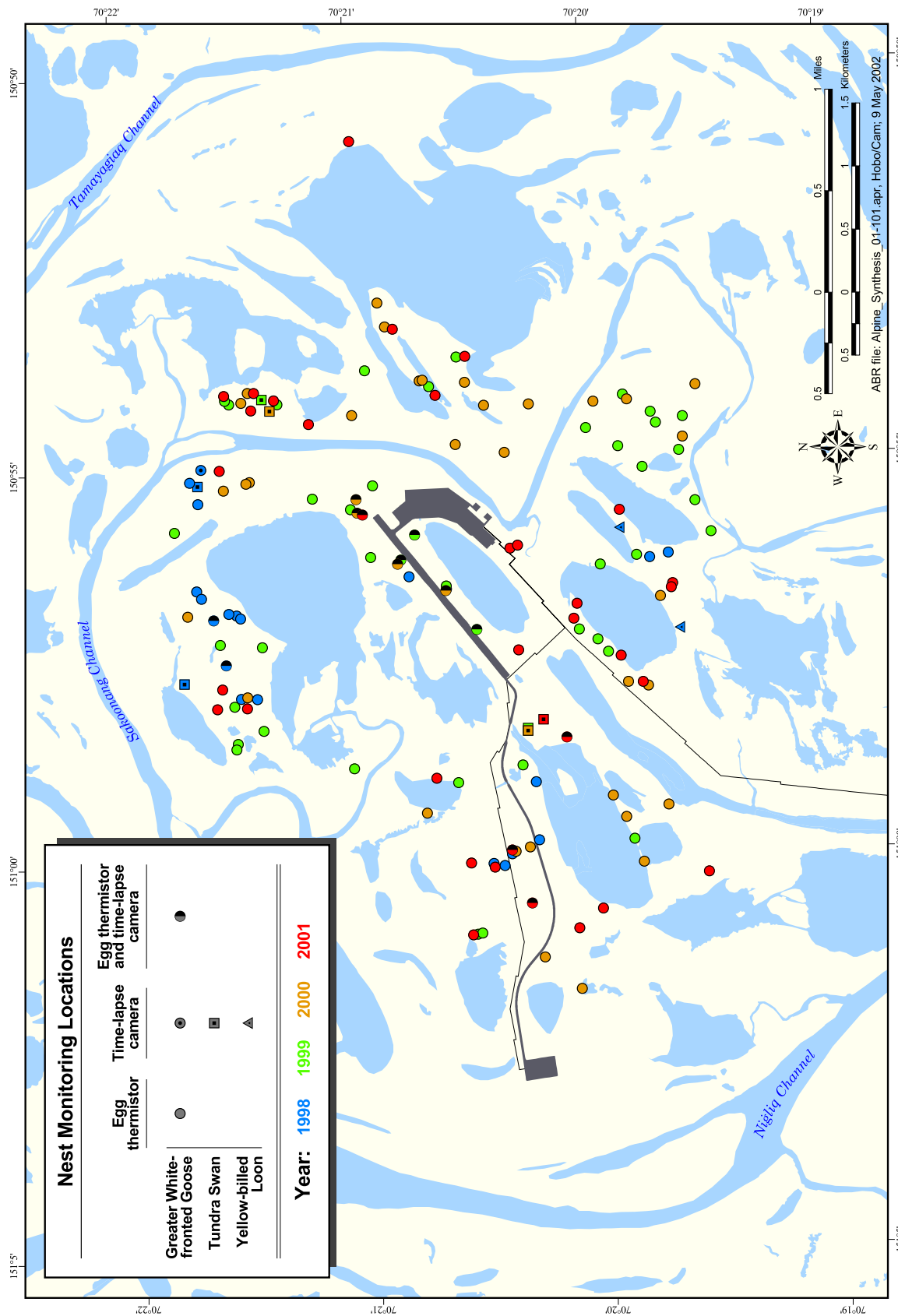


Figure 25. Locations of nests monitored with egg thermistors and time-lapse cameras in the Alpine project area, Colville River Delta, 1998–2001.

Table 40. Comparisons of nesting activities of 7 incubating Greater White-fronted Geese monitored simultaneously by video camera at 1-min intervals and by thermistored eggs at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 1999–2001.

|                            | Thermistored Egg |      |       | Video Camera |      |       | Wilcoxon Signed Ranks |       |
|----------------------------|------------------|------|-------|--------------|------|-------|-----------------------|-------|
|                            | $\bar{x}$        | SE   | $n^a$ | $\bar{x}$    | SE   | $n^a$ | Z                     | P     |
| Incubation Constancy (%/d) | 97.3             | 0.24 | 129   | 97.3         | 0.24 | 129   | -0.61                 | 0.54  |
| Recess Frequency (no./d)   | 2.0              | 0.17 | 129   | 2.2          | 0.17 | 129   | -3.39                 | <0.01 |
| Recess Length (min/recess) | 17.3             | 0.56 | 284   | 17.6         | 0.53 | 284   | -0.27                 | 0.79  |
| Time off Nest (min/d)      | 38.6             | 3.43 | 129   | 39.5         | 3.55 | 129   | -0.54                 | 0.59  |
| Break Frequency (no./d)    | 9.6              | 0.42 | 129   | 20.6         | 0.82 | 129   | -8.95                 | <0.01 |

<sup>a</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

collecting nesting material within 2 m of the nest. Thus, thermistors underestimated the number of incubation breaks and short recesses (<5 min) near the nest, behaviors related to nest maintenance, but accurately recorded long recesses (>5 min), which would be related to feeding, grooming, or disturbance.

The proportions of successful and failed White-fronted Goose nests equipped with egg thermistors (regardless of whether data were collected) and those without were compared to determine if egg thermistors affected nest fate. Fate was determined for 132 nests equipped with thermistors and 76 nests without thermistors. The proportion of nests that were successful was similar between nests with and without thermistors ( $\chi^2 = 1.52$ ,  $df = 1$ ,  $P = 0.25$ ). Fifty-three percent of the nests with thermistors, and 62% of the nests without thermistors were successful. Although there was a slight increase in nest failures with thermistors (4 more nests than expected), we believe these nests served as a representative sample of all White-fronted Goose nests in the common search area for examining nest-attendance patterns and responses to sources of disturbance.

Nest attendance variables were compared between failed and successful nests to evaluate whether fate was related to differing nest attendance estimates. Data from 59 White-fronted Goose nests that were successful and at 38 nests that subsequently failed were used to estimate nest attendance variables in 1998–2001. White-fronted Geese at successful nests had higher incubation constancy (mean = 98.6%) than geese at failed

nests (mean = 97.0%,  $P < 0.01$ ) (Table 41). Incubation constancy was higher for geese at successful nests because they took significantly fewer recesses (mean = 1.2 recesses/d,  $P = 0.01$ ) and recesses were significantly shorter (mean = 16.2 min/recess,  $P = 0.02$ ) than did geese at failed nests (mean = 2.0 recesses/d, mean = 22.0 min/recess). Consequently, geese tending successful nests spent significantly less time off the nest (mean = 19.6 min/d) than geese tending failed nests (mean = 43.0 min/d,  $P < 0.01$ ). Both successful and failed nesting geese sometimes incubated 1–2 d without taking a recess. The number of breaks taken by geese did not differ between failed nests (mean = 11.0 breaks/d) and successful nests (mean = 10.5 breaks/d;  $P = 0.54$ ). Similar differences were found between failed and successful nests in individual years, although fate comparisons were more often significant in 1998 and 1999, and less often in subsequent years (Table 41).

During each year of nest attendance monitoring, the daily number of recesses and mean time off the nest for geese at failed nests sharply increased during the 5 days prior to failure (for 2001 see Figure 11; for 1998–2000 see Johnson et al. 1999b, 2000b, 2001). Exclusion of the 5 days prior to hatch or failure in the comparative analysis of geese at successful and failed nests resulted in similar measures of nest attendance for nests of both fates (Table 42), indicating that the differences in incubation behavior between failed and successful nesting geese are related to changes during the last 5 days of an otherwise normal



Table 41. Comparison of nesting activities of incubating Greater White-fronted Geese between successful and failed nests in the Alpine project area, Colville River Delta, Alaska. Fifty-nine successful nests and 38 nests that later failed were monitored with egg thermistors or time-lapse video cameras. A nested ANOVA was used with individual geese as the nested variable.

|   | Successful |      |       |           | Failed |       |       |          | Nested ANOVA |  |  |
|---|------------|------|-------|-----------|--------|-------|-------|----------|--------------|--|--|
|   | $\bar{x}$  | SE   | $n^a$ | $\bar{x}$ | SE     | $n^a$ | $F$   | df       | $P$          |  |  |
| 1998                                    |            |      |       |           |        |       |       |          |              |  |  |
| Incubation Constancy (%/d) <sup>b</sup> | 98.9       | 0.13 | 116   | 94.4      | 1.70   | 20    | 99.80 | 1, 0.3   | 0.31         |  |  |
| Recess Frequency (no./d) <sup>c</sup>   | 1.3        | 0.11 | 116   | 3.8       | 0.74   | 20    | 8.16  | 1, 5.9   | 0.03         |  |  |
| Recess Length (min/recess) <sup>d</sup> | 12.9       | 1.19 | 148   | 21.7      | 3.28   | 75    | 2.69  | 1, 6.5   | 0.15         |  |  |
| Time off Nest (min/d) <sup>c</sup>      | 16.5       | 1.81 | 116   | 80.0      | 24.51  | 20    | 90.51 | 1, 0.4   | 0.27         |  |  |
| Break Frequency (no./d) <sup>c</sup>    | 13.4       | 0.44 | 116   | 16.5      | 1.16   | 20    | 0.87  | 1, 11.4  | 0.37         |  |  |
| 1999                                    |            |      |       |           |        |       |       |          |              |  |  |
| Incubation Constancy                    | 99.0       | 0.12 | 228   | 97.8      | 0.28   | 211   | 4.65  | 1, 29.9  | 0.04         |  |  |
| Recess Frequency                        | 0.9        | 0.06 | 228   | 1.7       | 0.14   | 211   | 6.47  | 1, 30.4  | 0.02         |  |  |
| Recess Length                           | 15.9       | 2.39 | 200   | 18.1      | 1.02   | 366   | 0.51  | 1, 34.1  | 0.48         |  |  |
| Time off Nest                           | 14.0       | 1.71 | 228   | 31.5      | 3.95   | 211   | 4.67  | 1, 29.8  | 0.04         |  |  |
| Break Frequency                         | 10.3       | 0.21 | 228   | 12.5      | 0.34   | 211   | 7.22  | 1, 28.7  | 0.01         |  |  |
| 2000                                    |            |      |       |           |        |       |       |          |              |  |  |
| Incubation Constancy                    | 98.5       | 0.13 | 229   | 96.1      | 0.56   | 182   | 3.24  | 1, 24.2  | 0.08         |  |  |
| Recess Frequency                        | 1.4        | 0.12 | 229   | 2.5       | 0.22   | 182   | 2.20  | 1, 23.7  | 0.15         |  |  |
| Recess Length                           | 16.0       | 0.35 | 315   | 23.1      | 1.85   | 446   | 1.23  | 1, 30.8  | 0.28         |  |  |
| Time off Nest                           | 22.1       | 1.90 | 229   | 56.5      | 8.04   | 182   | 3.33  | 1, 24.0  | 0.08         |  |  |
| Break Frequency                         | 10.0       | 0.44 | 229   | 9.4       | 0.43   | 182   | 0.02  | 1, 22.4  | 0.90         |  |  |
| 2001                                    |            |      |       |           |        |       |       |          |              |  |  |
| Incubation Constancy                    | 98.4       | 0.12 | 343   | 97.4      | 0.61   | 135   | 1.78  | 1, 26.1  | 0.19         |  |  |
| Recess Frequency                        | 1.3        | 0.08 | 343   | 1.4       | 0.15   | 135   | 0.39  | 1, 26.2  | 0.54         |  |  |
| Recess Length                           | 17.7       | 0.43 | 438   | 27.1      | 2.94   | 186   | 2.55  | 1, 31.7  | 0.12         |  |  |
| Time off Nest                           | 22.7       | 1.70 | 343   | 37.3      | 8.85   | 135   | 1.58  | 1, 26.0  | 0.22         |  |  |
| Break Frequency                         | 9.9        | 0.25 | 343   | 10.1      | 0.36   | 135   | 0.12  | 1, 25.9  | 0.73         |  |  |
| All Years                               |            |      |       |           |        |       |       |          |              |  |  |
| Incubation Constancy                    | 98.6       | 0.07 | 916   | 97.0      | 0.27   | 548   | 10.07 | 1, 105.9 | <0.01        |  |  |
| Recess Frequency                        | 1.2        | 0.05 | 916   | 2.0       | 0.10   | 548   | 6.28  | 1, 106.2 | 0.01         |  |  |
| Recess Length                           | 16.2       | 0.51 | 1,101 | 22.0      | 1.02   | 1073  | 5.90  | 1, 119.8 | 0.02         |  |  |
| Time off Nest                           | 19.6       | 0.94 | 916   | 43.0      | 3.90   | 548   | 9.91  | 1, 105.5 | <0.01        |  |  |
| Break Frequency                         | 10.5       | 0.17 | 916   | 11.0      | 0.23   | 548   | 0.38  | 1, 94.5  | 0.54         |  |  |

<sup>a</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

<sup>b</sup> Arcsine transformation of incubation constancy in all years.

<sup>c</sup> Square-root transformation of recess frequency, break frequency, and time off nest in all years.

<sup>d</sup> Logarithmic transformation of recess length in all years.

Table 42. Comparison of nesting activities of incubating Greater White-fronted Geese between successful and failed nests prior to 5 days before hatch or failure in the Alpine project area, Colville River Delta, Alaska. Fifty-nine successful nests and 38 nests that later failed were monitored with egg thermistors or time-lapse video cameras. A nested ANOVA was used with individual geese as the nested variable.

|   | Successful |      |       |           | Failed |       |           |    | Nested ANOVA |          |      |   |
|---|------------|------|-------|-----------|--------|-------|-----------|----|--------------|----------|------|---|
|   | $\bar{x}$  | SE   | $n^a$ | $\bar{x}$ | SE     | $n^a$ | $\bar{x}$ | SE | $n^a$        | F        | df   | P |
| 1998 <sup>b</sup>                       |            |      |       |           |        |       |           |    |              |          |      |   |
| Incubation Constancy (%/d) <sup>c</sup> | 99.0       | 0.20 | 37    | 97.1      | 0.83   | 15    |           |    |              |          |      |   |
| Recess Frequency (no./d) <sup>c</sup>   | 1.1        | 0.18 | 37    | 2.5       | 0.52   | 15    |           |    |              |          |      |   |
| Recess Length (min/recess) <sup>c</sup> | 12.7       | 1.81 | 41    | 16.5      | 1.93   | 38    |           |    |              |          |      |   |
| Time off Nest (min/d) <sup>c</sup>      | 14.1       | 2.75 | 37    | 41.7      | 12.01  | 15    |           |    |              |          |      |   |
| Break Frequency (no./d) <sup>c</sup>    | 12.4       | 0.71 | 37    | 17.7      | 1.06   | 15    |           |    |              |          |      |   |
| 1999                                    |            |      |       |           |        |       |           |    |              |          |      |   |
| Incubation Constancy                    | 99.1       | 0.12 | 173   | 98.4      | 0.19   | 132   |           |    | 1.19         | 1, 30.7  | 0.28 |   |
| Recess Frequency                        | 0.9        | 0.06 | 173   | 1.4       | 0.15   | 132   |           |    | 1.36         | 1, 34.1  | 0.25 |   |
| Recess Length                           | 16.3       | 3.09 | 154   | 16.3      | 0.87   | 182   |           |    | 0.004        | 1, 29.0  | 0.95 |   |
| Time off Nest                           | 13.3       | 1.73 | 173   | 22.6      | 2.75   | 132   |           |    | 1.19         | 1, 30.8  | 0.28 |   |
| Break Frequency                         | 10.7       | 0.24 | 173   | 12.8      | 0.42   | 132   |           |    | 4.67         | 1, 30.4  | 0.04 |   |
| 2000                                    |            |      |       |           |        |       |           |    |              |          |      |   |
| Incubation Constancy                    | 99.1       | 0.12 | 170   | 98.1      | 0.22   | 126   |           |    | 1.41         | 1, 26.9  | 0.25 |   |
| Recess Frequency                        | 0.9        | 0.08 | 170   | 1.7       | 0.17   | 126   |           |    | 2.03         | 1, 26.2  | 0.17 |   |
| Recess Length                           | 15.2       | 0.62 | 145   | 15.9      | 0.90   | 210   |           |    | 0.07         | 1, 44.1  | 0.80 |   |
| Time off Nest                           | 13.0       | 1.23 | 170   | 26.7      | 3.15   | 126   |           |    | 1.64         | 1, 26.4  | 0.21 |   |
| Break Frequency                         | 9.7        | 0.51 | 170   | 9.3       | 0.51   | 126   |           |    | 0.02         | 1, 22.9  | 0.88 |   |
| 2001                                    |            |      |       |           |        |       |           |    |              |          |      |   |
| Incubation Constancy                    | 98.6       | 0.13 | 253   | 98.9      | 0.12   | 95    |           |    | 0.001        | 1, 34.1  | 0.98 |   |
| Recess Frequency                        | 1.1        | 0.08 | 253   | 1.0       | 0.09   | 95    |           |    | 0.001        | 1, 37.2  | 0.98 |   |
| Recess Length                           | 17.9       | 0.55 | 282   | 16.6      | 0.70   | 90    |           |    | 0.39         | 1, 49.4  | 0.53 |   |
| Time off Nest                           | 20.0       | 1.82 | 253   | 15.7      | 1.76   | 95    |           |    | 0.001        | 1, 34.2  | 0.97 |   |
| Break Frequency                         | 10.0       | 0.28 | 253   | 9.8       | 0.38   | 95    |           |    | 0.12         | 1, 30.3  | 0.73 |   |
| All Years                               |            |      |       |           |        |       |           |    |              |          |      |   |
| Incubation Constancy                    | 98.9       | 0.07 | 633   | 98.4      | 0.11   | 368   |           |    | 2.46         | 1, 160.1 | 0.12 |   |
| Recess Frequency                        | 1.0        | 0.04 | 633   | 1.4       | 0.09   | 368   |           |    | 2.69         | 1, 170.6 | 0.10 |   |
| Recess Length                           | 16.5       | 0.83 | 622   | 16.2      | 0.51   | 520   |           |    | 0.36         | 1, 167.8 | 0.55 |   |
| Time off Nest                           | 16.0       | 0.95 | 633   | 23.0      | 1.63   | 368   |           |    | 2.56         | 1, 158.3 | 0.11 |   |
| Break Frequency                         | 10.2       | 0.19 | 633   | 11.0      | 0.28   | 368   |           |    | 0.37         | 1, 109.2 | 0.54 |   |

<sup>a</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

<sup>b</sup> ANOVA not calculated because only one nest failed in 1998.

<sup>c</sup> Arcsine transformation of incubation constancy; square-root transformation of recess frequency, break frequency, and time off nest; and logarithmic transformation of recess length, in all years.

pattern of incubation. Therefore, failed nests were not the result of inattentive pairs, but possibly the result of nest predation, disturbance, or dwindling body reserves in incubating females that reduced their ability to tend nests late in the incubation period.

#### Effects of Disturbance on Nest Attendance

Severe disturbance, such as a human or helicopter approaching a nest and flushing an incubating female goose from its nest can have a negative effect on nest attendance by increasing time off nest and reducing incubation constancy. Geese react to lesser disturbances with alert or concealment behaviors that do not interrupt incubation, but less clear is how such activities affect overall nest attendance. We investigated the effects of construction activity on nest attendance of White-fronted Geese by comparing attendance variables among years with varying levels of human activity at the Alpine facilities. Nested ANOVAs were used to evaluate whether nesting activities monitored with egg thermistors, regardless of fate, differed among years (Table 43). Incubation constancy, recess frequency, and time off nest did not vary significantly among years (all 3 tests  $P \geq 0.70$ ). Mean recess length increased each year from 15.9 min in 1998 to 20.5 min in 2001 ( $P = 0.01$ ), and all years, except 2000 and 2001 ( $P = 0.89$ ), were significantly different from one another ( $P < 0.01$ , Tukey multiple comparisons). Break frequency differed among years ( $P = 0.01$ ) and decreased each year from 1998 (13.8 breaks/d) to 2000 (9.7 breaks/d;  $P < 0.01$ , Tukey multiple comparisons), but changed little between 2000 and 2001 (9.9 breaks/d;  $P = 0.19$ ). The biological significance of incubation breaks is unclear, but because they are considered an activity within normal incubation, they do not affect incubation constancy. Although recess length appeared to increase in years that construction activity increased, variation in recess frequency must have compensated for those increases because no net change in nest attendance was detected in the overall sample of White-fronted Goose nests. Therefore, the varying levels of human activity each year did not affect nest attendance negatively.

Although nest attendance did not vary among years for all White-fronted Goose nests, nest

attendance might vary among nest locations exposed to different levels of construction-related disturbance. One would expect that nests close to sources of disturbance would exhibit greater effects than nests far from disturbance.

We first investigated whether the proximity of facilities influenced the success or failure of the nests monitored with thermistors. The distance of 3 potential disturbance factors—the airstrip, the flight path, and the nearest gravel—to thermistor monitored nests was compared between the 2 nest fates. Similar to the comparison using all White-fronted Goose nests in the common search area (see Clutch Size and Nest Fate section), mean distances did not differ between successful and failed nests for distance to the airstrip ( $P = 0.44$ ), distance to the flight path ( $P = 0.12$ ), or distance to nearest gravel ( $P = 0.15$ ; Table 44). In each year and in all years pooled, successful nests were nearer to the airstrip and the flight path than were failed nests. Successful nests also were closer to the nearest gravel than were failed nests in all years except 2001, and the difference that year was non-significant ( $P = 0.77$ ). Because successful nests were nearer to potential disturbance sources than were failed nests, these features did not have a substantial negative effect on nest fate of geese, at least at the distances that nests occurred in the Alpine project area. Furthermore, the monitored nests appeared to be a representative sample of the White-fronted Goose nests in the common search area, because the distance-with-fate relationships were similar for both datasets.

To evaluate the effects of the frequency of potential disturbance events on incubation activity, we used 2 different time scales and included environmental variables that might also explain the variation in incubation activity. Only the data from the heavy-construction years was analyzed, because the focus was on the effects of disturbance on incubation behavior. First we related the probability that a recess was taken during a specific hour to the frequency of different disturbance events, time of day, and weather variables. Because White-fronted Geese averaged less than 2 recesses/d, normal incubation (i.e., no recesses) was the only activity occupying most hours of each day. Therefore, we conducted a second set of analyses investigating the same set of explanatory variables but summarized for each day (12 hr).

Table 43. Comparison among years of nesting activities of 97 incubating Greater White-fronted Geese in the Alpine project area, Colville River Delta, Alaska. A nested ANOVA was used with individual geese as the nested variable.

|                            | 1998  | 1999  | 2000  | 2001  | Nested ANOVA |          |          |
|----------------------------|-------|-------|-------|-------|--------------|----------|----------|
|                            |       |       |       |       | <i>F</i>     | df       | <i>P</i> |
| Incubation Constancy (%/d) |       |       |       |       | 0.48         | 3, 102.7 | 0.70     |
| $\bar{x}$                  | 98.2  | 98.4  | 97.4  | 98.1  |              |          |          |
| SE                         | 0.003 | 0.001 | 0.003 | 0.002 |              |          |          |
| <i>n</i> <sup>a</sup>      | 136   | 439   | 411   | 478   |              |          |          |
| Recess Frequency (no./d)   |       |       |       |       | 0.31         | 3, 103.1 | 0.81     |
| $\bar{x}$                  | 1.6   | 1.3   | 1.9   | 1.3   |              |          |          |
| SE                         | 0.16  | 0.08  | 0.12  | 0.07  |              |          |          |
| <i>n</i> <sup>a</sup>      | 136   | 439   | 411   | 478   |              |          |          |
| Recess Length (min/recess) |       |       |       |       | 6.67         | 3, 125.4 | <0.01    |
| $\bar{x}$                  | 15.9  | 17.3  | 20.2  | 20.5  |              |          |          |
| SE                         | 1.38  | 1.07  | 1.10  | 0.94  |              |          |          |
| <i>n</i> <sup>b</sup>      | 223   | 566   | 761   | 624   |              |          |          |
| Time off Nest (min/d)      |       |       |       |       | 0.42         | 3, 102.4 | 0.73     |
| $\bar{x}$                  | 25.8  | 22.4  | 37.3  | 26.8  |              |          |          |
| SE                         | 4.31  | 2.14  | 3.80  | 2.79  |              |          |          |
| <i>n</i> <sup>a</sup>      | 136   | 439   | 411   | 478   |              |          |          |
| Break Frequency (no./d)    |       |       |       |       | 4.59         | 3, 97.7  | <0.01    |
| $\bar{x}$                  | 13.8  | 11.4  | 9.7   | 9.9   |              |          |          |
| SE                         | 0.42  | 0.20  | 0.31  | 0.21  |              |          |          |
| <i>n</i> <sup>a</sup>      | 136   | 439   | 411   | 478   |              |          |          |

<sup>a</sup> *n* = days.<sup>b</sup> *n* = recesses.

We investigated which disturbance and/or environmental factors would explain the probability of a recess occurring during a particular hour with a stepwise logistic regression model. The logistic model was run with all days monitored (Table 45) and with the 5 days before hatch or failure excluded (Appendix E3). Our analysis focused on the model which included all days monitored, because incubating geese might be more sensitive to disturbance late in the incubation period when the frequency and duration of recesses increases before hatch or failure. The model was run with and without nest site as a categorical variable to account for individual variation among incubating birds; when nest site was included, distance to the airstrip was removed by the model.

With the nest site included in the model ( $P < 0.01$ ), 3 other variables were retained: day before hatch or failure ( $P < 0.01$ ), temperature ( $P = 0.01$ ), and time of day ( $P < 0.01$ ; Table 45). The probability of taking a recess during an hour increased as the day before hatch or failure approached, was higher in the afternoon than in the morning or during midday, and increased with lower temperatures. The nest identification variable indicated there was significant variation among incubating birds and/or different nest locations.

When nest site was removed from the model, 8 variables were retained: day before hatch or failure ( $P < 0.01$ ), temperature ( $P < 0.01$ ), time of day ( $P < 0.01$ ), fate ( $P = 0.05$ ), maximal noise level ( $L_{\max}$ ,  $P = 0.15$ ), presence of airplanes

Table 44. Comparison of distance to airstrip, flight path, and nearest gravel between successful and failed Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Equal variances not assumed for *t* test unless otherwise noted.

| Year      | Feature        | Distance (m) of Successful Nests |        |          | Distance (m) of Failed Nests |        |          | <i>t</i> test     |      |          |
|-----------|----------------|----------------------------------|--------|----------|------------------------------|--------|----------|-------------------|------|----------|
|           |                | $\bar{x}$                        | SE     | <i>n</i> | $\bar{x}$                    | SE     | <i>n</i> | <i>t</i>          | df   | <i>P</i> |
| 1998      | Airstrip       | 1,253.6                          | 126.02 | 16       | 1,451.2                      | -      | 1        | 0.38 <sup>a</sup> | 15   | 0.71     |
|           | Flight Path    | 1,064.8                          | 139.17 | 16       | 1,477.6                      | -      | 1        | 0.72 <sup>a</sup> | 15   | 0.48     |
|           | Nearest Gravel | 900.2                            | 170.30 | 16       | 1,229.4                      | -      | 1        | 0.47 <sup>a</sup> | 15   | 0.65     |
| 1999      | Airstrip       | 1,121.8                          | 253.57 | 12       | 1,223.6                      | 157.78 | 17       | 0.34              | 19.2 | 0.74     |
|           | Flight Path    | 968.4                            | 272.99 | 12       | 1,010.1                      | 182.38 | 17       | 0.13              | 20.2 | 0.90     |
|           | Nearest Gravel | 815.8                            | 193.65 | 12       | 1,034.1                      | 126.38 | 17       | 0.94              | 19.9 | 0.36     |
| 2000      | Airstrip       | 1,091.6                          | 199.25 | 12       | 1,205.9                      | 168.43 | 12       | 0.44              | 21.4 | 0.67     |
|           | Flight Path    | 504.0                            | 127.08 | 12       | 1,076.5                      | 177.91 | 12       | 2.62              | 19.9 | 0.02     |
|           | Nearest Gravel | 501.6                            | 121.91 | 12       | 947.0                        | 140.17 | 12       | 2.40              | 21.6 | 0.03     |
| 2001      | Airstrip       | 1,250.9                          | 133.62 | 19       | 1,539.6                      | 149.22 | 8        | 1.44              | 18.2 | 0.17     |
|           | Flight Path    | 769.9                            | 135.75 | 19       | 1,032.6                      | 155.11 | 8        | 1.27              | 17.8 | 0.22     |
|           | Nearest Gravel | 884.7                            | 137.96 | 19       | 811.5                        | 199.11 | 8        | -0.30             | 14.1 | 0.77     |
| All Years | Airstrip       | 1,193.0                          | 83.66  | 59       | 1,290.5                      | 94.09  | 38       | 0.77              | 84.8 | 0.44     |
|           | Flight Path    | 836.2                            | 86.11  | 59       | 1,048.1                      | 102.58 | 38       | 1.58              | 81.7 | 0.12     |
|           | Nearest Gravel | 797.0                            | 79.72  | 59       | 964.9                        | 99.34  | 38       | 1.47              | 89.1 | 0.15     |

<sup>a</sup> Equal variances assumed.

Table 45. Logistic regression models of the influence of potential disturbance and environmental variables on the probability of incubating Greater White-fronted Geese taking a recess during an hour in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Seventy-nine Greater White-fronted Goose nests were monitored with egg thermistors between 0600 and 1800 ADT. Models were run with and without nest site as a categorical variable. Nagelkerke  $R^2 = 0.11$  with nest site in model and Nagelkerke  $R^2 = 0.05$  without nest site;  $n = 13,333$  hr.

| Model                             | $\beta$ | SE   | Wald   | df | $P$   | Odds Ratio (Exp[ $\beta$ ]) |
|-----------------------------------|---------|------|--------|----|-------|-----------------------------|
| <b>With Nest Site</b>             |         |      |        |    |       |                             |
| Intercept                         | -2.07   | 0.60 | 11.96  | 1  | <0.01 |                             |
| Day before Hatch or Failure       | -0.08   | 0.01 | 135.41 | 1  | <0.01 | 0.92                        |
| Temperature (°C)                  | -0.02   | 0.01 | 6.56   | 1  | 0.01  | 0.98                        |
| Time of Day                       |         |      | 61.73  | 2  | <0.01 |                             |
| 0600–1000                         | -0.73   | 0.10 | 56.32  | 1  | <0.01 | 0.48                        |
| 1000–1400                         | -0.10   | 0.08 | 1.66   | 1  | 0.20  | 0.90                        |
| 1400–1800                         | 0       |      |        |    |       |                             |
| Nest Site                         |         |      | 385.52 | 78 | <0.01 |                             |
| <b>Without Nest Site</b>          |         |      |        |    |       |                             |
| Intercept                         | -2.43   | 0.20 | 147.10 | 1  | <0.01 |                             |
| Day Before Hatch or Failure       | -0.06   | 0.01 | 89.70  | 1  | <0.01 | 0.94                        |
| Temperature (°C)                  | -0.02   | 0.01 | 9.16   | 1  | <0.01 | 0.98                        |
| Presence of Airplanes             | 0.13    | 0.08 | 2.65   | 1  | 0.10  | 1.14                        |
| Number of Vehicles                | -0.01   | 0.01 | 5.58   | 1  | 0.02  | 0.99                        |
| Maximal Noise Level ( $L_{max}$ ) | 0.01    | 0.01 | 2.10   | 1  | 0.15  | 1.01                        |
| Fate (Failed)                     | 0.14    | 0.07 | 3.84   | 1  | 0.05  | 1.15                        |
| Time of Day                       |         |      | 49.68  | 2  | <0.01 |                             |
| 0600–1000                         | -0.66   | 0.10 | 46.27  | 1  | <0.01 | 0.52                        |
| 1000–1400                         | -0.10   | 0.08 | 1.73   | 1  | 0.20  | 0.90                        |
| 1400–1800                         | 0       |      |        |    |       |                             |
| Distance to Airstrip              |         |      | 39.34  | 2  | <0.01 |                             |
| 0–1,000 m                         | 0.51    | 0.15 | 11.49  | 1  | <0.01 | 1.66                        |
| 1,000–2,000 m                     | 0.78    | 0.13 | 33.77  | 1  | <0.01 | 2.18                        |
| >2,000 m                          | 0       |      |        |    |       |                             |

( $P = 0.10$ ), number of vehicles ( $P = 0.02$ ), and distance from airstrip ( $P = 0.15$ ; Table 45). The relationship of day before hatch or failure, temperature, and time of day to the probability of taking a recess was the same as in the previous model with nest site included. Geese at failed nests were more likely to take recesses than geese at successful nests. The probability of taking a recess increased as noise level increased, when airplanes were present, and when the number of vehicles decreased; however, only the relationship with vehicles was significant. Geese nesting <1,000 m ( $P < 0.01$ ) and 1,000–2,000 m ( $P < 0.01$ ) from the airstrip had a higher probability of taking a recess

than geese nesting >2,000 m from the airstrip. Therefore, recess probability was influenced by distance to the airstrip and the occurrence of aircraft, noise, and vehicles, but these effects were contingent upon the responses of individual geese at different nest locations. Temperature, time of day, and day before hatch were consistent factors whether individual nests were accounted for or not, and we interpret those effects to be stronger because they explained recess probability across all nests.

Daily summaries of incubation allowed evaluation of a longer time scale and of more incubation variables than was possible with the

hourly summary above. Relationships of recess frequency, time off nest, and recess length with sources of potential disturbance and environmental conditions in 1999–2001 were analyzed using generalized linear models (Tables 46 and 47, Appendix E4). Based on Akaike's Information Criterion (AIC), models with daily noise level ( $L_{eq}$ ) were superior to models with daily maximal noise level ( $L_{max}$ ), and therefore, daily noise level was used in the analyses. When all days monitored were included in the models with nest site as a variable, the same 5 variables were retained in the models for recess frequency and time off nest: day before hatch or failure, daily noise level, number of airplanes, number of helicopters, and nest site (Table 46). In the model for recess length, day before hatch or failure and nest site were retained (Table 47). Nest site was significant in all 3 models ( $P < 0.01$ ), indicating that recess frequency, time off nest, and recess length differed among incubating birds and among nest locations. Geese took more recesses, took longer recesses, and spent more time off the nest as the day before hatch or failure approached (all 3 models,  $P < 0.01$ ). Nesting geese spent more time off nests on days when the number of airplanes ( $P = 0.03$ ) and the number of helicopters ( $P = 0.04$ ) were high. Geese also took more recesses on days when the number of airplanes ( $P = 0.06$ ) and the number of helicopters ( $P = 0.12$ ) was high, but the relationships were not significant. As the daily noise level increased, geese took fewer recesses and spent less time off nests ( $P = 0.04$  and  $0.01$ , respectively), which was inconsistent with the effect of airplanes and helicopters. Those three variables had small coefficients in the model, which suggests that none had large effects on nest attendance.

When nest site was excluded in the models for recess frequency, recess length, and time off nest, the same variables that were in the models with nest site were retained in each model, but daily noise level was removed and 2–4 variables were added to each model (Tables 46 and 47). Recess frequency, recess length, and time spent off nests were higher for geese at failed nests than at successful nests (all 3 models,  $P \leq 0.03$ ) and all 3 nest attendance variables increased as the day before hatch or failure approached (all 3 models,  $P < 0.01$ ). Geese took more recesses, took longer

recesses, and spent more time off the nest on days when the number of airplanes was high (all 3 models,  $P < 0.01$ ). However, geese took fewer recesses on days when the number of helicopters ( $P < 0.01$ ) and the amount of time pedestrians were on the airstrip ( $P = 0.01$ ) were high. Recesses were longer when the time pedestrians were on the airstrip was short ( $P = 0.15$ ). Geese nesting <1,000 m from the airstrip took more recesses and spent more time off nests than geese nesting >2,000 m (both models,  $P = 0.01$ ), but they took fewer recesses and spent less time off nests than geese nesting 1,000–2,000 m from the airstrip. Recess length did not differ significantly for geese nesting at different distances from the airstrip ( $P \geq 0.18$ ).

Although significant relationships were found between some sources of disturbance and nest attendance variables of geese, the most consistent and significant explanatory variables were nest site and day before hatch or failure. Airplane takeoffs and landings also had a consistent relationship with increased recess frequency, recess length, and time off nest, but coefficients were low. Recess frequency and time off nest increased with helicopter frequency when nest site was included in the model (but coefficients were low) but not when it was excluded. The duration of pedestrians on the airstrip, the distance of nests from the airstrip, and the fate of nests were factors only when individual nest sites were not accounted for, which may result from some nesting geese being more responsive because of individual variation or the proximity of their nests to the airstrip or to pedestrians. We conclude that airplane traffic at the airstrip did have a small negative effect on incubation constancy, but the effect was weak relative to nest fate or to day before hatch or failure.

#### *Effects of Disturbance on Concealment Responses*

Geese conceal on nests in response to predators, humans, caribou, other large birds, moving vehicles, and aircraft when the source of disturbance is perceived as a threat (Murphy and Anderson 1993). Alert postures may occur in response to the same sorts of stimuli. In 1998 and 1999, video cameras were not focused closely enough on White-fronted Goose nests to consistently record concealment postures. At nests

Table 46. Generalized linear models of the effects of potential disturbance and environmental variables on daily values for recess frequency and time off nest of incubating Greater White-fronted Geese in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Seventy-nine nests were monitored with egg thermistors between 0600 and 1800 ADT. Models were run with and without nest site as a categorical variable.

| Model                                       | $\beta$ | SE   | Z                   | df | P     |
|---|---------|------|---------------------|----|-------|
| <b>Recess Frequency (no./d)<sup>a</sup></b> |         |      |                     |    |       |
| With Nest Site                              |         |      |                     |    |       |
| Intercept                                   | 1.32    | 1.38 | 0.95                |    | 0.34  |
| Daily Noise Level ( $L_{eq}$ )              | -0.04   | 0.02 | -2.00               |    | 0.04  |
| Day Before Hatch or Failure                 | -0.07   | 0.01 | -9.98               |    | <0.01 |
| Number of Airplanes                         | 0.01    | 0.01 | 1.85                |    | 0.06  |
| Number of Helicopters                       | 0.02    | 0.01 | 1.53                |    | 0.12  |
| Nest Site                                   |         |      | 358.17 <sup>b</sup> | 78 | <0.01 |
| Without Nest Site                           |         |      |                     |    |       |
| Intercept                                   | 0.27    | 0.18 | 1.52                |    | 0.13  |
| Day Before Hatch or Failure                 | -0.04   | 0.01 | -5.69               |    | <0.01 |
| Wind Speed                                  | 0.02    | 0.01 | 1.76                |    | 0.08  |
| Number of Airplanes                         | 0.02    | 0.01 | 3.92                |    | <0.01 |
| Number of Helicopters                       | -0.02   | 0.01 | -3.03               |    | <0.01 |
| Min Pedestrians on Airstrip (ln)            | -0.04   | 0.02 | -2.55               |    | 0.01  |
| Fate (Successful)                           | -0.20   | 0.08 | -2.62               |    | 0.01  |
| Distance to Airstrip                        |         |      | 21.81 <sup>b</sup>  | 2  | <0.01 |
| 0–1,000 m                                   | 0       |      |                     |    |       |
| 1,000–2,000 m                               | 0.12    | 0.09 | 1.32                |    | 0.19  |
| >2,000 m                                    | -0.49   | 0.15 | -3.28               |    | <0.01 |
| <b>Time off Nest (min/d)<sup>c</sup></b>    |         |      |                     |    |       |
| With Nest Site                              |         |      |                     |    |       |
| Intercept                                   | 4.05    | 1.65 | 2.45                |    | 0.01  |
| Daily Noise Level ( $L_{eq}$ )              | -0.07   | 0.03 | -2.54               |    | 0.01  |
| Day Before Hatch or Failure                 | -0.07   | 0.01 | -7.57               |    | <0.01 |
| Number of Airplanes                         | 0.02    | 0.01 | 2.22                |    | 0.03  |
| Number of Helicopters                       | 0.03    | 0.02 | 2.05                |    | 0.04  |
| Nest Site                                   |         |      | 282.81 <sup>b</sup> | 78 | <0.01 |
| Without Nest Site                           |         |      |                     |    |       |
| Intercept                                   | 1.54    | 0.16 | 9.45                |    | <0.01 |
| Day Before Hatch or Failure                 | -0.07   | 0.01 | -7.26               |    | <0.01 |
| Number of Airplanes                         | 0.02    | 0.01 | 3.04                |    | <0.01 |
| Distance to Airstrip                        |         |      | 16.34 <sup>b</sup>  | 2  | <0.01 |
| 0–1,000 m                                   | 0       |      |                     |    |       |
| 1,000–2,000 m                               | 0.25    | 0.12 | 1.99                |    | 0.05  |
| >2,000 m                                    | -0.45   | 0.18 | -2.46               |    | 0.01  |
| Fate (Successful)                           | -0.23   | 0.11 | -2.19               |    | 0.03  |

<sup>a</sup> Model assumes a poisson distribution.

<sup>b</sup> Likelihood ratio  $\chi^2$ .

<sup>c</sup> Model assumes a negative binomial distribution.



Table 47. Generalized linear models of the effects of potential disturbance and environmental variables on daily values for recess length of incubating Greater White-fronted Geese in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Seventy-nine nests were monitored with egg thermistors between 0600 and 1800 ADT. Models were run with and without nest site as a categorical variable.

| Model  | $\beta$ | SE   | <i>t</i>          | df      | <i>P</i> |
|--|---------|------|-------------------|---------|----------|
| <b>Average Recess Length (min/d)<sup>a</sup></b> |         |      |                   |         |          |
| With Nest Site                                   |         |      |                   |         |          |
| Intercept  | 2.73    | 0.23 | 11.72             | 1       | <0.01    |
| Day Before Hatch or Failure                      | -0.01   | 0.01 | -3.91             | 1       | <0.01    |
| Nest Site  |         |      | 4.31 <sup>b</sup> | 78, 510 | <0.01    |
| Without Nest Site                                |         |      |                   |         |          |
| Intercept  | 2.71    | 0.08 | 35.49             | 1       | <0.01    |
| Day Before Hatch or Failure                      | -0.01   | 0.01 | -3.33             | 1       | <0.01    |
| Number of Airplanes                              | 0.01    | 0.01 | 4.72              | 1       | <0.01    |
| Min Pedestrians on Airstrip (ln)                 | -0.01   | 0.01 | -1.45             | 1       | 0.15     |
| Fate (Failure)                                   | 0.09    | 0.04 | 2.34              | 1       | 0.02     |
| Distance to Airstrip                             |         |      | 2.67 <sup>b</sup> | 2, 650  | 0.07     |
| 0–1,000 m  | -0.10   | 0.07 | -1.36             | 1       | 0.18     |
| 1,000–2,000 m                                    | 0.01    | 0.07 | 0.05              | 1       | 0.96     |
| >2,000 m   | 0       |      |                   |         |          |

<sup>a</sup> Model assumes a normal distribution.

<sup>b</sup> *F*-statistic

monitored by video in 2000 (4 nests) and 2001 (3 nests), the frequency and duration of concealment postures by each incubating bird varied with the frequency of the potential disturbance and with the location of the nest (Table 48). For 6 of the 7 geese, concealment postures occurred most often (39–61% of all concealments) when airplanes were taxiing, landing, or taking off. All 6 of these nests were nearer to either the airstrip or the flight path than they were to the infield road. The 7th nest was nearer to the infield road than the airstrip (154 m vs. 923–1,789 m), and the incubating bird at this nest concealed most often (40% of all concealments) when vehicles were present on the infield road.

The percentage of all concealments related to helicopters was higher for geese monitored in 2000 (mean = 13%) than in 2001 (mean = 7%; Table 48), even though the number of helicopters differed little between 2000 (20 events/d) and 2001 (17 events/d) during the period of nest monitoring. In 2000, the helipad was on the airstrip apron (Figure 1) and was nearer to nests than it was in 2001 (mean = 454 m in 2000 vs. mean = 2,071 m in 2001). In 2001, most helicopter takeoffs and landings (~95%) occurred on the southeastern

corner of CD-1 (Figure 1), and none of the nests monitored by video camera that year were in the flight path for helicopter takeoffs and landings (Figure 25). Pedestrians were the least frequent of the human sources of disturbance (Figure 14), and that was reflected in the percentage of concealment postures while pedestrians were on the airstrip (5% for all nests pooled). For all geese monitored, 12% of all concealments occurred when large birds (primarily White-fronted Geese) were feeding or loafing near monitored nests, and 1% of all concealments occurred when predators, the least common disturbance event, were near monitored nests. Predators and other birds near the nests were recorded less frequently (5 predator events/nest and 82 bird events/nest in 2001) than human sources of disturbance on the airstrip and infield road (range 140 pedestrian events/nest to 5,809 vehicle events/nest in 2001). These comparisons of relative frequency of concealments among disturbance types indicate that White-fronted Geese concealed most often to airplane events. The results also show that the frequency of concealment responses vary with disturbance frequency and vary among nests depending on their proximity to different types of disturbance

Table 48. The relative frequency of all concealment postures of incubating Greater White-fronted Geese among potential disturbance events in the Alpine project area, Colville River Delta, Alaska, 2000–2001. Seven nests were monitored with time-lapse video cameras. Nest 002 failed and all other nests were successful.

| Year/<br>Nest No. | Distance (m) from Nest |      |         |       | Concealment Postures |    |            |    |          |    |            |    |                         |    |                       |   | Total   |    |       |     |     |   |  |
|-------------------|------------------------|------|---------|-------|----------------------|----|------------|----|----------|----|------------|----|-------------------------|----|-----------------------|---|---------|----|-------|-----|-----|---|--|
|                   | Flight                 |      | Helipad |       | Airplane             |    | Helicopter |    | Vehicles |    | Pedestrian |    | Large Bird <sup>a</sup> |    | Predator <sup>b</sup> |   | Unknown |    | Total |     |     |   |  |
|                   | Airstrip               | path | Road    |       | No.                  | %  | No.        | %  | No.      | %  | No.        | %  | No.                     | %  | No.                   | % | No.     | %  | No.   | %   | No. | % |  |
| 2000              |                        |      |         |       |                      |    |            |    |          |    |            |    |                         |    |                       |   |         |    |       |     |     |   |  |
| 002               | 32                     | 58   | 841     | 575   | 41                   | 52 | 6          | 8  | 13       | 16 | 2          | 3  | 10                      | 13 | 1                     | 1 | 6       | 8  | 79    | 100 |     |   |  |
| 917               | 77                     | 106  | 1,244   | 314   | 91                   | 56 | 24         | 15 | 17       | 10 | 16         | 10 | 0                       | 0  | 1                     | 1 | 14      | 9  | 163   | 100 |     |   |  |
| 001               | 130                    | 101  | 1,760   | 441   | 51                   | 44 | 20         | 17 | 7        | 6  | 5          | 4  | 16                      | 14 | 2                     | 2 | 15      | 13 | 116   | 100 |     |   |  |
| 914               | 194                    | 43   | 1,846   | 487   | 122                  | 61 | 24         | 12 | 16       | 8  | 6          | 3  | 11                      | 6  | 1                     | 1 | 19      | 10 | 199   | 100 |     |   |  |
| 2000 Nests Pooled |                        |      |         |       | 305                  | 55 | 74         | 13 | 53       | 10 | 29         | 5  | 37                      | 7  | 5                     | 1 | 54      | 10 | 557   | 100 |     |   |  |
| 2001              |                        |      |         |       |                      |    |            |    |          |    |            |    |                         |    |                       |   |         |    |       |     |     |   |  |
| 007               | 85                     | 76   | 1,721   | 797   | 58                   | 39 | 20         | 14 | 30       | 20 | 8          | 5  | 19                      | 13 | 0                     | 0 | 13      | 9  | 148   | 100 |     |   |  |
| 1001              | 669                    | 90   | 452     | 2,112 | 34                   | 45 | 4          | 5  | 9        | 12 | 2          | 3  | 22                      | 29 | 3                     | 4 | 1       | 1  | 75    | 100 |     |   |  |
| 1106              | 1,789                  | 923  | 154     | 3,303 | 23                   | 13 | 3          | 2  | 70       | 40 | 9          | 5  | 38                      | 22 | 1                     | 1 | 32      | 18 | 176   | 100 |     |   |  |
| 2001 Nests Pooled |                        |      |         |       | 115                  | 29 | 27         | 7  | 109      | 27 | 19         | 5  | 79                      | 20 | 4                     | 1 | 46      | 12 | 399   | 100 |     |   |  |
| Both Years Pooled |                        |      |         |       | 420                  | 44 | 101        | 11 | 162      | 17 | 48         | 5  | 116                     | 12 | 9                     | 1 | 100     | 10 | 956   | 100 |     |   |  |

<sup>a</sup> Includes swans, geese, and ducks.

<sup>b</sup> Includes foxes and jaegers; Glaucous Gulls and Common Ravens were observed, but did not cause concealments.

and possibly the individual goose's responsiveness to each disturbance type.

Mean time spent in concealment postures in response to different sources of disturbance also may be an indicator of the effect of these disturbances on nesting White-fronted Geese (Table 49). The duration of concealments by incubating geese differed significantly among disturbance types, between years, and among levels of the interaction term (i.e., the relationship among types differed between years) (ANOVA,  $F = 64.16$ ,  $df = 11, 844$ ,  $P < 0.01$ ). Because the interaction was significant, we compared the duration of concealments among each disturbance type in each year with those for disturbance types in the other year using all pairwise multiple comparisons. Only pedestrian events had significantly different concealment durations between 2000 and 2001 ( $P < 0.01$ ), which probably explains the significant interaction in the model. The longest concealments were in response to pedestrians in 2001 (mean = 15.8 min), which were significantly longer than concealments during all other disturbance types (all  $P < 0.05$ ), except for birds ( $P > 0.64$ ). Other birds also elicited long concealments from nesting geese—significantly longer than concealments to all other types of events ( $P < 0.01$ ) other than pedestrians in 2001 and predators in 2000 (both  $P \geq 0.55$ ). Concealments during airplane and helicopter events in both years were similar in length, but were significantly shorter than those during bird events in both years and significantly shorter than those during vehicle and pedestrian events in 2001 (all  $P < 0.01$ ). The length of concealments by incubating geese during disturbance events probably reflect the duration of those events near each nest. Although we do not have data on the elapsed time each potential disturbance source was near a nest, the relative speed at which airplanes, helicopters, vehicles, and pedestrians travel and the tendency of other birds and predators to stop at nests seems to explain the differences in concealment durations among the disturbance types. The duration of concealments should be considered along with the frequency of concealments (discussed above) if one is trying to judge the total time concealment occurs in response to different disturbance types. However, these 2 factors are not directly related to the sensitivity or responsiveness

of geese to different types of disturbance, which is evaluated below.

The responsiveness of nesting geese monitored by video to different types of potential human disturbance (Table 50) was evaluated by comparing the proportion of disturbance events during which geese concealed among different disturbance types and with distance of nests to disturbance sources as a covariate. The effect of distance on concealment did not differ among disturbance types ( $P = 0.71$ ), so the model was run without that interaction term (ANCOVA,  $F = 19.81$ ,  $df = 4, 23$ ,  $P < 0.01$ ). For the 7 monitored geese, the proportion of events during which concealments occurred differed significantly among the 4 types of disturbance ( $P < 0.01$ ) and with distance to disturbance ( $P < 0.01$ ). The proportion of airplane events eliciting concealments was higher than for helicopter and vehicle events, but pedestrian events had a higher proportion of concealments in 2000 than all other types that year (Table 50). Overall, the proportion of concealments significantly differed between vehicles and all other types of disturbance ( $P < 0.01$ , pairwise comparisons), but did not significantly differ among those other types ( $P > 0.34$ ).

Because the monitored White-fronted Goose nests were not equivalent distances from each of the potential disturbance sources, we investigated the effect of distance on concealment frequency. The ANCOVA model above showed that the proportion of human-caused disturbance events during which nesting geese concealed decreased with increasing distance of nests to the disturbance source ( $P < 0.01$ ; Figure 26). The slopes of the relationships were similar for the 4 different disturbance types. However, we caution that this comparison is valid only over the range of distances for which the types overlap. Nests were not located as close to helicopters (mean = 1,147 m to helipads) as they were to the airplanes, vehicles, and pedestrians (mean = 425 m to the airstrip and mean = 200 m to the flight path; Table 50), which prevented direct comparisons among the disturbance types when they are near to nests and probably elicit the most reactions. The response rate to helicopters would probably differ for geese nesting closer to helipads, and the slope of the distance function for helicopters (Figure 26)

Table 49. The duration of all concealment postures of incubating Greater White-fronted Geese during potential disturbance events in the Alpine project area, Colville River Delta, Alaska, 2000–2001. Nest 002 failed and all other nests were successful. See Table 48 for number of concealment postures.

| Year/<br>Nest<br>No. | Distance (m) from Nests |     |        |       | Duration of Concealment Postures by Disturbance Type |      |         |      |                       |      |                         |       |          |      |            |      |                         |      |                       |      |         |    |       |    |  |
|----------------------|-------------------------|-----|--------|-------|--|------|---------|------|-----------------------|------|-------------------------|-------|----------|------|------------|------|-------------------------|------|-----------------------|------|---------|----|-------|----|--|
|                      | Airstrip                |     | Flight |       | Road   |      | Helipad |      | Airplane <sup>a</sup> |      | Helicopter <sup>a</sup> |       | Vehicles |      | Pedestrian |      | Large Bird <sup>b</sup> |      | Predator <sup>c</sup> |      | Unknown |    | Total |    |  |
|                      | path                    | SE  | SE     | SE    | SE   | SE   | SE      | SE   | SE                    | SE   | SE                      | SE    | SE       | SE   | SE         | SE   | SE                      | SE   | SE                    | SE   | SE      | SE | SE    | SE |  |
| 2000                 |                         |     |        |       |  |      |         |      |                       |      |                         |       |          |      |            |      |                         |      |                       |      |         |    |       |    |  |
| 002                  | 32                      | 58  | 841    | 575   | 1.6  | 0.22 | 4.0     | 2.29 | 3.9                   | 1.33 | 1.0                     | 0.00  | 18.4     | 3.95 | 8.0        | –    | 6.7                     | 3.96 | 4.7                   | 0.88 |         |    |       |    |  |
| 917                  | 77                      | 106 | 1,244  | 314   | 1.5  | 0.16 | 2.3     | 0.76 | 2.2                   | 0.51 | 2.9                     | 0.85  | –        | –    | 2.0        | –    | 1.7                     | 0.65 | 1.8                   | 0.18 |         |    |       |    |  |
| 001                  | 130                     | 101 | 1,760  | 441   | 1.2  | 0.08 | 1.4     | 0.20 | 1.1                   | 0.15 | 1.8                     | 0.58  | 5.3      | 1.35 | 3.5        | 0.49 | 3.1                     | 1.52 | 2.1                   | 0.30 |         |    |       |    |  |
| 914                  | 194                     | 43  | 1,846  | 487   | 1.2  | 0.07 | 1.2     | 0.10 | 1.6                   | 0.55 | 2.0                     | 0.82  | 7.6      | 2.68 | 1.0        | –    | 2.2                     | 1.15 | 1.7                   | 0.22 |         |    |       |    |  |
| 2000 Nests Pooled    |                         |     |        |       | 1.3  | 0.06 | 1.8     | 0.31 | 2.3                   | 0.41 | 2.4                     | 0.50  | 9.5      | 1.68 | 3.6        | 1.21 | 2.8                     | 0.75 | 2.3                   | 0.17 |         |    |       |    |  |
| 2001                 |                         |     |        |       |  |      |         |      |                       |      |                         |       |          |      |            |      |                         |      |                       |      |         |    |       |    |  |
| 007                  | 85                      | 76  | 1,721  | 797   | 1.9  | 0.35 | 1.5     | 0.22 | 2.7                   | 0.47 | 14.1                    | 2.69  | 10.5     | 1.86 | –          | –    | 5.7                     | 2.02 | 4.1                   | 0.48 |         |    |       |    |  |
| 1001                 | 669                     | 90  | 452    | 2,112 | 1.3  | 0.15 | 1.0     | 0.00 | 1.8                   | 0.53 | 16.0                    | 11.03 | 6.1      | 1.07 | 1.3        | 0.35 | 2.0                     | –    | 3.2                   | 0.52 |         |    |       |    |  |
| 1106                 | 1,789                   | 923 | 154    | 3,303 | 1.7  | 0.27 | 1.3     | 0.35 | 3.3                   | 0.51 | 17.3                    | 7.90  | 15.1     | 2.37 | 4.0        | –    | 3.8                     | 0.88 | 6.4                   | 0.81 |         |    |       |    |  |
| 2001 Nests Pooled    |                         |     |        |       | 1.7  | 0.19 | 1.4     | 0.17 | 3.0                   | 0.35 | 15.8                    | 3.88  | 11.5     | 1.33 | 2.0        | 0.70 | 4.3                     | 0.84 | 4.9                   | 0.42 |         |    |       |    |  |
| Both Years Pooled    |                         |     |        |       | 1.4  | 0.07 | 1.7     | 0.24 | 2.8                   | 0.28 | 7.7                     | 1.82  | 10.9     | 1.05 | 2.9        | 0.75 | 3.5                     | 0.56 | 3.4                   | 0.20 |         |    |       |    |  |

<sup>a</sup> Includes takeoffs and landings, not overflights.

<sup>b</sup> Includes swans, geese, and ducks.

<sup>c</sup> Includes foxes and jaegers; Glaucous Gulls and Common Ravens were observed, but did not cause concealments.

Table 50. The proportion of events in which incubating Greater White-fronted Geese concealed during human disturbance events on the airstrip or infield road in the Alpine project area, Colville River Delta, Alaska, 2000–2001. Seven nests were monitored with time-lapse video cameras. Nest 002 failed, but all other nests were successful.

| Year/<br>Nest<br>No.   | Distance (m) from Nest |                |       |              | Incubation<br>Behavior/<br>Events | Airplane<br>Landings or<br>Takeoffs |     | Helicopter<br>Landings or<br>Takeoffs |     | Vehicles |     | Pedestrians |     | No. Potential<br>Disturbance<br>Events |       |
|------------------------|------------------------|----------------|-------|--------------|-----------------------------------|-------------------------------------|-----|---------------------------------------|-----|----------|-----|-------------|-----|--|-------|
|                        | Air-<br>strip          | Flight<br>path | Road  | Heli-<br>pad |                                   | No.                                 | %   | No.                                   | %   | No.      | %   | No.         | %   |  |       |
| 2000                   |                        |                |       |              |                                   |                                     |     |                                       |     |          |     |             |     |  |       |
| 002                    | 32                     | 58             | 841   | 575          | Conceal <sup>a</sup>              | 54                                  | 42  | 24                                    | 18  | 38       | 19  | 13          | 65  |  |       |
|                        |                        |                |       |              | Normal                            | 76                                  | 58  | 110                                   | 82  | 161      | 81  | 7           | 35  |  |       |
|                        |                        |                |       |              | Total Events                      | 130                                 | 100 | 134                                   | 100 | 199      | 100 | 20          | 100 |  | 483   |
|                        |                        |                |       |              | % of Events                       |                                     | 27  |                                       | 28  |          | 41  |             | 4   |  |       |
| 917                    | 77                     | 106            | 1,244 | 314          | Conceal                           | 118                                 | 29  | 41                                    | 20  | 54       | 12  | 46          | 58  |  |       |
|                        |                        |                |       |              | Normal                            | 285                                 | 71  | 168                                   | 80  | 382      | 88  | 34          | 42  |  |       |
|                        |                        |                |       |              | Total Events                      | 403                                 | 100 | 209                                   | 100 | 436      | 100 | 80          | 100 |  | 1,128 |
|                        |                        |                |       |              | % of Events                       |                                     | 36  |                                       | 18  |          | 39  |             | 7   |  |       |
| 001                    | 130                    | 101            | 1,760 | 441          | Conceal                           | 82                                  | 20  | 44                                    | 12  | 51       | 10  | 15          | 26  |  |       |
|                        |                        |                |       |              | Normal                            | 331                                 | 80  | 326                                   | 88  | 475      | 90  | 43          | 74  |  |       |
|                        |                        |                |       |              | Total Events                      | 413                                 | 100 | 370                                   | 100 | 526      | 100 | 58          | 100 |  | 1,367 |
|                        |                        |                |       |              | % of Events                       |                                     | 30  |                                       | 27  |          | 38  |             | 4   |  |       |
| 914                    | 194                    | 43             | 1,846 | 487          | Conceal                           | 168                                 | 31  | 41                                    | 12  | 54       | 9   | 17          | 18  |  |       |
|                        |                        |                |       |              | Normal                            | 369                                 | 69  | 296                                   | 88  | 554      | 91  | 75          | 82  |  |       |
|                        |                        |                |       |              | Total Events                      | 537                                 | 100 | 337                                   | 100 | 608      | 100 | 92          | 100 |  | 1,574 |
|                        |                        |                |       |              | % of Events                       |                                     | 34  |                                       | 21  |          | 39  |             | 6   |  |       |
| Mean for Nests in 2000 |                        |                |       |              | Conceal                           |                                     | 31  |                                       | 16  |          | 12  |             | 42  |  |       |
|                        |                        |                |       |              | Normal                            |                                     | 69  |                                       | 84  |          | 88  |             | 58  |  |       |
|                        |                        |                |       |              | Total Events                      |                                     | 100 |                                       | 100 |          | 100 |             | 100 |  |       |
|                        |                        |                |       |              | % of Events                       |                                     | 32  |                                       | 24  |          | 39  |             | 5   |  |       |
| 2001                   |                        |                |       |              |                                   |                                     |     |                                       |     |          |     |             |     |  |       |
| 007                    | 85                     | 76             | 1,721 | 797          | Conceal                           | 71                                  | 21  | 45                                    | 9   | 214      | 3   | 41          | 18  |  |       |
|                        |                        |                |       |              | Normal                            | 265                                 | 79  | 443                                   | 91  | 6,013    | 97  | 188         | 82  |  |       |
|                        |                        |                |       |              | Total Events                      | 336                                 | 100 | 488                                   | 100 | 6,227    | 100 | 229         | 100 |  | 7,280 |
|                        |                        |                |       |              | % of Events                       |                                     | 5   |                                       | 7   |          | 85  |             | 3   |  |       |
| 1001                   | 669                    | 90             | 452   | 2,112        | Conceal                           | 37                                  | 16  | 21                                    | 6   | 215      | 3   | 27          | 17  |  |       |
|                        |                        |                |       |              | Normal                            | 194                                 | 84  | 332                                   | 94  | 7,519    | 97  | 132         | 83  |  |       |
|                        |                        |                |       |              | Total Events                      | 231                                 | 100 | 353                                   | 100 | 7,734    | 100 | 159         | 100 |  | 8,477 |
|                        |                        |                |       |              | % of Events                       |                                     | 3   |                                       | 4   |          | 91  |             | 2   |  |       |
| 1106                   | 1,789                  | 923            | 154   | 3,303        | Conceal                           | 49                                  | 18  | 24                                    | 6   | 238      | 7   | 5           | 16  |  |       |
|                        |                        |                |       |              | Normal                            | 221                                 | 82  | 389                                   | 94  | 3,228    | 93  | 27          | 84  |  |       |
|                        |                        |                |       |              | Total Events                      | 270                                 | 100 | 413                                   | 100 | 3,466    | 100 | 32          | 100 |  | 4,181 |
|                        |                        |                |       |              | % of Events                       |                                     | 6   |                                       | 10  |          | 83  |             | 1   |  |       |
| Mean for Nests in 2001 |                        |                |       |              | Conceal                           |                                     | 18  |                                       | 7   |          | 4   |             | 17  |  |       |
|                        |                        |                |       |              | Normal                            |                                     | 82  |                                       | 93  |          | 96  |             | 83  |  |       |
|                        |                        |                |       |              | Total Events                      |                                     | 100 |                                       | 100 |          | 100 |             | 100 |  |       |
|                        |                        |                |       |              | % of Events                       |                                     | 5   |                                       | 7   |          | 86  |             | 2   |  |       |

<sup>a</sup> One concealment posture may occur during multiple aircraft, vehicle, or pedestrian events

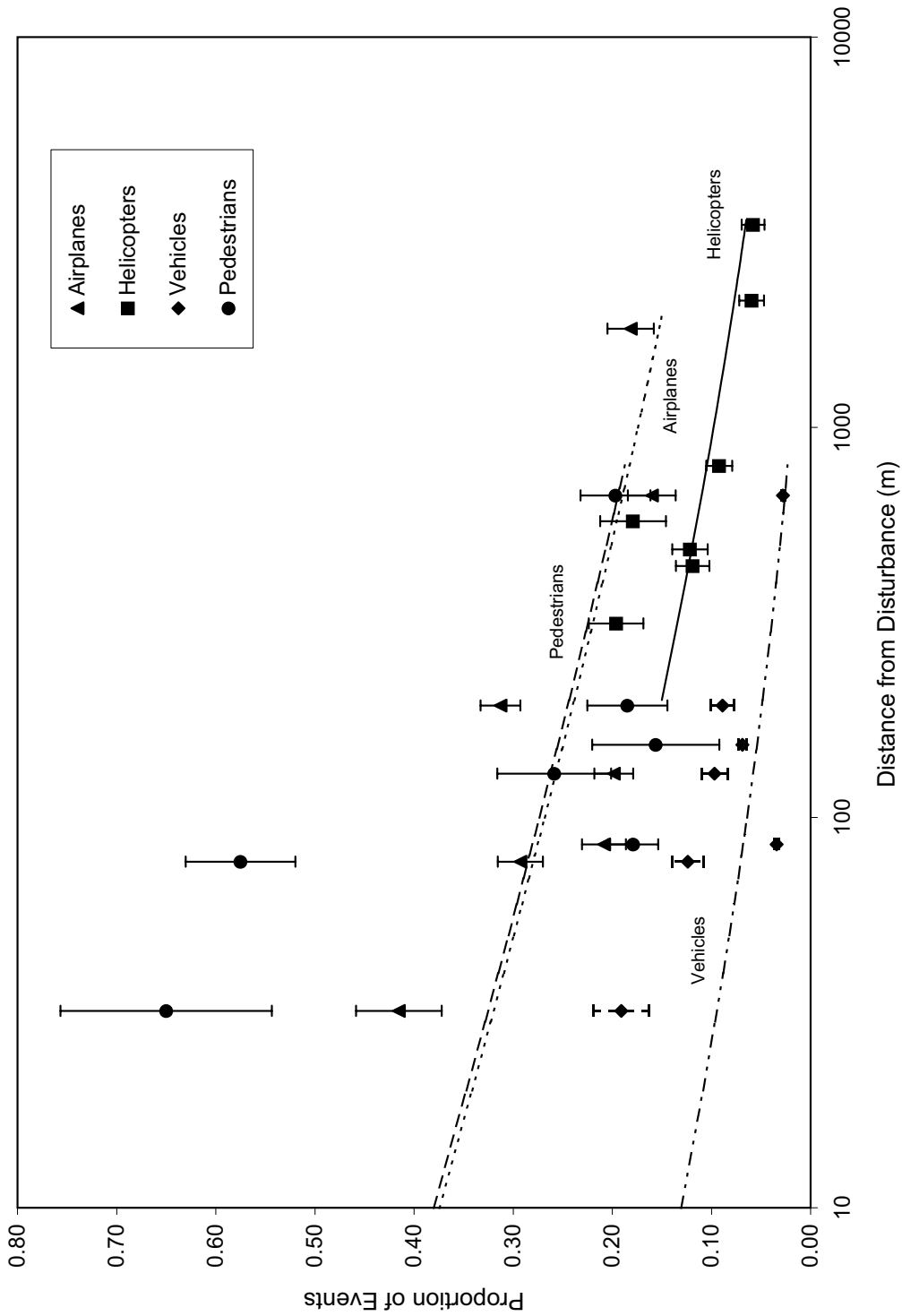


Figure 26. The proportion of disturbance events during which incubating Greater White-fronted Geese (4 in 2000 and 3 in 2001) concealed as a function of distance from nests to disturbance source in the Alpine project area, Colville River Delta, Alaska. Symbols represent means  $\pm$  SE. The source of disturbance for airplanes was the Alpine airstrip, the source for helicopters was the helipad (different location in each year), and the source for vehicles and pedestrians was the airstrip for 6 geese and the infield road for 1 goose.

might become steeper, if incubating birds at closer nests were disproportionately more reactive. Helicopters were louder than all other aircraft using the Alpine airstrip but departing DC-6s (see contour widths, Table 5) and have been reported to cause stronger reactions in non-nesting geese than did fixed-wing aircraft (Owens 1977, Ward and Stehn 1994). Consequently, helicopters have the potential to be more disturbing than single- or twin-engine aircraft at the same distances and altitudes. Therefore, the comparison among types of potential disturbance presented here is valid only for the sample of nests and aircraft locations (airstrip and helipads) analyzed and should not be used to make generalizations about the relative impacts on nesting birds of helicopters compared with other disturbance types.

For the 7 nests monitored and the particular locations of human types of potential disturbance in the Alpine project area, pedestrians and airplanes elicited the highest rates of concealment and vehicles the lowest rates of concealment. Helicopters elicited intermediate rates of concealment. Geese concealed most frequently to airplanes followed by vehicles and helicopters. Of these human sources of disturbance, pedestrians elicited the longest concealments and highest rates of concealment, which indicates that the nesting White-fronted Geese in our sample were most sensitive to humans on foot.

#### *Recesses Caused by Human Disturbance*

The most dramatic reaction to disturbance is when a nesting bird flees its nest suddenly. Although observation of these disturbance recesses, commonly known as flushes, were not frequent in video monitoring, flushes have the potential to indirectly cause nest failure by allowing predators access to undefended nests. Here we describe some observations on the flushing of geese from nests that are relevant to the evaluation of different types of disturbance. When egg thermistors were deployed in White-fronted Goose nests, the incubating birds were flushed from their nests. The length of time females took to return to incubate after installing an egg thermistor averaged 118 min (range 10–852 min,  $n = 115$  installations), which is approximately 6 $\times$  the mean length for undisturbed recesses (mean = 19 min, range 2–670 min,  $n = 2,174$

recesses at 97 nests). Some geese were still laying when thermistors were installed, and these geese probably took longer to return to their nests than geese that were incubating. The length of time that we were at the nest (mean = 21 min, range 5–85 min,  $n = 107$  installations) and in the vicinity probably affected the amount of time that the incubating bird was away. The thermistors were deployed during nest searching, and it might have taken ~1–9 hours (the longest times were on breeding-bird plots) before the researchers were no longer visible from each nest site. The temperature pattern of only 5 of 115 egg thermistors indicated that nest failure occurred between the time the thermistors were installed and the return of the incubating geese. The mean time it took 4 of these birds to return to incubate was 85 min; the fifth incubating bird may have abandoned her nest because the thermistor recordings tracked ambient temperature. As reported earlier, nesting success, on average, was no different between nests of White-fronted Geese with thermistor eggs and those without, but some nest losses (~5%) obviously resulted from the disturbance associated with flushing birds off nests.

Between 1998 and 2001, 11 incubating White-fronted Geese that previously were equipped with egg thermistors were flushed from nests during nest-searching activities. After these disturbances, the eggs were covered with nest material and researchers departed the area soon (5–45 min) after the bird was flushed. After being disturbed, the incubating birds remained off their nests for an average of 62 min (range 25–130 min). Nine of these 11 nests hatched. While nest searching in the breeding-bird plots, 15 different geese were flushed off nests 20 times (5 geese were flushed twice) and the mean recess length was 170 min (range 35–800 min), nearly 3 $\times$  that during nest searching. Our presence on the breeding-bird plots after flushing an incubating bird ranged from 40 to 500 min, which delayed the return of geese to their nests. Eleven out of these 20 times geese returned to the nest while researchers were still working within 500 m. The remaining 9 times, incubating birds returned to their nest after researchers had left the plot. Of these 15 nests, 7 failed and 8 were successful. Temperature patterns from the egg thermistors indicated that geese at nests that were disturbed during nest

searching and breeding-bird plot searches and that ultimately failed, did not fail immediately; those geese resumed normal incubation behavior after disturbance and for 2–20 d (mean = 11.4 d,  $n = 9$  nests) before nest failure was recorded.

In 1999 and 2001, people (unrelated to this study) on the tundra were recorded by video cameras causing disturbances to nesting White-fronted Geese. In 2001, a goose nesting 85 m from the airstrip was flushed by a man walking recreationally on the tundra, and although she remained off the nest for 40 min, the nest eventually hatched. Cleanup personnel caused 3 flushes to 2 geese in 1999 and 3 flushes to 1 goose in 2001. Geese were off the nest for an average of 61 min (range 35–90 min) after these 6 disturbances, similar to the amount of time geese were off nests after being flushed during nest searching activities. The rate of travel across the tundra during nest searching and cleanup activities was similar, and consequently, people were present in the area for a similar amount of time. No predation was observed during these disturbance flushes even though nests probably were not covered with nesting material. One nest failed 3 d after the disturbance flush and the other 2 nests were successful.

In 1999, 5 recesses (5% of 92 total recesses) taken by a White-fronted Goose monitored by video occurred when aircraft were taking off from the airstrip. Mean recess length for the 5 recesses (mean = 46.8 min/recess) was more than twice as long as the mean for all other recesses for that goose (mean = 18.7 min/recess,  $n = 87$ ), but only the first recess (143 min), which occurred on or before the first day of incubation (estimated by backdating from hatch), was longer than normal recesses. This nest was 25 m from the southwest end of the airstrip, where aircraft took off most often into prevailing winds (from the northeast), and was closer to the airstrip than all other goose nests after the airstrip began operation. Four of the recesses occurred during DC-6 takeoffs (25% of 16 total DC-6 events for this nest) and one occurred during a Twin Otter takeoff (1% of 72 total Twin Otter events). During the period that this nest was monitored, 106 airplane events (another 368 helicopter events occurred at the far end of the airstrip) were recorded at the airstrip, and disturbance recesses occurred during 5% of these

airplane events. Comparisons of the proportions of aircraft events indicates that the incubating bird at this nest was most reactive to the DC-6. The maximal noise level ( $L_{\max}$ ) from a DC-6 estimated for this nest site was 109 dBA, the loudest noise level attained at any nest in the project area in 1999–2001. The recess length declined from the first disturbance recess to 20–26 min for the remaining 4 recesses suggesting a reduction in sensitivity; nonetheless, the disturbance recesses occurred on 5 different days spread throughout the first 16 d of incubation, so the incubating bird continued to react to some airplanes for over 2 weeks. This nest failed in a predation event that was unrelated to aircraft disturbance—a red fox flushed the goose and took all its eggs on or near the expected day of hatch.

Another incubating goose monitored in 1999 nested 109 m from the helipad and 119 m from the airstrip and was repeatedly exposed to low-altitude helicopter flights. Because of prevailing winds, the helicopter's approach path passed directly over the nest. The day the thermistor was installed, which was estimated to be either the first day of incubation or the day before, the incubating goose initiated 4 recesses near the time (<5 min) that aircraft took off or landed (2 recesses each for a DC-6 and a helicopter). These 4 disturbance recesses accounted for 9% of the 46 recesses recorded and occurred during less than 1% of the 497 aircraft events that occurred while the nest was monitored. One of these recesses was observed by our researchers from the helicopter, which flew directly over the nest on its way to the helipad. The goose flushed as the helicopter descended over the nest at an estimated altitude of 30–50 m above ground, which could produce an estimated maximal noise level ( $L_{\max}$ ) of 102–106 dBA over that range of altitudes. For comparison, the DC-6 was estimated to produce 100 dBA at this nest site. Mean recess length for the 4 disturbance recesses (mean = 25.0 min/recess) was similar to the mean of all other recesses for that goose (mean = 22.8 min/recess,  $n = 34$ ), and this nest hatched. The incubating bird at this nest did not take any more recesses that were associated with aircraft after that day, despite many similar aircraft events, and we suspect this change in response to be the result of the goose beginning incubation the next day (i.e.,



had not yet established an incubation schedule) or because the goose became less sensitive to aircraft.

To evaluate the possibility that incubating White-fronted Geese habituated (became less sensitive) to repeated aircraft visits, we compared the proportion of recesses that occurred during aircraft events among years. In 2000 and 2001, no geese were observed on video-recordings taking recesses when an aircraft was in view. However, aircraft were not always visible on the video recordings, so cases in which geese did not cover their eggs for a recess were identified as an indicator of a disturbance recess and matched those recesses with time records of aircraft landings or take-offs. In 2000, 6 disturbance recesses out of 74 recesses (8%) occurred during time periods that were associated with aircraft events. In 2001, only one disturbance recess out of 95 recesses (1%) matched the time of an aircraft event. Although fewer disturbance recesses by video-monitored geese were associated with aircraft in 2000 and 2001 than in 1999, geese were not necessarily less sensitive to aircraft in the later 2 years. The location of nests relative to the airstrip may have moderated the responses, because monitored nests, which were the closest nests to sources of disturbance, were farther from the airstrip in 2000 (mean = 108 m) and 2001 (mean = 848 m) than in 1999 (mean = 59 m).

The observations above illustrate that recesses caused by disturbance can be longer than normal and that the risk of predation or exposure of eggs to cold can increase when nesting geese are flushed. The length of recesses caused by pedestrian disturbances are longer than those caused by aircraft, but the length varies among individual geese and depends on the length of time the disturbance source (particularly pedestrians) remains in the vicinity of the nest. Long recesses increase the risk of predation, because most of the predators in the project area take advantage of unattended nests. Furthermore, the risk of predation is higher when recesses are in response to disturbance, because geese do not cover their nests when flushed, thereby increasing the chances avian predators will detect the eggs. The low rates of recesses observed to occur in response to aircraft suggests that aircraft did not substantially increase the risk of predation for the goose nests monitored by video camera, even though these nests were

selected for monitoring because they were the closest to the airstrip or road. Pedestrian disturbances may be the most serious of the human caused disturbances, because they elicited the longest recesses, and geese had the highest rates of response to pedestrians, as demonstrated by the evaluation of concealment postures above. These conclusions generally agree with the findings of other studies that pedestrians or other unusual and severe types of disturbance (e.g., helicopters landing) caused nest abandonment by geese when the disturbance source was near nests (Murphy and Anderson 1993) and that pedestrians caused high rates of disruption to normal behavior (Owens 1977, Murphy and Anderson 1993, Ward and Stehn, 1989).

#### *Reactions to Predators*

The reactions of nesting White-fronted Geese to predators also were monitored by video in 1998–2001, but were not analyzed quantitatively with reactions to human-related disturbance because predators occurred independently at different nests and the distance of predator to nest was not constant. Arctic or red foxes were seen in the camera view at 11 of the 14 goose nests monitored. Incubating geese reacted to an approaching fox by standing and defending the nest (defensive break), by assuming an alert or concealment posture, or by fleeing the nest. Twelve defensive breaks were recorded at 6 different nests when arctic foxes were near the nest. During all but one defensive break the fox was <5 m from the nest. On 7 of these breaks (58%), nesting pairs reacted by standing erect and flapping their wings in the direction of the fox for 1–5 recording intervals (~1–5 min). During the other 5 breaks (42%), incubating geese either stood over their nests in an alert posture or remained sitting on their nests and hissed at the fox for 1–7 recording intervals (~1–7 min). Incubating geese frequently sat in an alert posture for 1–4 recording intervals (~1–4 min) before or after defensive breaks. On 22 occasions an arctic fox was seen on video and the incubating goose did not take a defensive break but was alert (4 times), concealed (6 times), or showed no reaction (12 times). A fox was >5 m from the nest during 19 of these 22 events. On 12 other occasions the female and male geese showed defensive behavior (flapping of

wings, hissing), but no predators were seen on the video.

On one occasion a red fox flushed the female and male from a nest and took 4 eggs during 4 visits to the nest. The pair remained near the nest and returned to incubate, but the fox flushed the geese from the nest again 5 min later. The fox was at the nest for 1–3 recording intervals/visit (~1–3 min/visit) and the predation event lasted 30 min. The pair returned to the nest 18 min after the last visit by the fox and continued to incubate; the only egg remaining in the nest was an artificial egg with a thermistor. Red foxes were seen on video recordings on 3 other occasions >25 m from goose nests and did not appear to be aware of the nests. The incubating goose was alert, had no reaction, or was on recess during each of these 3 events.

Nesting geese did not react as strongly to avian predators as they did to foxes. On 27 occasions in 1998–2001, an avian predator was seen on video while incubating geese were on or near their nests. During 11 (41%) of those events, a jaeger or a raven was on the ground (6 times) or flying over (5 times) <5 m from each nest. The incubating geese reacted during 3 of these 5 flyovers with alert or concealment postures. An incubating goose hissed at a raven that landed <5 m from the nest, but no reactions were noted during the other 5 times a raven or jaeger was on the ground <5 m from the nest. No defensive breaks by geese occurred when avian predators were seen on video recordings. A raven appeared for 1 min during the same video frame as an arctic fox, but the nesting pair already was standing and defending their nest from the fox when the raven appeared 10 m from the nest. Incubating geese showed no reaction during all 16 occasions when jaegers or ravens were >5 m from nests, whether they were on the ground (7 times) or flying over (9 times).

## TUNDRA SWAN

### Nest Attendance

Tundra Swan nests were monitored with video cameras to evaluate the effects of construction-related disturbance and other factors on the incubation behavior of swans. Seven Tundra Swan nests were monitored with video cameras from 1998–2001 (Figure 25). All 7 nests

could not be analyzed simultaneously for differences in nest attendance because one nest failed almost immediately, 2 nests had abnormal attendance patterns, and 3 nests likely were used by the same pair in different years, and therefore, were not independent. The 2 Tundra Swan nests monitored in 1998 were monitored for baseline data before airplanes used the airstrip, but nest attendance at both nests was poor, resulting in low incubation constancy (82.3%,  $n = 9$  d and 83.9%,  $n = 4$  d) with frequent (2.4 and 4.7 recesses/d) and long (101.0 and 48.9 min/recess) recesses. Predation by jaegers occurred at both nests (not during camera servicing); one nest failed and the other hatched 2 eggs after 2 were lost to jaegers. In 1999, mean daily incubation constancy was high ( $\geq 97\%$ ) at 2 monitored nests, but the nest closest to the airstrip (nest 105) had a higher incubation constancy ( $P < 0.01$ ) than the nest farther from the airstrip (nest 008; Table 51). Mean recess length was similar for these 2 nests (12.2 and 15.2 min/recess,  $P = 0.25$ ), but the swans at nest 105 took fewer recesses (mean = 0.5 recesses/d) and spent less time off the nest each day (mean = 12.6 min/d) than the swans at nest 008 (mean = 2.4 recesses/d and mean = 43.7 min/d,  $P = 0.01$  for both tests). Mean number of exchanges (between male and female) for both nests (2.5 and 2.7 exchanges/d,  $P = 0.92$ ) and mean time off nest for exchanges (6.3 min/d and 7.1 min/d,  $P = 0.50$ ) were similar. In 2000, the swans at nests 008 and 105 (same nest site used in 1996–2000) also were monitored with video, but nest 008 failed the day after the camera was installed.

If construction-related disturbance had affected incubation activity negatively, we would expect to find reduced incubation constancy at nests closer to disturbance sources (e.g., the airstrip) and in years with higher levels of construction activity (i.e., 1999–2001). Neither of these trends was found, in fact, the trends were for increased nest attendance at swan nests close to facilities and in years with high-levels of construction. Therefore, we conclude that the swans monitored in the Alpine project area did not exhibit any negative impacts to their incubation activities from construction-related disturbance.

Earlier in the Nest Densities and Distribution section (Part II of this report), a nest site was described that was occupied for at least 7 years and

Table 51. Comparison of nesting activities of incubating Tundra Swans in the Alpine project area, Colville River Delta, Alaska, 1999. Tundra Swan nests were monitored with time-lapse video cameras. Both nests were successful.

|                            | Nest 105 <sup>a</sup> |       | Nest 008 <sup>b</sup> |       | Mann-Whitney |       |
|----------------------------|-----------------------|-------|-----------------------|-------|--------------|-------|
|                            | $\bar{x}$             | $n^c$ | $\bar{x}$             | $n^c$ | $\chi^2$     | $P$   |
| Incubation Constancy (%/d) | 99.1                  | 22    | 97.0                  | 19    | 7.90         | <0.01 |
| Recess Frequency (no./d)   | 0.5                   | 22    | 2.4                   | 19    | 8.54         | <0.01 |
| Recess Length (min/recess) | 12.2                  | 11    | 15.2                  | 45    | 1.34         | 0.25  |
| Time off nest (min/d)      | 12.6                  | 22    | 43.7                  | 19    | 7.90         | <0.01 |
| Break Frequency (no./d)    | 9.9                   | 22    | 13.7                  | 19    | 4.71         | 0.03  |
| Time on Break (min/d)      | 16.3                  | 22    | 16.3                  | 19    | 0.91         | 0.34  |
| Exchange Frequency (no./d) | 2.5                   | 22    | 2.7                   | 19    | 0.01         | 0.92  |
| Time on Exchange (min/d)   | 6.3                   | 22    | 7.1                   | 19    | 0.45         | 0.50  |

<sup>a</sup> Nest 105 was 449 m from the airstrip and 124 m from the flight path.

<sup>b</sup> Nest 008 was 1,283 m from the airstrip and 157 m from the flight path.

<sup>c</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

likely was used by one pair of swans. That nest site (nest 105) was monitored with a video camera in 1999–2001 and provided a unique opportunity to compare incubation behavior at one nest site with annually varying levels of disturbance. Incubation constancy for those 3 years was higher than for any other swan nest monitored and was nearly the same each year ( $P = 0.78$ ; Table 52). Mean number of recesses and mean time off nest were similar among years ( $P \geq 0.74$  for both tests), but mean recess length differed ( $P = 0.05$ ). Mean recess length was longest in 1999 (12.2 min/recess) and shortest in 2000 (5.7 min/recess). Break frequency, time on breaks, and exchange frequency all differed significantly among years ( $P \leq 0.01$ ). Breaks and exchanges are events of short duration and probably were undercounted in 1999 because each recording on the video was 1 sec compared with 2 sec recordings in 2000 and 2001, making this behavior more difficult to detect in 1999. Each year that the nest was video-monitored, all eggs hatched and 2–4 young fledged. Thus, the incubation behavior at nest 105 was relatively consistent among the 3 years, and was less variable among years than was the variation in behavior among 2 nests (nests 008 and 105) in the same year (1999). Recess length did not increase from 1999 to subsequent years when aircraft, vehicle, and pedestrian events increased in frequency, suggesting increasing levels of disturbance did not affect that aspect of incubation negatively.

Furthermore, incubation constancy did not vary among years, indicating that the change in recess length had no influence on overall nest attendance.

The differences in nest attendance among swans monitored with video cameras in 1998–2001 appeared to be the result of individual variation among nesting pairs. Swans nesting both close to and far from the airstrip during years of moderate-to-high construction activity had high nest attendance and successfully fledged young. In contrast, 2 pairs of swans nesting far from the airstrip during the year of lowest airstrip activity had poor nest attendance with long and frequent recesses, and predation occurred during those recesses; the cause of those long recesses was not determined. Although sample sizes of Tundra Swan nests were small in the Alpine project area, the levels of disturbance produced at the Alpine facilities did not have any detectable effects on swan nest attendance.

#### Effects of Disturbance on Alert Responses

The most frequent observable responses of Tundra Swans to sources of disturbance were alert and concealment postures. Concealment postures occurred less often than alert postures (20× less in 2001) and occurred primarily in response to pedestrians. Alert postures occurred often, were easily identified on video recordings, and occurred in reaction to all sources of disturbance. At 4 Tundra Swan nests monitored with video (2 in

Table 52. Comparison of nesting activities of incubating Tundra Swans among years at one nest site (no.105) in the Alpine project area, Colville River Delta, Alaska, 1999–2001. The nest was monitored with time-lapse video cameras. The nest was successful in all three years.

|                            | 1999 <sup>a</sup> |       | 2000 <sup>a</sup> |       | 2001 <sup>b</sup> |       | Kruskal-Wallis |       |
|----------------------------|-------------------|-------|-------------------|-------|-------------------|-------|----------------|-------|
|                            | $\bar{x}$         | $n^c$ | $\bar{x}$         | $n^c$ | $\bar{x}$         | $n^c$ | $\chi^2$       | $P$   |
| Incubation Constancy (%/d) | 99.1              | 22    | 99.2              | 17    | 99.2              | 29    | 0.51           | 0.78  |
| Recess Frequency (no./d)   | 0.5               | 22    | 0.6               | 17    | 0.4               | 29    | 0.60           | 0.74  |
| Recess Length (min/recess) | 12.2              | 11    | 5.7               | 11    | 8.1               | 12    | 6.14           | 0.05  |
| Time off nest (min/d)      | 12.6              | 22    | 11.7              | 17    | 11.8              | 29    | 0.50           | 0.78  |
| Break Frequency (no./d)    | 9.9               | 22    | 22.3              | 17    | 26.9              | 29    | 37.69          | <0.01 |
| Time on Break (min/d)      | 16.3              | 22    | 24.8              | 17    | 31.3              | 29    | 20.39          | <0.01 |
| Exchange Frequency (no./d) | 2.5               | 22    | 3.6               | 17    | 3.6               | 29    | 9.10           | 0.01  |
| Time on Exchange (min/d)   | 6.3               | 22    | 8.0               | 17    | 8.4               | 29    | 4.55           | 0.10  |

<sup>a</sup> Nest was 449 m from the airstrip, 124 m from the flight path, and 145 m from the infield road.

<sup>b</sup> Nest was 442 m from the airstrip, 28 m from the flight path, and 243 m from the infield road.

<sup>c</sup>  $n$  = days, except for recess length, where  $n$  = recesses.

1999 and 1 in both 2000 and 2001), the relative frequency and duration of alert postures by incubating swans were calculated in response to aircraft, vehicles, pedestrians, predators, and other large birds (swans, geese, or ducks) (Table 53). In 1999, the frequency of alert postures in response to different sources of disturbance was similar between the 2 swan nests monitored despite differences in distances to the sources of potential disturbance. For both nests, alert postures occurred most often (32 and 33% of all alert postures at each nest) when vehicles were on the airstrip. Airplanes and pedestrians were associated with the second and third highest frequency of alert postures for known disturbances at each nest. Although the number of vehicles on the airstrip in 1999 was less than the number of airplanes and the number of people (Figure 14), machinery was working on the airstrip for long periods of time (mean = 405 min/d). Few alert postures were attributed to the presence of helicopters, predators, and large birds, but the number of events of these disturbance sources was low. For these 2 nests, approximately half of the alert postures could not be associated with a disturbance source.

The effect of different levels of activity on the airstrip and infield road in 1999–2001 can be illustrated by comparing the relative frequency of alert postures among years at Tundra Swan nest 105. In each year, the highest percentage of alert postures occurred in response to vehicles (25–55%

of all alert postures at each nest; Table 53), which also were the most frequent disturbance events at each nest. The strongest response to vehicles occurred in 2001, when the number of vehicles on the airstrip (313 vehicles/d) and the infield road (176 vehicles/d) was highest (Figure 14, Appendix D2). The percentage of alert postures in response to airplanes was highest in 2000, when the highest number of airplanes used the airstrip during the nesting season (Figure 14). The percentage of alert postures in response to pedestrians was highest in 2001, when work was being conducted on the pipeline to CD-2 and the number of pedestrians near the west end of the airstrip (16 people/d) was highest. The percentage of alert postures when helicopters were landing or taking off was low in all years, but the helipads were farther from the monitored nests than was the airstrip (Table 53), so fewer reactions were expected to helicopters than to sources of disturbance on the airstrip and infield road. The frequency of alert postures was low (1–2% of all alert postures) when predators and other birds were near nests, but these disturbances occurred considerably less often than did airplane, helicopter, vehicle, or pedestrian events.

The relative frequency of alert postures by nesting Tundra Swans occurring in response to the different sources of disturbance was affected by the frequency of occurrence of those disturbance events. The rate of alert postures for each disturbance type, calculated as the proportion of

Table 53. The relative frequency and duration of all alert postures of incubating Tundra Swans during potential disturbance events in the Alpine project area, Colville River Delta, Alaska. Four nests were monitored with time-lapse video cameras. All nests were successful.

| Year    | Nest No. <sup>a</sup> | Distance (m) from Nest |             |       |          | Alert Postures          |     |     |                |     |           |      |
|---------|-----------------------|------------------------|-------------|-------|----------|-------------------------|-----|-----|----------------|-----|-----------|------|
|         |                       | Air-strip              | Flight path | Road  | Heli-pad | Disturbance             | No. | %   | Duration (min) |     |           |      |
|         |                       |                        |             |       |          |                         |     |     | Sum            | %   | $\bar{x}$ | SE   |
| 1999    | 008                   | 1,283                  | 157         | 2,934 | 1,427    | Airplane                | 20  | 5   | 52             | 4   | 2.6       | 0.36 |
|         |                       |                        |             |       |          | Helicopter              | 1   | <1  | 3              | <1  | 3.0       | –    |
|         |                       |                        |             |       |          | Vehicle                 | 136 | 32  | 373            | 27  | 2.7       | 0.24 |
|         |                       |                        |             |       |          | Pedestrian              | 14  | 3   | 37             | 3   | 2.6       | 0.80 |
|         |                       |                        |             |       |          | Large Bird <sup>b</sup> | 2   | <1  | 2              | <1  | 1.0       | 0.00 |
|         |                       |                        |             |       |          | Predator <sup>c</sup>   | 3   | <1  | 8              | <1  | 2.7       | 0.87 |
|         |                       |                        |             |       |          | Unknown                 | 245 | 58  | 886            | 65  | 3.6       | 0.24 |
|         |                       |                        |             |       |          | Total                   | 421 | 100 | 1,361          | 100 | 3.2       | 0.17 |
|         | 105                   | 449                    | 124         | 146   | 1,991    | Airplane                | 33  | 8   | 100            | 7   | 3.0       | 0.37 |
|         |                       |                        |             |       |          | Helicopter              | 2   | <1  | 13             | 1   | 6.5       | 2.47 |
|         |                       |                        |             |       |          | Vehicle                 | 141 | 33  | 455            | 32  | 3.2       | 0.25 |
|         |                       |                        |             |       |          | Pedestrian              | 24  | 6   | 94             | 7   | 3.9       | 0.78 |
|         |                       |                        |             |       |          | Large Bird <sup>b</sup> | 4   | 1   | 22             | 2   | 5.5       | 2.35 |
|         |                       |                        |             |       |          | Predator <sup>c</sup>   | 8   | 2   | 40             | 3   | 5.0       | 1.34 |
| Unknown |                       |                        |             |       |          | 214                     | 50  | 705 | 49             | 3.3 | 0.19      |      |
| Total   | 426                   | 100                    | 1,429       | 100   | 3.4      | 0.14                    |     |     |                |     |           |      |
| 2000    | 105                   | 449                    | 124         | 146   | 1,863    | Airplane                | 44  | 13  | 82             | 12  | 1.9       | 0.26 |
|         |                       |                        |             |       |          | Helicopter              | 27  | 8   | 40             | 6   | 1.5       | 0.25 |
|         |                       |                        |             |       |          | Vehicle                 | 86  | 25  | 193            | 29  | 2.2       | 0.27 |
|         |                       |                        |             |       |          | Pedestrian              | 30  | 9   | 55             | 8   | 1.8       | 0.26 |
|         |                       |                        |             |       |          | Large Bird <sup>b</sup> | 1   | <1  | 1              | <1  | 1.0       | –    |
|         |                       |                        |             |       |          | Predator <sup>c</sup>   | 6   | 2   | 17             | 3   | 2.8       | 0.78 |
|         |                       |                        |             |       |          | Unknown                 | 153 | 44  | 282            | 42  | 1.8       | 0.13 |
|         |                       |                        |             |       |          | Total                   | 347 | 100 | 670            | 100 | 1.9       | 0.10 |
| 2001    | 105                   | 442                    | 28          | 243   | 1,912    | Airplane                | 63  | 7   | 94             | 7   | 1.5       | 0.18 |
|         |                       |                        |             |       |          | Helicopter              | 34  | 4   | 57             | 4   | 1.7       | 0.26 |
|         |                       |                        |             |       |          | Vehicle                 | 469 | 55  | 751            | 57  | 1.6       | 0.06 |
|         |                       |                        |             |       |          | Pedestrian              | 106 | 13  | 168            | 13  | 1.6       | 0.19 |
|         |                       |                        |             |       |          | Large Bird <sup>b</sup> | 5   | 1   | 5              | <1  | 1.0       | 0.00 |
|         |                       |                        |             |       |          | Predator <sup>c</sup>   | 16  | 2   | 35             | 3   | 2.2       | 0.43 |
|         |                       |                        |             |       |          | Unknown                 | 154 | 18  | 205            | 16  | 1.3       | 0.06 |
|         |                       |                        |             |       |          | Total                   | 847 | 100 | 1,315          | 100 | 1.6       | 0.05 |

<sup>a</sup> Nest 008 was monitored for 20.3 d. Nest 105 was monitored for 25.4 d in 1999, 21.3 d in 2000, and 31.1 d in 2001.

<sup>b</sup> Includes swans, geese, and ducks.

<sup>c</sup> Includes foxes, jaegers, Glaucous Gulls, and Common Ravens.

events of each type of disturbance during which alert postures occurred, is an indicator of the sensitivity of nesting swans to these disturbances (Table 54). At each of the 2 nests monitored in 1999, the proportion of events eliciting alert postures differed among disturbance types ( $\chi^2 = 63.6$  and  $72.6$ ,  $df = 3$ ,  $P < 0.01$  for both nests). At nest 008, the incubating swan responded most often to vehicles (27% of all vehicle events) and least often to helicopters (5% of all helicopter events). At nest 105, the incubating swan responded most often to pedestrians (55% of all pedestrian events) and least often to helicopters (12% of all helicopter events). However, the helipad was well over 1 km from each of these nests, which probably explains the low response rates to helicopters. Both nests were closer to the flight path than any other feature, but aircraft were not associated with the highest response rates. For each disturbance source (airplanes, helicopters, vehicles, and pedestrians), the proportion of events with alert postures was higher at nest 105, the nest closest to the airstrip, than at nest 008 (loglinear model,  $Z = 3.3$ ,  $P < 0.01$ ). Therefore, distance of nests from the source of disturbance explained some, but not all, of the differences in responses among types of disturbance.

Consistently during 3 years at nest 105, the nest closest to the airstrip and road, pedestrians accounted for the highest proportion of events during which the swans were alert (54–59% of all pedestrian events, Table 54), and the proportions were similar among years ( $\chi^2 = 0.74$ ,  $df = 2$ ,  $P = 0.69$ ). The rate of alert postures differed significantly among years for airplanes ( $\chi^2 = 15.6$ ,  $df = 2$ ,  $P < 0.01$ ), helicopters ( $\chi^2 = 9.1$ ,  $df = 2$ ,  $P = 0.01$ ), and vehicles ( $\chi^2 = 151.2$ ,  $df = 2$ ,  $P < 0.01$ ). The rate of alert postures for helicopters was highest in 2001 (17% of all helicopter events), compared with rates in 1999 and 2000 (12% and 11% of all helicopter events, respectively). In 1999, the rates of alert postures for airplanes (30% of all airplane events) and vehicles (30% of all vehicle events) were higher than in 2000 and 2001 (Table 54). The change in the proportion of events that swans at nest 105 responded to since 1999 fits a pattern of declining sensitivity to airplanes and vehicles, but not to pedestrians and helicopters. However, this comparison does not account for changes in the location or behavior of the

disturbance sources (for example pedestrians working primarily at the southwest end of the airstrip in 2001 as opposed to being more dispersed in 1999–2000) which could affect the reaction rates of swans.

Mean time spent in alert postures in response to different sources of disturbance also may be an indicator of the overall effect of these disturbances. In 1999, the swans at nest 105 were alert for a longer amount of time during disturbances than were the swans at nest 008 (ANOVA,  $F = 6.1$ ,  $df = 1$ ,  $P = 0.01$ ). Mean time spent alert in response to helicopters was over twice as long at nest 105 (mean = 6.5 min) as at nest 008 (mean = 3.0 min), although the number of responses at each nest was low (Table 53). The length of alert responses to airplanes, vehicles, and pedestrians at nest 008 was almost the same (range = 2.6–2.7 min), whereas at nest 105, the swans were alert longer when pedestrians were on the airstrip (mean = 3.9 min) than when airplanes (mean = 3.0 min) and vehicles (mean = 3.2 min) were present. In the 3 years of monitoring the swans at nest 105, both disturbance type and year explained the variation in alert durations (ANOVA,  $F = 26.7$ ,  $df = 7$ , 1091,  $P = 0.01$ ). The time spent alert in response to disturbance sources differed significantly among years ( $P < 0.01$ ), but differences between disturbance types was marginal ( $P = 0.07$ ). Mean time spent in alert posture decreased each year for all sources of disturbance, except for helicopters (Table 53). When comparing the response among disturbance types at nest 105, the duration of alert postures when predators were near the nest was significantly longer than the durations in response to airplanes, helicopters, vehicles, and pedestrians ( $P \leq 0.03$  pairwise comparisons).

Not surprisingly, swans nesting at different locations responded differently to human disturbances that emanated from the airstrip, infield road, and helipad. Swans nesting near the airstrip were alert more often and for longer to all sources of human disturbance than were the swans that nested over 1 km away. The swans monitored at that nearer nest were most responsive in each of 3 years to pedestrians, but their response rates and duration of alert postures to airplanes and vehicles declined after the first year the airstrip was used. The swans at the nest nearest the airstrip, thought

Table 54. The proportion of events during which incubating Tundra Swans were in alert postures during human disturbance events on the airstrip or infield road in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Four nests were monitored with time-lapse video cameras. All nests were successful.

| Year | Nest No. <sup>a</sup> | Distance (m) from Nest |             |       | Behavior/Events | Airplane Landings or Takeoffs |     | Helicopter Landings or Takeoffs |     | Vehicles |        | Pedestrians |     | No. Potential Disturbance Events |
|------|-----------------------|------------------------|-------------|-------|-----------------|-------------------------------|-----|---------------------------------|-----|----------|--------|-------------|-----|----------------------------------|
|      |                       | Air-strip              | Flight path | Road  |                 | Heli-pad                      | No. | %                               | No. | %        | No.    | %           | No. |                                  |
| 1999 | 008                   | 1,283                  | 157         | 2,934 | 1,427           | Alert Posture <sup>b</sup>    | 24  | 18                              | 18  | 5        | 132    | 27          | 7   | 22                               |
|      |                       |                        |             |       |                 | Normal Incubation             | 112 | 82                              | 350 | 95       | 350    | 73          | 25  | 78                               |
|      |                       |                        |             |       |                 | Total                         | 136 | 100                             | 368 | 100      | 482    | 100         | 32  | 100                              |
|      |                       |                        |             |       |                 | Percent of Events             |     | 13                              |     | 36       |        | 47          |     | 3                                |
| 1999 | 105                   | 449                    | 124         | 146   | 1,991           | Alert Posture <sup>b</sup>    | 46  | 30                              | 46  | 12       | 165    | 30          | 23  | 55                               |
|      |                       |                        |             |       |                 | Normal Incubation             | 108 | 70                              | 334 | 88       | 383    | 70          | 19  | 45                               |
|      |                       |                        |             |       |                 | Total                         | 154 | 100                             | 380 | 100      | 548    | 100         | 42  | 100                              |
|      |                       |                        |             |       |                 | Percent of Events             |     | 14                              |     | 34       |        | 49          |     | 4                                |
| 2000 | 105                   | 449                    | 124         | 146   | 1,863           | Alert Posture <sup>b</sup>    | 77  | 14                              | 39  | 11       | 132    | 18          | 60  | 54                               |
|      |                       |                        |             |       |                 | Normal Incubation             | 475 | 86                              | 316 | 89       | 606    | 82          | 50  | 46                               |
|      |                       |                        |             |       |                 | Total                         | 552 | 100                             | 355 | 100      | 738    | 100         | 110 | 100                              |
|      |                       |                        |             |       |                 | Percent of Events             |     | 31                              |     | 20       |        | 42          |     | 6                                |
| 2001 | 105                   | 442                    | 28          | 243   | 1,912           | Alert Posture <sup>b</sup>    | 98  | 20                              | 111 | 17       | 1,418  | 12          | 162 | 59                               |
|      |                       |                        |             |       |                 | Normal Incubation             | 382 | 80                              | 540 | 83       | 9,947  | 88          | 113 | 41                               |
|      |                       |                        |             |       |                 | Total                         | 480 | 100                             | 651 | 100      | 11,365 | 100         | 275 | 100                              |
|      |                       |                        |             |       |                 | Percent of Events             |     | 4                               |     | 5        |        | 89          |     | 2                                |

<sup>a</sup> Nest 008 was monitored for 20.3 d. Nest 105 was monitored for 25.4 d in 1999, 21.3 d in 2000, and 31.1 d in 2001.

<sup>b</sup> One alert posture may occur during multiple aircraft, vehicle, or pedestrian events.

to be the same pair of swans each year because of repeated use of the same nest site, may have habituated to human-caused disturbance after 1999, the first year of high levels of construction activity.

#### Responses to Pedestrians

Reactions of swans to pedestrian activities ranged from alert and concealment postures to flushes. Human activities in the vicinity of swan nests in 1998–2001 sometimes caused the incubating swan to conceal, “sneak-off” (i.e., walking slowly with head down in a crouched position and using surface relief for concealment) the nest but remain beside it, or leave the nest area. Some activities by biologists, such as servicing the video cameras and nest searching, occurred near each monitored swan nest and the frequency and duration of these activities were similar among years. Other activities, such as work by surveyors, pipeline maintenance personnel, and researchers conducting vegetation experiments, varied in both frequency and duration among years and only were recorded in the area of swan nest 105.

Swans at different nests displayed varying levels of tolerance to the presence of researchers changing the camera videotapes or searching for nests nearby. In 1998, one of the swans monitored left the nest area during each of the 4 times the camera (75 m from the nest) was serviced. The mean time that the swan was away from the nest after these disturbances was 208 min (range 73–435 min). Partial nest predation by jaegers occurred during one of those recesses. In 1999, the swan incubating a different nest left the nest area during the last 3 of 5 visits to the camera (140 m from the nest). During the first 2 visits to this nest, the incubating swan remained on the nest and concealed. The mean time that this swan was away from the nest during these disturbances was 36 min (range 22–52 min). When servicing the camera (150–165 m from the nest) at nest 105 during 1999–2001, the researcher walked at least 100 m from the nest. During the 3 years of monitoring, the incubating swan sneaked-off the nest twice, for 14–20 min, while the camera was being serviced. During the remaining 15 visits in 1999–2001, the incubating swan concealed and remained on the nest.

The reactions of monitored swans to nest searching crews were generally more severe and prolonged. One nest site suffered total predation by a fox in one year and a jaeger and a fox in another, after the incubating swans left their nests in response to nest searching. During 3 years of monitoring, the incubating swans left this nest for 1–8 hr on 7 occasions while nest searching was conducted on the breeding-bird plot adjacent to the nest. At nest 105, the incubating swan reacted with alert and concealment postures, but stayed on the nest during one nest search and sneaked-off and concealed next to the nest for 84–149 min during 3 others. Nest 105 hatched cygnets every year it was monitored. The incubating swan at nest 105 also was flushed when a research technician unaffiliated with this study directly approached the nest; the swan returned to the nest 60 min after the person left the area.

Off-airstrip pedestrian activities that were not related to our research also were recorded on video at nest 105. In 1999, surveyors and researchers conducting vegetation experiments frequently worked off the west end of the airstrip  $\geq 150$  m from swan nest 105. On 9 occasions when these activities were recorded, the swan sneaked-off the nest 3 times for 37–246 min, and on the other 6 occasions, the swans concealed on the nest. In 2000, the incubating swan concealed and remained on the nest when pedestrian traffic (36 groups of people) walked by on the infield road (142 m to the nest at the closest point). In 2001, cleanup and pipeline maintenance personnel were recorded working on the tundra near the airstrip and infield road 300–400 m from the nest on 56 occasions. The incubating swan was alert on 38% of these events, concealed on 14%, on recess for 2%, and in normal incubation for the remaining events.

From this small sample of swan nests, it should be clear that reactions to pedestrians are highly variable, from alert and concealment postures on the nest to flushing and flying away from the nest for extended periods of time. Reactions varied among individual swans and the distance at which flushes occurred also seemed to vary among swans. During nest searching on the delta over the preceding 12 years, we have observed swans leave nests when we were  $\sim 300$  m away, and many others leave their nests before we detect them, perhaps at greater distances. Nest



105, which was encountered annually on nest searches since 1995 and monitored with video cameras during 1999–2001, was attended by swans that appear to have habituated to pedestrians. These swans increasingly tolerated people at closer distances each successive year. Other pairs were intolerant. The importance of reactions to people is not related so much to the direct response of the swans, but to the indirect effects if swans leave their nest unattended. Few predators can directly confront a swan defending its nest and successfully take its eggs. Therefore, predation of swan nests primarily is opportunistic, and typically takes place when the nesting pair is absent. Any disturbance that causes incubating swans to leave nests makes the eggs vulnerable to predation, as demonstrated by our own encounters with swans nesting in the study area.

#### Reactions to Predators

Tundra Swans monitored with video cameras in 1999–2001 successfully deterred foxes that approached attended nests. Tundra Swans reacted to foxes by standing over the nest and flapping or holding their wings open, by sitting and holding their head alert, or with normal incubation. Seventeen defensive breaks by incubating swans were observed when foxes approached the nest. During 10 encounters, a fox was on or <5 m from the nest mound and sometimes jumped towards the swan. Each encounter lasted 1–4 recording intervals (~1–4 min). During 5 of these encounters, the mate to the incubating swan also was on the mound defending the nest from the fox. During another encounter, a fox was within 5 m of the incubating swan and the swan remained sitting and turned to hiss at the fox. On 20 other occasions a fox was seen on the video >25 m from the nest and the incubating swan either was alert (10 times) or did not react (10 times).

Swans were less reactive to avian predators than to foxes. Defensive breaks were not observed when avian predators were near nests. On 6 occasions a raven or a jaeger stood or flew within 5 m of swans on nests, and incubating swans either showed no reaction (2 times), were alert (2 time), concealed on the nest (1 time), or was on a recess (1 time). On 7 of 20 occasions when avian predators flew >5m from swan nests, incubating

swans were alert, but on the remaining 13 events no reactions were observed.

Defensive breaks by incubating swans also occurred when geese or swans flew over or walked near the nest. During these breaks, the incubating swan and its mate (present during 33 of 40 occurrences) stood at the nest, raised their heads trumpeting in unison and performed vertical head-bobbing and a quivering-wing display (wings are partially extended and held parallel to the ground and rapidly moved from the wrist). Other studies of swan nesting behavior also have noted this same territorial behavior when geese or other swans entered the nesting territory (Scott 1977, Cooper 1979).

#### YELLOW-BILLED LOON

##### Nest Attendance

Two Yellow-billed Loon nests monitored by video in 1998 failed partway through the monitoring period after predation of the eggs by Parasitic Jaegers. These nests were 1,403 and 1,413 m from the airstrip (Figure 25). One nest was monitored for 2 d before it failed. Incubation constancy of the loons was low (65%) because recess frequency (mean = 13 recesses/d) and recess length (mean = 39 min/recess,  $n = 26$  recesses) were high. Total time off the nest increased from 173 to 835 min/d each day. Predation by a jaeger occurred 60 min into a recess that lasted 224 min. Mean incubation constancy of the second nest was high (92.2%,  $n = 7$  d), but daily incubation constancy varied from 75.1 to 99.8%. Mean recess length for the 7 days monitored was 22 min/recess (range 1–138 min,  $n = 36$  recesses), and the loons averaged 5 recesses/d. However, on the day of failure, the incubating bird took 9 recesses that averaged 41 min each. This nest failed when a jaeger visited after the incubating loon had been gone for 86 min. Neither of the recesses during which jaegers attacked the nests was associated with aircraft, vehicle, or pedestrian disturbance events.

#### CLUTCH SIZE AND NEST FATE

##### ALL SPECIES

The potential effects of disturbance on clutch size were analyzed by relating clutch size to the variation among years having different levels of

construction activity. Several species or species groups had mean clutch sizes that differed significantly among years: Bar-tailed Godwit, Greater Scaup, Green-winged Teal, Long-tailed Duck, Northern Shoveler, Pacific Loon, all dabbling ducks, and all loons (Table 55). None of those species or species groups had consistently smaller clutch sizes in the heavy-construction years (1999–2001) than in the pre- and light-construction years (1996–1998), as might be expected if clutch size was affected by disturbance. For example, the smallest clutch sizes for dabbling ducks were in 1996, 1999, and 2001, whereas the largest occurred in 1998 and 2000, and none of the pairwise annual comparisons was significant (Bonferroni all-possible pairwise comparisons,  $P \geq 0.06$ ).

To evaluate the effects of disturbance on nest fate, the distance of nests to each of 3 sources of disturbance (airstrip, flight path, and nearest gravel) were analyzed for differences between fates and among years. If construction activity increased the proportion of nests that failed, one would expect failed nests to be closer than successful nests to potential sources of disturbance, and that differences between nest fates might be largest in years with the most human activity. The fate of nests varied annually among species groups. Swan nests usually experienced high nesting success ( $\geq 60\%$ ) each year, while ducks usually had low success (6–28%). Some nests, such as those of loons, often lacked evidence for determining fate. For the combined nests of all species other than White-fronted Goose, the distance of nests to the airstrip, nearest gravel (pad, road, or airstrip) or the flight path did not differ between failed and successful nests or among years (Table 56). Although neither nest fate nor the year-by-fate interaction term was significant (for all models,  $P \geq 0.14$ ), failed nests on average were closer to the airstrip and nearest gravel in 1999–2001, indicating a possible negative effect on nesting success with proximity to those features during heavy-construction years (Figure 27).

#### GREATER WHITE-FRONTED GOOSE

Similar evaluations of the effects of disturbance on clutch size and nest fate were conducted for White-fronted Goose nests. The mean clutch size of White-fronted Geese was similar among years ( $P = 0.9$ ), ranging between 3.7

and 4.0 eggs/nest (Table 55). The strongest correlation between clutch size and weather variables was date of snow-free tundra ( $r = 0.7$ ,  $P = 0.08$ ,  $n = 5$ ), indicating a tendency towards larger clutches in years with later snow melt (Table 29), which was counter findings from elsewhere (Barry 1962, Ely and Raveling 1984). We suspect that the low variation in average clutch size and small sample size of years may have produced a misleading correlation. The clutch sizes observed at Alpine were similar to values reported in earlier studies on the Colville Delta (Simpson et al. 1982; Simpson 1983; Smith et al. 1993, 1994).

Although clutch sizes of White-fronted Geese were relatively consistent each year, apparent nesting success (the number of nests where at least one egg hatched divided by the number of nests of known fate) was highly variable. The lowest nesting success occurred in 1999 (34%) and 2000 (36%), whereas the highest success occurred in 1997 (88%) and 1998 (73%) (Table 57). The annual trend in nesting success was negatively correlated with frequency of aircraft and annual noise levels (both with Spearman's  $r = -0.7$ ,  $P = 0.2$ ,  $n = 5$ ), frequency of vehicles on the airstrip (Spearman's  $r = -0.6$ ,  $P = 0.3$ ,  $n = 5$ ), and pedestrians on the airstrip (Spearman's  $r = -0.6$ ,  $P = 0.3$ ,  $n = 5$ ), suggesting a possible negative response to increasing levels of oilfield activity (Figure 14), although the correlations were non-significant, and all 4 measures of human activity were highly intercorrelated ( $r \geq 0.9$ ,  $P \leq 0.04$ ,  $n = 5$ ; Table 29). Nesting success also was positively correlated with number of thawing degree-days through the middle of June (Spearman's  $r = 0.9$ ,  $P = 0.04$ ,  $n = 5$ ), June mean temperatures (Spearman's  $r = 0.5$ ,  $P = 0.3$ ,  $n = 5$ ), and negatively correlated with date of river breakup (Spearman's  $r = -0.7$ ,  $P = 0.2$ ,  $n = 5$ ), although only thawing degree-days was significantly correlated. Nesting success was not correlated with the number of occupied fox dens (within 5 km of the airstrip; Spearman's  $r = 0.4$ ,  $P = 0.6$ ,  $n = 5$ ) or the amount of fox activity recorded on videos of goose and swan nests (Spearman's  $r = -0.4$ ,  $P = 0.6$ ,  $n = 4$ ). The strength of these correlations suggests that weather variables may explain more of the variation in nesting success than did disturbance or predator factors, however, the human activity variables and

Table 55. Comparison of mean clutch size among years for selected species and species groups found in the Alpine project area, Colville River Delta, Alaska.

| Species                     | 1996      |      |    | 1997      |      |    | 1998      |      |    | 1999      |      |    | 2000      |      |    | 2001      |      |    | ANOVA |      |
|-----------------------------|-----------|------|----|-----------|------|----|-----------|------|----|-----------|------|----|-----------|------|----|-----------|------|----|-------|------|
|                             | $\bar{X}$ | SE   | n  | $\bar{X}$ | SE   | n  | $\bar{X}$ | SE   | n  | $\bar{X}$ | SE   | n  | $\bar{X}$ | SE   | n  | $\bar{X}$ | SE   | n  | F     | P    |
| Red-throated Loon           | 1.0       | 0.00 | 2  | 1.4       | 0.24 | 5  | 1.5       | 0.50 | 2  | 1.5       | 0.50 | 2  | 2.0       | -    | 1  | 1.5       | 0.50 | 2  | 0.43  | 0.82 |
| Pacific Loon                | 1.3       | 0.33 | 3  | 1.4       | 0.20 | 7  | 1.9       | 0.13 | 8  | 1.9       | 0.11 | 9  | 2.0       | 0.00 | 3  | 1.3       | 0.21 | 6  | 2.76  | 0.04 |
| Yellow-billed Loon          | 2.0       | -    | 1  | 1.0       | -    | 1  | 2.0       | 0.00 | 2  | 2.0       | -    | 1  | -         | -    | -  | -         | -    | -  | -     | -    |
| Red-necked Grebe            | -         | -    | -  | 2.0       | -    | 1  | 4.0       | 1.00 | 2  | 4.0       | -    | 1  | -         | -    | -  | 3.0       | -    | 1  | 0.53  | 0.74 |
| Greater White-fronted Goose | 3.8       | 0.34 | 28 | 3.8       | 0.20 | 37 | 4.0       | 0.20 | 58 | 3.6       | 0.19 | 65 | 3.8       | 0.19 | 52 | 3.8       | 0.20 | 39 | 0.31  | 0.90 |
| Brant                       | 4.0       | -    | 1  | 3.0       | 2.00 | 2  | 5.0       | -    | 1  | 2.0       | 0.00 | 2  | 3.0       | 0.58 | 3  | 3.0       | -    | 1  | 0.55  | 0.74 |
| Tundra Swan                 | 3.8       | 0.31 | 6  | 3.0       | 0.41 | 4  | 3.0       | 0.37 | 6  | 2.5       | 0.29 | 4  | 2.7       | 0.67 | 3  | 3.0       | 0.55 | 5  | 1.27  | 0.31 |
| Northern Shoveler           | 4.0       | -    | 1  | -         | -    | -  | 8.6       | 0.40 | 5  | -         | -    | -  | -         | -    | -  | -         | -    | -  | 22.04 | 0.01 |
| Northern Pintail            | 7.0       | -    | 1  | 5.2       | 0.66 | 5  | 6.3       | 0.47 | 9  | 5.2       | 0.20 | 5  | 6.4       | 0.90 | 7  | 5.0       | 0.58 | 6  | 1.11  | 0.38 |
| Green-winged Teal           | 1.0       | -    | 1  | -         | -    | -  | 8.0       | -    | 1  | 4.8       | 0.85 | 4  | 8.0       | 0.00 | 2  | -         | -    | -  | 6.29  | 0.05 |
| Greater Scaup               | -         | -    | -  | 5.0       | 1.00 | 2  | 7.8       | 0.45 | 8  | 6.8       | 0.60 | 6  | 10.0      | -    | 1  | 3.0       | -    | 1  | 5.03  | 0.01 |
| Lesser Scaup                | -         | -    | -  | -         | -    | -  | 9.0       | -    | 1  | -         | -    | -  | -         | -    | -  | -         | -    | -  | -     | -    |
| Unidentified scaup          | -         | -    | -  | -         | -    | -  | 7.2       | 0.75 | 4  | 4.5       | 0.50 | 2  | 3.0       | -    | 1  | 7.0       | 1.00 | 2  | 3.90  | 0.09 |
| Spectacled Eider            | -         | -    | -  | -         | -    | -  | 4.0       | -    | 1  | 5.0       | -    | 1  | -         | -    | -  | -         | -    | -  | -     | -    |
| Long-tailed Duck            | 6.0       | 1.00 | 2  | 5.8       | 0.58 | 5  | 7.5       | 0.50 | 4  | 5.2       | 1.11 | 4  | 6.0       | 0.41 | 4  | 3.0       | 1.41 | 4  | 2.79  | 0.05 |
| Unidentified duck           | -         | -    | -  | -         | -    | -  | 6.7       | 1.20 | 3  | 3.0       | 1.00 | 2  | -         | -    | -  | 3.0       | -    | 1  | 2.84  | 0.20 |
| Willow Ptarmigan            | -         | -    | -  | 7.7       | 0.92 | 10 | 7.0       | -    | 1  | 8.0       | 0.64 | 18 | 7.4       | 0.36 | 12 | 7.6       | 0.65 | 8  | 0.14  | 0.97 |
| Rock Ptarmigan              | -         | -    | -  | 5.0       | -    | 1  | -         | -    | -  | -         | -    | -  | 2.0       | -    | 1  | -         | -    | -  | -     | -    |
| Unidentified ptarmigan      | -         | -    | -  | -         | -    | -  | -         | -    | -  | -         | -    | -  | 5.0       | -    | 1  | 11.0      | -    | 1  | -     | -    |
| Bar-tailed Godwit           | 4.0       | -    | 1  | -         | -    | -  | 3.8       | 0.25 | 4  | 1.5       | 0.50 | 2  | -         | -    | -  | 4.0       | -    | 1  | 8.80  | 0.03 |
| Parasitic Jaeger            | 2.0       | -    | 1  | -         | -    | -  | 2.0       | 0.00 | 2  | 2.0       | 0.00 | 2  | 2.0       | 0.00 | 2  | 2.0       | 0.00 | 2  | -     | -    |
| Long-tailed Jaeger          | 1.0       | -    | 1  | -         | -    | -  | 1.0       | -    | 1  | -         | -    | -  | 2.0       | -    | 1  | 1.0       | -    | 1  | -     | -    |
| Arctic Tern                 | -         | -    | -  | 1.5       | 0.50 | 2  | 1.7       | 0.14 | 11 | 2.2       | 0.11 | 12 | 2.0       | 0.00 | 4  | 1.8       | 0.17 | 6  | 2.26  | 0.09 |
| All Loons                   | 1.3       | 0.21 | 6  | 1.4       | 0.14 | 13 | 1.8       | 0.11 | 12 | 1.8       | 0.11 | 12 | 2.0       | 0.00 | 4  | 1.4       | 0.18 | 8  | 3.43  | 0.01 |
| All Scaup                   | -         | -    | -  | 5.0       | 1.0  | 2  | 7.7       | 0.36 | 13 | 6.2       | 0.59 | 8  | 6.5       | 3.5  | 2  | 5.7       | 1.45 | 3  | 1.68  | 0.19 |
| Dabbling Ducks              | 4.0       | 1.73 | 3  | 5.2       | 0.66 | 5  | 7.2       | 0.42 | 15 | 5.0       | 0.37 | 9  | 6.8       | 0.72 | 9  | 5.0       | 0.58 | 6  | 3.89  | 0.01 |
| All Ducks                   | 4.8       | 1.11 | 5  | 5.4       | 0.38 | 12 | 7.3       | 0.26 | 36 | 5.3       | 0.34 | 24 | 6.5       | 0.56 | 15 | 4.4       | 0.59 | 14 | 7.53  | 0.00 |
| All Ptarmigan               | -         | -    | -  | 7.4       | 0.87 | 11 | 7.0       | -    | 1  | 8.0       | 0.64 | 18 | 6.9       | 0.51 | 14 | 8.1       | 0.68 | 9  | 0.56  | 0.69 |

Table 56. Tests of mean distances (m) of nests of Greater White-fronted Geese and other birds to infrastructure features among years and nest fates in the Alpine project area, Alaska, 1997–2001. Distances from the airstrip, gravel (any infrastructure), and the flight path of planes were calculated for nests of known fate.

| Species/Feature                                | Factor Statistics |      |      | ANOVA Model Statistics |      |      |                |
|--|-------------------|------|------|------------------------|------|------|----------------|
|  | df                | F    | P    | df                     | F    | P    | R <sup>2</sup> |
| <b>Greater White-fronted Goose<sup>a</sup></b> |                   |      |      |                        |      |      |                |
| Airstrip                                       |                   |      |      |                        |      |      |                |
| Year   | 4                 | 0.70 | 0.59 | 9, 176                 | 0.66 | 0.75 | 0.033          |
| Fate   | 1                 | 1.00 | 0.32 |                        |      |      |                |
| Year * Fate                                    | 4                 | 0.55 | 0.70 |                        |      |      |                |
| Gravel   |                   |      |      |                        |      |      |                |
| Year   | 4                 | 0.89 | 0.47 | 9, 176                 | 1.94 | 0.05 | 0.090          |
| Fate   | 1                 | 2.24 | 0.14 |                        |      |      |                |
| Year * Fate                                    | 4                 | 2.04 | 0.09 |                        |      |      |                |
| Flight Path                                    |                   |      |      |                        |      |      |                |
| Year   | 4                 | 0.95 | 0.43 | 9, 176                 | 1.55 | 0.14 | 0.073          |
| Fate   | 1                 | 5.84 | 0.02 |                        |      |      |                |
| Year * Fate                                    | 4                 | 1.21 | 0.31 |                        |      |      |                |
| <b>Other Birds<sup>b</sup></b>                 |                   |      |      |                        |      |      |                |
| Airstrip                                       |                   |      |      |                        |      |      |                |
| Year   | 4                 | 1.57 | 0.19 | 9, 121                 | 1.62 | 0.12 | 0.107          |
| Fate   | 1                 | 1.69 | 0.20 |                        |      |      |                |
| Year * Fate                                    | 4                 | 1.19 | 0.32 |                        |      |      |                |
| Gravel   |                   |      |      |                        |      |      |                |
| Year   | 4                 | 1.89 | 0.12 | 9, 121                 | 1.86 | 0.07 | 0.121          |
| Fate   | 1                 | 1.65 | 0.20 |                        |      |      |                |
| Year * Fate                                    | 4                 | 1.99 | 0.10 |                        |      |      |                |
| Flight Path                                    |                   |      |      |                        |      |      |                |
| Year   | 4                 | 0.31 | 0.87 | 9, 121                 | 0.56 | 0.83 | 0.040          |
| Fate   | 1                 | 0.01 | 0.92 |                        |      |      |                |
| Year * Fate                                    | 4                 | 0.88 | 0.48 |                        |      |      |                |

<sup>a</sup>  $n = 186$  nests.

<sup>b</sup> Other birds included loons, Brant, Canada Geese, Tundra Swans, ducks, Sandhill Cranes, jaegers, gulls, Arctic Terns, Barred-tail Godwit, and Common Snipe;  $n = 131$  nests.

Table 57. Number, fate, and mean distance from the airstrip for nests of Greater White-fronted Geese, Tundra Swan, and other birds in the Alpine project area, Colville River Delta, Alaska. Fate was not determined for nests in 1996.

| Year                        | Distance (m) of Successful Nests |     |          | Distance (m) of Failed Nests |     |          | % Nest Success <sup>a</sup> |
|-----------------------------|----------------------------------|-----|----------|------------------------------|-----|----------|-----------------------------|
|                             | $\bar{x}$                        | SE  | <i>n</i> | $\bar{x}$                    | SE  | <i>n</i> |                             |
| Greater White-fronted Goose |                                  |     |          |                              |     |          |                             |
| 1997                        | 1,179                            | 113 | 29       | 1,188                        | 178 | 4        | 88                          |
| 1998                        | 1,113                            | 130 | 22       | 1,008                        | 185 | 8        | 73                          |
| 1999                        | 1,025                            | 136 | 18       | 1,130                        | 80  | 35       | 34                          |
| 2000                        | 1,102                            | 150 | 14       | 1,257                        | 97  | 25       | 36                          |
| 2001                        | 1,099                            | 117 | 19       | 1,412                        | 131 | 12       | 61                          |
| All Years                   | 1,112                            | 57  | 102      | 1,199                        | 52  | 84       | 55                          |
| Tundra Swan                 |                                  |     |          |                              |     |          |                             |
| 1997                        | 1,212                            | 298 | 4        |                              |     |          | 100                         |
| 1998                        | 628                              | 333 | 3        | 1,348                        | 61  | 2        | 60                          |
| 1999                        | 1,055                            | 203 | 4        |                              |     |          | 100                         |
| 2000                        | 873                              | 425 | 2        | 1,173                        |     | 1        | 67                          |
| 2001                        | 1,160                            | 243 | 5        |                              |     |          | 100                         |
| All Years                   | 1,028                            | 122 | 18       | 1,290                        | 68  | 3        | 86                          |
| Other Birds <sup>b</sup>    |                                  |     |          |                              |     |          |                             |
| 1997                        | 1,127                            | 184 | 13       | 1,241                        | 171 | 20       | 39                          |
| 1998                        | 741                              | 153 | 8        | 838                          | 71  | 20       | 29                          |
| 1999                        | 1,117                            | 130 | 12       | 978                          | 150 | 17       | 41                          |
| 2000                        | 908                              | 154 | 4        | 787                          | 139 | 13       | 24                          |
| 2001                        | 1,350                            | 190 | 9        | 816                          | 297 | 7        | 56                          |
| All Years                   | 1,082                            | 81  | 46       | 956                          | 70  | 77       | 37                          |

<sup>a</sup> Nest success = [successful/(successful+failed)].

<sup>b</sup> Other birds included loons, Brant, Canada Geese, Tundra Swans, ducks, Sandhill Cranes, jaegers, gulls, Arctic Terns, Barred-tail Godwit, and Common Snipe.

number of fox dens also were highly correlated with weather variables (e.g., arrival thawing degree-days with aircraft, Spearman's  $r = -0.9$ ,  $P = 0.04$ ,  $n = 5$ ; and with fox dens, Spearman's  $r = 0.8$ ,  $P = 0.07$ ,  $n = 6$ ), which confounds any conclusion about causal factors.

If nesting success was negatively affected by disturbance at the airstrip, one would expect to see differences among White-fronted Goose nests with respect to their relative location to the airstrip or other human activities during those years with the most construction activity. Among comparisons of the effects of nest fate and year on distance of nests to 3 potential disturbance sources, distance to nearest gravel (pads or road) was the only significant model ( $P = 0.05$ ), although distance to

nearest gravel did not vary significantly with fate or year (both  $P \geq 0.09$ ; Table 56). In most years, failed nests tended to be farther from the airstrip, gravel, and flight path than were successful nests (Figure 27), but distance to flight path was the only measure that differed significantly between nest fates ( $P = 0.02$ ). Failed nests were closer to the airstrip in 1998 (Figure 27), when only helicopters used the airstrip and at the lowest frequency (mean = 1.8 helicopters/day) of the 4 years the airstrip was in place. Failed nests also were closer to the future gravel footprint in 1997 (i.e., prior to gravel placement) and in 2001, when vehicle and pedestrian traffic peaked (Figure 27). Therefore, the distances of White-fronted Goose nests to

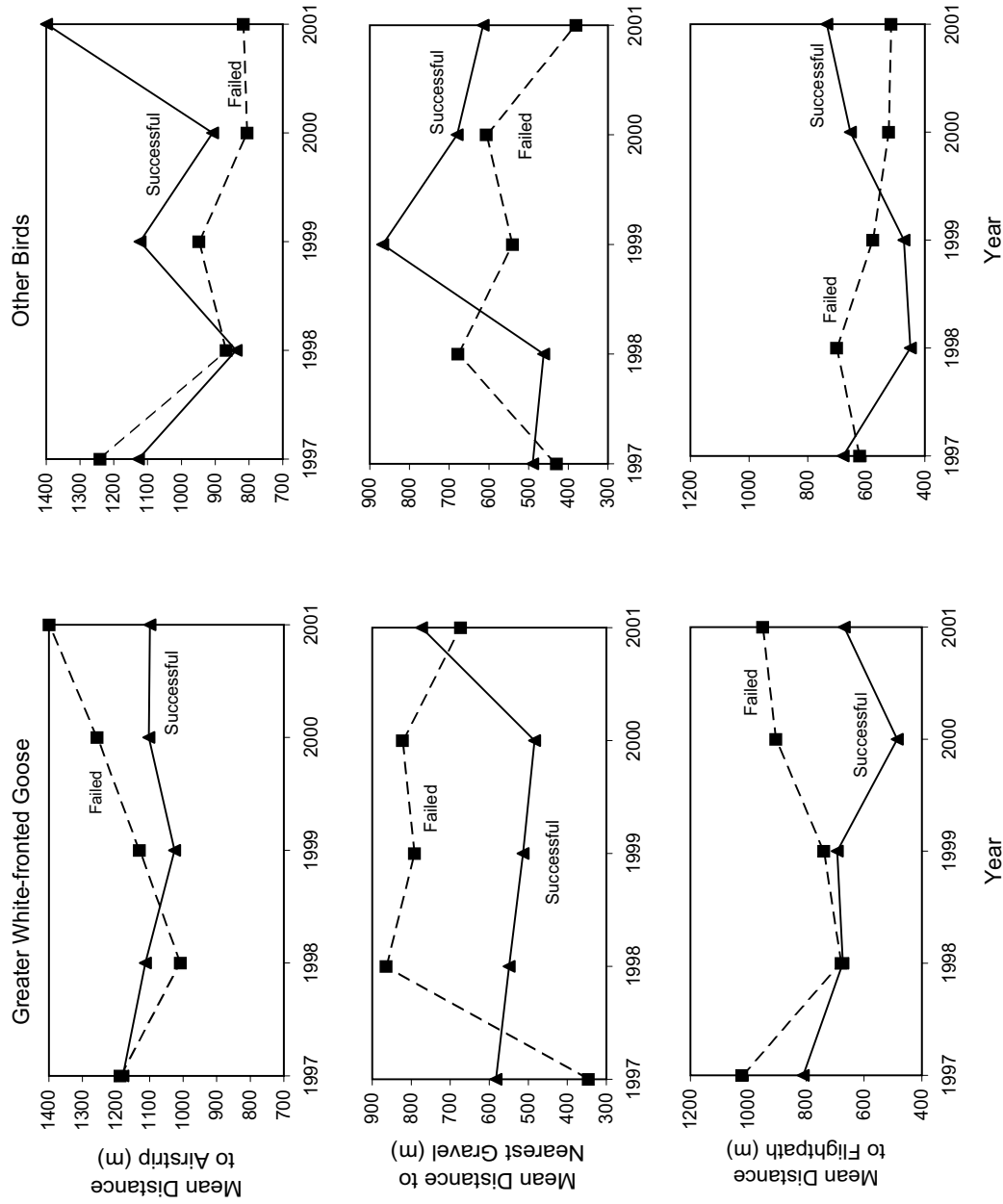


Figure 27. Mean distances (m) of failed and successful nests from human activity in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Distance to nearest gravel is measured from nests to nearest gravel; road, or airstrip. Distance to flight path is measured from nests perpendicularly to a line through the long axis of the airstrip.

infrastructure or the flight path were not related to nest fate nor were they related to year.

The comparison of distances to potential disturbance sources between failed and successful nests (above) does not directly test the effect of nest location on the probability of nesting success. To address this question, an analysis of daily survival rates of nests (Mayfield 1961, 1975) comparing among years and between distance categories was conducted using a sample of nests that were instrumented with thermistored eggs. Daily nest survival rate was highest in 1998, decreased to the lowest level in 1999, then increased in 2000, and again in 2001 (Table 58). Only 1999 had a significantly lower rate than 1998 ( $P = 0.03$ ). The daily nest survival rate in any year did not differ between nests  $\leq 1$  km from the airstrip and nests  $> 1$  km from the airstrip (all years  $P > 0.78$ ). An assumption of the Mayfield method is that survival rate is constant among nests and throughout the study period. Nests were found later and hatched earlier in 1998 than in 1999–2001, however. Therefore, nests were observed for a shorter length of time in 1998 than in subsequent years, which may have biased the 1998 survival rates. Inspection of daily nest failure rates in 1998 indicated that rates were constant over the entire study period. To confirm those results, we conducted the same analysis with only the last 8 days of incubation, and found the difference between 1998 and 1999 was still marginally significant ( $P = 0.05$ ) despite the smaller sample size. Thus, nest survival was lower in only one heavy-construction year (1999) when compared with 1998. However, survival rates in 1999 tended to be slightly higher near the airstrip, which is contrary to what was expected from a disturbance effect. Because nest survival was not lower near the primary source of disturbance in 1999, we interpret the decline in nest survival that year to be a result of annual variation rather than a result of disturbance levels.

#### TUNDRA SWAN

Because the sample of Tundra Swan nests was small, statistical evaluations of the effects of disturbance on clutch size and nest fate were not very powerful, but trends among nests were nonetheless illuminating. Mean clutch sizes of Tundra Swan nests ranged between 2.5 eggs/nest

(1999,  $n = 4$  nests) and 3.8 eggs/nest (1996,  $n = 6$ ), but clutch sizes did not vary significantly among years ( $P = 0.31$ ; Table 55). The overall mean for 6 years was 3.1 eggs/nest, which was slightly lower than clutch sizes recorded in other studies on the Colville Delta; in 1981, mean clutch size was 3.6 eggs (Rothe et al. 1983), and in 1982, it was 3.4 eggs (Simpson et al. 1982). Swan nesting success generally was high in the Alpine project area (mean = 81%), ranging between 71% in 1998 and 100% in 1997, 1999, and 2001. These rates are comparable to success rates in 1981 and 1982 reported in studies conducted over most of the Colville Delta (70–91% in 1981 and 1982; Simpson et al. 1982, Rothe et al. 1983). In the Alpine common search area, sample sizes of failed nests were small (0–2 nests each year), so tests of the effects of fate and year on distance of nests to potential disturbance features were not conducted. The swan nest closest to the airstrip in each year was successful (range of distances to airstrip 161–491 m), and one nest site (nest 105) was in virtually the same location from 1995 to 2001 (range 442–491 m from the airstrip). Nest 105 hatched every year it was checked despite being in or near the flight path (range 28–148 m from the flight path; Figure 20). As was the case with White-fronted Goose nests, failed swan nests tended to be farther from the airstrip than were successful nests (Table 57), suggesting that human activity at the airstrip did not affect the fate of swan nests.

#### YELLOW-BILLED LOON

Clutch sizes for Yellow-billed Loons ranged between 1–2 eggs/nest during this study, although the sample size of nests for which clutch sizes were known was small (5 nests total, Table 55). Nest fate information for these loons also was limited. One nest from the 1997 nest search was known to have hatched successfully; the fates of the other nests found during nest searches in 1996 and 2001 were unknown. Additional nests found in the common search area during other activities mostly failed (2 in 1998, 1 each in 2000 and 2001) or had unknown fates (1 nest in 1999). The successful nest in 1997 was 1,407 m from the future airstrip location. Failed nests ranged between 775 and 1,408 m from the airstrip, and those with unknown fates ranged between 1,030 and 1,369 m.

Table 58. Comparisons of daily survival rates of Greater White-fronted Goose nests among years and between distance-to-airstrip categories ( $\leq 1,000$  m and  $>1,000$  m) in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Daily survival rates were calculated with the Mayfield method and differences were compared using Z scores with Bonferroni multiple comparisons.

|                            | Year | Failed Nests | Total Nests | Exposure Days | Daily Survival Rate | SE    | Bonferroni <i>P</i> -value <sup>a</sup> | 24-d Survival Rate <sup>b</sup> |
|----------------------------|------|--------------|-------------|---------------|---------------------|-------|---|---------------------------------|
| All Nests                  | 1998 | 1            | 17          | 137           | 0.99                | 0.007 |   | 0.84                            |
|                            | 1999 | 17           | 29          | 459           | 0.96                | 0.009 | 0.028 <sup>c</sup>                      | 0.40                            |
|                            | 2000 | 12           | 24          | 425           | 0.97                | 0.008 | 0.160 <sup>c</sup>                      | 0.50                            |
|                            | 2001 | 8            | 27          | 492           | 0.98                | 0.006 | 0.997 <sup>c</sup>                      | 0.67                            |
| Nests $\leq 1$ km Airstrip | 1998 | 0            | 3           | 22            | 1.00                | 0.000 |   | 1.00                            |
|                            | 1999 | 4            | 10          | 171           | 0.98                | 0.012 |   | 0.57                            |
|                            | 2000 | 3            | 6           | 87            | 0.96                | 0.020 |   | 0.43                            |
|                            | 2001 | 1            | 7           | 136           | 0.99                | 0.007 |   | 0.84                            |
| Nests $>1$ km Airstrip     | 1998 | 1            | 14          | 115           | 0.99                | 0.009 | 1.000 <sup>d</sup>                      | 0.81                            |
|                            | 1999 | 13           | 19          | 288           | 0.95                | 0.012 | 0.785 <sup>d</sup>                      | 0.33                            |
|                            | 2000 | 9            | 18          | 338           | 0.97                | 0.009 | 1.000 <sup>d</sup>                      | 0.52                            |
|                            | 2001 | 7            | 20          | 356           | 0.98                | 0.007 | 0.943 <sup>d</sup>                      | 0.62                            |

<sup>a</sup> Compares daily survival rates.

<sup>b</sup> Estimated for 24-d incubation period.

<sup>c</sup> Compared to 1998 daily survival rate of all nests.

<sup>d</sup> Compared to the daily survival rate of nests  $<1$  km from the airstrip for the same year.

## BREEDING-BIRD PLOTS

To evaluate the effects of disturbance on shorebirds and passerines in the Alpine project area, the annual and spatial variation in nesting were analyzed on 12 breeding-bird plots (Table 59). Effects of disturbance conditions on nest abundance for 5 common species and 4 species groupings were evaluated by comparing between treatment plots, which were near the airstrip or in the flight path (all plots  $\leq 1,500$  m from airstrip), and reference plots, which were  $>1,500$  m from the airstrip (Figure 2). We expected that if nesting habitats were similar across all plots, nest abundance would be lower on treatment than on reference plots if disturbance influenced the abundance of shorebird and passerine nests. Annual variation also was evaluated to determine if nest abundance declined during the years with the highest construction activities. In ANOVA models of the effects of plot type and year on nest

abundance, the interaction of year and plot type was non-significant for all taxa evaluated; that is, the difference in nest numbers between treatment and reference plots was similar among years. Based on this result, the interaction terms were removed from the final models (Table 60). The number of nests for all avian species combined differed among years ( $P = 0.02$ ) and between plot types ( $P < 0.01$ , Table 60), with significantly more nests on treatment plots (mean = 18.9 nests) than reference plots (mean = 13.7 nests). Significantly more Semipalmated Sandpiper and Lapland Longspur nests were detected on treatment plots than on reference plots (both species  $P \leq 0.04$ ). Consistent with those individual species trends, significantly more nests were found on treatment than on reference plots for shorebirds and passerines (both  $P \leq 0.01$ ), but not for waterfowl ( $P = 0.33$ ; Table 60). Treatment and reference plots did not differ in abundance of White-fronted



Table 59. Annual mean nest densities (nests/km<sup>2</sup>) and species counts on treatment and reference plots in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Six plots (10 ha each) ≤1,500 m from the airstrip were classified as treatment plots and 6 plots >1,500 m were classified as reference plots.

| Species                     | Treatment Plots |       |       |       |           | Reference Plots |       |       |       |           |
|-----------------------------|-----------------|-------|-------|-------|-----------|-----------------|-------|-------|-------|-----------|
|                             | 1998            | 1999  | 2000  | 2001  | All Years | 1998            | 1999  | 2000  | 2001  | All Years |
| Red-throated Loon           | 1.7             |       |       |       | 0.4       |                 | 1.7   |       |       | 0.4       |
| Greater White-fronted Goose | 10.0            | 10.0  | 13.3  | 6.7   | 10.0      | 16.7            | 5.0   | 3.3   | 8.3   | 8.3       |
| Tundra Swan                 | 5.0             | 1.7   | 1.7   |       | 2.1       |                 |       |       |       | 0         |
| Northern Shoveler           |                 |       |       |       | 0.0       | 1.7             |       |       |       | 0.4       |
| Northern Pintail            | 1.7             |       |       |       | 0.4       |                 |       | 1.7   |       | 0.4       |
| Greater Scaup               |                 |       |       |       | 0         | 1.7             |       |       |       | 0.4       |
| Oldsquaw                    |                 | 3.3   |       |       | 0.8       |                 | 1.7   |       |       | 0.4       |
| Unidentified Duck           | 3.3             |       | 5.0   |       | 2.1       |                 | 1.7   |       | 3.3   | 1.3       |
| <b>All Waterfowl</b>        | 20.0            | 15.0  | 20.0  | 6.7   | 15.4      | 20.0            | 8.3   | 5.0   | 8.3   | 11.3      |
| Willow Ptarmigan            |                 | 5.0   | 1.7   | 1.7   | 2.1       | 1.7             |       | 5.0   | 3.3   | 2.5       |
| Unidentified ptarmigan      |                 | 1.7   | 1.7   |       | 0.8       |                 |       |       |       | 0         |
| Black-bellied Plover        | 1.7             |       |       |       | 0.4       | 3.3             | 3.3   |       |       | 1.7       |
| American Golden Plover      | 1.7             | 1.7   | 3.3   | 1.7   | 2.1       |                 | 3.3   | 3.3   | 1.7   | 2.1       |
| Bar-tailed Godwit           | 1.7             | 1.7   |       | 1.7   | 1.3       | 1.7             |       |       |       | 0.4       |
| Semipalmated Sandpiper      | 23.3            | 40.0  | 45.0  | 35.0  | 35.8      | 11.7            | 21.7  | 33.3  | 11.7  | 19.6      |
| Pectoral Sandpiper          | 56.7            | 25.0  | 63.3  | 35.0  | 45.0      | 45.0            | 15.0  | 53.3  | 35.0  | 37.1      |
| Dunlin                      | 6.7             | 3.3   | 5.0   | 5.0   | 5.0       | 1.7             | 1.7   | 1.7   |       | 1.3       |
| Stilt Sandpiper             | 3.3             | 6.7   | 5.0   | 1.7   | 4.2       | 3.3             |       | 1.7   | 1.7   | 1.7       |
| Long-billed Dowitcher       |                 | 1.7   | 6.7   | 8.3   | 4.2       | 1.7             |       | 5.0   | 5.0   | 2.9       |
| Common Snipe                |                 |       | 1.7   |       | 0.4       |                 |       |       |       | 0.0       |
| Red-necked Phalarope        | 8.3             | 3.3   | 16.7  | 11.7  | 10.0      | 11.7            | 1.7   | 11.7  | 11.7  | 9.2       |
| Red Phalarope               | 5.0             | 6.7   | 5.0   | 6.7   | 5.8       | 5.0             | 5.0   | 6.7   | 8.3   | 6.3       |
| <b>All Shorebirds</b>       | 108.3           | 90.0  | 151.7 | 106.7 | 114.2     | 85.0            | 51.7  | 116.7 | 75.0  | 82.1      |
| Long-tailed Jaeger          |                 | 1.7   |       |       | 0.4       |                 |       |       |       | 0         |
| Arctic Tern                 |                 |       | 1.7   |       | 0.4       |                 |       |       |       | 0         |
| Yellow Wagtail              |                 | 1.7   | 10.0  | 10.0  | 5.4       |                 |       |       | 1.7   | 0.4       |
| Savannah Sparrow            | 1.7             |       | 10.0  |       | 2.9       | 5.0             | 2.0   |       | 1.7   | 2.1       |
| Lapland Longspur            | 43.3            | 55.0  | 45.0  | 40.0  | 45.8      | 38.3            | 48.3  | 40.0  | 23.3  | 37.5      |
| Common Redpoll              | 1.7             |       | 3.3   |       | 1.3       |                 |       | 1.7   |       | 0.4       |
| <b>All Passerines</b>       | 46.7            | 56.7  | 68.3  | 50.0  | 55.4      | 43.3            | 50.0  | 41.7  | 26.7  | 33.8      |
| <b>Total Nest Density</b>   | 176.7           | 170.0 | 245.0 | 165.0 | 189.2     | 150.0           | 111.7 | 168.3 | 116.7 | 136.7     |
| <b>Number of Species</b>    | 16              | 16    | 17    | 13    | 23        | 15              | 13    | 13    | 12    | 22        |

Table 60. Tests of the effects of year and plot type on nest density for the 5 most common species, and species groups nesting in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Six plots (10 ha each)  $\leq 1,500$  m from the airstrip were classified as treatment plots and 6 plots  $>1,500$  m were classified as reference plots.

| Species/Model Parameters              | Factor Statistics |          |          | ANCOVA Model Statistics |          |          |                       |
|---------------------------------------|-------------------|----------|----------|-------------------------|----------|----------|-----------------------|
|                                       | df                | <i>F</i> | <i>P</i> | df                      | <i>F</i> | <i>P</i> | <i>R</i> <sup>2</sup> |
| Greater White-fronted Goose           |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 0.650    | 0.587    | 4, 43                   | 0.545    | 0.704    | 0.048                 |
| Plot                                  | 1                 | 0.229    | 0.634    |                         |          |          |                       |
| All Waterfowl Species                 |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 1.237    | 0.308    | 4, 43                   | 1.175    | 0.335    | 0.099                 |
| Plot                                  | 1                 | 0.987    | 0.326    |                         |          |          |                       |
| Pectoral Sandpiper                    |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 6.832    | 0.001    | 4, 43                   | 5.492    | 0.001    | 0.338                 |
| Plot                                  | 1                 | 1.470    | 0.232    |                         |          |          |                       |
| Semipalmated Sandpiper                |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 3.011    | 0.040    | 4, 43                   | 4.513    | 0.004    | 0.296                 |
| Plot                                  | 1                 | 9.020    | 0.004    |                         |          |          |                       |
| Red-necked Phalarope                  |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 3.780    | 0.017    | 4, 43                   | 2.839    | 0.036    | 0.209                 |
| Plot                                  | 1                 | 0.016    | 0.900    |                         |          |          |                       |
| All Shorebird Species (log transform) |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 4.282    | 0.010    | 4, 43                   | 5.833    | 0.001    | 0.352                 |
| Plot                                  | 1                 | 10.487   | 0.002    |                         |          |          |                       |
| Lapland Longspur                      |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 4.116    | 0.012    | 4, 43                   | 4.151    | 0.006    | 0.279                 |
| Plot                                  | 1                 | 4.257    | 0.045    |                         |          |          |                       |
| All Passerine Species                 |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 2.392    | 0.082    | 4, 43                   | 4.038    | 0.007    | 0.273                 |
| Plot                                  | 1                 | 8.977    | 0.005    |                         |          |          |                       |
| All Avian Species                     |                   |          |          |                         |          |          |                       |
| Year                                  | 3                 | 3.852    | 0.016    | 4, 43                   | 5.644    | 0.001    | 0.344                 |
| Plot                                  | 1                 | 11.021   | 0.002    |                         |          |          |                       |

Goose, Pectoral Sandpiper, or Red-necked Phalarope nests (all  $P \geq 0.23$ ), although numbers were higher on treatment plots. Significant annual variation was exhibited in the number of Pectoral Sandpiper ( $P \leq 0.01$ ), Semipalmated Sandpiper ( $P = 0.04$ ), Red-necked Phalarope ( $P = 0.02$ ), and Lapland Longspur nests ( $P = 0.01$ ), but not by White-fronted Goose nests ( $P = 0.59$ ). Generally, nest abundance was highest in 2000, but the annual trends in abundance varied by species. None of the common species or species groups, with the exception of waterfowl, exhibited declines in nest

abundance coinciding with increases in construction activity from 1998 to 2000 and 2001. Likewise, the differences in nest numbers between treatment and reference plots for all common species were counter to what was expected from a disturbance effect. That is, treatment plots, 3 of which were in the flight path and all of which were within 1,500 m of the airstrip, contained more nests than did reference plots that were farther than 1,500 m from the airstrip.

Because the plots were distributed over a large area ( $\leq 3,200$  m from the airstrip), and disturbance

from the airstrip might not affect nesting birds over such a broad area, we investigated the effect of the distance of each plot from the airstrip on nest abundance while comparing among heavy-construction years (1999–2001), when disturbance effects should have been greatest. As in the previous analysis of treatment vs. reference plots, the effect of distance to the airstrip did not change among years and was removed from the analysis of covariance models (Table 61). In all heavy-construction years, nest abundance for all avian species combined was negatively related to distance to the airstrip, such that abundance decreased with increasing distance from the airstrip ( $P \leq 0.01$ ). Of the 5 common species nesting in the Alpine project area, only Semipalmated Sandpipers exhibited a significant negative association with distance to the airstrip ( $P \leq 0.01$ ), but the remaining species had similar negative relationships that were not significant ( $P \geq 0.16$ ). Among the 3 species groups, shorebirds and passerines exhibited a significant decrease in nest abundance as a function of increasing distance from the airstrip (both,  $P \leq 0.01$ ). Waterfowl nest abundance was not related to distance to airstrip ( $P = 0.38$ ), but the trend was negative as with the other species and groups. Based on these results, none of species or species groups appeared to be deterred from nesting near the airstrip, at the scale of these analyses (Table 61).

The number of nests for all avian species combined found on the 12 breeding-bird plots fluctuated among years ( $P \leq 0.01$ ), primarily because of large changes in numbers of shorebird nests (Table 61). Pectoral Sandpiper, Red-necked Phalarope, Lapland Longspur, all shorebird, and all passerine nests exhibited significant annual variation ( $P \leq 0.05$ , Table 61), but the annual fluctuations were not suggestive of a disturbance effect. Nest abundance did not decline with increasing levels of aircraft and other activity after 1998. The highest numbers for all species occurred in 1998 (196 nests) and 2000 (248 nests), whereas 1999 and 2001 both had the lowest number (169 nests each). The number of shorebird nests declined from 116 in 1998 to 85 in 1999, then nearly doubled to 160 in 2000 and decreased to 109 in 2001. The number of waterfowl nests, in contrast, appeared to decline from 24 in 1998 to 11 nests in 2001, paralleling the numbers of duck and

goose nests (adjusted for search effort) found in the common search area (Table 3). Nevertheless, declines in White-fronted Goose and all waterfowl nests combined were not significant ( $P \geq 0.31$ ; Table 60). Passerine nests (primarily Lapland Longspurs) increased each year from 1998 to 2000 (54, 62, and 64 nests, respectively) and then declined in 2001 (46 nests). Neither the number of passerine nests nor the number of shorebird nests was significantly correlated with annual levels of aircraft, vehicles, pedestrians, or noise ( $r \leq |0.4|$ ,  $P \geq 0.60$ , Table 29). The abundance of passerine nests was positively correlated with the first snow-free date ( $r = 0.8$ ,  $P = 0.2$ ) and negatively correlated with thawing degree-days in late May and early June ( $r = -0.6$ ,  $P = 0.4$ ), whereas the abundance of shorebird nests was positively related to mean June temperatures ( $r = 0.6$ ,  $P = 0.4$ ). The correlations for waterfowl nests were discussed previously in the section on Nest Densities and Distribution.

In conclusion, neither annual trends in nest abundance nor the distribution of nests suggested that disturbance from human activity at the Alpine airstrip had an impact on shorebird or passerine nest abundance in the breeding-bird plots. However, declines in abundance around the airstrip might have occurred at a scale smaller than was measurable on our plots. Some shorebird species avoided nesting within 100 m of roads in the Prudhoe Bay Oilfield (TERA 1993). Our plots had only 3 grids within 100 m of gravel pads or the airstrip, so our analyses could not detect changes in nest abundance that might occur at that scale.

#### HABITAT ASSOCIATIONS

We examined nesting habitat on the breeding bird plots as an additional factor that might explain the distribution of shorebird, passerine, and waterfowl nests in conjunction with their distribution relative to the airstrip. Habitat characteristics along with distance to the airstrip (divided into 4 distance categories) of individual grids (50 × 50 m) on the breeding-bird plots were analyzed using logistic regression models for each of 6 common species and 3 species groups. Annual models varied by year and generally had small sample sizes for this type of analysis (Table 25; Johnson et al. 2001). Models using nesting data pooled across all 4 years demonstrated some

Table 61. Test of the effects of year (1999–2001) and distance to the airstrip on number of nests on breeding-bird plots ( $n = 12$  plots) using analysis of covariance for the 5 most common species and species groups nesting in the Alpine project area, Colville River Delta, Alaska.

| Species/Model Parameters              | Factor Statistics |          |          | Ancova Model Statistics |          |          |                       |
|---------------------------------------|-------------------|----------|----------|-------------------------|----------|----------|-----------------------|
|                                       | df                | <i>F</i> | <i>P</i> | df                      | <i>F</i> | <i>P</i> | <i>R</i> <sup>2</sup> |
| Greater White-fronted Goose           |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 0.021    | 0.979    | 3, 32                   | 0.407    | 0.749    | 0.037                 |
| Distance to Airstrip                  | 1                 | 1.179    | 0.286    |                         |          |          |                       |
| All Waterfowl Species                 |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 0.183    | 0.834    | 3, 32                   | 0.387    | 0.763    | 0.035                 |
| Distance to Airstrip                  | 1                 | 0.796    | 0.379    |                         |          |          |                       |
| Pectoral Sandpiper                    |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 9.376    | 0.001    | 3, 32                   | 6.938    | 0.001    | 0.394                 |
| Distance to Airstrip                  | 1                 | 2.062    | 0.161    |                         |          |          |                       |
| Semipalmated Sandpiper                |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 2.164    | 0.131    | 3, 32                   | 5.200    | 0.005    | 0.328                 |
| Distance to Airstrip                  | 1                 | 11.271   | 0.002    |                         |          |          |                       |
| Red-necked Phalarope (log transform)  |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 5.382    | 0.010    | 3, 32                   | 3.854    | 0.018    | 0.265                 |
| Distance to Airstrip                  | 1                 | 0.797    | 0.379    |                         |          |          |                       |
| All Shorebird Species (log transform) |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 6.279    | 0.005    | 3, 32                   | 9.074    | <0.001   | 0.460                 |
| Distance to Airstrip                  | 1                 | 14.665   | 0.001    |                         |          |          |                       |
| Lapland Longspur                      |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 5.836    | 0.007    | 3, 32                   | 4.156    | 0.014    | 0.280                 |
| Distance to Airstrip                  | 1                 | 0.794    | 0.380    |                         |          |          |                       |
| All Passerine Species                 |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 3.434    | 0.045    | 3, 32                   | 4.905    | 0.006    | 0.315                 |
| Distance to Airstrip                  | 1                 | 7.849    | 0.009    |                         |          |          |                       |
| All Avian Species                     |                   |          |          |                         |          |          |                       |
| Year                                  | 2                 | 6.083    | 0.006    | 3, 32                   | 9.160    | <0.001   | 0.462                 |
| Distance to Airstrip                  | 1                 | 15.315   | <0.001   |                         |          |          |                       |

common tendencies for bird–habitat associations on the breeding-bird plots (Table 62). Moist sedge shrub was the most common vegetation type, entering 5 of 7 models, and the probability of nest occurrence increased with increasing moist sedge shrub cover (odds ratio > 1.0). Sedge marsh was a significant explanatory variable in 2 models, and the probability of nest occurrence also increased with this vegetation type. Polygon density was a significant explanatory variable in 3 models, with a higher probability of nest occurrence in grids characterized by high-density polygons. In addition, polygon center type was a significant

explanatory variable in 2 models, with a higher probability of nest occurrence in grids characterized by low-centered polygons. Distance to the airstrip was included in 4 final models, all of which indicated increasing probabilities of nests in zones near the airstrip, but the responses were not linear in all cases.

The probability of occurrence for nests of White-fronted Geese, all waterfowl, and Pectoral Sandpipers was highest in the 2 mid-distance zones from 780 m to 2,412 m, somewhat lower in the 0–789-m zone, and lowest in the >2,412-m zone (Table 62). The probability of shorebird and

Table 62. Logistic regression models for predicting the occurrence of nest sites of the most common nesting birds on 480 grids (50 × 50 m each) within 12 plots (10 ha each), Alpine project area, Colville River Delta, Alaska, 1998-2001. All years were pooled.

| Variable Type  | Variable              | $\beta$ | SE    | Wald   | df | <i>P</i> | Odds Ratio<br>(Exp[ $\beta$ ]) |
|--|-----------------------|---------|-------|--------|----|----------|--------------------------------|
| <b>Greater White-fronted Goose, 44 grids with <math>\geq 1</math> nest. [<math>LR^a = 19.681</math>, 6 df, <math>P = 0.003</math>]</b> |                       |         |       |        |    |          |                                |
| Polygon  | Center                |         |       | 6.724  | 2  | 0.035    |                                |
|  | Low                   | 1.098   | 0.789 | 1.939  | 1  | 0.164    | 2.998                          |
|  | High                  | 0.029   | 0.877 | 0.001  | 1  | 0.370    | 1.029                          |
|  | None <sup>c</sup>     | 0       |       |        |    |          |                                |
| Distance   | Airstrip (m)          |         |       | 9.512  | 3  | 0.023    |                                |
|  | 0–780                 | 0.828   | 0.629 | 1.735  | 1  | 0.188    | 2.290                          |
|  | 780–1,430             | 1.285   | 0.558 | 5.306  | 1  | 0.021    | 3.616                          |
|  | 1,430–2,412           | 1.597   | 0.550 | 8.419  | 1  | 0.004    | 4.938                          |
|  | >2,412 <sup>c</sup>   | 0       |       |        |    |          |                                |
| Vegetation Cover   | Sedge Marsh (%)       | 0.492   | 0.247 | 3.958  | 1  | 0.047    | 1.636                          |
| Constant   |                       | -4.211  | 0.916 | 21.118 | 1  | <0.001   | 0.015                          |
| <b>Pectoral Sandpiper, 152 grids with <math>\geq 1</math> nest. [<math>LR^a = 21.957</math>, 8 df, <math>P = 0.005</math>]</b>         |                       |         |       |        |    |          |                                |
| Polygon  | Center                |         |       | 5.030  | 2  | 0.081    |                                |
|  | Low                   | 0.965   | 0.450 | 4.598  | 1  | 0.032    | 2.998                          |
|  | High                  | 0.709   | 0.482 | 2.166  | 1  | 0.141    | 2.032                          |
|  | None <sup>c</sup>     | 0       |       |        |    |          |                                |
| Distance   | Airstrip (m)          |         |       | 7.645  | 3  | 0.054    |                                |
|  | 0–780                 | 0.355   | 0.324 | 1.203  | 1  | 0.273    | 1.427                          |
|  | 780–1,430             | 0.711   | 0.302 | 5.542  | 1  | 0.019    | 2.037                          |
|  | 1,430–2,412           | 0.726   | 0.303 | 5.737  | 1  | 0.017    | 2.066                          |
|  | >2,412 <sup>c</sup>   | 0       |       |        |    |          |                                |
| Water  | Depth (cm)            | -0.014  | 0.009 | 2.658  | 1  | 0.103    | 0.985                          |
| Vegetation Cover   | Moist Sedge Shrub (%) | 0.014   | 0.006 | 5.127  | 1  | 0.024    | 1.015                          |
|  | Open Low Willow (%)   | 0.031   | 0.020 | 2.425  | 1  | 0.119    | 1.031                          |
| Constant   |                       | -2.361  | 0.521 | 20.552 | 1  | <0.001   | 0.094                          |
| <b>Semipalmated Sandpiper, 100 grids with <math>\geq 1</math> nest. [<math>LR^a = 39.946</math>, 6 df, <math>P &lt; 0.001</math>]</b>  |                       |         |       |        |    |          |                                |
| Distance   | Airstrip (m)          |         |       | 11.573 | 3  | 0.009    |                                |
|  | 0–780                 | 1.287   | 0.386 | 11.410 | 1  | 0.001    | 3.622                          |
|  | 780–1,430             | 1.078   | 0.397 | 7.370  | 1  | 0.007    | 2.937                          |
|  | 1,430–2,412           | 1.024   | 0.392 | 6.811  | 1  | 0.009    | 2.785                          |
|  | >2,412 <sup>c</sup>   | 0       |       |        |    |          |                                |
| Water  | Depth (cm)            | -0.014  | 0.006 | 4.958  | 1  | 0.026    | 0.986                          |
| Vegetation Cover   | Moist Sedge Shrub (%) | 0.038   | 0.008 | 24.009 | 1  | <0.001   | 1.039                          |
|  | Wet Sedge Willow (%)  | 0.017   | 0.009 | 3.464  | 1  | 0.063    | 1.017                          |
| Constant   |                       | -3.444  | 0.533 | 41.714 | 1  | <0.001   |                                |

Table 62. Continued.

| Variable Type  | Variable                    | $\beta$ | SE    | Wald    | df | $P$    | Odds Ratio<br>(Exp[ $\beta$ ]) |
|--|-----------------------------|---------|-------|---------|----|--------|--------------------------------|
| <b>Red-necked Phalarope, 43 grids with <math>\geq 1</math> nest. [<math>LR^a = 16.543</math>, 2 df, <math>P &lt; 0.001</math>]</b> |                             |         |       |         |    |        |                                |
| Water  | Depth (cm)                  | 0.021   | 0.006 | 10.569  | 1  | 0.001  | 1.021                          |
| Vegetation Cover   | Wet Sedge Willow (%)        | -0.026  | 0.016 | 2.564   | 1  | 0.109  | 0.975                          |
| Constant   |                             | -2.500  | 0.402 | 38.642  | 1  | <0.001 | 0.082                          |
| <b>Red Phalarope, 25 grids with <math>\geq 1</math> nest. [<math>LR^a = 13.833</math>, 3 df, <math>P = 0.003</math>]</b>           |                             |         |       |         |    |        |                                |
| Water  | Depth (cm)                  | 0.022   | 0.008 | 7.834   | 1  | 0.005  | 1.022                          |
| Vegetation Cover   | Partially Vegetated         | 0.332   | 0.134 | 6.181   | 1  | 0.013  | 1.394                          |
|  | <i>Dryas</i> Tundra         | 0.138   | 0.056 | 6.053   | 1  | 0.014  | 1.147                          |
| Constant   |                             | -3.680  | 0.363 | 102.624 | 1  | <0.001 | 0.025                          |
| <b>Lapland Longspur, 158 grids with <math>\geq 1</math> nest. [<math>LR^a = 17.094</math>, 5 df, <math>P = 0.004</math>]</b>       |                             |         |       |         |    |        |                                |
| Polygon  | Density/Center <sup>b</sup> |         |       | 7.442   | 4  | 0.114  |                                |
|  | Low/Low                     | 0.114   | 0.372 | 0.093   | 1  | 0.760  | 1.120                          |
|  | Low/High                    | -0.446  | 0.457 | 0.951   | 1  | 0.330  | 0.640                          |
|  | High/High                   | 0.422   | 0.448 | 0.890   | 1  | 0.345  | 1.525                          |
|  | High/Low                    | 0.999   | 0.687 | 2.147   | 1  | 0.146  | 2.716                          |
|  | None <sup>c</sup>           | 0       | –     | –       | –  | –      | 1.000                          |
| Vegetation Cover   | Moist Sedge Shrub (%)       | 0.017   | 0.006 | 6.695   | 1  | 0.010  | 1.017                          |
| Constant   |                             | -1.315  | 0.398 | 10.909  | 1  | 0.001  | 0.268                          |
| <b>Waterfowl, 63 grids with <math>\geq 1</math> nest. [<math>LR^a = 22.951</math>, 7 df, <math>P = 0.002</math>]</b>               |                             |         |       |         |    |        |                                |
| Polygon  | Center                      |         |       | 8.468   | 2  | 0.014  |                                |
|  | Low                         | 0.599   | 0.569 | 1.111   | 1  | 0.292  | 1.821                          |
|  | High                        | -0.539  | 0.661 | 0.663   | 1  | 0.415  | 0.583                          |
|  | None <sup>c</sup>           | 0       | –     | –       | –  | –      | 1.000                          |
| Distance   | Airstrip (m)                |         |       | 6.520   | 3  | 0.089  |                                |
|  | 0–780                       | 0.534   | 0.492 | 1.181   | 1  | 0.277  | 1.707                          |
|  | 780–1,430                   | 0.979   | 0.436 | 5.039   | 1  | 0.025  | 2.663                          |
|  | 1,430–2,412                 | 0.975   | 0.437 | 4.984   | 1  | 0.026  | 2.652                          |
|  | >2,412 <sup>c</sup>         | 0       | –     | –       | –  | –      | 1.000                          |
| Vegetation Cover   | Wet Sedge Willow (%)        | -0.021  | 0.012 | 2.847   | 1  | 0.092  | 0.979                          |
|  | Sedge Marsh (%)             | 0.319   | 0.240 | 1.761   | 1  | 0.184  | 1.375                          |
| Constant   |                             | -2.554  | 0.669 | 13.363  | 1  | <0.001 | 0.078                          |
| <b>Shorebird, 275 grids with <math>\geq 1</math> nest. [<math>LR^a = 21.629</math>, 6 df, <math>P = 0.001</math>]</b>              |                             |         |       |         |    |        |                                |
| Polygon  | Density                     |         |       | 4.250   | 2  | 0.119  |                                |
|  | Low                         | 0.546   | 0.341 | 2.567   | 1  | 0.109  | 1.726                          |
|  | High                        | 0.889   | 0.434 | 4.202   | 1  | 0.040  | 2.432                          |
|  | None <sup>c</sup>           | 0       | –     | –       | –  | –      | 1.000                          |
| Distance   | Airstrip (m)                |         |       | 8.198   | 3  | 0.042  |                                |
|  | 0–780                       | 0.655   | 0.278 | 5.525   | 1  | 0.019  | 1.924                          |
|  | 780–1,430                   | 0.632   | 0.267 | 5.618   | 1  | 0.018  | 1.882                          |
|  | 1,430–2,412                 | 0.616   | 0.268 | 5.285   | 1  | 0.022  | 1.851                          |
|  | >2,412 <sup>c</sup>         | 0       | –     | –       | –  | –      | 1.000                          |
| Vegetation Cover   | Moist Sedge Shrub (%)       | 0.011   | 0.006 | 3.113   | 1  | 0.078  | 1.011                          |
| Constant   |                             | -1.043  | 0.399 | 6.829   | 1  | 0.009  | 0.352                          |

Table 62. Continued.

| Variable Type  | Variable                    | $\beta$ | SE    | Wald   | df | $P$   | Odds Ratio<br>(Exp[ $\beta$ ]) |
|--|-----------------------------|---------|-------|--------|----|-------|--------------------------------|
| <b>Passerine, 169 grids with <math>\geq 1</math> nest. [LR = 19.989, 5 df, <math>P = 0.001</math>]</b> |                             |         |       |        |    |       |                                |
| Polygon  | Density/Center <sup>b</sup> |         |       | 9.670  | 4  | 0.046 |                                |
|  | Low/Low                     | 0.203   | 0.371 | 0.299  | 1  | 0.585 | 1.225                          |
|  | Low/High                    | -0.357  | 0.453 | 0.623  | 1  | 0.430 | 0.700                          |
|  | High/High                   | 0.709   | 0.446 | 2.524  | 1  | 0.112 | 2.031                          |
|  | High/Low                    | 1.007   | 0.687 | 2.147  | 1  | 0.143 | 2.737                          |
|  | None <sup>c</sup>           | 0       | –     | –      | –  | –     | 1.000                          |
| Vegetation Cover   | Moist Sedge Shrub (%)       | 0.016   | 0.006 | 6.183  | 1  | 0.014 | 1.016                          |
| Constant   |                             | -1.291  | 0.396 | 10.607 | 1  | 0.001 |                                |

<sup>a</sup> LR = likelihood ratio statistic, tests the null hypothesis that all coefficients in the final model except the constant are 0.

<sup>b</sup> No coefficients calculated for the reference category; this is the category against which all other categories are compared with the indicator contrast method and, therefore, has an odds ratio of 1.0.

<sup>c</sup> Polygon density and polygon centers were collapsed into 1 variable with 5 categories because polygons without centers were linearly related to density.

Semipalmated Sandpiper nests occurring was greater in the 3 distance zones closest to the airstrip versus the category farthest away (i.e., >2,412 m). The estimated probability of nest occurrence was greatest between 0 and 780 m from the airstrip for all shorebirds and for Semipalmated Sandpipers.

The probability of nest occurrence on grids increased with increasing cover of moist sedge shrub for Pectoral and Semipalmated sandpipers, all shorebirds, Lapland Longspurs, and all passerines (Table 62). The probability of White-fronted Geese and all waterfowl nests was higher on grids with increased sedge marsh cover. Waterfowl nest probability decreased with increasing wet sedge willow vegetation, whereas Semipalmated Sandpiper nests were more likely to occur with wet sedge willow vegetation. The presence of low-center polygons was associated with increased probabilities of White-fronted Goose, all waterfowl, and Pectoral Sandpiper nests. High-density polygons were associated with the occurrence of shorebird nests. For both passerine and Lapland Longspur nests, the probability of nests increased with the combined features of high-density, low-center polygons and high-density, high-center polygons. The logistic models that described variables associated with the occurrence of nests for all passerines and Lapland Longspurs were essentially the same, which

resulted from the high proportion of Lapland Longspur nests in the passerine species group.

Differences in habitat characteristics between treatment and reference plots combined with the habitat associations explain a few but not all of the differences between treatment and reference plots described above. Comparisons of habitat measurements between treatment and reference plots were presented by Johnson et al. (2001b). Wet sedge willow was less abundant on treatment (mean = 18% cover) than on reference plots (mean = 22%;  $P < 0.01$ ). In contrast, moist sedge shrub cover was slightly higher on treatment (mean = 31%) than reference plots (mean = 28%), but not significantly higher ( $P = 0.15$ ). Open low willow and *Dryas* tundra were more common on reference plots ( $P \leq 0.01$ ). Although surface form and polygon density did not differ significantly among treatment and reference plots, low-center polygons and non-polygon forms (nonpatterned, dunes, or disjunct polygons) occupied a higher proportion of grids on reference plots and high-center polygons occupied higher proportions of grids on treatment plots ( $P < 0.01$ ). Other vegetation and surface features either did not differ between plot types or were of little explanatory value in habitat models. Therefore, nests of those species or species groups associated with moist sedge shrub and high-center polygons might be expected to be more common on treatment plots

and those associated with wet sedge willow, open low willow, *Dryas* tundra, low-center polygons, and non-polygon forms might be more common on reference plots. Association with moist sedge shrub vegetation appears to partially explain the distribution of nests between treatment and reference plots for Semipalmated Sandpipers, Lapland Longspurs, and the corresponding species groups of shorebirds and passerines. The association with other vegetation types, surface form, and polygon type and density appeared to be contrary to the differences in nest numbers between treatment and reference plots. The habitat models evidently had low predictive abilities. The failure of the habitat models to explain observed differences in nest abundance between treatment and reference plots implies that the wrong habitat characteristics were measured, that habitat selection by these species is operating at a different scale, or that the habitat heterogeneity of the plots was not high enough for nesting species to exhibit preferences. Although we may have been successful at limiting habitat heterogeneity among the plots when plots were installed, as was intended, we are unable to explain the observed distribution of nests and suspect that some relevant habitat gradients or features were not identified. Nonetheless, the distribution of nests relative to the airstrip indicated that nesting shorebirds and passerines either were attracted or indifferent to areas close to the Alpine airstrip. TERA (1993) found nesting Red-necked Phalaropes were attracted to areas close (<100 m) to roads in Prudhoe Bay, but most other species had reduced nest densities close to roads. Although those findings appear to disagree with results from the Alpine study plots, we do not conclude that nesting shorebirds were reacting differently to gravel roads and an airstrip in the 2 studies. Each study was designed to investigate changes in nest abundance in response to different types of disturbance and, perhaps more importantly, at different scales of distance to disturbance sources.

### SEASONAL USE OF LAKES

Previous sections evaluated the effects of disturbance on nesting birds, but a large number of birds ( $\leq 2,511$  waterbirds on a single survey) use lakes in the Alpine project area for feeding,

loafing, molting, and brood-rearing. The effects of disturbance on these birds that are mobile and not restricted to nest sites may be different from the effects on nesting birds. The potential for aircraft and other construction activity to displace birds could affect the overall use of the Alpine project area as well as the availability of birds to local subsistence users. Use of lakes by all large avian species in the Alpine project area was evaluated for changes among lakes and among years that might be in response to disturbance from the airstrip. As in the previous disturbance evaluations, we predicted that if aircraft disturbance had a negative effect on the distribution of non-nesting birds, densities of birds would decline in lakes close to the airstrip. However, we did not expect bird use of lakes to be constant in the absence of disturbance, because annual fluctuations in waterfowl abundance on the Arctic Coastal Plain are high (Derksen and Eldridge 1980, Malleck 2001). We investigated the effects of year and habitat along with distance to the airstrip to evaluate whether the possible distributional differences in bird densities were related to habitat or annual changes in human-activity levels.

Annual levels of use over all lakes declined from 69.6 birds/km<sup>2</sup> in 1998 to 37.4 birds/km<sup>2</sup> in 2001 (Table 63). Differences among years can be attributed largely to changes in the abundance of ducks, which decreased markedly in the Alpine area over the 4 years of study (Figure 28). The numbers of birds of other groups (loons and grebes, geese, swans, and gulls, terns, and jaegers) remained relatively stable through all 4 years.

The numbers of birds observed during each month of the summer differed in relation to breeding activities and migration patterns. For example, most waterfowl were more abundant pre- and post-nesting than they were during the incubation period, and pre-migration staging could bring large numbers of waterfowl into the Colville Delta during August. In general, the total number of birds observed on lakes in the Alpine area decreased slightly between June and July and then increased (markedly in 1998 and 1999) during August (Figure 29). However, the pattern of abundance differed among years and among species. For example, ducks were much more abundant in June of 1998 and 2000 than they were in either 1999 or 2001, and their numbers increased



Table 63. Mean density (birds/km<sup>2</sup>) of large waterbirds by year observed on lakes (total area = 16.1 km<sup>2</sup>) in the Alpine project area, Colville River Delta, Alaska. Mean density based on 8 surveys per year.

| Lake                    | 1998  | 1999  | 2000  | 2001  |
|-------------------------|-------|-------|-------|-------|
| R 6.1                   | 134.2 | 35.3  | 66.4  | 96.1  |
| R 7.1                   | 85.0  | 46.3  | 77.2  | 27.0  |
| S 6.1 <sup>a</sup>      | 68.1  | 37.5  | 47.0  | 49.8  |
| S 6.2                   | 36.8  | 52.1  | 44.4  | 32.2  |
| S 7.1                   | 77.8  | 91.4  | 52.5  | 128.3 |
| S 7.2 <sup>a</sup>      | 80.1  | 56.0  | 48.5  | 30.1  |
| S 7.3                   | 34.0  | 14.4  | 17.4  | 6.8   |
| T 4.1                   | 16.4  | 38.8  | 103.1 | 20.9  |
| T 4.2                   | 60.7  | 45.0  | 61.3  | 18.8  |
| T 4.3                   | 118.5 | 76.9  | 137.7 | 201.8 |
| T 4.4, 5.3, 5.4         | 61.4  | 66.1  | 77.9  | 33.1  |
| T 4.5                   | 57.5  | 30.5  | 10.2  | 27.1  |
| T 4.6                   | 180.0 | 110.7 | 110.7 | 249.2 |
| T 5.1                   | 18.2  | 17.4  | 31.3  | 20.2  |
| T 5.2                   | 25.7  | 44.1  | 39.2  | 20.8  |
| T 5.5                   | 78.7  | 100.6 | 88.6  | 127.1 |
| T 5.6                   | 168.4 | 186.0 | 322.9 | 231.6 |
| T 6.1                   | 5.2   | 10.0  | 11.2  | 9.6   |
| T 6.2                   | 150.7 | 173.4 | 116.8 | 71.6  |
| T 7.1, 7.2, 7.5         | 9.2   | 12.4  | 9.1   | 10.8  |
| T 7.3, 7.4              | 13.1  | 6.2   | 14.3  | 28.6  |
| T 8.1                   | 14.3  | 6.4   | 7.9   | 18.3  |
| U 4.1 <sup>a</sup>      | 72.0  | 35.3  | 41.6  | 16.6  |
| U 4.2                   | 60.2  | 36.1  | 60.2  | 36.1  |
| U 5.1                   | 397.1 | 270.4 | 309.1 | 191.9 |
| U 5.2                   | 23.9  | 8.4   | 42.2  | 36.6  |
| U 5.3                   | 38.6  | 52.4  | 46.9  | 35.8  |
| U 6.1                   | 8.4   | 6.4   | 23.7  | 5.3   |
| U 6.2                   | 38.8  | 11.6  | 10.3  | 15.5  |
| U 6.3, 6.4              | 6.0   | 15.5  | 19.4  | 24.5  |
| V 5.1 <sup>a</sup>      | 112.9 | 69.9  | 61.0  | 49.4  |
| Grand Mean <sup>b</sup> | 69.6  | 45.4  | 46.6  | 37.4  |

<sup>a</sup> Indicates a tapped lake basin.

<sup>b</sup> Total birds per survey/16.1 km<sup>2</sup>.

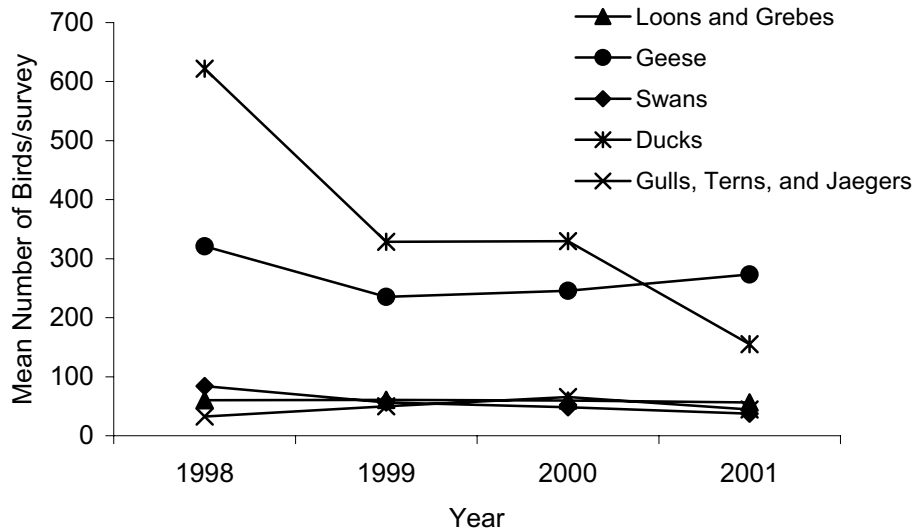


Figure 28. Mean number of waterbirds observed per lake aerial survey, all months pooled, in the Alpine project area, Colville River Delta, Alaska, 1998–2001. A mean of 8 surveys were conducted each year.

markedly during August only in 1998 and 1999 (Figure 29). Geese typically increased in abundance between June and July, except in 1999, when they decreased in abundance between those months. With the exception of ducks (see below), these differences among years in monthly abundance may be attributed to slight variation in phenology among years.

To investigate the effects of disturbance on avian use of lakes in the Alpine project area, repeated measures ANOVAs were used to estimate the influence of distance to facility features, year, and lake type on density of all large waterbirds. In exploratory analyses, lake area ( $\text{km}^2$ ) was not significantly correlated with bird densities ( $P = 0.48$ ), so lake area was excluded from further consideration. Lake type was more obviously related to bird abundance, with Tapped Lakes with Low-water Connections (grouped with associated lakes as tapped lake basins) consistently supporting higher numbers of birds than all other lake types (see Table 27). The most influential distance measure was distance of lakes from the airstrip, which was slightly more highly correlated ( $r^2 = 0.02$ ,  $P < 0.01$ ) than distance to gravel or distance to flight path (both  $r^2 \leq 0.01$ ,  $P \leq 0.01$ ). Final models were computed separately for each month, because of monthly variation (Figure 29), using total bird density at each lake on each survey

as a repeated measure related to distance of each lake from the airstrip, lake type, year, and 2 interaction terms (Table 64). No significant association was detected between bird density and distance from airstrip in any month ( $P \geq 0.26$ ), indicating that bird densities were not reduced in lakes near the airstrip (Figure 30). The 2 lake types differed significantly only during August, with tapped lake basins having significantly higher densities than the other lake types ( $P \leq 0.001$ ). The models identified one significant interaction term in June—between year and distance from airstrip—and 2 significant interaction terms in the August models—between year and lake type and between year and distance from airstrip. Interaction terms can be difficult to interpret, but because these included distance from the airstrip, which may be indicative of a disturbance effect, an attempt was made to determine whether these interactions were consistent with a potential impact of the airstrip on birds (i.e., if bird densities in August increased with distance from the airstrip in any year or if they decreased between years with low air-traffic levels and years with high air-traffic levels, particularly in lakes nearer to the airstrip). To evaluate the effect of distance in those 2 interaction terms, the mean density of all birds combined was calculated each year for June (Figure 31) and for August (Figure 32).

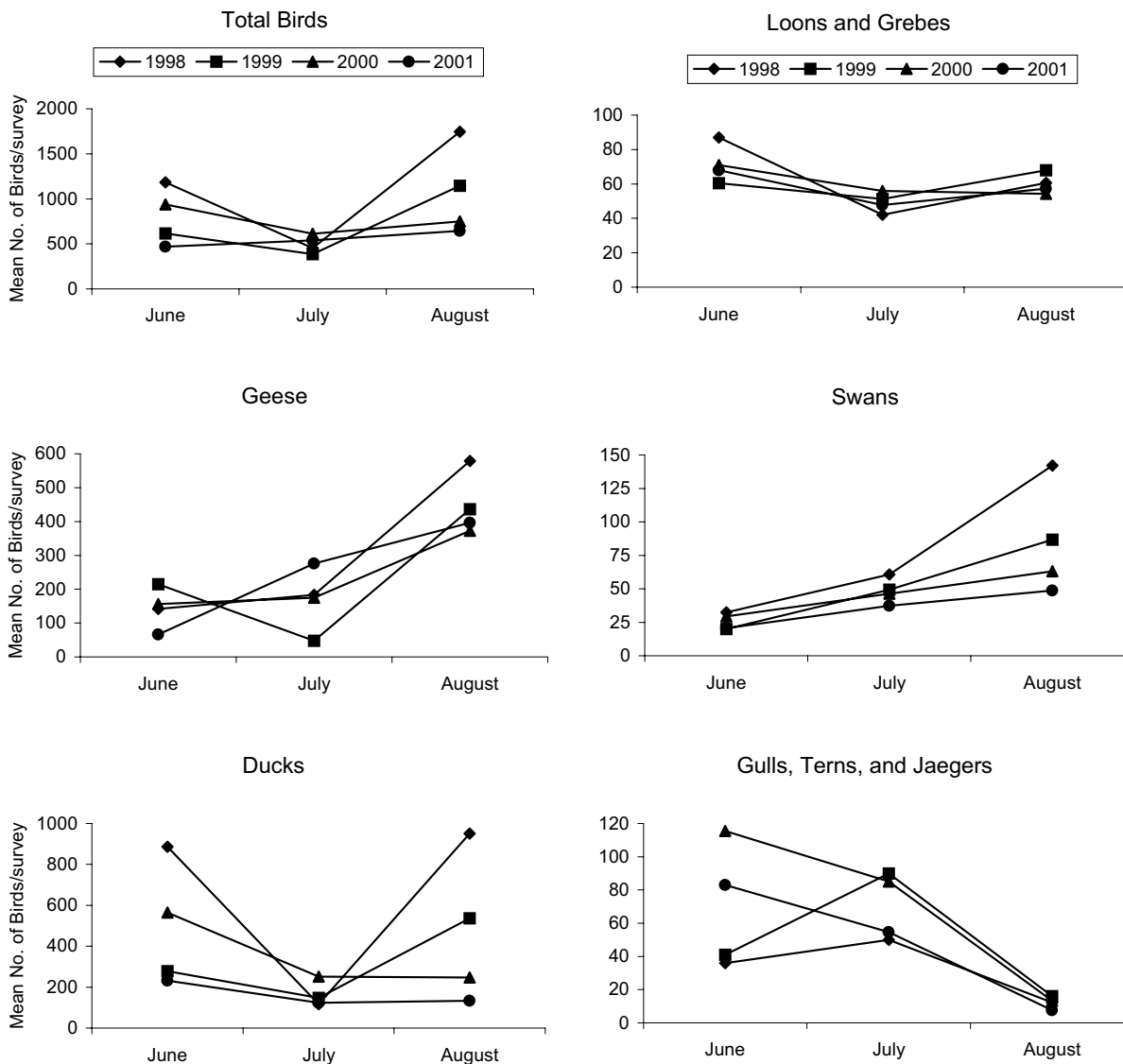


Figure 29. Mean number of birds observed per lake aerial survey by month and year, in the Alpine project area, Colville River Delta, Alaska, 1998–2001.  $n = 8$  surveys for June;  $n = 12$  surveys each for July and August.

In June, bird densities did not differ between lake types, so they were combined for a comparison of densities among years and distance zones in 3 distance categories (near [ $<1,000$  m], middle [ $1000\text{--}2,000$  m], and far [ $>2,000$  m]; Figure 31). Overall densities decreased from 1998 to 1999, increased slightly in 2000, then decreased again in 2001. Despite this annual variation, densities were highest every year in the near zone. In August, mean bird density on both lake types showed no evidence of an increasing trend with distance from airstrip, except in 1998 in tapped

lake basins (Figure 32b) and in 2000 in other lake types (Figure 32c). Because air traffic was infrequent in 1998 and because bird densities in other lake types decreased with distance from the airstrip, this result was not interpreted as a disturbance effect. Similarly for 2000, the trend in bird densities with distance reversed between tapped lake basins and other lakes. However, the highest mean densities in August in all lakes combined were achieved in the near zone every year, which is contrary to what would be expected if the activity at the airstrip had a strong effect on

Table 64. Evaluation of the effect of year, distance of lakes to the airstrip, and lake type (tapped lake basins [6 basins] and all other lakes [25 lakes]) on the density of all large waterbirds seen in each month during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1998–2001. Density was rank transformed in repeated measures ANOVAs run with each month separately. Eight surveys were conducted in June, 9 in July, and 9 in August.

| Month/Factors               | df   | F      | P      |
|-----------------------------|------|--------|--------|
| <b>June</b>                 |      |        |        |
| Between Subjects            |      |        |        |
| Intercept                   | 1    | 53.69  | <0.001 |
| Lake Type                   | 1    | 0.27   | 0.608  |
| Distance to Airstrip        | 1    | 0.31   | 0.583  |
| Within Subjects             |      |        |        |
| Year                        | 2.64 | 1.132  | 0.338  |
| Year * Lake Type            | 2.64 | 2.281  | 0.094  |
| Year * Distance to Airstrip | 2.64 | 4.739  | 0.006  |
| <b>July</b>                 |      |        |        |
| Between Subjects            |      |        |        |
| Intercept                   | 1    | 74.53  | <0.001 |
| Lake Type                   | 1    | 0.56   | 0.459  |
| Distance to Airstrip        | 1    | 1.32   | 0.260  |
| Within Subjects             |      |        |        |
| Year                        | 2.96 | 1.10   | 0.355  |
| Year * Lake Type            | 2.96 | 0.62   | 0.605  |
| Year * Distance to Airstrip | 2.96 | 1.101  | 0.392  |
| <b>August</b>               |      |        |        |
| Between Subjects            |      |        |        |
| Intercept                   | 1    | 101.01 | <0.001 |
| Lake Type                   | 1    | 18.52  | <0.001 |
| Distance to Airstrip        | 1    | 0.89   | 0.354  |
| Within Subjects             |      |        |        |
| Year                        | 2.88 | 1.30   | 0.281  |
| Year * Lake Type            | 2.88 | 3.01   | 0.037  |
| Year * Distance to Airstrip | 2.88 | 3.78   | 0.015  |

bird distribution (Figure 32a). In addition, no evidence was found in August of a decrease in bird densities in each distance zone between 1998 (low frequency of air traffic) and other years (with higher air traffic levels). In fact, bird densities in lakes closest to the airstrip tended to increase after 1998 (the only exception being in 2000 in the other lake types, Figure 32c). When all months are considered together, the trends among years and different distances from the airstrip were inconsistent (Figure 30). Although these observations are difficult to interpret, they do not

appear to be indicative of a disturbance effect on birds in the vicinity of the airstrip.

Annual variation in weather and in the availability of nesting habitat strongly influences the number of waterbirds in the study area. Fluctuations in the abundance of ducks on the Arctic Coastal Plain, the predominant taxa among the birds in these surveys, are strongly influenced by annual differences in spring habitat conditions in southern portions of the migratory paths and breeding grounds of ducks (Derksen and Eldridge 1980). For ducks, the relatively high abundance during June 1998 and 2000 and during August

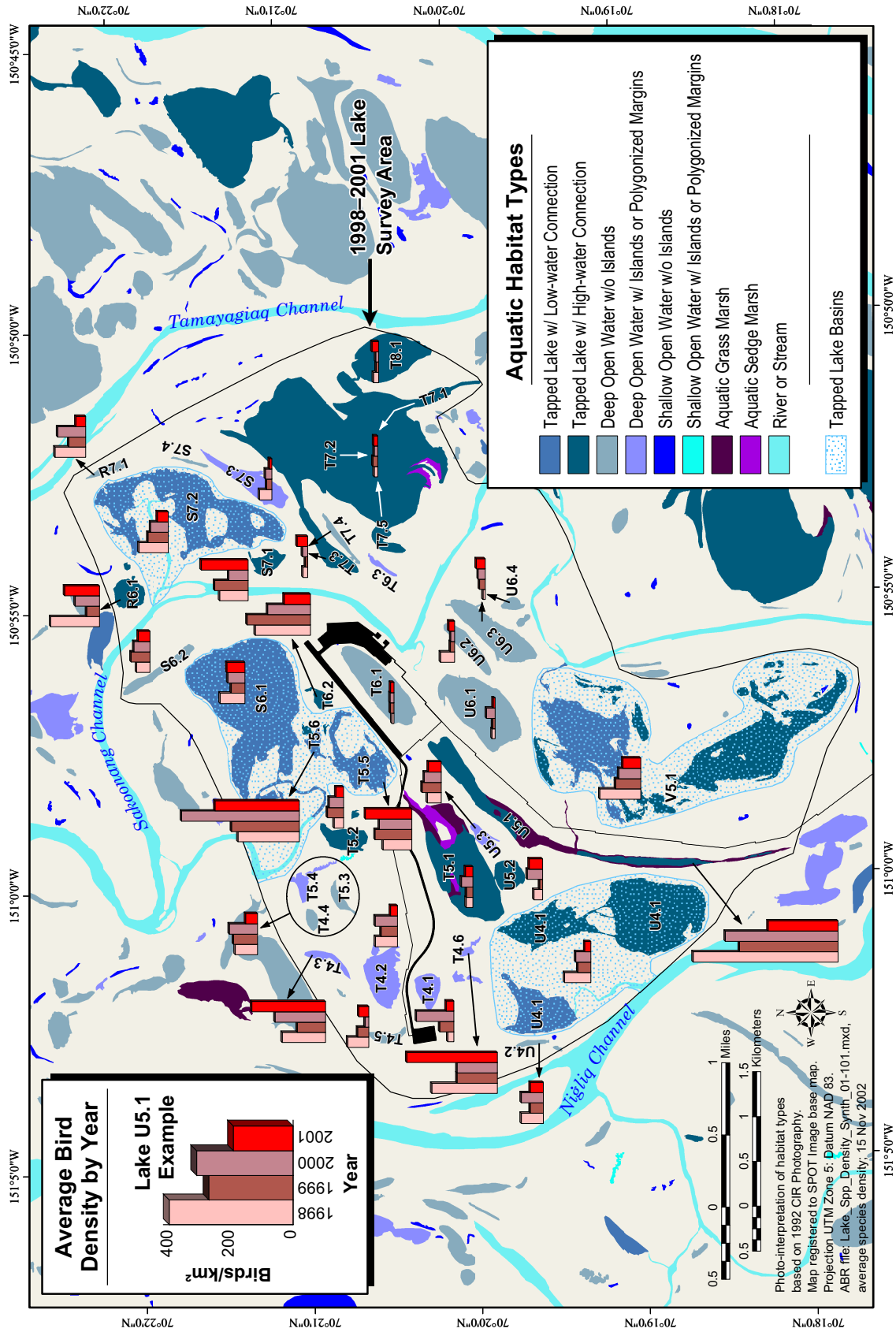


Figure 30. Mean density (birds/km<sup>2</sup>) of waterbirds in each lake by year and lake habitat in the Alpine project area, Colville River Delta, Alaska, 1998–2001.

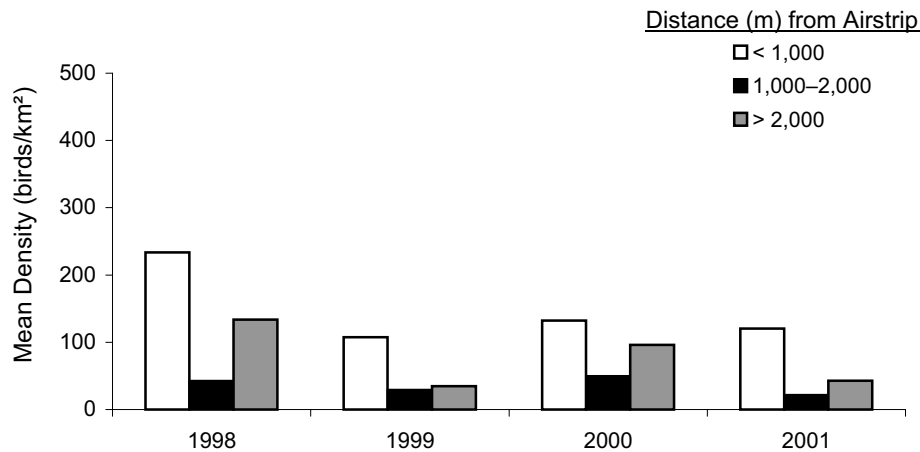


Figure 31. Mean density (birds/km<sup>2</sup>) of waterbirds on 31 lakes in June, by year and by distance-from-airstrip category in the Alpine project area, Colville River Delta, Alaska, 1998–2001. A mean of 8 surveys were conducted each year.

1998 and 1999 probably resulted from regional movements related to conditions in major breeding areas outside of the Alpine project area. Between 1986 and 2001, population estimates for ducks on the Arctic Coastal Plain during June have varied from about 533,000 in 1989 down to 257,000 in 2000 (Malleck 2002). Northern Pintails are by far the most abundant ducks on the Arctic Coastal Plain (Malleck 2002) and their numbers are known to fluctuate dramatically annually, declining by as much as 62% from one year to the next (see also Derksen et al. 1981). Among the 4 years of lake surveys in the Alpine project area, Northern Pintail numbers on the Arctic Coastal Plain varied from a high of 283,000 in 1999 to a low of 131,000 in 2000 (Malleck 2002). Although numbers of ducks observed during the Alpine lake surveys do not closely track these regional trends, they do reflect dramatic differences in abundance of ducks among years (Figure 28). The high annual variation in abundance of the birds that breed in the region complicate analysis of disturbance effects, making it crucial to understand the natural range of variability, and limits the conclusions that can be made about annual changes in abundance alone. Thus the decline in ducks from 1998 to 2001 in the Alpine project area does not clearly suggest a disturbance effect, and the analysis of changes in densities with distance among years indicates that

aircraft disturbance is not an explanation for the patterns observed among lakes.

In summary, our analyses failed to identify any reliable trends that were consistent with the potential effects of disturbance. Bird densities did not decrease significantly in lakes close to the Alpine airstrip. Waterbird densities in the study area differed significantly between lake types (with higher densities in tapped lake basins) in the month of August, and the trend in density with distance from the airstrip differed significantly among years during June and August, but was not suggestive of a disturbance effect.

## PREDATORS

### NEST PREDATION

Monitoring predators and nest predation is important to an evaluation of development impacts, because nest predation can depress the productivity of tundra-nesting birds and some of the most effective nest predators on the coastal plain (foxes, Glaucous Gulls, and Common Ravens) are suspected to be attracted to human development. Since 1997, 271 nests failed out of 550 nests of known fate. Fifty-four nests (20%) were known or suspected to have been preyed on by birds, 47 nests (17%) were known or suspected to have been preyed on by foxes, and 3 nests (1%) were abandoned. The cause of failure of the

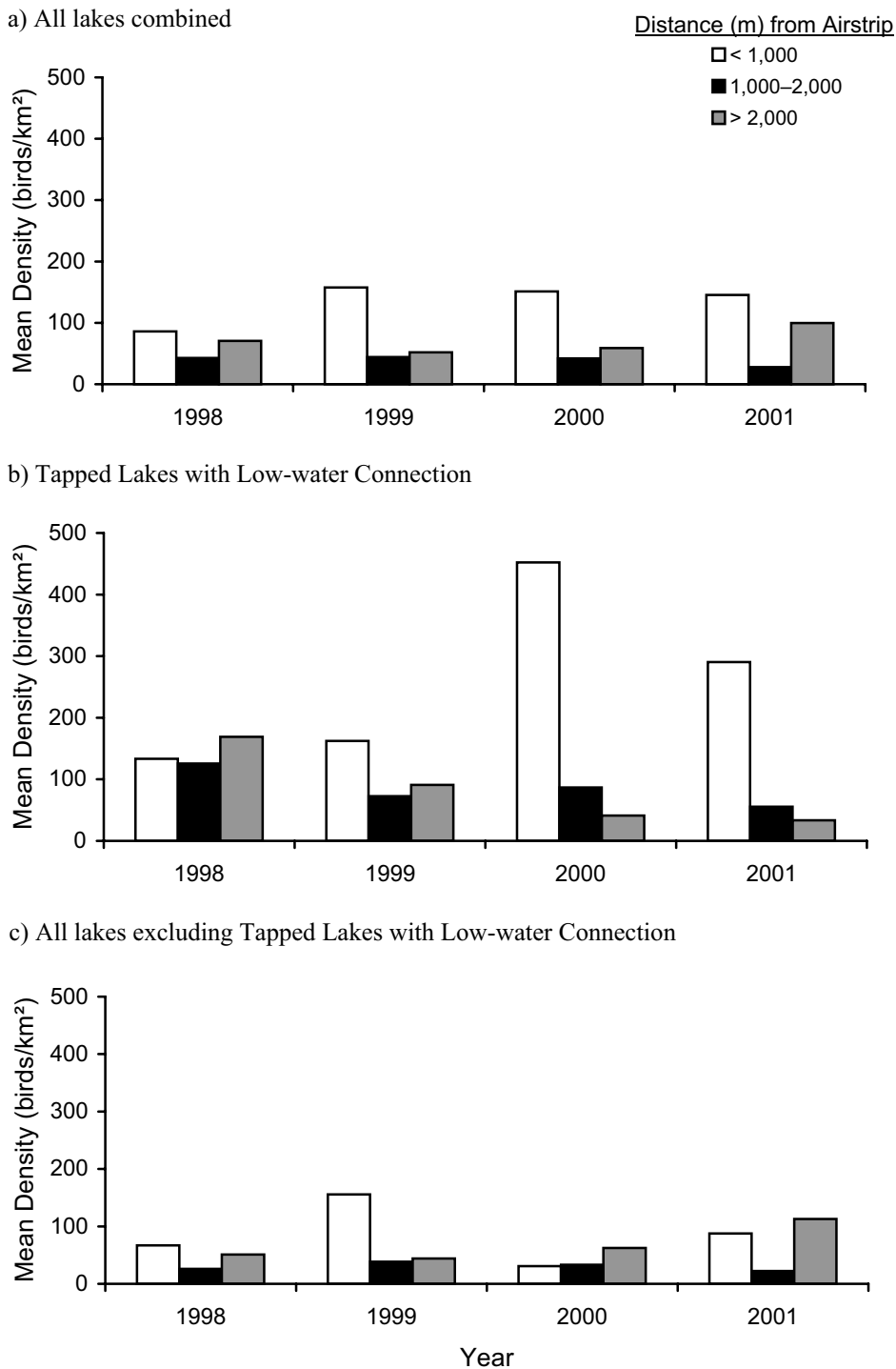


Figure 32. Mean density (birds/km<sup>2</sup>) of waterbirds on 31 lakes in August, by lake type, by year, and by distance-from-airstrip category in the Alpine project area, Colville River Delta, Alaska, 1998–2001. A mean of 8 surveys were conducted each year.

remaining 167 nests (62%) was unknown. Predation likely contributed to the failure of many of those nests, but no signs of predators were found for identification. Nest predators were identified for a small sample of nests monitored by video. From 1998 to 2001, video cameras at 18 nests that were observed through hatch or failure recorded egg predation by foxes at 3 nests and by avian predators at 8 nests.

Based on video records, foxes were more active in the Alpine project area in 1999–2001 than in 1998, and based on observations during nest searching, fox activity in 1998 was similar to 1997. The frequency of fox occurrence (determined by the number of detections on video) was 4× higher in 1999 (0.29 foxes/d of video recording, or 33 foxes), 2000 (0.28 foxes/d, or 23 foxes), and 2001 (0.30 foxes/d, or 28 foxes) than in 1998 (0.07 foxes/d, or 3 foxes). Although arctic foxes have been observed almost daily every year since 1996 in the Alpine project area, 1999 was the first year red foxes were seen on a regular basis. Of the 90 times that foxes were seen on video, 65 (72%) were identified as arctic fox, 14 (16%) as red fox, and 12 (12%) were unidentified.

Arctic or red foxes were seen on the video of 17 of 23 nests that were monitored in 1998–2001, but at only 12 of those nests was the fox threatening the incubating goose or swan. Arctic fox always were deterred from nests by the attending geese or swans and never were seen taking eggs, even at unattended nests monitored by video. A red fox was successful in flushing a pair of geese from their nest and took all their eggs, except the thermistored egg. Red Fox were not successful in flushing swans from nests, but egg predation occurred at 2 unattended nests.

Avian predators occurred less frequently than foxes on video tapes of monitored nests, but flying birds were probably under sampled because the view of the sky was restricted or absent in most of the camera views, and therefore, avian predators hunting near nests were missed. Based on the video records, avian predators appeared to be more active in 1998 than 1999, 2000, or 2001. Nest predation was recorded on video at 8 nests during 4 years of monitoring and 5 of those events occurred in 1998. The rate of occurrence of avian predators (Parasitic and Long-tailed jaegers, Glaucous Gulls, Common Raven) on video also was highest in 1998

(0.91 birds/d of video recording, or 38 birds) compared with 1999 (0.15 birds/d, or 17 birds), 2000 (0.07 birds/d, or 6 birds), and 2001 (0.05 birds/d, or 5 birds). Of the 96 times that an avian predator was seen on video, 74 (77%) were jaegers (30 Parasitic Jaegers and 44 unidentified jaegers), 13 (14%) were Common Ravens, and 9 (9%) were Glaucous Gulls.

In all 4 years of video monitoring and ≥6 years of nest searching in the study area, avian predators were never seen displacing an incubating bird from a nest and were only seen taking eggs from unattended nests. On video, only jaegers were seen standing at unattended nests and pecking eggs. Predation by jaegers occurred at 2 Yellow-billed Loon, 3 Tundra Swan, and 3 White-fronted Goose nests. At 4 of these 8 nests, jaegers visited the nest multiple times, sometimes during different recesses and sometimes during the same recess. A total of 36 visits by jaegers were recorded, 31 occurred during normal recesses and 5 occurred when incubating birds were flushed by pedestrians.

Parasitic Jaegers caused the failure of 2 Yellow-billed Loon nests. Both nests were visited by jaegers during normal recesses by the incubating loon, and the eggs of each nest were destroyed during those visits. Predation at both nests occurred during long recesses (138–224 min) and the jaegers were not seen at the nests until after the loon had been gone for >1 hr. Predation by jaegers at 3 swan nests also occurred during abnormally long recesses (113, 174, and 1,225 min). Two of these recesses were caused by researchers working near the nests. Jaegers damaged 2 of 4 eggs at 1 swan nest and an unknown number at the other 2 nests, which failed from fox predation after the visits by jaegers. Partial predation by jaegers occurred at 3 White-fronted Goose nests—2 nests lost one egg and 1 nest lost 2 eggs during different events.

Fox and avian predation also were observed during nest searching and other research activities. Nine observations of nest predation by arctic foxes occurred during our research activities in 1998 and 1999. Arctic fox were seen preying upon nests of Tundra Swan (1 nest), Long-tailed Jaeger (1 nest), Long-tailed Duck (1 nest), Willow Ptarmigan (2 nests), and White-fronted Goose (3 nests). An additional observation of fox (species unknown)



predation at a White-fronted Goose nest was observed by an Alpine worker in 1999. Two weeks later when the fate of that nest was checked, a carcass of an adult goose was found next to the nest. Carcasses of adult geese were found at 2 other White-fronted Goose nests in 1999 and at 1 nest in 2001, indicating probable predation by foxes.

Seventeen direct observations were made of jaegers (mostly Parasitic Jaegers) taking or attempting to take eggs from nests in 1997–2001. In 1999, a Pomarine Jaeger and a Long-tailed Jaeger were seen preying upon different White-fronted Goose nests. Overall, Parasitic Jaegers were observed at nests of 1 Red-necked Grebe, 1 Willow Ptarmigan, 1 Arctic Tern, 2 Pacific Loons, and 10 White-fronted Geese. Approximately half of all jaeger predation events occurred when the incubating bird was flushed during nest-searching. Ravens were seen hunting in the project area in each year from 1998 to 2001. On a few occasions in 2000 and 2001, ravens were seen carrying eggs in their bills, and one was observed picking up an egg (the size of a duck or large shorebird egg) from the tundra. However, we did not directly observe ravens preying on nests either during nest searching or during video monitoring of nests.

Although foxes (both red and arctic) occurred more frequently than avian predators on video recordings from monitored nests, the video recordings were biased against what are probably brief appearances of flying birds. Avian predators probably are able to evaluate whether nests are being incubated without flying close to or landing on the ground within view of our video cameras. Therefore, we estimate that avian predators were more frequent visitors to nests than foxes in the Alpine project area, albeit at distances that were not readily detectable. From the sample of video recordings, avian predators preyed upon eggs more often than did foxes, and more direct observations during nest searching were made of avian predators than of foxes at nests. Foxes were observed always to remove all the eggs from nests, whereas avian predators frequently removed 1 or 2 eggs from goose and swan nests (i.e., partial predation), leaving some viable eggs that hatched later. Because of partial predation, the overall impact of avian predators may be less than that of foxes to

the nesting success of loons, swans, and geese. Avian predators were opportunistic predators and never were observed taking eggs from nests that were attended. In contrast, foxes frequently were observed approaching incubated nests and attempting to drive off the attending birds, although foxes too would take eggs from unattended nests. The opportunistic approach appeared to work well for jaegers, and disturbances by pedestrians accounted for 46% of the recesses observed on video recordings that were taken advantage of by jaegers. No other source of disturbance was observed causing recesses that led to predation.

The number of active fox dens and pup production in the study area did not vary greatly after 1996 (see Fox Den Monitoring section below), nor did the number of nests of the different avian predators from 1996 to 2001. The primary avian predator in the project area was the Parasitic Jaeger, which accounted for most of the egg predation observed. Jaegers (Parasitic, Long-tailed, and Pomarine) generally are not attracted to human foods or structures, and did not change in abundance during the study. The 2 species that are attracted to human food sources (Glaucous Gull and Common Raven [also attracted to artificial structures for its nest sites]) accounted for 23% of the avian predators observed on video and none of the egg predation that was observed on video or directly by researchers. However, Common Ravens rarely were observed in the Alpine project area before 1998, when buildings were used as roosting sites (a nest site was suspected but not confirmed). Since 1998, ravens were observed at the Alpine pads daily each year, with nesting confirmed in 2000 and 2001, and they clearly augmented the number of avian predators in the study area. Nonetheless, we did not detect any change in the rates or sources of predation on the nests of birds for which we monitored nesting success (loons and waterfowl) since construction of the Alpine project.

#### FOX DEN MONITORING

The principal development issue concerning foxes on the North Slope is the potential for population increases resulting from food supplementation from human activities. Such augmentation of predator populations is presumed

to lead in turn to increased predation on birds (Martin 1997, Day 1998, Burgess 2000). This concern has led to concerted efforts in recent development projects, including Alpine (outlined in the predator management plan for the project), to control the access of mammalian and avian predators and scavengers to anthropogenic (human-generated) foods. This element of the monitoring study quantified the background of natural variation and looked for evidence of changes in the fox population due to project construction. We evaluated changes in fox denning and productivity among years for relationships with annually changing levels of human activity. We also evaluated whether fox denning and productivity varied with distance of dens from facilities, which could indicate a relationship with accessibility to the facilities, and therefore, availability of supplemental food.

Our monitoring efforts were focused on the annual occupancy rate and pup production at as many fox dens as we could reasonably monitor, both near to and distant from the Alpine facilities. We used 5-km distance buffer increments around CD-1 (location of the main camp), because that distance is a generous estimate of the foraging range around a den. Macpherson (1969) reported an average distance of 5 km between occupied dens and Eberhardt et al. (1982) reported an average adult home range of 20.8 km<sup>2</sup>, from which we inferred an average foraging radius of ~2.6 km.

#### Den Use

By 1995, all of the dens included in our analysis within the 10-km buffer around Alpine had been located, except for 2 dens found in 2001 (and thus not included in our analyses of index dens, because their status was not evaluated in all years): Den 102, a small, inactive resting den ~8 km north of Alpine, and Den 103, found late in the season ~2 km southwest of CD-1 (Figures 33 and 34). Den 103 was a well-established site when located in August 2001, but no foxes were seen at or near the site in previous years; it was not newly excavated. We found no indication of new dens being excavated within 10 km of Alpine during our study period; thus, the density of dens did not increase in the Alpine area during project construction.

Several pairs of natal and secondary dens used by the same litters were noted during our study, and other instances were suspected on the basis of proximity and sequential use, but could not be confirmed. On the Colville Delta, Dens 45 and 61 were used by arctic foxes as a natal–secondary pair in 1995 and 1999, and probably also in 1996 and 1998 (when both were active simultaneously). Dens 2 and 58 were used sequentially by arctic foxes in 1995. Red foxes used Dens 82 and 87 as a natal–secondary pair in 2000 and 2001. On the coastal plain east of the Colville Delta, Dens 39 and 71 and Dens 66 and 68 were natal–secondary pairs used by arctic foxes in 1996, as were Dens 50 and 86 in 1999.

Additional adults (besides breeding pairs) were observed at arctic fox dens on 2 occasions during our study, when 3 adults were seen at each of Dens 45 and 64 in 1996. Other researchers have noted similar rare occurrences of extra adults at dens (Eberhardt et al. 1983, Frafjord 1991, Tannerfeldt and Angerbjörn 1998), possibly related ‘helpers’ at the den or, less likely, parents of multiple litters using the same den. We only observed additional adults at dens in 1996, the year of highest productivity by foxes.

#### Den Occupancy Rate

Occupancy rate, or the proportion of dens that were active (natal, secondary, or active categories combined) was evaluated for differences that might indicate whether development had increased the numbers of fox dens used in the Alpine area. Data was analyzed from an index group of 38 dens (Table 65) that were checked in each of the 6 years (1996–2001) to examine the influence of factors affecting occupancy rate. The proportion of dens active each year differed significantly ( $\chi^2 = 26.26$ ,  $df = 5$ ,  $P < 0.01$ ) as a result of the high proportion of active dens in 1996, when high rodent populations led to the highest den occupancy rate and litter sizes throughout the region during the study period (Appendix I2; Johnson et al. 1997). When 1996 was removed from the analysis, there was no difference among years ( $\chi^2 = 1.12$ ,  $df = 4$ ,  $P = 0.89$ ). Significantly more dens were active before construction (1996–1997) than during construction (1998–2001;  $\chi^2 = 5.31$ ,  $df = 1$ ,  $P = 0.02$ ), but there was no significant difference when 1996 was excluded ( $\chi^2 < 0.01$ ,  $df = 1$ ,

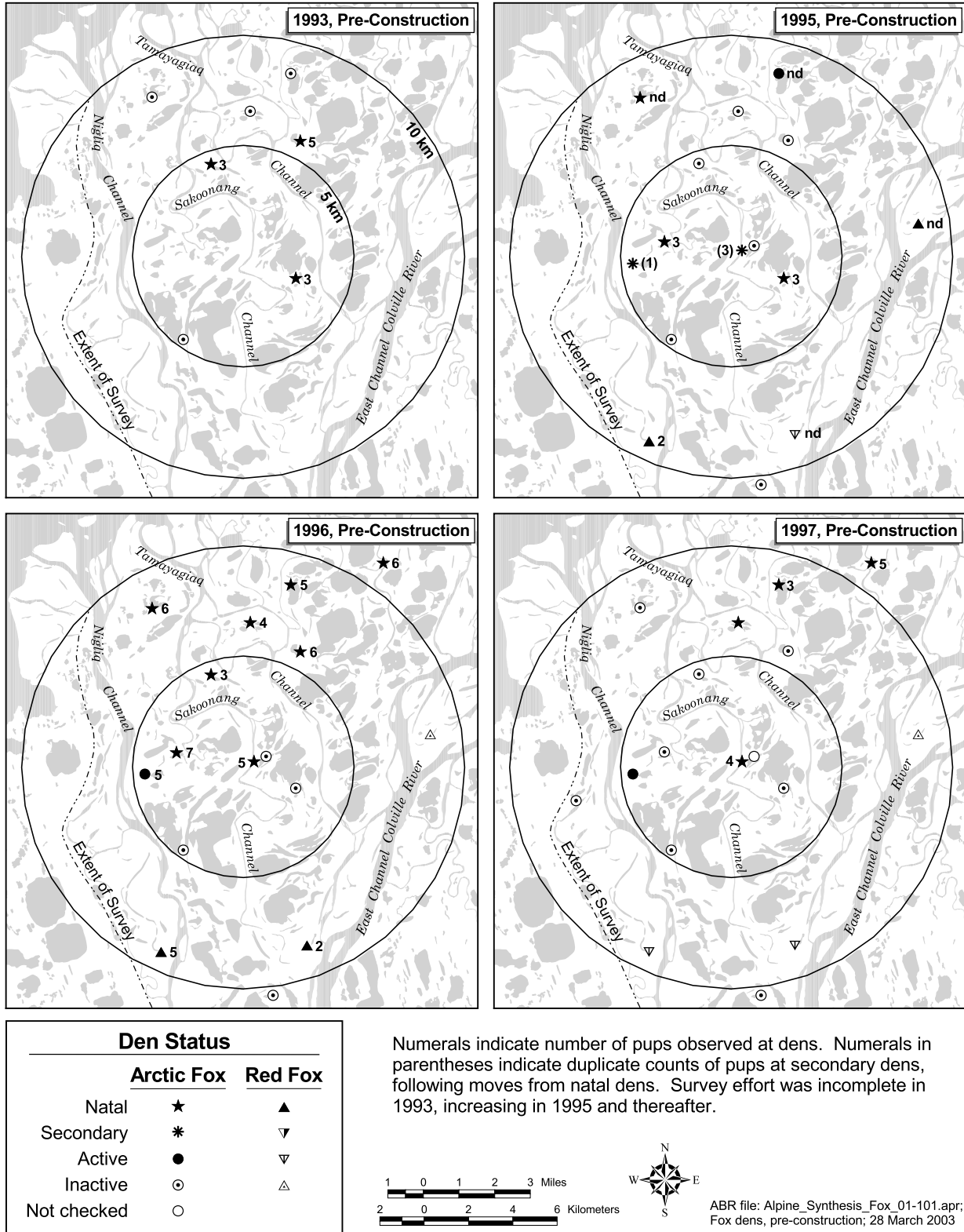


Figure 33. Arctic and red fox den occupancy and pup counts within 5 km and 10 km of the Alpine CD-1 location before construction (1993, 1995–1997), Colville River Delta, Alaska.

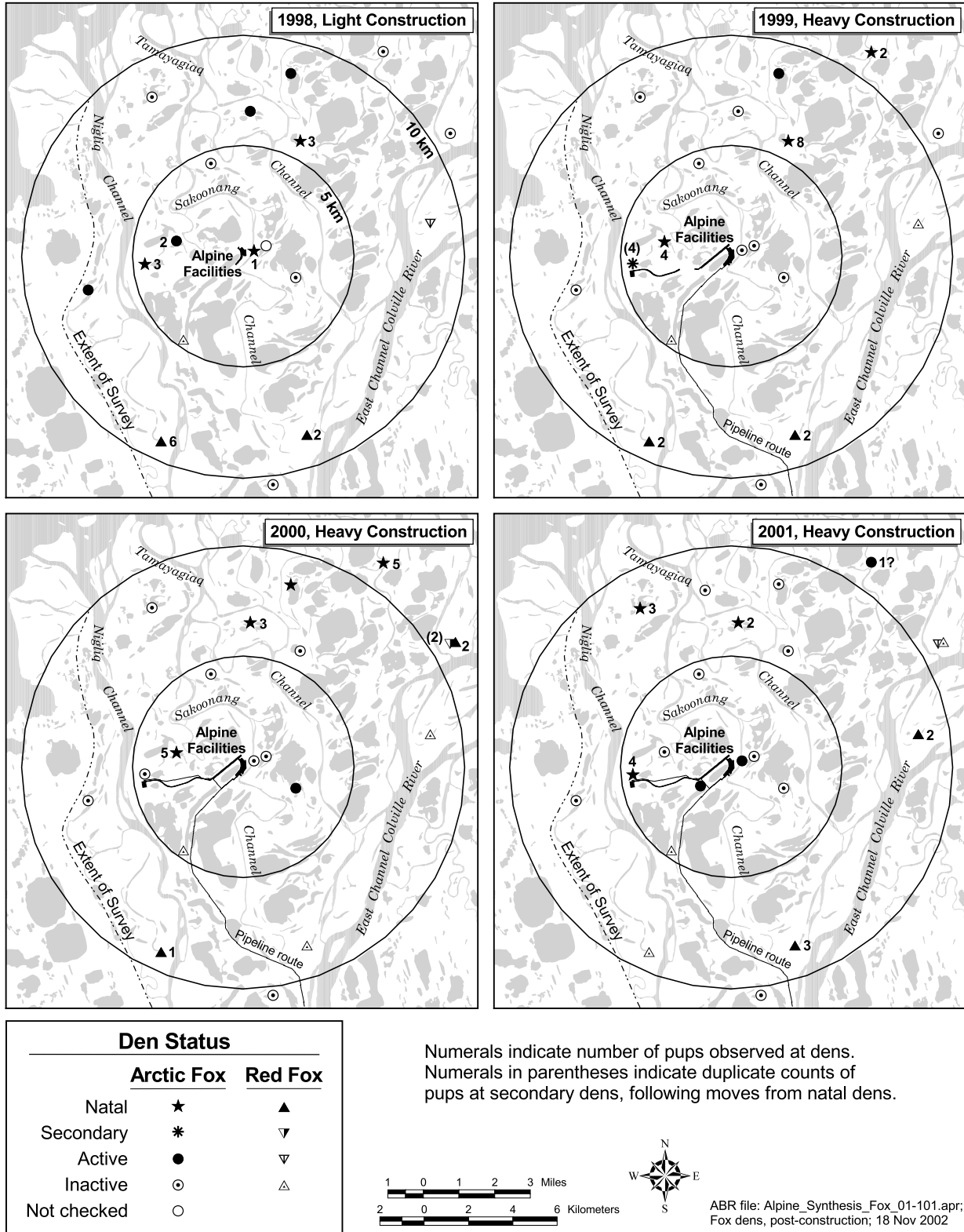


Figure 34. Arctic and red fox den occupancy and pup counts within 5 km and 10 km of the Alpine CD-1 during construction (1998–2001), Colville River Delta, Alaska.

Table 65. Annual occupancy rate (percentage), mean litter size, and average productivity of 38 monitored fox dens in distance zones centered on Alpine CD-1 pad, Colville River Delta, Alaska.

| Distance Zone | Year     | Occupancy Rate <sup>a</sup> |     | Litter Size <sup>b</sup> |      | Pup Production <sup>c</sup> |
|---------------|----------|-----------------------------|-----|--------------------------|------|-----------------------------|
|               |          | <i>n</i>                    | %   | <i>n</i>                 | Mean | Mean                        |
| <5 km         | 1996     | 6                           | 67  | 4                        | 5.0  | 3.33                        |
|               | 1997     | 6                           | 33  | 1                        | 4.0  | 1.33                        |
|               | 1998     | 6                           | 50  | 2                        | 2.0  | 1.00                        |
|               | 1999     | 6                           | 33  | 1                        | 4.0  | 1.33                        |
|               | 2000     | 6                           | 33  | 1                        | 5.0  | 1.67                        |
|               | 2001     | 6                           | 33  | 1                        | 4.0  | 1.33                        |
|               | Subtotal |                             | 36  | 42                       | 10   | 4.1                         |
| 5–10 km       | 1996     | 7                           | 86  | 5                        | 5.2  | 4.46                        |
|               | 1997     | 7                           | 57  | 1                        | 3.0  | 1.71                        |
|               | 1998     | 7                           | 86  | 3                        | 3.7  | 3.14                        |
|               | 1999     | 7                           | 57  | 3                        | 4.0  | 2.29                        |
|               | 2000     | 7                           | 43  | 1                        | 3.0  | 1.29                        |
|               | 2001     | 7                           | 57  | 4                        | 2.5  | 1.43                        |
|               | Subtotal |                             | 42  | 64                       | 17   | 3.8                         |
| >10 km        | 1996     | 25                          | 76  | 8                        | 6.6  | 5.04                        |
|               | 1997     | 25                          | 24  | 2                        | 5.5  | 1.32                        |
|               | 1998     | 25                          | 16  | 3                        | 4.0  | 0.64                        |
|               | 1999     | 25                          | 32  | 12                       | 5.3  | 1.68                        |
|               | 2000     | 25                          | 20  | 8                        | 4.1  | 0.83                        |
|               | 2001     | 25                          | 28  | 8                        | 3.3  | 0.91                        |
|               | Subtotal |                             | 150 | 33                       | 41   | 4.8                         |
| Overall       | 1996     | 38                          | 76  | 17                       | 5.8  | 4.44                        |
|               | 1997     | 38                          | 32  | 4                        | 4.5  | 1.42                        |
|               | 1998     | 38                          | 34  | 8                        | 3.4  | 1.15                        |
|               | 1999     | 38                          | 37  | 16                       | 4.9  | 1.82                        |
|               | 2000     | 38                          | 26  | 10                       | 4.1  | 1.08                        |
|               | 2001     | 38                          | 34  | 13                       | 3.1  | 1.05                        |
|               | Total    |                             | 228 | 40                       | 68   | 4.5                         |

<sup>a</sup> Based on 38 dens observed every year, 1996–2001; occupied dens included natal, secondary, and active sites.

<sup>b</sup> Based on all dens with complete litter counts.

<sup>c</sup> Proportion active multiplied by mean litter size.

$P = 0.95$ ). Therefore, there was no evidence of a construction effect in the annual trend of den occupancy, because den occupancy did not increase during construction years.

The proportion of active dens within 10 km of CD-1 (including most of the dens on the Colville Delta) was significantly higher than >10 km away, both before and during construction ( $\chi^2 = 9.52$ ,  $df = 1$ ,  $P < 0.01$ ). This difference did not change significantly during construction of the Alpine

project whether 1996 was included ( $\chi^2 = 0.24$ ,  $df = 1$ ,  $P = 0.62$ ) or not included ( $\chi^2 = 2.25$ ,  $df = 1$ ,  $P = 0.32$ ).

Within 10 km of Alpine, significantly more dens were active in the 5–10-km zone than within 5 km both before and during construction ( $\chi^2 = 4.21$ ,  $df = 1$ ,  $P = 0.04$ ). Again, the difference between the two zones did not change during construction whether 1996 was included ( $\chi^2 = 0.15$ ,  $df = 1$ ,  $P = 0.70$ ) or not ( $\chi^2 = 0.19$ ,

$df = 1$ ,  $P = 0.66$ ). Therefore, no evidence was found of a development effect in the distribution of active dens, because the distribution of dens (at 2 different scales) did not change with the construction of Alpine.

#### Litter Size

To evaluate how litter size might be affected by the Alpine development, we compared 68 litters from the index group of 38 dens in all 3 distance zones (<5 km, 5–10 km, and >10 km) before and during construction, eliminating incomplete counts and possible duplication of pups seen at both natal and secondary dens (Table 65). No significant differences were found among distance zones ( $F = 2.21$ ;  $df = 2$ , 58;  $P = 0.12$ ), construction phase ( $F = 0.51$ ;  $df = 1$ , 58;  $P = 0.48$ ), or the interaction of the two ( $F = 1.09$ ;  $df = 2$ , 58;  $P = 0.34$ ). Litter size did differ significantly among years ( $F = 3.91$ ;  $df = 4$ , 58;  $P = 0.01$ ), but the only significant difference was that litter size was greater in 1996 than 2001 (Bonferroni multiple comparisons,  $P = 0.02$ ). The largest litters observed during the study period occurred in 1996 (Appendices I1 and I2), with the maximum being 15 pups at Den 64 in the Alpine Transportation Corridor; large litters were found throughout the area monitored that year (Johnson et al. 1997).

Similar results were obtained for the 27 litters at dens within 10 km of CD-1. There were no significant differences between the 2 distance zones ( $F = 0.26$ ;  $df = 1$ , 19;  $P = 0.62$ ), construction phase ( $F < 0.01$ ;  $df = 1$ , 19;  $P = 0.98$ ), or the interaction of the two ( $F = 1.92$ ;  $df = 1$ , 19;  $P = 0.18$ ). Litter size did not differ significantly among years ( $F = 0.14$ ;  $df = 4$ , 19;  $P = 0.14$ ) within these zones.

Fox populations produce more pups in years when prey (primarily small mammals) are abundant than in years when they are not. Den occupancy rates and litter sizes both increase in years when rodents are abundant (Macpherson 1969, Chesemore 1975, Eberhardt et al. 1983, Johnson et al. 1997, Tannerfeldt and Angerbjörn 1998, Strand et al. 1999). Food supplementation in late winter has been shown to increase den occupancy rates and the number of pups at weaning (Angerbjörn et al. 1991) and food supplementation in summer decreases pup mortality (Tannerfeldt et al. 1994).

Evidence from the Prudhoe Bay Oilfield, strongly suggests that arctic foxes using that area have been more productive than outside the oilfield. The density of fox dens was 2–3 times higher in the oilfield than in undeveloped areas nearby (Garrott 1980, Eberhardt et al. 1983, Burgess et al. 1993, Ballard et al. 2000), and litters were significantly larger in the oilfield (Eberhardt et al. 1983, Burgess et al. 1993). In addition, biologists trapping and marking arctic fox pups in summer 1992 (Burgess et al. 1993) noted that pups at dens in the Prudhoe Bay Oilfield tended to be larger and heavier than those in undeveloped areas outside the field (B. Lawhead and J. Rose, ABR, Inc., personal observations).

In contrast, this investigation found no evidence indicating that the local fox population increased during Alpine project construction. The density of dens did not increase during construction, the den occupancy rate did not differ significantly (when the effect of the high lemming year of 1996 was removed), and litter size did not differ significantly. Furthermore, the number of occupied dens and sizes of fox litters did not increase in areas near the Alpine development during construction. Thus, construction of the Alpine project did not attract more breeding foxes or increase their productivity in the project area.

If any development effects occurred in the Alpine project area during construction, they were too small to be detected against the background of natural variation, which is dictated primarily by population fluctuations of small mammals. Abundant rodent prey in the pre-construction year of 1996 produced the highest den occupancy rates and litter sizes observed during the study period. These results suggest that control of food wastes and related mitigation measures of the predator management plan for the Alpine development have been effective at preventing increases in the breeding population of foxes in the project area during the study period.

## SUMMARY AND CONCLUSIONS

After collecting 4–6 years of data on birds and nest predators in the Alpine project area, we can conclude that the construction of the oilfield and operation of the airstrip affected some aspects of the local bird community, but population-level

effects were limited. We monitored abundance, distribution, habitat use, productivity, incubation behavior, and predator numbers and investigated 2 lines of evidence that could indicate a response to project-related disturbance: 1) annual changes or trends that coincided with changing levels of human activity, and 2) differences among locations that coincided with disturbance intensity along distance gradients. When contradictory evidence of disturbance effects was evaluated from annual trends and distributional trends, we favored the evidence from distributional data (i.e., gradient analyses; Ellis and Schneider 1997), because we could not factor out the inherent annual variability of weather and other factors that confound interpretations (Wiens and Parker 1995). Below we summarize the findings for each aspect of the investigation.

### NEST ABUNDANCE

The abundance of nests of all species studied in the Alpine project area varied among the years, but other than White-fronted Geese and all ducks as a group, no taxa exhibited trends clearly suggesting a decline from the pre-construction to construction periods. The numbers of White-fronted Goose and duck nests declined from a peak in 1997 to a low in 2001 and were correlated with both weather conditions and levels of disturbance. Because the heavy-construction years coincided with cool temperatures and late spring phenologies, which could have affected nest abundance, we were unable to directly link declines in numbers of nests with levels of disturbance. Annual fluctuations in abundance of ducks (and presumably duck nests) are typical on the Arctic Coastal Plain (Derksen and Eldridge 1980, Malleck 2001). Nesting by arctic breeding geese is affected by cold, late springs (Barry 1962, de Boer and Drent 1989) and may fail totally in extreme years (McLaren and Alliston 1985). White-fronted Goose nest abundance can decline during late springs (Mickelson 1975) and flood events (Ely and Raveling 1984). Murphy and Anderson (1993) also found high annual variability in the abundance of goose and swan nests in an arctic oilfield under construction and concluded that few changes in abundance could be attributed solely to construction-related effects.

### NEST DISTRIBUTION

Most species of nesting birds did not have detectable differences in distribution relative to the airstrip during years of varying levels of human activity. Nest densities of shorebirds and passerines were higher close to the airstrip than farther away, a trend contrary to what would be expected under a disturbance hypothesis. The distribution of all waterbird nests in the study area did not differ during 1996–2001 with respect to the airstrip or flight path, but did differ with respect to the gravel footprint. As might be expected, some nest sites in 1997 that occurred in the future gravel footprint were eliminated after deposition of gravel pads. The distribution of Tundra Swan nests also did not change among years. White-fronted Geese, however, did shift nests from areas close to the airstrip to areas farther away during the heavy-construction years; that is, nesting was reduced within 1,000 m of the airstrip and increased 1,000–1,500 m from the airstrip relative to nest distributions in pre- and light-construction years. Specifically, we estimated that the zone within ~700 m of the airstrip was where nest densities were most reduced. Similar changes in nest distribution around gravel roads have been documented for shorebirds (Troy 1988). Some species displaced by gravel-pad construction nested the following year in new locations away from the pad with a net increase in densities >100 m from the pad (Troy and Carpenter 1990). Although we did not mark nesting geese to investigate nest relocation, the increases in nest densities in the 1,000–1,500-m zone around the airstrip during heavy-construction activity appeared to be the result of redistribution of nesting pairs.

Although White-fronted Geese modified their nest distribution relative to the Alpine airstrip, their selection and use of habitats did not vary. Consistent habitat use despite the redistribution of nests during heavy-construction years implies preferred nesting habitats are not saturated with nests in the Alpine project area. The capacity of these habitats to absorb more nests may be even greater, because the density of White-fronted Geese in similar habitats on the outer Colville Delta was approximately 3× higher (Johnson et al. 2002). Geese in other areas may behave differently

to changing habitat availability, however. For example, White-fronted Geese on the Yukon-Kuskokwim Delta varied their use of nesting habitat to take advantage of snow-free areas during late springs, but did not avoid areas when they were flooded infrequently; the difference in these 2 responses might reflect the frequency that geese were exposed to these events (Ely and Raveling 1984). White-fronted Geese in the Alpine area experienced frequent human disturbance in the heavy-construction years, and apparently were able to choose nest locations that reduced their exposure without having to choose different nesting habitat.

#### **INCUBATION ACTIVITY AND BEHAVIORAL RESPONSES TO DISTURBANCE**

The proximate causes for the changing distribution of White-fronted Goose nests may have been incubating birds experiencing increased levels of stress from multiple sources of disturbance in the areas of the airstrip and gravel pads. Although this study did not evaluate stress or the energetic consequences of disturbance directly, incubating White-fronted Geese and Tundra Swans were monitored during each heavy-construction year in locations near the Alpine facilities, where disturbance effects were expected to be most pronounced. Behaviorally, incubating geese and swans reacted to sources of disturbance with concealment and alert postures, which demonstrated variation in sensitivity to different types of human disturbance, but did not indicate negative impacts to nest attendance. Murphy and Anderson (1993) found no effects on incubation behavior of geese, other than an increase in concealments, from construction activity in the Lisburne Oilfield. In the Alpine project area, airplanes, helicopters, vehicular traffic, and proximity to the airstrip were implicated in longer or more frequent incubation recesses, but nest site (or individual geese), the proximity to hatch date, and nest fate accounted for more variation than did any other explanatory variables. Concealment and alert postures are considered normal incubation activity because the incubating bird does not leave the nest during these responses, so the impacts of increased concealment and alert frequencies to nest

incubation probably are minimal. Increases in recess length and recess frequency may be more important to the eventual outcome of the nest, not because of effects on egg viability, but because of the indirect effects that increased time off the nest may have on the risk of egg predation. However, evidence linking increased recess length and frequency with reduced nest success was weak. Longer and more frequent recesses distinguished failed from successful White-fronted Goose nests, but the differences were not significant when the last 5 days of incubation before failure were removed, because on those days incubation was erratic and uncharacteristic of the prior incubation period. This increased recess activity could be symptomatic or a cause of nest failure. Nonetheless, our observations of nest predation during this study lead us to suspect that any increase in the time spent off nests by incubating geese increases the risk of predation.

#### **PREDATION**

We have no evidence to indicate whether predation rates changed during our study. Predator numbers, however, appeared to be stable from pre-construction to construction periods. The number of occupied fox dens and overall pup production did not increase during construction of the Alpine project, nor did the density of occupied dens or pup production in the zone nearest the development increase during the construction period. Similarly, nests of avian predators (Glaucous Gull and Parasitic and Long-tailed jaegers) did not increase during construction of Alpine. The exception was that Common Ravens were first attracted to the Alpine project area in 1998. Ravens were seen daily in 1999, and nesting at Alpine was confirmed in 2000 and 2001. Although ravens were observed at video-monitored nests, they were not observed preying on nests in the study area, so the impact of ravens on nesting birds in the Alpine area was unclear. The primary avian predator observed preying on nests in the Alpine project area was the Parasitic Jaeger, which is unlikely to increase in developed areas because it generally does not feed on human foods nor is it attracted to artificial nesting structures.



## PRODUCTIVITY

Little evidence was found indicating that productivity of nesting birds was negatively affected by the Alpine project. Clutch sizes were relatively consistent among years for all waterbirds and for White-fronted Geese and did not differ with proximity to the airstrip. The daily survival rate of White-fronted Goose nests in 1999 (but not other heavy-construction years) was significantly lower than in 1998, but failed nests of White-fronted Geese were farther from the airstrip than were successful nests in all heavy-construction years; therefore, we interpreted the reduced survival rate to be unrelated to disturbance from the airstrip. Although trends in the location of successful and failed waterbird nests (primarily ducks) suggested possible effects of disturbance on waterbird productivity, those relationships were not significant, and therefore, were interpreted as weak evidence of a disturbance effect. The productivity of geese and swans nesting in a new oilfield in Prudhoe Bay also was unaffected by construction activity, but production in that study area was limited by predation and weather conditions (Murphy and Anderson 1993).

## DISTRIBUTION OF NON-NESTING BIRDS

The effects of the Alpine project on non-nesting birds using lakes appeared to be minor and less obvious than the annual variation in the abundance of birds in the project area. The abundance of waterbirds using lakes in the project area declined from 1998 to 2001, and the decline was primarily among ducks, with other birds remaining at relatively stable numbers during the 4 years of surveys. Generally, numbers and densities of all waterbirds differed significantly among months and between tapped lakes and non-tapped lakes. Densities of waterbirds did not decline in the distance zones nearest the airstrip with increased human activity in 1999–2001 and generally were highest in the closest zone. Therefore, the distribution of birds provided evidence that was contradictory for a disturbance effect. High annual variation in waterfowl abundance in Arctic breeding areas is typical, however. The estimated number of Northern Pintails on the Arctic Coastal Plain during 1998–2001 varied by more than a factor of 2

(Malleck 2002). We concluded that the annual trend in waterfowl use of lakes was not evidence of a decline related to construction activity, because the distribution of birds did not fit the declining trend expected along the disturbance gradient.

## RELATIVE EFFECTS OF TYPES OF DISTURBANCE

We were unable to directly compare the relative effects of the different sources of disturbance on nesting geese or swans. Our data clearly show individual variation in the responses of geese and swans to potential disturbance, and a reduction in response with increasing distance to the source, consistent with a gradient of exposure. The potential disturbance sources we evaluated were mobile, were sometimes concurrent, and were not equidistant from all the response locations (nest sites), the latter of which is required to make direct comparisons among the impacts of different disturbance types. Therefore, results of comparisons among disturbance types should not be generalized to nests in other locations. Of all the human-caused disturbance types, helicopters were the least predictable because they were not restricted to any flight pattern. Neither incubating White-fronted Geese nor Tundra Swans reacted to helicopters more often than airplanes. However, monitored nests were closer to the airstrip than they were to the helipad. The helicopters used at Alpine (Bell 206 Long Ranger and Jet Ranger) were second only to the DC-6 in maximal noise levels produced during landings and takeoffs, so helicopters conceivably could have more of a disturbance effect than twin- or single-engine planes. Brant were more reactive (alert and flight responses) to helicopters than airplanes during fall and winter (Owens 1977, Ward et al. 1994). Helicopter disturbance caused alert and locomotion reactions in molting Brant (Derksen et al. 1992), but similar reactions by other waterfowl have been recorded in response to airplanes (Mosbech and Boertmann 1999). For the sample of nesting geese at Alpine, airplanes and pedestrians elicited the highest, and vehicles the lowest, rates of response. The highest rate of response by swans also was to pedestrians. We were unable to include predators and other birds in these comparisons. Murphy and Anderson (1993) concluded that predators and

pedestrians disturbed geese and swans more than vehicle traffic in an oilfield that did not contain an airstrip. Vehicular traffic had no detectable effect on the distribution of geese during nesting, but did lead to avoidance of areas within 200 m of roads during the brood-rearing season (Murphy and Anderson 1993). Observations from Alpine are in general agreement with these findings, although we did not evaluate distribution and habitat use of terrestrial areas during the brood-rearing period. We observed the most severe responses to disturbance—incubating geese flushing from nests—in response to pedestrians, and less often to airplanes, helicopters, and foxes, but these responses were not frequent and occurred only at nests that were near the source of disturbance.

### **EFFECTS OF AIRCRAFT NOISE**

The effect of noise on birds was raised as an important issue when this monitoring study was first proposed. We did not evaluate noise independently from visual stimuli of the sources of noise (e.g., airplanes, helicopters, vehicles, and pad activities), nor were we able to monitor noise levels continuously at nests to determine responses to individual noise events. Using models to predict noise levels allowed us to estimate noise levels throughout the study area at all nest sites each year, and thus to evaluate changes in behavior and distribution with varying noise levels. Neither evaluation found aircraft noise to be a significant explanatory variable. The estimated noise exposure at nests increased with aircraft traffic levels, but did not have a significant effect on changes in waterbird nest distribution among years. The results were similar for evaluations of noise levels at White-fronted Goose nests, suggesting that geese and other waterbirds did not move nests between years to reduce noise exposure. Although a trend of declining average noise levels suggested that geese nested in areas of reduced noise exposure in successive years, the differences were small and non-significant.

Noise (as perceived from the tundra) in the Alpine project area was assumed to vary primarily with aircraft traffic, so noise levels and the numbers of aircraft and their visual stimuli were not independent of each other in our analyses, nor could they be. Waterfowl can respond to noise

alone (i.e., no visual stimulus); Black Ducks and Wood Ducks both responded to simulated aircraft noise with alert and locomotion behaviors and Black Ducks showed signs of habituation (a decline in response to a repeated stimulus) (Conomy et al. 1998). Although we suspect that some of the nesting birds (certain geese and swans) in the Alpine project area habituated to aircraft during a nesting period, we do not have enough quantitative data to evaluate that hypothesis.

### **OVERALL CONCLUSIONS**

From numerous analyses and evaluations of various aspects of breeding and non-breeding bird use of the Alpine project area, we conclude that the greatest observable impact to birds from the construction of the Alpine project was the change in nest distribution for a few species, primarily White-fronted Geese, around the gravel pads and airstrip. As expected, some nest sites were lost to gravel placement for the airstrip, pads, and road. Beyond that, White-fronted Goose nests declined within 1,000 m of the airstrip and increased outside that area, suggesting that the area near the airstrip was less attractive for nesting during construction. The redistribution of White-fronted Goose nests was more pronounced in the heavy-construction years (1999–2001) than in 1998, when the airstrip was present but not used by airplanes, indicating that disturbance and not some change in habitat suitability (e.g., dust-shadow effects or impoundments, which likely existed in 1998) was the cause. That conclusion is supported by behavioral data that showed nesting geese exhibited disturbance-related activities and that those activities diminished as the distance between the disturbance source and nests increased. The change in nest distribution apparently did not have a population-level effect because nest densities increased away from the airstrip, suggesting that nesting habitat was not limiting in the Alpine project area (at least for the nest densities observed). These conclusions may not apply to species that have more specific habitat requirements, reuse the same nest sites annually, or have some sort of density limitation, such as nesting territories. The Alpine project also did not affect the productivity of nesting birds (clutch sizes or nesting success), at least at the scale of the study

area (11 km<sup>2</sup>). We cannot rule out that nest success was reduced at some finer scale of disturbance zones near the airstrip (for example, ≤100 m of the airstrip), but fewer nests occurred in narrower zones (because less nesting habitat is available), so the effect size would be reduced proportionately. We observed cases of birds flushing from nests in response to airplanes, helicopters, people, and predators, and we related partial and total predation of nests to the increased recess frequency and length that was associated with disturbance of incubating birds. However, the frequency of flushes caused by disturbance was low and probably would not be a significant factor except in cases of a rare species.

Based on these conclusions and our observations during the Alpine monitoring program, we recommend that oilfield developments, particularly airstrips, be located in areas with low densities of nesting birds, avoid areas containing species that are vulnerable to small losses of nests, and avoid areas that provide habitats that may be limiting for a particular species (e.g., Brant brood-rearing and molting habitat). We also recommend that off-pad pedestrian activity and predator access to food and artificial nesting structures be limited. The small numbers of significant negative effects that we have found for the Alpine development project may be credited, in part, to locating the gravel footprint in an area with low nest densities, but they are also a testament to the resilience of tundra nesting birds that often face a harsh and unpredictable environment.

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## Appendix A. Common and scientific names of birds and mammals observed on the Colville River Delta, Alaska, 1992–2001.

| COMMON NAME                 | SCIENTIFIC NAME                 | COMMON NAME             | SCIENTIFIC NAME                  |
|-----------------------------|---------------------------------|-------------------------|----------------------------------|
| <b>BIRDS</b>                |                                 |                         |                                  |
| Red-throated Loon           | <i>Gavia stellata</i>           | Upland Sandpiper        | <i>Bartramia longicauda</i>      |
| Pacific Loon                | <i>Gavia pacifica</i>           | Whimbrel                | <i>Numenius phaeopus</i>         |
| Yellow-billed Loon          | <i>Gavia adamsii</i>            | Bar-tailed Godwit       | <i>Limosa lapponica</i>          |
| Red-necked Grebe            | <i>Podiceps grisegena</i>       | Ruddy Turnstone         | <i>Arenaria interpres</i>        |
| Greater White-fronted Goose | <i>Anser albifrons</i>          | Semipalmated Sandpiper  | <i>Calidris pusilla</i>          |
| Snow Goose                  | <i>Chen caerulescens</i>        | Western Sandpiper       | <i>Calidris mauri</i>            |
| Canada Goose                | <i>Branta canadensis</i>        | Least Sandpiper         | <i>Calidris minutilla</i>        |
| Brant                       | <i>Branta bernicla</i>          | White-rumped Sandpiper  | <i>Calidris fuscicollis</i>      |
| Tundra Swan                 | <i>Cygnus columbianus</i>       | Baird's Sandpiper       | <i>Calidris bairdii</i>          |
| American Wigeon             | <i>Anas americana</i>           | Pectoral Sandpiper      | <i>Calidris melanotos</i>        |
| Mallard                     | <i>Anas platyrhynchos</i>       | Dunlin                  | <i>Calidris alpina</i>           |
| Northern Shoveler           | <i>Anas clypeata</i>            | Stilt Sandpiper         | <i>Calidris himantopus</i>       |
| Northern Pintail            | <i>Anas acuta</i>               | Buff-breasted Sandpiper | <i>Trygites subfricollis</i>     |
| Green-winged Teal           | <i>Anas crecca</i>              | Ruff                    | <i>Philomachus pugnax</i>        |
| Greater Scaup               | <i>Aythya marila</i>            | Long-billed Dowitcher   | <i>Limnodromus scolopaceus</i>   |
| Lesser Scaup                | <i>Aythya affinis</i>           | Common Snipe            | <i>Gallinago gallinago</i>       |
| Steller's Eider             | <i>Polysticta stelleri</i>      | Red-necked Phalarope    | <i>Phalaropus lobatus</i>        |
| Spectacled Eider            | <i>Somateria fischeri</i>       | Red Phalarope           | <i>Phalaropus fulicarius</i>     |
| King Eider                  | <i>Somateria spectabilis</i>    | Pomarine Jaeger         | <i>Stercorarius pomarinus</i>    |
| Common Eider                | <i>Somateria mollissima</i>     | Parasitic Jaeger        | <i>Stercorarius parasiticus</i>  |
| Surf Scoter                 | <i>Melanitta perspicillata</i>  | Long-tailed Jaeger      | <i>Stercorarius longicaudus</i>  |
| White-winged Scoter         | <i>Melanitta fusca</i>          | Ring-billed Gull        | <i>Larus delawarensis</i>        |
| Black Scoter                | <i>Melanitta nigra</i>          | Glaucous Gull           | <i>Larus hyperboreus</i>         |
| Long-tailed Duck            | <i>Clangula hyemalis</i>        | Sabine's Gull           | <i>Xema sabini</i>               |
| Red-breasted Merganser      | <i>Mergus serrator</i>          | Arctic Tern             | <i>Sterna paradisaea</i>         |
| Bald Eagle                  | <i>Haliaeetus leucocephalus</i> | Snowy Owl               | <i>Nyctea scandiaca</i>          |
| Northern Harrier            | <i>Circus cyaneus</i>           | Short-eared Owl         | <i>Asio flammeus</i>             |
| Rough-legged Hawk           | <i>Buteo lagopus</i>            | Common Raven            | <i>Corvus corax</i>              |
| Golden Eagle                | <i>Aquila chrysaetos</i>        | Horned Lark             | <i>Eremophila alpestris</i>      |
| Merlin                      | <i>Falco columbarius</i>        | Violet-green Swallow    | <i>Tachycineta bicolor</i>       |
| Gyr Falcon                  | <i>Falco rusticolus</i>         | American Robin          | <i>Turdus migratorius</i>        |
| Peregrine Falcon            | <i>Falco peregrinus</i>         | Bluethroat              | <i>Luscinia svecica</i>          |
| Willow Ptarmigan            | <i>Lagopus lagopus</i>          | Yellow Wagtail          | <i>Motacilla flava</i>           |
| Rock Ptarmigan              | <i>Lagopus mutus</i>            | Wilson's Warbler        | <i>Wilsonia pusilla</i>          |
| Sandhill Crane              | <i>Grus canadensis</i>          | American Tree Sparrow   | <i>Spizella arborea</i>          |
| Black-bellied Plover        | <i>Pluvialis squatarola</i>     | Savannah Sparrow        | <i>Passerculus sandwichensis</i> |
| American Golden-Plover      | <i>Pluvialis dominica</i>       | Lapland Longspur        | <i>Calcarius lapponicus</i>      |
| Semipalmated Plover         | <i>Charadrius semipalmatus</i>  | Snow Bunting            | <i>Plectrophenax nivalis</i>     |
| Lesser Yellowlegs           | <i>Tringa flavipes</i>          | Common Redpoll          | <i>Carduelis flammea</i>         |
| <b>MAMMALS</b>              |                                 |                         |                                  |
| Snowshoe Hare               | <i>Lepus americanus</i>         | Polar Bear              | <i>Ursus maritimus</i>           |
| Arctic Ground Squirrel      | <i>Spermophilus parryii</i>     | Ermine                  | <i>Mustela erminea</i>           |
| Brown Lemming               | <i>Lemmus sibiricus</i>         | Wolverine               | <i>Gulo gulo</i>                 |
| Collared Lemming            | <i>Dicrostonyx rubricatus</i>   | Spotted Seal            | <i>Phoca largha</i>              |
| Gray Wolf                   | <i>Canis lupus</i>              | Moose                   | <i>Alces alces</i>               |
| Arctic Fox                  | <i>Alopex lagopus</i>           | Caribou                 | <i>Rangifer tarandus</i>         |
| Red Fox                     | <i>Vulpes vulpes</i>            | Muskox                  | <i>Ovibus moschatus</i>          |
| Grizzly Bear                | <i>Ursus arctos</i>             |                         |                                  |

Appendix B. Alpine noise level measurement and analysis. Final technical report prepared for ABR, Inc., Fairbanks, AK and ConocoPhillips Alaska, Inc., Anchorage, by Michael Minor and Associates, Portland, OR.

Appendix C. Classification of incubation behavior of Greater White-fronted Geese monitored with time-lapse cameras and egg thermistors in the Alpine project area, Colville River Delta, Alaska, 1998–2001.

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In 2001, the same decision rules were used that were developed in 1998 for interpretation of the egg thermistor data. In 1998, two White-fronted Goose nests were simultaneously monitored with both an egg thermistor and a time-lapse camera. In that year, 867 temperature records (recorded at 5-min intervals) and 4,335 video pictures (1-sec recordings at 1-min intervals) were collected from the two nests combined. (Camera malfunctions interrupted video recording while nests were monitored with the egg thermistors, so that video coverage was incomplete.) The occurrence of incubation, breaks, and recesses were identified on the video recordings and those behaviors compared 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  $\leq 3$  consecutive recordings (hereafter, 1 video recording is represented 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  $\geq 4$  consecutive recordings (4 min). The female, at times, was observed 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, 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  $+0.3^\circ\text{C}$  for incubation [ $n = 804$ ],  $-1.9^\circ\text{C}$  for breaks [ $n = 65$ ], and  $-4.4^\circ\text{C}$  for recesses [ $n = 13$ ].) Because the temperatures of nests were lower during recesses (mean =  $24.3^\circ\text{C}$ ,  $n = 13$ ) than during breaks (mean =  $32.2^\circ\text{C}$ ,  $n = 13$ ), nest temperature was used to distinguish a break from a recess. To establish numeric cutpoints for classifying each behavior type, the 5<sup>th</sup> and 95<sup>th</sup> percentiles were calculated for the observed frequency distribution of temperature difference and nest temperature. The 5<sup>th</sup> and 95<sup>th</sup> percentiles for temperature difference were  $-0.4^\circ$  and  $+1.6^\circ\text{C}$  for incubation ( $n = 804$ ),  $-5.08^\circ$  and  $+0.4^\circ\text{C}$  for breaks ( $n = 65$ ), and  $-7.4^\circ$  and  $-1.1^\circ\text{C}$  for recesses ( $n = 13$ ). The 5<sup>th</sup> and 95<sup>th</sup> percentiles for nest temperature were  $30.3^\circ$  and  $37^\circ\text{C}$  for incubation,  $28.3^\circ$  and  $35.7^\circ\text{C}$  for breaks, and  $18.9^\circ$  and  $30.3^\circ\text{C}$  for recesses.

In the thermistor data, the occurrence of a break or recess was distinguished from incubation by a temperature difference of  $\geq 1^\circ\text{C}$  during a 5-min recording interval. A record was classified as a break if the temperature decreased by  $\geq 1^\circ\text{C}$  and the nest temperature of that record was  $\geq 28.3^\circ\text{C}$ , the 5<sup>th</sup> percentile value of breaks. Breaks occurred in consecutive temperature records, but we considered them separate discontinuous events, because video records of breaks were  $\leq 3$  min. Each break was counted as lasting 5 min (hereafter, each temperature record is represented as 5 min). A record was classified as a recess if the temperature decreased by  $\geq 1^\circ\text{C}$  and the nest temperature of that record was  $< 28.3^\circ\text{C}$ . A recess was considered to continue into succeeding intervals, regardless of the temperature difference, as long as the nest temperature remained  $< 28.3^\circ\text{C}$ . 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  $\geq 1^\circ\text{C}$  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.

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Appendix D1. The number of vehicles passing between CD-1 and CD-2 as recorded by the Alpine security CD-2 checkpoint between 6:00–18:00, June 18–30 in the Alpine project area, Colville River Delta, Alaska, 2001.

| Hour (ADT) | Number of Vehicles Passes |         |         |
|------------|---------------------------|---------|---------|
|            | $\bar{x}$                 | Minimum | Maximum |
| 6:00       | 16.8                      | 8       | 32      |
| 7:00       | 13.7                      | 4       | 31      |
| 8:00       | 14.9                      | 8       | 24      |
| 9:00       | 11.3                      | 8       | 16      |
| 10:00      | 12.1                      | 4       | 20      |
| 11:00      | 11.5                      | 2       | 26      |
| 12:00      | 12.8                      | 8       | 21      |
| 13:00      | 13.3                      | 6       | 21      |
| 14:00      | 12.6                      | 7       | 22      |
| 15:00      | 12.8                      | 7       | 24      |
| 16:00      | 11.6                      | 5       | 19      |
| 17:00      | 13.0                      | 3       | 27      |

Appendix D2. The number, duration, and type of vehicles observed on the infield road during the nesting period in the Alpine project area, Colville River Delta, Alaska, 2001. Data were recorded by a video camera at Greater White-fronted Goose nest 1106.

| Date                 | Small Truck |                             |                       | Large Truck |                             |                       | Machinery |                             |                       | Unknown Vehicle Type |                             |                       | All Vehicles |                             |                       | Total Min Monitored |
|----------------------|-------------|-----------------------------|-----------------------|-------------|-----------------------------|-----------------------|-----------|-----------------------------|-----------------------|----------------------|-----------------------------|-----------------------|--------------|-----------------------------|-----------------------|---------------------|
|                      | No.         | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.         | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.       | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.                  | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.          | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> |                     |
| 18 June              | 20          | 34                          | 57                    | 9           | 25                          | 26                    | 2         | 2                           | 2                     | 0                    | 0                           | 0                     | 31           | 25                          | 85                    | 407                 |
| 19 June              | 92          | 120                         | 132                   | 71          | 158                         | 192                   | 6         | 8                           | 8                     | 1                    | 1                           | 1                     | 170          | 140                         | 333                   | 1,420               |
| 20 June              | 123         | 242                         | 371                   | 67          | 148                         | 154                   | 14        | 94                          | 94                    | 0                    | 0                           | 0                     | 204          | 151                         | 619                   | 1,440               |
| 21 June              | 112         | 149                         | 172                   | 82          | 190                         | 216                   | 17        | 38                          | 38                    | 0                    | 0                           | 0                     | 211          | 167                         | 426                   | 1,408               |
| 22 June              | 144         | 217                         | 255                   | 80          | 147                         | 169                   | 19        | 148                         | 149                   | 2                    | 2                           | 2                     | 245          | 175                         | 575                   | 1,440               |
| 23 June              | 124         | 161                         | 255                   | 90          | 176                         | 183                   | 16        | 80                          | 81                    | 0                    | 0                           | 0                     | 230          | 181                         | 519                   | 1,437               |
| 24 June              | 120         | 132                         | 156                   | 107         | 209                         | 224                   | 9         | 27                          | 27                    | 0                    | 0                           | 0                     | 236          | 202                         | 407                   | 1,440               |
| 25 June              | 135         | 222                         | 474                   | 55          | 148                         | 164                   | 7         | 36                          | 36                    | 0                    | 0                           | 0                     | 197          | 154                         | 674                   | 1,440               |
| 26 June              | 94          | 149                         | 181                   | 57          | 145                         | 163                   | 8         | 37                          | 38                    | 3                    | 7                           | 7                     | 162          | 130                         | 389                   | 1,440               |
| 27 June              | 106         | 135                         | 159                   | 79          | 227                         | 264                   | 3         | 8                           | 8                     | 4                    | 10                          | 10                    | 192          | 147                         | 441                   | 1,408               |
| 28 June              | 102         | 145                         | 204                   | 72          | 152                         | 176                   | 10        | 165                         | 169                   | 0                    | 0                           | 0                     | 184          | 143                         | 549                   | 1,433               |
| 29 June              | 82          | 155                         | 230                   | 58          | 190                         | 278                   | 6         | 27                          | 27                    | 1                    | 1                           | 1                     | 147          | 105                         | 536                   | 963                 |
| 30 June              | 71          | 145                         | 156                   | 26          | 43                          | 44                    | 10        | 14                          | 14                    | 0                    | 0                           | 0                     | 107          | 88                          | 214                   | 1,440               |
| 01 July              | 114         | 120                         | 133                   | 51          | 82                          | 83                    | 10        | 24                          | 26                    | 0                    | 0                           | 0                     | 175          | 149                         | 242                   | 1,325               |
| 02 July              | 109         | 137                         | 202                   | 75          | 185                         | 214                   | 4         | 50                          | 50                    | 0                    | 0                           | 0                     | 188          | 140                         | 466                   | 1,440               |
| 03 July              | 109         | 228                         | 251                   | 67          | 171                         | 182                   | 7         | 14                          | 14                    | 1                    | 1                           | 1                     | 184          | 133                         | 448                   | 1,434               |
| 04 July              | 115         | 547                         | 615                   | 44          | 127                         | 169                   | 5         | 12                          | 12                    | 2                    | 4                           | 4                     | 166          | 75                          | 800                   | 1,440               |
| 05 July              | 116         | 305                         | 325                   | 66          | 172                         | 179                   | 6         | 252                         | 257                   | 1                    | 1                           | 1                     | 189          | 107                         | 762                   | 1,440               |
| 06 July              | 107         | 195                         | 239                   | 62          | 167                         | 208                   | 9         | 20                          | 20                    | 1                    | 1                           | 1                     | 179          | 138                         | 468                   | 1,440               |
| 07 July              | 106         | 233                         | 293                   | 63          | 239                         | 267                   | 5         | 60                          | 60                    | 0                    | 0                           | 0                     | 174          | 108                         | 620                   | 1,440               |
| 08 July              | 40          | 31                          | 131                   | 21          | 94                          | 102                   | 3         | 7                           | 7                     | 0                    | 0                           | 0                     | 64           | 47                          | 245                   | 619                 |
| Total                | 2,141       | 3,802                       | 4,991                 | 1,302       | 3,195                       | 3,657                 | 176       | 1,123                       | 1,142                 | 16                   | 28                          | 28                    | 3,635        | 2,705                       | 9,818                 | 27,694              |
| Average <sup>c</sup> | 111.3       | 197.7                       | 259.5                 | 67.7        | 166.1                       | 190.2                 | 9.2       | 58.4                        | 59.4                  | 0.8                  | 1.5                         | 1.5                   | 189.0        | 140.7                       | 511.4                 | 1,319               |

<sup>a</sup> Duration = number of min  $\geq$  1 vehicle was on airstrip.

<sup>b</sup> Veh. Min = sum of min each vehicle was on airstrip.

<sup>c</sup> Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored = sum of total min monitored/no. of days monitored.

Appendix D3. The number, group size, and duration of pedestrians observed on the airstrip, infield road, and on tundra adjacent to the airstrip during the nesting period in the Alpine project area, Colville River Delta, Alaska, 2001. Data were recorded by video cameras at White-fronted Goose nests 007, 1001, and 1106, and Tundra Swan nest 105.

| Date                 | Airstrip      |           |                             |                         | Infield Road        |               |           |                             | Tundra Travel           |                     |               |           |                             |                         |                     |
|----------------------|---------------|-----------|-----------------------------|-------------------------|---------------------|---------------|-----------|-----------------------------|-------------------------|---------------------|---------------|-----------|-----------------------------|-------------------------|---------------------|
|                      | No. of Groups | Max. Size | Duration (Min) <sup>a</sup> | Person Min <sup>b</sup> | Total Min Monitored | No. of Groups | Max. Size | Duration (Min) <sup>a</sup> | Person Min <sup>b</sup> | Total Min Monitored | No. of Groups | Max. Size | Duration (Min) <sup>a</sup> | Person Min <sup>b</sup> | Total Min Monitored |
| 13 June              | 4             | 4         | 21                          | 37                      | 175                 | -             | -         | -                           | -                       | -                   | 1             | 1         | 78                          | 78                      | 175                 |
| 14 June              | 17            | 6         | 165                         | 430                     | 1,350               | -             | -         | -                           | -                       | -                   | 3             | 6         | 175                         | 885                     | 1,440               |
| 15 June              | 8             | 4         | 74                          | 123                     | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 16 June              | 12            | 2         | 119                         | 292                     | 1,440               | -             | -         | -                           | -                       | -                   | 3             | 3         | 588                         | 1,700                   | 1,440               |
| 17 June              | 6             | 3         | 46                          | 52                      | 1,440               | -             | -         | -                           | -                       | -                   | 1             | 3         | 645                         | 1,935                   | 1,440               |
| 18 June              | 16            | 4         | 118                         | 189                     | 1,440               | 0             | 0         | 0                           | 0                       | 407                 | 1             | 1         | 351                         | 351                     | 1,440               |
| 19 June              | 3             | 2         | 42                          | 58                      | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               |
| 20 June              | 13            | 3         | 21                          | 35                      | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 2             | 1         | 30                          | 30                      | 1,440               |
| 21 June              | 26            | 3         | 126                         | 283                     | 1,440               | 1             | 2         | 5                           | 10                      | 1,440               | 2             | 6         | 179                         | 614                     | 1,440               |
| 22 June              | 13            | 4         | 361                         | 543                     | 1,440               | 1             | 1         | 1                           | 1                       | 1,440               | 7             | 2         | 68                          | 75                      | 1,440               |
| 23 June              | 20            | 3         | 357                         | 546                     | 1,440               | 0             | 0         | 0                           | 0                       | 1,434               | 6             | 7         | 271                         | 995                     | 1,440               |
| 24 June              | 7             | 2         | 107                         | 330                     | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 6             | 2         | 138                         | 142                     | 1,440               |
| 25 June              | 15            | 3         | 308                         | 106                     | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 8             | 9         | 151                         | 766                     | 1,440               |
| 26 June              | 11            | 2         | 62                          | 72                      | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 9             | 3         | 101                         | 148                     | 1,440               |
| 27 June              | 7             | 3         | 37                          | 71                      | 1,440               | 1             | 1         | 1                           | 1                       | 1,440               | 2             | 7         | 76                          | 442                     | 1,440               |
| 28 June              | 4             | 2         | 18                          | 29                      | 1,440               | 1             | 2         | 3                           | 6                       | 1,433               | 3             | 5         | 173                         | 297                     | 1,440               |
| 29 June              | 0             | 0         | 0                           | 0                       | 1,118               | 2             | 4         | 14                          | 41                      | 1,440               | 2             | 1         | 46                          | 46                      | 1,440               |
| 30 June              | 4             | 2         | 55                          | 98                      | 957                 | 0             | 0         | 0                           | 0                       | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               |
| 1 July               | 8             | 2         | 12                          | 16                      | 1,418               | 1             | 1         | 2                           | 2                       | 1,440               | 1             | 2         | 11                          | 12                      | 1,440               |
| 2 July               | 6             | 1         | 11                          | 11                      | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               | 4             | 1         | 4                           | 4                       | 1,440               |
| 3 July               | 4             | 3         | 13                          | 29                      | 1,440               | 1             | 1         | 4                           | 4                       | 1,434               | 1             | 1         | 150                         | 150                     | 1,440               |
| 4 July               | 3             | 1         | 45                          | 45                      | 1,377               | 7             | 3         | 126                         | 230                     | 1,440               | 2             | 1         | 2                           | 2                       | 1,440               |
| 5 July               | 4             | 1         | 16                          | 16                      | 1,440               | 11            | 2         | 128                         | 177                     | 1,395               | 1             | 1         | 1                           | 1                       | 1,440               |
| 6 July               | 8             | 2         | 16                          | 19                      | 1,440               | 1             | 1         | 7                           | 7                       | 1,440               | 1             | 3         | 31                          | 35                      | 1,440               |
| 7 July               | 6             | 2         | 91                          | 103                     | 1,440               | 1             | 1         | 1                           | 1                       | 1,440               | 0             | 0         | 0                           | 0                       | 1,440               |
| 8 July               | 3             | 2         | 4                           | 5                       | 1,440               | 0             | 0         | 0                           | 0                       | 864                 | 1             | 3         | 150                         | 450                     | 1,440               |
| 9 July               | 0             | 0         | 0                           | 0                       | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 10 July              | 4             | 1         | 6                           | 6                       | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 11 July              | 4             | 1         | 7                           | 7                       | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 12 July              | 1             | 2         | 4                           | 8                       | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 13 July              | 0             | 0         | 0                           | 0                       | 1,440               | -             | -         | -                           | -                       | -                   | 1             | 2         | 51                          | 102                     | 1,369               |
| 14 July              | 3             | 2         | 4                           | 5                       | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| 15 July              | 4             | 2         | 8                           | 14                      | 1,440               | -             | -         | -                           | -                       | -                   | 0             | 0         | 0                           | 0                       | 1,440               |
| Total                | 244           | 74        | 2,274                       | 3,578                   | 45,275              | 28            | 19        | 292                         | 480                     | 28,567              | 68            | 71        | 3,470                       | 9,260                   | 46,184              |
| Average <sup>c</sup> | 7.8           | 2.4       | 72.3                        | 113.8                   | 1,372               | 1.4           | 1.0       | 14.7                        | 24.2                    | 1,360               | 2.1           | 2.2       | 108.2                       | 288.7                   | 1,400               |

<sup>a</sup> Duration = number of min  $\geq 1$  person was present in camera view.  
<sup>b</sup> Person min = sum of min each person was at location.  
<sup>c</sup> Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored = sum of total min monitored/no. of days monitored.

Appendix D4. The number, duration, and type of vehicles observed on the airstrip during the nesting period in the Alpine project area, Colville River Delta, Alaska, 2001. Data were recorded by video cameras at Tundra Swan nest 105 and at the CD2 checkpoint station.

| Date                 | Small Truck |                             |                       | Large Truck |                             |                       | Machinery |                             |                       | Unknown Vehicle Type |                             |                       | All Vehicles |                             |                       | Total Min Monitored |
|----------------------|-------------|-----------------------------|-----------------------|-------------|-----------------------------|-----------------------|-----------|-----------------------------|-----------------------|----------------------|-----------------------------|-----------------------|--------------|-----------------------------|-----------------------|---------------------|
|                      | No.         | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.         | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.       | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.                  | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> | No.          | Duration (min) <sup>a</sup> | Veh. Min <sup>b</sup> |                     |
| 13 June              | 7           | 10                          | 10                    | 6           | 7                           | 7                     | 4         | 7                           | 7                     | 0                    | 0                           | 0                     | 17           | 14                          | 34                    | 175                 |
| 14 June              | 67          | 88                          | 163                   | 33          | 73                          | 73                    | 10        | 135                         | 135                   | 0                    | 0                           | 0                     | 135          | 110                         | 271                   | 1,440               |
| 15 June              | 84          | 175                         | 109                   | 30          | 86                          | 87                    | 17        | 408                         | 576                   | 0                    | 0                           | 0                     | 166          | 111                         | 331                   | 1,440               |
| 16 June              | 82          | 98                          | 109                   | 42          | 150                         | 171                   | 23        | 524                         | 598                   | 0                    | 0                           | 0                     | 176          | 84                          | 352                   | 1,440               |
| 17 June              | 68          | 81                          | 83                    | 38          | 72                          | 74                    | 14        | 121                         | 217                   | 0                    | 0                           | 0                     | 145          | 124                         | 290                   | 1,440               |
| 18 June              | 103         | 129                         | 139                   | 32          | 49                          | 49                    | 6         | 17                          | 17                    | 0                    | 0                           | 0                     | 174          | 147                         | 348                   | 1,435               |
| 19 June              | 170         | 190                         | 213                   | 71          | 93                          | 103                   | 14        | 18                          | 18                    | 89                   | 97                          | 110                   | 344          | 343                         | 441                   | 1,440               |
| 20 June              | 178         | 205                         | 255                   | 59          | 77                          | 80                    | 4         | 8                           | 8                     | 92                   | 98                          | 111                   | 333          | 358                         | 454                   | 1,440               |
| 21 June              | 161         | 151                         | 180                   | 26          | 27                          | 28                    | 8         | 12                          | 12                    | 95                   | 109                         | 119                   | 290          | 279                         | 339                   | 1,429               |
| 22 June              | 209         | 213                         | 238                   | 39          | 55                          | 57                    | 11        | 30                          | 30                    | 88                   | 97                          | 98                    | 347          | 368                         | 423                   | 1,440               |
| 23 June              | 220         | 214                         | 246                   | 46          | 71                          | 72                    | 8         | 8                           | 9                     | 78                   | 169                         | 181                   | 352          | 413                         | 509                   | 1,433               |
| 24 June              | 222         | 222                         | 249                   | 83          | 136                         | 140                   | 7         | 9                           | 9                     | 54                   | 63                          | 65                    | 366          | 390                         | 463                   | 1,440               |
| 25 June              | 202         | 199                         | 234                   | 60          | 82                          | 87                    | 7         | 20                          | 20                    | 97                   | 91                          | 111                   | 366          | 344                         | 451                   | 1,440               |
| 26 June              | 172         | 182                         | 213                   | 50          | 64                          | 69                    | 6         | 64                          | 64                    | 43                   | 51                          | 53                    | 271          | 331                         | 399                   | 1,440               |
| 27 June              | 205         | 209                         | 253                   | 53          | 61                          | 65                    | 9         | 28                          | 28                    | 73                   | 83                          | 96                    | 340          | 336                         | 442                   | 1,413               |
| 28 June              | 228         | 203                         | 247                   | 75          | 100                         | 102                   | 9         | 21                          | 21                    | 52                   | 58                          | 58                    | 364          | 345                         | 429                   | 1,434               |
| 29 June              | 157         | 128                         | 170                   | 69          | 85                          | 95                    | 8         | 12                          | 12                    | 25                   | 27                          | 27                    | 258          | 203                         | 303                   | 1,371               |
| 30 June              | 182         | 172                         | 211                   | 24          | 25                          | 25                    | 11        | 36                          | 36                    | 32                   | 30                          | 34                    | 250          | 267                         | 306                   | 1,440               |
| 01 July              | 213         | 210                         | 245                   | 46          | 65                          | 65                    | 9         | 10                          | 10                    | 64                   | 74                          | 76                    | 332          | 337                         | 395                   | 1,409               |
| 02 June              | 255         | 263                         | 311                   | 71          | 97                          | 101                   | 20        | 30                          | 30                    | 35                   | 37                          | 38                    | 381          | 384                         | 480                   | 1,440               |
| 03 June              | 208         | 217                         | 246                   | 47          | 52                          | 57                    | 11        | 12                          | 12                    | 55                   | 54                          | 56                    | 321          | 307                         | 372                   | 1,438               |
| 04 July              | 83          | 72                          | 84                    | 19          | 20                          | 21                    | 14        | 14                          | 15                    | 45                   | 41                          | 47                    | 161          | 139                         | 167                   | 1,440               |
| 05 July              | 62          | 58                          | 64                    | 26          | 25                          | 26                    | 21        | 23                          | 25                    | 101                  | 114                         | 120                   | 210          | 211                         | 235                   | 1,440               |
| 06 July              | 86          | 73                          | 88                    | 35          | 43                          | 43                    | 7         | 7                           | 7                     | 91                   | 102                         | 106                   | 219          | 209                         | 244                   | 1,440               |
| 07 July              | 61          | 61                          | 63                    | 36          | 38                          | 39                    | 20        | 25                          | 25                    | 111                  | 105                         | 117                   | 228          | 212                         | 244                   | 1,440               |
| 08 July              | 82          | 78                          | 82                    | 31          | 34                          | 35                    | 14        | 19                          | 20                    | 65                   | 68                          | 73                    | 192          | 190                         | 210                   | 1,440               |
| 09 July              | 93          | 84                          | 94                    | 19          | 24                          | 24                    | 4         | 5                           | 5                     | 61                   | 64                          | 67                    | 177          | 165                         | 190                   | 1,440               |
| 10 July              | 126         | 109                         | 132                   | 35          | 36                          | 36                    | 15        | 18                          | 18                    | 88                   | 81                          | 89                    | 264          | 225                         | 275                   | 1,440               |
| 11 July              | 34          | 30                          | 34                    | 16          | 17                          | 18                    | 6         | 7                           | 7                     | 48                   | 48                          | 52                    | 104          | 98                          | 111                   | 720                 |
| 12 July              | 92          | 84                          | 98                    | 19          | 19                          | 19                    | 17        | 17                          | 18                    | 59                   | 67                          | 73                    | 187          | 178                         | 207                   | 1,440               |
| 13 July              | 85          | 75                          | 90                    | 21          | 19                          | 21                    | 18        | 18                          | 20                    | 57                   | 55                          | 58                    | 181          | 159                         | 190                   | 1,440               |
| 14 July              | 94          | 93                          | 116                   | 37          | 34                          | 39                    | 23        | 26                          | 26                    | 90                   | 117                         | 125                   | 244          | 250                         | 306                   | 1,440               |
| 15 July              | 124         | 113                         | 126                   | 29          | 31                          | 31                    | 37        | 92                          | 95                    | 94                   | 94                          | 98                    | 284          | 314                         | 350                   | 1,440               |
| Total                | 4,415       | 4,489                       | 5,195                 | 1,323       | 1,867                       | 1,959                 | 412       | 1,801                       | 2,150                 | 1,882                | 2,094                       | 2,258                 | 8,179        | 7,945                       | 10,561                | 45,377              |
| Average <sup>c</sup> | 140.1       | 142.5                       | 164.9                 | 42.0        | 59.2                        | 62.2                  | 13.1      | 57.2                        | 68.2                  | 59.7                 | 66.5                        | 71.7                  | 259.6        | 252.1                       | 335.1                 | 1,375.1             |

<sup>a</sup> Duration = number of min ≥ 1 vehicle was on airstrip.

<sup>b</sup> Veh. Min = sum of min each vehicle was on airstrip.

<sup>c</sup> Average is calculated per day where number of days = sum of total min monitored/1440 min. Average total min monitored/no. of days monitored.



Appendix D5. The number of landings or takeoffs by aircraft using the Alpine airstrip after the waterfowl nesting period in the Alpine project area, Colville River Delta, Alaska, 2001. Numbers are takeoffs plus landings. Data are from Alpine security.

| Date                   | Aircraft Type     |      |      |                           |                           |            | Total |
|------------------------|-------------------|------|------|---------------------------|---------------------------|------------|-------|
|                        | C-130<br>Hercules | DC-6 | CASA | Twin Otter/<br>Beech 1900 | Small Planes <sup>a</sup> | Helicopter |       |
| 16 July                | 0                 | 0    | 10   | 14                        | 0                         | 36         | 60    |
| 17 July                | 0                 | 2    | 10   | 8                         | 0                         | 34         | 54    |
| 18 July                | 0                 | 2    | 10   | 6                         | 0                         | 34         | 52    |
| 19 July                | 0                 | 4    | 6    | 4                         | 0                         | 52         | 66    |
| 20 July                | 0                 | 2    | 10   | 8                         | 2                         | 30         | 52    |
| 21 July                | 2                 | 4    | 6    | 0                         | 0                         | 24         | 36    |
| 22 July                | 0                 | 2    | 4    | 0                         | 0                         | 6          | 12    |
| 23 July                | 0                 | 0    | 8    | 8                         | 0                         | 14         | 30    |
| 24 July                | 0                 | 2    | 4    | 8                         | 0                         | 30         | 44    |
| 25 July                | 0                 | 6    | 0    | 14                        | 2                         | 20         | 42    |
| 26 July                | 0                 | 0    | 8    | 6                         | 2                         | 12         | 28    |
| 27 July <sup>b</sup>   | —                 | —    | —    | —                         | —                         | —          | —     |
| 28 July                | 0                 | 2    | 4    | 0                         | 0                         | 32         | 38    |
| 29 July <sup>b</sup>   | —                 | —    | —    | —                         | —                         | —          | —     |
| 30 July                | 0                 | 0    | 16   | 0                         | 0                         | 20         | 36    |
| 31 July                | 0                 | 2    | 8    | 6                         | 0                         | 20         | 36    |
| 1 August               | 0                 | 4    | 10   | 6                         | 0                         | 12         | 32    |
| 2 August               | 0                 | 2    | 10   | 6                         | 0                         | 10         | 28    |
| 3 August               | 0                 | 2    | 10   | 6                         | 0                         | 16         | 34    |
| 4 August               | 0                 | 6    | 6    | 0                         | 0                         | 14         | 26    |
| 5 August               | 0                 | 0    | 4    | 0                         | 2                         | 8          | 14    |
| 6 August               | 0                 | 0    | 12   | 8                         | 0                         | 24         | 44    |
| 7 August               | 0                 | 2    | 12   | 8                         | 0                         | 22         | 44    |
| 8 August               | 0                 | 6    | 10   | 8                         | 0                         | 12         | 36    |
| 9 August               | 0                 | 2    | 8    | 4                         | 0                         | 8          | 22    |
| 10 August              | 0                 | 0    | 6    | 6                         | 0                         | 8          | 20    |
| 11 August              | 0                 | 2    | 6    | 0                         | 0                         | 8          | 16    |
| 12 August              | 0                 | 0    | 4    | 2                         | 2                         | 18         | 26    |
| 13 August              | 0                 | 0    | 10   | 10                        | 0                         | 6          | 26    |
| 14 August              | 0                 | 2    | 8    | 8                         | 0                         | 10         | 28    |
| 15 August              | 0                 | 4    | 8    | 4                         | 0                         | 20         | 36    |
| 16 August <sup>b</sup> | —                 | —    | —    | —                         | —                         | —          | —     |
| 17 August              | 2                 | 2    | 8    | 6                         | 0                         | 16         | 34    |
| 18 August              | 0                 | 2    | 6    | 0                         | 0                         | 18         | 26    |
| 19 August              | 0                 | 0    | 8    | 2                         | 4                         | 18         | 32    |
| 20 August              | 0                 | 0    | 12   | 8                         | 0                         | 28         | 48    |
| 21 August              | 0                 | 4    | 8    | 6                         | 0                         | 24         | 42    |
| 22 August              | 0                 | 2    | 10   | 6                         | 0                         | 24         | 42    |
| 23 August              | 0                 | 2    | 2    | 10                        | 2                         | 18         | 34    |
| 24 August              | 0                 | 2    | 8    | 4                         | 0                         | 16         | 30    |
| 25 August              | 0                 | 0    | 4    | 0                         | 0                         | 32         | 36    |
| 26 August              | 0                 | 0    | 6    | 0                         | 0                         | 26         | 32    |
| 27 August              | 0                 | 4    | 10   | 10                        | 4                         | 14         | 42    |
| 28 August              | 0                 | 0    | 4    | 6                         | 0                         | 26         | 36    |
| 29 August              | 0                 | 0    | 0    | 4                         | 0                         | 8          | 12    |
| 30 August              | 0                 | 8    | 6    | 6                         | 4                         | 20         | 44    |
| 31 August              | 0                 | 0    | 6    | 2                         | 0                         | 8          | 16    |
| Daily Mean             | 0.1               | 2.0  | 7.4  | 5.2                       | 0.5                       | 19.5       | 34.6  |
| Total                  | 4                 | 86   | 326  | 228                       | 24                        | 856        | 1,524 |

<sup>a</sup> Includes Cessna 185, Cessna 206, and Cessna 207.

<sup>b</sup> No security records available.

Appendix E1. Daily air temperature (° C) and wind speed (mph) data obtained from weather records at the Alpine airport, Colville River Delta, Alaska, 2001.

| Date    | Temperature (°C) |      |      | Wind Speed (mph) |      |      | Direction (degree) |
|---------|------------------|------|------|------------------|------|------|--------------------|
|         | Mean             | Min. | Max. | Mean             | Min. | Max. |                    |
| 1 June  | 2.0              | -1   | 5    | 7.7              | 1    | 11   | 181                |
| 2 June  | 0.9              | 0    | 2    | 4.8              | 2    | 7    | 182                |
| 3 June  | -0.6             | -2   | 1    | 13.3             | 10   | 18   | 190                |
| 4 June  | 0.3              | -1   | 1    | 7.1              | 4    | 10   | 184                |
| 5 June  | 2.1              | 0    | 3    | 5.2              | 0    | 8    | 180                |
| 6 June  | 1.1              | 0    | 2    | 7.3              | 2    | 14   | 2                  |
| 7 June  | 0.1              | -1   | 2    | 13.5             | 12   | 16   | 12                 |
| 8 June  | -0.6             | -3   | 2    | 10.7             | 9    | 14   | 9                  |
| 9 June  | -0.7             | -4   | 3    | 9.9              | 6    | 14   | 186                |
| 10 June | 4.0              | -1   | 9    | 9.5              | 2    | 14   | 182                |
| 11 June | 5.7              | 1    | 11   | 7.3              | 0    | 12   | 0                  |
| 12 June | 8.4              | 7    | 10   | 9.1              | 6    | 14   | 6                  |
| 13 June | 12.9             | 6    | 20   | 6.0              | 0    | 11   | 0                  |
| 14 June | 5.5              | 0    | 10   | 9.5              | 4    | 16   | 364                |
| 15 June | 5.4              | -1   | 11   | 6.1              | 0    | 12   | 180                |
| 16 June | 11.2             | 6    | 15   | 10.5             | 7    | 15   | 187                |
| 17 June | 8.1              | 5    | 11   | 8.6              | 4    | 14   | 184                |
| 18 June | 5.8              | 2    | 9    | 10.7             | 7    | 14   | 367                |
| 19 June | 2.4              | -2   | 7    | 5.1              | 2    | 8    | 362                |
| 20 June | 4.3              | 2    | 7    | 4.9              | 0    | 9    | 0                  |
| 21 June | 1.5              | 0    | 3    | 9.5              | 6    | 14   | 6                  |
| 22 June | 4.4              | 0    | 8    | 10.5             | 8    | 13   | 8                  |
| 23 June | 6.9              | 1    | 12   | 10.8             | 7    | 15   | 7                  |
| 24 June | 6.9              | 2    | 10   | 12.1             | 9    | 16   | 9                  |
| 25 June | 5.6              | 3    | 8    | 7.4              | 0    | 12   | 360                |
| 26 June | 4.7              | 3    | 7    | 6.4              | 3    | 9    | 3                  |
| 27 June | 5.9              | 4    | 7    | 6.1              | 0    | 10   | 360                |
| 28 June | 5.7              | 3    | 9    | 8.3              | 4    | 14   | 4                  |
| 29 June | 2.1              | 1    | 3    | 10.6             | 8    | 13   | 8                  |
| 30 June | 3.6              | 0    | 9    | 9.5              | 6    | 15   | 6                  |
| 1 July  | 9.3              | 4    | 16   | 9.2              | 6    | 14   | 6                  |
| 2 July  | 16.2             | 5    | 25   | 6.1              | 2    | 12   | 182                |
| 3 July  | 12.9             | 9    | 15   | 6.5              | 0    | 13   | 0                  |
| 4 July  | 1.8              | 1    | 3    | 14.6             | 9    | 18   | 9                  |
| 5 July  | 2.9              | -1   | 6    | 7.3              | 2    | 11   | 362                |
| 6 July  | 2.0              | -1   | 3    | 2.9              | 0    | 8    | 0                  |
| 7 July  | 2.0              | 1    | 3    | 10.7             | 8    | 14   | 8                  |
| 8 July  | 0.3              | -1   | 2    | 11.0             | 8    | 16   | 8                  |
| 9 July  | 1.6              | 1    | 2    | 12.2             | 9    | 16   | 9                  |
| 10 July | 1.9              | 1    | 3    | 10.4             | 8    | 13   | 8                  |
| 11 July | 2.6              | 1    | 4    | 17.0             | 14   | 22   | 14                 |
| 12 July | 2.8              | 1    | 4    | 15.7             | 12   | 20   | 12                 |
| 13 July | 5.3              | 1    | 7    | 15.8             | 12   | 18   | 12                 |
| 14 July | 7.0              | 2    | 10   | 14.4             | 10   | 20   | 10                 |
| 15 July | 10.8             | 3    | 17   | 10.3             | 8    | 12   | 8                  |

Appendix E2. Matrix of pairwise Pearson correlation coefficients for environmental and potential disturbance variables monitored during the Greater White-fronted Goose nesting season (excluding the 5 days prior to hatch or failure) in the Alpine project area, Colville River Delta, Alaska, 2001. Pedestrians were monitored with video cameras and aircraft and vehicles were monitored by Alpine security.

|                                  | No. Landings and Takeoffs |            | No. Vehicles | Pedestrians on Airstrip (ln) | Noise Levels     |                 | Day before Hatch or Failure | Julian Date | Mean Temperature | Mean Wind Speed |
|----------------------------------|---------------------------|------------|--------------|------------------------------|------------------|-----------------|-----------------------------|-------------|------------------|-----------------|
|                                  | Airplane                  | Helicopter |              |                              | L <sub>max</sub> | L <sub>eq</sub> |                             |             |                  |                 |
| No. Landings and Takeoffs        |                           |            |              |                              |                  |                 |                             |             |                  |                 |
| Airplane                         | 1.00                      |            |              |                              |                  |                 |                             |             |                  |                 |
| Helicopter                       | -0.26**                   | 1.00       |              |                              |                  |                 |                             |             |                  |                 |
| No. Vehicles                     | 0.20**                    | 0.72**     | 1.00         |                              |                  |                 |                             |             |                  |                 |
| Min Pedestrians on Airstrip (ln) | 0.43**                    | 0.35**     | 0.44**       | 1.00                         |                  |                 |                             |             |                  |                 |
| Noise Levels                     |                           |            |              |                              |                  |                 |                             |             |                  |                 |
| Maximal (L <sub>max</sub> )      | 0.04                      | 0.01       | 0.02         | -0.05                        | 1.00             |                 |                             |             |                  |                 |
| Daily (L <sub>eq</sub> )         | 0.09                      | 0.31**     | 0.29**       | 0.17**                       | 0.78**           | 1.00            |                             |             |                  |                 |
| Day before Hatch or Failure      | 0.23**                    | 0.19**     | 0.28**       | 0.23**                       | -0.08            | 0.09            | 1.00                        |             |                  |                 |
| Julian Date                      | -0.25**                   | -0.21**    | -0.32**      | -0.26**                      | 0.03             | -0.12*          | -0.88**                     | 1.00        |                  |                 |
| Mean Temperature                 | -0.18**                   | 0.61**     | 0.32**       | 0.63**                       | -0.08            | 0.14*           | -0.09                       | 0.09        | 1.00             |                 |
| Mean Wind Speed                  | -0.56**                   | 0.46**     | 0.30**       | 0.06                         | -0.04            | 0.06            | -0.05                       | 0.07        | 0.37**           | 1.00            |

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

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

Appendix E3.

Logistic regression models of the influence of potential disturbance and environmental variables on the probability of incubating Greater White-fronted Geese taking recesses during an hour. Twenty-seven Greater White-fronted Goose nests were monitored with egg thermistors between 0600 and 1800 ADT in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Models were run with and without nest site, and the 5 days prior to hatch or failure were excluded. Nagelkerke  $R^2 = 0.09$  with nest site in model and Nagelkerke  $R^2 = 0.02$  without nest site;  $n = 10,272$  hr.

| Model                       | $\beta$ | SE    | Wald    | df | P      | Odds Ratio<br>(Exp[ $\beta$ ]) |
|-----------------------------|---------|-------|---------|----|--------|--------------------------------|
| <b>With Nest Site</b>       |         |       |         |    |        |                                |
| Intercept                   | -2.240  | 0.615 | 13.285  | 1  | <0.001 |                                |
| Day before Hatch or Failure | -0.052  | 0.010 | 25.299  | 1  | <0.001 | 0.949                          |
| Wind Speed                  | -0.026  | 0.012 | 4.715   | 1  | 0.030  | 0.974                          |
| Time of Day                 |         |       | 51.885  | 2  | <0.001 |                                |
| 0600–1000                   | -0.823  | 0.119 | 47.457  | 1  | <0.001 | 0.439                          |
| 1000–1400                   | -0.094  | 0.098 | 0.929   | 1  | 0.335  | 0.910                          |
| 1400–1800                   | 0       |       |         |    |        |                                |
| Nest Site                   |         |       | 187.826 | 74 | <0.001 |                                |
| <b>Without Nest Site</b>    |         |       |         |    |        |                                |
| Intercept                   | -2.302  | 0.226 | 103.67  | 1  | <0.001 |                                |
| Day Before Hatch or Failure | -0.033  | 0.010 | 11.190  | 1  | 0.001  | 0.968                          |
| Wind Speed                  | -0.024  | 0.012 | 4.207   | 1  | 0.040  | 0.977                          |
| Time of Day                 |         |       | 50.381  | 2  | <0.001 |                                |
| 0600–1000                   | -0.800  | 0.118 | 46.112  | 1  | <0.001 | 0.449                          |
| 1000–1400                   | -0.090  | 0.096 | 0.878   | 1  | 0.349  | 0.914                          |
| 1400–1800                   | 0       |       |         |    |        |                                |
| Distance to Airstrip        |         |       | 9.051   | 2  | 0.011  |                                |
| 0–1,000 m                   | 0.412   | 0.170 | 5.894   | 1  | 0.015  | 1.510                          |
| 1,000–2,000 m               | 0.472   | 0.157 | 9.046   | 1  | 0.003  | 1.603                          |
| >2,000 m                    | 0       |       |         |    |        |                                |

Appendix E4. Generalized linear models of the effects of potential disturbance and environmental variables on daily values for recess frequency, time off nest, and recess length for Greater White-fronted Goose nests. Seventy-nine nests were monitored with egg thermistors between 0600 and 1800 ADT in the Alpine project area, Colville River Delta, Alaska, 1999–2001. Models were run with and without nest site, and the 5 days prior to hatch or failure were excluded.

| Model  | $\beta$ | SE   | Z                   | t                 | df      | P     |
|--|---------|------|---------------------|-------------------|---------|-------|
| <b>Recess Frequency (no./d)<sup>a</sup></b>      |         |      |                     |                   |         |       |
| With Nest Site                                   |         |      |                     |                   |         |       |
| Intercept  | 5.93    | 1.92 | 3.09                |                   |         | <0.01 |
| Daily Noise Level ( $L_{eq}$ )                   | -0.11   | 0.03 | -3.51               |                   |         | <0.01 |
| Day Before Hatch or Failure                      | -0.05   | 0.01 | -5.10               |                   |         | <0.01 |
| Wind Speed                                       | -0.03   | 0.02 | -1.79               |                   |         | 0.07  |
| Number of Airplanes                              | 0.02    | 0.01 | 1.61                |                   |         | 0.11  |
| Number of Helicopters                            | 0.06    | 0.02 | 3.20                |                   |         | <0.01 |
| Nest Site  |         |      | 242.31 <sup>b</sup> |                   | 74      | <0.01 |
| Without Nest Site                                |         |      |                     |                   |         |       |
| Intercept  | -1.33   | 0.64 | -2.06               |                   |         | 0.04  |
| Daily Noise Level ( $L_{eq}$ )                   | 0.04    | 0.01 | 3.88                |                   |         | <0.01 |
| Wind Speed                                       | -0.06   | 0.03 | -2.12               |                   |         | 0.03  |
| Number of Airplanes                              | -0.07   | 0.04 | -1.67               |                   |         | 0.10  |
| Number of Helicopters                            | -0.04   | 0.02 | -2.18               |                   |         | 0.03  |
| Min Pedestrians on Airstrip (ln)                 | -0.12   | 0.04 | -2.56               |                   |         | 0.01  |
| <b>Time off Nest (min/d)<sup>c</sup></b>         |         |      |                     |                   |         |       |
| With Nest Site                                   |         |      |                     |                   |         |       |
| Intercept  | 8.50    | 2.19 | 3.88                |                   |         | <0.01 |
| Day Before Hatch or Failure                      | -0.04   | 0.01 | -3.23               |                   |         | <0.01 |
| Wind Speed                                       | -0.03   | 0.02 | -1.57               |                   |         | 0.12  |
| Number of Airplanes                              | 0.03    | 0.01 | 2.10                |                   |         | 0.04  |
| Number of Helicopters                            | 0.07    | 0.02 | 3.27                |                   |         | <0.01 |
| Nest Site  |         |      | 229.24 <sup>b</sup> |                   | 74      | <0.01 |
| Without Nest Site                                |         |      |                     |                   |         |       |
| Intercept  | 1.63    | 0.27 | 6.11                |                   |         | <0.01 |
| Day Before Hatch or Failure                      | -0.04   | 0.01 | -2.94               |                   |         | <0.01 |
| Wind Speed                                       | -0.04   | 0.02 | -2.21               |                   |         | 0.03  |
| Distance to Airstrip                             |         |      | 8.07 <sup>b</sup>   |                   | 2       | 0.02  |
| 0–1,000 m  | 0       |      |                     |                   |         |       |
| 1,000–2,000 m                                    | 0.18    | 0.14 | 1.30                |                   |         | 0.19  |
| >2,000 m   | -0.36   | 0.21 | -1.70               |                   |         | 0.09  |
| <b>Average Recess Length (min/d)<sup>d</sup></b> |         |      |                     |                   |         |       |
| With Nest Site                                   |         |      |                     |                   |         |       |
| Intercept  | 2.66    | 0.22 |                     | 12.06             | 1       | <0.01 |
| Day Before Hatch or Failure                      | -0.01   | 0.01 |                     | -1.53             | 1       | 0.13  |
| Nest Site  |         |      |                     | 3.37 <sup>e</sup> | 71, 355 | <0.01 |
| Without Nest Site                                |         |      |                     |                   |         |       |
| Intercept  | 2.76    | 0.06 |                     | 42.96             | 1       | <0.01 |
| Day Before Hatch or Failure                      | -0.01   | 0.01 |                     | -2.65             | 1       | <0.01 |
| Number of Airplanes                              | 0.01    | 0.01 |                     | 2.59              | 1       | 0.01  |

<sup>a</sup> Model assumes a poisson distribution.

<sup>b</sup> Likelihood ratio  $\chi^2$ .

<sup>c</sup> Model assumes a negative binomial distribution.

<sup>d</sup> Model assumes a normal distribution.

<sup>e</sup> F-statistic.

Appendix F. Elapsed time (min) from engine startup to takeoff and from landings to engine shutdown estimated from visual and audio video recordings at the Alpine airstrip, Colville River Delta, Alaska, 2000–2001.

| Aircraft               | Minimum | Maximum | Values used in Time Buffers |
|------------------------|---------|---------|-----------------------------|
| DC6                    |         |         |                             |
| Departure              | 1       | 10      | 10                          |
| Arrival                | 3       | 8       | 8                           |
| C130                   |         |         |                             |
| Departure              | 5       | 8       | 8                           |
| Arrival                | 2       | 7       | 7                           |
| Otter                  |         |         |                             |
| Departure              | 1       | 6       | 6                           |
| Arrival                | 1       | 4       | 4                           |
| Caravan                |         |         |                             |
| Departure              |         |         | 4                           |
| Arrival                |         |         | 2                           |
| CASA                   |         |         |                             |
| Departure              | 1       | 5       | 5                           |
| Arrival                | 1       | 4       | 4                           |
| Small Planes           |         |         |                             |
| Departure              | <1      | 1       | 1                           |
| Arrival                | <1      | 1       | 1                           |
| Helicopter             |         |         |                             |
| Departure <sup>a</sup> | <1      | 1       | 3                           |
| Arrival <sup>b</sup>   | <1      | 1       | 3                           |

Appendix G1. Numbers and densities (unadjusted for search effort) of nests of selected species found during ground-searches in the Alpine project area, Colville River Delta, Alaska, 1996–2001. Annual search area boundaries are displayed in Figure 3. For 1998, only the results of the first nest search are presented.

| Species                               | Number of Nests |      |                 |                |                 |      | Density (nests/km <sup>2</sup> ) |      |                  |                  |                  |      |
|---------------------------------------|-----------------|------|-----------------|----------------|-----------------|------|----------------------------------|------|------------------|------------------|------------------|------|
|                                       | 1996            | 1997 | 1998            | 1999           | 2000            | 2001 | 1996                             | 1997 | 1998             | 1999             | 2000             | 2001 |
| Red-throated Loon                     | 2               | 7    | 2               | 2              | 1               | 3    | 0.1                              | 0.5  | 0.1              | 0                | 0.1              | 0.3  |
| Pacific Loon                          | 3               | 8    | 9               | 11             | 3               | 6    | 0.2                              | 0.6  | 0.6              | 0.7              | 0.2              | 0.5  |
| Yellow-billed Loon <sup>a</sup>       | 1               | 1    | 1               | 1              | 2               | 1    | 0.1                              | 0.1  | 0.1              | 0.1              | 0.2              | 0.1  |
| Red-necked Grebe                      | 0               | 3    | 2               | 2              | 1               | 2    | 0                                | 0.2  | 0.1              | 0.1              | 0.1              | 0.2  |
| Greater White-fronted Goose           | 35              | 45   | 48              | 79             | 51 <sup>b</sup> | 37   | 2.0                              | 3.1  | 3.2              | 5.0              | 3.8 <sup>b</sup> | 3.3  |
| Canada Goose                          | 0               | 0    | 2               | 1              | 1               | 2    | 0                                | 0    | 0.1              | 0.1              | 0.1              | 0.2  |
| Brant                                 | 3               | 7    | 1               | 4 <sup>b</sup> | 3               | 2    | 0.2                              | 0.5  | 0.1              | 0.3 <sup>b</sup> | 0.2              | 0.2  |
| Tundra Swan                           | 7               | 6    | 5               | 6              | 5               | 5    | 0.4                              | 0.4  | 0.3              | 0.4              | 0.4              | 0.4  |
| Northern Shoveler                     | 1               | 0    | 5 <sup>b</sup>  | 0              | 0               | 0    | 0.1                              | 0    | 0.3 <sup>b</sup> | 0                | 0                | 0    |
| Northern Pintail                      | 2 <sup>b</sup>  | 5    | 9 <sup>b</sup>  | 9 <sup>b</sup> | 8 <sup>b</sup>  | 7    | 0.1 <sup>b</sup>                 | 0.3  | 0.6 <sup>b</sup> | 0.6 <sup>b</sup> | 0.6 <sup>b</sup> | 0.6  |
| Green-winged Teal                     | 1               | 0    | 1               | 4 <sup>b</sup> | 2 <sup>b</sup>  | 0    | 0.1                              | 0    | 0.1              | 0.3 <sup>b</sup> | 0.2 <sup>b</sup> | 0    |
| Greater Scaup                         | 0               | 2    | 1               | 6              | 1               | 1    | 0                                | 0.1  | 0.1              | 0.4              | 0.1              | 0.1  |
| Lesser Scaup                          | 0               | 0    | 1               | 0              | 0               | 0    | 0                                | 0    | 0.1              | 0                | 0                | 0    |
| Unidentified scaup                    | 0               | 0    | 2               | 2 <sup>b</sup> | 1               | 6    | 0                                | 0    | 0.1              | 0.1 <sup>b</sup> | 0.1              | 0.5  |
| Spectacled Eider                      | 0               | 0    | 1               | 1              | 0               | 1    | 0                                | 0    | 0.1              | 0.1              | 0                | 0.1  |
| King Eider                            | 1               | 0    | 0               | 0              | 0               | 0    | 0.1                              | 0    | 0                | 0                | 0                | 0    |
| Long-tailed Duck                      | 7 <sup>b</sup>  | 9    | 6 <sup>b</sup>  | 5 <sup>b</sup> | 5 <sup>b</sup>  | 3    | 0.4 <sup>b</sup>                 | 0.6  | 0.4 <sup>b</sup> | 0.2 <sup>b</sup> | 0.4 <sup>b</sup> | 0.3  |
| Unidentified duck                     | 0               | 0    | 4               | 2              | 1               | 0    | 0                                | 0    | 0.3              | 0.1              | 0.1              | 0    |
| Willow Ptarmigan                      | 1               | 12   | nd <sup>c</sup> | 21             | 12              | 6    | 0.1                              | 0.8  | nd <sup>c</sup>  | 1.3              | 0.9              | 0.5  |
| Rock Ptarmigan                        | 0               | 1    | nd <sup>c</sup> | 0              | 1               | 0    | 0                                | 0.1  | nd <sup>c</sup>  | 0                | 0.1              | 0    |
| Unidentified ptarmigan                | 0               | 0    | nd <sup>c</sup> | 3              | 1               | 1    | 0                                | 0    | nd <sup>c</sup>  | 0.2              | 0.1              | 0.1  |
| Sandhill Crane                        | 0               | 0    | 0               | 1              | 0               | 0    | 0                                | 0    | 0                | 0.1              | 0                | 0    |
| Bar-tailed Godwit                     | 1               | 0    | 2               | 3              | 0               | 1    | 0.1                              | 0    | 0.1              | 0.2              | 0                | 0.1  |
| Common Snipe                          | 0               | 1    | 0               | 0              | 1               | 0    | 0                                | 0.1  | 0                | 0                | 0.1              | 0    |
| Parasitic Jaeger                      | 1               | 1    | 2               | 2              | 2               | 2    | 0.1                              | 0.1  | 0.1              | 0.1              | 0.2              | 0.2  |
| Long-tailed Jaeger                    | 1               | 0    | 1               | 1              | 1               | 1    | 0.1                              | 0    | 0.1              | 0.1              | 0.1              | 0.1  |
| Glaucous Gull                         | 0               | 2    | 0               | 1              | 1               | 1    | 0                                | 0.1  | 0                | 0.1              | 0.1              | 0.1  |
| Sabine's Gull                         | 1               | 0    | 0               | 0              | 1               | 0    | 0.1                              | 0    | 0                | 0                | 0.1              | 0    |
| Arctic Tern                           | 0               | 5    | 4               | 15             | 4               | 9    | 0                                | 0.3  | 0.3              | 1.0              | 0.3              | 0.8  |
| Short-eared Owl                       | 1               | 0    | 0               | 0              | 0               | 0    | 0.1                              | 0    | 0                | 0                | 0                | 0    |
| Area (km <sup>2</sup> )               | 17.2            | 14.3 | 14.8            | 15.7           | 13.3            | 11.4 |                                  |      |                  |                  |                  |      |
| Total Nests or Densities <sup>d</sup> | 68              | 102  | 109             | 158            | 95              | 90   | 4.0                              | 7.1  | 7.4              | 10.1             | 7.1              | 7.9  |
| Total Species <sup>e</sup>            | 16              | 14   | 19              | 19             | 18              | 17   |                                  |      |                  |                  |                  |      |

<sup>a</sup> Three nests in 1998, 1 in 1999, 3 in 2000 and 2 in 2001 were found during activities other than the nest search.

<sup>b</sup> Includes nests identified from feather and down samples.

<sup>c</sup> nd = no data.

<sup>d</sup> Total does not include ptarmigan.

<sup>e</sup> Total does not include ptarmigan or unidentified ducks.

Appendix G2. Numbers and densities (unadjusted for search effort) of nests of selected species found during ground searches within the common search area (10.6 km<sup>2</sup>) in the Alpine project area, Colville River Delta, Alaska, 1996–2001. The search area boundary is displayed in Figure 3.

| Species                               | Number of Nests |      |                 |                |                 |      | Density (nests/km <sup>2</sup> ) |      |                  |                  |                  |      |
|---------------------------------------|-----------------|------|-----------------|----------------|-----------------|------|----------------------------------|------|------------------|------------------|------------------|------|
|                                       | 1996            | 1997 | 1998            | 1999           | 2000            | 2001 | 1996                             | 1997 | 1998             | 1999             | 2000             | 2001 |
| Red-throated Loon                     | 1               | 5    | 2               | 2              | 0               | 3    | 0.1                              | 0.5  | 0.1              | 0.2              | 0                | 0.3  |
| Pacific Loon                          | 2               | 4    | 6               | 7              | 2               | 5    | 0.2                              | 0.4  | 0.6              | 0.7              | 0.2              | 0.5  |
| Yellow-billed Loon <sup>a</sup>       | 1               | 1    | 1               | 0              | 1               | 1    | 0.1                              | 0.1  | 0.1              | 0                | 0.1              | 0.1  |
| Red-necked Grebe                      | 0               | 3    | 2               | 2              | 1               | 2    | 0                                | 0.3  | 0.2              | 0.2              | 0.1              | 0.2  |
| Greater White-fronted Goose           | 25              | 35   | 32              | 53             | 39 <sup>b</sup> | 33   | 2.4                              | 3.3  | 2.9              | 5.0              | 3.7 <sup>b</sup> | 3.1  |
| Canada Goose                          | 0               | 0    | 0               | 0              | 0               | 1    | 0                                | 0    | 0                | 0                | 0                | 0.1  |
| Brant                                 | 1               | 4    | 1               | 2 <sup>b</sup> | 0               | 1    | 0.1                              | 0.4  | 0.1              | 0.2 <sup>b</sup> | 0                | 0.1  |
| Tundra Swan                           | 5               | 4    | 5               | 4              | 4               | 5    | 0.5                              | 0.4  | 0.5              | 0.4              | 0.4              | 0.5  |
| Northern Shoveler                     | 0               | 0    | 5 <sup>b</sup>  | 0              | 0               | 0    | 0                                | 0    | 0.5 <sup>b</sup> | 0                | 0                | 0    |
| Northern Pintail                      | 2               | 4    | 7 <sup>b</sup>  | 8 <sup>b</sup> | 5 <sup>b</sup>  | 4    | 0.2                              | 0.4  | 0.7 <sup>b</sup> | 0.8 <sup>b</sup> | 0.5 <sup>b</sup> | 0.4  |
| Green-winged Teal                     | 1               | 0    | 1               | 2 <sup>b</sup> | 2 <sup>b</sup>  | 0    | 0.1                              | 0    | 0.1              | 0.2 <sup>b</sup> | 0.2 <sup>b</sup> | 0    |
| Greater Scaup                         | 0               | 1    | 1               | 0              | 0               | 1    | 0                                | 0.1  | 0.1              | 0                | 0                | 0.1  |
| Lesser Scaup                          | 0               | 0    | 1               | 0              | 0               | 0    | 0                                | 0    | 0.1              | 0                | 0                | 0    |
| Unidentified scaup                    | 0               | 0    | 0               | 1 <sup>b</sup> | 0               | 3    | 0                                | 0    | 0                | 0.1 <sup>b</sup> | 0                | 0.3  |
| Long-tailed Duck                      | 6               | 9    | 5 <sup>b</sup>  | 5 <sup>b</sup> | 4 <sup>b</sup>  | 1    | 0.6                              | 0.8  | 0.5 <sup>b</sup> | 0.4 <sup>b</sup> | 0.4 <sup>b</sup> | 0.1  |
| Unidentified duck                     | 0               | 0    | 3               | 2              | 1               | 0    | 0                                | 0    | 0.2              | 0.2              | 0.1              | 0    |
| Willow Ptarmigan                      | 1               | 11   | nd <sup>c</sup> | 16             | 9               | 6    | 0.1                              | 1.0  | nd <sup>c</sup>  | 1.5              | 0.8              | 0.6  |
| Rock Ptarmigan                        | 0               | 0    | nd <sup>c</sup> | 0              | 1               | 0    | 0                                | 0    | nd <sup>c</sup>  | 0                | 0.1              | 0    |
| Unidentified Ptarmigan                | 0               | 0    | nd <sup>c</sup> | 3              | 1               | 1    | 0                                | 0    | nd <sup>c</sup>  | 0.3              | 0.1              | 0.1  |
| Sandhill Crane                        | 0               | 0    | 0               | 1              | 0               | 0    | 0                                | 0    | 0                | 0.1              | 0                | 0    |
| Bar-tailed Godwit                     | 0               | 0    | 2               | 2              | 0               | 1    | 0                                | 0    | 0.2              | 0.2              | 0                | 0.1  |
| Common Snipe                          | 0               | 1    | 0               | 0              | 1               | 0    | 0                                | 0.1  | 0                | 0                | 0.1              | 0    |
| Parasitic Jaeger                      | 1               | 1    | 2               | 2              | 2               | 2    | 0.1                              | 0.1  | 0.2              | 0.2              | 0.2              | 0.2  |
| Long-tailed Jaeger                    | 1               | 0    | 1               | 1              | 1               | 1    | 0.1                              | 0    | 0.1              | 0.1              | 0.1              | 0.1  |
| Glaucous Gull                         | 0               | 1    | 0               | 0              | 0               | 1    | 0                                | 0.1  | 0                | 0                | 0                | 0.1  |
| Sabine's Gull                         | 1               | 0    | 0               | 0              | 0               | 0    | 0.1                              | 0    | 0                | 0                | 0                | 0    |
| Arctic Tern                           | 0               | 5    | 3               | 6              | 2               | 4    | 0                                | 0.5  | 0.3              | 0.5              | 0.2              | 0.4  |
| Total Nests or Densities <sup>d</sup> | 47              | 78   | 80              | 100            | 65              | 69   | 4.4                              | 7.4  | 7.5              | 9.4              | 6.1              | 6.5  |
| Total Species <sup>e</sup>            | 12              | 14   | 17              | 14             | 12              | 16   |                                  |      |                  |                  |                  |      |

<sup>a</sup> One nest in 1997, 2 in 1998, and 1 in 1999–2001 were found during activities other than the nest search.

<sup>b</sup> Includes nests identified from feather and down samples.

<sup>c</sup> nd = no data.

<sup>c</sup> Total does not include ptarmigan.

<sup>d</sup> Total does not include ptarmigan or unidentified ducks.



Appendix G3. Habitat use (% of nests) by selected species during nesting in the Alpine project area, Colville River Delta, 1996–2001.

| Habitat Type   | Red-throated Loon | Pacific Loon | Yellow-billed Loon | Red-necked Grebe | Greater White-fronted Goose | Brant | Canada Goose | Tundra Swan | Green-Winged Teal | Northern Pintail | Northern Shoveler | Greater Scaup | Lesser Scaup | Unidentified scaup | Spectacled Eider |
|--|-------------------|--------------|--------------------|------------------|-----------------------------|-------|--------------|-------------|-------------------|------------------|-------------------|---------------|--------------|--------------------|------------------|
| Tapped Lake with Low-water Connection                  | 0                 | 0            | 0                  | 0                | 0                           | 0     | 0            | 0           | 0                 | 0                | 0                 | 0             | 0            | 0                  | 0                |
| Tapped Lake with High-water Connection                 | 0                 | 21.7         | 0                  | 5.9              | 0.3                         | 30.4  | 16.7         | 0           | 0                 | 0                | 0                 | 0             | 0            | 0                  | 0                |
| Salt Marsh   | 0                 | 8.7          | 0                  | 0                | 0.6                         | 4.3   | 0            | 4.7         | 0                 | 2.0              | 0                 | 0             | 0            | 0                  | 0                |
| Deep Open Water without Islands                        | 0                 | 3.5          | 0                  | 5.9              | 0.3                         | 0     | 0            | 0           | 0                 | 0                | 0                 | 0             | 0            | 6.7                | 0                |
| Deep Open Water with Islands or Polygonized Margins    | 0                 | 16.5         | 0                  | 0                | 1.5                         | 43.5  | 50           | 2.3         | 0                 | 0                | 0                 | 0             | 0            | 6.7                | 25.0             |
| Shallow Open Water without Islands                     | 0                 | 0            | 0                  | 0                | 0                           | 0     | 0            | 0           | 0                 | 0                | 0                 | 0             | 0            | 0                  | 0                |
| Shallow Open Water with Islands or Polygonized Margins | 0                 | 0            | 0                  | 0                | 0                           | 0     | 0            | 0           | 0                 | 0                | 0                 | 0             | 0            | 0                  | 0                |
| Aquatic Sedge Marsh                                    | 0                 | 15.7         | 15.4               | 29.4             | 0                           | 0     | 0            | 0           | 0                 | 0                | 0                 | 5.6           | 0            | 0                  | 0                |
| Aquatic Sedge with Deep Polygons                       | 27.8              | 2.6          | 0                  | 0                | 5.4                         | 4.3   | 33.3         | 0           | 0                 | 9.8              | 0                 | 11.1          | 0            | 33.3               | 50               |
| Aquatic Grass Marsh                                    | 0                 | 2.6          | 0                  | 58.8             | 0                           | 4.3   | 0            | 0           | 0                 | 0                | 0                 | 5.6           | 0            | 6.7                | 0                |
| Nonpatterned Wet Meadow                                | 22.2              | 14.8         | 15.4               | 0                | 3.9                         | 8.7   | 0            | 2.3         | 0                 | 15.7             | 57.1              | 50            | 100          | 26.7               | 0                |
| Patterned Wet Meadow                                   | 50.0              | 13.9         | 69.2               | 0                | 75.9                        | 4.3   | 0            | 58.1        | 88.9              | 45.1             | 42.9              | 27.8          | 0            | 20                 | 25.0             |
| Moist Sedge-Shrub Meadow                               | 0                 | 0            | 0                  | 0                | 11.0                        | 0     | 0            | 30.2        | 11.1              | 15.7             | 0                 | 0             | 0            | 0                  | 0                |
| Riverine or Upland Shrub                               | 0                 | 0            | 0                  | 0                | 1.2                         | 0     | 0            | 2.3         | 0                 | 11.8             | 0                 | 0             | 0            | 0                  | 0                |
| Barrens (riverine, eolian, or lacustrine)              | 0                 | 0            | 0                  | 0                | 0                           | 0     | 0            | 0           | 0                 | 0                | 0                 | 0             | 0            | 0                  | 0                |
| Total  | 100               | 100          | 100                | 100              | 100                         | 100   | 100          | 100         | 100               | 100              | 100               | 100           | 100          | 100                | 100              |
| Total Nests  | 18                | 115          | 13                 | 17               | 337                         | 23    | 6            | 43          | 9                 | 50               | 7                 | 18            | 1            | 15                 | 4                |

Appendix G3. Continued.

| Habitat Type   | King Eider | Long-Tailed Duck | Sandhill Crane | Willow Ptarmigan | Rock Ptarmigan | Bar-tailed Godwit | Common Snipe | Parasitic Jaeger | Long-tailed Jaeger | Short-eared Owl | Glaucous Gull | Sabine's Gull | Arctic Terns | Total % | Total Nests |
|--|------------|------------------|----------------|------------------|----------------|-------------------|--------------|------------------|--------------------|-----------------|---------------|---------------|--------------|---------|-------------|
| Tapped Lake with Low-water Connection                  | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 12.5          | 0             | 0            | 0.2     | 2           |
| Tapped Lake with High-water Connection                 | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 6.3           | 0             | 2.1          | 4.3     | 37          |
| Salt Marsh   | 0          | 0                | 0              | 1.8              | 0              | 0                 | 0            | 0                | 0                  | 0               | 6.3           | 0             | 0            | 2.1     | 18          |
| Deep Open Water without Islands                        | 0          | 2.5              | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 0             | 0            | 0.8     | 7           |
| Deep Open Water with Islands or Polygonized Margins    | 0          | 17.5             | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 43.8          | 50.0          | 22.9         | 7.6     | 66          |
| Shallow Open Water without Islands                     | 0          | 2.5              | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 0             | 0            | 0.1     | 1           |
| Shallow Open Water with Islands or Polygonized Margins | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 0             | 2.1          | 0.1     | 1           |
| Aquatic Sedge Marsh                                    | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 0             | 8.3          | 3.5     | 30          |
| Aquatic Sedge with Deep Polygons                       | 100.0      | 2.5              | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 50.0          | 31.3         | 7.0     | 61          |
| Aquatic Grass Marsh                                    | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 0             | 0             | 0            | 1.8     | 16          |
| Nonpatterned Wet Meadow                                | 0          | 7.5              | 100            | 3.6              | 0              | 44.4              | 33.3         | 10               | 40                 | 100             | 0             | 0             | 10.4         | 9.8     | 85          |
| Patterned Wet Meadow                                   | 0          | 52.5             | 0              | 67.3             | 50             | 44.4              | 33.3         | 90               | 60                 | 0               | 18.8          | 0             | 22.9         | 51.7    | 449         |
| Moist Sedge-Shrub Meadow                               | 0          | 15.0             | 0              | 21.8             | 50             | 0                 | 33.3         | 0                | 0                  | 0               | 0             | 0             | 0            | 9.1     | 79          |
| Riverine or Upland Shrub                               | 0          | 0                | 0              | 5.5              | 0              | 11.1              | 0            | 0                | 0                  | 0               | 0             | 0             | 0            | 1.7     | 15          |
| Barrens (riverine, eolian, or lacustrine)              | 0          | 0                | 0              | 0                | 0              | 0                 | 0            | 0                | 0                  | 0               | 12.5          | 0             | 0            | 0.2     | 2           |
| Total  | 100        | 100              | 100            | 100              | 100            | 100               | 100          | 100              | 100                | 100             | 100           | 100           | 100          | 100     | 869         |
| Total Nests  | 1          | 40               | 1              | 55               | 2              | 9                 | 3            | 10               | 5                  | 1               | 16            | 2             | 48           | 869     |             |

Appendix G4. Habitat selection by Greater White-fronted Geese during nesting in the common search area in the Alpine project area, Colville River Delta, Alaska, 1996, 1997, 1998, 1999, and 2000.

| Year/Habitat   | Area (km <sup>2</sup> ) | No. of Nests | Use (%) | Availability (%) | Monte Carlo Results <sup>a</sup> |
|--|-------------------------|--------------|---------|------------------|----------------------------------|
| 1996   |                         |              |         |                  |                                  |
| Tapped Lake with Low-water Connection                  | 0.28                    | 0            | 0       | 2.6              | ns                               |
| Tapped Lake with High-water Connection                 | 0.80                    | 0            | 0       | 7.6              | ns                               |
| Salt Marsh   | 0.62                    | 0            | 0       | 5.8              | ns                               |
| Deep Open Water without Islands                        | 0.90                    | 0            | 0       | 8.5              | ns                               |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                    | 0            | 0       | 0.9              | ns                               |
| Shallow Open Water without Islands                     | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                    | 0            | 0       | 0.1              | ns                               |
| River or Stream  | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Aquatic Sedge Marsh                                    | 0.08                    | 0            | 0       | 0.8              | ns                               |
| Aquatic Sedge with Deep Polygons                       | 0.12                    | 2            | 8.0     | 1.1              | prefer                           |
| Aquatic Grass Marsh                                    | 0.10                    | 0            | 0       | 1.0              | ns                               |
| Nonpatterned Wet Meadow                                | 0.97                    | 0            | 0       | 9.1              | ns                               |
| Patterned Wet Meadow                                   | 4.57                    | 18           | 72.0    | 42.9             | prefer                           |
| Moist Sedge-Shrub Meadow                               | 1.27                    | 5            | 20      | 12.0             | ns                               |
| Riverine or Upland Shrub                               | 0.64                    | 0            | 0       | 6.0              | ns                               |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                    | 0            | 0       | 1.7              | ns                               |
| Artificial (water, fill, peat road)                    | 0                       | -            | -       | 0                | -                                |
| Total  | 10.64                   | 25           | 100     | 100              |                                  |
| 1997   |                         |              |         |                  |                                  |
| Tapped Lake with Low-water Connection                  | 0.28                    | 0            | 0       | 2.6              | ns                               |
| Tapped Lake with High-water Connection                 | 0.80                    | 0            | 0       | 7.6              | ns                               |
| Salt Marsh   | 0.62                    | 0            | 0       | 5.8              | ns                               |
| Deep Open Water without Islands                        | 0.90                    | 0            | 0       | 8.5              | ns                               |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                    | 1            | 2.9     | 0.9              | ns                               |
| Shallow Open Water without Islands                     | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                    | 0            | 0       | 0.1              | ns                               |
| River or Stream  | <0.01                   | 0            | 0       | <0.1             | ns                               |
| Aquatic Sedge Marsh                                    | 0.08                    | 0            | 0       | 0.8              | ns                               |
| Aquatic Sedge with Deep Polygons                       | 0.12                    | 1            | 2.9     | 1.1              | ns                               |
| Aquatic Grass Marsh                                    | 0.10                    | 0            | 0       | 1.0              | ns                               |
| Nonpatterned Wet Meadow                                | 0.97                    | 0            | 0       | 9.1              | ns                               |
| Patterned Wet Meadow                                   | 4.57                    | 29           | 82.9    | 42.9             | prefer                           |
| Moist Sedge-Shrub Meadow                               | 1.27                    | 3            | 8.6     | 12.0             | ns                               |
| Riverine or Upland Shrub                               | 0.64                    | 1            | 2.9     | 6.0              | ns                               |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                    | 0            | 0       | 1.7              | ns                               |
| Artificial (water, fill, peat road)                    | 0                       | -            | -       | 0                | -                                |
| Total  | 10.64                   | 35           | 100     | 100              |                                  |

## Appendix G4 Continued.

| Year/Habitat   | Area<br>(km <sup>2</sup> ) | No. of<br>Nests | Use (%) | Availability<br>(%) | Monte Carlo<br>Results <sup>a</sup> |
|--|----------------------------|-----------------|---------|---------------------|-------------------------------------|
| 1998   |                            |                 |         |                     |                                     |
| Tapped Lake with Low-water Connection                  | 0.28                       | 0               | 0       | 2.6                 | ns                                  |
| Tapped Lake with High-water Connection                 | 0.80                       | 0               | 0       | 7.6                 | ns                                  |
| Salt Marsh   | 0.62                       | 0               | 0       | 5.8                 | ns                                  |
| Deep Open Water without Islands                        | 0.90                       | 0               | 0       | 8.5                 | ns                                  |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                       | 0               | 0       | 0.9                 | ns                                  |
| Shallow Open Water without Islands                     | <0.01                      | 0               | 0       | <0.1                | ns                                  |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                       | 0               | 0       | 0.1                 | ns                                  |
| River or Stream  | <0.01                      | 0               | 0       | <0.1                | ns                                  |
| Aquatic Sedge Marsh                                    | 0.08                       | 0               | 0       | 0.8                 | ns                                  |
| Aquatic Sedge with Deep Polygons                       | 0.12                       | 2               | 6.3     | 1.1                 | ns                                  |
| Aquatic Grass Marsh                                    | 0.10                       | 0               | 0       | 1.0                 | ns                                  |
| Nonpatterned Wet Meadow                                | 0.97                       | 1               | 3.1     | 9.1                 | ns                                  |
| Patterned Wet Meadow                                   | 4.46                       | 25              | 78.1    | 41.9                | prefer                              |
| Moist Sedge-Shrub Meadow                               | 1.17                       | 4               | 12.5    | 11.0                | ns                                  |
| Riverine or Upland Shrub                               | 0.63                       | 0               | 0       | 5.9                 | ns                                  |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                       | 0               | 0       | 1.7                 | ns                                  |
| Artificial (water, fill, peat road)                    | 0.22                       | 0               | 0       | 2.1                 | ns                                  |
| Total  | 10.64                      | 32              | 100     | 100                 |                                     |
| 1999   |                            |                 |         |                     |                                     |
| Tapped Lake with Low-water Connection                  | 0.28                       | 0               | 0       | 2.6                 | ns                                  |
| Tapped Lake with High-water Connection                 | 0.80                       | 0               | 0       | 7.6                 | avoid                               |
| Salt Marsh   | 0.62                       | 1               | 1.9     | 5.8                 | ns                                  |
| Deep Open Water without Islands                        | 0.90                       | 0               | 0       | 8.5                 | avoid                               |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                       | 0               | 0       | 0.9                 | ns                                  |
| Shallow Open Water without Islands                     | <0.01                      | 0               | 0       | <0.1                | ns                                  |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                       | 0               | 0       | 0.1                 | ns                                  |
| River or Stream  | <0.01                      | 0               | 0       | <0.1                | ns                                  |
| Aquatic Sedge Marsh                                    | 0.08                       | 0               | 0       | 0.8                 | ns                                  |
| Aquatic Sedge with Deep Polygons                       | 0.12                       | 4               | 7.5     | 1.1                 | prefer                              |
| Aquatic Grass Marsh                                    | 0.10                       | 0               | 0       | 1.0                 | ns                                  |
| Nonpatterned Wet Meadow                                | 0.96                       | 3               | 5.7     | 9.0                 | ns                                  |
| Patterned Wet Meadow                                   | 4.39                       | 34              | 64.2    | 41.2                | prefer                              |
| Moist Sedge-Shrub Meadow                               | 1.16                       | 9               | 17.0    | 10.9                | ns                                  |
| Riverine or Upland Shrub                               | 0.63                       | 2               | 3.8     | 5.9                 | ns                                  |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                       | 0               | 0       | 1.7                 | ns                                  |
| Artificial (water, fill, peat road)                    | 0.31                       | 0               | 0       | 2.9                 | ns                                  |
| Total  | 10.64                      | 53              | 100     | 100                 |                                     |

## Appendix G4. Continued.

| Year/Habitat   | Area<br>(km <sup>2</sup> ) | No. of<br>Nests | Use (%) | Availability<br>(%) | Monte Carlo<br>Results <sup>a</sup> |
|--|----------------------------|-----------------|---------|---------------------|-------------------------------------|
| 2000   |                            |                 |         |                     |                                     |
| Tapped Lake with Low-water Connection                  | 0.28                       | 0               | 0       | 2.6                 | ns                                  |
| Tapped Lake with High-water Connection                 | 0.80                       | 0               | 0       | 7.6                 | ns                                  |
| Salt Marsh   | 0.62                       | 0               | 0       | 5.8                 | ns                                  |
| Deep Open Water without Islands                        | 0.90                       | 0               | 0       | 8.5                 | ns                                  |
| Deep Open Water with Islands or Polygonized Margins    | 0.10                       | 0               | 0       | 0.9                 | ns                                  |
| Shallow Open Water without Islands                     | <0.01                      | 0               | 0       | 0                   | ns                                  |
| Shallow Open Water with Islands or Polygonized Margins | 0.01                       | 0               | 0       | 0.1                 | ns                                  |
| River or Stream  | <0.01                      | 0               | 0       | <0.1                | ns                                  |
| Aquatic Sedge Marsh                                    | 0.08                       | 0               | 0       | 0.8                 | ns                                  |
| Aquatic Sedge with Deep Polygons                       | 0.12                       | 3               | 7.7     | 1.1                 | prefer                              |
| Aquatic Grass Marsh                                    | 0.10                       | 0               | 0       | 1.0                 | ns                                  |
| Nonpatterned Wet Meadow                                | 0.96                       | 0               | 0       | 9.0                 | avoid                               |
| Patterned Wet Meadow                                   | 4.39                       | 28              | 71.8    | 41.2                | prefer                              |
| Moist Sedge-Shrub Meadow                               | 1.16                       | 8               | 20.5    | 10.9                | ns                                  |
| Riverine or Upland Shrub                               | 0.63                       | 0               | 0       | 5.9                 | ns                                  |
| Barrens (riverine, eolian, lacustrine)                 | 0.18                       | 0               | 0       | 1.7                 | ns                                  |
| Artificial (water, fill, peat road)                    | 0.31                       | 0               | 0       | 2.9                 | ns                                  |
| Total  | 10.64                      | 39              | 100     | 100                 |                                     |

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

Appendix H1. Frequency and length of nesting activities of an incubating White-fronted Goose at nest 007 monitored by a video camera at 1-min intervals and thermistored egg at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 2001.

| Date                 | Day Before Hatch | Video Camera         |     |         |     |       |        |                          |     |       |            |                              |                       | Thermistored Egg     |           |            |                          |        |        |           |                              |     |        |     |      |
|----------------------|------------------|----------------------|-----|---------|-----|-------|--------|--------------------------|-----|-------|------------|------------------------------|-----------------------|----------------------|-----------|------------|--------------------------|--------|--------|-----------|------------------------------|-----|--------|-----|------|
|                      |                  | On Nest <sup>a</sup> |     |         |     |       |        | Recesses                 |     |       |            |                              |                       | On Nest <sup>a</sup> |           |            |                          |        |        | Recesses  |                              |     |        |     |      |
|                      |                  | Breaks               |     | Defense |     | Total |        | Incubation Constancy (%) | No. | Nest  | Total Min. | Total Monitored <sup>b</sup> | Normal Incubation Min | No. of Breaks        | Total Min | Total Nest | Incubation Constancy (%) | No.    | Nest   | Total Min | Total Monitored <sup>b</sup> |     |        |     |      |
|                      |                  | No.                  | Min | No.     | Min | Min.  | Nest   |                          |     |       |            |                              |                       |                      |           |            |                          |        |        |           |                              | Min | Nest   | Min | Nest |
| 13 June <sup>e</sup> | 24               | -                    | -   | -       | -   | -     | -      | -                        | -   | -     | -          | 200                          | 5                     | 225                  | -         | -          | -                        | -      | -      | -         | -                            | 0   | 0      | 225 |      |
| 14 June <sup>d</sup> | 23               | 505                  | 3   | 5       | 0   | 0     | 0      | 510                      | -   | 510   | 1,300      | 6                            | 1,330                 | 1,340                | 99.3      | 1          | 10                       | 1,340  | 1,340  | 1,340     | 1                            | 10  | 1,340  |     |      |
| 15 June              | 22               | 1,306                | 32  | 43      | 1   | 1     | 1,350  | 93.8                     | 90  | 1,440 | 1,325      | 8                            | 1,365                 | 1,440                | 94.8      | 7          | 75                       | 1,440  | 1,440  | 1,440     | 7                            | 75  | 1,440  |     |      |
| 16 June <sup>e</sup> | 21               | 710                  | 12  | 14      | 0   | 0     | 724    | 94.6                     | 1   | 41    | 830        | 5                            | 855                   | 855                  | 100       | 0          | 0                        | 855    | 855    | 855       | 0                            | 0   | 855    |     |      |
| 17 June              | 20               | 1,386                | 27  | 37      | 0   | 0     | 1,423  | 98.8                     | 1   | 17    | 1,375      | 9                            | 1,420                 | 1,440                | 98.6      | 1          | 20                       | 1,440  | 1,440  | 1,440     | 1                            | 20  | 1,440  |     |      |
| 18 June              | 19               | 1,325                | 21  | 28      | 0   | 0     | 1,353  | 98.5                     | 1   | 20    | 1,310      | 8                            | 1,350                 | 1,370                | 98.5      | 1          | 20                       | 1,370  | 1,370  | 1,370     | 1                            | 20  | 1,370  |     |      |
| 19 June              | 18               | 1,376                | 25  | 31      | 0   | 0     | 1,407  | 97.7                     | 3   | 33    | 1,385      | 5                            | 1,410                 | 1,440                | 97.9      | 2          | 30                       | 1,440  | 1,440  | 1,440     | 2                            | 30  | 1,440  |     |      |
| 20 June              | 17               | 1,414                | 19  | 26      | 0   | 0     | 1,440  | 100                      | 0   | 0     | 1,420      | 4                            | 1,440                 | 1,440                | 100       | 0          | 0                        | 1,440  | 1,440  | 1,440     | 0                            | 0   | 1,440  |     |      |
| 21 June              | 16               | 1,389                | 24  | 36      | 0   | 0     | 1,425  | 99.0                     | 1   | 15    | 1,385      | 8                            | 1,425                 | 1,440                | 99.0      | 1          | 15                       | 1,440  | 1,440  | 1,440     | 1                            | 15  | 1,440  |     |      |
| 22 June              | 15               | 1,363                | 31  | 42      | 0   | 0     | 1,405  | 97.6                     | 2   | 35    | 1,355      | 10                           | 1,405                 | 1,440                | 97.6      | 2          | 35                       | 1,440  | 1,440  | 1,440     | 2                            | 35  | 1,440  |     |      |
| 23 June              | 14               | 1,289                | 31  | 41      | 0   | 0     | 1,330  | 97.2                     | 2   | 38    | 1,295      | 7                            | 1,330                 | 1,365                | 97.4      | 2          | 35                       | 1,365  | 1,365  | 1,365     | 2                            | 35  | 1,365  |     |      |
| 24 June              | 13               | 1,369                | 28  | 36      | 1   | 1     | 1,406  | 97.6                     | 2   | 34    | 1,370      | 8                            | 1,410                 | 1,440                | 97.9      | 2          | 30                       | 1,440  | 1,440  | 1,440     | 2                            | 30  | 1,440  |     |      |
| 25 June              | 12               | 1,298                | 24  | 31      | 0   | 0     | 1,329  | 99.0                     | 1   | 14    | 1,285      | 8                            | 1,325                 | 1,345                | 98.5      | 1          | 20                       | 1,345  | 1,345  | 1,345     | 1                            | 20  | 1,345  |     |      |
| 26 June              | 11               | 1,413                | 20  | 26      | 1   | 1     | 1,440  | 100                      | 0   | 0     | 1,430      | 2                            | 1,440                 | 1,440                | 100       | 0          | 0                        | 1,440  | 1,440  | 1,440     | 0                            | 0   | 1,440  |     |      |
| 27 June              | 10               | 1,389                | 28  | 37      | 0   | 0     | 1,426  | 99.0                     | 2   | 14    | 1,390      | 6                            | 1,420                 | 1,440                | 98.6      | 2          | 20                       | 1,440  | 1,440  | 1,440     | 2                            | 20  | 1,440  |     |      |
| 28 June              | 9                | 1,301                | 28  | 40      | 0   | 0     | 1,341  | 97.7                     | 2   | 31    | 1,330      | 1                            | 1,335                 | 1,370                | 97.4      | 2          | 35                       | 1,370  | 1,370  | 1,370     | 2                            | 35  | 1,370  |     |      |
| 29 June              | 8                | 1,391                | 24  | 31      | 0   | 0     | 1,422  | 98.8                     | 1   | 18    | 1,390      | 7                            | 1,425                 | 1,440                | 99.0      | 1          | 15                       | 1,440  | 1,440  | 1,440     | 1                            | 15  | 1,440  |     |      |
| 30 June              | 7                | 1,296                | 30  | 40      | 0   | 0     | 1,336  | 92.8                     | 7   | 104   | 1,300      | 13                           | 1,365                 | 1,440                | 94.8      | 5          | 75                       | 1,440  | 1,440  | 1,440     | 5                            | 75  | 1,440  |     |      |
| 01 July              | 6                | 1,357                | 34  | 43      | 0   | 0     | 1,400  | 97.2                     | 3   | 40    | 1,360      | 8                            | 1,400                 | 1,440                | 97.2      | 3          | 40                       | 1,440  | 1,440  | 1,440     | 3                            | 40  | 1,440  |     |      |
| 02 July              | 5                | 1,362                | 42  | 44      | 0   | 0     | 1,406  | 97.6                     | 2   | 34    | 1,410      | 0                            | 1,410                 | 1,440                | 97.9      | 2          | 30                       | 1,440  | 1,440  | 1,440     | 2                            | 30  | 1,440  |     |      |
| 03 July              | 4                | 1,290                | 31  | 36      | 1   | 5     | 1,331  | 97.2                     | 2   | 38    | 1,320      | 2                            | 1,330                 | 1,365                | 97.4      | 2          | 35                       | 1,365  | 1,365  | 1,365     | 2                            | 35  | 1,365  |     |      |
| 04 July              | 3                | 1,431                | 8   | 9       | 0   | 0     | 1,440  | 100                      | 0   | 0     | 1,425      | 3                            | 1,440                 | 1,440                | 100       | 0          | 0                        | 1,440  | 1,440  | 1,440     | 0                            | 0   | 1,440  |     |      |
| 05 July              | 2                | 1,294                | 21  | 25      | 0   | 0     | 1,319  | 95.4                     | 5   | 63    | 1,295      | 6                            | 1,325                 | 1,385                | 95.7      | 5          | 60                       | 1,385  | 1,385  | 1,385     | 5                            | 60  | 1,385  |     |      |
| 06 July              | 1                | 1,395                | 29  | 33      | 0   | 0     | 1,428  | 99.2                     | 1   | 12    | 1,385      | 8                            | 1,425                 | 1,440                | 99.0      | 1          | 15                       | 1,440  | 1,440  | 1,440     | 1                            | 15  | 1,440  |     |      |
| 07 July              | Hatch            |                      |     |         |     |       |        |                          |     |       |            |                              |                       |                      |           |            |                          |        |        |           |                              |     |        |     |      |
| Total <sup>f</sup>   |                  | 28,434               | 557 | 715     | 4   | 8     | 29,157 | -                        | 47  | 650   | 28,540     | 131                          | 29,195                | 29,800               | -         | 42         | 605                      | 29,800 | 29,800 | 29,800    | 42                           | 605 | 29,800 |     |      |
| Mean <sup>f</sup>    |                  | 1,354                | 26  | 34      | <1  | <1    | 1,388  | 97.8                     | 2   | 31    | 1,419      | 6                            | 1,390                 | 1,419                | 98.0      | 2          | 29                       | 1,419  | 1,419  | 1,419     | 2                            | 29  | 1,419  |     |      |

Appendix H2. Frequency and length of nesting activities of an incubating White-fronted Goose at nest 1001 monitored by a video camera at 1-min intervals and thermistored egg at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 2001.

| Date                 | Day Before Hatch | Video Camera          |            |             |     |                    |                            |          |         |                                   |                       |            |                            | Thermistored Egg     |         |                                  |                       |            |                            |                   |         |                                  |        |   |
|----------------------|------------------|-----------------------|------------|-------------|-----|--------------------|----------------------------|----------|---------|-----------------------------------|-----------------------|------------|----------------------------|----------------------|---------|----------------------------------|-----------------------|------------|----------------------------|-------------------|---------|----------------------------------|--------|---|
|                      |                  | On Nest <sup>a</sup>  |            |             |     |                    |                            | Recesses |         |                                   |                       |            |                            | On Nest <sup>a</sup> |         |                                  | Recesses              |            |                            |                   |         |                                  |        |   |
|                      |                  | Normal Incubation Min | Breaks No. | Defense No. | Min | Total Min. on Nest | Incubation Consistency (%) | No.      | Min off | Total Min. Monitored <sup>b</sup> | Normal Incubation Min | Breaks No. | Incubation Consistency (%) | Total Min on Nest    | Min off | Total Min Monitored <sup>b</sup> | Normal Incubation Min | Breaks No. | Incubation Consistency (%) | Total Min on Nest | Min off | Total Min Monitored <sup>b</sup> |        |   |
| 13 June <sup>e</sup> | 23               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 490                              | 10                    | 540        | -                          | 0                 | 0       | 0                                | 540    |   |
| 14 June              | 22               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,345                            | 16                    | 1,425      | 99.0                       | 2                 | 15      | 0                                | 1,440  |   |
| 15 June              | 21               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,330                            | 20                    | 1,430      | 99.3                       | 1                 | 10      | 0                                | 1,440  |   |
| 16 June              | 20               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,335                            | 18                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 17 June              | 19               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,335                            | 18                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 18 June              | 18               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,330                            | 20                    | 1,430      | 99.3                       | 1                 | 10      | 0                                | 1,440  |   |
| 19 June              | 17               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,325                            | 18                    | 1,415      | 98.3                       | 2                 | 25      | 0                                | 1,440  |   |
| 20 June              | 16               | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | 1,380                            | 12                    | 1,440      | 100                        | 0                 | 0       | 0                                | 1,440  |   |
| 21 June <sup>d</sup> | 15               | 708                   | 10         | 19          | 0   | 0                  | 0                          | 727      | -       | -                                 | -                     | 37         | 764                        | -                    | -       | 1,240                            | 14                    | 1,310      | 97.4                       | 1                 | 35      | 0                                | 1,345  |   |
| 22 June              | 14               | 1,392                 | 26         | 35          | 0   | 0                  | 0                          | 1,427    | 99.1    | 1                                 | 13                    | 1,440      | 1,440                      | 13                   | 1,440   | 1,335                            | 18                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 23 June <sup>e</sup> | 13               | 1,149                 | 20         | 34          | 0   | 0                  | 0                          | 1,183    | 100     | 0                                 | 0                     | 1,183      | 1,183                      | 0                    | 0       | 1,115                            | 15                    | 1,190      | 100                        | 0                 | 0       | 0                                | 1,190  |   |
| 24 June              | 12               | 1,384                 | 29         | 47          | 0   | 0                  | 0                          | 1,431    | 99.4    | 1                                 | 9                     | 1,440      | 1,440                      | 1                    | 9       | 1,335                            | 18                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 25 June              | 11               | 1,395                 | 23         | 32          | 0   | 0                  | 0                          | 1,427    | 99.1    | 1                                 | 13                    | 1,440      | 1,440                      | 1                    | 13      | 1,350                            | 14                    | 1,420      | 98.6                       | 1                 | 20      | 0                                | 1,440  |   |
| 26 June              | 10               | 1,402                 | 25         | 38          | 0   | 0                  | 0                          | 1,425    | 100     | 0                                 | 0                     | 1,440      | 1,440                      | 0                    | 0       | 1,375                            | 13                    | 1,440      | 100                        | 0                 | 0       | 0                                | 1,440  |   |
| 27 June              | 9                | 1,379                 | 28         | 46          | 0   | 0                  | 0                          | 1,425    | 99.0    | 1                                 | 15                    | 1,440      | 1,440                      | 1                    | 15      | 1,305                            | 12                    | 1,365      | 100                        | 0                 | 0       | 0                                | 1,365  |   |
| 28 June              | 8                | 1,279                 | 21         | 31          | 0   | 0                  | 0                          | 1,310    | 100     | 0                                 | 0                     | 1,310      | 1,310                      | 0                    | 0       | 1,340                            | 16                    | 1,420      | 98.6                       | 2                 | 20      | 0                                | 1,440  |   |
| 29 June              | 7                | 1,385                 | 22         | 37          | 0   | 0                  | 0                          | 1,422    | 98.8    | 2                                 | 18                    | 1,440      | 1,440                      | 2                    | 18      | 1,340                            | 17                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 30 June              | 6                | 1,382                 | 25         | 46          | 0   | 0                  | 0                          | 1,428    | 99.2    | 1                                 | 12                    | 1,440      | 1,440                      | 1                    | 12      | 1,355                            | 14                    | 1,425      | 99.0                       | 1                 | 15      | 0                                | 1,440  |   |
| 01 July              | 5                | 1,388                 | 25         | 35          | 0   | 0                  | 0                          | 1,423    | 98.8    | 1                                 | 17                    | 1,440      | 1,440                      | 1                    | 17      | 1,360                            | 12                    | 1,420      | 98.6                       | 1                 | 20      | 0                                | 1,440  |   |
| 02 July              | 4                | 1,353                 | 48         | 73          | 1   | 1                  | 1                          | 1,427    | 99.1    | 1                                 | 13                    | 1,440      | 1,440                      | 1                    | 13      | 1,295                            | 12                    | 1,355      | 100                        | 0                 | 0       | 0                                | 1,375  |   |
| 03 July              | 3                | 1,319                 | 30         | 42          | 0   | 0                  | 0                          | 1,361    | 99.1    | 1                                 | 12                    | 1,373      | 1,373                      | 0                    | 0       | 1,400                            | 8                     | 1,440      | 100                        | 0                 | 0       | 0                                | 1,440  |   |
| 04 July              | 2                | 1,333                 | 14         | 22          | 0   | 0                  | 0                          | 1,355    | 100     | 0                                 | 0                     | 1,355      | 1,355                      | 0                    | 0       | 1,330                            | 20                    | 1,430      | 99.3                       | 1                 | 10      | 0                                | 1,440  |   |
| 05 July              | 1                | 1,393                 | 25         | 35          | 0   | 0                  | 0                          | 1,428    | 99.2    | 1                                 | 12                    | 1,440      | 1,440                      | 1                    | 12      | 1,330                            | 20                    | 1,430      | 99.3                       | 1                 | 10      | 0                                | 1,440  |   |
| 06 July              | Hatch            | -                     | -          | -           | -   | -                  | -                          | -        | -       | -                                 | -                     | -          | -                          | -                    | -       | -                                | -                     | -          | -                          | -                 | -       | -                                | -      | - |
| Total <sup>f</sup>   |                  | 17,784                | 341        | 519         | 1   | 1                  | 1                          | 18,304   | -       | 11                                | 134                   | 18,438     | 18,438                     | 11                   | 134     | 16,160                           | 166                   | 16,990     | -                          | 10                | 150     | 0                                | 17,140 |   |
| Mean <sup>f</sup>    |                  | 1,368                 | 26         | 40          | <1  | <1                 | <1                         | 1,408    | 99.3    | <1                                | 10                    | 1,418      | 1,418                      | <1                   | 10      | 1,346                            | 14                    | 1,417      | 99.1                       | <1                | 13      | 0                                | 1,429  |   |

<sup>a</sup> On-nest activities include normal incubation, breaks (nest maintenance activities) and defense bouts.

<sup>b</sup> Total min monitored excludes disturbance min.

<sup>c</sup> Day thermistored egg was deployed, data not included in summary.

<sup>d</sup> Day camera was deployed, data not included in summary.

<sup>e</sup> Disturbance by ground crews near nest for >150 min, data not included in summary.

<sup>f</sup> Includes days 1-12 and 14 before hatching.

Appendix H3. Frequency and length of nesting activities of an incubating White-fronted Goose at nest 1105 monitored by a video camera at 1-min intervals and thermistored egg at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 2001.

| Date                 | Day Before Hatch | Video Camera         |        |         |                    |                          |                    |       |     |     |         | Thermistored Egg     |        |         |                   |                          |                    |     |      |         |     |
|----------------------|------------------|----------------------|--------|---------|--------------------|--------------------------|--------------------|-------|-----|-----|---------|----------------------|--------|---------|-------------------|--------------------------|--------------------|-----|------|---------|-----|
|                      |                  | On Nest <sup>a</sup> |        |         |                    |                          | Recesses           |       |     |     |         | On Nest <sup>a</sup> |        |         |                   |                          | Recesses           |     |      |         |     |
|                      |                  | Normal Incubation    | Breaks | Defense | Total Min. on Nest | Incubation Constancy (%) | Total Min off Nest | No.   | Min | No. | Min     | Normal Incubation    | Breaks | No. of  | Total Min on Nest | Incubation Constancy (%) | Total Min off Nest | No. | Min  | No.     | Min |
| 18 June <sup>c</sup> | 21               | 148                  | 2      | 7       | 0                  | 0                        | 155                | —     | 0   | 0   | 155     | 180                  | 0      | 180     | —                 | 0                        | 180                | 1   | 15   | 195     |     |
| 19 June              | 20               | 1,355                | 28     | 80      | 0                  | 0                        | 1,435              | 99.7  | 1   | 5   | 1,440   | 1,310                | 17     | 1,395   | 96.9              | 4                        | 45                 | 4   | 45   | 1,440   |     |
| 20 June              | 19               | 1,411                | 19     | 29      | 0                  | 0                        | 1,440              | 100.0 | 0   | 0   | 1,440   | 1,395                | 9      | 1,440   | 100.0             | 0                        | 0                  | 0   | 0    | 1,440   |     |
| 21 June <sup>d</sup> | 18               | 521                  | 6      | 8       | 0                  | 0                        | 529                | —     | 0   | 0   | 529     | 1,245                | 17     | 1,330   | 97.8              | 1                        | 30                 | 1   | 30   | 1,360   |     |
| 22 June              | 17               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,380                | 12     | 1,440   | 100.0             | 0                        | 0                  | 0   | 0    | 1,440   |     |
| 23 June              | 16               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,370                | 14     | 1,440   | 100.0             | 0                        | 0                  | 0   | 0    | 1,440   |     |
| 24 June              | 15               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,265                | 14     | 1,335   | 92.7              | 4                        | 105                | 4   | 105  | 1,440   |     |
| 25 June              | 14               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,350                | 14     | 1,420   | 98.6              | 1                        | 20                 | 1   | 20   | 1,440   |     |
| 26 June              | 13               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,400                | 8      | 1,440   | 100.0             | 0                        | 0                  | 0   | 0    | 1,440   |     |
| 27 June              | 12               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,380                | 12     | 1,440   | 100.0             | 0                        | 0                  | 0   | 0    | 1,440   |     |
| 28 June              | 11               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,350                | 14     | 1,420   | 98.6              | 1                        | 20                 | 1   | 20   | 1,440   |     |
| 29 June              | 10               | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,350                | 15     | 1,425   | 99.0              | 1                        | 15                 | 1   | 15   | 1,440   |     |
| 30 June              | 9                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,320                | 16     | 1,400   | 97.2              | 2                        | 40                 | 2   | 40   | 1,440   |     |
| 01 July <sup>e</sup> | 8                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | 1,315                | 15     | 1,390   | 96.5              | 2                        | 50                 | 2   | 50   | 1,440   |     |
| 02 July              | 7                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 03 July              | 6                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 04 July              | 5                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 05 July              | 4                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 06 July              | 3                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 07 July              | 2                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 08 July              | 1                | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| 09 July              | Hatch            | —                    | —      | —       | —                  | —                        | —                  | —     | —   | —   | —       | —                    | —      | —       | —                 | —                        | —                  | —   | —    | —       |     |
| Total <sup>f</sup>   |                  | 2,766                | 47     | 109     | 0                  | 0                        | 2,875              | —     | 1   | 5   | 2,880   | 2,075                | 26     | 2,835   | —                 | 4                        | 45                 | 4   | 45   | 2,880   |     |
| Mean <sup>f</sup>    |                  | 1,383.0              | 23.5   | 54.5    | 0                  | 0                        | 1,437.5            | 99.8  | 0.5 | 2.5 | 1,440.0 | 1,352.5              | 13.0   | 1,417.5 | 98.4              | 2.0                      | 22.5               | 2.0 | 22.5 | 1,440.0 |     |

<sup>a</sup> On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts.

<sup>b</sup> Total min monitored excludes disturbance min.

<sup>c</sup> Day thermistored egg and camera were deployed, data not included in summary.

<sup>d</sup> Video coverage ends; camera is moved to different nest.

<sup>e</sup> Temperature readings from thermistored egg become unreliable.

<sup>f</sup> Includes days 19 and 20 before hatching.



Appendix H4. Frequency and length of nesting activities of an incubating White-fronted Goose at nest 1106 monitored by a video camera at 1-min intervals and thermistored egg at 5-min intervals in the Alpine project area, Colville River Delta, Alaska, 2001.

| Date                 | Day Before Hatch | Video Camera         |        |         |                    |                          |          |      |     |                    |                          | Thermistored Egg     |        |     |                   |        |          |       |        |                    |                          |       |        |     |
|----------------------|------------------|----------------------|--------|---------|--------------------|--------------------------|----------|------|-----|--------------------|--------------------------|----------------------|--------|-----|-------------------|--------|----------|-------|--------|--------------------|--------------------------|-------|--------|-----|
|                      |                  | On Nest <sup>a</sup> |        |         |                    |                          | Recesses |      |     |                    |                          | On Nest <sup>a</sup> |        |     |                   |        | Recesses |       |        |                    |                          |       |        |     |
|                      |                  | Normal Incubation    | Breaks | Defense | Total Min. on Nest | Incubation Constancy (%) | No.      | Min  | Max | Total Min. on Nest | Incubation Constancy (%) | No.                  | Min    | Max | Normal Incubation | Breaks | No.      | Min   | Max    | Total Min. on Nest | Incubation Constancy (%) | No.   | Min    | Max |
| 18 June <sup>e</sup> | 18               | 335                  | 7      | 12      | 0                  | 0                        | 347      | -    | 0   | 0                  | 0                        | 347                  | 347    | 325 | 3                 | 340    | 340      | -     | 0      | 0                  | 340                      | 0     | 0      | 340 |
| 19 June              | 17               | 1,403                | 12     | 15      | 0                  | 0                        | 1,418    | 98.5 | 1   | 22                 | 1,440                    | 1,440                | 1,355  | 12  | 1,415             | 98.3   | 1        | 25    | 1,440  | 1,440              | 1                        | 25    | 1,440  |     |
| 20 June              | 16               | 1,384                | 11     | 19      | 0                  | 0                        | 1,403    | 97.4 | 1   | 37                 | 1,440                    | 1,440                | 1,385  | 4   | 1,405             | 97.6   | 1        | 35    | 1,440  | 1,440              | 1                        | 35    | 1,440  |     |
| 21 June              | 15               | 1,249                | 9      | 13      | 0                  | 0                        | 1,262    | 97.1 | 1   | 38                 | 1,300                    | 1,300                | 1,235  | 7   | 1,270             | 97.3   | 1        | 35    | 1,305  | 1,305              | 1                        | 35    | 1,305  |     |
| 22 June              | 14               | 1,376                | 17     | 30      | 0                  | 0                        | 1,406    | 97.6 | 1   | 34                 | 1,440                    | 1,440                | 1,360  | 8   | 1,400             | 97.2   | 2        | 40    | 1,440  | 1,440              | 2                        | 40    | 1,440  |     |
| 23 June <sup>d</sup> | 13               | 1,025                | 13     | 13      | 0                  | 0                        | 1,038    | 97.2 | 1   | 30                 | 1,068                    | 1,068                | 1,030  | 5   | 1,055             | 97.2   | 1        | 30    | 1,085  | 1,085              | 1                        | 30    | 1,085  |     |
| 24 June              | 12               | 1,288                | 14     | 25      | 0                  | 0                        | 1,313    | 97.8 | 1   | 30                 | 1,343                    | 1,343                | 1,270  | 7   | 1,305             | 97.4   | 2        | 35    | 1,340  | 1,340              | 2                        | 35    | 1,340  |     |
| 25 June              | 11               | 1,259                | 30     | 43      | 0                  | 0                        | 1,302    | 90.4 | 4   | 138                | 1,440                    | 1,440                | 1,275  | 7   | 1,310             | 91.0   | 4        | 130   | 1,440  | 1,440              | 4                        | 130   | 1,440  |     |
| 26 June              | 10               | 1,348                | 12     | 14      | 0                  | 0                        | 1,362    | 94.6 | 4   | 78                 | 1,440                    | 1,440                | 1,340  | 3   | 1,355             | 94.1   | 4        | 85    | 1,440  | 1,440              | 4                        | 85    | 1,440  |     |
| 27 June              | 9                | 1,288                | 24     | 34      | 0                  | 0                        | 1,322    | 91.8 | 7   | 118                | 1,440                    | 1,440                | 1,300  | 4   | 1,320             | 91.7   | 6        | 120   | 1,440  | 1,440              | 6                        | 120   | 1,440  |     |
| 28 June              | 8                | 1,264                | 22     | 39      | 0                  | 0                        | 1,303    | 96.1 | 2   | 53                 | 1,356                    | 1,356                | 1,235  | 10  | 1,285             | 95.5   | 2        | 60    | 1,345  | 1,345              | 2                        | 60    | 1,345  |     |
| 29 June              | 7                | 1,360                | 17     | 19      | 1                  | 1                        | 1,380    | 95.8 | 3   | 60                 | 1,440                    | 1,440                | 1,340  | 7   | 1,375             | 95.5   | 3        | 65    | 1,440  | 1,440              | 3                        | 65    | 1,440  |     |
| 30 June              | 6                | 1,327                | 19     | 24      | 0                  | 0                        | 1,351    | 93.8 | 3   | 89                 | 1,440                    | 1,440                | 1,320  | 6   | 1,350             | 93.8   | 3        | 90    | 1,440  | 1,440              | 3                        | 90    | 1,440  |     |
| 01 July              | 5                | 1,269                | 24     | 34      | 0                  | 0                        | 1,303    | 90.5 | 5   | 137                | 1,440                    | 1,440                | 1,250  | 10  | 1,300             | 90.3   | 5        | 140   | 1,440  | 1,440              | 5                        | 140   | 1,440  |     |
| 02 July              | 4                | 1,234                | 38     | 59      | 0                  | 0                        | 1,293    | 89.8 | 4   | 147                | 1,440                    | 1,440                | 1,265  | 21  | 1,370             | 95.1   | 2        | 70    | 1,440  | 1,440              | 2                        | 70    | 1,440  |     |
| 03 July              | 3                | 1,197                | 26     | 35      | 0                  | 0                        | 1,232    | 93.6 | 3   | 84                 | 1,316                    | 1,316                | 1,180  | 8   | 1,220             | 93.1   | 3        | 90    | 1,310  | 1,310              | 3                        | 90    | 1,310  |     |
| 04 July              | 2                | 1,363                | 7      | 9       | 2                  | 3                        | 1,375    | 95.5 | 3   | 65                 | 1,440                    | 1,440                | 1,350  | 3   | 1,365             | 94.8   | 3        | 75    | 1,440  | 1,440              | 3                        | 75    | 1,440  |     |
| 05 July              | 1                | 1,161                | 34     | 71      | 0                  | 0                        | 1,232    | 88.3 | 5   | 163                | 1,395                    | 1,395                | 1,190  | 13  | 1,255             | 87.2   | 7        | 185   | 1,440  | 1,440              | 7                        | 185   | 1,440  |     |
| 06 July              | Hatch            | -                    | -      | -       | -                  | -                        | -        | -    | -   | -                  | -                        | -                    | -      | -   | -                 | -      | -        | -     | -      | -                  | -                        | -     | -      | -   |
| Total <sup>e</sup>   |                  | 20,770               | 316    | 483     | 3                  | 4                        | 21,257   | -    | 48  | 1,293              | 22,550                   | 22,550               | 20,650 | 130 | 21,300            | -      | 49       | 1,280 | 22,580 | 22,580             | 49                       | 1,280 | 22,580 |     |
| Mean <sup>e</sup>    |                  | 1,298                | 20     | 30      | <1                 | <1                       | 1,329    | 94.3 | 3   | 81                 | 1,409                    | 1,409                | 340    | 33  | 1,300             | 94.4   | 72       | 997   | 1,432  | 1,432              | 72                       | 997   | 1,432  |     |

<sup>a</sup> On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts.

<sup>b</sup> Total min monitored excludes disturbance min.

<sup>c</sup> Day thermistored egg and camera were deployed, data not included in summary.

<sup>d</sup> Disturbance by ground crews near nest for >150 min, data not included in summary.

<sup>e</sup> Includes days 1-12 and 14-17 before hatching.

Appendix H5. Frequency and duration of nesting activities of incubating Tundra Swans at nest 105 monitored by video camera at 1-min intervals in the Alpine project area, Colville River Delta, Alaska, 2001.

| Date                 | Day Before Hatch | On-Nest Activities <sup>a</sup> |        |     |         |     |                   | Incubation Constancy (%) | Off-Nest Activities |     |          |    | Total Min off Nest <sup>b</sup> | Total Min Monitored <sup>c</sup> |     |
|----------------------|------------------|---------------------------------|--------|-----|---------|-----|-------------------|--------------------------|---------------------|-----|----------|----|---------------------------------|----------------------------------|-----|
|                      |                  | Normal Incubation Min           | Breaks |     | Defense |     | Total Min on Nest |                          | Exchanges           |     | Recesses |    |                                 |                                  |     |
|                      |                  |                                 | No.    | Min | No.     | Min |                   | No.                      | Min                 | No. | Min      |    |                                 |                                  |     |
| 13 June <sup>d</sup> | 31               | 105                             | 2      | 2   | 1       | 1   | 108               |                          |                     | 1   | 4        | 0  | 0                               | 4                                | 112 |
| 14 June              | 30               | 1,259                           | 23     | 27  | 4       | 11  | 1,297             | 98.3                     | 6                   | 11  | 1        | 11 | 22                              | 1,319                            |     |
| 15 June              | 29               | 1,376                           | 24     | 27  | 2       | 8   | 1,411             | 98.0                     | 1                   | 2   | 1        | 27 | 29                              | 1,440                            |     |
| 16 June              | 28               | 1,412                           | 19     | 21  | 2       | 3   | 1,436             | 99.7                     | 2                   | 4   | 0        | 0  | 4                               | 1,440                            |     |
| 17 June              | 27               | 1,399                           | 24     | 33  | 1       | 1   | 1,433             | 99.5                     | 3                   | 7   | 0        | 0  | 7                               | 1,440                            |     |
| 18 June              | 26               | 1,332                           | 19     | 21  | 0       | 0   | 1,353             | 98.8                     | 3                   | 16  | 0        | 0  | 16                              | 1,369                            |     |
| 19 June              | 25               | 1,393                           | 23     | 26  | 3       | 11  | 1,430             | 99.3                     | 2                   | 10  | 0        | 0  | 10                              | 1,440                            |     |
| 20 June              | 24               | 1,406                           | 22     | 23  | 1       | 1   | 1,430             | 99.3                     | 3                   | 10  | 0        | 0  | 10                              | 1,440                            |     |
| 21 June              | 23               | 1,290                           | 18     | 18  | 1       | 3   | 1,311             | 99.4                     | 4                   | 8   | 0        | 0  | 8                               | 1,319                            |     |
| 22 June              | 22               | 1,410                           | 18     | 18  | 1       | 2   | 1,430             | 99.3                     | 4                   | 10  | 0        | 0  | 10                              | 1,440                            |     |
| 23 June <sup>e</sup> | 21               | 1,117                           | 17     | 17  | 0       | 0   | 1,134             | 99.0                     | 4                   | 9   | 1        | 3  | 12                              | 1,440                            |     |
| 24 June              | 20               | 1,403                           | 25     | 27  | 0       | 0   | 1,430             | 99.3                     | 4                   | 10  | 0        | 0  | 10                              | 1,440                            |     |
| 25 June              | 19               | 1,390                           | 26     | 28  | 1       | 1   | 1,419             | 98.5                     | 2                   | 4   | 1        | 17 | 21                              | 1,440                            |     |
| 26 June              | 18               | 1,398                           | 29     | 29  | 0       | 0   | 1,427             | 99.1                     | 4                   | 13  | 0        | 0  | 13                              | 1,440                            |     |
| 27 June              | 17               | 1,330                           | 35     | 40  | 1       | 1   | 1,371             | 99.3                     | 3                   | 9   | 0        | 0  | 9                               | 1,380                            |     |
| 28 June              | 16               | 1,254                           | 27     | 27  | 2       | 6   | 1,287             | 99.2                     | 4                   | 11  | 0        | 0  | 11                              | 1,298                            |     |
| 29 June              | 15               | 1,390                           | 27     | 31  | 1       | 2   | 1,423             | 98.8                     | 4                   | 7   | 1        | 10 | 17                              | 1,440                            |     |
| 30 June              | 14               | 1,401                           | 25     | 26  | 0       | 0   | 1,427             | 99.1                     | 4                   | 9   | 2        | 4  | 13                              | 1,440                            |     |
| 01 July              | 13               | 1,390                           | 35     | 41  | 0       | 0   | 1,431             | 99.4                     | 5                   | 9   | 0        | 0  | 9                               | 1,440                            |     |
| 02 July              | 12               | 1,357                           | 40     | 54  | 0       | 0   | 1,411             | 98.0                     | 4                   | 11  | 2        | 18 | 29                              | 1,440                            |     |
| 03 July              | 11               | 1,316                           | 39     | 45  | 1       | 1   | 1,362             | 99.6                     | 3                   | 6   | 0        | 0  | 6                               | 1,368                            |     |
| 04 July              | 10               | 1,325                           | 10     | 10  | 0       | 0   | 1,335             | 99.6                     | 4                   | 5   | 0        | 0  | 5                               | 1,340                            |     |
| 05 July              | 9                | 1,407                           | 23     | 26  | 0       | 0   | 1,433             | 99.5                     | 4                   | 7   | 0        | 0  | 7                               | 1,440                            |     |
| 06 July              | 8                | 1,407                           | 22     | 23  | 0       | 0   | 1,430             | 99.3                     | 4                   | 9   | 1        | 1  | 10                              | 1,440                            |     |
| 07 July              | 7                | 1,398                           | 31     | 36  | 0       | 0   | 1,434             | 99.6                     | 4                   | 6   | 0        | 0  | 6                               | 1,440                            |     |
| 08 July              | 6                | 1,336                           | 25     | 25  | 0       | 0   | 1,361             | 99.4                     | 2                   | 6   | 1        | 2  | 8                               | 1,369                            |     |
| 09 July              | 5                | 1,400                           | 25     | 27  | 0       | 0   | 1,427             | 99.1                     | 3                   | 8   | 1        | 5  | 13                              | 1,440                            |     |
| 10 July              | 4                | 1,392                           | 32     | 35  | 1       | 1   | 1,428             | 99.2                     | 5                   | 12  | 0        | 0  | 12                              | 1,440                            |     |
| 11 July              | 3                | 1,412                           | 18     | 18  | 1       | 2   | 1,432             | 99.4                     | 3                   | 6   | 1        | 2  | 8                               | 1,440                            |     |
| 12 July              | 2                | 1,403                           | 27     | 29  | 0       | 0   | 1,432             | 99.4                     | 4                   | 8   | 0        | 0  | 8                               | 1,440                            |     |
| 13 July              | 1                | 1,319                           | 29     | 29  | 2       | 16  | 1,364             | 99.6                     | 3                   | 5   | 0        | 0  | 5                               | 1,369                            |     |
| 14 July              | Hatch            |                                 |        |     |         |     |                   |                          |                     |     |          |    |                                 |                                  |     |
| Total <sup>f</sup>   |                  | 39,705                          | 740    | 820 | 25      | 70  | 40,595            |                          | 101                 | 239 | 12       | 97 | 336                             | 40,931                           |     |
| Mean <sup>f</sup>    |                  | 1,369                           | 26     | 28  | <1      | 2   | 1,400             | 99.2                     | 3                   | 8   | <1       | 3  | 12                              | 1,411                            |     |

<sup>a</sup> On-nest activities include normal incubation, breaks (nest maintenance activities), and defense bouts.

<sup>b</sup> Total min off nest includes exchange min and recess min.

<sup>c</sup> Total min. monitored excludes disturbance min.

<sup>d</sup> Day camera deployed, data not included in summary.

<sup>e</sup> Disturbance by ground crews near nest for > 150 min, data not included in summary.

<sup>f</sup> Includes days 1–20 and 22–30 before hatching.

Appendix II. Landforms, activity status, and number of pups counted at fox dens during 1992–2001 on the Colville River Delta and adjacent coastal plain, northern Alaska.

| Location / Species /<br>Site No. / Landform | Annual Den Status <sup>a</sup> |               |               |            |           |            |                |           |           |          |
|---|--------------------------------|---------------|---------------|------------|-----------|------------|----------------|-----------|-----------|----------|
|   | 2001                           | 2000          | 1999          | 1998       | 1997      | 1996       | 1995           | 1993      | 1992      |          |
| <b>COLVILLE DELTA</b>                       |                                |               |               |            |           |            |                |           |           |          |
| <u>Arctic Fox</u>                           |                                |               |               |            |           |            |                |           |           |          |
| 1 old dune                                  | inactive                       | inactive      | natal (8)     | natal (3)  | inactive  | natal (6)  | inactive       | natal (5) | inactive  | inactive |
| 2 old dune                                  | inactive                       | active        | inactive      | inactive   | inactive  | inactive   | natal (3)      | natal (3) | natal (2) |          |
| 10 dune/lake bank                           | inactive                       | inactive      | inactive      | inactive   | inactive  | natal (3)  | inactive       | natal (3) | --        |          |
| 11 lake bank                                | natal (2)                      | natal (3)     | inactive      | active     | natal     | natal (4)  | inactive       | inactive  | --        |          |
| 33 dune/lake bank                           | natal (3)                      | inactive      | inactive      | inactive   | inactive  | natal (6)  | natal          | inactive  | --        |          |
| 34 dune/lake bank                           | inactive                       | natal         | active        | active     | natal (3) | natal (5)  | active         | inactive  | --        |          |
| 45 dune ridge                               | inactive                       | natal (5)     | natal         | active (2) | inactive  | natal (7)  | natal (3)      | --        | --        |          |
| 54 dune mound                               | inactive                       | inactive      | inactive      | inactive   | inactive  | inactive   | inactive       | --        | --        |          |
| 58 dune/riverbank                           | active                         | inactive      | inactive      | natal (1)  | natal (4) | natal (5)  | secondary (3)  | --        | --        |          |
| 59 dune/lake bank                           | inactive                       | inactive      | inactive      | nc         | nc        | inactive   | inactive       | --        | --        |          |
| 61 low ridge                                | natal (4)                      | inactive      | secondary (4) | natal (3)  | active    | active (5) | secondary? (1) | --        | --        |          |
| 62 low dune ridge                           | active (1?)                    | natal (5)     | natal (2)     | inactive   | natal (5) | natal (6)  | --             | --        | --        |          |
| 76 low mound                                | inactive                       | inactive      | inactive      | active     | inactive  | --         | --             | --        | --        |          |
| 102 low mound                               | inactive                       | --            | --            | --         | --        | --         | --             | --        | --        |          |
| 103 old lake bank                           | active?                        | --            | --            | --         | --        | --         | --             | --        | --        |          |
| <u>Red Fox</u>                              |                                |               |               |            |           |            |                |           |           |          |
| 26 <sup>b</sup> dune/lake bank              | inactive                       | inactive      | inactive      | inactive   | inactive  | inactive   | inactive       | inactive  | --        |          |
| 48 sand dune                                | natal (2)                      | inactive      | inactive      | active     | inactive  | inactive   | natal          | --        | --        |          |
| 49 sand dune                                | natal (3)                      | inactive      | natal (2)     | natal (2)  | active    | natal (2)  | active         | --        | --        |          |
| 55 dune/riverbank                           | active                         | natal (4)     | active        | active     | inactive  | natal (1)  | natal (5)      | --        | --        |          |
| 60 sand dune                                | inactive                       | natal (1)     | natal (2)     | natal (6)  | active    | natal (5)  | natal (2)      | --        | --        |          |
| 73 sand dune                                | inactive                       | inactive      | inactive      | inactive   | inactive  | nc         | --             | --        | --        |          |
| 82 <sup>b</sup> sand dune                   | active                         | secondary (2) | inactive      | inactive   | --        | --         | --             | --        | --        |          |
| 87 sand dune                                | inactive                       | natal         | --            | --         | --        | --         | --             | --        | --        |          |
| <b>TRANSPORTATION CORRIDOR</b>              |                                |               |               |            |           |            |                |           |           |          |
| <u>Arctic Fox</u>                           |                                |               |               |            |           |            |                |           |           |          |
| 4 pingo                                     | natal (3)                      | inactive      | natal (8)     | inactive   | inactive  | natal (2)  | active         | inactive  | --        |          |
| 35 drained-lake bank                        | inactive                       | inactive      | inactive      | inactive   | inactive  | inactive   | inactive       | inactive  | --        |          |
| 36 pingo                                    | inactive                       | inactive      | inactive      | inactive   | inactive  | inactive   | inactive       | inactive  | --        |          |
| 37 lake bank                                | inactive                       | inactive      | inactive      | inactive   | inactive  | natal (2)  | natal (2)      | active    | --        |          |

Appendix II. continued.

| Location / Species /<br>Site No. / Landform      |                     | Annual Den Status <sup>a</sup> |           |           |           |            |               |           |               |      |    |  |
|--|---------------------|--------------------------------|-----------|-----------|-----------|------------|---------------|-----------|---------------|------|----|--|
|  |                     | 2001                           | 2000      | 1999      | 1998      | 1997       | 1996          | 1995      | 1993          | 1992 |    |  |
| 38   | lake bank           | inactive                       | inactive  | inactive  | inactive  | inactive   | natal (9)     | inactive  | active        | --   | -- |  |
| 43   | low ridge           | inactive                       | nc        | inactive  | nc        | inactive   | inactive      | inactive  | secondary (1) | --   | -- |  |
| 44   | low ridge           | inactive                       | nc        | inactive  | nc        | inactive   | inactive      | inactive  | secondary?    | --   | -- |  |
| 53   | drained-lake bank   | inactive                       | inactive  | inactive  | inactive  | active     | inactive      | inactive  | --            | --   | -- |  |
| 64   | lake bank           | active?                        | inactive  | inactive  | inactive  | inactive   | natal (15)    | --        | --            | --   | -- |  |
| 66   | terrace bank        | inactive                       | inactive  | inactive  | inactive  | active     | secondary (5) | --        | --            | --   | -- |  |
| 67   | low mound           | inactive                       | active?   | active    | inactive  | active     | natal (6)     | --        | --            | --   | -- |  |
| 68   | terrace bank        | inactive                       | inactive  | inactive  | inactive  | inactive   | natal (3)     | --        | --            | --   | -- |  |
| 69   | lake bank           | inactive                       | inactive  | inactive  | inactive  | inactive   | natal (2)     | --        | --            | --   | -- |  |
| 72   | drained-lake bank   | inactive                       | inactive  | inactive  | inactive  | inactive   | active (4)    | --        | --            | --   | -- |  |
| 74   | low mound           | inactive                       | inactive  | inactive  | inactive  | active     | --            | --        | --            | --   | -- |  |
| 75   | drained-lake island | inactive                       | inactive  | inactive  | inactive  | inactive   | --            | --        | --            | --   | -- |  |
| 80   | pingo ridge         | natal (2)                      | inactive  | natal (5) | inactive  | --         | --            | --        | --            | --   | -- |  |
| 81   | drained-lake bank   | natal (3)                      | inactive  | natal (5) | inactive  | --         | --            | --        | --            | --   | -- |  |
| 83   | stream bank         | inactive                       | natal (5) | natal (7) | --        | --         | --            | --        | --            | --   | -- |  |
| 91   | drained-lake island | inactive                       | --        | --        | --        | --         | --            | --        | --            | --   | -- |  |
| <u>Red Fox</u>                                   |                     |                                |           |           |           |            |               |           |               |      |    |  |
| 5 <sup>b</sup>                                   | pingo               | inactive                       | inactive  | natal (5) | inactive  | inactive   | natal         | inactive  | inactive      | --   | -- |  |
| 8 <sup>b</sup>                                   | stream bank         | active?                        | nc        | natal (4) | inactive  | inactive   | natal (2)     | natal (3) | inactive      | --   | -- |  |
| <u>NORTH OR SOUTH OF TRANSPORTATION CORRIDOR</u> |                     |                                |           |           |           |            |               |           |               |      |    |  |
| <u>Arctic Fox</u>                                |                     |                                |           |           |           |            |               |           |               |      |    |  |
| 6  | pingo               | inactive                       | inactive  | inactive  | inactive  | inactive   | natal (3)     | inactive  | inactive      | --   | -- |  |
| 7  | pingo               | inactive                       | natal (6) | inactive  | natal (3) | nc         | inactive      | natal (5) | secondary     | --   | -- |  |
| 15   | pingo               | natal (1)                      | natal (3) | inactive  | inactive  | inactive   | natal (6)     | inactive  | inactive      | --   | -- |  |
| 16   | stream bank         | inactive                       | inactive  | inactive  | inactive  | nc         | natal (1)     | inactive  | natal (3)     | --   | -- |  |
| 30   | drained-lake bank   | inactive                       | inactive  | inactive  | inactive  | inactive   | inactive      | inactive  | inactive      | --   | -- |  |
| 39   | drained-lake bank   | natal (4)                      | natal (1) | natal (7) | natal (5) | natal (6)  | natal (3)     | inactive  | active        | --   | -- |  |
| 42   | old gravel pad      | inactive                       | inactive  | nc        | inactive  | nc         | inactive      | inactive  | inactive      | --   | -- |  |
| 50   | lake bank           | natal (3)                      | natal (5) | natal (4) | natal (4) | inactive   | active        | inactive? | --            | --   | -- |  |
| 51   | stream bank         | inactive                       | inactive  | inactive  | inactive  | inactive   | inactive      | natal (3) | --            | --   | -- |  |
| 52   | stream bank         | nc                             | inactive  | inactive  | inactive  | inactive   | inactive      | inactive  | --            | --   | -- |  |
| 56   | stream bank         | inactive                       | inactive  | inactive  | inactive  | active (4) | natal (3)     | inactive  | --            | --   | -- |  |
| 57   | drained-lake bank   | natal (3)                      | inactive  | natal (1) | inactive  | nc         | natal (3)     | natal     | --            | --   | -- |  |
| 70   | drained-lake bank   | inactive                       | inactive  | natal (6) | inactive  | inactive   | active        | --        | --            | --   | -- |  |
| 71   | drained-lake bank   | inactive                       | inactive  | inactive  | inactive  | inactive   | secondary (3) | --        | --            | --   | -- |  |
| 84   | terrace bank        | inactive                       | inactive  | natal (7) | --        | --         | --            | --        | --            | --   | -- |  |

Appendix II. continued.

| Site No. / Species / Landform | Annual Den Status <sup>a</sup> |           |               |      |      |      |      |      |      |  |  |
|-------------------------------|--------------------------------|-----------|---------------|------|------|------|------|------|------|--|--|
|                               | 2001                           | 2000      | 1999          | 1998 | 1997 | 1996 | 1995 | 1993 | 1992 |  |  |
| 85 old lake shore             | natal (5)                      | natal (3) | natal (3)     | --   | --   | --   | --   | --   | --   |  |  |
| 86 peat road                  | inactive                       | inactive  | secondary (3) | --   | --   | --   | --   | --   | --   |  |  |
| 88 stream bank                | inactive                       | inactive  | --            | --   | --   | --   | --   | --   | --   |  |  |
| 89 pingo                      | natal (1)                      | active    | --            | --   | --   | --   | --   | --   | --   |  |  |
| 90 pingo                      | inactive                       | active    | --            | --   | --   | --   | --   | --   | --   |  |  |
| 92 stream bank                | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 93 stream bank                | natal (3)                      | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 94 low mound                  | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 95 lake bank                  | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 96 low mound                  | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 97 low mound                  | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 98 low mound                  | natal (1?)                     | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 99 stream bank                | active                         | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 100 stream bank               | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |
| 101 peat road                 | inactive                       | --        | --            | --   | --   | --   | --   | --   | --   |  |  |

<sup>a</sup> Numbers in parentheses indicate minimum pup count; ? indicates some uncertainty about status; "active" indicates natal vs. secondary status could not be determined; nc = not checked; dashes indicate site had not yet been found or examined.

<sup>b</sup> Den site was originally an arctic fox den that was appropriated by red foxes during the period of study.

Appendix I2. Occupancy (activity) status and litter sizes at arctic fox dens during the 1993 and 1995–2001 denning seasons on the Colville River Delta and adjacent coastal plain, Alaska.

| Den Status / Litter Size | 1993 |      | 1995 |      | 1996 |      | 1997 |      | 1998 |      | 1999 |      | 2000 |      | 2001 |      |
|--------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|                          | No.  | %    | No.  | %    | No.  | %    | No.  | %    | No.  | %    | No.  | %    | No.  | %    | No.  | %    |
| Den Status               |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Natal                    | 5    | 21.7 | 9    | 26.5 | 23   | 53.5 | 5    | 11.9 | 6    | 13.0 | 14   | 28.0 | 10   | 20.0 | 14   | 22.2 |
| Secondary                | 3    | 13.0 | 2    | 5.9  | 2    | 4.7  | --   | --   | --   | --   | 2    | 4.0  | --   | --   | --   | --   |
| Active <sup>a</sup>      | 3    | 13.0 | 2    | 5.9  | 4    | 9.3  | 6    | 14.3 | 5    | 10.9 | 2    | 4.0  | 4    | 8.0  | 4    | 6.3  |
| Inactive <sup>b</sup>    | 12   | 52.2 | 21   | 61.8 | 14   | 32.6 | 31   | 73.8 | 35   | 76.1 | 32   | 64.0 | 36   | 72.0 | 45   | 71.4 |
| Total                    | 23   |      | 34   |      | 43   |      | 42   |      | 46   |      | 50   |      | 50   |      | 63   |      |
| Litter Size <sup>c</sup> |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Pups counted             | 17   |      | 24   |      | 92   |      | 18   |      | 19   |      | 70   |      | 35   |      | 35   |      |
| Litters ( <i>n</i> )     | 5    |      | 7    |      | 15   |      | 4    |      | 6    |      | 13   |      | 8    |      | 11   |      |
| Mean litter size         | 3.40 |      | 3.43 |      | 6.13 |      | 4.50 |      | 3.17 |      | 5.38 |      | 4.38 |      | 3.18 |      |

<sup>a</sup> Dens showing regular, heavy use, but for which natal vs. secondary status or presence of pups could not be confirmed.

<sup>b</sup> Dens showing either no signs of activity or limited use by adults, but not pups.

<sup>c</sup> Litters judged to have been counted completely during den observations, eliminating duplication of litters seen at both natal and secondary sites.