FINAL REPORT

ALPINE AVIAN MONITORING PROGRAM, 1998

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EXECUTIVE SUMMARY

- The Alpine Avian Monitoring Program was initiated in 1998 with the issuance of construction permits for the Alpine Development, which stipulated that ARCO and Anadarko conduct a three-year monitoring program on the effects of airplane disturbance on waterfowl. The Alpine airstrip was in place by spring 1998, and the gravel was reworked during the summer by three to five pieces of heavy equipment. Surveyors, hydrologists, and biologists were active in the airstrip area and commuted to the site by helicopter.

- Noise levels were monitored at a site 300 m from the airstrip for three days during heavy equipment operation in June. Sound levels (L_{eq}) ranged from 43.2 to 55.1 dBA during hours when equipment was inactive and from 39.8 to 67.8 dBA during daytime hours when equipment was active. The effects of windspeed were not accounted for in noise measurements, so some of the noise levels recorded probably were elevated by wind effects.

- Nest densities of all species of large waterbirds in the area common to search areas in 1996–1998 was highest in 1997 (7.1 nests/km^2), intermediate in 1998 (6.7 nests/km^2), and lowest in 1996 (3.7 nests/km^2). Greater White-fronted Geese were the most abundant nesting birds in the area, followed by several species of ducks. Nineteen species of large birds were found nesting during 1996–1998. Nest densities in 1998 were lowest within 500 m of the airstrip, and greatest between 1,000 and 1,500 m. This distribution may be explained by the distribution of favored habitat; most nests occurred in Wet Sedge–Willow Meadow and Nonpatterned Wet Meadow, which were least abundant in the 500-m zone. The distance of nests to the airstrip location did not differ (P = 0.37) among the two years before the airstrip was in place (1996, 1997) and the year of "light" construction (1998).

- The density of Greater White-fronted Geese was highest in 1997 (3.3 nests/km^2) compared to 1998 (2.9 nests/km^2) and 1996 (2.4 nests/km^2). Although search effort increased from 1996 to 1998, the rates at which nests were found in the common ground-search area were similar among years (0.10–0.13 nests/h of searching). Greater White-fronted Geese nested in 5 of 15 habitats in the project area in 1998; they preferred Wet Sedge–Willow Meadow and avoided Nonpatterned Wet Meadow and two lake habitats. The distance of goose nests from the airstrip location did not vary (P = 0.66) among years (1996–1998).

- Similar numbers of Tundra Swan nests were found in the common ground-search area in all three years (5 nests in 1996 and 1998, 4 nests in 1997). The distance of nests to the airstrip did not differ significantly among the three years (P = 0.64). The closest nest was 159 m away in 1998 and hatched three eggs successfully despite multiple helicopter landings on the airstrip and two prolonged disturbances caused by nest searching in the vicinity.

- Baseline data on nest attendance by Greater White-fronted Geese was collected with time-lapse cameras at three nests and temperature recording eggs at 17 nests. At 16 nests that hatched successfully, geese spent 99% of the time (10 d before hatch) incubating. Recesses averaged 1.3/d, recess length averaged 13 min, and time off nest averaged 16 min/d. The female goose at the one monitored nest that failed had longer recesses, more recesses/d, and spent more time off the nest than did successful females. The failed nest was incubated until 10 July, when it was depredated, but the eggs probably were infertile. Geese that were flushed while we conducted our studies averaged 90 min off the nest (range = 15–455 min, n = 25 events), which was greater than the average recess length of non-disturbed geese.

- Two Yellow-billed Loon nests were monitored with time-lapse cameras and both failed after predation by Parasitic Jaegers. One Tundra Swan nest that was monitored with a camera also was depredated by Parasitic Jaegers. A successful Tundra Swan nest also was monitored by camera and had an average incubation constancy of 82%, took an average of 2.4 recesses/d at an average of

101 min/recess. Total time off nest averaged 246 min/d.

- Few duck nests (13% of 38 nests) were successful at hatching in 1998. The distance to the airstrip of successful and failed ducks nests was similar (P = 0.73). Of 70 Greater White-fronted Goose nests that were checked for fate, 71% hatched successfully in 1998. The distance from the airstrip of successful and failed nests was essentially identical ($\bar{x}$ = 1,366 and 1,359 m, respectively; P = 0.56). Clutch sizes of goose nests were negatively related to distance from the airstrip, but the regression explained only 7% of the variation.

- We found 196 nests of 21 species on 12 breeding-bird plots (10 ha each). The predominant species was Pectoral Sandpiper (61 nests), followed by Lapland Longspurs (49 nests), and Semipalmated Sandpipers (21 nests). The most nests were found on treatment plots with mixed habitat ($\bar{x}$ = 193 nests/km^2) and the least were found on reference plots with mixed habitat ($\bar{x}$ = 123 nests/km^2). Numbers of nests were not clearly independent of treatment and habitat condition (P = 0.053). Numbers of Pectoral Sandpiper nests were dependent on treatment and habitat condition (P = 0.02). Pectoral Sandpipers are known to have high annual variability in nesting, and it appears that 1998 was an unusually high year for Pectoral Sandpipers on the Colville delta.

- Twenty species of waterbirds were recorded on 10 aerial surveys of lakes in the Alpine project area. Ducks were the most numerous species, making up 61% of the 12,394 birds recorded on all surveys combined. The highest numbers of birds were recorded on surveys in mid-June and in August. Five lakes were used by >1,000 birds over the course of 10 surveys. All but one of these lakes were Tapped Lakes with Low-water Connection. The exception was a Deep Lake with Islands or Polygonized Margins that contained extensive areas of Aquatic Grass Marsh.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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INTRODUCTION

Oil exploration has occurred on the Colville River Delta (hereafter, the Colville Delta or the delta) intermittently over the last several decades. The Alpine development project is the first oilfield development to occur west of the Kuparuk Oilfield and the first on the Colville Delta. Abundant and rich wildlife and fish fauna inhabit the Colville Delta, providing subsistence and commercial resources that support two isolated communities: the native village of Nuiqsut and the Helmericks' family homesite. The delta is known to be 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, 1996, 1997, 1998) and fish resources (Moulton 1996, 1998), while exploring for potentially economic oil reservoirs. The physical, biological, and human resources of the delta were summarized in an environmental evaluation of the Alpine development (ARCO 1997).

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

1. to monitor noise levels of aircraft and assess possible effects on nest abundance, distribution, and fate, and the distribution of non-nesting large waterbirds (waterfowl, loons, gulls, terns, and jaegers);
2. to investigate nest abundance, distribution, and fate for large waterbirds and evaluate the relationships of these variables with distance from the airstrip;
3. to monitor a sample of nests for changes in nesting behavior that may result from disturbance from aircraft landings and takeoffs;
4. to identify changes in nest densities of all avian species on breeding-bird plots at different locations relative to the airstrip; and
5. to monitor use of nearby lakes for changes in numbers of waterbirds throughout the breeding season.

STUDY AREA

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

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

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

The completed oilfield development will include a gravel airstrip (~1.8 km long) and two gravel pads (Alpine Pad 1, a drill site and processing facility, and Alpine Pad 2, a drill site), all connected by ~3 km of gravel road (Figure 1). The total area projected to be covered with gravel fill is ~39 ha. A sales-quality pipeline will connect this development to existing infrastructure in the Kuparuk Oilfield. No all-season road is planned to access the Alpine facilities from the Kuparuk Oilfield; materials, equipment, and personnel will travel by air or, during winter, overland on ice roads.

METHODS

To achieve the objectives of identifying the effects of aircraft disturbance on avian use of the Alpine project area, we need to isolate aircraft from other forms of disturbance and compare birds exposed to aircraft with those which are not exposed. Although on the surface this would seem a simple process, in practice there are many confounding factors. To help us identify the operational effects, we incorporated elements of a before-after-control-impact design (BACI; Stewart-Oaten et al. 1986) and gradient analysis (Ellis and Schneider 1997). The BACI design calls for sampling before and after an impact in control and impacted areas; replicating these samples in the before and after periods increases our ability to detect differences. To evaluate annual variation and evaluate potential effects from the first year of construction, we compared data from 1996 and 1997 (Johnson et al. 1997, 1998) with data from the current field study. The gradient design requires sampling over some continuous measure from a point

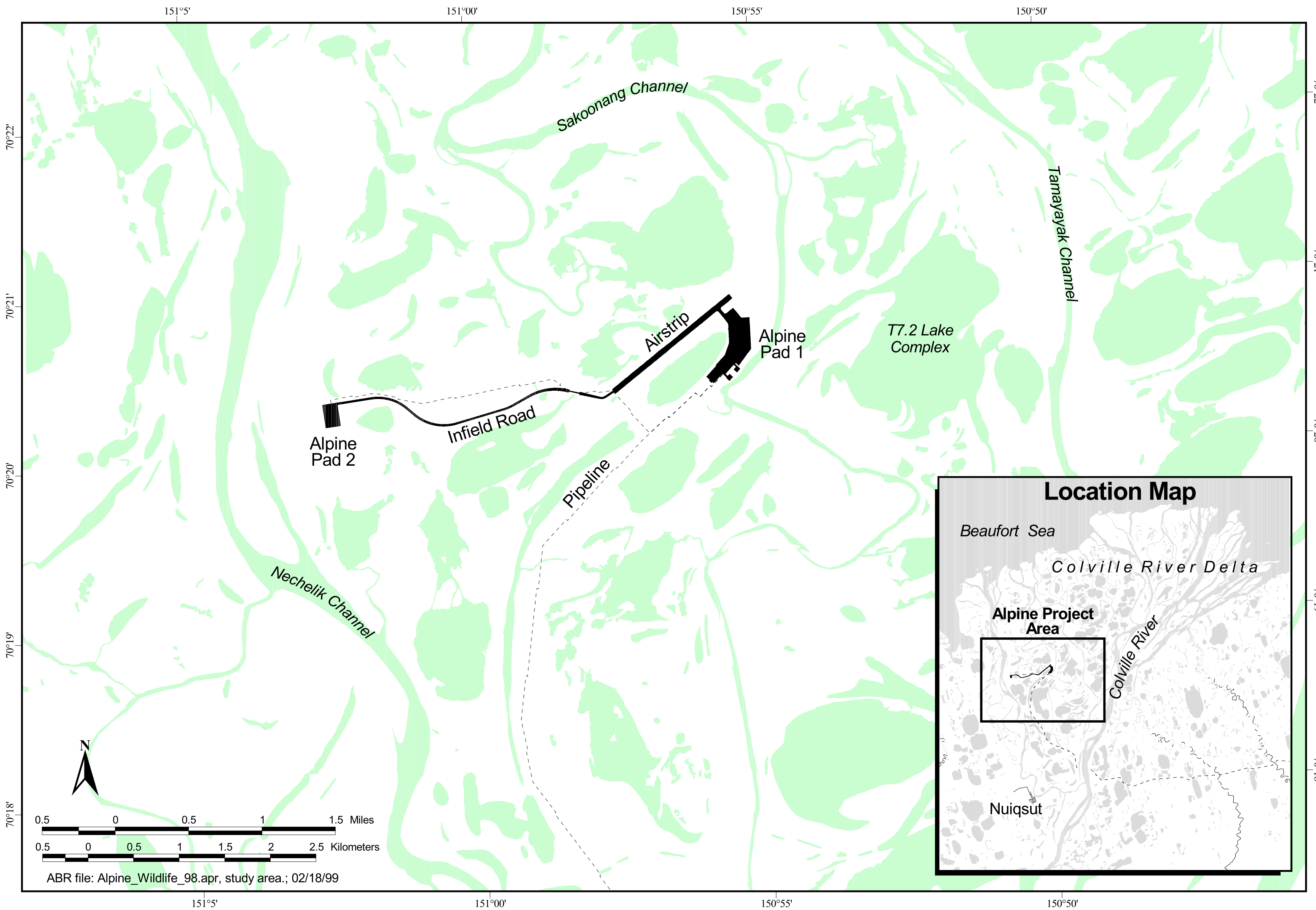

Figure 1. Study area map showing the Alpine project area, Colville River, Alaska Delta, 1998.

source, in this case, we used distance from the airstrip as the gradient. We conducted these and other analyses on data from the suite of all large, nesting waterbirds in the project area; from a single species, Greater White-fronted Goose (specifically because their nests are relatively abundant and well-distributed in the project area); and from individual nests (in evaluations of nesting behavior).

CONDITIONS IN THE STUDY AREA

We evaluated conditions in the study area to assess factors such as weather, timing of snowmelt, and human activity that could affect avian use of the Alpine project area and annual comparisons. Snow and ice conditions in the Alpine project area were monitored during aerial surveys conducted for other studies on the Colville Delta (see Johnson et al. 1999, Lawhead 1999). Several factors were used to gauge the phenological stage of the season: the date of snowmelt, the date meltwater formed on lakes, the first date of midge (Chironomidae) emergence, the first date of mosquito (*Aedes* sp.) emergence, and first dates of egg hatch for nesting birds.

Initial construction of the Alpine facilities began during winter 1998. Construction is scheduled to continue during winter-spring of 1999 with operation to begin in 2000 (Table 1). Prior to construction, surveyors, hydrologists, botanists, and wildlife biologists conducted pre-development evaluations in the project area. Because human activity has varied among the years of study, it was necessary to document the timing and extent of the disturbance each year. Human activity in the Alpine project area was not monitored directly, but was assessed from records of activities kept by the contractors and others working in the area.

NOISE MONITORING

Baseline noise conditions were monitored in the Alpine project area with a Larsen-Davis Model 870 Sound Level Meter. The sound monitor was placed 300 m from the airstrip and recorded from 10:30 on 23 June to 17:06 on 26 June, when the monitor malfunctioned and ceased recording. The sound monitor recorded the equivalent continuous sound level or L_{eq}, which is essentially an average of the acoustical energy over a stated time period; for the baseline condition, we recorded the L_{eq} over each hour. The sound level was recorded in A-weighted decibels (dBA).

Table 1. Current and projected summer construction status of Alpine development project, Colville River Delta, Alaska, 1998.

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 active	surveyors, hydrologists, biologists, operators	airstrip and Pad 1 in place	helicopter
1999	facility construction	unknown	biologists, construction workers	airstrip and pad 1 complete, pipeline in place	helicopter, Twin Otter, DC6
2000	none	unknown	biologists, oil field workers	airstrip, pad1, and pad2 operational	737, Twin Otter

HABITAT CLASSIFICATION AND MAPPING

The Alpine project area was classified and mapped for wildlife habitats as part of the Colville wildlife studies (Johnson et al. 1999). Detailed methods for the mapping and classification were presented by Johnson et al. (1996), and the accuracy of the habitat map was assessed by Jorgenson et al. (1997).

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

HABITAT SELECTION

Because the Greater White-fronted Goose (henceforth, White-fronted Goose) was a focal species in our disturbance analyses, we investigated habitat selection as one factor that could affect its nest distribution. We based the quantitative analyses of habitat selection on the locations of nests found during ground surveys each year from 1996 to 1998. We calculated percent use as the percentage of the total number of nests that were observed in each habitat. The availability of each habitat was the percentage of that habitat in the survey area

We tested for significant habitat selection (i.e., use ≠ availability) by conducting Monte Carlo simulations (Haefner 1996, Manly 1997). Each simulation used random numbers (range 0–100) to choose a habitat from the cumulative relative frequency distribution of habitat availability. The number of "random choices" in a simulation was equal to the number of nests from which percent use was calculated. We conducted 1,000 simulations and summarized the frequency distribution by percentiles. We defined habitat preference (i.e., use > availability) to occur when the observed use was greater than the 97.5 percentile of simulated random use. Conversely, we defined habitat avoidance (i.e., use < availability) to occur when the observed use was less than the 2.5 percentile of simulated random use. These percentiles were chosen to achieve an alpha level (Type I error) of 5% for a two-tailed test. Habitats with nonsignificant selection (i.e., observed use ≥2.5 and ≤97.5 percentiles) were deemed to have been used approximately in proportion to their availability. The simulations and calculations of percentiles were conducted in a Microsoft® Excel spreadsheet on a personal computer.

NEST DENSITIES AND NESTING SUCCESS

We conducted nest searches on the ground using the same techniques as were used in the Colville wildlife studies in 1996 and 1997 (Johnson et al. 1997, 1998). The survey area in 1998 was restricted to the Alpine project area near the planned gravel footprint (Figure 1). We searched on foot within 10 m of the shorelines of all waterbodies, and in all intervening habitat we searched with ~10-m spacing between observers walking zig-zag paths. Using four to nine observers, we searched for nests of all ducks, geese, Tundra Swans, loons, gulls, terns, and other large birds (including the Common Snipe and Bar-tailed Godwit). Willow and Rock ptarmigan nests were sometimes found when they flushed from their nests, but their nests were not detected consistently because their eggs were cryptic; therefore, they were not included in our analyses. For each nest, we recorded the species, distance to nearest waterbody, waterbody class, habitat type, and, if the bird flushed, the number of eggs in the nest. In 1998, we conducted two different nest searches; the first was conducted between 12 and 20 June, while the second was conducted between 21 and 28 June. In addition, some waterbird nests were located during the surveys of the breeding-bird plots and during two searches of the perimeter of a neighboring lake (T7.2 lake complex). For the purposes of annual comparisons, we used only nests found on the first nest search (12–20 June), unless specifically stated otherwise.

We mapped all nest locations on 1:18,000-scale color aerial photographs and added the locations found in 1998 to the existing GIS database containing locations found in 1992–1997. For nests of waterbirds in or near the gravel footprint of the facility, we recorded their exact locations with a GPS and differential correction. Down and feather samples were taken from all waterfowl nests found during the regular nest searches. For those nests that were unattended and could not be identified to species, the down and feather samples were used to make a preliminary identification. Eight researchers experienced with nesting tundra birds compared these unknown samples with samples from known nests and identified them to species when possible. The assessments were compiled and nest samples receiving ≥75% of the assignments to one species were so identified with the modifier "probable". All others were recorded as unidentified.

We revisited nest sites of waterbirds in the ground-search area after hatch (on 10–13 July for waterfowl, and 23, 25, and 26 August for loons) to determine their fate. Nests were classified as successful if we found egg membranes that had thickened and were detached from the eggshells, or for loons, if a brood was associated with a nest site. Any sign of predators at the nest (e.g., fox scats or scent, broken eggs with yolk or albumen) was identified and recorded. During our revisits to nests, we opportunistically recorded broods in the area on 1:18,000-scale color aerial photographs.

To facilitate comparisons of the distribution and density of nests among years, we delineated the common area that had been searched in 1996–1998 and then calculated with GIS the number of nests by species that occurred in what we henceforth refer to as the "common ground-search area". Also, we identified the nests occurring within four distance buffers (500, 1,000, 1,500, and 2,000 m) of the airstrip. The search effort was less intensive in 1995 (focusing on Spectacled Eiders, Johnson et al. 1996) than in subsequent years, so we will not discuss the results of that year's nest survey in the context of density comparisons.

Because the amount of effort (number of personnel and hours) spent searching for nests, as well as the total area searched, varied among years, we calculated a standardized value for annual comparison. We standardized nest-search effort for each year by summing the number of search-hours spent during the ground searches and dividing by the area searched (h/km^2). We calculated the number of hours spent in the common ground-search area by multiplying the total number of hours searched each year by the ratio of the common ground-search area (10.6 km^2) to each of the annual ground-search areas (17.2 km^2, 14.3 km^2, and 14.6 km^2, in 1996, 1997, and 1998, respectively). In 1998, we calculated the nest-search effort for the first nest search only.

Statistical analyses were conducted with Microsoft® Excel or SPSS (SPSS, Inc., v7.0, Chicago, IL). Variances were tested for homogeneity, distributions were evaluated for normality, and plots of residuals were reviewed prior to final analysis. We used parametric two-sample t-tests and one-way ANOVAs or their nonparametric equivalents (Mann-Whitney U or Kruskal-Wallis tests, respectively) depending on whether the data satisfied assumptions of normality and homogeneity of variance that are required for traditional parametric tests. We measured nearest neighbor distances between White-fronted Goose nests with ArcView (ESRI v1.8, Redlands, CA) and analyzed the distances for distributional patterns with a nearest-neighbor program (Clark and Evans 1954 cited in Krebs 1989).

NEST ATTENDANCE

Egg thermistors and time-lapse video cameras have been used to measure incubation constancy and to document incidences of nest predation at King and Spectacled eider nests in the Kuparuk Oilfield (Anderson et al. 1999), and time-lapse movie cameras have been used similarly for Canada and White-fronted goose nests in the Lisburne Development Area (Murphy and Anderson 1993). We used egg thermistors and time-lapse video cameras to monitor nest attendance for a sample of focal species nesting in the Alpine project area. Egg thermistors were placed only in White-fronted Goose nests, whereas cameras were placed at White-fronted Goose, Tundra Swan, and Yellow-billed Loon nests. Cameras were used to record occurrences of predation and other disturbances at nests, as well as to monitor nest attendance.

We implanted thermistors in domestic goose or large duck eggs that had the contents removed and a coating of epoxy added to the interior of the shell to strengthen the egg. To four eggs, we also filled the egg with polyurethane foam to improve structural integrity. Into each egg, we glued a temperature probe with a 6-ft lead (TMC6-HA) and connected it to a data-logger (HOBO® H8 temperature logger, Onset Computer Corp., Pocasset, MA). We glued the bottom of each egg to a plastic base attached to a large nail, which was pushed into the ground under the nest so that the egg could not be removed by a predator or rolled out of the nest by the incubating female.

We deployed the egg thermistors on the day the nest was found or shortly thereafter. Because we intend to use the nest behavior data recorded by thermistors in 1998 as a pre-operation baseline (i.e., prior to aircraft landings), we deployed egg thermistors in White-fronted Goose nests that were primarily ≥1,000 m from the airstrip, to minimize the potential effects of construction equipment operating on the airstrip in 1998. After installing an egg thermistor, we covered it and the rest of the clutch with the down and nesting material from the nest. The data-loggers were programmed to record the temperature (°C and °F) of the egg at 5-min intervals and had a storage capacity large enough to record the remaining incubation period. We programmed one data-logger to record ambient temperature in addition to nest temperature. The sensor for recording ambient temperature was housed in the data-logger. After hatch (or failure), we checked each nest to judge its fate and retrieved the egg thermistor.

We used Samsung SCF-32 video cameras controlled by a programmable electronic board (LJ&L Products, Ringgold, LA) and powered by one 12V, 33 amp-hour battery (Power Sonic PS-12330) connected to a solar battery charger (Uni-Solar MBC-262). Each unit, including the battery, was housed in a customized plastic case with a plastic window (LJ&L Products, Ringgold, LA). For deployment at the nest, we strapped the case to an aluminum sawhorse stand and secured the stand with guy lines to the surrounding tundra to stabilize the camera during windy conditions. We staked the solar battery charger to the ground near the unit.

We placed the video camera a minimum of 50 m from the nest and used the zoom lens to center the nest in a field of view approximately 5 m across at the nest site. During setup, we connected a 2.2-inch video monitor (Citizen ST055) to the video camera to act as a viewfinder for reviewing camera control features. We programmed the cameras to record 1 sec of videotape (Sony T160 or BASF T200) every minute continuously throughout the day, and set them to display the date and time on the videotape at each recording interval. The camera recorded in Alaska Daylight Time (ADT). Each videotape lasted approximately 5–7 d before it needed to be changed.

We used two White-fronted Goose nests monitored with both an egg thermistor and a time-lapse camera to develop decision rules for interpretation of the egg temperature data. We matched nesting behavior seen on videotape with patterns of egg temperatures recorded by thermistors. We distinguished three types of behavior from the videotapes based on definitions used by Cooper (1978): incubation, breaks, and recesses. Time on the nest is composed of incubation (also known as sitting spells), when the female is on the nest incubating, and breaks, when the female stands above the nest and rearranges the eggs and nest material or when she repositions herself on the nest. Periods off the nest, when the female is standing beside the nest or when she is away from the nest and out of the camera view completely, are recesses.

After matching the video-recorded behaviors to the temperature data, we used the temperature difference between recording intervals and egg temperature as indicators for the occurrence of incubation, breaks, and recesses. We calculated the 5^{th} and 95^{th} percentiles of the observed frequency distribution of temperature differences and egg temperatures for each behavior type. We then chose values for temperature differences and egg temperatures that gave the fewest classification errors, as determined by behaviors recorded on videotape (see Appendix B for details of behavior classification from temperature records).

For all nests monitored with egg thermistors and/ or time-lapse cameras, we calculated incubation constancy (the percentage of time that a female bird spends on the nest per day), the frequency and length of incubation recesses, and total time off the nest. For calculations of incubation constancy from the temperature data, we eliminated any days of partial monitoring, which included the day the egg thermistor was placed in the nest, the day of hatch, and days when our presence caused the female to be absent from the nest. From the record of videotaped behaviors, we subtracted from the total time of video coverage the time that poor viewing conditions (i.e. heavy fog, moisture on the lens, or too little or too much light for correct photographic exposure) prevented us from judging whether the female was incubating or off the nest. In such cases, incubation constancy was calculated as the percentage of time the bird was observed incubating out of the total time the nest was visible.

Video monitoring allowed us to document the occurrence of predators at the nest. Potential nest predators in the Alpine project area include Glaucous Gulls, jaegers, Common Ravens, Snowy Owls and arctic and red foxes. We recorded the time and duration of any periods that predators were observed near the nest. Other sources of disturbance included humans, caribou, non-predatory bird species (e.g., loons, swans, and ducks), and helicopter traffic. We listened for the sound of a helicopter when reviewing the videotape and noted any observable reaction from the incubating bird.

BREEDING-BIRD PLOTS

Twelve plots for sampling nesting birds were established in 1998. Plots measured 200 x 500 m (10 ha) and were marked by two rows of surveyor's lath that demarked 50 x 50 m grids (Figure 2). We placed six 10-ha plots ("treatment plots") in locations that are expected to be exposed to loud noise during aircraft landings and take-offs from the airstrip; that is, locations near (within 1,500 m) the airstrip (plots 1, 2, 4, and 5) or directly in the flight path (plots 3 and 6; Figure 3). The remaining six plots ("reference" plots) were located away from the airstrip (>1,500 m). We attempted to match the habitat composition between the treatment and reference plots; three treatment and three reference plots were in Wet Sedge–Willow Meadow (plots 4–9) and the remaining plots were placed in areas of mixed habitat, predominantly Wet Sedge–Willow Meadow with varying proportions of Moist Sedge–Shrub Meadow and Aquatic Sedge with Deep Polygons. We used a hand-held compass and 50-m tape to measure and mark the plots on 10–13 June. During plot layout, we recorded the locations of nests we encountered opportunistically. We conducted one sample of each plot between 15 and 21 June. A rope ~53-m long was dragged between two people (one walking the centerline while the other walked the outer border of the grid) followed by an observer walking between the ends of the rope. When a bird was flushed, all three people stopped and observed. If the bird would not return to its nest, the observers moved away or used the terrain as cover until the bird returned. For each nest found, we recorded the species, the number of birds present, the number of eggs or young, the surface form (e.g., polygon rim or center, island, nonpatterned) and habitat at the nest, and its location by grid number and quadrant within the grid (Figure 2).

SEASONAL USE OF LAKES

We conducted 10 surveys of lakes in the Alpine project area to assess seasonal use of lakes by large waterbirds (Figure 4). A Bell 206L Long Ranger helicopter was used to fly aerial surveys during June (4 surveys), July (3), and August (3). Flight altitude and speed varied, depending on weather, visibility, and other factors. In general, altitude ranged from 45–90 m above ground level, and speed was ~123 km/h but was slowed when necessary to count or identify groups of birds. A single observer was seated in the front left side of the helicopter. Observations were recorded with a small, hand-held, cassette-tape recorder and/or on a schematic map of the study area. In addition to numbers and species of waterbirds using the lakes and lake margins, any nests or broods of waterbirds also were noted. All tape-recorded information was transcribed onto data forms soon after the completion of the aerial survey.

We assigned numbers to the lakes and wetlands to be surveyed, and the survey path was flown for the most part according to the numerical sequence of the lakes. Several of the larger lakes were subdivided and each portion given a number to facilitate data recording. At a later date, lakes were assigned identification numbers from the Emergency Response Grid (Moulton 1998; Moulton, pers. comm.), which are the lake numbers used in this report.

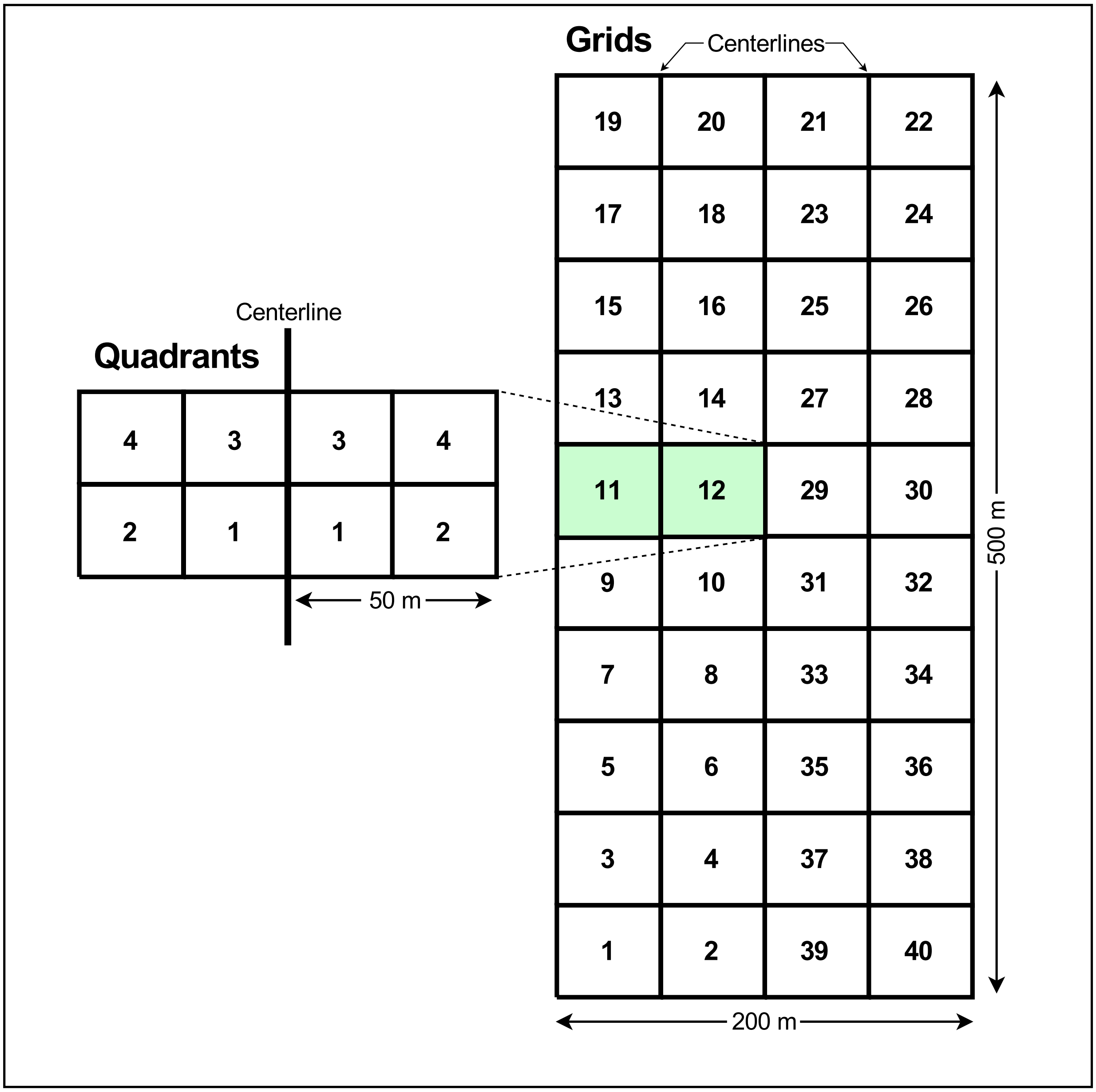

Figure 2. Diagram of layout for breeding bird plots in the Alpine project area, Colville River Delta, Alaska, 1998.

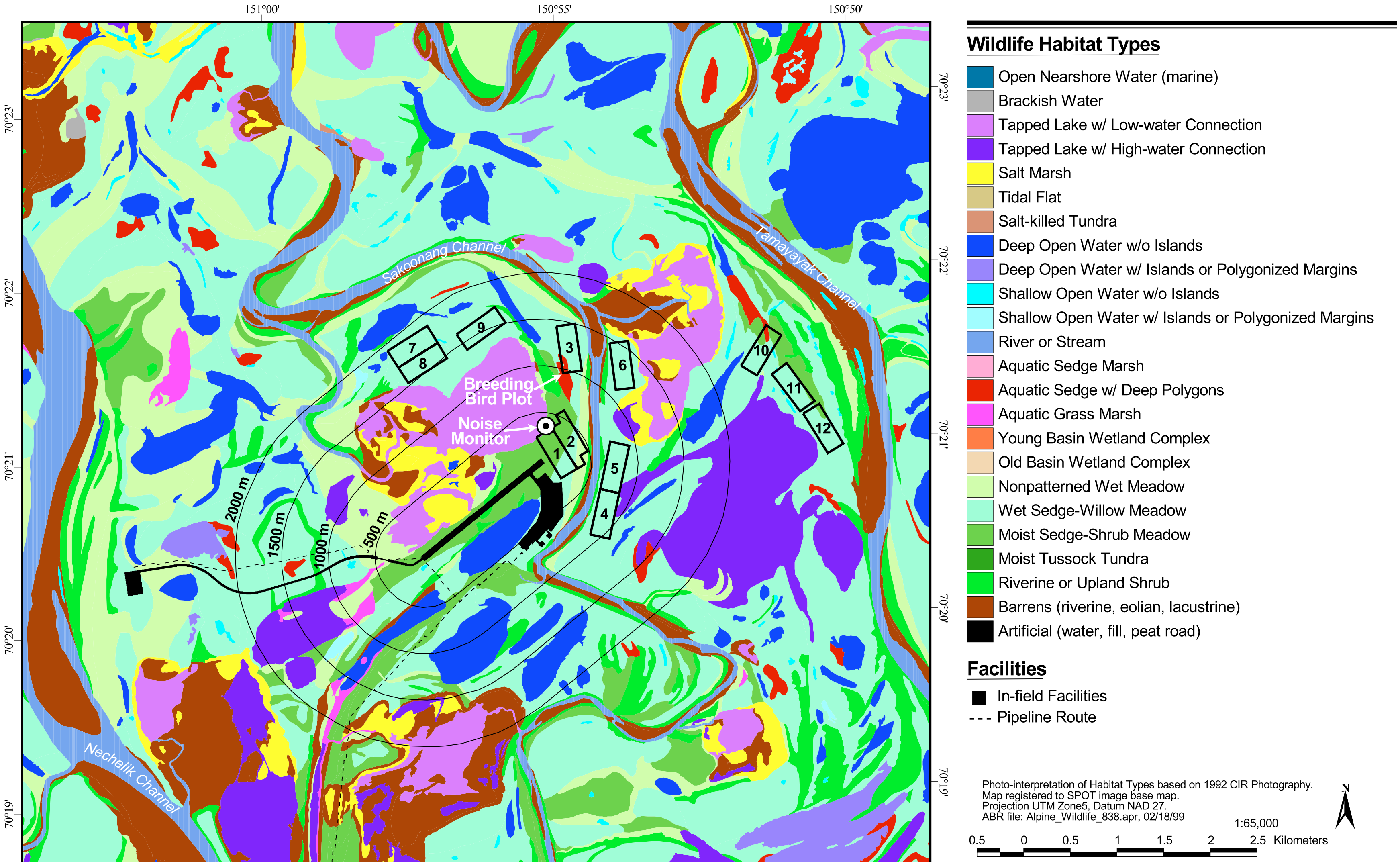

Figure 3. Habitats, breeding bird plots, noise monitor location, and 500-m buffers around the airstrip in the Alpine project area, Colville River, Alaska, 1998.

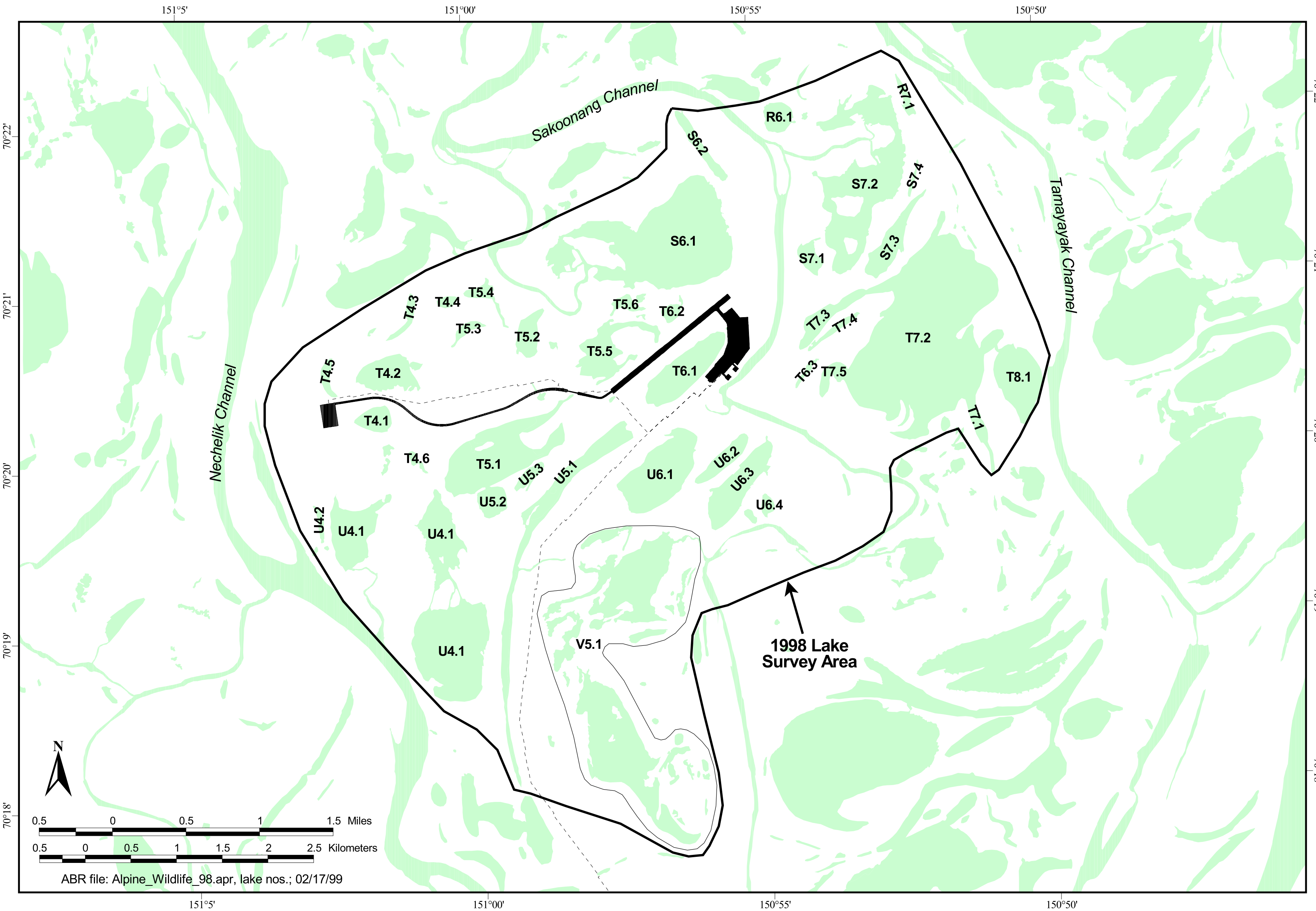

Figure 4. Lake numbers and boundary for lake surveys conducted in the Alpine project area, Colville River Delta, Alaska, 1998.

T7.2 LAKE COMPLEX

We conducted surveys specifically to evaluate the use by birds of one large lake system that was a candidate to be the primary water source for the Alpine facilities; after our surveys, another lake was chosen to be the water source. The T7.2 lake complex is so named because it comprises multiple interconnected and nearby lakes (lakes T7.1, T7.2, T7.3, T7.4, T7.5, and T8.1; Figure 4). On four occasions, 24 and 29 June, 12 July, and 25 August, ground observers circumnavigated the T7.2 lake complex, recording locations of nesting and brood-rearing waterbirds. As part of a nest search of the Alpine project area, intensive searches also were conducted along the west and southwest shores and adjacent wetlands on 20, 21, and 27 June; nest fate and brood-rearing surveys were conducted on 11 July. The T7.2 lake complex also was one of many lakes on the delta that was a subject of aerial surveys focused on nesting and brood-rearing loons, and brood-rearing and fall-staging waterfowl (see Johnson et al. 1998, 1999). In addition, the lake has been sampled for use by fish in both summer and early winter (Moulton 1996). We have relied on multiple sources of data to describe the avian use of the T7.2 lake complex.

RESULTS AND DISCUSSION

CONDITIONS IN THE STUDY AREA

PHENOLOGICAL TIMING

The timing of snow and ice melt on the delta can be highly variable among years. In 1998, most of the snow cover and ice on shallow lakes on the delta had melted by 3 June, with only large and deep lakes remaining frozen (with melt-water borders) at the time our surveys began. After snow melt, however, temperatures remained cool and conditions were windy through the third week of June. Midges emerged on 19 June and mosquitoes were first noticed in abundance on 20 June. The first hatchlings of Lapland Longspurs were found on 10 June, our first visit to the study area. Other observation dates of first young were: Semipalmated Sandpiper, 23 June; Savannah Sparrow, 18 June; Pectoral Sandpiper, 26 June; and White-fronted Goose, Common Redpoll, and Arctic Tern, 27 June. The timing of snow melt and appearance of open water on the delta in 1998 was more similar to conditions in 1996 than in 1997. In 1996, snow cover essentially was gone and all but deep lakes were open on the delta by the first week of June. Mosquitoes already were abundant on our first day in the Alpine project area, 17 June. In sharp contrast, snow cover in 1997 was 25–30% and many shallow lakes were still frozen in the second week of June; snow decreased to 0–5% by the third week and all but the deep lakes were open. Midges hatched on 20 June and mosquitoes were abundant on 23 June.

HUMAN ACTIVITY

During late-winter and early-spring 1998, gravel was hauled to the project area and spread for Pad 1 and the airstrip. Temporary buildings were installed on the pad and a housing facility was placed on pilings. All materials were transported via ice roads. During summer, construction activity consisted of improving the airstrip; the gravel was moved, spread, and compacted to dry and consolidate the wet, loose materials. The gravel work began 23 June and ended ~30 August, requiring three to five equipment operators using bulldozers, graders, compacters, and large trucks. Hours of operation were generally 07:30 to 19:00 ADT. The operators were billeted in Nuiqsut and transported to and from the Alpine airstrip by helicopter (Bell 206 LR). Two hydrologists monitored water levels in the airstrip area for 1-5 h on 8 d from 23 May to 5 June. Two to four surveyors also worked in this area for 1-2 h on 11 d and 8-10 h on 3 d during 25 May-30 June. All workers were transported to and from the project area by helicopter.

NOISE MONITORING

Noise levels were monitored 23–26 June, at a site 300 m from the airstrip. Sound levels (L_{eq}) varied from 39.8 to 67.8 dBA. The overall level during this period was 48.7 dBA. The recording period included hours (~07:00–20:00) when heavy equipment were operating on the airstrip 300 m away and a helicopter was transporting personnel in the area. The sound levels recorded during times without these noise sources ranged from 43.2 to 55.1 dBA. Ambient noise levels without wind in wilderness settings are typically 20–30 dBA (day-night average; FICON 1992 in USAF 1995). We did not monitor windspeeds at the recording site, but winds at the Kuparuk airfield (~49 km east) primarily were northeasterly and varied from 10 to 25 mph during the recording period. Consequently, some of the sound-level records may be inflated from noise generated by wind on the microphone.

NEST DENSITIES AND DISTRIBUTION

ALL SPECIES

During two nest searches in 1998 within the ground-search area (14.8 km^2; Figure 5), we found 135 nests belonging to 18 species of large waterbirds. Because the second nest search was an additional effort over that in previous years, and its coverage was not as extensive as the first, we will use only the nests found on the first nest search for annual comparisons. The highest density of nests (7.1 nests/km^2) in the three years of surveys occurred in 1997, whereas the lowest density (3.7 nests/km^2) occurred in 1996 (Table 2). The nest density from the first nest search in 1998 (6.7 nests/km^2) was intermediate, but species richness (18 species) was the highest of the three years.

By far, the most abundant nesting large waterbird in the Alpine project area was the White-fronted Goose (48 nests, Appendix C). Ducks were the second most abundant group, led by Northern Pintails (9 nests), Northern Shovelers (5), and Oldsquaws (6). Five Tundra Swan nests were found in the 1998 search area. One Spectacled Eider nest and one Canada Goose nest were found in 1998, which is the first record of these birds nesting in the Alpine project area. Both these species nest on the Colville Delta in other areas, although Canada Geese appear to have begun nesting on the delta only recently (Johnson et al. 1999). In 1997 and 1998, we found three Red-necked Grebe nests on a lake that is partially within 1,000 m of the Alpine airstrip (Figure 5; Johnson et al. 1998: Figure 23) and one additional nest in the southern part of the delta in both years. 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), the only other record, to our knowledge, of a Red-necked Grebe nesting in this area was a nest found south of the delta, at the junction of the Itkillik and Colville rivers in 1949 (Nelson 1953).

The ground-search area in 1998 overlapped extensively with the areas searched in previous years; the area that was searched in common in all years comprised 10.6 km^2 (henceforth referred to as the common ground-search area; for 1996 and 1997 search area boundaries, see Johnson et al. 1998: Figure 10). In the common ground-search area, we found the nests of 19 species between 1996 and 1998 (Table 2). Nests of only eight of these species were found in all three years. The annual pattern of nest density was similar to that reported above: the highest density occurred in 1997 and the lowest was in 1996.

Search effort varied among years, but the number of nests found each year was not directly related to search effort. The number of hours spent in the common ground-search area (based on proportional size), increased through the three years: 218 h in 1996, 271 h in 1997, and 300 h in 1998 (Table 2). Standardizing the number of nests by our search effort measures the rate at which nests were found, which is an index of the relative number of nests found each year in the common ground-search area. The highest rate that nests were found was in 1997 (0.28 nests/h), followed by the rate in 1998 (0.24 nests/h), and 1996 (0.19 nests/h). We emphasize that these rates are indices that do not take into account differences in observer abilities among years.

During the two nest searches in 1998, we found 129 nests of waterbirds within 2,000 m of the airstrip; 76 of these were nests of species other than White-fronted Geese (Table 3, Figure 5). The density of nests in 1998 was lowest within 500 m of the airstrip and greatest between 1,000 and 1,500 m. Habitat may be a contributing factor to the distribution of nests observed around the airstrip. Most of the nests that were found in the search area were in two habitats: Wet Sedge-Willow Meadow (60%, 77 of 129 nests) and Nonpatterned Wet Meadow (19%, 24 nests). The proportion of the distance buffers occupied by these highly used habitats increased with distance from the airstrip; they occupied 29% of the 500-m buffer and 46%, 51%, and 58% of each successive buffer to 2,000 m.

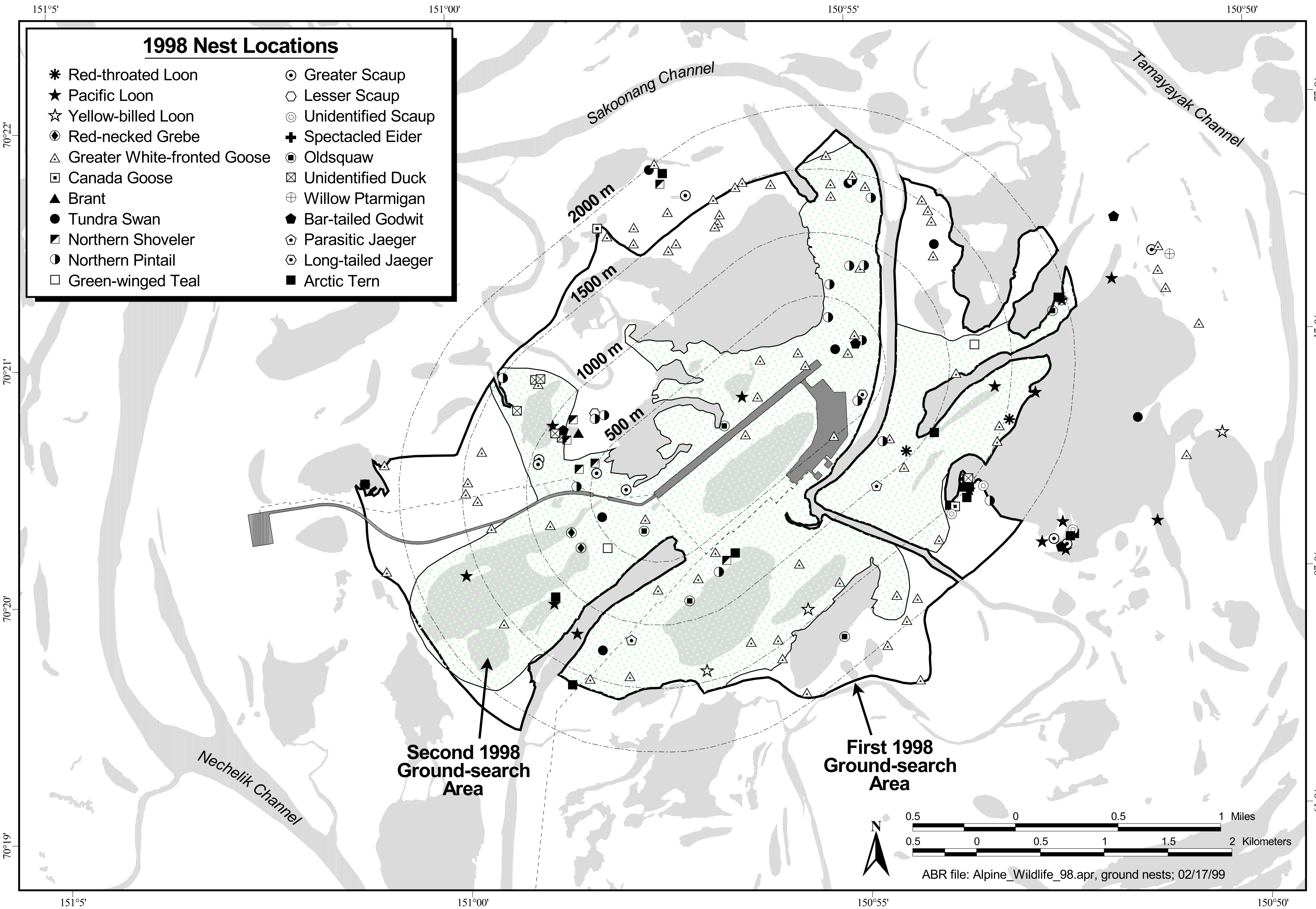

Figure 5. Locations of nests found during nest searches in the Alpine project area, Colville River Delta, Alaska, 1998.

Table 2. Nest densities of selected species found during ground searches in 1996, 1997, and 1998, and within the area searched in common in all three years, in the Alpine project area, Colville River Delta, Alaska.

	Density (nests/km^2)					
	Total Search Area			Common Search Area		
Species	1996	1997	1998	1996	1997	1998
Red-throated Loon	0.1	0.5	0.1	0.1	0.5	0.1
Pacific Loon	0.2	0.6	0.1	0.2	0.4	0.1
Yellow-billed Loon	0.1	0.1	0	0.1	0.1	0
Red-necked Grebe	0.0	0.2	0.1	0.0	0.3	0.2
Greater White-fronted	2.0	3.1	3.2	2.4	3.3	2.9
Canada Goose	0.0	0	0.1	0	0	0
Brant	0.1	0.5	0.1	0	0.4	0.1
Tundra Swan	0.2	0.4	0.3	0.3	0.4	0.5
Northern Shoveler	0.1	0	0.3[a]	0.0	0	0.5[a]
Northern Pintail	0.1	0.3	0.6[a]	0.2	0.4	0.7[a]
Green-winged Teal	0.1	0	0.1	0.1	0	0.1
Greater Scaup	0.0	0.1	0.1	0	0.1	0.1
Lesser Scaup	0.0	0	0.1	0	0	0.1
Unidentified scaup	0.0	0	0.1	0	0	0
Spectacled Eider	0.0	0	0.1	0	0	0
King Eider	0.1	0	0	0	0	0
Oldsquaw	0.4	0.6	0.4[a]	0.6	0.8	0.5[a]
Unidentified duck	0	0	0.3	0	0	0.3
Bar-tailed Godwit	0.1	0	0.1	0	0	0.2
Common Snipe	0	0.1	0	0	0	0
Parasitic Jaeger	0.1	0.1	0.1	0.1	0.1	0.2
Long-tailed Jaeger	0.1	0	0.1	0.1	0	0.1
Glaucous Gull	0	0.1	0	0	0.1	0
Sabine's Gull	0.1	0	0	0.1	0	0
Arctic Tern	0	0.3	0.3	0	0.5	0.3
Short-eared Owl	0.1	0	0	0	0	0
Area (km^2)	17.2	14.3	14.8	10.6	10.6	10.6
Search Hours	354	366	420	218	271	300
Total Nests	63	102	99	44	78	72
Nest density (nests/km^2)	3.7	7.1	6.7	4.1	7.3	6.8
Total number of species	16	14	18	11	14	16

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

Table 3. Nest densities of selected species found within exclusive distance buffers around the Alpine airstrip, and the mean distance from the airstrip, during the two nest searches of the Alpine project area, Colville River Delta, Alaska, June 1998.

Species	Density (nests/km^2) by Distance Buffer				Total Nests	Distance (m) from Airstrip	
	500 m	1000 m	1500 m	2000 m		$\bar{x}$	Range
Red-throated Loon	0	0.3	0	0.3	2	1,241	947–1,534
Pacific Loon	0.4	0.3	0.4	0.7	6	1,167	147–1,689
Yellow-billed Loon	0	0	0.2	0	1	1,405	
Red-necked Grebe	0	0.6	0	0	2	718	717–718
Greater White-fronted Goose	3.6	1.7	5.2	4.1	53	1,161	22–1,974
Canada Goose	0	0	0	0.7	2	1,706	1,527–1,885
Brant	0	0.3	0	0	1	754	
Tundra Swan	0.8	0	0.6	0	5	914	159–1,404
Northern Shoveler[a]	0	0.7	0	0	5	700	518–853
Northern Pintail[b]	1.2	2.2	0.6	0.3	15	856	340–1,696
Green-winged Teal	0	0.3	0.2	0	2	884	560–1,208
Greater Scaup	0.8	0.6	0	0	4	643	222–939
Lesser Scaup	0	0.3	0	0	1	773	
Unidentified scaup	0	0	0.2	0.7	3	1,536	1,472–1,584
Spectacled Eider	0	0	0.2	0	1	1,430	
Oldsquaw[c]	0.8	0.3	0	1.0	6	1,126	57–1,951
Unidentified duck	0	0.6	0.8	0	6	1,166	843–1,454
Bar-tailed Godwit	0.4	0.3	0	0	2	588	315–862
Parasitic Jaeger	0	0	0.4	0	2	1,070	1,005–1,135
Long-tailed Jaeger	0.4	0	0	0	1	397	
Arctic Tern	0	0.3	0.8	1.4	9	1,410	715–1,927
Area (km^2) searched	2.5	3.6	5.0	2.9			
Total density	8.4	9.1	9.6	9.3	9.2		
Total nests	21	33	48	27	129	1,087	22–1,974

[a] Includes a probable Northern Shoveler nest determined from feather and down samples.
[b] Includes probable Northern Pintails nests (8) determined from feather and down samples.
[c] Includes a probable Oldsquaw nest determined from feather and down samples.

Another approach we used to evaluate the effects of activity around the airstrip in 1998 was to compare the distance of nests from the airstrip in 1998 with the distance of nests from the airstrip's current location in years prior to its construction (1996 and 1997). Despite varying levels of human activity in the project area from 1996 to 1998 (Table 1), the distance of nests from the airstrip did not differ significantly among the years (using data from only the common ground-search area, one-way ANOVA, $P = 0.37$). The mean distance from the airstrip was highest in 1997 and lowest in 1998, the only year the airstrip was actually in place (Table 4).

GREATER WHITE-FRONTED GEESE

During two ground surveys in 1998, we located 57 White-fronted Goose nests (3.8 nests/km^2) in the 1998 ground-search area (Figure 6); we found 48 nests (3.2 nests/km^2) during the first nest search (Table 2) and 9 additional nests (1.0 nests/km^2) during the second search. The density of nests found on both nest searches combined was higher than in any previous year, but the level of effort also was greater. The density of nests found during the first nest search was similar to that recorded in 1997 (3.1 nests/km^2; Johnson et al. 1998) and greater than the density (2.0 nests/km^2) recorded in 1996 (Johnson et al. 1997). However, as discussed above, the search effort varied widely among these years and contributed to the high density found in 1998. The number of White-fronted Goose nests in the common ground-search area standardized by time spent searching was highest in 1997 (0.13 nests/h), lowest in 1998 (0.10 nests/h), and intermediate in 1996 (0.11 nests/h). Although the pattern among years differed from that reported above for nests of all species, the differences among years were relatively small for White-fronted Goose nests. The densities of White-fronted Goose nests in the Alpine project area are high compared with other data collected on the delta. In the early 1980s, the USFWS reported mean densities of 1.8 nests/km^2, which were among

Table 4. Mean distances of nests from the airstrip in the Alpine project area, Colville River Delta, Alaska, 1996–1998.

Year	Distance (m) $\bar{x}$	SE	*n*	Test	*F*	*P*-value
All Species						
1996	1,341	331.0	45			
1997	1,156	68.4	88			
1998	1,028	64.0	72			
All Years	1,152	81.3	205	ANOVA	0.998	0.37
Greater White-fronted Goose						
1996	1,140	113.6	25			
1997	1,173	101.7	35			
1998	1,085	102.8	31			
All Years	1,106	60.7	91	ANOVA	0.409	0.66

the highest densities recorded for White-fronted Geese on the Arctic Coastal Plain of Alaska at that time (Simpson et al. 1982, Rothe et al. 1983, Simpson 1983).

White-fronted Geese nested in 5 of 15 available habitats in the area searched in 1998 (Table 5). For the habitat analysis, we used only those nests found on the first ground search, because the second ground search was less extensive. Only one habitat, Wet Sedge–Willow Meadow, was preferred (use was significantly greater than availability at $P \leq 0.025$) within the search area. Nesting White-fronted Geese avoided (use was significantly less than availability at $P \leq 0.025$) Tapped Lake with Low-water Connection, Deep Open Water without Islands, and Nonpatterned Wet Meadow. Most nests (39 of 48, 81%) found in 1998 were in Wet Sedge–Willow Meadow, but other habitats were used as well: Moist Sedge–Shrub Meadow (5 nests, 10%), Aquatic Sedge with Deep Polygons (2 nests; 4%), Nonpatterned Wet Meadow (1 nest, 2%) and Riverine or Upland Shrub (1 nest, 2%). Within these habitats, most nests (90%) occurred on polygon ridges or small hummocks, microsites similar to the nesting sites reported by Simpson et al. (1982). Nests ranged from <1 to 400 m ($\bar{x}$ = 39.2 m) from the nearest permanent waterbody. In 1996 and 1997, White-fronted Geese also preferred Wet Sedge–Willow Meadow (Appendix D).

During the two nest searches in 1998, we found 53 nests <2,000 m from the airstrip ($\bar{x}$ = 1,161 m, range 22–1,974 m; Table 3). Thirty-eight nests (72%) were >1,000 m from the airstrip; this distribution may be the result of habitat selection by nesting geese. The preferred nesting habitat for White-fronted Geese, Wet Sedge-Willow Meadow, was more abundant (48% of the total) in the area >1,000 m from the airstrip than in the area <1,000 m (27%).

We measured nearest-neighbor distances between nests each year as an indicator of distributional pattern and nest density. The pattern of nest distribution was clumped in all three years ($0.45 \leq R \leq 0.69$, $-4.89 \leq Z \leq -3.31$). The distance of nests to the airstrip in 1998, or to its current location in 1996 and 1997, did not explain the variation in nearest neighbor distances ($r^2 < 0.03$; $P > 0.39$); that is, distances between nests were not linearly related to distance from the airstrip. However, nearest neighbor distances did differ among distance buffers (500, 1,000, 1,500, and 2,000 m) around the airstrip in 1997 ($P = 0.02$, Kruskal-Wallis test), but not in the other two years ($P > 0.36$). In 1997, nearest neighbor distances between nests were significantly less (i.e., density of nests was higher) in the 500-m buffer than in the 1,000, 1,500, and 2,000-m buffers ($P \leq 0.04$, Mann-Whitney tests).

Comparing the distance of White-fronted Goose nests from the airstrip in 1998 with the distance of nests in the two years prior to its construction, the distribution of White-fronted Goose nests relative to the airstrip was similar to that of all nests discussed above. The distance of nests from the airstrip did not differ significantly among 1996–1998 (one-way

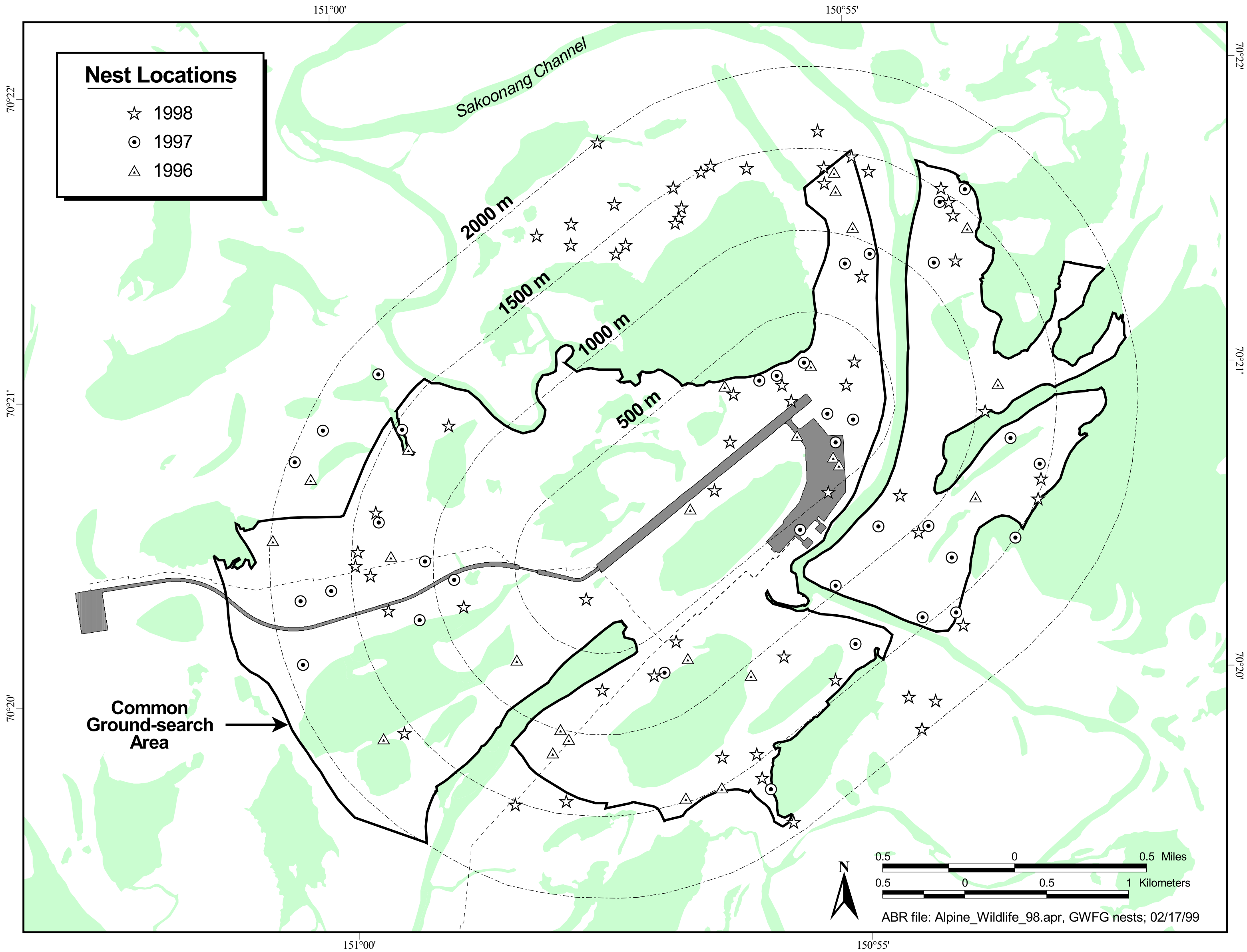

Figure 6. Locations of Greater White-fronted Goose nests in the Alpine project area, Colville River Delta, Alaska, 1996–1998.

Table 5. Habitat selection by Greater White-fronted Geese during nesting in the Alpine project area, Colville River Delta, Alaska, 1998.

Habitat	Area (km^2)	No. of Nests	Use (%)	Availability (%)	Monte Carlo Results[a]
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/Low-water Connection	1.64	0	0.0	11.0	avoid
Tapped Lake w/High-water Connection	0.79	0	0.0	5.3	ns
Salt Marsh	0.71	0	0.0	4.8	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	1.31	0	0.0	8.8	avoid
Deep Open Water w/Islands or Polygonized Margins	<0.01	0	0.0	<0.1	-
Shallow Open Water w/o Islands	0.01	0	0.0	0.1	ns
Shallow Open Water w/Islands or Polygonized Margins	0.04	0	0.0	0.3	ns
River or Stream	<0.01	0	0.0	<0.1	-
Aquatic Sedge Marsh	0	-	-	0	-
Aquatic Sedge w/Deep Polygons	0.16	2	4.2	1.1	ns
Aquatic Grass Marsh	0.10	0	0.0	0.6	ns
Young Basin Wetland Complex	0	-	-	0	ns
Old Basin Wetland Complex	0	-	-	0	ns
Nonpatterned Wet Meadow	1.22	1	2.1	8.2	avoid
Wet Sedge–Willow Meadow	5.93	39	81.3	40.1	prefer
Moist Sedge–Shrub Meadow	1.57	5	10.4	10.6	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.75	1	2.1	5.1	ns
Barrens (riverine, eolian, lacustrine)	0.57	0	0.0	3.9	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	14.81	48	100	100	

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

ANOVA, $P = 0.66$). The mean distance of nests in 1997 (1,173 m, $n = 35$) was only slightly greater than the mean distances in 1996 (1,140, $n = 25$) and 1998 (1,085 m, $n = 31$) (Table 4). Similar to the results of nearest-neighbor analyses presented above, the lack of significant relationships among years for nests of White-fronted Geese and all species combined suggests that the construction activity in 1998 was no more or less disruptive to nest establishment than the human activity that occurred in 1996 and 1997. In both those years, surveyors and hydrologists, as well as the biologists participating in this study, worked in the area of the Alpine footprint, undoubtedly disturbing some of birds nesting near the site of the present airstrip.

TUNDRA SWANS

Similar numbers and densities of Tundra Swan nests were found in the common ground-search area during all three years. In 1998, five swan nests were found during nest searches and all were in the common ground-search area (0.47 nests/km^2). Five also were found in the common ground-search area in 1996, and four (0.38 nests/km^2) were found in 1997. The sample size of nests was too small to test for habitat selection, but all but one occurred in habitats that were preferred in a larger study on the Colville delta (Johnson et al. 1999). In 1998, three nests were found in Moist Sedge–Shrub Meadow and two were in Wet Sedge–Willow Meadow. In

1997, three nests occurred in those same habitats, and one occurred in Nonpatterned Wet Meadow. In 1996, three nests were found in Wet Sedge–Willow Meadow, and one nest each was found in Moist Sedge–Shrub Meadow and Salt Marsh.

The distance of nests from the airstrip did not differ between 1998 ($\bar{x}$ = 914 m, *n* = 5), 1997 ($\bar{x}$ = 1,212 m, *n* = 4), or 1996 ($\bar{x}$ = 1,309 m, *n* = 5) (ANOVA, *P* = 0.64). In 1998, the closest nest to the airstrip was 159 m from the northeast end of the strip (Figure 5). Despite the nest's proximity to the airstrip (where heavy equipment was operated and a helicopter landed nearly daily during the later part of June), and two prolonged absences (~4 h and ~8 h) during nest searches of the area, this nest hatched three eggs successfully.

NESTING BEHAVIOR

GREATER WHITE-FRONTED GEESE

In the Alpine project area in 1998, we deployed one egg thermistor in each of 20 White-fronted Goose nests (Figure 7). Two nests with egg thermistors and one nest without a thermistor were monitored with time-lapse video cameras. The mean distance from nests monitored with egg thermistors to the airstrip was 1,298 m (range = 46–1,710 m, *n* = 20) and the mean distance of nests monitored with video cameras was 1,514 m (range = 1,409–1,636 m, *n* = 3). Of the 20 egg thermistors that we deployed in White-fronted Goose nests, we obtained temperature data for 17 nests from the time of deployment to the time of brood departure or nest failure. In the remaining three nests, the thermistor either was expelled from the nest or the thermistor/data-logger malfunctioned.

Nest Attendance

Incubation constancy was measured using the temperature data at 16 White-fronted Goose nests that were successful and at 1 nest that subsequently failed. Successful female White-fronted Geese spent 98.9% of their time incubating (Table 6). Each bird maintained a high nest-attendance rate during the monitoring period, sometimes incubating 1–2 d without a recess. Mean number of recesses for the successful nests remained relatively constant during the 10 d before hatch and averaged 1.3 recesses/d (*n* = 116 nest·d; Figure 8). For all days combined, mean recess length was 13 min/recess (*n* = 148 recesses), and mean time off the nest was 16 min/d (*n* = 116 nest·d). White-fronted Geese nesting in the Lisburne Development Area spent the same percentage of time incubating (98.9%) and took recesses at a similar frequency (1.2 recesses/d; Murphy and Anderson 1993). In the Alpine project area, the females at successful nests took the same number of incubation recesses from 06:00 to 18:00 and 18:00 to 06:00 ($\bar{x}$ = 0.6 recesses/d, *n* = 116 nest·d), but mean recess length was greater from 06:00 to 18:00 ($\bar{x}$ = 15 min/recess) than from 18:00 to 06:00 ($\bar{x}$ = 10 min/recess). Most females departed the nest with broods between the hours of 05:00 to 13:00.

We monitored the female White-fronted Goose at the failed nest for 20 d and found that she spent >90% of her time incubating until 3 d before failure (Table 6). Recess frequency, recess length, and time off the nest (3.8 recesses/d, 21 min/recess, and 80 min/d, respectively) all were greater for the female at the failed nest than for females at successful nests (Figure 8). We collected the egg thermistor from the failed nest on 10 July and found the nest recently had been destroyed by an avian predator, based on the egg remains at the nest. The temperature data indicated that the female was still attending the nest until 80 min before our visit. Possibly, the eggs were infertile at this time; the modal date of hatch for successful goose nests was 28 June, yet we found yolk in the broken eggs on 10 July. We observed Parasitic Jaegers at two other White-fronted Goose nests that we monitored with video cameras; each nest hatched successfully, but their clutches appeared to have lost one egg each, based on counts of egg membranes after hatch.

We monitored one female White-fronted Goose with a time-lapse camera only for 116.7 hours, which included the 4 d prior to brood departure (1 July at 12:32). During this time, the female took 14 recesses that ranged in length from 5–21 min ($\bar{x}$ = 13.5 min). For the three complete days of monitoring, excluding the day of hatch, the female spent 96.1 % of her time incubating. The frequency of recesses, recess length, and time off the nest during these three days (3.7 recesses/d, 15 min/recess, and 55 min/d, respectively) were greater on average than those of the females at successful nests (monitored with egg thermistors), but less than those of the female at the failed nest.

Disturbance

When we deployed the egg thermistors in the White-fronted Goose nests, we flushed each incubating female from the nest. The time from when we installed the egg thermistors to the time the female returned to incubate averaged 94 min (range = 15–455 min, *n* = 19). The length of time that we were at the nest may have affected the amount of time that the female was away. During nest searching, we flushed four female White-fronted Geese, on one occasion each, from nests equipped with egg thermistors. In these instances, we covered the eggs with nest material and departed the area soon after the bird was flushed. The mean length of time the female was off the nest after these four disturbances was 69 min (range = 40–95 min). We disturbed a White-fronted Goose female twice while servicing a time-lapse camera, resulting in absences from the nest of 86 and 97 min, which was similar to the response of the geese monitored with egg thermistors. The mean length of time that the females were absent from the nest following these disturbances (90 min/recess, *n* = 25) was greater than the mean recess length of geese at successful nests (13 min/recess, *n* = 148). All of the monitored nests hatched except for one that was incubated until 10 July, when it was depredated (see Nest Attendance section).

YELLOW-BILLED LOONS

Two Yellow-billed Loon nests that we monitored with time-lapse video cameras failed partway through the monitoring period after predation by Parasitic Jaegers. We monitored one nest for 2 d before the nest failed. The loon at that nest incubated for 65% of the 2 d and averaged 13 recesses/d at 39 min/recess (*n* = 26 recesses). Total time off nest increased from 173 min to 835 min over the 2 d. Predation by a jaeger occurred during a long recess (224 min) on the morning of the third day. We monitored the other nest for 7 d before it failed. Mean incubation constancy for the 7 d was high (92.2%), but daily incubation constancy varied from 75.1 to 99.8%. The incubating loon took 5.1 recesses/d at 22 min/recess (*n* = 36 recesses). Total time off the nest averaged 112 min/d (range = 3–359 min). On the eighth day of monitoring, when the nest failed, the incubating bird took 9 recesses that averaged 41 min each. Predation occurred while the loon was on a recess that lasted 138 min. The nests were 1,406 and 1,414 m from the airstrip (Figure 7), and we detected no disturbance at either nest during the video recording, with the possible exception of caribou. During two separate recordings that occurred within 10 min of incubation recesses, we saw caribou near the loon nest, but we did not observe an obvious reaction by the loon.

TUNDRA SWANS

Of the two Tundra Swan nests that we monitored with time-lapse cameras, one hatched successfully and the other failed. The distance to the airstrip was 1405 m for the failed nest and 1984 m for the successful nest. We monitored the successful nest for 10 d and the failed nest for 5 d. Mean incubation constancy was 82.1% (*n* = 9 d) for the successful nest and 83.9% (*n* = 4 d) for the failed nest. The swan at the successful nest took fewer recesses ($\bar{x}$ = 2.4 recesses/d) than the swan at the failed nest ($\bar{x}$ = 4.8 recesses/d), but mean recess length was longer at the successful nest ($\bar{x}$ = 101 min/recess, *n* = 22 recesses) than at the failed nest ($\bar{x}$ = 49 min/recess, *n* = 19 recesses). Total time spent off the nest was similar for both the successful and failed nest ($\bar{x}$ = 246 and 232 min/d, respectively). During some recesses at the successful nest, another swan would “guard” (stand next to the nest) the nest, while the incubating swan took a recess. We did not observe this occurring at the failed nest. We first observed a cygnet at the successful nest on 9 July and the brood of two cygnets departed 20 h later. At the failed swan nest, we identified Parasitic Jaegers at the nest for 7–30 min during 5 of the swan’s 22 recesses, with the last recess continuing for 20.4 h. When the swan finally returned to the nest, it did not resume incubating. During video recording at the failed nest, we did not detect any disturbances to the incubating swan.

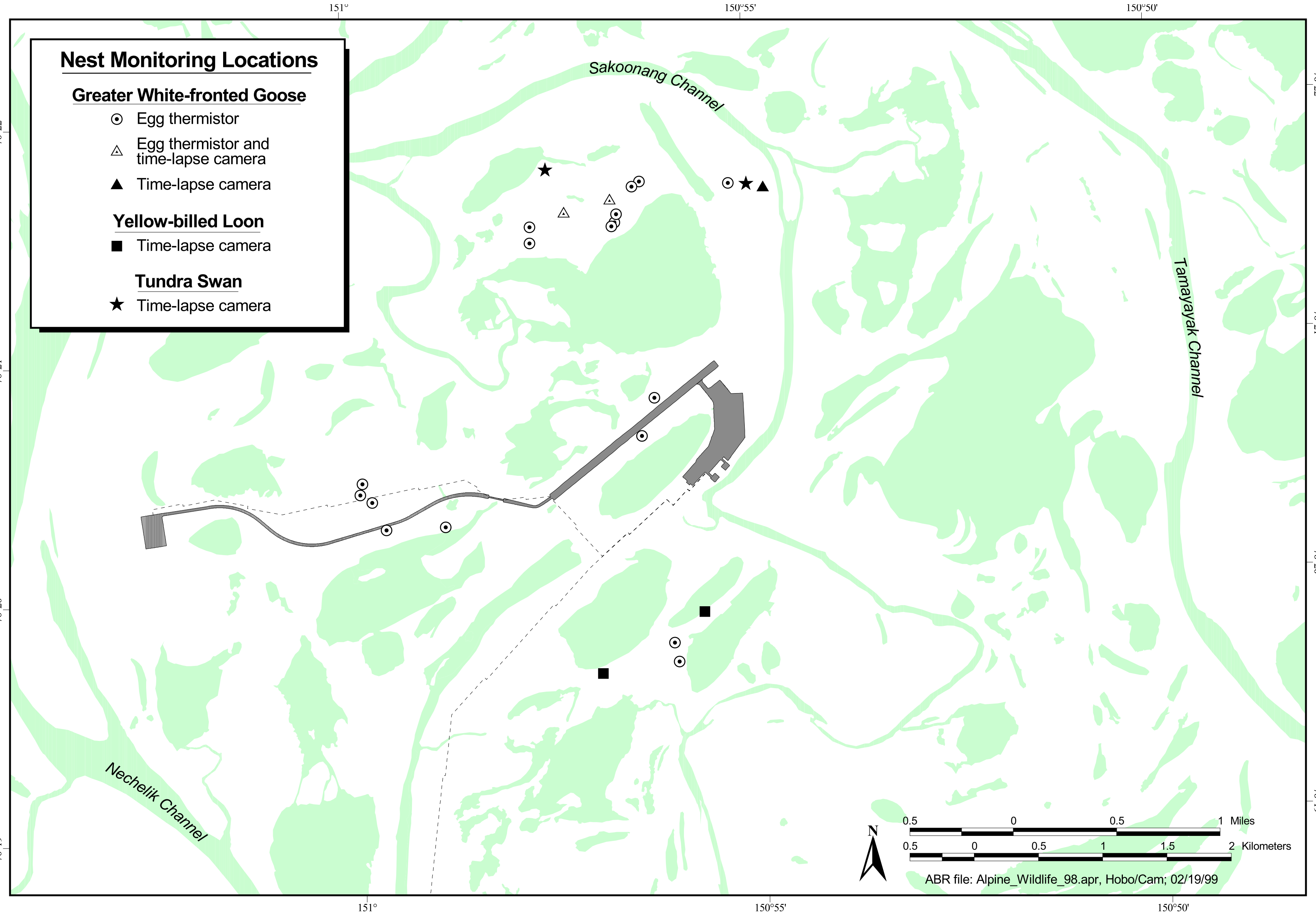

Figure 7. Locations of thermistor eggs and time-lapse cameras in the Alpine project area, Colville River Delta, 1998.

Table 6. Mean incubation constancy (% of time) of Greater White-fronted Geese at successful and failed nests, as determined by egg thermistors (1 recording interval/5 min) in the Alpine project area, Colville River Delta, Alaska, 1998.

Day before hatch	Successful		Day before failure	Failed	
	%	n[a]		%	n[a]
10	98.6	2	20	99.3	1
9	98.5	2	19	97.9	1
8	99.5	6	18	94.1	1
7	98.7	11	17	99.3	1
6	99.3	16	16	100.0	1
5	99.0	16	15	97.6	1
4	98.9	16	14	100.0	1
3	98.4	16	13	89.9	1
2	99.0	16	12	97.6	1
1	98.7	15	11	100.0	1
Hatch	–	–	10	98.3	1
			9	98.3	1
Overall Mean	98.9	116	8	97.2	1
			7	90.3	1
			6	96.9	1
			5	99.0	1
			4	92.4	1
			3	86.1	1
			2	86.8	1
			1	68.1	1
			Failure	–	–
			Overall Mean	94.4	20

[a] n = number of nests monitored each day.

CLUTCH SIZE AND NEST FATE

ALL SPECIES

Despite our efforts to find nests without disturbing incubating birds, some were flushed from their nests. For those that were flushed, we recorded clutch sizes and then covered the eggs with down and nest material to conceal them from predators. Mean clutch sizes for loons, jaegers, and Arctic Terns were ≤2 eggs, whereas mean clutch sizes for various duck species varied from 4 to 9 eggs (Table 7). Mean clutch sizes were intermediate for Red-necked Grebes (4 eggs), various goose species (3.9–5 eggs), and Tundra Swans (3 eggs). All clutch sizes were within the range of numbers that are reported in the literature (Baicich and Harrison 1997).

We revisited nest sites of waterfowl in July 1998 (after the hatch) to determine the fate of nests in the ground-search area (Table 8). Nests were determined to be successful if we found egg membranes that were detached from the eggshells. Using this technique, we could determine nest fate for most waterfowl species, but not for species such as loons, ptarmigan, gulls, or Arctic Terns, whose eggshells and membranes rarely are found after hatch. We also did not determine the fate of nests on inaccessible islands, as was the case for two Red-necked Grebe nests. Of the 38 duck nests found during the two nesting surveys in the ground-search area, only 5 (one each of Spectacled Eider, Northern Pintail, Greater Scaup, unidentified scaup, and Oldsquaw) were successful, a success rate of 13%. The fate of duck nests in 1998 was not influenced by their distance from the airstrip (Table 9). Although successful nests were slightly closer to the airstrip than were failed nests, the difference was not significant (P = 0.73).

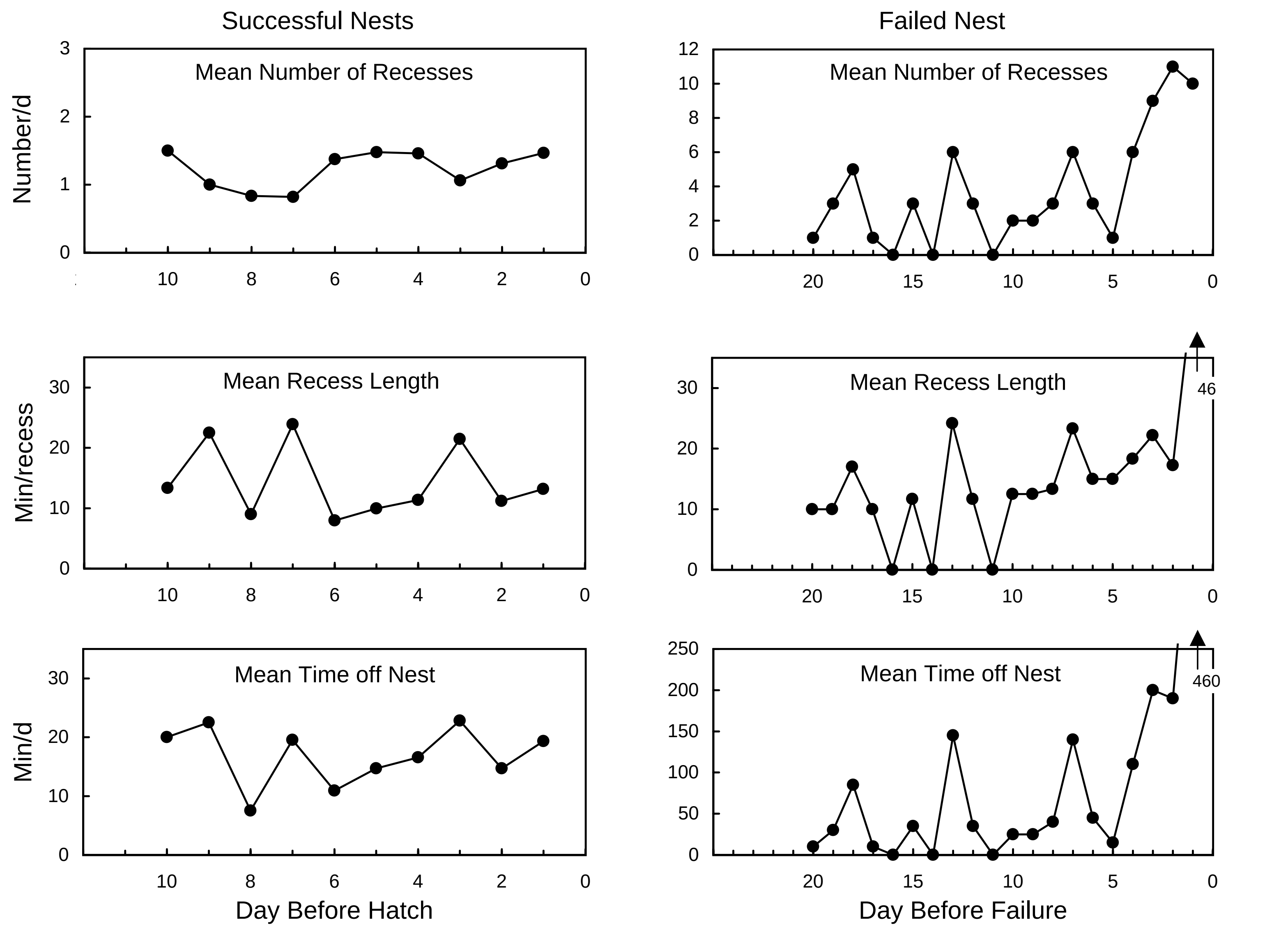

Figure 8. Mean frequency, length, and total time of incubation recesses for 16 successful nests and 1 failed nest of Greater White-fronted Geese monitored by egg thermistors (1 temperature recording/5-min interval) in the Alpine project area, Colville River Delta, Alaska, 1998.

Table 7. Clutch sizes of nests found during ground nest searches in the Alpine project area, Colville River Delta, Alaska, 1998.

Species	Clutch size $\bar{x}$	SE	n
Red-throated Loon	1.5	0.71	2
Pacific Loon	1.8	0.35	8
Yellow-billed Loon	1.3	1.15	3
Red-necked Grebe	4.0	1.41	2
Greater White-fronted Goose	3.9	1.52	57
Brant	5.0	-	1
Tundra Swan	3.0	0.89	6
Northern Shoveler	8.6	0.89	5
Northern Pintail	6.0	1.41	7
Probable Northern Pintail	7.5	0.71	2
Green-winged Teal	8.0	-	1
Greater Scaup	7.7	1.28	8
Lesser Scaup	9.0	-	1
Unknown scaup	7.2	1.50	4
Spectacled Eider	4.0	-	1
Oldsquaw	7.5	1.00	4
Unidentified duck	6.6	2.08	3
Willow Ptarmigan	7.0	-	1
Bar-tailed Godwit	3.7	0.50	4
Parasitic Jaeger	2.0	0.00	2
Long-tailed Jaeger	1.0	-	1
Arctic Tern	1.5	0.67	1

[a] Probable Northern Pintail nests determined from feather and down samples.

GREATER WHITE-FRONTED GEESE

The mean clutch size of White-fronted Geese in 1998 was 3.9 eggs (n = 57 nests), similar to the values reported in other studies on the Colville Delta (Simpson et al. 1982; Simpson 1983; Smith et al. 1993, 1994). In the Alpine project area, the mean clutch size in other years was 4.1 eggs in 1995 (n = 14 nests; Johnson et al. 1996), 3.7 eggs in 1996 (n = 30 nests; Johnson et al. 1997), and 3.8 eggs in 1997 (n = 37 nests; Johnson et al. 1998). In 1998, proximity to the Alpine airstrip did not have a negative effect on clutch size. The relationship between clutch size and distance of nest from the airstrip was marginally non-significant (P = 0.053), but clutch size actually increased as distance to the airstrip decreased, and distance explained only 7% of the variance ($y = -0.0006x + 4.79$, $r^2 = 0.066$).

Of 70 White-fronted Goose nests found throughout the project area in 1998, 50 (71%) were successful, 13 (19%) failed, and 7 (10%) had unknown fates. Six nests had failed already by the time we initiated our nest search. The success rate of nests in 1998 was higher than that of nests found in 1981 and 1982 on the delta (57% and 54%, respectively; Rothe et al. 1983, Simpson et al. 1982), but similar to the rates found in the Alpine project area in 1997 (82%; Johnson et al. 1998). The proximity of White-fronted Goose nests to the airstrip had little effect on their fate in 1998; the distance of successful ($\bar{x}$ = 1,366 m) and failed nests ($\bar{x}$ = 1,359 m) was virtually the same (P = 0.56, Table 9).

TUNDRA SWANS

Clutch sizes of Tundra Swans averaged 3.0 eggs in 1998 (n = 6 nests). In 1996 and 1997, the mean clutch sizes were 4 and 3 eggs, respectively (n = 4 each year). Because sample sizes and the range of

Table 8. The number, fate and mean distance from the airstrip of nests of selected species found during ground nest searches in Alpine project area, Colville River delta, Alaska, 1998.

	Successful Nests				Failed Nests			
			Distance (m)				Distance (m)	
Species	No.	%	$\bar{x}$	SE	No.	%	$\bar{x}$	SE
Red-throated Loon	–	–	–	–	2	100	1,241	294
Pacific Loon	5	71.4	2,072	294	2	28.6	550	403
Yellow-billed Loon	–	–	–	–	2	100	1,410	4
Greater White-fronted Goose	50	79.4	1,366	94	13	20.6	1,359	226
Canada Goose	1	100	1,527	–	–	–	–	–
Brant	–	–	–	–	1	100	754	–
Tundra Swan	5	71.4	1,276	445	2	28.6	1,345	60
Northern Shoveler[a]	–	–	–	–	5	100	946	232
Northern Pintail[b]	1	14.3	399	–	13	85.7	826	81
Green-winged Teal	–	–	–	–	2	100	884	324
Greater Scaup	2	40.0	1,248	1027	3	60.0	784	154
Unidentified scaup	1	50.0	1,472	–	1	50.0	1,584	–
Spectacled Eider	1	100	1,431	–	–	–	–	–
Oldsquaw[c]	1	50.0	57	–	1	50.0	281	–
Unidentified duck	1	20.0	1,454	–	4	80.0	1,071	115
Bar-tailed Godwit	1	50.0	2,359	–	1	50.0	315	–
Parasitic Jaeger	2	100	1,070	65	–	–	–	–
Long-tailed Jaeger	1	100	397	–	–	–	–	–
Arctic Tern	8	100	1,640	203	–	–	–	–
Total nests	80	60.6	1,399	79	52	39.4	1,030	79

[a] includes a probable Northern Shoveler nest determined from feather and down samples.
[b] includes probable Northern Pintail nests (8) determined from feather and down samples.
[c] includes a probable Oldsquaw nest determined from feather and down samples.

Table 9. Mean distances of nests from the airstrip in the Alpine project area, Colville River, Alaska, 1998.

	Distance (m)					
Nest Fate	$\bar{x}$	SE	*n*	Test	Statistic (*Z*)	*P*-value
All Ducks						
Successful	1,044	312	7			
Failed	887	73	29	Mann-Whitney	-0.34	0.73
Greater White-fronted Goose						
Successful	1,366	94	50			
Failed	1,359	226	13	Mann-Whitney	-0.58	0.56

clutch sizes were small, we did not test for relationships between clutch size and distance to the airstrip. Clutch sizes were similar in other studies on the Colville delta; average clutch size was 3.6 eggs (n = 28) in 1981 (Rothe et al. 1983) and 3.4 eggs (n = 43) in 1982 (Simpson et al. 1982).

In 1998, three of five (60%) Tundra Swan nests succeeded in hatching. One nest was destroyed by a fox and the other was destroyed by Parasitic Jaegers. The two failed nests were 1,285 and 1,405 m from the airstrip, both farther than the mean distance for all swan nests, 914 m. In 1997, all four nests were successful and in 1996 we did not check the fate of nests. Nesting success for 32 nests in 1981 was 91% (Rothe et al. 1983) and was 70% for 43 nests in 1982 (Simpson et al. 1982).

BREEDING-BIRD PLOTS

We found 196 nests belonging to 21 species of birds on the 12 breeding-bird plots we sampled in 1998 (Table 10). The predominant nesting species were Pectoral Sandpipers (61 nests, 31% of all nests), Lapland Longspurs (49 nests, 25%), and Semipalmated Sandpipers (21 nests, 11%). The number of nests per plot ranged from 8 to 26 (80–260 nests/km^2) and averaged 16.3 nests (163.3 nests/km^2).

The number of nests found was not clearly independent of treatment and habitat (χ^2 = 3.61, P = 0.058); the lowest number was found in reference plots with mixed habitat ($\bar{x}$ = 123.3 nests/km^2, n = 3 plots). Treatment plots with mixed habitat contained the most nests ($\bar{x}$ = 193.3 nests/km^2, n = 3 plots), whereas both treatment and reference plots with Wet Sedge–Willow Meadow contained intermediate numbers of nests ($\bar{x}$ = 160.0 nests/km^2 and 176.7 nests/km^2, respectively, n = 3 plots each). Therefore, the proximity of plots (generally treatment plots were near and reference plots were distant) to the Alpine airstrip did not appear to negatively affect nest densities in 1998.

The number of Pectoral Sandpiper nests, the most abundant of all nests in 1998, was not independent of treatment and habitat (χ^2 = 5.67, P = 0.017), following the same pattern as did all nests. Pectoral Sandpiper nests appear to be the major influence on the disproportional distribution of nests among plot conditions, because all other nests occurred independent of plot condition (χ^2 = 0.45, P = 0.50). Annual densities of territorial Pectoral Sandpipers can vary considerably (Pitelka 1959). Despite having no other years of data for Pectoral Sandpipers on the delta for comparison, nest densities appear to have been unusually high in 1998 ($\bar{x}$ = 50.8 nests/km^2, n =12 plots) compared to densities in other studies on the coastal plain. In the Pt. McIntyre area, Pectoral Sandpiper densities varied from 1 to 33 nests/km^2 ($\bar{x}$ = 8.7 nests/km^2, n = 10 years; TERA 1993), and in the Kuparuk Oilfield densities varied from 2.9 to 18.4 nests/km^2 ($\bar{x}$ = 7.9 nests/km^2) and 4.0 to 23.5 nests/km^2 ($\bar{x}$ = 12.7 nests/km^2) on two different plots over five years (Moitoret et al. 1996). Nonetheless, we have no immediate explanation for the differences in frequency of nests among plot types; one likely explanation is that the habitat composition of the plots is more variable than the mixed and single habitat categorization presented here. It must be emphasized that the scale of habitat mapping that currently exists in the Alpine project area (the entire Colville Delta, 551 km^2, was classified with minimum mappable units of 0.5 ha) probably is not of sufficient resolution for the scale at which shorebirds and passerines are selecting nest sites on 10-ha plots. In 1999, we will identify the habitat in each grid of the plots so that we can evaluate nest occurrence at a finer scale and compare the habitat composition of individual plots.

BROOD-REARING

We did not conduct a specific survey for broods of large waterbirds in the Alpine project area during 1998. Broods were recorded during nest fate checks in early July, during a ground search for loon broods in August, and during aerial surveys conducted for goose and loon broods as part of the Colville wildlife studies (Johnson et al. 1999). We recorded 34 broods belonging to 11 species in the ground-search area (Figure 9). We saw broods of Pacific and Red-throated loons, White-fronted and Canada geese, Tundra Swan, Green-winged Teal, Greater Scaup, Red-breasted Merganser, Parasitic Jaeger, Glaucous Gull, and Arctic Tern.

SEASONAL USE OF LAKES

Twenty species of waterbirds were recorded during 10 aerial surveys of lakes in the Alpine project area (Table 11). Ducks were the most numerous birds observed (61% of the total, Appendix G). The most

Table 10. Numbers and densities of nests found on 10-ha plots in the Alpine project area, Colville River Delta, Alaska, 1998. Plots within 1,500 m of the airstrip were classified as Treatment and those greater than 1,500 m were classified as Reference. Plots containing combinations of Wet Sedge–Willow Meadow, Moist Sedge–Shrub Meadow, or Aquatic Sedge with Deep Polygon habitats were classified as "Mixed"; all others contained only Wet Sedge–Willow Meadow.

	Treatment and Habitat Classification and Plot Number													
	Treat.-Mixed			Treatment			Reference			Ref.-Mixed				
Species	1	2	3	4	5	6	7	8	9	10	11	12	Total Nests	Density (nests/km^2)
Red-throated Loon				1									1	0.8
Greater White-fronted Goose	1	1	1			3		3	3		3	1	16	13.3
Tundra Swan	1		1			1							3	2.5
Northern Shoveler							1						1	0.8
Norther Pintail			1										1	0.8
Greater Scaup											1		1	0.8
Unidentified duck		1	1										2	1.7
Willow Ptarmigan											1		1	0.8
Black-bellied Plover					1			1				1	3	2.5
American Golden-Plover	1												1	0.8
Bar-tailed Godwit		1								1			2	1.7
Semipalmated Sandpiper	2	2	1	1	4	4		5		1		1	21	17.5
Pectoral Sandpiper	7	7	9	3	3	5	5	9	3	3	5	2	61	50.8
Dunlin	1			3						1			5	4.2
Stilt Sandpiper				1		1	1		1				4	3.3
Long-billed Dowitcher									1				1	0.8
Red-necked Phalarope	1			1	2	1	3	1		1	1	1	12	10.0
Red Phalarope			1	1	1		1				1	1	6	5.0
Savannah Sparrow		1					1	1			1		4	3.3
Lapland Longspur	4	5	6	2	5	4	4	6	3	1	5	4	49	40.8
Common Redpoll		1											1	0.8
Total Nests	18	19	21	13	16	19	16	26	11	8	18	11	196	163.3
Density (nests/km^2)	180	190	210	130	160	190	160	260	110	80	180	110	163.3	
Total Species	6	5	6	4	3	5	3	4	4	4	4	4	15	

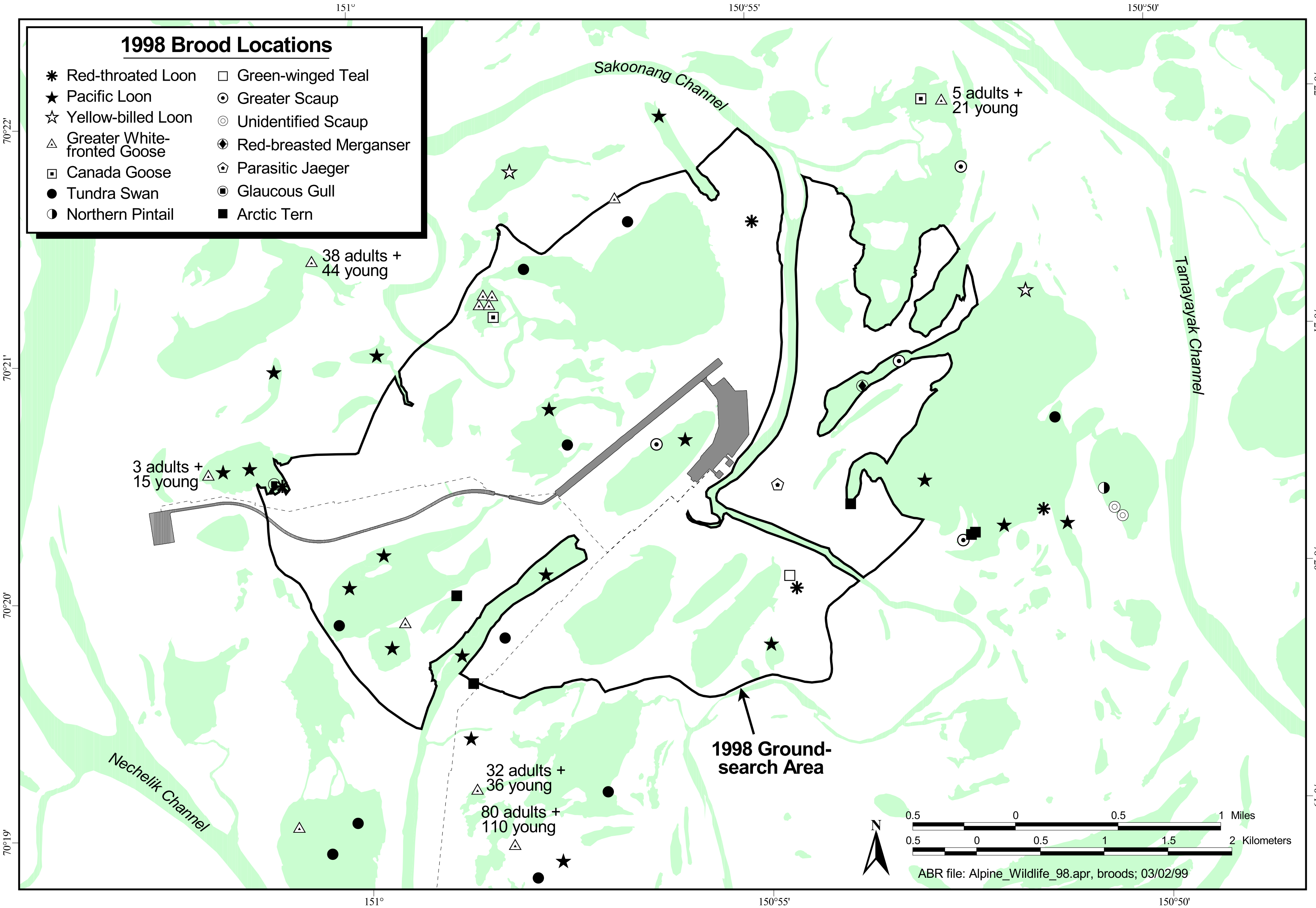

Figure 9. Locations of broods found incidental to nest-fate checks in the Alpine project area, Colville River Delta, Alaska, 1998. Symbols represent single family groups unless otherwise indicated.

Table 11. Species and numbers of waterbirds observed during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1998.

	Survey Date										
	June				July			August			Total
Species	16	17	21	29	8	14	27	13	24	27	Birds
Red-throated Loon	4	7	9	5	3	2	0	1	7	3	41
Pacific Loon	56	62	43	49	24	53	33	39	57	53	469
Yellow-billed Loon	16	22	22	10	3	5	2	8	8	3	99
Red-necked Grebe	7	7	1	12	0	1	0	2	1	0	31
Greater White-fronted	45	106	399	171	316	65	181	654	54	246	2,237
Canada Goose	0	2	1	0	13	0	0	220	243	270	749
Tundra Swan	56	27	26	38	54	56	72	62	231	133	755
American Wigeon	221	325	440	201	19	0	0	0	132	165	1,503
Mallard	2	3	9	2	13	0	0	0	0	10	39
Northern Shoveler	0	26	95	8	3	0	0	3	1	3	139
Northern Pintail	173	430	1272	384	39	36	56	208	512	825	3,935
Green-winged Teal	0	0	24	12	0	0	0	0	0	0	36
Scaup spp.	172	205	68	90	5	4	14	117	390	475	1,540
Surf Scoter	0	1	0	0	0	0	0	0	0	0	1
Black Scoter	2	15	0	0	0	0	0	0	0	0	17
Oldsquaw	84	69	38	2	1	4	0	0	0	0	198
Unidentified duck	0	0	0	0	0	1	156	6	0	6	169
Glaucous Gull	6	6	15	0	10	5	13	11	9	7	82
Sabine's Gull	1	7	0	0	0	0	2	0	0	0	10
Arctic Tern	34	59	48	0	58	30	32	9	0	0	270
Total Birds	883	1,379	2,511	989	561	263	575	1,340	1,645	2,248	12,394

commonly occurring ducks were Northern Pintail (52% of all ducks), American Wigeon (20%), and scaup spp. (20%). Except for American Wigeon, all of these species, along with less abundant species (Northern Shoveler, Green-winged Teal, Oldsquaw), were found nesting in the Alpine project area (Table 2, Appendix C). Loons (Pacific, Red-throated, and Yellow-billed), geese (White-fronted, Canada, and Brant), and Tundra Swans also nested in the area and were well represented throughout the surveys. Shorebirds, raptors, and other birds were noted; however, the focus of these surveys was primarily large waterbirds.

Most of the lakes we surveyed probably are used primarily by locally nesting and brood-rearing waterbirds. Exceptions to this general observation were basins containing Tapped Lakes with Low-water Connections (henceforth, tapped basins; Figure 3) that attracted large assemblages of waterbirds. Four of these basins were included in the area surveyed (Table 12, Figure 4). Throughout the summer, these tapped basins were important to waterbirds. The percentage of total waterbirds that were found in these tapped basins ranged from 56% (of 264 waterbirds on 14 July) to 97% (of 2,252 waterbirds on 27 August). We found few nests on the perimeters of these basins; rather, they seem to be used primarily for resting and feeding by aggregations of pre-nesting birds, post-breeding males, failed and nonbreeders, molting birds, and fall-staging groups. Brood-rearing waterfowl (geese, swans, and ducks) also use tapped basins, but they comprise a small proportion of the total birds counted on these lakes in July and August.

Waterbirds using the lakes in the Alpine project area were most numerous in mid-June and August (Table 11). During July we saw greatly reduced waterbird activity and recorded the lowest counts on 14 July. The high counts of birds in early summer was largely due to aggregations of ducks and geese using tapped basins (Table 13).

As would be expected, the amount of use by waterbirds varied widely among lakes. The lakes receiving the greatest activity—lakes S6.1, S7.2, U4.1, U5.1, and V5.1—were each used by >1,000 birds over the course of our 10 surveys combined (Table 12). Of these lakes, the only one that was not a Tapped Lake with Low-water Connection was lake U5.1, which was a Deep Open Lake with Islands or Polygonized Margins and contained extensive areas of Aquatic Grass Marsh (Figures 3 and 4). Lake U5.1 received the majority of its use, apparently for foraging, by various species of ducks during the month of June. Throughout the rest of the summer this lake was used by locally nesting and brood-rearing species (e.g., Red-necked Grebes, Pacific Loons, Tundra Swans, Greater Scaup) but never hosted the large numbers of waterbirds that were seen there earlier in the summer. The largest numbers of birds and species were counted in lake V5.1, the largest tapped basin in the survey area; it was used by more than twice as many birds as used any other lake (Table 12). Lakes T5.1 and U5.1 were the focus of nesting and brood-rearing by Red-necked Grebes in the Alpine project area (Figure 4). In 1998, two nests were found in lake T5.1 by ground searchers, and two more nests were found on lake U5.1 during aerial surveys. In 1997, three nests were found on lake T5.1 and a brood was seen on lake U5.1 (Figures 23 and 29: Johnson et al. 1998).

T7.2 LAKE COMPLEX

The T7.2 lake complex lies east of the facility and airstrip footprint, across the Sakoonang Channel of the Colville River (Figures 4 and 10). The T7.2 lake complex was being considered as a potential water source for the Alpine project but a different lake was chosen after our surveys were completed. We conducted surveys at the lake complex to evaluate bird use during nesting and brood-rearing. On ground searches in 1998, we found 31 waterbird nests, representing 9 species, within 100 m of the shores of the T7.2 lake complex (Figure 10, Appendix E). Most nests (21) were clumped in two areas of emergent vegetation along the south and southwestern margins of lake T7.2. The most common nests belonged to Pacific Loons, Arctic Terns, and scaup (2 identified as Greater Scaup, and 4 unidentified scaup). Other notable nests belonging to Yellow-billed Loon, Tundra Swan, Canada Goose, Spectacled Eider, and Bar-tailed Godwit were found within a few meters of the T7.2 lake complex. The T7.2 lake complex appears to be favored by Pacific Loons, because we found eight nests during ground searches and, during 10 aerial surveys, we counted almost twice as many Pacific Loons there (91 total) as were counted on other lakes (Table 12).

Table 12. Cumulative numbers of waterbirds seen during ten aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1998. See Figure 3 for lake identification.

	Lake Number													
Species	R6.1	R7.1	S6.1[a]	S6.2	S7.1	S7.2[a]	S7.3	T4.1	T4.2	T4.3	T4.4,T5.3, T5.4	T4.5	T4.6	T5.1,U5.2
Red-throated Loon	0	0	2	0	0	9	0	0	11	0	0	4	2	0
Pacific Loon	10	5	25	15	4	14	7	11	17	9	19	5	12	35
Yellow-billed Loon	0	0	10	0	0	3	0	2	0	0	0	0	0	7
Red-necked Grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Greater White-fronted Goose	13	8	48	0	0	81	37	0	42	13	33	8	8	29
Canada Goose	0	0	337	0	0	85	0	0	0	1	0	0	0	0
Brant	0	0	13	0	0	7	0	0	0	0	0	0	2	0
Tundra Swan	39	0	38	14	4	157	6	1	5	0	4	0	3	21
American Wigeon	27	0	205	0	1	275	2	0	0	0	0	0	0	2
Mallard	0	0	12	0	0	0	0	0	0	0	2	0	0	2
Northern Shoveler	9	0	44	0	4	0	0	0	4	0	0	0	0	1
Northern Pintail	37	6	462	0	12	304	2	7	12	8	1	1	2	39
Green-winged Teal	0	0	20	0	2	0	0	0	0	0	0	0	0	3
Unidentified scaup	0	2	11	0	0	295	2	0	8	0	0	2	0	0
Surf Scoter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Black Scoter	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oldsquaw	22	3	7	4	0	2	0	0	4	0	0	0	1	6
Unidentified duck	0	0	28	0	0	75	0	0	0	0	0	0	0	6
Glaucous Gull	0	1	3	0	0	3	1	1	12	6	0	0	1	1
Sabine's Gull	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Arctic Tern	5	0	3	0	27	2	7	0	3	3	1	2	0	13
Total Birds	162	25	1,268	33	54	1,312	64	22	118	40	60	22	31	176
Total Species	8	6	16	3	7	13	8	5	10	6	6	6	8	14

[a] Tapped Lake with Low-water Connection.

Table 12. continued.

Species	Lake Number													
	T5.2	T5.5	T5.6	T6.1	T6.2	T7.1,T7.2,T7.3, T7.4,T8.1[b]	U4.1[a]	U4.2	U5.1	U5.3	U6.1	U6.2	U6.3, 6.4	V5.1[a]
Red-throated Loon	0	0	1	0	0	0	6	2	0	0	0	0	0	4
Pacific Loon	14	32	1	6	5	91	14	6	49	6	1	2	2	52
Yellow-billed Loon	2	0	0	4	0	44	0	0	8	1	6	4	7	1
Red-necked Grebe	0	0	0	0	0	0	0	0	21	2	0	0	0	0
Greater White-fronted Goose	1	17	15	0	18	133	236	0	64	0	6	18	0	1,409
Canada Goose	0	0	10	1	0	1	4	0	0	0	0	0	0	310
Brant	0	0	0	0	0	0	0	0	0	0	0	0	0	52
Tundra Swan	9	26	7	0	0	46	35	0	38	0	6	2	4	290
American Wigeon	0	67	4	0	0	0	592	0	122	0	0	0	0	206
Mallard	0	0	0	0	0	0	0	0	9	0	0	0	0	14
Northern Shoveler	2	0	8	0	0	0	20	0	19	0	0	0	0	28
Northern Pintail	3	96	84	2	1	4	889	0	1,003	0	2	7	6	945
Green-winged Teal	0	0	0	0	0	0	0	0	11	0	0	0	0	0
Unidentified scaup	0	4	0	5	0	19	370	0	168	1	0	0	0	653
Surf Scoter	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Black Scoter	0	0	0	0	0	0	15	0	0	0	0	0	0	2
Oldsquaw	0	16	0	2	0	5	29	4	69	4	0	6	0	14
Unidentified ducks	0	0	0	0	0	0	36	0	1	0	3	0	0	20
Glaucous Gull	0	1	0	0	1	4	10	0	5	0	4	0	0	26
Sabine's Gull	0	0	0	0	0	0	0	0	0	0	0	0	2	5
Arctic Tern	3	5	1	1	16	52	6	0	6	1	13	0	1	99
Total Birds	34	264	131	21	41	399	2,262	12	1,594	15	41	39	22	4,130
Total Species	7	9	9	7	5	10	13	3	15	6	7	6	6	17

[a] Tapped Lake with Low-water Connection.
[b] T7.2 lake complex, see Figure 4.

Table 13. Mean number of waterbirds by lake category recorded during ten aerial surveys in the Alpine project area, Colville River Delta, Alaska, 1998. Lake categories include Tapped Lake with Low-water Connection, the T7.2 lake complex, and all other lakes.

	June (*n* = 4 surveys)			July (*n* = 3 surveys)			August (*n* = 3 surveys)		
Species	Tapped	T7.2[a]	Other	Tapped	T7.2[a]	Other	Tapped	T7.2[a]	Other
Red-throated Loon	3.5	0.0	2.5	0.0	0.00	1.7	2.3	0.0	1.3
Pacific Loon	13.8	11.8	27.0	13.0	6.7	17.0	16.3	8.0	25.3
Yellow-billed Loon	1.8	7.3	8.5	1.0	1.3	1.0	1.3	3.7	1.3
Red-necked Grebe	0.0	0.0	6.8	0.0	0.0	0.3	0.0	0.0	1.0
Greater White-fronted Goose	122.3	27.5	30.5	168.0	2.3	17.0	277.0	5.3	35.7
Canada Goose	0.0	0.3	0.5	4.3	0.0	0.0	244.3	0.0	0.0
Brant	2.0	0.0	0.5	5.0	0.0	0.0	16.3	0.0	0.0
Tundra Swan	23.5	3.8	9.5	29.0	8.7	23.0	124.0	1.7	16.3
American Wigeon	258.3	0.0	38.5	6.3	0.0	0.0	99.0	0.0	0.0
Mallard	0.8	0.0	3.3	4.3	0.0	0.0	3.3	0.0	0.0
Northern Shoveler	23.5	0.0	8.8	1.0	0.0	0.0	1.0	0.0	1.3
Northern Pintail	285.8	1.0	278.0	32.7	0.0	11.0	513.3	0.0	1.7
Green-winged Teal	5.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Scaup spp.	85.8	3.5	43.5	7.0	0.7	0.0	321.7	1.0	4.7
Surf Scoter	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Black Scoter	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oldsquaw	17.0	1.3	30.0	0.0	0.0	1.7	0.0	0.0	0.0
Unidentied duck	0.0	0.0	0.0	51.0	0.0	1.3	2.0	0.0	2.0
Glaucous Gull	3.5	0.3	3.0	4.0	0.7	4.0	6.0	0.3	2.7
Sabine's Gull	1.3	0.0	0.8	0.0	0.0	0.7	0.0	0.0	0.0
Arctic Tern	20.5	10.3	4.5	13.7	3.7	22.7	3.0	0.0	0.0
Total Birds	872.3	66.8	500.3	341.0	24.0	101.3	1,631.0	20.0	93.3
Total Species	17	10	19	13	7	11	14	6	10

[a] Lakes T7.1,T7.2, T7.3, T7.4, T8.1 combined, see Figure 4.

We observed 15 broods of 8 species of waterbirds using the T7.2 lake complex during and ground searches of the T7.2 lake complex (Figure 11, Appendix F). We counted four broods of Scaup, three broods each of Pacific Loons and Arctic Terns, and one each of Yellow-billed Loon, Red-throated Loon, Tundra Swan, Red-breasted Merganser, and Northern Pintail.

Compared to other lakes in the Alpine project area, the T7.2 complex supported more waterbird nests and a more diverse assemblage of breeding waterbird species than any other lake where we conducted ground surveys (Figure 5). Throughout the summer, the T7.2 lake complex was not used by as many birds or species as the tapped basins, but among the other lakes it was second only to lake U5.1 in total numbers and species richness (Table 12).

CONCLUSIONS

Although 1998 in the Alpine project area could not be considered a pre-construction year for the purposes of evaluating the effects of the airstrip in a "before-after" comparison, construction activity was less than what ordinarily occurs during years of full construction in oilfield developments. We analyzed nesting data for all waterbirds and Greater White-fronted Geese found during foot searches to look for relationships with distance from the airstrip, hypothesizing that if the construction activity in 1998 was sufficient to disturb nesting birds—nest fate, clutch size, or nest density would be affected. We did not detect any effects, except possibly, that nest density was lower near the airstrip than it was away from the airstrip. However, the greater abundance of preferred nesting habitat that was >1,000 m than

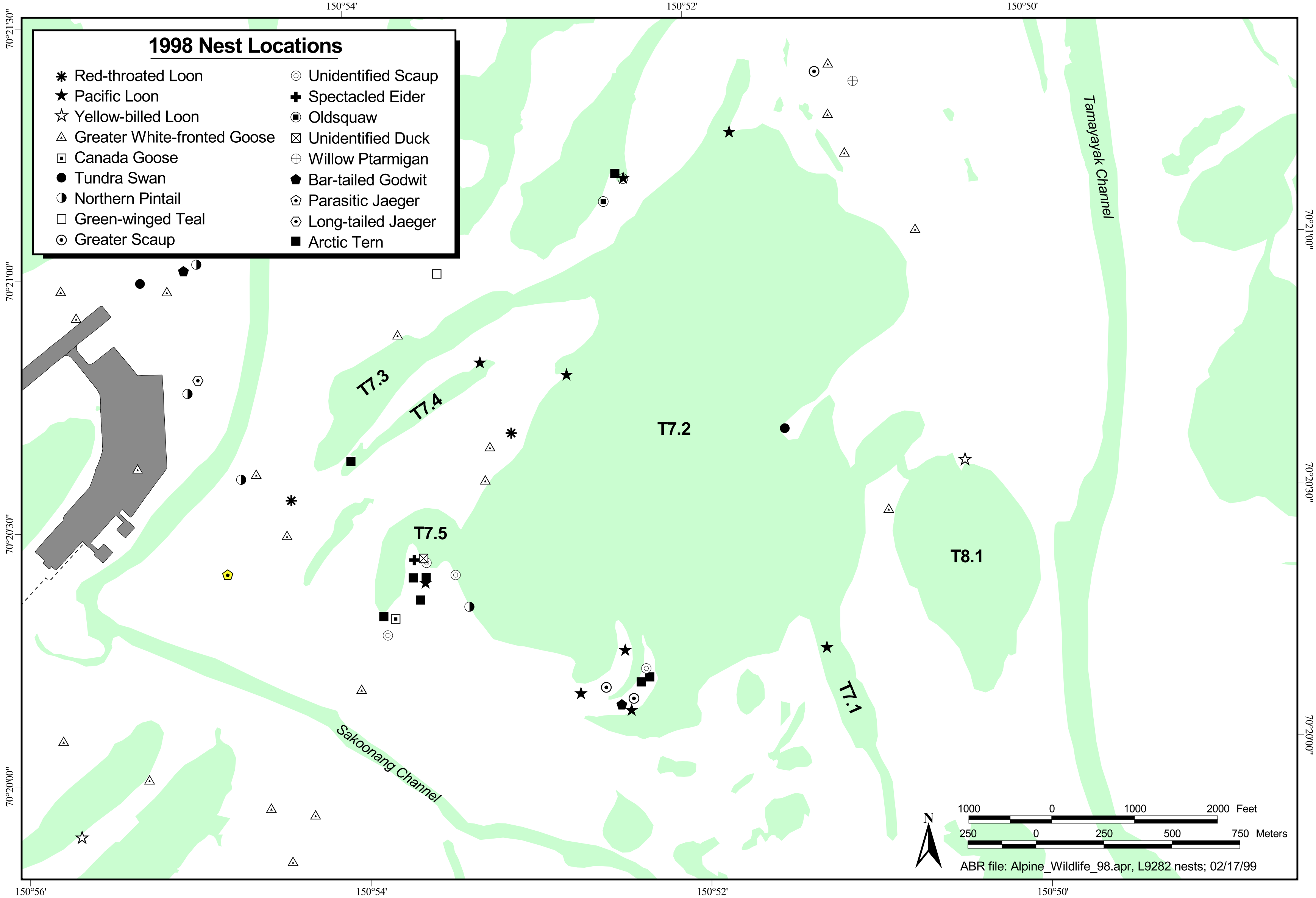

Figure 10. Locations of nests found around the T7.2 lake complex, Alpine project area, Colville River Delta, Alaska, 1998.

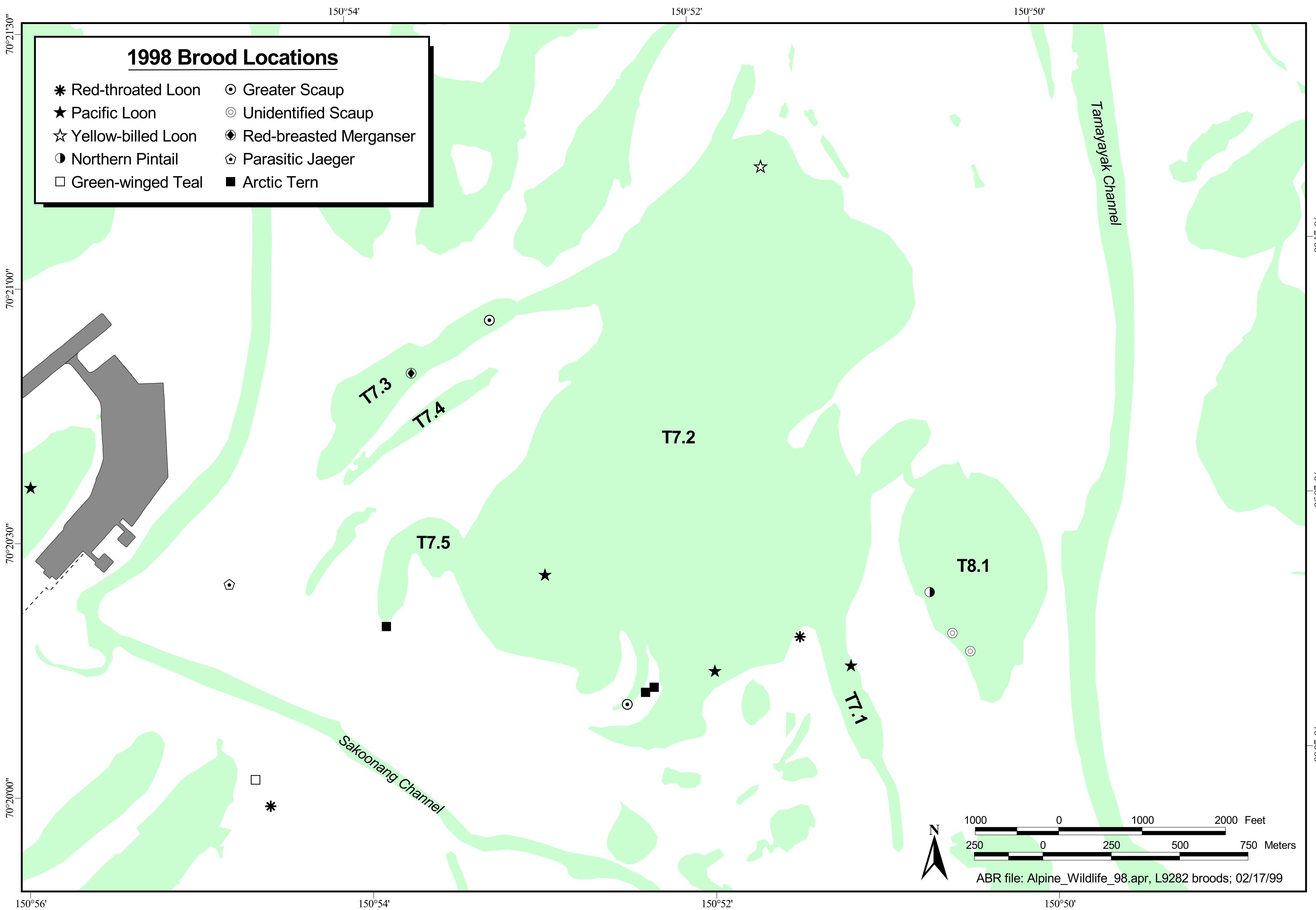

Figure 11. Locations of broods found incidental to nest-fate checks around the T7.2 lake complex, Alpine project area, Colville River Delta, Alaska, 1998.

was <1,000 m from the airstrip may explain part, if not all, of the distributional patterns of nests around the airstrip. We compared nest numbers of all bird species on 10-ha plots and found that habitat and distance to the airstrip were interacting factors, but that proximity to the airstrip did not correspond with decreases in nest densities. Furthermore, we compared the distribution of large waterbird nests in 1998 with those in 1996 and 1997, before the airstrip was in place, and could detect no differences in the distance of nests from the current airstrip location. Although no construction occurred in 1996 and 1997, human activity occurred in the form of surveyors, hydrologists, and engineers working at the site of the airstrip, likely resulting in disturbance to some nesting birds.

In the next two years, we will investigate whether the "full" construction and operation years result in any additional disturbance to nesting birds over that in 1996–1998. The use of BACI and gradient-style analyses should allow us to measure impacts in the absence of a pre-construction year. Finally, further analysis of the role of habitat in the distribution of nests will be conducted, so that patterns of distribution can be related to potential disturbance sources without the confounding effects of habitat distribution.

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Appendix A. Common and scientific names of birds and mammals seen during the Colville River Delta Wildlife Study, May–October 1992–1998.

BIRDS

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

MAMMALS

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

APPENDIX B. CLASSIFICATION OF INCUBATION BEHAVIOR OF GREATER WHITE-FRONTED GEESE MONITORED WITH TIME-LAPSE CAMERAS AND EGG THERMISTORS IN THE ALPINE PROJECT AREA, 1998.

At the two White-fronted Goose nests that were monitored simultaneously with both an egg thermistor and a time-lapse camera, we collected 867 temperature records (recorded at 5-min intervals) and 4335 video pictures (1-sec recordings at 1-min intervals). (Camera malfunctions interrupted video recording while nests were monitored with the egg thermistors, so that video coverage was incomplete.) We identified the occurrence of incubation, breaks, and recesses on the video recordings and compared those behaviors to temperature changes in thermistors recorded during the same time period. From the video recording, we determined that breaks, when the female turned the eggs or repositioned herself on the nest, occurred in ≤3 consecutive recordings (hereafter, we represent 1 video recording as 1 min, recognizing that the behavior recorded could last from >0 min to <2 min) and that recesses, when the female was off the nest, either standing beside it or out of the video picture, occurred in ≥4 consecutive recordings (4 min). We observed the female, at times, repositioning herself on the nest before and/or after a recess, and therefore, a break could precede or follow a recess. The female was considered incubating during a video recording when she was sitting on the nest and her body position had not changed relative to her position in the previous recording.

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

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

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

Appendix C. Numbers of nests of selected species found during ground searches in 1996, 1997 and 1998, and within the area searched in common in all three years in the Alpine project area, Colville River Delta, Alaska. Search area boundaries are displayed in Figure 8 and in Johnson et al. (1998: Figure 10). For 1998, only the results of the first nest search are presented.

	Number of Nests					
	Total Search Area			Common Search Area		
Species	1996	1997	1998	1996	1997	1998
Red-throated Loon	2	7	1	1	5	1
Pacific Loon	3	8	1	2	4	1
Yellow-billed Loon	1	1	0	1	1	0
Red-necked Grebe	0	3	2	0	3	2
Greater White-fronted Goose	35	45	48	25	35	31
Canada Goose	0	0	2	0	0	0
Brant	2	7	1	0	4	1
Tundra Swan	3	6	5	3	4	5
Northern Shoveler	1	0	5[a]	0	0	5[a]
Northern Pintail	2	5	9[a]	2	4	7[a]
Green-winged Teal	1	0	1	1	0	1
Greater Scaup	0	2	1	0	1	1
Lesser Scaup	0	0	1	0	0	1
Unidentified scaup	0	0	2	0	0	0
Spectacled Eider	0	0	1	0	0	0
King Eider	1	0	0	0	0	0
Oldsquaw	7	9	6[a]	6	9	5[a]
Unidentified duck	0	0	4	0	0	3
Bar-tailed Godwit	1	0	2	0	0	2
Common Snipe	0	1	0	0	1	0
Parasitic Jaeger	1	1	2	1	1	2
Long-tailed Jaeger	1	0	1	1	0	1
Glaucous Gull	0	2	0	0	1	0
Sabine's Gull	1	0	0	1	0	0
Arctic Tern	0	5	4	0	5	3
Short-eared Owl	1	0	0	0	0	0
Area (km^2)	17.2	14.3	14.8	10.6	10.6	10.6
Search Hours	354	366	420	218	271	300
Total Nests	63	102	99	44	78	72
Nest density (nests/km^2)	3.7	7.1	6.7	4.1	7.3	6.8
Total number of species	16	14	18	11	14	16

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

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

Habitat	Area (km^2)	No. of Groups	Use (%)	Availability (%)	Monte Carlo Results[a]
1996					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.7	ns
Tapped Lake w/ High-water Connection	0.79	0	0	7.4	ns
Salt Marsh	0.60	0	0	5.7	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.93	0	0	8.7	ns
Deep Open Water w/ Islands or Polygonized Margins	<0.01	0	0	<0.1	-
Shallow Open Water w/o Islands	0.01	0	0	0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.04	0	0	0.4	ns
River or Stream	<0.01	0	0	<0.1	-
Aquatic Sedge Marsh	0	-	-	0	-
Aquatic Sedge w/ Deep Polygons	0.12	1	4.5	1.1	ns
Aquatic Grass Marsh	0.10	0	0	0.9	ns
Young Basin Wetland Complex	0	-	-	0	ns
Old Basin Wetland Complex	0	-	-	0	ns
Nonpatterned Wet Meadow	1.01	0	0	9.5	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.61	16	72.7	43.4	prefer
Moist Sedge-Shrub Meadow	1.40	5	22.7	13.2	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.50	0	0	4.7	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0	2.2	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.63	22	100	100	
1997					
Open Nearshore Water (marine)	0	-	-	0	-
Brackish Water	0	-	-	0	-
Tapped Lake w/ Low-water Connection	0.28	0	0	2.7	ns
Tapped Lake w/ High-water Connection	0.79	0	0	7.4	ns
Salt Marsh	0.60	0	0	5.7	ns
Tidal Flat	0	-	-	0	-
Salt-killed Tundra	0	-	-	0	-
Deep Open Water w/o Islands	0.93	0	0	8.7	ns
Deep Open Water w/ Islands or Polygonized Margins	<0.01	0	0	<0.1	-
Shallow Open Water w/o Islands	0.01	0	0	0.1	ns
Shallow Open Water w/ Islands or Polygonized Margins	0.04	0	0	0.4	ns
River or Stream	<0.01	0	0	<0.1	-
Aquatic Sedge Marsh	0	-	-	0	-
Aquatic Sedge w/ Deep Polygons	0.12	1	4.3	1.1	ns
Aquatic Grass Marsh	0.10	0	0	0.9	ns
Young Basin Wetland Complex	0	-	-	0	ns
Old Basin Wetland Complex	0	-	-	0	ns
Nonpatterned Wet Meadow	1.01	0	0	9.5	ns
Wet Sedge-Willow Meadow w/ Low-relief Polygons	4.61	18	78.3	43.4	prefer
Moist Sedge-Shrub Meadow	1.40	3	13.0	13.2	ns
Moist Tussock Tundra	0	-	-	0	-
Riverine or Upland Shrub	0.50	1	4.3	4.7	ns
Barrens (riverine, eolian, lacustrine)	0.23	0	0	2.2	ns
Artificial (water, fill, peat road)	0	-	-	0	-
Total	10.63	23	100	100	

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

Appendix E. Waterbird nests found during ground searches within 100 m of the T7.2 lake complex, Colville River Delta, Alaska, June and July, 1998.

Species	Date Found	Nest Fate
Red-throated Loon	27 June	Failed
Pacific Loon	20 June	Unknown
Pacific Loon	24 June	Unknown
Pacific Loon	27 June	Unknown
Pacific Loon	28 June	Successful
Pacific Loon	28 June	Successful
Pacific Loon	28 June	Successful
Pacific Loon	28 June	Unknown
Pacific Loon	11 July	Unknown
Yellow-billed Loon	24 June	Successful
Greater White-fronted Goose	12 June	Successful
Greater White-fronted Goose	20 June	Successful
Greater White-fronted Goose	24 June	Successful
Greater White-fronted Goose	27 June	Successful
Canada Goose	20 June	Successful
Tundra Swan	20 June	Successful
Northern Pintail[a]	20 June	Unknown
Greater Scaup	24 June	Successful
Greater Scaup	28 June	Unknown
Unidentified scaup	20 June	Successful
Unidentified scaup	20 June	Failed
Unidentified scaup	21 June	Unknown
Unidentified scaup	28 June	Unknown
Spectacled Eider	20 June	Successful
Unidentified duck	20 June	Successful
Bar-tailed Godwit	24 June	Successful
Arctic Tern	21 June	Successful
Arctic Tern	21 June	Unknown
Arctic Tern	21 June	Unknown
Arctic Tern	21 June	Unknown
Arctic Tern	27 June	Successful
Arctic Tern	28 June	Successful
Arctic Tern	28 June	Successful

[a] Nest identified from down and feathers.

Appendix F. Waterfowl broods found in the T7.2 lake complex, Colville River Delta, Alaska, 1998.

	Number of		
Species	Adults	Young	Date
Red-throated Loon	1	1	24 August
Pacific Loon	1	2	25 August
Pacific Loon	2	1	25 August
Pacific Loon	1	1	25 August
Yellow-billed Loon	2	2	25 August
Tundra Swan	2	2	8 July
Northern Pintail	1	5	25 August
Greater Scaup	1	4	25 August
Unidentified scaup	1	4	25 August
Unidentified scaup	1	4	25 August
Unidentified scaup	1	3	25 August
Red-breasted Merganser	1	10	25 August
Arctic Tern	2	1	11 August
Arctic Tern	2	2	11 August
Arctic Tern	2	1	11 August

Appendix G. Counts of birds by waterbird groups during aerial surveys of lakes in the Alpine project area, Colville River Delta, Alaska, 1998.

	Date of Survey										Total
	June				July			August			
Waterbird groups	16	17	21	29	8	14	27	13	24	27	
Loons, Grebes	83	98	75	76	30	61	35	50	73	59	640
Geese	49	108	401	176	329	66	195	874	297	565	3,060
Swans	56	27	26	38	54	56	72	62	231	133	755
Dabbling ducks	396	784	1,840	607	74	36	56	211	645	1,003	5,652
Diving ducks	258	290	106	92	6	8	14	117	390	475	1,756
Total Ducks[a]	654	1,074	1,946	699	80	45	226	334	1,035	1,484	7,577
Gulls, Terns	41	72	63	0	68	35	47	20	9	7	362
Total Birds	883	1,379	2,511	989	561	263	575	1,340	1,645	2,248	12,394

[a] Includes unidentified ducks.