TWELFTH ANNUAL REPORT

AVIAN STUDIES FOR THE ALPINE SATELLITE DEVELOPMENT PROJECT, 2014

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Prepared for

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Anchorage, Alaska

and

Anadarko Petroleum Corporation
Anchorage, Alaska

Prepared by

ABR, Inc.—Environmental Research & Services
Fairbanks, Alaska

Cover: Aerial view of Yellow-billed Loon near nest. Photo by ABR © ConocoPhillips Alaska.

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EXECUTIVE SUMMARY

Aerial and ground-based surveys of bird populations were conducted in the Colville River delta and in the northeastern National Petroleum Reserve in Alaska (NE NPR-A) in 2014 in support of the Alpine Satellite Development Project (ASDP) for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation. The surveys continued long-term data acquisition begun in 1992 on the Colville River delta and in 1999 in the NE NPR-A. Surveys focused on the abundance, distribution, and habitat use of 5 focal species groups: Spectacled Eider, King Eider, Tundra Swan, Yellow-billed Loon, and geese. These 5 taxa were selected because of 1) threatened or sensitive status, 2) indications of declining populations, 3) restricted breeding range, and/or 4) concern of regulatory agencies regarding development impacts. A new task was added in 2013—a ground-based nesting study of Greater White-fronted Geese in the CD5 area—because of concerns by the North Slope Borough for an important subsistence species. Aerial surveys for eiders, swans, and geese were conducted from a fixed-wing airplane. Surveys for Yellow-Billed Loons were conducted from a helicopter.

The Colville Delta study area (552 km²) encompassed the entire delta from the East Channel of the Colville River to the westernmost distributary of the Niġliq Channel. The Alpine Facility (CD1 and CD2) began oil production on the Colville River delta in 2000. Two ASDP satellite drill sites were built in the winter of 2005: CD3 was designed as a roadless drill site to reduce its gravel footprint in Spectacled Eider (a federally listed threatened species) breeding habitat on the outer delta, and CD4 was connected by a road on the south side of the Alpine Facility. The CD3 site began producing oil in August 2006, and CD4 began producing in November 2006. The NE NPR-A study area (686.8 km² in 2014) abuts the western edge of the Colville Delta study area and encompasses CD5, for which gravel pads were constructed in the winter of 2014, and 2 proposed development sites that are part of the ASDP: drill sites GMT1 and GMT2.

Aerial surveys in the Colville Delta and NE NPR-A study areas in 2014 generally indicated average to above average observed numbers of breeding adults and below average productivity as measured by number of nests, nesting success, or production of young, although there were exceptions. Production of young was particularly poor for Yellow-billed Loons in both the Colville Delta and NE NPR-A study areas, whereas Tundra Swans did better in NE NPR-A study area than they did in the Colville Delta study area. We suspect that predation of nests was the primary factor that contributed to low productivity in 2014.

Spring conditions in 2014 were near average for several benchmarks. Average snow fall and unseasonably warm temperature in the foothills in early May brought the first of 2 peak stage events on 20 May. River levels dropped during a week of freezing temperatures, and then peaked again at the head of the delta (Monument 1) on 31 May. Timing of river break-up was average, cumulative thawing degree-days (an index to days with temperatures above freezing) were below average for 15 May to 15 June, and mosquito emergence (an index to ground and water warming) occurred at the end of June, within the range of normal dates. Fall temperatures were mild and lakes were free of ice at least until late September.

The indicated number of pre-nesting Spectacled Eiders in the Colville Delta study area in 2014 (68 indicated birds) was higher than the long-term mean. As in previous years, Spectacled Eiders were found primarily in the CD North subarea. Some of the highest counts of Spectacled Eiders on the Colville Delta study area during the last 2 decades have been recorded over the last 7 years, reversing the depressed numbers recorded in this area during the early 2000s. The long-term trend in numbers of Spectacled Eiders on the Colville Delta study area is slightly positive (growth rate = 1.01) whereas the trend for the entire Arctic Coastal Plain (ACP) is slightly negative (growth rate = 0.99). Spectacled Eiders occurred at average numbers in the NE NPR-A study area in 2014 and at 21% of the density found on the Colville Delta study area. The long-term trend in numbers in the NE NPR-A study area also is slightly positive (growth rate = 1.05). None of the trends (ACP, Colville Delta, NE NPRA) was significantly different from equilibrium, however, suggesting that the population likely is stable. Spectacled Eiders preferred 7 habitats on the Colville Delta study area, all consistent with

their primarily coastal distribution: 3 coastal salt-affected habitats, 3 aquatic habitats, and 1 terrestrial habitat. In the NE NPR-A study area, Spectacled Eiders preferred 6 habitats, 4 of which were also preferred in the Colville Delta study area.

King Eiders (66 indicated birds) were nearly as numerous as Spectacled Eiders in the Colville Delta study area during pre-nesting in 2014, with densities well above the long-term mean. Annually we record high numbers of King Eiders on the delta in habitats unsuitable for nesting, particularly the eastern channels of the Colville River. Those locations during pre-nesting and the low frequency of King Eider nests relative to Spectacled Eider nests in areas searched, lead us to conclude that King Eiders primarily use the Colville River delta as a stopover while moving to breeding areas farther east. In contrast, King Eiders breed in high numbers in the NE NPR-A study area (120 indicated birds in 2014) and the density of King Eiders in the NE NPR-A study area in 2014 was about 3 times that in the Colville Delta study area. King Eiders have increased at a significant rate in the NE NPR-A study area (growth rate = 1.064) and on the ACP (growth rate = 1.047), but not in the Colville Delta study area (growth rate = 1.006), where they breed in relatively low numbers.

Despite high numbers of adults and nests, the numbers of Yellow-billed Loon chicks and broods in 2014 were among the lowest since surveys began in the Colville Delta study area. Record numbers of adults were counted during the nesting survey (78 birds), the number of nests (32) was the third highest on record, and territory occupancy by nests (74%) was well above the 20-year mean. Only 8 nests hatched young, however, resulting in the lowest apparent nesting success (26%) since monitoring surveys began in 2005. The number of Yellow-billed Loons seen on the brood-rearing survey (48 birds) was slightly below the long-term mean, whereas the number of broods (4) and occupation of territories by broods (19%) were among the lowest on record. The number of Yellow-billed Loon adults appears to be increasing on the ACP (growth rate = 1.05 over 10 years) and in the Colville Delta study area (growth rate = 1.03 over 12 years, when flood years are excluded).

In addition to low nesting success and chick production at hatch, chick survival also was low for Yellow-billed Loons in the Colville Delta study area in 2014. The 10 chicks at hatch (0.32 chicks/nest) was the lowest recorded since monitoring began in 2008. Four chicks survived to the last survey in mid-September (yielding 0.13 chicks/nest at or near fledging), which was the highest proportion of chicks lost between hatch and September in 7 years of records. Loon chicks were 9.5–10.5 weeks old during the last monitoring survey and none were observed flying.

The NE NPR-A study area also had high numbers of Yellow-billed Loon adults (47) and nests (20) in 2014, but nesting success (55%) was much higher than it was in the Colville Delta study area. The number of broods (11) was higher than the 4-year mean for surveys on the same lakes. Brood occupancy (35%) also was well above average. Similar to the Colville Delta study area, chick survival was quite low in the NE NPR-A study area. Although the number of chicks at hatch (0.65 chicks/nest) was near the long-term mean, the number of chicks seen during the final survey (0.36 chicks/nest) was below average.

Ten cameras were deployed in 2014 to record nest initiation in late May at nest sites repeatedly used by Yellow-billed Loons on the Colville Delta study area. One camera was knocked over by ice when the Colville River flooded. The start of incubation was documented at 7 nests; incubation began an average of 9 days after nest sites appeared accessible; the median start of incubation was 16 June (range = 15–20 June). Egg laying was observed on images at 5 nests. The median interval between the 2 eggs was 2.4 d (range = 2.4–2.5 d). Only 2 nests with known start dates hatched. A chick appeared on day 27 of incubation at one nest and day 28 at the other.

Twenty-one Yellow-billed Loon nests on the Colville Delta study area and 13 in NE NPR-A study area were monitored with time-lapse cameras. Apparent nesting success for camera-monitored nests in the Colville Delta and NE NPR-A study areas was 38% and 54%, respectively. Of the 13 nests that failed in the Colville Delta study area, 4 failures were attributed to predation by Glaucous Gulls, 3 to brown bears, 1 to Parasitic Jaegers, 1 to a red fox, and 3 failed from an unidentified predator. One nest failed after wind-blown ice crushed the nest and eggs. Of 6 camera-monitored nests that failed in the NE NPR-A study area, 3 were attributed to Glaucous Gulls, 1 to a Parasitic Jaeger, 1 to a wolverine, and 1 nest failed from an unidentified predator. Six of the above nests failed while the incubating loons interacted with intruding Yellow-billed loons, at which time gulls and jaegers took advantage of the unprotected nests. Yellow-billed Loons at hatched and failed nests in the Colville Delta study area exhibited fairly high incubation constancy, spending 96.8% and 95.2% of monitored time on nests, respectively. Incubation constancy at hatched and failed nests in the NE NPR-A study area was 98.0% and 93.6%, respectively.

Although Tundra Swan abundance was above average in 2014, productivity in the Colville Delta study area was the second-lowest in 21 years of surveys. Twenty-three Tundra Swan nests were found in the Colville Delta study area, many fewer than the long-term mean of 34 nests/year. Apparent nesting success (61%) was noticeably lower than the 21-year mean of 71%. Both number of broods (14) and brood size (2.1 cygnets/brood) in the Colville Delta study area were below long-term means of 24 broods and 2.5 cygnets/brood, respectively. In the NE NPR-A study area, 15 Tundra Swan nests were found in June and 10 broods were seen in August, for a relatively high apparent nesting success of 67%, but with slightly smaller mean brood sizes (2.0 cygnets) than in the Colville Delta study area. The number of pairs of Tundra Swans has grown at a significant rate in the Colville Delta study area (growth rate = 1.030) since 1992, as has the total number of adult Tundra Swans over 27 years on the ACP (growth rate = 1.046).

Nest survival of Greater White-fronted Geese was evaluated on 40 10-hectare (ha) plots in the CD5 drill site area in the NE NPR-A study area. Plots contained 0–8 Greater White-fronted Goose nests, for an overall density of 28.7 nests/km^2. The median date of nest initiation was 5 June and the median start date of incubation was 9 June. Forty of 147 Greater White-fronted Goose nests were instrumented with temperature thermistors to monitor nest survival. Apparent nesting success was 62% for nests without thermistors and 68% for nests with thermistors. The daily survival rate for instrumented nests was 0.98, and nesting success calculated from daily survival rates was 68% for a 24-day incubation period. The daily survival rate for instrumented nests in 2013 was 0.97. The most common predators recorded on timed predator scans were jaegers (53% of observations, comprising Parasitic, Long-tailed, and Pomarine jaegers) and Glaucous Gulls (45%); 1 arctic fox and 1 brown bear family group also were recorded on predator scans.

Brant production was high in both the Colville Delta and NE NPR-A study areas in 2014. The count of adult Brant during brood-rearing surveys in the Colville Delta study area (1,049) was well above average, as was the number of goslings (1,018). In the NE NPR-A study area, numbers of adult Brant (2,741) and goslings (1,141) were among the highest on record. The percent composition of goslings in brood-rearing/molting groups was above average in the Colville Delta study area and near average in the NE NPR-A study area.

Numbers of adult Snow Geese were high in both survey areas in 2014 (1,524 in the Colville Delta study area and 299 in NE NPR-A study area), but the number of goslings (1,021) was near average in the Colville Delta study area and the number of goslings in the NE NPRA study area (93) was well below the 10-year average of 152 goslings. Snow Goose gosling percentages (percent of total Snow Geese) were below average in both study areas in 2014.

Glaucous Gulls are monitored because they are frequent predators of other bird's eggs. The number of Glaucous Gull nests counted in the Colville Delta study area was the highest in 13 years of surveys. Eighty-four Glaucous Gull nests were counted during 2014. Based on 50 index lakes monitored annually in the Colville Delta study area, the number of Glaucous Gull nests increased significantly (growth rate = 1.056) between 2002 and 2014. That growth rate is nearly the same as reported for Glaucous Gulls on the entire ACP over 10 recent years (growth rate = 1.058).

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INTRODUCTION

The Colville River delta and Northeast Planning Area of the National Petroleum Reserve in Alaska (NE NPR-A) have been a focal point of exploration and development for oil and gas since at least the 1990s. During 2014, ABR, Inc., conducted wildlife surveys for selected birds and mammals in the Colville River delta and NE NPR-A in support of the Alpine Satellite Development Project (ASDP) of ConocoPhillips Alaska, Inc., (CPAI) and Anadarko Petroleum Corporation (APC). The avian studies in 2014 were a continuation of work initiated by CPAI's predecessors, ARCO Alaska, Inc., and Phillips Alaska, Inc., on the Colville River delta in 1992 (Smith et al. 1993, 1994; Johnson 1995; Johnson et al. 1996, 1997, 1998, 1999a, 1999b, 2000a, 2000b, 2001, 2002, 2003a, 2003b, 2004, 2005, 2006a, 2006b, 2007a, 2007b, 2008a, 2008b, 2009, 2010, 2011, 2012, 2013a, 2014a; Burgess et al. 2000, 2002a, 2003a) and in the NE NPR-A in 1999 (Anderson and Johnson 1999; Murphy and Stickney 2000; Johnson and Stickney 2001; Burgess et al. 2002b, 2003b; Johnson et al. 2004, 2005, 2006b, 2007b, 2009, 2010, 2011, 2012, 2013a, 2014a).

The ASDP studies augment long-term wildlife monitoring programs that have been conducted by CPAI (and its predecessors) across large areas of the central Arctic Coastal Plain (ACP) since the early 1980s (see Murphy and Anderson 1993, Stickney et al. 1993, Stickney et al. 2013, Lawhead et al. 2013). The primary goal of wildlife investigations in the region since 1992 has been to describe the seasonal distribution and abundance of selected species before, during, and after construction of oil development projects. CPAI began producing oil on the Colville River delta in 2000 with the development of the CD1 and CD2 drill sites. Production increased in 2006 with oil produced from the CD3 and CD4 drill sites, which were constructed in 2005 and winter of 2006. CPAI has proposed additional oil and gas development sites in the NE NPR-A as part of the Alpine Satellite Development Project (BLM 2004) at CD5 (Alpine West) and GMT1 (Lookout) (Figure 1). Readers are directed to prior reports for wildlife information from previous years.

In this report, we present the results of avian surveys that were conducted in the Colville River delta and NE NPR-A in 2014 along with brief comparisons of results from previous years and other surveys. The surveys were designed to collect data on the distribution, abundance, and habitat use of 5 focal taxa (common names followed by Iñupiaq names): Spectacled Eider (Qavaasuk), King Eider (Qiŋalik), Tundra Swan (Qugruk), geese (Niġliq), and Yellow-billed Loon (Tuullik) (scientific names and Iñupiaq names are listed in Appendix A). These 5 taxa were selected in consultation with resource agencies and communities because of 1) threatened or sensitive status, 2) indications of declining populations, 3) restricted breeding range, 4) importance to subsistence hunting, and/or 5) concern by regulatory agencies for development impacts. A sixth species, the Greater White-fronted Goose (Niġlivik), was added as a focal species in 2013 at the request of the North Slope Borough Department of Wildlife Management, out of concern for development effects on this important subsistence species.

Aerial surveys for the focal species generally began in 1992, but coverage of the Colville Delta study area (Figure 1) that year was complete only for Tundra Swans and brood-rearing Brant and Snow Geese. Since 1993, aerial surveys in the Colville Delta study area have included pre-nesting eiders, nesting and brood-rearing Yellow-billed Loons, nesting and brood-rearing swans, and brood-rearing geese, with a few exceptions. Aerial surveys of the Colville Delta study area were conducted only for pre-nesting eiders in 1994 and no aerial surveys were conducted in 1999. Aerial surveys in the NE NPR-A study area (Figure 1) were initiated in 1999 for eiders and, since 2001, aerial surveys in the NE NPR-A study area also have included Yellow-billed Loons, swans, and brood-rearing geese. Aerial surveys in both study areas have reported nesting Glaucous Gulls since 2002. No aerial surveys were conducted in the NE NPR-A study area in 2007 (due to delays in permitting for the CD5 drill site) and only pre-nesting eiders and Yellow-billed Loons were surveyed in the NE NPR-A study area in 2010. Although survey boundaries have changed periodically, the Colville Delta study area has generally encompassed the entire Colville River

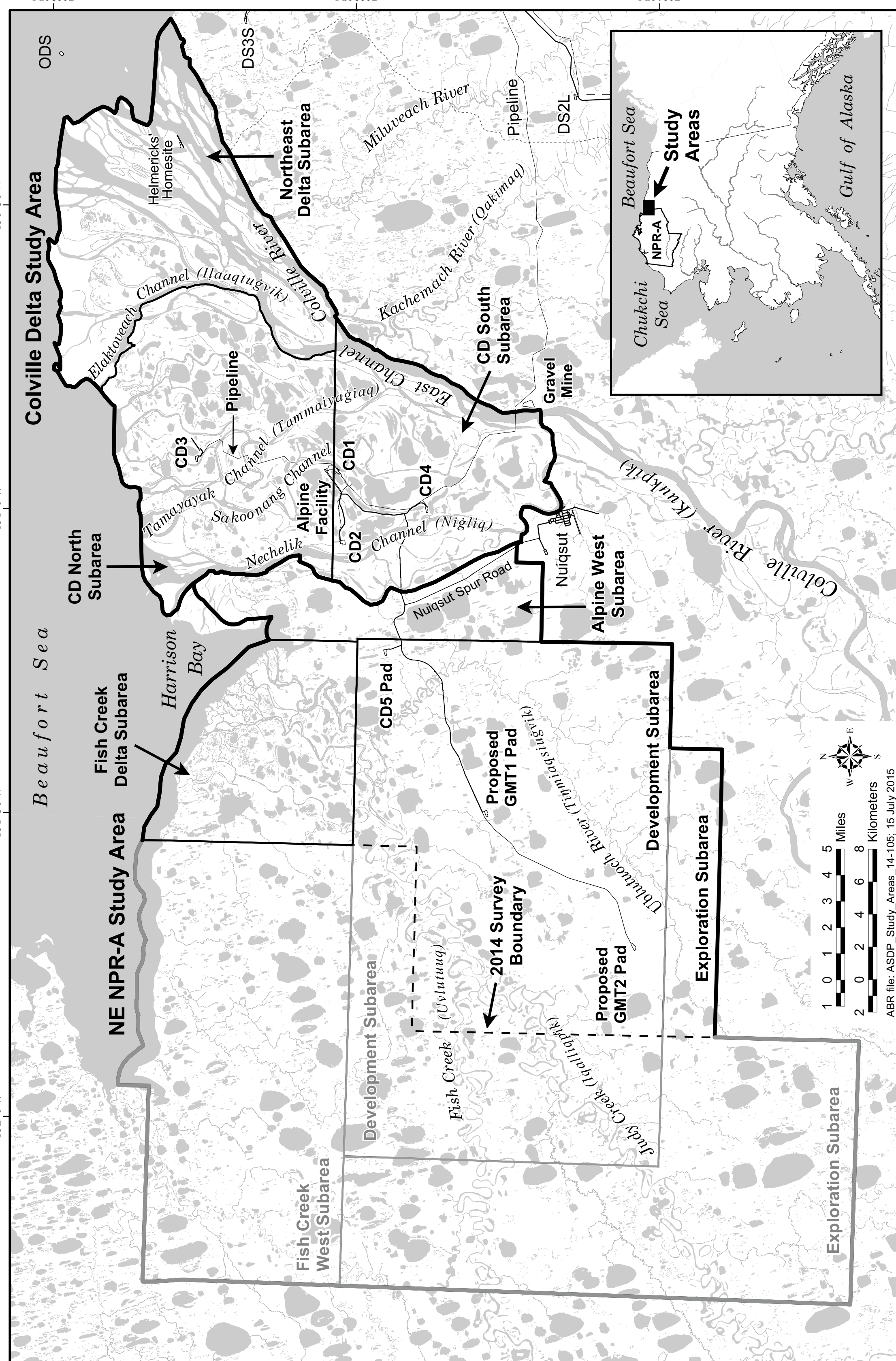


Figure 1. Wildlife study areas and subareas for the Alpine Satellite Development Project, northern Alaska, 2014.

delta. The NE NPR-A study area comprises that region of the NE NPR-A immediately adjacent to the Colville River delta and the survey area has expanded and contracted considerably over time, and has varied by target species. After shrinking in 2011 to include only the easternmost portions of the NE NPR-A, the survey area boundaries in 2014 were expanded westward and southward to encompass the proposed GMT2 development.

Since 2013, ground searches have been conducted for breeding birds on study plots near the proposed CD5 drill site. In 2013, we collected pre-construction data on nesting Greater White-fronted Geese (henceforth, White-fronted Geese) and, in 2014, we collected the first season of post-construction data, for a long-term comparison of the abundance, distribution, and nest survival of White-fronted Geese before and after construction of the proposed CD5 drill site. Additional ground-based surveys for nesting Spectacled Eiders that were conducted in select areas on the Colville River delta in 2014 as part of other studies are reported elsewhere (Seiser and Johnson 2014b).

Required state and federal permits were obtained for all survey activities, including a Scientific or Educational Permit (Permit No. 14-130) from the State of Alaska and a Federal Fish and Wildlife Permit—Threatened and Endangered Species [Permit No. TE012155-2 issued under Section 10(a)(1)(A) of the Endangered Species Act (58 FR 27474-27480)]. Similar avian species were monitored in the Kuparuk Oilfield on the eastern border of the Colville River delta in 2014 (Stickney et al. 2015). CPAI supported other avian research on the Arctic Coastal Plain in 2014 including a collaborative study of Yellow-billed Loon lake habitat by the University of Alaska Fairbanks, U. S. Geological Survey (USGS), Bureau of Land Management (BLM), and the Alaska Department of Fish and Game and a study of the effects of forage phenology and timing of reproduction on juvenile growth in Brant by USGS.

STUDY AREA

The ASDP study area comprises separate study areas on the Colville River delta and in the easternmost portion of the NE NPR-A (Figure 1). Wildlife studies began in the Colville Delta study area in 1992, and studies were initiated in the NE NPR-A study area in 1999. The 2 study areas were combined into 1 project and report in 2003 (Johnson et al. 2004). In the same year, CPAI proposed to develop drill sites CD3–CD7 on the Colville River delta and adjacent NE NPR-A, which were evaluated together under the National Environmental Protection Act of 1970 (42 USC 4321) in an environmental impact statement as the Alpine Satellite Development Plan (BLM 2004).

The place names used throughout this report are those depicted on USGS 1:63,360-scale topographic maps, because they are the most widely available published maps of the region. The corresponding local Iñupiaq names for drainages (and wildlife species) are provided in parentheses at the first usage in text and on the study area map (Figure 1). Iñupiaq names are presented out of respect for local residents, to facilitate clear communication with Iñupiaq speakers, and because they pre-date the English names used on USGS maps. We acknowledge that the Iñupiaq names presented are not comprehensive, and we recognize that the published USGS names for some streams (notably the Ublutuoch and Tiŋmiaqsiuġvik rivers) do not correctly reflect local usage. The Iñupiaq names we use for Fish (Uvlutuuq) and Judy (Iqalliqpik) creeks in NE NPR-A are taken from the Iñupiat–English Map of the North Slope Borough (NSB Planning Department, Barrow, Alaska, May 1997). Additional information was supplied to CPAI in recent years by Nuiqsut elders. Even in cases where USGS attempted to use the correct Iñupiaq names, the anglicized spellings are outdated and so have been corrected to the modern Iñupiaq spellings through consultation with Emily Ipalook Wilson and Dr. Lawrence Kaplan of the Alaska Native Language Center (ANLC) at the University of Alaska Fairbanks. Marjorie Kasak Ahnupkanna and Archie Ahkiviana were consulted to confirm the names of various channels of the Colville River (E. Wilson, ANLC, personal communication).

COLVILLE DELTA STUDY AREA

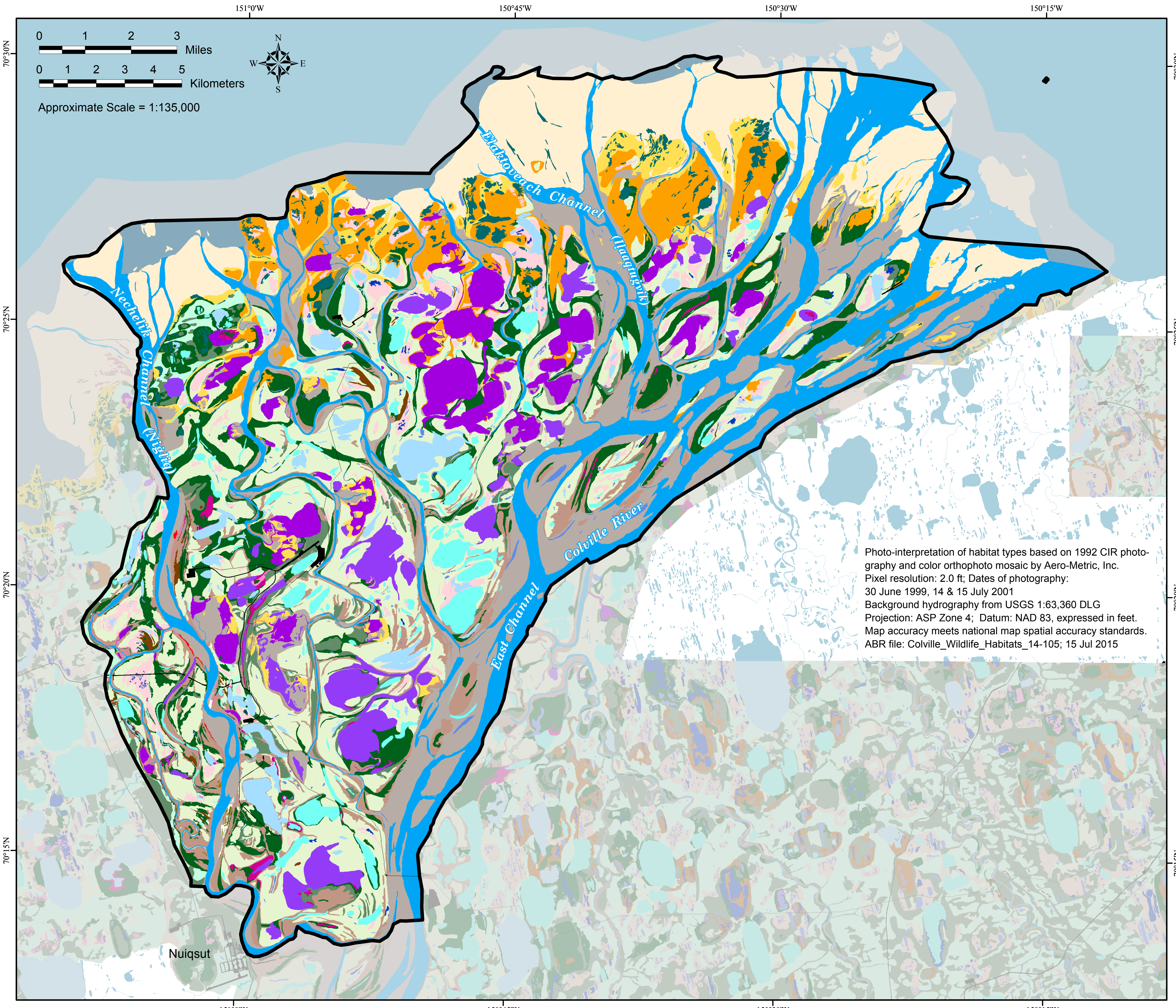
The Colville River delta is one of the most prominent and important landscape features on the ACP of Alaska, both because of its large size and because of the concentrations of birds, mammals, and fish that are found there. Two permanent human settlements occur on the delta—the Iñupiat village of Nuiqsut (population ~400) established in 1973 and Helmericks' family homesite established in the 1950s, also known as "Colville Village".

Oil development on the Colville River delta began in 1998 with construction of the Alpine Facility, a roadless oilfield including a full-production facility (comprising a processing plant, camp, airstrip, and the CD1 and CD2 drill sites) (Figure 1). Oil began flowing from Alpine east through the pipeline to Kuparuk in 2000. In 2005, construction began on 2 satellite drill sites, whose oil is also processed at Alpine. The CD3 satellite is a roadless drill site accessible by aircraft and boat during the summer and fall and by ice roads during winter. The CD4 satellite is connected to Alpine by an all-season road. Both the CD3 and CD4 drill sites began producing oil in 2006. Construction began in 2014 on the CD5 drill site, which involved a road from near CD4 west across a new bridge (completed in 2015) over the Nechelik (Niġliq) Channel.

Landforms, vegetation, and wildlife habitats in the Colville River delta were described in the Ecological Land Survey (Jorgenson et al. 1997), and the resulting habitat map was updated in 2004 to unify it with similar mapping of the surrounding Coastal Plain (Figure 2; Jorgenson et al. 2004).

Coastal and riverine landforms dominate the delta. Fluvial processes are most prominent, although eolian and ice-aggradation processes are important to landscape development, as are lacustrine and basin-drainage processes. Of the 26 wildlife habitat types identified on the delta, 4 habitats are clearly dominant (Figure 2, Table 1): Patterned Wet Meadow (17% of the entire delta), River or Stream (15%), Barrens (14%), and Tidal Flat Barrens (11%). No other habitats comprise more than 8% of the delta. Aquatic habitats are a major component of the delta, comprising 30% of the total area. Coastal salt-affected habitats—Tidal Flat Barrens, Salt-killed Tundra, Salt Marsh, Moist Halophytic Dwarf Shrub, Open Nearshore Water, and Brackish Water—together compose 21% of the total area and contribute greatly to avian diversity. Tapped lakes (Tapped Lake with Low-water Connection and Tapped Lake with High-water Connection, so named because their connections to river channels are dependent on river levels) are unique to delta environments and contribute to the physical and biological diversity of the delta, although they occupy slightly less than 8% of the total area. Other important habitats for birds are those that contain emergent aquatic vegetation (Deep Polygon Complex, Grass Marsh, Sedge Marsh, and Salt Marsh) and waterbodies with islands or complex shorelines (Deep Open Water with Islands or Polygonized Margins and Shallow Open Water with Islands or Polygonized Margins), which account for a combined total of 9% of the delta. Wildlife habitat types are described in detail in Appendix B. A strong north–south gradient occurs across the delta in the distribution of many of these habitats, with coastal habitats—Salt Marsh, Salt-killed Tundra, Brackish Water, and to a lesser extent, Deep Polygon Complex—decreasing in abundance with increasing distance from the coast, whereas Tapped Lakes with High-water Connections, Sedge Marsh, Grass Marsh, Patterned Wet Meadow, Moist Sedge-Shrub Meadow, and the non-halophytic shrub types are more prevalent away from the coast. These patterns of habitat distribution have strong effects on the distribution and abundance of various wildlife species, which are far from uniformly abundant across the delta.

As mentioned above, lakes and ponds are dominant physical features of the Colville River delta. The most abundant waterbodies on the delta are polygon ponds, which generally are too small to be mapped (<0.25 ha), shallow (i.e., ≤2 m deep), freeze to the bottom during winter, and thaw by June. Deep ponds and lakes (>2 m deep) with steep, vertical sides are more common on the delta than in adjacent areas of the ACP. Lakes >5 ha in size cover ~16% of the delta's surface (Walker 1978) and some of these lakes are deep (to 10 m), freezing only in the upper 2 m during winter and retaining floating ice as late as the first half of July (Walker 1978). Several other types of lakes occur on the delta, including oriented lakes, abandoned-channel lakes, point-bar lakes, perched ponds, thaw lakes, and tapped lakes (Walker 1983). Tapped lakes are connected to the river by narrow channels that result from thermokarsting of ice wedges and by the migration of river channels (Walker 1978). Channel connections allow water levels in tapped lakes to fluctuate with changes in coastal water level, resulting in barren or partially vegetated and often salt-affected shorelines.



Wildlife Habitat Type

- Open Nearshore Water
- Brackish Water
- Tapped Lake with Low-water Connection
- Tapped Lake with High-water Connection
- Salt Marsh
- Moist Halophytic Dwarf Shrub
- Tidal Flat Barrens
- Salt-killed Tundra
- Deep Open Water without Islands
- Deep Open Water with Islands or Polygonized Margins
- Shallow Open Water without Islands
- Shallow Open Water with Islands or Polygonized Margins
- River or Stream
- Sedge Marsh
- Deep Polygon Complex
- Grass Marsh
- Young Basin Wetland Complex
- Old Basin Wetland Complex
- Nonpatterned Wet Meadow
- Patterned Wet Meadow
- Moist Sedge-Shrub Meadow
- Moist Tussock Tundra
- Moist Low Shrub
- Dry Dwarf Shrub
- Barrens
- Human Modified

Note: Areas mapped outside the study area boundary are shown in muted colors.

Figure 2. Wildlife habitats in the Colville Delta study area, Alaska, 2014

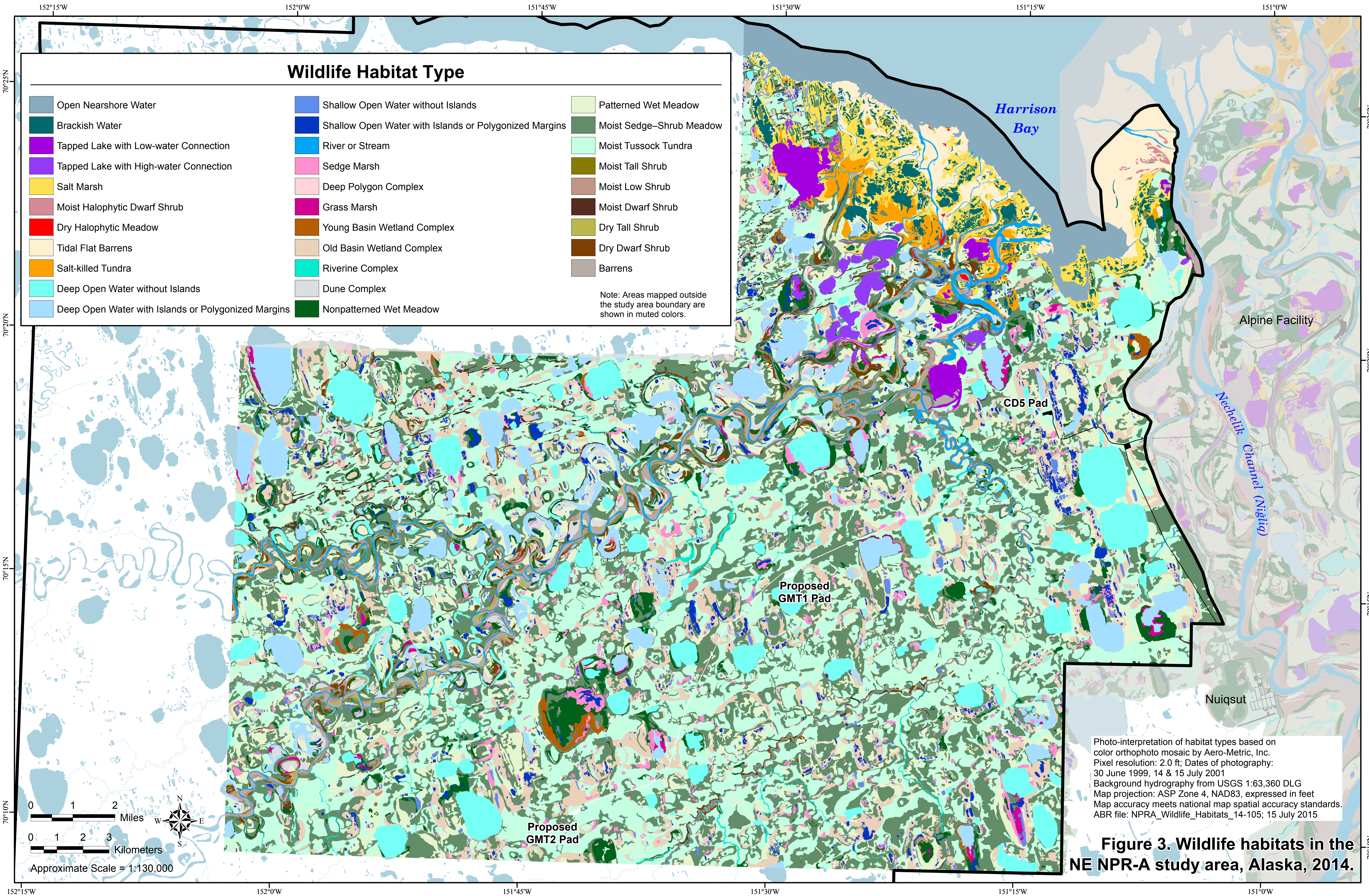


Figure 3. Wildlife habitats in the NE NPR-A study area, Alaska, 2014.

Table 1. Habitat availability in the Colville Delta and the NE NPR-A study areas, Alaska, 2014.

	Colville Delta		NE NPR-A	
Habitat	Area (km²)	Availability (%)	Area (km²)	Availability (%)
Open Nearshore Water	10.12	1.8	22.32	3.5
Brackish Water	6.55	1.2	9.50	1.5
Tapped Lake with Low-water Connection	22.73	4.1	6.20	1.0
Tapped Lake with High-water Connection	19.36	3.5	4.87	0.8
Salt Marsh[a]	16.87	3.1	16.95	2.7
Tidal Flat Barrens	58.42	10.6	16.63	2.6
Salt-killed Tundra	25.63	4.6	6.49	1.0
Deep Open Water without Islands	15.66	2.8	38.63	6.1
Deep Open Water with Islands or Polygonized Margins	13.33	2.4	23.76	3.8
Shallow Open Water without Islands	2.00	0.4	5.93	0.9
Shallow Open Water with Islands or Polygonized Margins	0.59	0.1	9.51	1.5
River or Stream	82.67	15.0	8.05	1.3
Sedge Marsh	0.17	<0.1	11.32	1.8
Deep Polygon Complex	15.35	2.8	0.35	0.1
Grass Marsh	1.58	0.3	1.69	0.3
Young Basin Wetland Complex	<0.01	<0.1	1.97	0.3
Old Basin Wetland Complex	0.08	<0.1	48.36	7.7
Riverine Complex	0	0	2.18	0.3
Dune Complex	0	0	4.17	0.7
Nonpatterned Wet Meadow	43.31	7.8	18.03	2.9
Patterned Wet Meadow	96.35	17.4	65.62	10.4
Moist Sedge-Shrub Meadow	11.82	2.1	130.42	20.7
Moist Tussock Tundra	3.49	0.6	154.07	24.5
Tall, Low, or Dwarf Shrub	29.39	5.3	15.92	2.5
Barrens[b]	75.84	13.7	6.64	1.1
Human Modified	0.87	0.2	0.29	<0.1
Subtotal (total mapped area)	552.19	100	629.90	100
Unknown (unmapped areas)	0		56.88	
Total	552.19		686.77	

[a] Salt Marsh includes 0.67 km² and 0.44 km² of Moist Halophytic Dwarf Shrub in the Colville Delta and NE NPR-A study areas, respectively

[b] Barrens in the NE NPR-A study area includes 0.21 km² of Dry Halophytic Meadow, and in the Colville Delta study area Barrens includes 0.09 km² Dry Halophytic Meadow and 0.22 km² of Moist Herb Meadow

Because tapped lakes and river channels are the first areas of the delta to become flooded in spring, they constitute important stop-over habitat for migrating waterfowl in that season (Rothe et al. 1983).

The Colville Delta study area (552 km²) comprises the CD North, CD South, and the Northeast Delta subareas (Figure 1). These subareas are useful in describing the distribution of birds on the delta, and together they encompass the entire delta from the eastern bank of the East Channel of the Colville River to the west bank of the westernmost distributary of the Nechelik (Niġliq) Channel and inland to the juncture of these channels.

NE NPR-A STUDY AREA

The NE NPR-A study area (1,571 km²) abuts the western edge of the Colville Delta study area and comprises 5 subareas, which are useful subdivisions for comparisons with past years: the Development, Exploration, Alpine West, Fish Creek Delta, and Fish Creek West subareas (Figure 1). The NE NPR-A study area is the northeastern portion of the Northeast Planning Area of the NPR-A (BLM 2008), where CPAI has funded wildlife surveys since 1999. The study area extends from 6 to 39 km west of the village of Nuiqsut and 1 to 43 km west of the Alpine Facility. The NE NPR-A study area encompasses 1 permitted and 2 proposed development sites (CD5, and GMT1 and GMT2, respectively) and exploration sites that may be proposed for development in the future. The CD5 pad and all-season road were constructed in 2014; when completed in 2015, CD5 will connect to the Alpine Facility near CD4 by a gravel road, a pipeline, and a bridge across the Niġliq Channel (Figure 1). In 2014, the Nuiqsut Spur Road was constructed by the Kuukpik Corporation from Nuiqsut to the CD5 Road. In 2011–2013, avian surveys were conducted in the eastern portions of the NE NPR-A study area; the Fish Creek Delta and Alpine West subareas were surveyed in their entirety, whereas only the northeast corner of the Development subarea was surveyed. Neither the Fish Creek West nor the Exploration subareas were included in the avian studies in 2011–2013. In 2014, the study area boundary expanded westward and southward to include the eastern portion of the Development and Exploration subareas.

Three major streams flow through the NE NPR-A study area (Figure 1). On USGS topographic maps (Harrison Bay Quad, 1:63,360 series, 1955) these drainages are labeled as Fish Creek, Judy Creek, and the Ublutuoch River, but they are commonly known by other names among Iñupiat residents: Fish Creek is called Uvlutuuq, Judy Creek is Iqalliqpik, and the Ublutuoch River is Tiŋmiaqsiuġvik.

Landforms, vegetation, and wildlife habitats in the NE NPR-A study area were described in the Environmental Impact Statement for the lease area and the Alpine Satellite Development Project (BLM 2004) and in Jorgenson et al. (2003, 2004). Coastal plain and riverine landforms dominate the NE NPR-A study area. Coastal landforms are present but limited to the northeast corner of the study area (i.e., the Fish Creek delta; Figure 1). On the coastal plain, lacustrine processes, basin drainage, and ice aggradation are the primary geomorphic factors that modify the landscape. In riverine areas along Fish and Judy creeks, fluvial processes predominate, although eolian and ice-aggradation processes also contribute to ecological development (Jorgenson et al. 2003).

Six of the 31 wildlife habitats identified in the NE NPR-A study area are not present on the Colville Delta study area (Figure 3, Table 1). Three habitats dominate the NE NPR-A study area landscape: Moist Tussock Tundra (24% of area), Moist Sedge-Shrub Meadow (21%), and Patterned Wet Meadow (10%; Table 1). Aquatic habitats comprise 19% of the study area. Although the NE NPR-A study area includes some coastal habitats in the Fish Creek delta, they are much less abundant than in the adjacent Colville Delta study area (Table 1). Riparian habitats also are much less common in the NE NPR-A study area.

Like the Colville River delta, the NE NPR-A is an important area for wildlife and for subsistence harvest activities. The NE NPR-A supports a wide array of wildlife, providing breeding habitat for geese, swans, passerines, shorebirds, gulls, and predatory birds, such as jaegers and owls. The Fish Creek and Judy Creek drainages in the NE NPR-A study area are a regionally important nesting area for Yellow-billed Loons, annually supporting a similar number of nesting pairs as does the Colville

Delta study area (Burgess et al. 2003b, Johnson et al. 2004).

METHODS

Aerial surveys were the primary means for collecting data on eiders, loons, swans, gulls, and geese using the Colville Delta and NE NPR-A study areas because of the large size of the study areas and the short periods of time that each species is at the optimal stage for data collection. In 2014, 4 aerial surveys were conducted using fixed-wing aircraft: 1 for eiders during pre-nesting, 2 for Tundra Swans during nesting and brood-rearing, and 1 for geese (primarily Brant and Snow Geese) during brood-rearing. Each of these surveys was scheduled specifically (see Table 2 for survey details) for the period when the species was most easily detected (for example, when Spectacled Eider males in breeding plumage were present) or when the species was at an important stage of its breeding cycle (nesting or raising broods).

Sixteen aerial surveys (~1 per week) for loons were conducted from a helicopter, targeting specific lakes suitable to Yellow-billed Loons. Nesting gulls also were recorded during loon surveys. The survey area in the NE NPR-A study area was increased from that surveyed in 2011–2013 with a larger proportion of the Development subarea and a portion of the Exploration subarea (total area = 672 km^2, Figure 1). Concerns about disturbance to local residents and wildlife from survey flights have dictated that we conduct the fewest survey flights necessary and at the highest altitudes possible. Flight altitudes were set at the maximum level at which the target species could be adequately detected and counted (see survey protocols for each species group below). Survey flights specifically avoid the areas around the village of Nuiqsut, the Helmericks' homesite, and any active hunting parties. All survey flights are reported to local residents the week before and after in weekly updates submitted to the Kuukpik Corporation and the Kuukpik Subsistence Oversight Panel.

During the surveys, locations of eiders, loons, and swans, and brood-rearing geese were recorded on digital orthophoto mosaics of 1 ft resolution natural color imagery acquired in 2004–2012 (the Colville Delta study area and the Alpine West subarea in the NE NPR-A study area, by Quantum Spatial), 2 ft resolution natural color imagery acquired in 1999–2004 (Development Area and Fish Creek Delta subareas in the NE NPR-A study area, by Quantum Spatial), or 8.2 ft resolution color infrared imagery acquired in 2002 (Fish Creek West and Exploration subareas in the NE NPR-A study area, by USGS). Bird locations plotted on maps were reviewed in the field and later in the office before they were entered into a geographical information system (GIS) database. See DATA MANAGEMENT, below, for data management protocols.

In this report, we typically present data summaries with means plus or minus standard errors (mean ± SE). In some cases we report the median values. Statistical significance is assigned at $P \leq 0.05$ unless otherwise stated. Analyses were conducted in Microsoft® Excel (Office 2010) and SPSS 18 (IBM SPSS Inc., Chicago, IL).

EIDER SURVEYS

We evaluated the regional abundance, distribution, and habitat selection of 2 species of eiders with data collected on 1 aerial survey flown annually during the pre-nesting period (Table 2), when male eiders (the more visible of the 2 sexes in breeding plumage) were still present on the breeding grounds. Spectacled and King eiders are the only species of eiders that are abundant in the Colville Delta and NE NPR-A study areas; the other 2 species, Common Eiders and Steller's Eiders, are seen infrequently. We conducted the pre-nesting survey during 12–15 June using the same methods that were used on the Colville Delta study area in 1993–1998 and 2000–2013 and in the NE NPR-A study area in 1999–2006 and 2008–2013. Survey areas and survey coverage differed among years (see Anderson and Johnson 1999; Burgess et al. 2000, 2002a, 2003a; Johnson 1995; Johnson and Stickney 2001; Johnson et al. 1996, 1997, 1998, 1999a, 2000a, 2002, 2003b, 2004, 2005, 2006b, 2007b, 2008b, 2009, 2010, 2011, 2012, 2013a, 2014a; Murphy and Stickney 2000; Smith et al. 1993, 1994). The pre-nesting survey in 2014 covered the same areas surveyed in 2013 and most prior years in the Colville Delta. In the NE NPR-A, the survey area for eiders in 2014 expanded westward and southward from the prior

Table 2. Avian surveys conducted in the Colville Delta and the NE NPR-A study areas, Alaska, 2014.

Survey Type / Season / Study Area	Number of Surveys	Survey Dates	Aircraft[a]	Transect Width (km)	Transect Spacing (km)	Aircraft Altitude (m)	Notes
Eider survey							
Pre-nesting							
Colville Delta	1	12–14 June	C185	0.4	0.4	30–35	100% coverage
NE NPR-A	1	14–15 June	C185	0.4	0.8	30–35	50% coverage
Yellow-billed Loon surveys[b]							
Nesting	2	11 June and 19–22 June	206L	–	–	60–75	All lakes ≥5 ha and adjacent lakes
Brood-rearing	1	18–19 Aug.	206L	–	–	60–90	Yellow-billed Loon territory lakes
Nest and brood monitoring	13 (1/week)[c]	25 June–24 Sept.	206L	–	–	60–90	Lakes with active nests and broods
Tundra Swan surveys							
Nesting							
Colville Delta	1	24–25 June	C185	1.6	1.6	150	100% coverage
NE NPR-A	1	24–25 June	C185	1.6	1.6	150	100% coverage
Brood-rearing	1						
Colville Delta	1	20, 21, 23 Aug.	C185	1.6	1.6	150	100% coverage
NE NPR-A	1	23–24 Aug.	C185	1.6	1.6	150	100% coverage
Goose surveys							
Brood-rearing	1	31 July	PA-18	–	–	75–150	Coastal and lake-to-lake pattern, all areas
Greater White-fronted Goose							
Ground nest searches	1	9–18 June	–	–	–	–	40 plots, 10 ha in size, CD5 area
Nest fate monitoring	1	15–17 July	–	–	–	–	Post-hatch visits to nest sites

[a] C185 = Cessna 185 fixed-wing airplane; 206L = Bell "Long Ranger" helicopter; PA-18 = Piper PA-18 "Super Cub" fixed-wing airplane
[b] Pacific and Red-throated loons, nests, and broods, and Glaucous and Sabine's gull nests and broods were recorded incidentally
[c] Total includes the brood-rearing survey conducted on 18–19 August

year's boundary, adding 160.7 km² to survey area in the Development and Exploration subareas (Figure 4). The survey was flown in a Cessna 185 airplane at 30–35 m above ground level (agl) and approximately 145 km/h. Two observers each counted eiders in a 200 m wide transect on each side of the airplane (400 m total transect width) and the pilot viewed the area ahead of the aircraft. A Global Positioning System (GPS) receiver was used to navigate pre-determined east–west transect lines that were spaced 800 m apart, achieving 50% coverage in the NE NPR-A study area and 400 m apart achieving 100% coverage over the Colville Delta study area (Figure 4). The lower coverage in the NE NPR-A study area was intended to sample a larger area with lower densities of Spectacled Eiders relative to the Colville Delta study area. Three areas were not surveyed in the Colville Delta study area: the extensive tidal flats and marine waters on the northernmost delta (Spectacled and King eiders rarely use those habitats during the survey time period; Johnson et al. 1996), a ~1.6-km-radius circle around the Helmericks' homesite, and the southernmost portion of the delta near Nuiqsut (Figure 4). The latter 2 areas were avoided to limit disturbance to residents. Eider locations were recorded on color photomosaic maps (1:63,360 scale) and digital voice recorders were used to record species, number of identifiable pairs, the sex and activity (flying or on the ground) of each individual, and a brief habitat description for non-flying birds.

We recorded the observed number of birds and pairs and calculated the "indicated" number of birds and densities (number/km²) following USFWS (1987a) protocols. The total indicated number of birds excludes flying birds and is twice the number of males in singles, pairs, or flocks (flocked males are 2–4 males with no females), plus the number of birds in groups (groups are defined as >3 birds of mixed sex that cannot be separated into singles or pairs; however, 1 female with 2 males are a pair and single male, and 1 female with 3 males is considered a pair and 2 single males). Annual growth rate for pre-nesting adults was calculated with log-linear regression on adjusted counts for the period from 1993–2014. Adjusted counts were calculated from the density of indicated birds, multiplied by the maximal area surveyed in all years (501 km²).

LOON SURVEYS

In 2014, we conducted 2 aerial surveys for nesting Yellow-billed Loons on 11 and 19–22 June and 1 aerial survey for brood-rearing Yellow-billed Loons on 18–19 August (Table 2). In the Colville Delta study area, we surveyed 211 lakes for nesting loons and 208 lakes for brood-rearing loons (Figure 5). Both surveys were conducted annually in the Colville Delta study area during 20 years from 1993 to 2014; surveys were not conducted in 1994 or 1999. The CD North and CD South subareas were surveyed each year and part of the Northeast Delta subarea was surveyed in all survey years except 2000. The number of lakes surveyed increased in 2002 because of a small expansion in the study area to include lakes between the eastern boundary of the NE NPR-A study area and the Niġliq Channel, and again in 2008 because the minimum size of lakes surveyed was reduced from 10 ha to 5 ha.

In the NE NPR-A study area during 2014, we surveyed 173 lakes for nesting Yellow-billed Loons and 176 lakes for brood-rearing loons (Figure 5, Table 2). We have conducted surveys for nesting and brood-rearing Yellow-billed Loons in the NE NPR-A study area in all years during 2001–2014 except for 2007. During these 12 years of surveys, we surveyed 6 different subareas in the NE NPR-A study area: the Development subarea in 2001–2004, the Exploration subarea in 2002–2004, the Alpine West subarea in 2002–2006 and 2008–2014, the Fish Creek Delta subarea in 2005–2006 and 2008–2014, the Fish and Judy Creek Corridor subarea, and the GMT Corridor subarea in 2014 (Figures 1 and 5). The Fish and Judy Creek Corridor subarea was created in 2008 only for loon surveys and it comprises a series of deep lakes adjacent to Fish and Judy creeks within the Development and Exploration subareas. We surveyed the entire Fish and Judy Creek Corridor subarea in 2008–2010, along with 4 additional Yellow-billed Loon territories in the Development and Exploration subareas that were identified in previous years. In 2011–2014, the surveyed portion of the Fish and Judy Creek Corridor subarea was reduced to its eastern quarter. In 2014, we surveyed south and westward from the Fish and Judy Creek Corridor subarea to include a 3-mile buffer around the proposed GMT1 and GMT2 developments

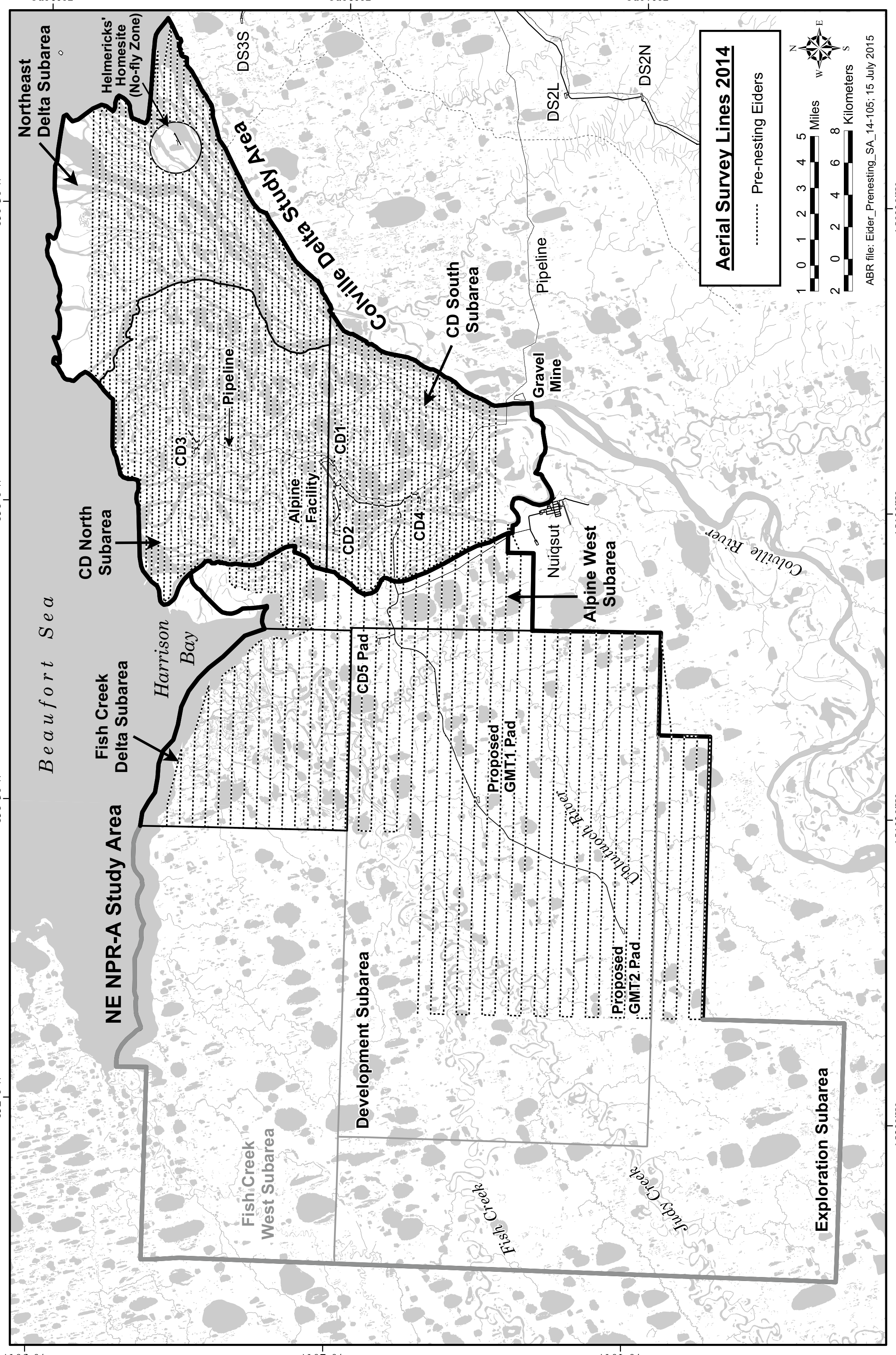


Figure 4. Transect lines for aerial surveys of pre-nesting eiders, Colville Delta and NE NPR-A study areas, Alaska, 2014.

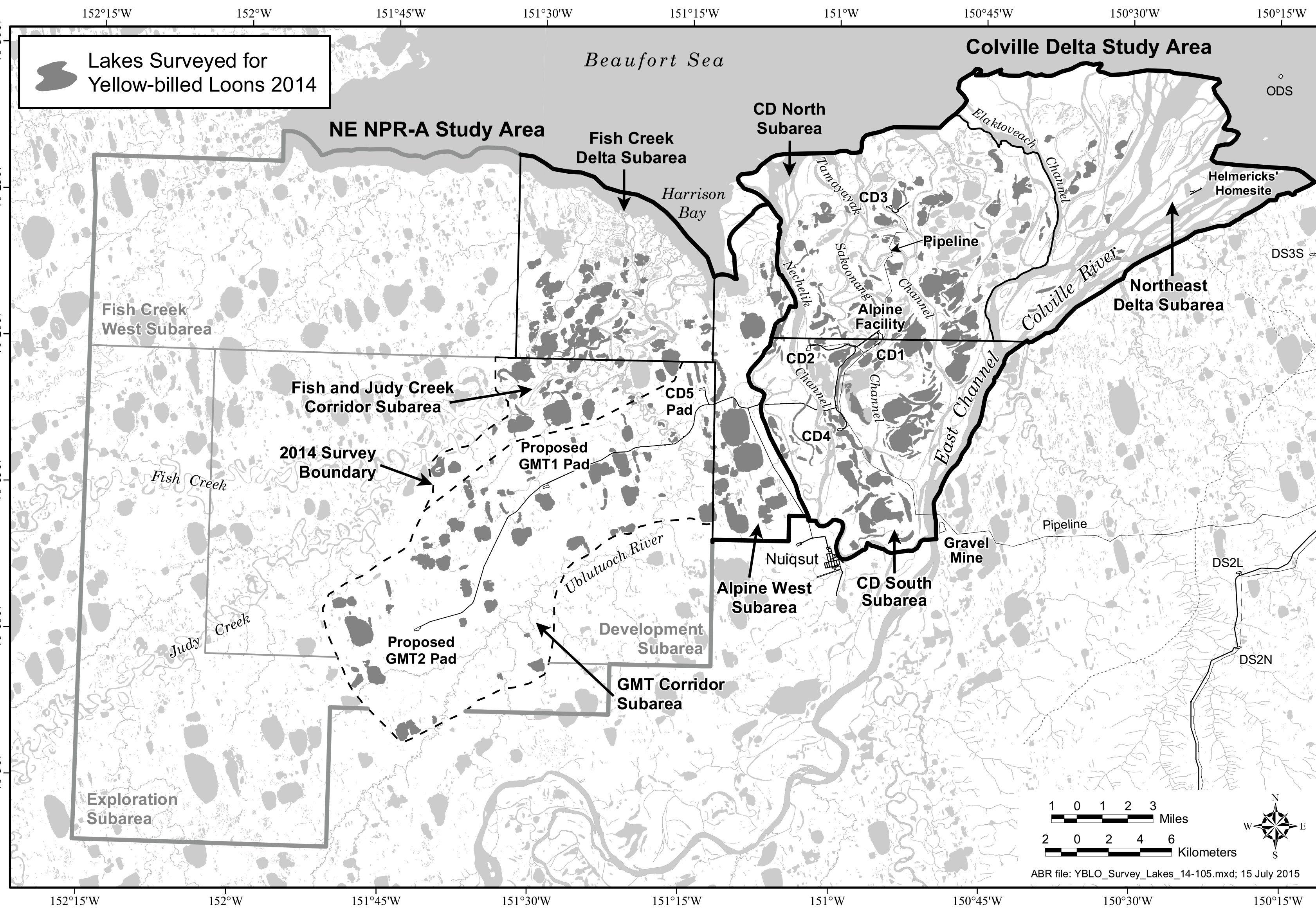


Figure 5. Lakes included in aerial surveys for Yellow-billed Loons, Colville Delta and NE NPR-A study areas, Alaska, 2014.

(referred to as the GMT Corridor subarea, Figure 5). The GMT Corridor subarea was exclusive of the Alpine West and Fish and Judy Creek Corridor subareas.

Each year the nesting survey was conducted between 19 and 30 June and the brood-rearing survey between 15 and 27 August. In 2011, 2012, and 2014, we added a survey for nests between 11 and 13 June, about a week prior to the nesting survey, to document early nesting phenology and early nest survival. During that survey, only lakes where Yellow-billed Loons nests had been recorded in previous years were surveyed. Nesting surveys were conducted from a Cessna 185 or PA-18 Super Cub fixed-wing airplane during 1993–1998 and a Bell 206L helicopter during 2000–2014. Brood-rearing surveys were conducted from a Cessna 185 in 1993 and a Bell 206L in all other years. All surveys were flown in a lake-to-lake pattern at 60–90 m above ground level. The perimeter of each lake was circled while 1 observer searched lake surfaces and shorelines for loons and nests during the nesting survey and loons and young during the brood-rearing survey. Survey lakes were selected before each survey and included most lakes ≥10 ha in size in 1993–2007 and most lakes ≥5 ha in size in 2008–2014. We reduced the minimum survey lake size to 5 ha for nesting surveys to increase survey efficiency. During nesting surveys each year, we also surveyed small lakes (1–10 ha) and aquatic habitats adjacent to survey lakes because Yellow-billed Loons sometimes nest on small lakes next to larger lakes that are used for brood-rearing (North and Ryan 1989, Johnson et al. 2014b). Tapped Lakes with Low-water Connections (lakes whose levels fluctuate with changing river levels) were excluded from surveys during all years because Yellow-billed Loons do not use such lakes for nesting (North 1986, Johnson et al. 2003b).

We recorded incidental observations of Pacific Loons (Malġi) and Red-throated Loons (Qaqsrauq) during all nesting and brood-rearing surveys. All locations of loons and their nests were recorded on USGS maps (1:63,000 scale) in 1993, 1995–1998, and 2000–2002, and on color photomosaics (1:30,000 scale) in 2003–2014. In 2005–2014, Yellow-billed Loon nest locations also were marked on high resolution color images of nest site areas (~1:1,500 scale). All loon locations were digitized into a GIS database.

We summarized numbers of adults, nests, broods, and young for each species counted on aerial surveys. Densities of adults, nests, and broods were calculated only for Yellow-billed Loons because Pacific and Red-throated loons commonly nest on lakes <5 ha in size and only a subset of lakes that size were included in the survey. Counts of Yellow-billed Loon adults, nests, young, and broods are presented from previous years of nesting and brood-rearing surveys, and additionally, from ground-based, revisit, and monitoring surveys. Ground-based surveys mostly occurred near drill sites and facility areas and were conducted within a week of the nesting survey during 1992–2007 in the Colville Delta study area and 1999–2004, 2009, 2010, and 2013, and 2014 in the NE NPR-A study area. Revisit and monitoring aerial surveys (described below) occurred after the nesting survey. We conducted revisit surveys in 1996–1998 and 2000–2002 to search for nests on previously identified Yellow-billed Loon breeding lakes where no nest was found on the nesting survey. Revisit surveys consisted of 1 or more surveys that took place anywhere from 3 to 12 d after the nesting survey. Weekly monitoring of active nests began in 2005, but lakes without nests identified on the nesting survey were not resurveyed that year. From 2006 on, all previously identified Yellow-billed Loon breeding lakes plus other lakes where Yellow-billed Loons were observed during the nesting survey were surveyed weekly for 2 weeks after the nesting survey to search for nests that were initiated after, or were missed, on previous surveys. In 2013, we surveyed breeding lakes for 3 weeks after the nesting survey because high water may have delayed nesting on some territories.

To make annual comparisons among years when different numbers of territories were sampled, we calculated territory occupancy by dividing the number of territories with nests, adults, or broods by the number of territories surveyed. We defined a territory as a single lake, several lakes, or portion of a lake occupied exclusively by 1 breeding pair with a nest or brood in 1 or more years. Territories were identified using data from all years; boundaries between territories were determined by locations where nests and broods occurred, and additionally, by the locations of adults on multi-territory lakes.

Population growth rates were calculated only for Yellow-billed Loons in the Colville Delta study area. Prior to calculating population growth rates, we adjusted the counts of adults, nests, and young for the number of territories surveyed in the Colville Delta study area by dividing those counts by the number of territories surveyed and multiplying by the highest number of territories surveyed in all years (43). Population growth rates for adults, nests, and young were estimated in the Colville Delta study area with log-linear regression on adjusted counts for the period from 2000 to 2014, when helicopters were used for all surveys.

NEST MONITORING AND NEST FATE

Weekly monitoring surveys were conducted in the Colville Delta and NE NPR-A study areas in 2005–2014 and 2008–2014, respectively. Weekly surveys were used to monitor the fate of Yellow-billed Loon nests and to search for nests that may have been missed or that were initiated later in the season. In 2005, we monitored the lakes with active nests. From 2006 on, we resurveyed lakes with active nests and all other lakes previously identified as breeding territories or lakes occupied by Yellow-billed Loons for 2 weeks after the nesting survey. After 2 weeks, we continued to monitor lakes with confirmed nests, but no attempt was made to search for additional nests.

Each active nest was surveyed weekly from a helicopter until the nest was no longer active. Active nests had an incubating adult or a nest with eggs, whereas inactive nests lacked eggs or, as in the case of abandonment, had eggs that were no longer being incubated. When a nest appeared inactive, we immediately searched the nesting lake for a brood by flying along the shoreline and across the lake. Adjacent lakes known from previous surveys to be brood-rearing lakes or part of a pair's territory also were searched.

Camera-monitored nests (see below) were not included in weekly surveys, because we used camera images to determine nest status. The weekly status of camera-monitored nests was determined from the camera images taken at 14:00 on the day of the monitoring survey, which approximated the middle of the period when we typically flew our aerial surveys. For monitoring surveys that spanned multiple days, we used camera data from the first survey day to indicate nest status during the monitoring survey. We resumed visiting camera-monitored nests during the week of hatch, which was estimated from the nest age at the time of camera installation (see below).

We inspected the contents of inactive nests to confirm nest fate. The nest and the surrounding area within 5 m, including the water adjacent to the nest, were examined closely for egg remains, including eggshell fragments, egg membranes, and broken eggs. Loons may reuse nests from previous years, so only the current year's layer of loose vegetation on top of the nest was inspected, to avoid recording evidence from previous years. In general, nests were assumed failed if they contained <20 egg fragments, eggshells had signs of predation (i.e., holes, albumen, yolk, or blood), or if eggs were unattended and cold (Parrett et al. 2008). Nests were assumed successful if a brood was present, or if the nest contained >20 egg fragments. We used egg fragments in addition to the presence of broods to classify nest fate because some broods may not survive the period between hatch and the following monitoring survey. Nest fate was based on the number of fragments as long as there was no conflicting evidence (e.g., too many or too few days of incubation for a particular fate). Images from time-lapse cameras (see below) were used to confirm nest fate where possible. If egg fragments were found, they were counted and, based on the length of their longest side, placed into 3 approximate size categories: 1–10, 11–20, and 21–30 mm to document differences between hatched and failed nests. Similarly, egg membranes or pieces of membranes also were counted and measured.

TIME-LAPSE CAMERAS

We began using time-lapse digital cameras in the Colville Delta and NE NPR-A study areas in 2008 and 2010, respectively, primarily to reduce helicopter traffic while monitoring nest survival, and secondarily, to record nest attendance patterns and identify causes of nest failures. Cameras were installed at active nests within several days of the nesting survey. We used 3 models of Silent Image® Professional cameras: PM35 cameras with custom 8× telephoto lens taking 0.3-megapixel images, and PC85 and PC800 cameras with custom 2.5× and 2× telephoto lenses taking 3.1-megapixel images (Reconyx, Lacrosse, WI). The cameras were mounted on tripods that were tied down to stakes to stabilize them against the wind. The PM35 cameras were equipped with 2-GB memory cards and programmed to take 1 image/60 sec. The PC85 and PC800 cameras were equipped with 32-GB memory cards and programmed to take 1 image/30 sec. All cameras were run on external rechargeable 12V sealed lead acid batteries. We chose settings, memory cards, and batteries so that cameras could take the maximum number of photos possible for 23–28 d without requiring maintenance (i.e., battery or memory card changes).

In late May 2014, prior to nesting, we deployed 10 cameras (10 PC800) in the Colville Delta study area at territories with regularly used nest sites in an effort to observe pre-nesting behavior and the start date of incubation. Cameras were not deployed during pre-nesting in NE NPR-A to reduce air traffic and potential conflicts with goose hunters from Nuiqsut. Cameras deployed during late May were revisited after the nesting survey. If a nest was in camera view, we replaced the camera with one that contained a new memory card and a fresh battery; otherwise cameras were collected, serviced, and redeployed at territories with active nests found during the nesting survey. Seven cameras deployed in May captured the start of incubation; otherwise, cameras were installed within 0–6 d (median = 4 d, n = 27) of nest discovery. Cameras were not installed at nests that lacked suitable views for camera-monitoring or at nests close to a nesting Glaucous Gull, which posed a predation risk to loon eggs during camera setup. A total of 21 nests were monitored in the Colville Delta study area using 5 PM35, 6 PC85, and 13 PC800 cameras (3 nests were monitored in part by 2 different camera types). Thirteen nests were monitored in NE NPR-A study area with 6 PM35, 5 PC85, and 2 PC800 cameras. We removed cameras when nests were no longer active.

We reviewed digital images on computers with Irfanview software (version 4.33). Loon behavior was classified into 3 major types of activity: incubation, break, and recess. Incubation included sitting postures of normal incubation (head up and posture relaxed, or head resting on back), alert incubation (head up in a rigid, attentive posture), concealed incubation (head and body down and flattened in vegetation), and gathering nest material while on the nest. Break activities included brief standing activities at the nest, including changing positions, settling on the nest after changing position, standing over the nest, and egg moving. We calculated incubation constancy by summing the time spent on the nest (incubation minutes plus break minutes) and dividing by the minutes monitored. Recess activities were absences from the nest, including incubation exchanges (a periodic switch between female and male incubation of the nest), sitting beside the nest, and those activities immediately preceding and following the recess or incubation exchange, including egg moving, swimming beside the nest, flying, and gone from view. We identified predators in camera view to species, estimated their distance from the nest, and described their behavior.

Nest images were reviewed from the day of camera set-up through nest failure or when the loons and their young were observed leaving the nest. Day of hatch was defined as occurring when the first chick was seen at the nest or when adults were seen removing egg membranes from the nest, whichever was observed first. Sometimes young were not detectable on images due to vegetation around the nest or a narrow field of view on the image. If eggshell evidence and/or aerial surveys indicated hatch but no chicks were observable on images, the day of hatch was identified by the increased presence of the non-incubating loon at the nest as it began to feed the hatchlings. If the mate's presence also was obscured on images, then egg flotation data were used to estimate hatch date (described below). We judged a nest to be failed if the loons did not resume incubation after a predator was seen at the nest. The time of failure was taken from the first image containing the predator. Some predation events were not captured on images, and in those cases we assigned nest failure to the time when the loons stopped incubating the eggs. After predation, loons swim next to the nest, often in alert posture, followed by frequent trips back to the nest before ending nest attendance. In these cases, eggshell evidence was used to confirm nest failure.

The date incubation started was estimated for successful nests by backdating 28 d from the day of hatch. North (1994) reported 27 and 28 d for the incubation period of Yellow-billed Loons, which begins with laying of the first egg. For failed nests, we estimated the start of incubation by using nest ages derived from an egg-flotation schedule that we developed from eggs in known-age Yellow-billed Loon nests in 2008–2014 (using a method developed for Semipalmated Sandpipers by Mabee et al. [2006]). During camera set up at Yellow-billed Loon nests in 2008–2014, we floated eggs in water and recorded the position of the egg in the water column (on the bottom [all eggs in 2014], suspended in the water column, or on the surface), measured the angle between the central axis of the egg and the water surface (from 0º when egg is first laid to a maximum of 90º when the egg is vertical in the water column), and estimated the percent volume of the egg above the surface (none in this study). For nests where the start of incubation was observed on camera images in 2013 and 2014 (n = 10 nests), we calculated the age of eggs (n = 14 eggs) on the day of floating by backtracking to the date incubation started. For nests that were observed hatching on camera images in 2008–2014 (n = 54 nests), the clutch age on the day of egg floating was determined by backdating from the hatch date to the day the eggs were floated. These known-age nests were used to develop a regression to estimate egg ages from flotation data at nests without known hatch dates. If a known-age nest had 2 eggs, we used the average of the float angles in the clutch age regression. The relationship between the float angle and clutch age for nests 1–14 d old was determined by linear regression (clutch age = 2.27 × float angle – 3.61, R^2 = 0.91, n = 64 nests). For nests with unknown clutch age, we used the regression equation to estimate nest age at discovery and backdated to the incubation start date. For nests with 2 eggs, the older of the 2 eggs was used for determining clutch age. Because we did not revisit active nests after camera installation in June, eggs were floated only once and only in the early stages of incubation.

The number of days monitored and incubation parameters (constancy, recess and exchange frequency, and recess length) were calculated for each nest from the time the loon returned to the nest after camera installation to the day before hatch, or to the time of nest failure. Periods of time when images could not be interpreted because of poor weather conditions were excluded. Mean daily number of recesses and exchanges were calculated as the sum of that activity divided by number of days monitored.

We compared the incubation constancy of loons on days with and without intruding loons. We used the subset of nests where intruding loons had been identified on images during 2010–2014. First, we calculated the difference between the mean incubation constancy on days with and without intruders at each nest and used a Kruskal-Wallis test to compare differences among years. Because years did not differ significantly (P = 0.405), we combined all years and used a Wilcoxon Signed Rank Test to test if incubation constancy differed between days with and days without intruders using individual nests as the sample unit.

BROOD MONITORING

We conducted weekly brood monitoring surveys after hatch to estimate chick survival and document juvenile recruitment (reaching flight capability) of Yellow-billed Loons during 2008–2014 in the Colville Delta study area and 2009–2014 in NE NPR-A study area. Brood-monitoring surveys were flown in a manner similar to the brood-rearing survey described above. We surveyed all territories with nests or broods by flying above the shoreline and scanning for loons on the water. If no young were seen, lakes were circled 2–3 more times, and for some large lakes, the helicopter was flown down the center of the lake at a higher altitude. If young still were not seen, the territory was revisited at the end of the survey, if time allowed. We considered a brood failed if no young were observed during 2 consecutive weekly surveys, unless conditions on those surveys may have prevented detection of young. Windy conditions with waves breaking in whitecaps can reduce detection of young loons during the surveys. When >2 adult Yellow-billed Loons (e.g., the breeding pair and intruding adults) are present on a brood lake, young often hide in shoreline vegetation. When either of those conditions occurred on a lake previously containing young, the lake was resurveyed the following week to compensate for reduced brood detection. Brood locations were mapped by hand and recorded with the number of adults and young.

The final age of each brood was calculated by subtracting the date of initial observation of the first chick from the date of the last observation, adjusting for the uncertainty of the actual dates. To account for the unknown number of days the brood was alive before the first observation, we used the midpoint between the date of first observation of young and the last observation of incubation. Similarly, to account for the number of days the brood was alive after its last observation, we used the midpoint of the interval between the date of its last observation alive and the first observation of its loss (absence). In the case of the typical 7 d interval between surveys, each chick was assumed to be 4 d old when first observed, and for the same interval, the date of death was assumed to be 4 d after it was last observed.

Chick production was estimated at hatch and again during the final monitoring survey in mid-September. Chick production at hatch was estimated as the number of chicks seen during the monitoring survey following hatch divided by the number of nests found. If a nest was classified as successful based on eggshell fragments and no chicks were observed, we assumed 1 chick was produced. Because only a sample of nests were monitored with cameras and because the images often revealed additional chicks at hatching that were not observed during surveys, we present chick production at hatch both with and without chicks only seen on images. Chick production in September is estimated as the number of chicks seen on our last survey divided by the total number of nests found.

TUNDRA SWAN SURVEYS

We flew 1 aerial survey for nesting Tundra Swans on 24–25 June and 1 survey for brood-rearing Tundra Swans on 20–23 August 2014 (Table 2). With the exception of areas within a ~1.6-km radius of the Helmericks' family homesite on Anachlik Island in the northeastern Colville River delta, and the southern Colville River delta and adjacent NPRA around Nuiqsut, each aerial survey covered the entire Colville Delta and NE NPR-A study areas (Figure 6). We conducted the surveys in accordance with USFWS (1987b, 1991) protocols, using the same methods employed for 20 years during 1992–2013 in the Colville Delta study area (no surveys occurred in 1994 or 1999) and 11 years during 2001–2013 in the NE NPR-A study area (no surveys occurred in 2007 or 2010). We followed east–west transects spaced 1.6 km apart in a Cessna 185 fixed-wing airplane that was navigated with the aid of a GPS receiver. Flight speed was 145 km/h and altitude was 150 m agl. Two observers each searched 800 m wide transects on opposite sides of the airplane while the pilot navigated and scanned for swans ahead of the airplane, providing 100% coverage of the surveyed area. Locations and counts of swans and their nests were recorded on color photomosaics (1:63,360 scale). Each nest was photographed for site verification using a Canon PowerShot SX10 IS (10 megapixel) or a Canon PowerShot SD850 IS (8 megapixel).

Numbers of swans, nests, and broods observed were summarized and densities were calculated for subareas and the larger study areas. Apparent nesting success was estimated from the ratio of broods to nests counted in each study area during aerial surveys only. The accuracy of these estimates can be affected by differential detection, predation, and movements of broods; therefore, the calculated estimates of nesting success should be considered relative indices. Population growth rates for adults, nests, broods, and young on the Colville Delta study area were calculated with log-linear regression for the period from 1992 to 2014.

GOOSE SURVEYS

NEST PLOT SELECTION

In 2013, we initiated a new task to study nesting by White-fronted Geese before and after construction of the proposed CD5 drill site. The study design included 1 year pre-construction (2013), 2 years of construction (2014 and 2015), and 2 years of operations (2017 and 2020). We randomly selected plot locations for conducting nest searches from a 6 × 6 km grid centered on the proposed CD5 drill site. The grid contained 3,600 total points spaced 100 m apart, of which 60 points were randomly selected. Each point was used to

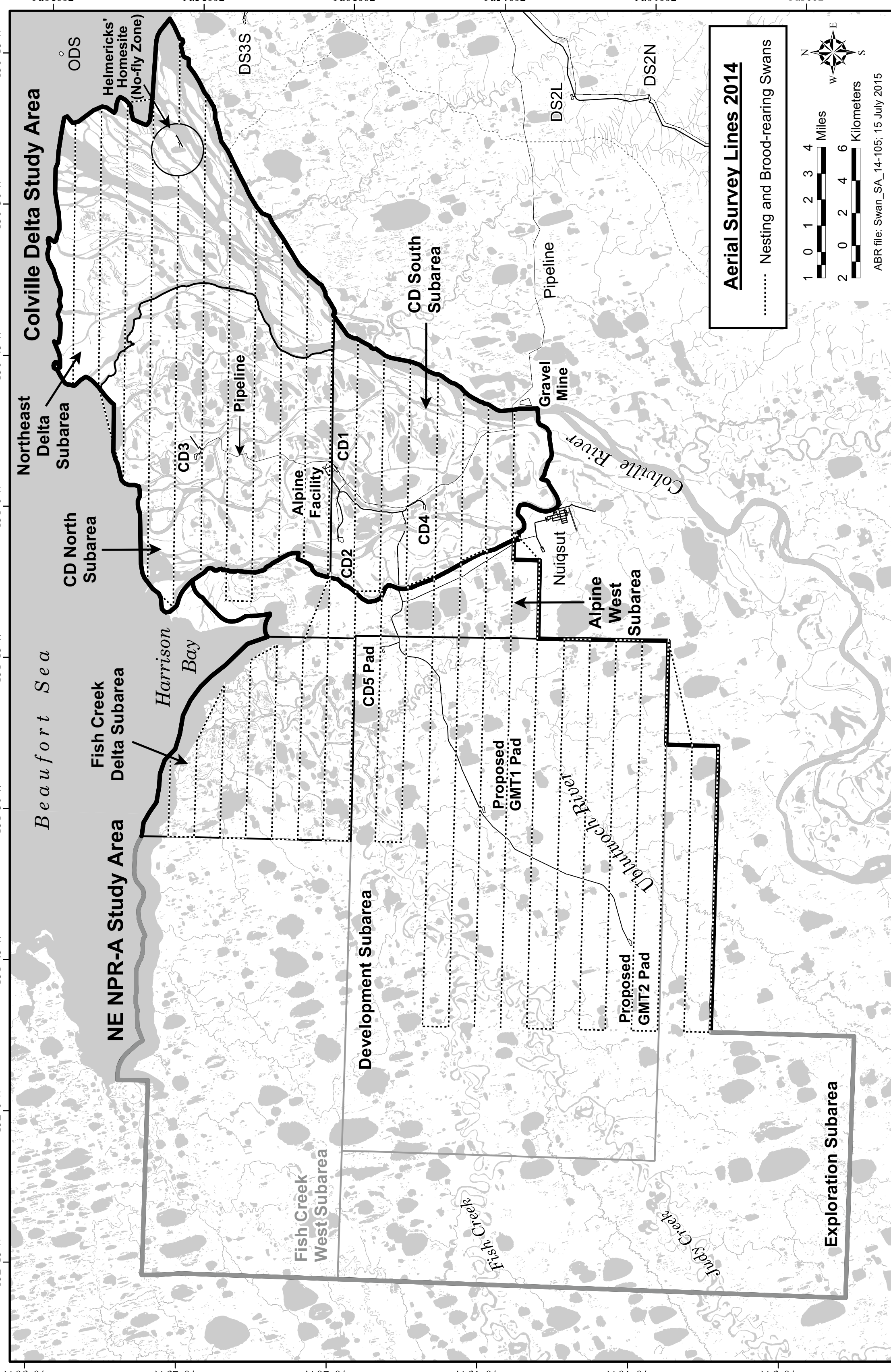


Figure 6. Transect lines for aerial surveys of nesting and brood-rearing Tundra Swans, Colville Delta and NE NPR-A study areas, Alaska, 2014.

locate the start of a 100 m × 1,000 m (10 ha) plot, oriented parallel to the nearest proposed road or pad. Plots were discarded if they overlapped a previously selected plot or had more than 25% of area in lakes. The same plots were sampled in 2013 and 2014 (Figure 7). During nest searches, we completed a cluster of 1–5 plots each day, all within walking distance (<2 km from the end of one to the start of another). Each successive day we alternated between clusters of plots that were near the proposed facility locations and those that were far from facility locations. Plots were searched in the same order each year, to avoid introducing a timing effect that might influence annual comparisons among plots.

NEST SEARCHING

In 2014, we conducted the first post-construction nest search of plots to determine the abundance, distribution, and nest survival of White-fronted Geese. Nests of other large waterbirds were recorded as they were encountered. We conducted 1 nest search on foot during 9–18 June, covering 3.97 km^2 in 40 plots, commuting by helicopter from Alpine each day. The total nest searching area in 2014 was 0.03 km^2 smaller than in 2013 due to roads and pads constructed over the previous winter, which intersected several study plots. The area that gravel covered in plots was subtracted from the area in each plot. A crew of 4 people spaced 20 m apart searched for nests by walking a zigzag pattern, to achieve total coverage of the tundra within each plot's boundaries. Plot boundaries were displayed on a moving map on handheld GPS units. Crew members searched for nests of large birds including Bar-tailed Godwits, waterfowl, ptarmigan, and larids (gulls, terns, and jaegers); all other shorebird and songbird nests were not recorded. Nest searchers communicated with hand-held radios when nests were spotted to avoid flushing incubating birds. For each nest found, we recorded the species, location, active status, distance to nearest water, distance to nearest waterbody, waterbody class, whether or not the bird flushed, the distance at which it flushed, and the number of eggs and the float angle of eggs for nests that were unoccupied or where the incubating bird flushed. Nests were recorded as active (nest attended or eggs were warm), or inactive (unattended and without eggs). We floated 1–3 eggs in water (Westerkov 1950, Mabee et al. 2006) from all nests of White-fronted Geese (intentionally flushed) and Cackling/Canada Geese (only those inadvertently flushed) to estimate age of eggs and incubation start dates. Nest data were recorded on a GPS and downloaded to a database at the end of the day.

Unattended nests were identified to species or species group based on the size and color pattern of contour feathers, down, or eggs in the nest (Anderson and Cooper 1994, Bowman 2004). Some nests were unidentified because too few feathers were in the nest or feathers were not clearly definitive in determining species. Wooden survey stakes (45 cm high) were placed ≥15 m from active nest sites to assist in relocating the nest. Before we departed from waterfowl nests where the incubating bird was absent, eggs were covered with nest material and additional vegetation to conceal the nest from predators.

TEMPERATURE-SENSING EGGS

Artificial temperature-sensing eggs and data loggers were installed in 40 White-fronted Goose nests to record incubation activity and data on daily nest survival. The eggs were constructed from plastic "Easter" eggs and painted white to approximate White-fronted Goose eggs. The thermistor (TMC1-HD, TMC6-HD, and TMC6-HA cables; Onset Computer Corporation, Bourne, MA) consisted of a 2.5 cm temperature sensor taped to the inside of each egg. The thermistor cable (connected to the temperature sensor) ranged from 0.3 m to 1.8 m long and exited the temperature-sensing egg where the egg was attached to a 15 cm threaded toggle-bolt (sheetrock wall anchor) and held in place with a nut and washer. The thermistor cable was connected to a small data logger (HOBO® models H8-002-02 or U12-006, Onset Computer Corporation, Bourne, MA). Loggers were programmed to record nest temperature every 5 min.

All eggs were removed from nests before installing temperature sensors. The thermistor cable was hidden in a shallow trench (2–3 cm deep) leading 15–30 cm from the nest to the data logger, which was sealed in a waterproof bag and buried 3–5 cm under the vegetation mat. To prevent the removal of equipment by geese or nest

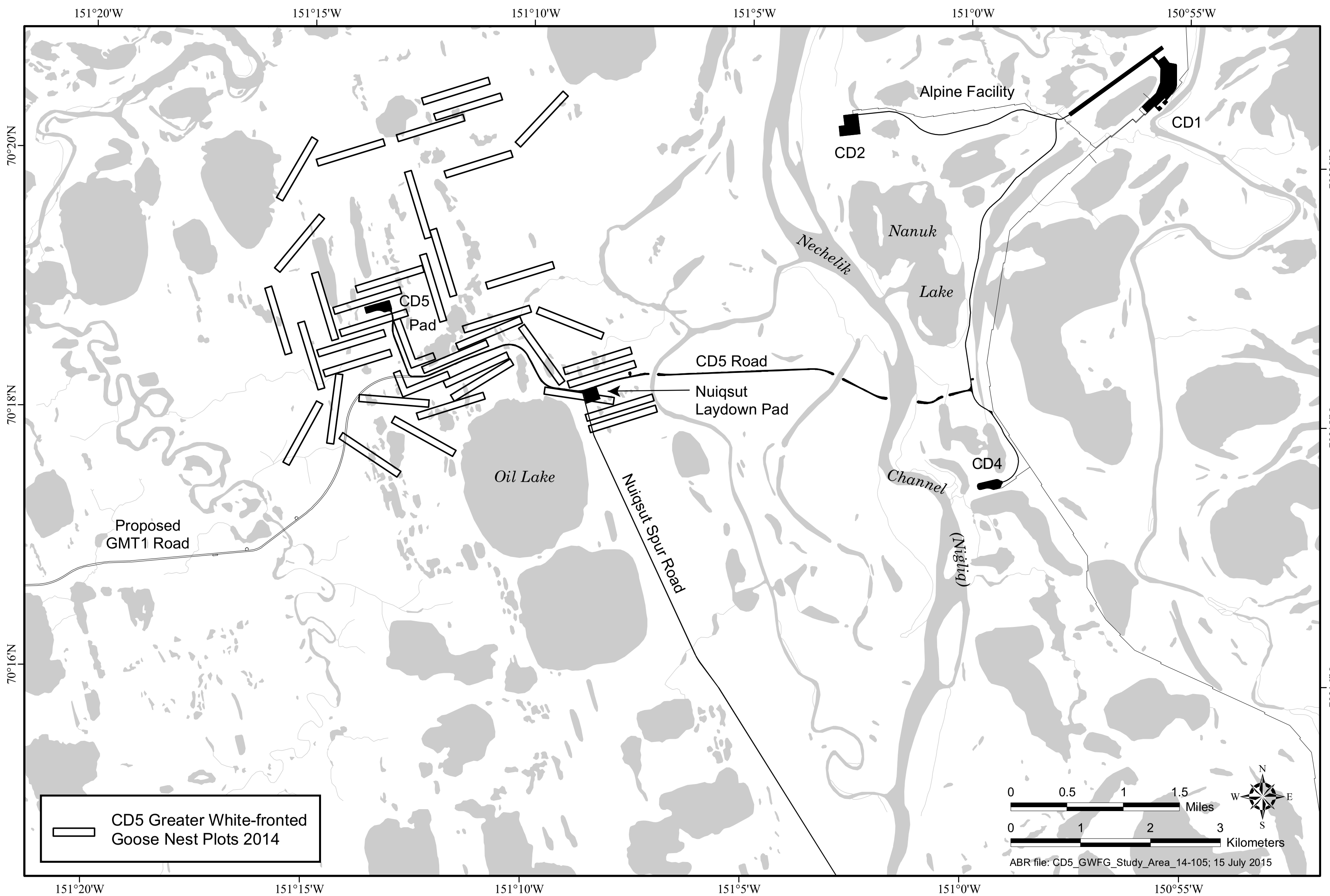


Figure 7. Plot locations for ground-based survey of nesting Greater White-fronted Geese at CD5, NE NPR-A study area, Alaska, 2013 and 2014.

predators, the toggle-bolt on the temperature-sensing egg was pressed into a hole in the center of the nest bowl so that the wings of the bolt could act as barbs and hinder removal. The thermistor cord was wrapped around a tent stake to anchor the thermistor cable to the ground. After installation, the eggs were returned to the nest and covered with down and vegetation. After the nesting season, artificial eggs and data loggers were retrieved and the temperature data were exported using BoxCar Pro version 4.0.7.0 or HOBOware version 3.7.1, depending on the model of the data logger used. Both programs provide a graphical representation and text files of the temperature data recorded at each nest. Microsoft® Access databases were used for data storage, analysis, and summaries.

Classifications of incubation activity were made using temperature data from the artificial eggs, applying rules of interpretation developed for White-fronted Geese in a previous multi-year study, which used time-lapse cameras in conjunction with temperature sensing eggs (Johnson et al. 2003a). Incubation classification was based on the minimum egg temperature during incubation (28.3 °C) and on the temperature changes between 2 consecutive 5 min recording intervals. When the egg temperature was ≥28.3 °C, the female was judged to be on the nest either incubating or taking an incubation break (e.g., rolling eggs, changing position, etc.). A female was judged to be on an incubation break when the egg temperature decreased by ≥1 °C from the previous interval but egg temperature remained ≥28.3 °C; if ≥28.3 °C and the temperature change did not decrease 1.0 °C or more (i.e., decreased <1 °C, no change, or increased), the female was considered to be incubating. If the egg temperature was <28.3 °C, the female was judged to be off the nest on a recess. Recess intervals also were identified when the egg temperature was ≥28.3 °C, when the temperature dropped >1 °C from the previous interval and continued to cool to <28.3 °C during successive intervals. A recess ended when the egg temperature rose above 28.3 °C. At high ambient temperatures (>12 °C), we used the same temperature threshold (28.3 °C) to determine whether or not the female was on a recess, but the difference in nest temperature required between intervals was reduced to ≥0.75 °C (from ≥1 °C) for the state of incubation to change from the previous interval. Incubation breaks prior to a recess were reclassified as part of the recess sequence, because we could not distinguish them from sequential recess intervals based on temperature (e.g., egg temperatures for the initial recess interval usually started above 28.3 °C and dropped >1 °C as the egg cooled). Therefore, in these cases we classified intervals with the same temperature changes defined for recesses as breaks when they were single-interval events, and as recesses when they occurred in 2 or more consecutive intervals. Incubation constancy was calculated as the percentage of records during which the female was on the nest (incubation plus incubation breaks).

NESTING SUCCESS

On 14–17 July, we revisited all nests to determine nest fates. For all species, a nest was considered successful if evidence suggested that at least 1 egg hatched. Hatch was determined by the presence at the nest of detached egg membranes, eggshells with thickened membranes that peeled easily from the shell, eggshell pipping fragments (>5 mm), and eggshell tops or bottoms. The presence of yolk, blood, eggshells with holes, egg fragments with attached membranes, or the total absence of egg remains indicated nest failure. Any evidence of predation (fox scent, fox scat, or a disturbed nest site) was recorded.

Temperature data from nests installed with thermistors were reviewed for indications of hatch or failure. Temperature records from nests that hatched showed a long period of nest attendance followed by an increasing frequency of breaks 24–36 h before the female and brood left the nest. The increase in break frequency is visually apparent in the graph of nest temperature against time as a gradual cooling of the nest temperature. The female and brood were judged to have departed the nest when 5 consecutive records had an average nest temperature of <9 °C. After brood departure, nest temperature cycles with ambient temperature. In contrast, temperature records from failed nests usually end abruptly before tracking ambient temperatures. The hatch date of a nest was recorded as the day before the female and brood departed the nest.

Apparent nesting success was estimated by dividing the number of nests that hatched by the number of nests found, including nests that were inactive at discovery. Apparent nesting success is generally acknowledged to overestimate success because it does not take into the account the length of time nests are exposed to predators and other risk factors (Mayfield 1961). We report apparent nesting success for all nests found, because it is easily calculated for large numbers of nests without the added disturbance or expense of periodic monitoring or monitoring devices. We also calculated nesting success for a sample of nests with daily survival rates (DSR). Daily survival rates can be used to calculate unbiased estimates of nesting success, but they require periodic monitoring of nests to determine status. We used the artificial eggs with thermistors to monitor nests and collect data to calculate DSR. DSRs were estimated in program MARK (White and Burnham 1999) and we examined competing models with covariates of year, nest age, and date using Akaike Information Criteria corrected for finite sample size (AIC_c). We constructed 6 models: constant (assuming non-varying DSR), year, age, date, year + age, and year + date. The incubation period for White-fronted Geese on the North Slope of Alaska is reported to be 22–27 d (Ely and Dzubin 1994). We used 24 d for the incubation period for White-fronted Geese, which was the modal incubation length for nests at CD5 in 2014. Nesting success over the incubation period was calculated by raising the DSR to the exponent of the number of days of incubation. We estimated incubation start dates and nest initiation dates for White-fronted Geese and Canada Geese using egg-flotation data or backdating in the case of nests with known hatch dates. Each floated egg was assigned an age from a float schedule based on the angle and position of the egg in the water column (Jerry Hupp, USGS, unpublished data). The float schedule provided estimates of ages in 2–4 d ranges; we used the midpoint of the range or the earlier date in the case of 2 d ranges. We used the youngest (last-laid) egg sampled in each nest to arrive at the start date for incubation. The date of nest initiation was calculated by multiplying the clutch size by the estimated laying interval (1.33 d/egg; Ely and Dzubin 1994, Mowbray et al. 2002, Burgess et al. 2013) and backdating from the incubation start date.

PREDATOR SCANS

We conducted predator scans visually on all of our plots to determine the types and numbers of potential nest predators in the CD5 area. During each scan, binoculars were used to search for predators. On each plot, we conducted 2 scans 10 min each for avian predators (i.e., jaegers, gulls, raptors, ravens, and owls) and mammalian predators (i.e., foxes and bears) observed within plot boundaries and ≤300 m outside plot boundaries. Predator scans were initiated on the center line at the beginning and end points of each plot (1 km apart) 10 min before the start and 10 min after the end of the nest-searching effort for each plot. Level of predator activity in the area was summarized by the number of predator observations per 10 min scan. Incidental observations of predators seen during nest searches were also recorded.

BROOD-REARING

We conducted 1 survey for brood-rearing and molting Brant and Snow Geese on 31 July 2014 in the coastal zone of the Colville Delta and NE NPR-A study areas (Table 2). We used similar methods for surveys conducted annually since 2005 and in some earlier years dating back to 1988. The survey was flown in a Piper PA-18 “Super Cub” aircraft at 75–150 m agl and approximately 100–120 km/h along the coast and in a lake-to-lake pattern (Figure 8). One pilot and 1 observer searched appropriate habitats along the coast, rivers, channels, and lakes. The numbers of adults and young Brant and Snow Geese were recorded and their locations were saved on a GPS receiver. Since 2005, the observer has taken photographs of geese in large brood-rearing groups. Digital or film images from SLR cameras were used to accurately enumerate groups containing ≥50 birds, whereas some smaller brood groups and groups without goslings were estimated visually. In 2014, a camera malfunction prevented the acquisition of photographs, and all groups were estimated visually, with the exception of the largest group of brood rearing Brant in the Colville River delta, which had been captured during a banding operation at the time of the survey and for which exact numbers were available (D. Ward, USGS, personal communication).

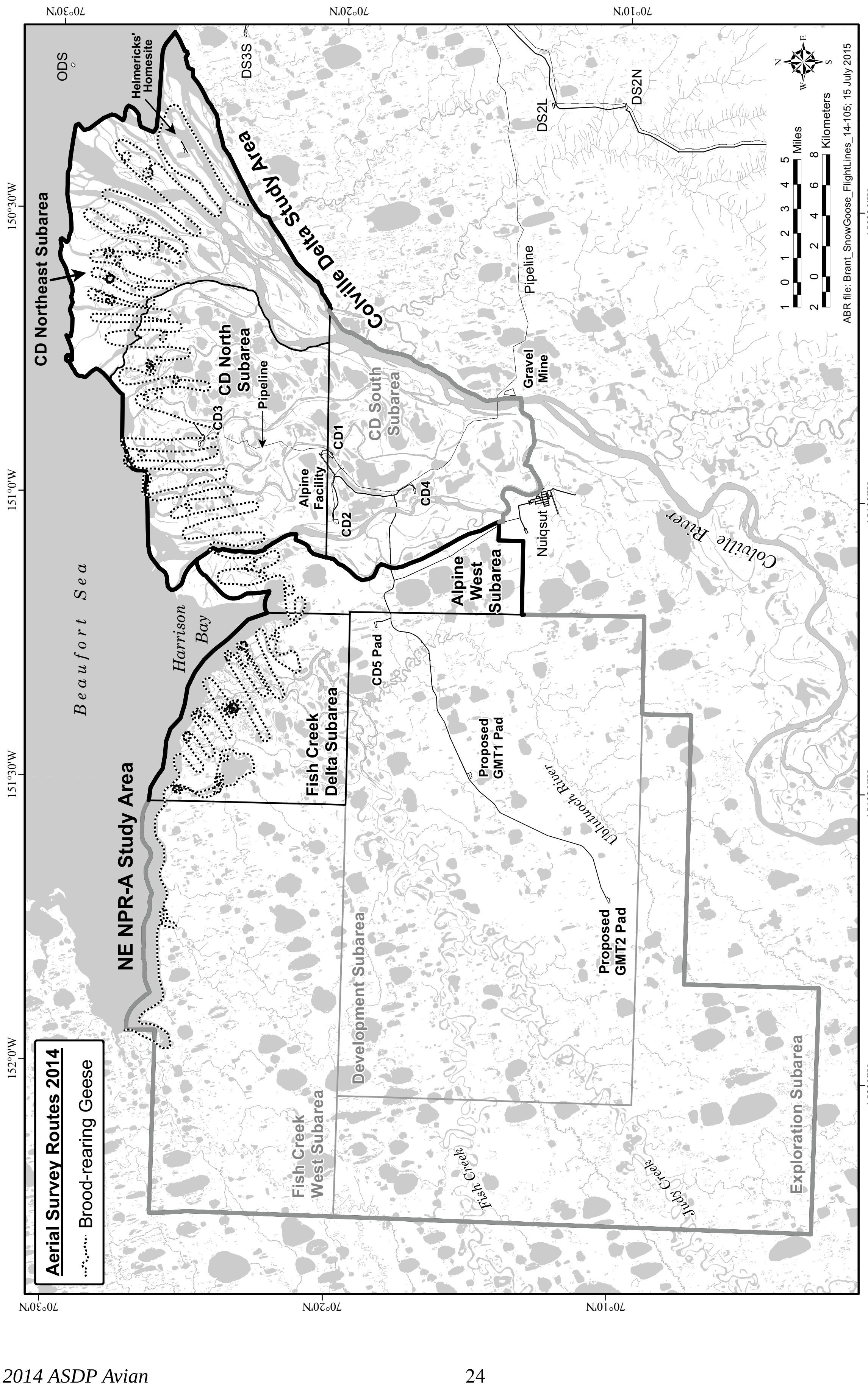


Figure 8. Flight lines for aerial surveys of brood-rearing Brant and Snow Geese, Colville Delta and NE NPR-A study areas, Alaska, 2014.

GULL SURVEYS

We recorded nests and broods of Glaucous and Sabine's gulls (Iqirgagiak) during the nesting and brood surveys conducted for Yellow-billed Loons in the Colville Delta and NE NPR-A study areas (see LOON SURVEYS, above, for methods). Both gull species nest singly and in loose aggregations or colonies. Gull nests and broods were recorded incidentally as they were encountered and traditional nest or colony locations within the study areas were checked for activity. We considered a group of 3 or more nests occurring in proximity on the same lake or wetland complex to be a colony. Once a Glaucous Gull colony was established, we used one central location for all nests, even though some nests may be as far as 350 m apart. For Sabine's Gulls, we estimated the number of nests, which can only be seen from the air when occupied. All nest and brood observations were recorded on color photomosaic field maps (1:30,000 scale) and later entered into a GIS database.

We monitored trends in nest numbers for Glaucous Gulls in the Colville Delta study area using a subset of 50 lakes surveyed for Yellow-billed Loon nests and broods since 2002. Index lakes included 26 lakes with 1–9 seasons of gull nesting history, and 24 lakes with no history of nesting gulls. Of the 50 lakes, 2 were in the Northeast Delta subarea, 20 in the CD South subarea, and 28 in the CD North subarea. The number of Glaucous Gull nests was summarized annually by subarea as an index for monitoring the population of nesting Glaucous Gulls in the Colville Delta study area.

DENSITY MAPS

To summarize mean annual distribution and abundance of eiders, swans, Brant, and Snow Geese, we used the inverse distance-weighted (IDW) interpolation technique of the Spatial Analyst extension of *ArcMap* software (Environmental Systems Research Institute, Inc. [ESRI], Redlands, CA) on a GIS platform. We mapped pre-nesting Spectacled and King eiders (1994–2014), Tundra Swan nests (1989–2014), and Brant and Snow Goose brood-rearing and molting groups (2005–2014). To calculate density, we first divided the survey areas into 1 km × 1 km grid cells for geese and 2 km × 2 km grid cells for eiders and swan nests. We used the indicated total numbers of pre-nesting eiders, number of swan nests, or number of adult Brant or Snow Geese to calculate annual mean density values for grid cells by dividing the cumulative number of birds or nests observed in each cell (total across all surveys) by the area surveyed in each cell and the number of times (years) the cell was surveyed. We assigned the calculated densities to the centroid of the cells. The IDW interpolation technique calculated a smoothed density surface for 500 ft pixels based on the distance-weighted density of up to 8 centroids of the nearest grid cells within 1.4 km (geese) or 2.8 km (eiders and swan nests) in the study area (power = 1). The analysis produced color maps exhibiting density distribution averaged among all survey years of comparable survey data over the entire survey area.

HABITAT MAPPING AND ANALYSIS

A wildlife habitat was assigned to each observation of birds, nests, or broods by plotting their coordinates on the wildlife habitat maps (Figures 2 and 3). We merged several habitats, based on similar composition or physiography and low areal coverage, to reduce the number of classes. For example, Moist Halophytic Dwarf Shrub (≤0.1% of both study areas; Table 1) was merged into Salt Marsh, Dry Halophytic Meadow (<0.1% of NE NPR-A study area) was merged into Tidal Flat Barrens, and all non-halophytic shrub types (all but 1 occupied <1% of each study area) were merged into Tall, Low, or Dwarf Shrub.

For each bird species, habitat use (% of all observations in each identified habitat type) was determined separately for various seasons (e.g., pre-nesting, nesting, and brood-rearing), as appropriate. For each species/season, we calculated 1) the number of adults, flocks, nests, or broods in each habitat, and 2) the percent of total observations in each habitat (habitat use). Habitat use was calculated from group locations for species or seasons when birds were in pairs, flocks, or broods, because individuals in groups are not likely to be independent in location or habitat selection (i.e., a few large groups could bias results). We also calculated habitat availability, the percent of each habitat in a survey area, separately for each species and season because the survey areas sometimes differed among species, seasons, and years.

For a subset of species/surveys, a statistical analysis of habitat selection was used to evaluate whether habitats were used in proportion to their availability. When multiple years of survey data were available, all comparable data were used in the analysis of habitat selection. For this purpose, annual surveys were considered comparable only when the survey areas were similar in habitat composition, because overall habitat availability was calculated by summing annual habitat availability over years.

Habitat selection was evaluated for the following species, seasons, and years:

- pre-nesting Spectacled Eiders and King Eiders (Colville Delta study area—1993–1998 and 2000–2014 and NE NPR-A study area—2001–2006 and 2008–2014)
- nesting and brood-rearing Tundra Swans (Colville Delta study area—1992–1998 and 2000–2014 and NE NPR-A study area—2001–2006, 2008–2009, and 2011– 2014)
- nesting and brood-rearing Yellow-billed Loons (Colville Delta study area nests—1993–1998 and 2000–2014 and Colville Delta study area broods—1995–1998 and 2000–2014, and NE NPR-A study area nests and broods—2008–2014)
- nesting White-fronted Geese (CD5 area—2013–2014)

For other species, the number of observations or number of comparable annual surveys was inadequate for statistical analysis.

We inferred habitat selection from comparisons of observed habitat use with random habitat use. Random habitat use was based on the percent availability of each habitat. Monte Carlo simulations (1,000 iterations) were used to calculate a frequency distribution of random habitat use, with the sample sizes in each simulation equaling the number of observed nests or groups of birds in that season. The resulting distribution was used to compute 95% confidence intervals around the expected value of habitat use (Haefner 1996, Manly 1997). We defined habitat preference (i.e., use > availability) as observed habitat use greater than the 95% confidence interval of simulated random use, which represents an alpha level of 0.05 (2-tailed test). Conversely, we defined habitat avoidance (i.e., use < availability) as observed habitat use below the 95% confidence interval of simulated random use. The simulations and calculations of confidence intervals were conducted with Microsoft® Excel.

DATA MANAGEMENT

All data collected during surveys for CPAI were compiled into a centralized database following CPAI's data management protocols (ver. 8.10, CPAI 2014). Locations of geese were recorded on a GPS receiver with decimal-degree coordinates in the WGS 84 map datum and later transferred into the NAD 83 map datum. All other nest, brood, bird, and bird group locations were digitized from survey maps directly into the NAD 83 map datum. Uniform attribute data were recorded for all observations and proofed after data collection and proofed again during data entry. Survey data were submitted in GIS-ready format with corresponding metadata.

RESULTS AND DISCUSSION

SEASONAL CONDITIONS IN THE STUDY AREAS

Birds arriving in mid-May experienced a cycle of thaw and refreezing of surface water on the delta. Warm temperatures in the foothills of the Brooks Range in early May created a surge of meltwater that reached the Colville River delta on 15 May. This first peak crested on 20 May and subsided by 23 May as temperatures dropped to below freezing (Michael Baker Jr. 2014). A second thaw a week later brought higher water levels on 31 May with the water surface elevation peaking at 4.6 m above mean sea level at the head of the Colville River delta (Monument 1). The second peak was also below the historical average of 5.1 m above mean sea level at Monument 1 (Michael Baker Jr. 2014). Peak discharge was 327, 000 cubic feet/second (cfs) on 1 June, which was above the historical average of 294,000 cfs but lower than peak discharges for the 3 previous years (Michael

Baker Jr. 2014). On the outer delta (Monument 35), water levels peaked a day later on 1 June at 2.0 m above mean sea level. Breakup of river ice occurred on 3 June (Michael Baker Jr. 2014). Although water levels peaked in 2 pulses during 2014, river breakup occurred near the average date. In the NE NPR-A, peak stage was also low; the maximum water elevation (6.6 m) at the Fish Creek hydrology station in early June 2014 was the lowest in 4 years of records (http://ine. uaf.edu/ werc/projects/npra-hydrology/fish-creek/).

Spring temperatures were relatively cool on the Colville River delta. During the period of waterfowl arrival and peak nest initiation (15 May–15 June), 30 cumulative thawing degree-days were measured at Colville Village, which was below the long-term mean of 37 cumulative thawing degree-days (Standard Error [SE] = 5 thawing degree-days, n = 18 years; Figure 9). The mean temperature in May (–2.4 °C) was cooler than the 18-year mean (–5.5 ± 0.5 °C), while the mean temperature in June (3.0 °C) was only slightly cooler than the 18-year mean (3.5 ± 0.4 °C). Daily mean temperatures at Alpine (24 km southwest of Colville Village) averaged 1.8 °C warmer than at Colville Village on the outer delta, indicating an earlier thaw in the central and southern delta. We have noted that incubating Yellow-billed Loons demonstrate gular fluttering, a method to dissipate heat, when the ambient temperature was ≥15 °C (ABR, unpublished data). During the nesting period (10 June–20 July), incubating birds experienced fewer high temperature days (maximum temperature >15 °C) during 2014 (12 high temperature days) compared with the 2013 (31 high temperature days).

Snow depth for birds arriving 15 May was 15 cm, well below 18-year average of 24 ± 2 cm (mean ± SE) for Colville Village. The snow depth at Alpine in mid-May was greater (41 cm), with measureable snow cover disappearing on 6 June, when high water replaced snow. Ice coverage on large lakes (>5 ha) was estimated visually during loon aerial surveys. Ice coverage was 100% on 27 May. By the 11 June loon survey, the majority of shallow waterbodies were open but deep waterbodies were ice covered with moats along shorelines. On the loon nesting survey, 19–22 June, the average ice coverage on lakes was 88%, the highest recorded in 6 years of record keeping

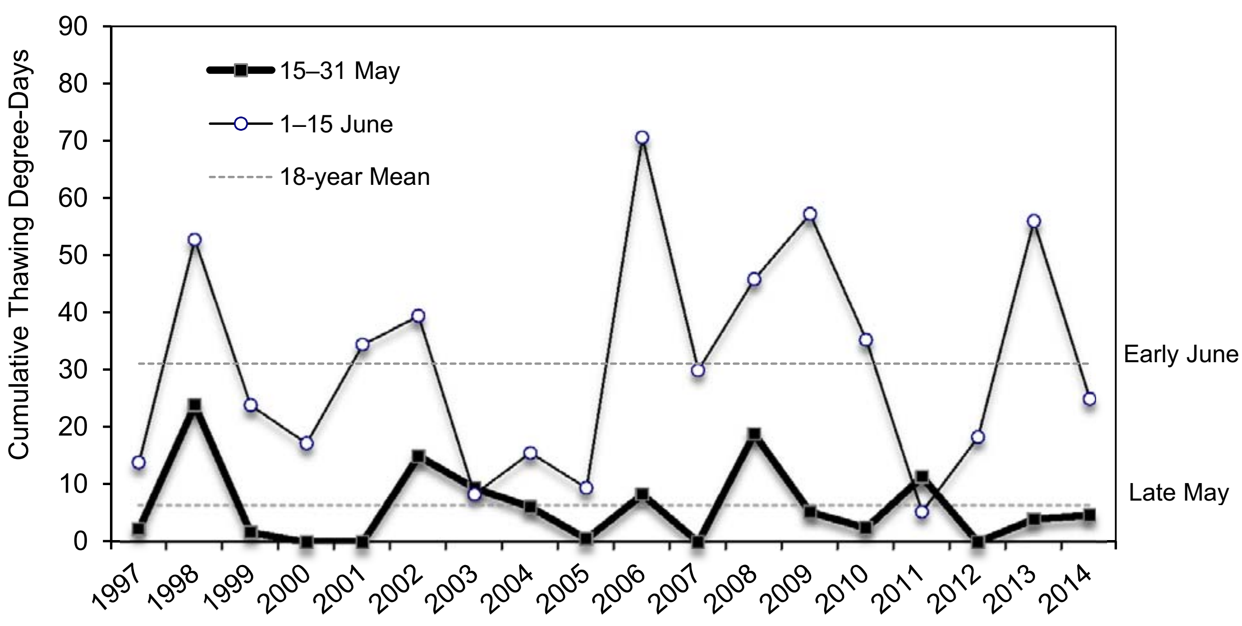


Figure 9. Cumulative number of thawing degree-days recorded 15 May–15 June at Colville Village, Colville Delta, Alaska, 1997–2014.

(range 31–88% ice cover). Ice continued to shrink until the 2 July survey, when ice remained only on the largest of deep water lakes (~ 30% coverage), mostly in the form of candle ice. Cool weather in June delayed the emergence of mosquitoes. Mosquitoes first reached moderate levels in the CD5 area on 28 June. Mosquito emergence typically is in late June to early July, which places 2014 near the average for timing. Nest searchers on the Colville River delta first encountered eggs of one of the later nesting species, Pacific Loons on 22 June and hatchlings of one of the earliest nesting species, Greater White-fronted Geese, on 28 July (Seiser and Johnson 2014b). Freeze-up occurred sometime after the third week of September. Large waterbodies on the Colville River delta were ice free on the last loon survey of the season on 24 September, except in shallow and wind protected regions of lakes. Surface water temperatures at the Fish Creek hydrology station first reached freezing temperatures on 26 September (http://ine.uaf.edu/werc/projects/npra-hydrology/data.aspx). No measureable snow cover was recorded at either Colville Village or Alpine weather stations in late September.

The landscape in the CD5 areas had changed between the 2013 and 2014 breeding seasons with new construction of bridges, gravel roads, and pads for development of CD5. Infrastructure development for CD5 increased the area of human modified habitat by 0.21 km^2 within the Colville Delta study area and 0.29 km^2 in the NE NPR-A study area (Table 1).

EIDERS

Four species of eiders may occur in the ASDP area, but each occurs at different frequencies and widely varying numbers. Of the 2 species of eiders that commonly occur in the Colville Delta and NE NPR-A study areas, the Spectacled Eider has received the most attention because it was listed as "threatened" in 1993 (58 FR 27474–27480) under the Endangered Species Act of 1973, as amended. The outer Colville River delta is a concentration area for breeding Spectacled Eiders relative to surrounding areas; nonetheless, Spectacled Eiders nest there at low densities and nest at even lower densities at inland portions of the delta and in scattered wetland basins in the NE NPR-A study area (Burgess et al. 2003a, 2003b; Johnson et al. 2004, 2005). The King Eider is more widespread and generally more numerous than the Spectacled Eider, although their relative abundance varies geographically. The Steller's Eider was listed as a threatened species in 1997 (62 FR 31748–31757). Steller's Eiders are rare on the Colville Delta and NE NPR-A study areas as these areas are east of their current Alaska breeding range centered around Barrow. Both the Colville Delta and NE NPR-A study areas are within the range of Common Eiders, which nest primarily on barrier islands and coastlines but are seen rarely on surveys of the Colville Delta and NE NPR-A study areas.

SPECTACLED EIDER

Colville Delta Study Area

Distribution and Abundance

Although Spectacled Eiders were not as abundant on the pre-nesting aerial survey in 2014 as they were in the record years of 2008, 2010, and 2011, their numbers and density were higher than average (Figure 10, Tables 3 and 4). In 2014, we recorded 69 Spectacled Eiders in the Colville Delta study area, of which 60 were on the ground and 9 were in flight, for a total of 68 indicated birds (Table 3). All observations of Spectacled Eiders in the Colville Delta study area during the pre-nesting survey in 2014 were in small groups of 1–4 birds, and 87% of those counted were found in the CD North subarea, where Spectacled Eiders traditionally have been most concentrated (Figure 11, Appendix C). The density of Spectacled Eiders in the CD North subarea during 2014 (0.29 indicated birds/km^2) was above the 21-year mean (0.21 indicated birds/km^2, SE = 0.02) as was the density in the larger Colville Delta study area (Table 4, Appendix C). Mean annual densities are highest north of Alpine (Figure 12). Densities of observed birds (birds on ground and in flight, 0.27 birds/km^2) and indicated birds (USFWS 1987a) in the CD North subarea (0.29 birds/km^2) were about double those in the entire Colville Delta study area (0.14 birds/km^2, for both observed and indicated birds). The lowest density (0.01 indicated birds/km^2) was recorded in the CD South subarea.

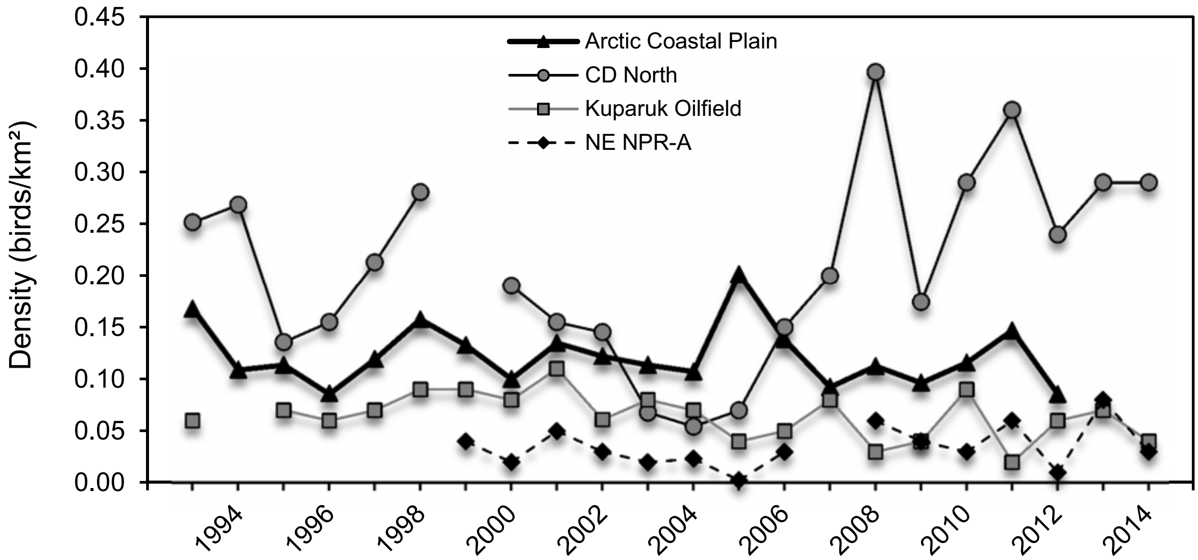


Figure 10. Annual densities of indicated total Spectacled Eiders during pre-nesting aerial surveys in 4 study areas on the Arctic Coastal Plain, Alaska, 1993–2014. Arctic Coastal Plain data from Stehn et al. 2013, Kuparuk data from Stickney et al. 2015, and CD North and NE NPR-A data from this study.

Table 3. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 2014.

SPECIES Location	Observed Males	Observed Females	Observed Total	Observed Pairs	Indicated Total[a]	Observed Density[b]	Indicated Density[a, b]
SPECTACLED EIDER							
On ground	34	26	60	26	68	0.12	0.14
In flight	7	2	9	2	–	0.02	–
All birds	41	28	69	28	–	0.14	–
KING EIDER							
On ground	33	31	64	31	66	0.13	0.13
In flight	5	2	7	2	–	0.01	–
All birds	38	33	71	33	–	0.14	–

[a] Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a)
[b] Numbers not corrected for sightability. Density based on 100% coverage of 501.4 km²

Table 4. Annual number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 1993–2014.

		Spectacled Eider				King Eider			
		Total[a]		Density[b]		Total[a]		Density[b]	
Year	Surveyed Area (km²)	Observed	Indicated	Observed	Indicated	Observed	Indicated	Observed	Indicated
1993	248.8	31	32	0.12	0.13	39	30	0.16	0.12
1994	455.7	79	57	0.17	0.13	58	35	0.13	0.08
1995	501.4	61	40	0.12	0.08	34	23	0.07	0.05
1996	501.4	41	40	0.08	0.08	59	43	0.12	0.09
1997	501.4	59	58	0.12	0.12	49	54	0.10	0.11
1998	501.4	71	70	0.14	0.14	57	18	0.11	0.04
2000	300.0	40	38	0.13	0.13	22	24	0.07	0.08
2001	501.4	38	36	0.08	0.07	35	22	0.07	0.04
2002	501.4	26	30	0.05	0.06	61	42	0.12	0.08
2003	501.4	24	20	0.05	0.04	50	38	0.10	0.08
2004	353.0	12	10	0.03	0.03	17	14	0.05	0.04
2005	501.4	16	14	0.03	0.03	46	22	0.09	0.04
2006	501.4	31	30	0.06	0.06	63	60	0.13	0.12
2007	501.4	52	48	0.10	0.10	30	28	0.06	0.06
2008	501.4	80	89	0.16	0.18	33	40	0.07	0.08
2009	501.4	41	42	0.08	0.08	33	30	0.07	0.06
2010	501.4	103	78	0.21	0.16	57	34	0.11	0.07
2011	501.4	99	95	0.20	0.19	133	129	0.27	0.26
2012	501.4	59	60	0.12	0.12	25	20	0.05	0.04
2013	501.4	63	66	0.13	0.13	38	24	0.08	0.05
2014	501.4	69	68	0.14	0.14	71	66	0.14	0.13
Mean		54.88	52.00	0.11	0.10	51.41	40.76	0.10	0.08
SE		6.07	5.71	0.01	0.01	6.07	6.52	0.01	0.01

[a] Observed total includes flying and non-flying eiders. Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a). Mean and standard error calculated for total observed or indicated when survey area = 501.4 km², *n* = 17 years

[b] Numbers not corrected for sightability. Density (birds/km²) based on 100% coverage of surveyed area. Means calculated for all years, *n* = 21 years

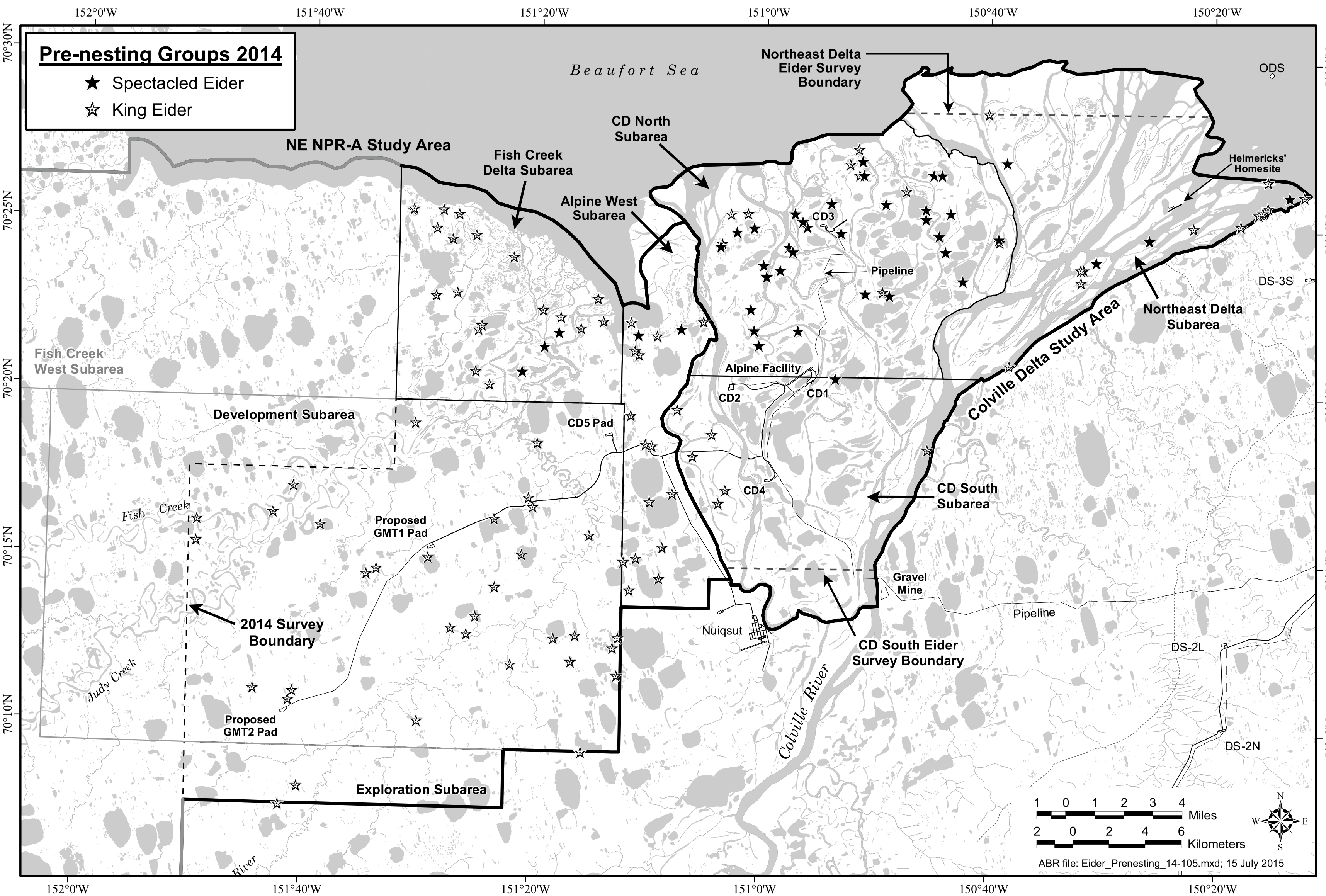


Figure 11. Spectacled and King eider groups during pre-nesting, Colville Delta and NE NPR-A study areas, Alaska, 2014.

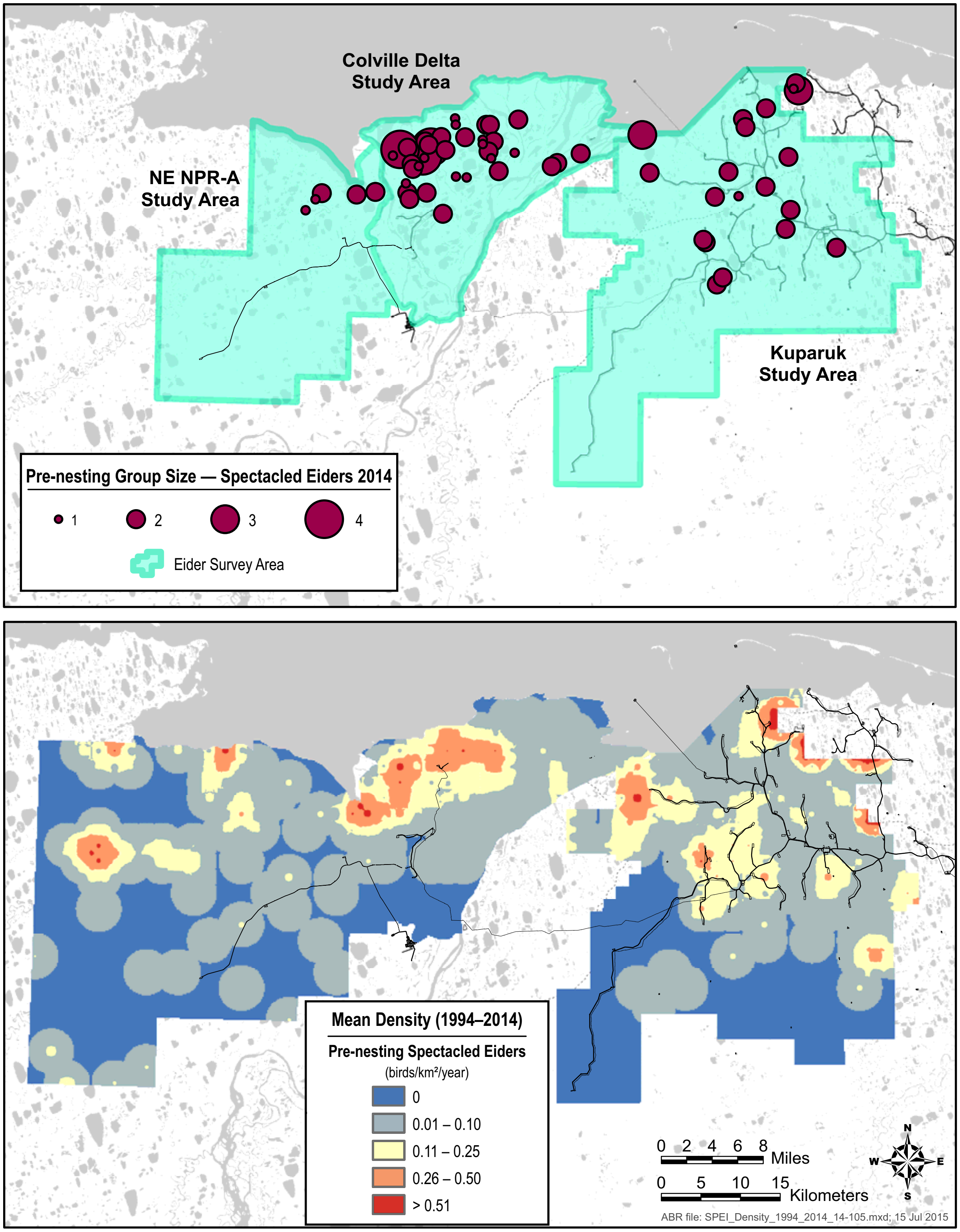


Figure 12. Spectacled Eider pre-nesting group locations in 2014 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE-NPRA study areas, 1994–2014 (bottom). Kuparuk data from Stickney et al. 2015.

Habitat Use

Pre-nesting Spectacled Eiders used 17 of 24 available habitats during 21 years of aerial surveys on the Colville Delta study area (Table 5). Seven habitats were preferred (i.e., use significantly greater than availability, $P \leq 0.05$) by pre-nesting Spectacled Eiders: 3 primarily coastal salt-affected habitats (Brackish Water, Salt Marsh, and Salt-killed Tundra), 3 aquatic habitats (Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, and Grass Marsh), and 1 terrestrial habitat (Deep Polygon Complex). Deep Polygon Complex, which consists of a mosaic of small, deep, polygon ponds with relatively narrow vegetated rims and sometimes with islets, is notable because of its disproportionate use; it was used by 28% of the Spectacled Eider groups yet was available on only 2.7% of the delta. Deep Polygon Complex is also preferred during the nesting season (Johnson et al. 2008a). Patterned Wet Meadow also had high use (19% of Spectacled Eider groups) but was not preferred because of its use was equal to availability. Six habitats were avoided (use significantly less than availability), including Open Nearshore Water, Tidal Flat Barrens, River or Stream, Moist Sedge-Shrub Meadow, Tall, Low, or Dwarf Shrub, and Barrens. All other habitats were used in proportion to their availabilities.

NE NPR-A Study Area

Distribution and Abundance

Compared with 14 previous years of pre-nesting surveys, the density of Spectacled Eiders in the NE NPR-A study area was near average in 2014 (Figure 10, Table 6). The density of Spectacled Eiders in the NE NPR-A study area in 2014 was 21% of the density of Spectacled Eiders on the Colville Delta study area, a geographic difference which has been consistent although the relative proportions have varied (Tables 4 and 6). Over the entire NE NPR-A study area, we counted 8 observed (on ground and in flight) and 10 indicated Spectacled Eiders resulting in a density of 0.02 observed birds/km² and 0.03 indicated birds/km². Spectacled Eiders were observed only in 2 subareas (Alpine West and Fish Creek Delta subareas) in the NE NPR-A study area in 2014, with the highest density in the Alpine West subarea (0.14 indicated birds/km²; Figure 11, Appendix D). The mean density distribution also shows high densities have occurred in the Alpine West area near the Colville River, as well as near the coast and Fish and Judy creeks in the western portions of the NE NPR-A study area (Figure 12).

Habitat Use

Pre-nesting Spectacled Eiders used 13 of 26 available habitats in the NE NPR-A study area over 13 years of aerial surveys that were used for the selection analysis (Table 7). Spectacled Eiders preferred 5 habitats in the NE NPR-A study area, 4 of which also were preferred in the Colville Delta study area: Brackish Water, Salt Marsh, Shallow Open Water with Islands or Polygonized Margins, and Grass Marsh. The other preferred habitat was Shallow Open Water without Islands. Two terrestrial habitats—Moist Sedge-Shrub Meadow and Moist Tussock Tundra—were significantly avoided and were notable because they occupy the majority of the study area. The sample size remains small (58 groups total) resulting in low power in the selection analysis; we expect that additional habitats may be designated preferred and avoided as more Spectacled Eiders are added to the selection analysis in the future.

OTHER EIDERS

Colville Delta Study Area

Distribution and Abundance

The number of King Eiders recorded in the Colville Delta study area in 2014 was well above average (Figure 13, Table 4). The indicated density of King Eiders (0.13 birds/km²) in 2014 was about 50% higher than the 21-year mean (Table 3). King Eiders (66 indicated birds) were almost as numerous as Spectacled Eiders (68 indicated birds) during the 2014 pre-nesting period (Table 3). King Eiders were seen in all 3 of the subareas, but they achieved their highest density (0.20 indicated birds/km²) in the Northeast Delta subarea in 2014 (Figure 11, Appendix C). The highest mean densities occur on the East Channel of the Colville River near the coast, where flocks of King Eiders collect in open water; negligible densities are seen elsewhere on the delta (Figure 14). Relatively few King Eiders nest on the Colville River delta, which leads us to surmise that most of those observed

Table 5. Habitat selection by Spectacled and King eider groups during pre-nesting, Colville Delta study area, Alaska, 1993–1998 and 2000–2014.

SPECIES Habitat	No. of Adults	No. of Groups	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
SPECTACLED EIDER						
Open Nearshore Water	0	0	0	1.6	avoid	
Brackish Water	78	35	7.6	1.3	prefer	
Tapped Lake with Low-water Connection	31	13	2.8	4.5	ns	
Tapped Lake with High-water Connection	19	11	2.4	3.7	ns	
Salt Marsh	62	34	7.4	3.2	prefer	
Tidal Flat Barrens	2	1	0.2	7.0	avoid	
Salt-killed Tundra	78	43	9.3	5.1	prefer	
Deep Open Water without Islands	31	19	4.1	3.5	ns	
Deep Open Water with Islands or Polygonized Margins	35	17	3.7	2.1	prefer	
Shallow Open Water without Islands	6	4	0.9	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	6	5	1.1	0.1	prefer	low
River or Stream	24	12	2.6	14.4	avoid	
Sedge Marsh	0	0	0	<0.1	ns	low
Deep Polygon Complex	231	131	28.4	2.7	prefer	
Grass Marsh	10	6	1.3	0.2	prefer	low
Young Basin Wetland Complex	0	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	79	39	8.5	8.2	ns	
Patterned Wet Meadow	167	89	19.3	19.4	ns	
Moist Sedge-Shrub Meadow	0	0	0	2.3	avoid	
Moist Tussock Tundra	1	1	0.2	0.6	ns	low
Tall, Low, or Dwarf Shrub	0	0	0	4.9	avoid	
Barrens	2	1	0.2	14.8	avoid	
Human Modified	0	0	0	0.1	ns	low
Total	862	461	100	100		
KING EIDER						
Open Nearshore Water	13	4	1.4	1.6	ns	low
Brackish Water	37	20	7.2	1.3	prefer	low
Tapped Lake with Low-water Connection	25	12	4.3	4.5	ns	
Tapped Lake with High-water Connection	10	4	1.4	3.7	avoid	
Salt Marsh	45	17	6.1	3.2	prefer	
Tidal Flat Barrens	4	2	0.7	7.0	avoid	
Salt-killed Tundra	51	27	9.7	5.1	prefer	
Deep Open Water without Islands	22	10	3.6	3.5	ns	
Deep Open Water with Islands or Polygonized Margins	15	7	2.5	2.1	ns	
Shallow Open Water without Islands	4	2	0.7	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	1	0.4	0.1	ns	low
River or Stream	355	100	36.0	14.4	prefer	
Sedge Marsh	0	0	0	<0.1	ns	low
Deep Polygon Complex	45	25	9.0	2.7	prefer	
Grass Marsh	8	3	1.1	0.2	ns	low
Young Basin Wetland Complex	0	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	14	9	3.2	8.2	avoid	
Patterned Wet Meadow	50	28	10.1	19.4	avoid	
Moist Sedge-Shrub Meadow	2	1	0.4	2.3	avoid	
Moist Tussock Tundra	0	0	0	0.6	ns	low
Tall, Low, or Dwarf Shrub	2	1	0.4	4.9	avoid	
Barrens	13	5	1.8	14.8	avoid	
Human Modified	0	0	0	0.1	ns	low
Total	717	278	100	100		

[a] Use = (groups / total groups) × 100

[b] 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

[c] Expected number < 5

Table 6. Annual number and density (birds/km²) of eiders during pre-nesting aerial surveys, NE NPR-A study area, Alaska, 1999–2014.

		Spectacled Eider				King Eider			
		Total[a]		Density[b]		Total[a]		Density[b]	
Year	Surveyed Area (km²)	Observed	Indicated	Observed	Indicated	Observed	Indicated	Observed	Indicated
1999	143.4	4	6	0.03	0.04	41	16	0.29	0.11
2000	278.3	6	6	0.02	0.02	68	44	0.24	0.16
2001	511.0	21	20	0.04	0.04	128	98	0.25	0.19
2002	550.1	12	14	0.02	0.03	208	211	0.38	0.38
2003	557.6	10	12	0.02	0.02	191	128	0.34	0.23
2004	430.3	14	10	0.03	0.02	168	130	0.39	0.30
2005	755.1	9	2	0.01	<0.01	253	192	0.34	0.25
2006	755.1	31	26	0.04	0.03	318	332	0.42	0.44
2007	–	–	–	–	–	–	–	–	–
2008	755.1	41	46	0.05	0.06	489	506	0.65	0.67
2009	755.1	29	30	0.04	0.04	387	360	0.51	0.48
2010	755.1	23	24	0.03	0.03	617	457	0.82	0.61
2011	172.0	9	10	0.05	0.06	119	94	0.69	0.55
2012	172.0	4	2	0.02	0.01	81	90	0.47	0.52
2013	172.0	17	14	0.10	0.08	118	96	0.69	0.56
2014	332.7	8	10	0.02	0.03	142	120	0.43	0.36
Mean				0.04	0.03			0.46	0.39
SE				0.01	0.01			0.05	0.05

[a] Observed total includes flying and non-flying eiders. Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a). Mean and standard error not calculated for total observed or indicated because survey area varied

[b] Numbers not corrected for sightability. Density (birds/km²) based on 100% coverage of surveyed area. Some numbers and densities differ from those in original reports because they refer to different study areas or because minor corrections were made in later years

during pre-nesting are in transit to other breeding areas (Johnson et al. 2003b).

No Steller's or Common eiders were seen in the Colville Delta study area in 2014. Steller's Eiders rarely are seen in the vicinity of the Colville River delta, but 5 flying birds were sighted there in 1995 (J. Bart, personal communication), a pair was spotted on the ground in the CD North subarea in 2001, single flying males were seen in the NE NPR-A study area in 2001 and in the Colville Delta study area in 2007 (Johnson and Stickney 2001, Johnson et al. 2008b), and several sightings of singles or pairs were reported in the Kuparuk Oilfield during 1995, 2000, 2001, 2007, and 2014 (not all sightings in the Kuparuk Oilfield were confirmed; Anderson et al. 2008; I. Helmericks, personal communication 2014). Since 1992, nest searches have been conducted in multiple locations on the Colville River delta, in the Kuparuk Oilfield, and in NE NPR-A; in over 2 decades of nest searches in those study areas, no nests or indications of breeding by Steller's Eiders have been observed.

Common Eiders are seen infrequently on the Colville River delta, but are more common in the nearshore marine waters and barrier islands that are mostly outside the survey area. One pair of Common Eiders was observed in 2007 in the nearshore marine water just northwest of the study area boundary (Johnson et al. 2008b). Pairs also have been recorded during pre-nesting in 1992, 1998, and 2001, and a nest was found near the coastline in 1994 (Johnson 1995).

Table 7. Habitat selection by Spectacled and King eider groups during pre-nesting, NE NPR-A study area, Alaska, 2001–2006 and 2008–2014.

SPECIES Habitat	No. of Adults	No. of Groups	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
SPECTACLED EIDER						
Open Nearshore Water	0	0	0	0.7	ns	low
Brackish Water	13	7	12.1	1.3	prefer	low
Tapped Lake with Low-water Connection	0	0	0	0.8	ns	low
Tapped Lake with High-water Connection	0	0	0	0.5	ns	low
Salt Marsh	10	5	8.6	2.5	prefer	low
Tidal Flat Barrens	0	0	0	1.4	ns	low
Salt-killed Tundra	0	0	0	0.8	ns	low
Deep Open Water without Islands	4	2	3.4	6.5	ns	low
Deep Open Water with Islands or Polygonized Margins	11	6	10.3	5.1	ns	low
Shallow Open Water without Islands	9	5	8.6	1.0	prefer	low
Shallow Open Water with Islands or Polygonized Margins	16	8	13.8	1.6	prefer	low
River or Stream	1	1	1.7	1.2	ns	low
Sedge Marsh	1	1	1.7	1.7	ns	low
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	3	2	3.4	0.3	prefer	low
Young Basin Wetland Complex	2	1	1.7	0.3	ns	low
Old Basin Wetland Complex	17	10	17.2	8.1	ns	low
Riverine Complex	0	0	0	0.3	ns	low
Dune Complex	0	0	0	1.0	ns	low
Nonpatterned Wet Meadow	4	2	3.4	3.2	ns	low
Patterned Wet Meadow	18	8	13.8	11.0	ns	low
Moist Sedge-Shrub Meadow	0	0	0	21.4	avoid	
Moist Tussock Tundra	0	0	0	25.0	avoid	
Tall, Low, or Dwarf Shrub	0	0	0	3.0	ns	low
Barrens	0	0	0	1.1	ns	low
Human Modified	0	0	0	<0.1	ns	low
Total	109	58	100	100		
KING EIDER						
Open Nearshore Water	30	12	1.9	0.7	prefer	low
Brackish Water	81	37	5.7	1.3	prefer	
Tapped Lake with Low-water Connection	49	16	2.5	0.8	prefer	
Tapped Lake with High-water Connection	13	5	0.8	0.5	ns	low
Salt Marsh	89	39	6.0	2.5	prefer	
Tidal Flat Barrens	14	5	0.8	1.4	ns	
Salt-killed Tundra	6	4	0.6	0.8	ns	
Deep Open Water without Islands	197	68	10.5	6.5	prefer	
Deep Open Water with Islands or Polygonized Margins	149	58	9.0	5.1	prefer	
Shallow Open Water without Islands	97	50	7.8	1.0	prefer	
Shallow Open Water with Islands or Polygonized Margins	216	85	13.2	1.6	prefer	
River or Stream	125	48	7.4	1.2	prefer	
Sedge Marsh	51	24	3.7	1.7	prefer	
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	17	5	0.8	0.3	ns	low
Young Basin Wetland Complex	0	0	0	0.3	ns	low
Old Basin Wetland Complex	213	106	16.4	8.1	prefer	
Riverine Complex	9	4	0.6	0.3	ns	low
Dune Complex	0	0	0	1.0	avoid	
Nonpatterned Wet Meadow	34	20	3.1	3.2	ns	
Patterned Wet Meadow	85	44	6.8	11.0	avoid	
Moist Sedge-Shrub Meadow	19	9	1.4	21.4	avoid	
Moist Tussock Tundra	9	5	0.8	25.0	avoid	
Tall, Low, or Dwarf Shrub	1	1	0.2	3.0	avoid	
Barrens	0	0	0	1.1	avoid	
Human Modified	0	0	0	<0.1	ns	low
Total	1,504	645	100	100		

[a] Use = (groups / total groups) × 100
[b] 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
[c] Expected number < 5

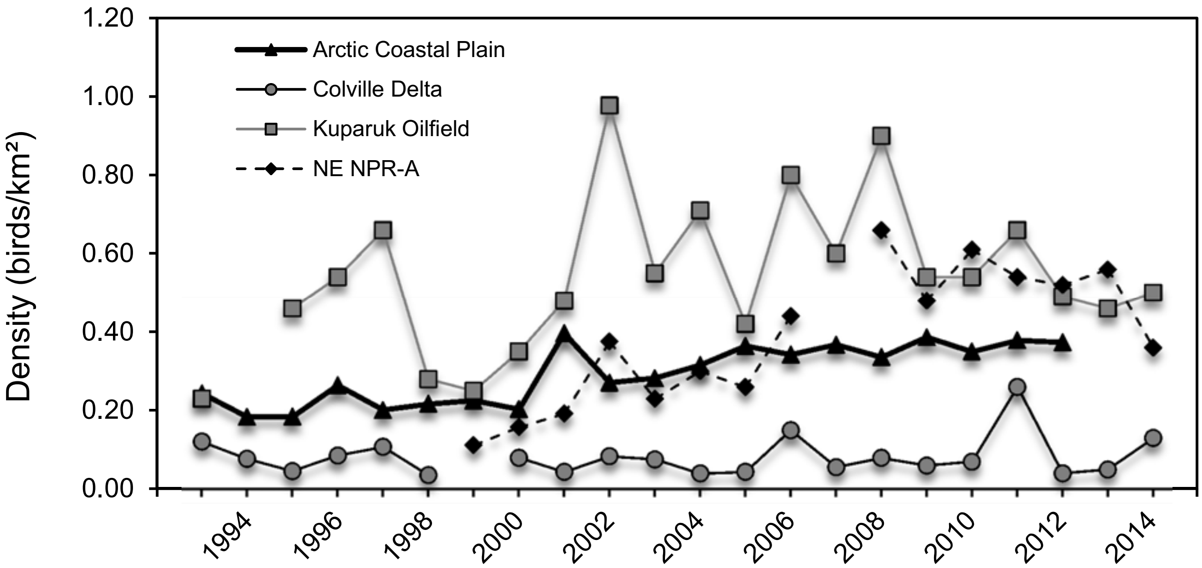


Figure 13. Annual densities of indicated total King Eiders during pre-nesting aerial surveys in 4 study areas on the Arctic Coastal Plain, Alaska, 1993–2014. Arctic Coastal Plain data from Stehn et al. 2013, Kuparuk data from Stickney et al. 2015, and Colville Delta and NE NPR-A data from this study.

Habitat Use

Steller's and Common eiders have not been numerous enough to evaluate habitat preferences on the Colville River delta. Pre-nesting King Eiders used 19 of 24 available habitats in the Colville Delta study area over 21 years of aerial surveys (Table 5). King Eiders preferred 4 of the same habitats preferred by pre-nesting Spectacled Eiders in the Colville Delta study area: Brackish Water, Salt Marsh, Salt-killed Tundra, and Deep Polygon Complex. King Eiders also preferred River or Stream, where the largest percentage (36%) of groups was found. The high use of River or Stream, which includes the river channels primarily in the NE Delta subarea (Figure 11), suggests that many King Eiders were moving through to breeding areas farther east, because River or Stream is not potential breeding habitat. In contrast, Spectacled Eiders, which occur in high numbers during pre-nesting and nest in relatively high concentrations on the outer Colville River delta (0.8–1.0 nests/km²; ABR, unpublished data) avoid River or Stream. Moreover, King Eiders nest at very low densities on the Colville River delta in the several locations where intensive nest searches have been conducted (Burgess et al. 2003a; Johnson et al. 2003a, 2008a; Seiser and Johnson 2010, 2011a, 2011b, 2012, 2013, 2014a, 2014b), affirming that most of the pre-nesting King Eiders seen on the delta are stopping over during migration.

NE NPR-A Study Area

Distribution and Abundance

King Eiders were abundant in the NE NPR-A study area in 2014, occurring at almost 3 times the density recorded in the Colville Delta study area (Tables 4 and 6). The indicated total number of King Eiders in the NE NPR-A study area was 120 birds, and density was 0.36 indicated birds/km², slightly below the long-term mean of 0.39 indicated birds/km² (n = 15 years). The highest density of King Eiders in 2014 was seen in the Alpine West subarea (0.8 indicated birds/km²; Figure 11, Appendix D). The highest mean densities of King Eiders occur in the eastern and northwestern portions of the NE NPR-A study area, where freshwater lakes are abundant (Figure 14). King Eiders were about 12 times more abundant than Spectacled Eiders in the NE NPR-A study area in 2014 (Table 8), which is typical for these species in this area. Unlike the Colville

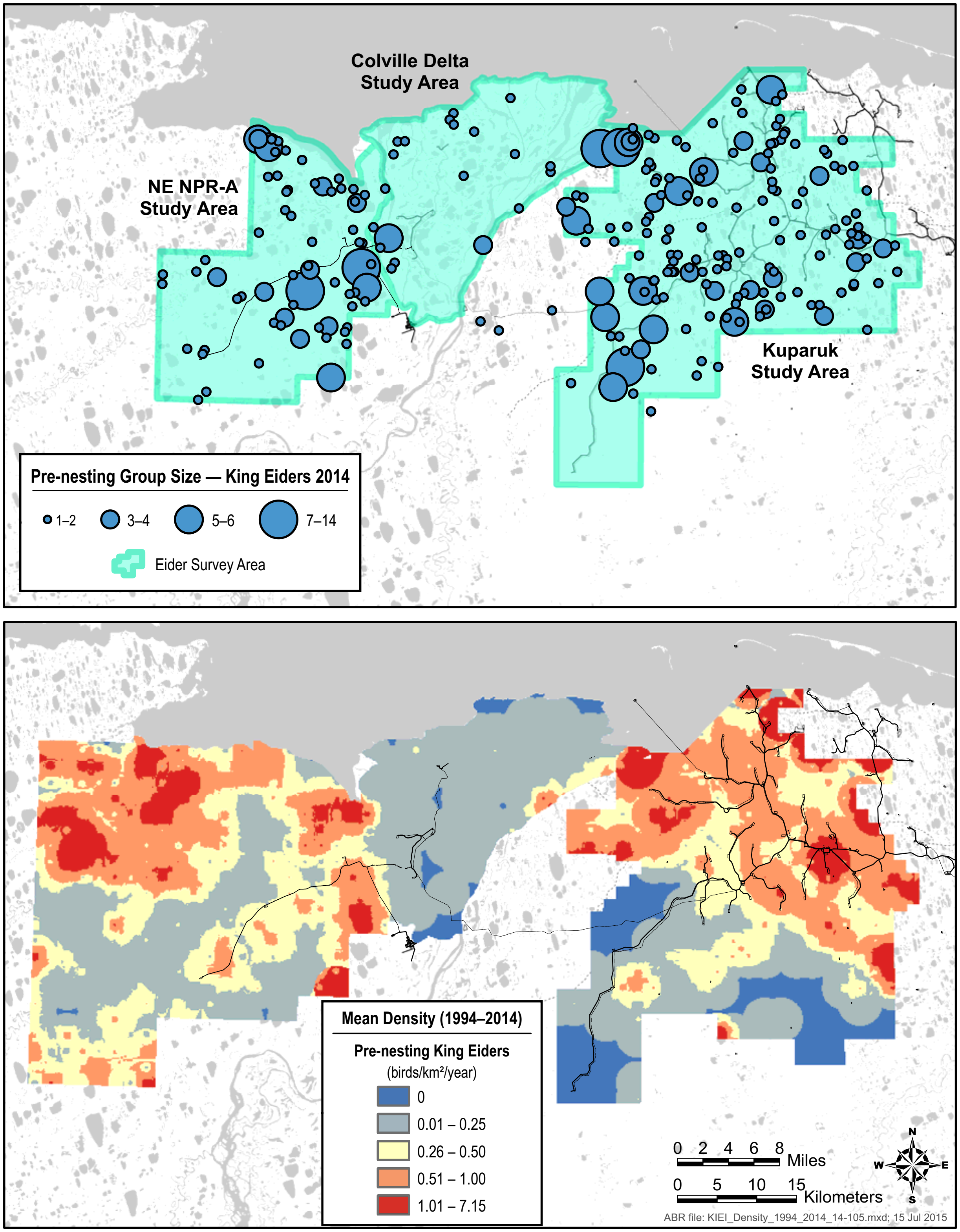


Figure 14. King Eider pre-nesting group locations in 2014 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE-NPRA study areas, 1994–2014 (bottom). Kuparuk data from Stickney et al. 2015.

Table 8. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, NE NPR-A study area, Alaska, 2014.

SPECIES Location	Observed Males	 Females	 Total	 Pairs	Indicated Total[a]	Observed Density[b]	Indicated Density[a, b]
SPECTACLED EIDER							
On ground	5	2	7	2	10	0.02	0.03
In flight	1	0	1	0	–	0.00	–
All birds	6	2	8	2	–	0.02	–
KING EIDER							
On ground	60	44	104	44	120	0.31	0.36
In flight	26	12	38	12	–	0.11	–
All birds	86	56	142	56	–	0.43	–

[a] Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a)
[b] Numbers not corrected for sightability. Density based on 50% coverage of the area; surveyed area = 332.7 km². Fish Creek West and the western portions of the Exploration and Development subareas were not surveyed in 2014

Delta study area, the NE NPR-A study area supports relatively high densities of nesting King Eiders (Anderson and Johnson 1999; Murphy and Stickney 2000; Burgess et al. 2002b, 2003b; Johnson et al. 2014a), and the distribution of pre-nesting birds is probably indicative of the distribution of nests.

Habitat Use

In the 13 years of pre-nesting surveys that were used to evaluate habitat selection, King Eiders used 21 of 26 available habitats and preferred 11 habitats in the NE NPR-A study area (Table 7). Old Basin Wetland Complex and both types of Deep and Shallow Open Water were the most frequently used habitats and also were preferred. The habitats preferred by King Eiders overlap with those preferred by Spectacled Eiders, but King Eiders have a broader array of preferences. The preferences for and high use of Open Nearshore Water, River or Stream, and Tapped Lake with Low-water Connection are likely from birds in transit or not yet settled into nesting habitat, because the fluctuating water levels of these waterbodies make their shorelines poor locations for nesting. Six habitats are significantly avoided, which include the 2 most available habitats in NE NPR-A study area, Moist Sedge-Shrub Meadow and Moist Tussock Tundra.

DISCUSSION

The annual number of pre-nesting Spectacled Eiders recorded in the Colville Delta study area has displayed dramatic swings over the past 2 decades, particularly in the CD North subarea, which is the core of their distribution on the delta (Figure 10, Appendix C). To simplify this discussion, all numbers and densities refer to indicated total birds. The CD North subarea contains the highest densities of Spectacled Eiders (0.21 birds/km², n = 21 years) of all the areas surveyed by ABR. The 2014 breeding season was the eighth year in a row of relatively high numbers of pre-nesting Spectacled Eiders in the Colville Delta study area. Our long-term records show 3 periods of high numbers: the early 1990s, the late 1990s, and the recent period of 2007–2014 (Figure 10). These fluctuations in abundance are unexplained, but the recent upswing in Spectacled Eiders is encouraging because numbers were quite low during 2003–2005. The population trend for Spectacled Eiders in the CD North subarea exhibits a slightly positive slope ($\ln(y) = 0.017x - 31.19$, $R^2 = 0.044$, $P = 0.36$, $n = 21$ years). That slope translates to a growth rate of 1.02 or 2% annually, which is not significantly different from equilibrium. The growth rate (1.01) for the larger Colville Delta study area is similar ($\ln(y) = 0.012x - 19.35$, $R^2 = 0.019$, $P = 0.55$, $n = 21$ years). A recent reanalysis combining 2 separate datasets of pre-nesting

Spectacled Eiders, the ACP breeding pair waterfowl survey conducted in late June with North Slope eider surveys conducted in early–mid June, estimated a slight decline in Spectacled Eiders for the entire ACP (growth rate = 0.99, *n* = 21 years; Stehn et al. 2013). However, none of the above growth rates has a slope significantly different from 1.0 (a growth rate of 1.0 equals 0% annual change or equilibrium).

The eastern portion of the NPR-A, where the present NE NPR-A study area is located, appears to be less important than the Colville Delta study area to breeding Spectacled Eiders (Figures 11 and 12). The density of Spectacled Eiders in the NE NPR-A study area has been consistently low (0.04 ± 0.006 [mean ± SE] indicated birds/km², *n* = 15 years). The mean density of Spectacled Eiders in the NE NPR-A study area was 39% of the mean density in the Colville Delta study area (*n* = 14 years) and 19% of the mean density in the CD North subarea. Although densities are low, the growth rate for Spectacled Eiders in the NE NPR-A study area is slightly positive (1.05) but still not significantly different from 1.0 or equilibrium ($\ln(y) = 0.047x - 90.803$, $R^2 = 0.053$, $P = 0.448$, $n = 13$ years). Spectacled Eider densities are similarly low east of the Colville River in the Kuparuk Oilfield (0.06 ± 0.005 indicated birds/km², *n* = 21 years), but there the long-term trend displays a significant decline (growth rate = 0.94) (Stickney et al. 2015). On a broader scale, regional maps of Spectacled Eider densities also indicate that the NE NPR-A study area and Kuparuk Oilfield are not significant concentration areas for Spectacled Eiders on the ACP (see Figure 17 in Larned et al. 2006 and Figure 19 in Larned et al. 2011). Although the geographic variation in Spectacled Eider growth rates presented above does not provide strong evidence of an overall decline or increase in the population, it may suggest possible shifts in distribution, with weakening numbers occurring east of the Colville River.

Unlike Spectacled Eiders, King Eiders are clearly increasing on their breeding grounds. On breeding pair surveys of the ACP, the growth rate for King Eiders was 1.047, which is significantly different from 1.0 (*n* = 27 years; Stehn et al. 2013.). Similarly, ABR surveys have recorded a positive growth rate (1.064) for King Eiders in the NE NPR-A study area ($\ln(y) = 0.064x - 122.77$, $R^2 = 0.496$, $P = 0.007$, $n = 13$ years) and in the Kuparuk Oilfield (1.024; Stickney et al. 2015). However, in the Colville Delta study area, where King Eiders have a small breeding presence, the growth rate is minimal (1.006) and not significantly different from 1.0 ($\ln(y) = 0.006x - 7.681$, $R^2 = 0.005$, $P = 0.754$, $n = 21$ years). The relative abundance of King Eiders in the NE NPR-A and Colville Delta study areas is the inverse of that observed for Spectacled Eiders. The NE NPR-A study area supports high densities of King Eiders (0.39 ± 0.05 indicated birds/km², *n* = 15 years), in contrast to low densities in the Colville Delta study area (0.08 ± 0.01 indicated birds/km², *n* = 21 years). Breeding Spectacled Eiders appear to prefer the aquatic and halophytic habitats that are relatively abundant on the Colville River delta, whereas King Eiders use a broader range of habitats and nest farther from waterbodies (Anderson and Cooper 1994). Although there is extensive overlap in habitat use by these 2 species, breeding season concentration areas for each species appear to be separated at the regional scale, with Spectacled Eiders most prevalent in the coastal regions of the ACP west of Harrison Bay and King Eiders most prevalent in more inland areas south of Teshekpuk Lake and to the east (see Figures 17 and 19 in Larned et al. 2006 and Figures 19 and 21 in Larned et al. 2011). The exception to this generalized distribution pattern of the 2 species is the Colville River delta, where Spectacled Eiders outnumber King Eiders.

LOONS

YELLOW-BILLED LOON

Colville Delta Study Area

Distribution and Abundance

The Colville River breakup occurred slowly in 2014, with rapid melting in mid-May being slowed by below freezing temperatures in late May. As a result, 2 peak flow events occurred on 18 May and 1 June. Localized flooding from the Colville River occurred in some areas during the second peak flow event (see *Time-Lapse Cameras*, below); however, widespread flooding was not observed in 2014 (Michael Baker Jr. 2014). We deployed time-lapse cameras during late May at 10 loon territories to document nest initiation (see

Time-Lapse Cameras, below). Camera images documented 1 nest that was initiated after the nesting survey and that failed prior to the first monitoring survey in the CD North subarea. No nests were found during the 11 June survey, although ≥1 Yellow-billed Loon was seen at 34 of the 43 territories (79%) surveyed. During the nesting survey on 19–22 June, we counted 78 Yellow-billed Loons and 26 nests (Figure 15, Table 9). Five more nests were found during weekly monitoring surveys. Of the 32 nests found in the Colville Delta study area in 2014, 15 nests were located in the CD North subarea, 16 nests in the CD South subarea, and 1 nest in the Northeast Delta subarea (Appendix E). The total number of nests found in 2014 (32 nests) was the third highest number found in 20 years of surveys in the Colville Delta study area. The count of 78 adults on the nesting survey was higher than the long-term mean (56.5 ± 2.6 [mean ± SE] adults) and the highest in 20 years of surveys (Table 9; for densities see Appendix F). The counts of adults and nests show that most territories were occupied by adults in 2014 and above average numbers attempted to nest (Figure 16, Table 9). The distribution of adults and nests in the Colville Delta study area was not uniform. The density of adult loons and nests in 2014 was higher in the CD South (0.24 birds/km²; 0.10 nests/km²) than the CD North (0.18 birds/km²; 0.07 nests/km²) subareas (Appendix E).

All but 1 of the 32 Yellow-billed Loon nests recorded in the Colville Delta study area in 2014 were on lakes where Yellow-billed Loons have nested previously (Figure 15; Johnson et al. 2009, 2010, 2011, 2012, 2013a, 2014a). One pair nested on a new lake. That lake was a small pond (<1 ha) at the polygonized margin of a lake previously used for nesting and brood rearing. Eighteen of the 32 nests were located at the same nest sites used in previous years, 11 were very close to nest sites used in previous years, and 2 were at new nest sites on lakes previously used for nesting.

Since the nesting survey was initiated in 1993, the number of nests recorded in the Colville Delta study area annually ranged from 10 nests in 1997 to 33 nests in 2008 (n = 20 years; Table 9). In most years, an additional 1–12 nests were found during ground, revisit, and/or monitoring surveys, and in some years inferred from the presence of a brood found during the brood-rearing survey on a nest lake where no nest was found during previous surveys. With the addition of these nests, the counts of nests ranged from 16 in 1993 and 2000 to 38 in 2008. These counts of nests are not directly comparable because survey coverage varied annually from 35 to 43 territories. To adjust for variable coverage, we used territory occupancy by nests, calculated as the number of nests found divided by the number of territories surveyed, to compare annual occupation by nests. Based on counts of all nests found, 74% of the territories surveyed in 2014 were occupied by nests, which was the fourth highest occupancy rate in 20 years of surveys (Table 9).

During the brood-rearing survey on 18–19 August 2014, 48 Yellow-billed Loons, 4 broods, and 4 young were recorded in the Colville Delta study area (Figure 15, Table 10). We inferred 1 additional brood based on eggshell fragments at the nest. Three more broods were seen during monitoring surveys but did not survive until the brood-rearing survey in mid-August. In total, 8 broods were recorded in the Colville Delta study area: 2 broods were found in the CD North subarea and 6 broods were found in the CD South subarea (Appendix E). The count of 48 adults recorded during the brood-rearing survey was only slightly lower than the 20-year mean (50.1 ± 2.8 adults), but the number of broods detected (4) was among the lowest observed (mean = 10.5 ± 1.1 broods, n = 20 years; Table 10; for densities see Appendix F). During the 20 years of brood-rearing surveys in the Colville Delta study area, the lowest number of broods recorded was 2 broods in 2000 and the highest was 22 broods in 2008 (Table 10). In most years, an additional 1–6 broods were found during ground and/or monitoring surveys, or were determined by eggshell fragments at the nest indicating that hatching occurred (see *Nest Monitoring and Nest Fate* below). With the addition of these broods, the range of brood counts was 3–27. Like nest counts, these raw counts of broods are not directly comparable because survey coverage varied annually from 34 to 43 territories (Table 10). We calculated territory occupancy by broods (the number of all broods seen divided by the number of territories surveyed) to standardize for survey effort. In 2014, brood occupancy (19%) was only about half the long-term mean (31.1 ± 3.3%); the only years with lower occupancy were

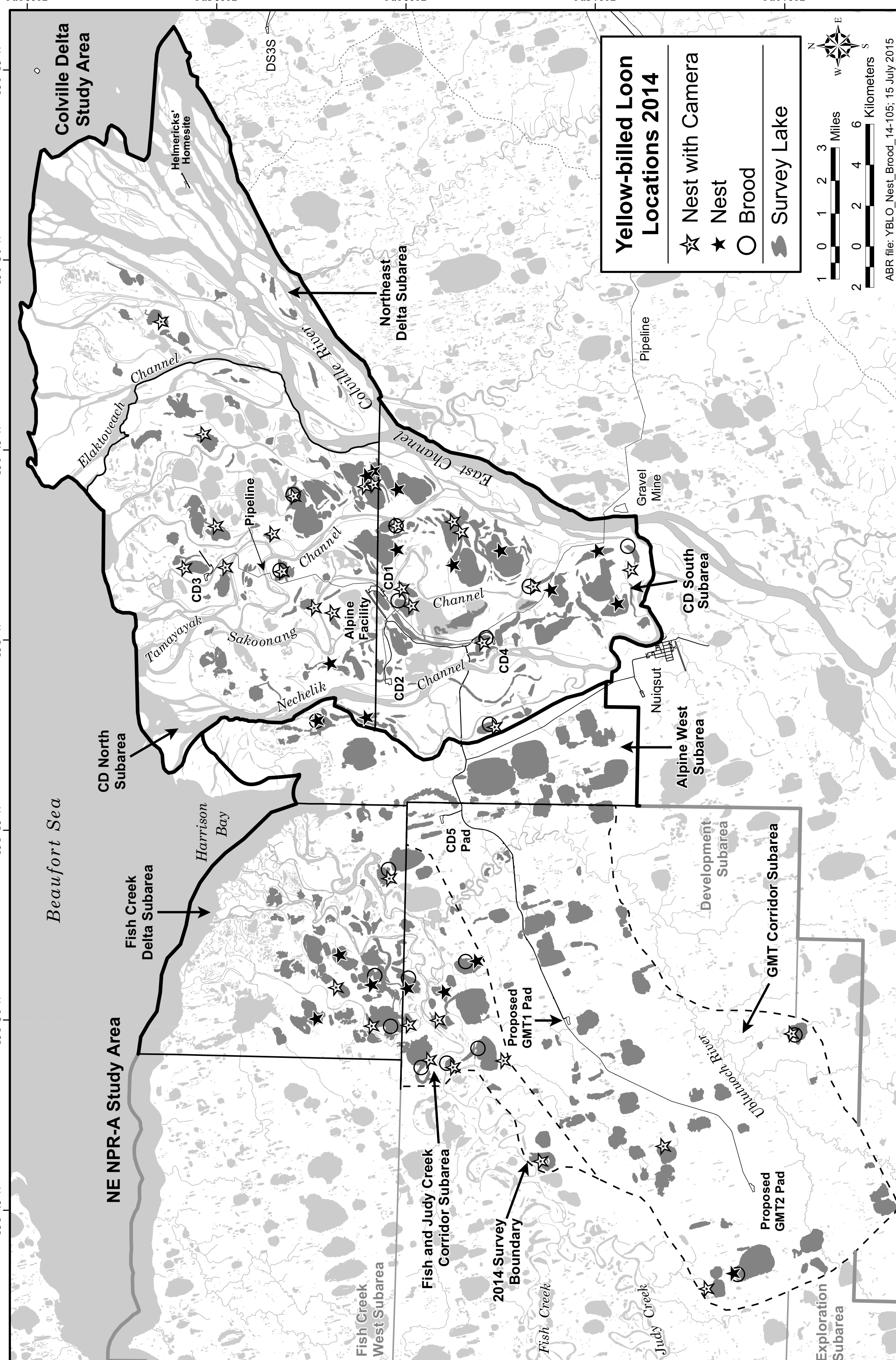


Figure 15. Yellow-billed Loon nests and broods, Colville Delta and NE NPR-A study areas, Alaska, 2014.

Table 9. Number of Yellow-billed Loons, nests, and territory occupancy by nests, Colville Delta (1992–2014) and NE NPR-A (2001–2014) study areas, Alaska.

STUDY AREA	Nesting Survey[a]		All Surveys[b]		Nest
Year	No. Adults	No. Nests	No. Nests	No. Territories Surveyed	Occupancy (%)[c]
COLVILLE DELTA[d]					
1993	50	11	16[e,f]	41	39
1995	42	12	21[e,f]	39	54
1996	45	11	20[e,f,g]	35	57
1997	48	10	18[e,g]	38	47
1998	35	17	24[e,f,g]	41	59
2000	53	16	16	37	43
2001	54	19	20[e]	37	54
2002	46	17	22[e,f,g]	41	54
2003	53	25	27[f]	41	66
2004	41	24	26[f]	41	63
2005	57	30	31[f]	40	78
2006	63	24	28[g]	41	68
2007	66	27	30[g]	41	73
2008	69	33	38[g]	42	90
2009	67	27	30[g]	43	70
2010	69	23	35[g]	43	81
2011	70	23	28[g]	43	65
2012	57	25	30[g]	43	70
2013	67	12	17[f,g,h]	43	40
2014	78	26	32[g,h]	43	74
Mean	56.5	20.6	25.5	40.7	62.3
SE	2.6	1.6	1.5	0.5	3.1
NE NPR-A					
2001	44	19	23[e]	36	64
2002	65	27	27	42	64
2003	53	26	28[e, f]	41	66
2004	60	23	24[e]	40	58
2005	24	8	8	13	62
2006	24	8	8	13	62
2008	82	23	29[g]	51	57
2009	65	27	29[g]	51	57
2010	75	29	36[g]	51	71
2011	32	8	13[g]	21	62
2012	36	15	18[g]	21	86
2013	39	12	14[g]	21	67
2014	47	18	20[g]	26	77
Mean[i]	-	-	-		66.2
SE	-	-	-	-	2.2

[a] Nesting survey is limited to survey conducted between 19 and 30 June
[b] Observation effort may have varied between years. Includes all nests found on loon aerial surveys, ground surveys, camera images or inferred by brood observations. Observation methods other than nesting survey are footnoted
[c] Calculated as the number of nests from all surveys divided by the number of territories surveyed. Excludes 1 renesting in 2007 and 2011 and 2 renestings in 2012 in the Colville Delta study area. Excludes 1 renesting in 2003 in the NE NPR-A study area
[d] Survey area included CD North, CD South, and Northeast Delta subareas for all years except 2000, when only CD North and CD South were surveyed
[e] Includes nest(s) found during ground surveys
[f] Includes nest(s) inferred by the presence of a brood observed on a territory lake during ground or aerial surveys
[g] Includes nest(s) found during revisit (1996–2002), monitoring (2006–2014), and early nesting (2011) surveys
[h] Includes nest(s) documented on camera images only
[i] Mean numbers not calculated because survey area differed among years

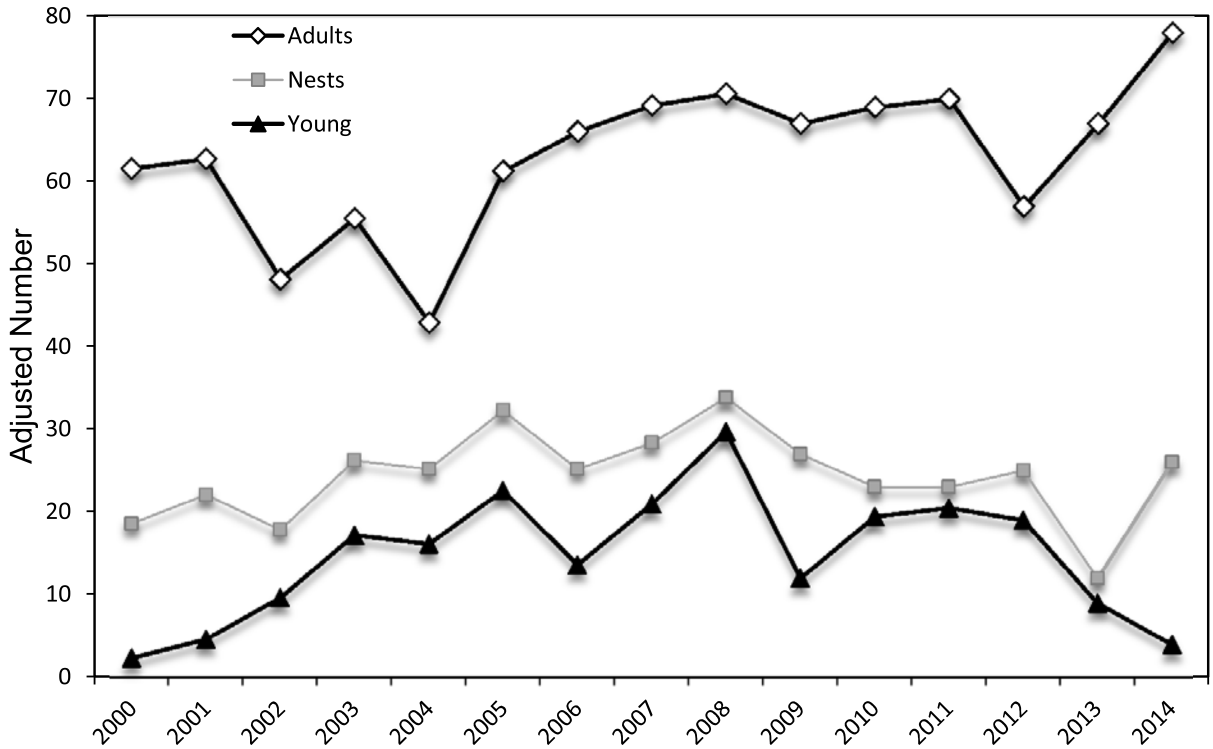


Figure 16. Annual numbers of Yellow-billed Loon adults and nests during the nesting survey and young during the brood-rearing survey, Colville Delta study area, 2000–2014. Adjusted numbers were standardized for the number of territories surveyed each year (number observed/number of territories surveyed × 43 territories [maximum number of territories surveyed]).

in 1997 and years when the Colville River flooded substantial portions of the delta—2000, 2001, and 2013.

Habitat Use

Yellow-billed Loons nested in 11 of 24 available habitats during 20 years of nesting aerial surveys in the Colville Delta study area (Table 11). Six habitats, supporting 395 of 457 total nests, were preferred for nesting (Deep Open Water with Islands or Polygonized Margins, Deep Open Water without Islands, Sedge Marsh, Grass Marsh, Nonpatterned Wet Meadow, and Patterned Wet Meadow). Within these habitats, nests were built on peninsulas, shorelines, islands, or in emergent vegetation. All nests were on shorelines of lakes, but only nests on islands or in emergent vegetation were assigned to the aquatic habitat of the lake; otherwise nests were assigned to the terrestrial habitat on the lakeshore. Patterned Wet Meadow was the habitat used most frequently for nesting (35% of all nests), and it also was the most abundant habitat on the delta (25% of the loon survey area; Table 11). Nesting Yellow-billed Loons avoided 11 habitats, which together occupied 50% of the Colville Delta study area.

Yellow-billed loons were highly selective in their use of brood-rearing habitat. All Yellow-billed Loon broods (209 broods over 20 years) were found in 4 lake habitats, 3 of which were preferred: Tapped Lake with High-water Connection, Deep Open Water without Islands, and Deep Open Water with Islands or Polygonized Margins (Table 11). The preferred habitats occupied only 13% of the delta. No shallow-water habitats were used during brood-rearing. The selection analyses for nesting and brood-rearing reaffirm the importance of large, deep waterbodies to breeding Yellow-billed Loons.

Table 10. Number of Yellow-billed Loons, broods, and territory occupancy by broods, Colville Delta (1993–2014) and NE NPR-A (2001–2014) study areas, Alaska.

	Brood-rearing Survey[a]			All Surveys[b]		
STUDY AREA Year	No. Adults	No. Young	No. Broods	No. Broods	No. Territories Surveyed	Brood Occupancy (%)[c]
COLVILLE DELTA[d]						
1993	29	7	7	10[e]	34	29
1995	51	13	10	13[e]	42	31
1996	62	6	6	9[e]	36	25
1997	66	8	5	5	38	13
1998	55	15	12	12	41	29
2000	21	2	2	3[f]	36	8
2001	33	4	4	4	37	11
2002	66	9	8	9[e]	40	23
2003	47	16	14	14	40	35
2004	54	15	12	12	40	30
2005	39	21	17	21[f,g]	40	53
2006	66	13	13	16[f]	41	39
2007	53	20	17	23[f,g]	41	56
2008	57	29	22	27[f,g]	42	64
2009	56	12	11	13[g]	43	30
2010	59	19	13	15[f,g,h]	42	36
2011	45	20	12	15[f,g,h]	42	36
2012	52	19	14	17[g,h]	43	40
2013	43	9	7	7	43	16
2014	48	4	4	8[f,g]	43	19
Mean	50.1	13.1	10.5	12.7		31.1
SE	2.8	1.6	1.1	1.4		3.3
NE NPR-A						
2001	47	5	5	7[e]	32	22
2002	47	7	6	6	39	15
2003	54	18	16	16	37	43
2004	67	12	10	10	40	25
2005	12	3	3	3	13	23
2006	16	2	2	2	12	17
2008	70	15	12	19[f,g]	50	38
2009	86	17	12	15[g]	51	29
2010	70	18	15	16[g]	49	33
2011	31	5	4	4	21	19
2012	42	14	12	12	21	57
2013	21	0	0	1[f]	21	5
2014	29	9	9	11[g]	26	35
Mean[i]						27.8
SE						3.8

[a] Brood-rearing surveys were conducted sometime between 15 and 27 August
[b] Includes all broods found on brood-rearing survey and any additional broods found during other types of surveys as footnoted
[c] Calculated as the number of broods from all surveys divided by the number of territories surveyed
[d] Survey area included CD North, CD South, and Northeast Delta subareas for all years except 2000, when only CD North and CD South were surveyed
[e] Includes brood(s) found during ground surveys
[f] Includes brood(s) found during monitoring surveys
[g] Includes broods from territories where no brood was seen but presence of a brood was determined from eggshell evidence
[h] Includes broods from territories where broods were seen on camera images
[i] Mean numbers not calculated because survey area differed among years

Table 11. Habitat selection by nesting (1993–1998 and 2000–2014) and brood-rearing (1995–1998 and 2000–2014) Yellow-billed Loons, Colville Delta study area, Alaska.

SEASON Habitat	No. of Nests or Broods	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
NESTING					
Open Nearshore Water	0	0	2.0	avoid	
Brackish Water	0	0	1.1	avoid	
Tapped Lake with Low-water Connection	0	0	5.4	avoid	
Tapped Lake with High-water Connection	31	6.8	5.3	ns	
Salt Marsh	0	0	2.6	avoid	
Tidal Flat Barrens	0	0	3.5	avoid	
Salt-killed Tundra	0	0	4.2	avoid	
Deep Open Water without Islands	44	9.6	4.8	prefer	
Deep Open Water with Islands or Polygonized Margins	123	26.9	2.5	prefer	
Shallow Open Water without Islands	0	0	0.3	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	0.4	0.1	ns	low
River or Stream	0	0	8.8	avoid	
Sedge Marsh	5	1.1	<0.1	prefer	low
Deep Polygon Complex	20	4.4	2.9	ns	
Grass Marsh	9	2.0	0.3	prefer	low
Young Basin Wetland Complex	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	53	11.6	8.7	prefer	
Patterned Wet Meadow	161	35.2	24.5	prefer	
Moist Sedge-Shrub Meadow	6	1.3	3.2	avoid	
Moist Tussock Tundra	0	0	0.9	avoid	low
Tall, Low, or Dwarf Shrub	3	0.7	6.5	avoid	
Barrens	0	0	12.1	avoid	
Human Modified	0	0	0.1	ns	low
Total	457	100	100		
BROOD-REARING					
Open Nearshore Water	0	0	2.0	avoid	low
Brackish Water	1	0.5	1.1	ns	low
Tapped Lake with Low-water Connection	0	0	5.4	avoid	
Tapped Lake with High-water Connection	44	21.1	5.3	prefer	
Salt Marsh	0	0	2.6	avoid	
Tidal Flat Barrens	0	0	3.5	avoid	
Salt-killed Tundra	0	0	4.2	avoid	
Deep Open Water without Islands	95	45.5	4.8	prefer	
Deep Open Water with Islands or Polygonized Margins	69	33.0	2.5	prefer	
Shallow Open Water without Islands	0	0	0.3	ns	low
Shallow Open Water with Islands or Polygonized Margins	0	0	0.1	ns	low
River or Stream	0	0	8.8	avoid	
Sedge Marsh	0	0	<0.1	ns	low
Deep Polygon Complex	0	0	2.9	avoid	
Grass Marsh	0	0	0.3	ns	low
Young Basin Wetland Complex	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	0	0	8.7	avoid	
Patterned Wet Meadow	0	0	24.5	avoid	
Moist Sedge-Shrub Meadow	0	0	3.2	avoid	
Moist Tussock Tundra	0	0	0.9	ns	low
Tall, Low, or Dwarf Shrub	0	0	6.5	avoid	
Barrens	0	0	12.1	avoid	
Human Modified	0	0	0.1	ns	low
Total	209	100	100		

[a] % use = (nests / total nests) × 100 or (broods / total broods) × 100

[b] 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

[c] Expected number < 5

Nest Monitoring and Nest Fate

We recorded 31 Yellow-billed Loon nests during the nesting, monitoring, and brood-rearing surveys in the Colville Delta study area in 2014; 1 more nest, known only from cameras set up before surveys began, was not included in the summaries for consistency with previous years data collection (Tables 12 and 13). The number of nests found was slightly above the 10-year mean (29.6 ± 2.0 nests; Table 13). Only 3 years had a higher number of nests. Apparent nesting success, however, was the lowest observed since monitoring surveys began in 2005. Only 8 nests hatched, resulting in a record-low apparent nesting success of 26%, which was less than half the 10-year mean (54.2 ± 4.7%; Table 13). The additional nest seen only on camera images survived <3 d and failed prior to nesting aerial surveys. Inclusion of this nest in the total lowers apparent nesting success to 25%.

The majority of successful nests in the Colville Delta study area in 2014 hatched in mid-July: 6 (75%) hatched by 16 July and the remaining 2 hatched between 16 July and 23 July (Tables 12 and 14). Broods were observed at all but 1 hatched nest. At that nest, hatching was confirmed by eggshell fragments and a chick was seen on camera images. The chick survived <4 d. Camera images did not document any second chicks at nests where only 1 chick was seen on aerial surveys.

Twenty-three of 31 Yellow-billed Loon nests recorded during aerial surveys failed to hatch (Table 12). The nest seen only on camera images also failed. Of the 23 failed nests recorded on aerial surveys, almost half (47%) failed within the week following the nesting survey; 6 (26%) additional nests failed by 2 July and 5 more by 9 July. The remaining nest failed by 16 July. We did not detect any second nesting attempts by loons after nest failure in 2014, but we may have missed renesting attempts at camera-monitored nests (n = 21 nests), which were not included in weekly surveys until 9 or 16 July.

The contents of 32 Yellow-billed Loon nests were examined after nests were no longer active. Seven nests were classified as successful based on the presence of a brood and 1 nest was classified as successful based only on eggshell fragments in the nest. Successful nests contained >20 eggshell fragments (range = 42–100 fragments). Of ~500 eggshell fragments found within 5 m of successful nests, 66% were ≤10 mm in length. Four successful nests also contained pieces of membrane that were either separate or loosely attached to fragments. The majority of egg membranes and eggshell fragments were found in nest bowls; <40 fragments were found in the water or on shore adjacent to successful nests. Twenty-four nests were judged failed by the absence of a brood and absence of eggshell fragments, or by the presence of <20 eggshell fragments. Of 24 failed nests, 16 did not contain any egg remains within 5 m of the nest, 5 contained 2–8 egg fragments, and 3 nests had a broken egg next to the nest.

Time-lapse Cameras

In 2014, we deployed 10 cameras in late May at traditional nest sites in an attempt to document pre-nesting behavior and the start of incubation. Five of the territories were flooded by the Colville River causing 1 camera to malfunction after it was knocked over by ice (Table 15). Small ice jams occurred in the Sakoonang, Tamayayak, and Nigliagvik channels (Michael Baker Jr. 2014). Those jams likely contributed to localized flooding from the Colville River, which was observed on camera images from 3 loon territories. The Colville River also spilled its banks near Colville Village, inundating 2 loon territories surveyed in the Northeast Delta subarea. Widespread flooding, however, was not observed in 2014 (Michael Baker Jr. 2014). The median date of river flooding among territories observed on cameras was 30 May (range = 30 May–2 June, n = 5 territories). Nest sites flooded by the river were submerged for 6–10 d (median = 8 d, n = 3 territories). Five of 10 camera-monitored territories were not flooded by the Colville River. Instead, a moat of open water formed around the shores of those lakes. The median date of moat formation was 3 June (n = 5 territories). Nest sites were not submerged at 3 of those lakes and were accessible as soon as the loons appeared at those territories. At 1 territory, however, local runoff submerged the nest site for 8 d, a duration similar to those at sites flooded by the river. Regardless of the flood source, loons generally were seen in camera view on lakes within 4 d of when water began to appear (replacing ice) on lakes (n = 9 territories).

Table 12. Weekly status and fate of Yellow-billed Loon nests monitored by aerial surveys, Colville Delta study area, Alaska, 2014. Status (A = active, I = inactive) determined from camera-monitored nests is presented in parentheses where it differed from status determined from aerial surveys.

Territory	June			July				Fate/Total
	11	19–21	25–26[a]	2[a]	9[a]	16	23	
1[b]	I	A	I	–	–	–	–	Failed
4[b]	I	I	A	I	–	–	–	Failed
6[b]	I	A	I	–	–	–	–	Failed
8[b]	I	A	I	–	–	–	–	Failed
11[b]	I	A	A	A (I)[c]	I	–	–	Failed
12[b]	I	A	A	A	A	I	–	Hatched
13[b]	I	A	A	A	I	–	–	Failed
14[b]	I	A	I	–	–	–	–	Failed
15[b]	I	A	A	A	A	I	–	Hatched
16[b]	I	I	A	A	I	–	–	Failed
17[b]	I	A	A	A	A	I	–	Hatched
18[b]	I	A	A[d]	A[d]	A[d]	A	I	Hatched
19	I	A	A	A	A	I	–	Failed
20	I	A	A	I	–	–	–	Failed
21	I	A	I	–	–	–	–	Failed
22	I	A	A	I	–	–	–	Failed
23[b]	I	A	A	A	I	–	–	Failed
24	I	A	I	–	–	–	–	Failed
25[b]	I	A	A	A	I	–	–	Failed
26[b]	I	A	A	A	A	I	–	Hatched
27	I	A	I	–	–	–	–	Failed
30	I	A	I	–	–	–	–	Failed
31	I	A	I	–	–	–	–	Failed
32[b]	I	I	A	I	–	–	–	Failed
33	I	A	I	–	–	–	–	Failed
34[b]	I	I (A)[e]	–(I)	–	–	–	–	Failed
39[b]	I	A	A	A	A	I	–	Hatched
42	I	I	A	I	–	–	–	Failed
43[b]	I	A	A	A[d]	A[d]	A	I	Hatched
45[b]	I	A	A	A	A	I	–	Hatched
46	–	A	I	–	–	–	–	Failed
47[b]	I	I	A (I)[c]	I	–	–	–	Failed
No. Active	0	26 (27)	20	14 (13)	9	2	0	31 (32)
No. Hatched	0	0	0	0	0	6	2	8
No. Failed	0	0	11 (12)	6 (7)	5	1	0	23 (24)

[a] Camera-monitored nests not surveyed by helicopter; nest status determined from camera images
[b] Nest monitored by camera
[c] Camera images showed nest failure occurred after 14:00 on the day of the survey
[d] No images collected by camera due to operator error; nest assumed active based on survey history
[e] Camera images show the pair began incubation on 21 June after the territory was surveyed and failed 23 June, so the nest was not detected during aerial surveys

Table 13. Number of nests, apparent nesting success, and number of chicks of Yellow-billed Loons observed during aerial monitoring surveys or determined from nest fate visits, Colville Delta (2005–2014) and NE NPR-A (2008–2014) study areas, Alaska.

STUDY AREA Year	No. Territories Surveyed	No. Nests	Nesting Success (%)	At Hatch No. Chicks	At Hatch Chicks/Nest	Mid-September No. Chicks	Mid-September Chicks/Nest
COLVILLE DELTA							
2005	40	31	68	29	0.94	–	–
2006	41	28	57	22	0.79	–	–
2007	42	31	74	36	1.16	–	–
2008	42	38	71	43	1.13	24[a]	0.63
2009	43	30	43	14	0.47	11	0.37
2010	42	35	43	22	0.63	17	0.49
2011	42	25[b]	60	24	0.96	19	0.76
2012	43	32	53	25	0.78	17	0.53
2013	43	15[c]	47	9[d]	0.60	8	0.53
2014	43	31[c]	26	10	0.32	4	0.13
Mean		29.6	54.2	23.4	0.78	14.3	0.49
SE		2.0	4.7	3.4	0.09	2.6	0.08
NE NPR-A							
2008	51	29	66	27	0.93	–	–
2009	51	29	52	24	0.83	15	0.52
2010	51	36	44	22	0.61	17	0.47
2011	21	12[e]	33	6	0.50	5	0.42
2012	21	18	67	14	0.78	14	0.78
2013	21	14	7	2	0.14	0	0
2014	26	20	55	13	0.65	7[f]	0.37[f]
Mean		–[g]	46.3	–[g]	0.63	–[g]	0.43
SE		–	7.9	–	0.10	–	0.10

[a] Data are from 8 September because survey conditions were poor on 16 September
[b] Total does not include 4 nests that were only seen prior to the nesting survey
[c] Total does not include 2 nests in 2013 and 1 nest in 2014 that were only seen on camera images
[d] Assumes 1 chick at a nest that was not found but inferred from a brood discovered during the brood-rearing survey on 21 August
[e] Total does not include 1 nest that was only seen prior to the nesting survey
[f] Data are from 10 September because survey conditions were poor on 19 September and because some chicks likely were fledged by the last survey on 24 September; excludes 1 chick and 1 nest because it was unknown if the chick survived to 10 September
[g] Means not calculated because the study area differed among years

Table 14. Number of Yellow-billed Loon chicks observed during weekly aerial surveys, Colville Delta study area, Alaska, 2014. Age of chicks determined by camera-monitoring presented in parentheses where it differed from age determined from aerial surveys.

	July			August				September				No.	Age (d)	
Territory	16	23	30	6	13	20	27	3	10	19	24	Chicks Hatched	When Last Seen	Brood Fate
12[a]	1	1	1	1	1	1	1	1[b]	1	1	1	1	74 (71)	Active
15[a]	1	1	1	1	1	1	1[b]	1[b]	1	1	1	1	74 (73)	Active
17[a]	2	1	1	1	0	0	–	–	–	–	–	2	29 (26)	Failed
18[a,c]	Inc[d]	1	1	1	1	1	1	1	1	1	1	1	67	Active
26[a]	0[e]	0	–	–	–	–	–	–	–	–	–	1[e]	4	Failed
39[a]	1	0	0	–	–	–	–	–	–	–	–	1	8	Failed
43[a,c]	Inc[d]	1	1	1	1	1	1[b]	1	1	1[b]	1	1	67	Active
45[a]	2	2	1	1	1	0	0	–	–	–	–	2	36 (31)	Failed
Totals														
Broods of 2	2	1	0	0	0	0	0	0	0	0	0	2	–	–
Broods of 1	3	5	6	6	5	4	4	4	4	4	4	6	–	–
Chick Loss	1	2	1	0	1	1	0	0	0	0	0	–	–	–

[a] Nest monitored by camera
[b] No chick observed; chick assumed present based on subsequent aerial surveys
[c] Camera malfunctioned due to operator error and no images were collected
[d] Inc = loon incubating at the time of the survey
[e] No chick observed; at least 1 egg hatched based on eggshell evidence at the nest; assumed 1 chick died

Table 15. Nesting chronology and observations of Yellow-billed Loons at territories monitored by time-lapse cameras deployed in late May, Colville Delta study area, Alaska, 2014.

FLOOD SOURCE Territory	Dates Monitored	Nesting Observed on Camera	Date Water Appeared on Lake	Date Loons First Seen	Date Nest Site Appeared Accessible[b]	Incubation Start Date
COLVILLE RIVER						
1	26 May–23 June	Yes	30 May	3 June	5 June	16 June
2	26 May–3 June[c]	No	30 May	–	–	–
6	26 May–23 June	Yes	30 May	3 June	7 June	15 June
45	28 May–24 June	Yes	1 June	6 June	11 June	16 June
46	27 May–19 June	No[d]	2 June	6 June	–	–
Median			30 May	4 June	7 June	16 June
LOCAL RUNOFF						
8	27 May–23 June	Yes	7 June	8 June	7 June	15 June
13	27 May–23 June	Yes	3 June	7 June	6 June	19 June
18	28 May–24 June	No[d]	3 June	6 June	–	–
26	27 May–25 June	Yes	3 June	4 June	4 June	16 June
34	27 May–23 June	Yes	3 June	8 June	16 June	20 June
Median			3 June	7 June	6 June	16 June

[a] Lakes were determined to have flooded by the river if shorelines and surrounding tundra were completely underwater and the lake was turbid, whereas lakes flooded by local runoff contained moats and were clear
[b] Qualitative assessment based on whether or not the site was above water and contained a moat so loons could access the site
[c] Camera knocked over by ice
[d] Nest was found at the territory but was not in camera view

The start of incubation was documented by 7 cameras deployed in May (Table 15). The median start date of incubation was 16 June (range = 15–20 June), which was an average of 9 d after nest sites appeared accessible (range = 4–13 d). We also viewed egg laying on images at 5 nests. During laying, females tipped forward for ~10 frames (~5 min) so that their tails appeared raised while feet and chests supported their bodies. The median laying interval between the 2 eggs was 2.4 d (n = 5 nests, range = 2.4–2.5 d). Only 2 of the 7 nests with known start dates hatched. At 1 nest, a chick was seen on day 27 of incubation whereas a chick was seen on day 28 at the other nest. In 2013, 1 nest had a pipped egg on day 29 of incubation. Our data suggest a 26–28 d incubation period, which agrees closely with the 27–28 d incubation period reported by North (1994).

After the nesting survey in the Colville Delta study area in 2014, we replaced 4 of the previously deployed time-lapse cameras and set up an additional 14 cameras at Yellow-billed Loon nests. Three of the 7 nests monitored by cameras setup in May had already failed by the time cameras were deployed in late June. In total, we monitored 21 of 32 nests in the Colville Delta study area with time-lapse cameras (Table 16). Cameras with 8× telephoto lenses were placed 60–100 m from nests (mean = 81 ± 7.1 m, n = 5), and 2× and 2.5× telephoto cameras were placed 30–75 m from nests (mean = 42 ± 2.5 m, n = 13). To deploy cameras, 2 researchers were transported to and from nesting lakes by helicopter. Researchers were at nests an average of 35 min (SE = 2.2 min, range = 23–63 min, n = 18 nests). All 18 loons that were incubating left the nest during camera setup: 1 left as the helicopter circled the nest prior to landing , 6 left as the helicopter landed, 5 left as researchers exited the helicopter, and 6 swam away from their nests as researchers approached the camera setup location on foot.

All 18 loons that left their nests during camera installation returned to incubate after installation. Loons returned an average of 7 min after we departed in the helicopter (SE = 2 min, range = 0–20 min, n = 16 nests). Loons were absent from nests for an average of 40 min during camera installation (SE = 3 min, range = 23–64 min, n = 16 nests). The length of time loons were absent was unknown at 2 nests.

Cameras successfully recorded daily nest survival at 19 of 21 nests. The cameras failed to start recording at 2 nests and did not record any images; both nests eventually hatched. We were able to use camera images to identify the day of hatch or failure at all 19 of the cameras that functioned for the entire period (Table 16). Of the 21 camera-monitored nests, 8 hatched and 13 failed for an apparent nesting success of 38%. The median start date for incubation was 16 June (range = 13–20 June, n = 8) at hatched nests and 19 June (range = 15–25 June, n = 13) at failed nests. The median hatch date was 13 July (range = 11–18 July, n = 8 nests), which agrees with results from monitoring surveys that indicated most nests hatched between visits on 9 and 16 July (Table 12).

Incubation constancy of Yellow-billed Loons in the Colville Delta study area in 2014 (Table 16) was similar to previous years, except for 2013, which was a year with low nest attendance compared to other years (Appendix G). During camera monitoring in 2014, loons at both hatched and failed nests exhibited high nest attendance, spending 96.8% (SE = 0.7%, n = 6 nests) and 95.2% (SE = 0.6%, n = 11 nests), respectively, of their time incubating.

Since camera monitoring began in 2008, predation of 1 or both eggs has been documented at 57 of 120 nests, including 10 nests where predators were not captured on images (Figure 17). The majority (49%) of identified predators were Glaucous Gulls and Parasitic Jaegers, which take advantage of unattended nests. Of the 13 nests that failed to hatch in 2014, 4 failures were attributed to predation by Glaucous Gulls, 3 to brown bears, 1 to a Parasitic Jaeger, and 1 to a red fox. The predator was not captured on images at 3 nests. The remaining nest failed when wind-blown ice covered the nest and destroyed the eggs (Table 16). All 5 nests lost to avian predators were unattended at the time of predation. At 4 of these nests, images showed incubating loons left nests to interact with intruding Yellow-billed Loons in the nesting lakes. At 1 nest, a jaeger arrived as the loon departed. Two loons could be seen chasing each other ~75 m from the nest. The jaeger was at the nest for ~12 min before the loon chased it away, but the loon did not resume incubation. At the second nest, the incubating loon left its nest ≥9 times to interact with an intruder on the day of failure. During 1

Table 16. Nest history and incubation activity of Yellow-billed Loon nests monitored by time-lapse digital cameras, Colville Delta study area, Alaska, 2014.

Territory	Fate[a]	Incubation Start Date[b]	Predator	No. Eggs[c]	Date Camera Setup	Date of Hatch or Failure	No. Days Monitored[d]	Incubation Constancy[d] (%)	Exchange Frequency[d] (no/d)	Recess Frequency[d] (no/d)	Recess Length[d] (min/recess)
12	S	17 June		1	23 June	15 July	21.2	94.9	1.7	2.8	26.6
15	S	15 June		1	24 June	13 July	18.5	98.1	1.8	2.4	10.7
17	S	13 June		2	24 June	11 July	11.2	94.4	1.7	1.4	10.8
18	S	20 June		2	24 June	18 July[e]	0[f]	–	–	–	–
26	S	16 June[g]	Parasitic Jaeger[h]	2	27 May	12 July	25.8	97.2	1.7	3.3	11.2
39	S	15 June	Glaucous Gull[h]	2	25 June	13 July	17.2	98.0	1.0	3.4	7.8
43	S	20 June		2	25 June	18 July[e]	0[f]	–	–	–	–
45	S	16 June[g]		2	28 May	13 July	33.3	98.0	1.5	1.8	9.6
Median/Average		16 June			–	13 July		96.8	1.6	2.5	12.8
SE		–			–	–		0.7	0.1	0.3	2.8
1	F	16 June[g]	Glaucous Gull	1	26 May	21 June	5.1	96.1	2.0	3.6	15.1
4	F	19 June	Glaucous Gull	2	25 June	2 July	6.3	92.2	1.6	5.9	22.6
6	F	15 June[g]	Glaucous Gull	–	26 May	2 July	16.4	93.8	1.7	4.5	15.9
8	F	15 June[g]	None, ice-covered	2	27 May	23 June	7.6	98.4	2.5	3.2	6.4
11	F	19 June	Glaucous Gull	2	23 June	2 July	9.0	95.8	1.7	3.7	15.8
13	F	19 June[g]	Brown Bear	2	27 May	6 July	17.3	96.0	1.5	3.6	14.3
14	F	16 June	Red Fox	1	23 June	24 June	0.2	–	–	–	–
16	F	25 June	Unknown	1	26 June	4 July	7.8	92.9	3.7	7.3	15.6
23	F	20 June	Unknown	2	25 June	5 July	10.0	93.9	0.9	4.8	18.8
25	F	17 June	Brown Bear	2	25 June	3 July	8.2	97.7	1.5	3.4	10.5
32	F	25 June	Unknown	–	25 June	30 June	4.5	97.0	1.8	3.6	14.6
34	F	20 June[g]	Brown Bear	2	27 May	23 June	3.0	93.8	0.7	7.4	12.4
47	F	20 June	Parasitic Jaeger	1	26 June	26 June	0.4	–	–	–	–
Median/Average		19 June			–	2 July	–	95.2	1.8	4.6	14.7
SE		–			–	–	–	0.6	0.2	0.5	1.3

[a] S = hatched, F = failed to hatch

[b] Incubation start dates for successful nests estimated by subtracting 28 d from date chick first observed on camera images; for failed nests, nest age estimated using egg flotation schedule; if either method resulted in a nest age that was younger than the using the date found, the date found was used as the start of incubation.

[c] Recorded on aerial surveys, during camera setup, or maximum seen on camera images

[d] Summarized from time loon returns to nest after camera installation to day before hatch, or to time of nest failure; excludes period of time when photo images could not be interpreted because of poor weather conditions

[e] Hatch date estimated using egg flotation

[f] Camera malfunctioned due to operator error; no image collected

[g] Start of incubation documented by camera images

[h] Predation occurred on the second egg while adults were away from the nest with the first-hatched chick

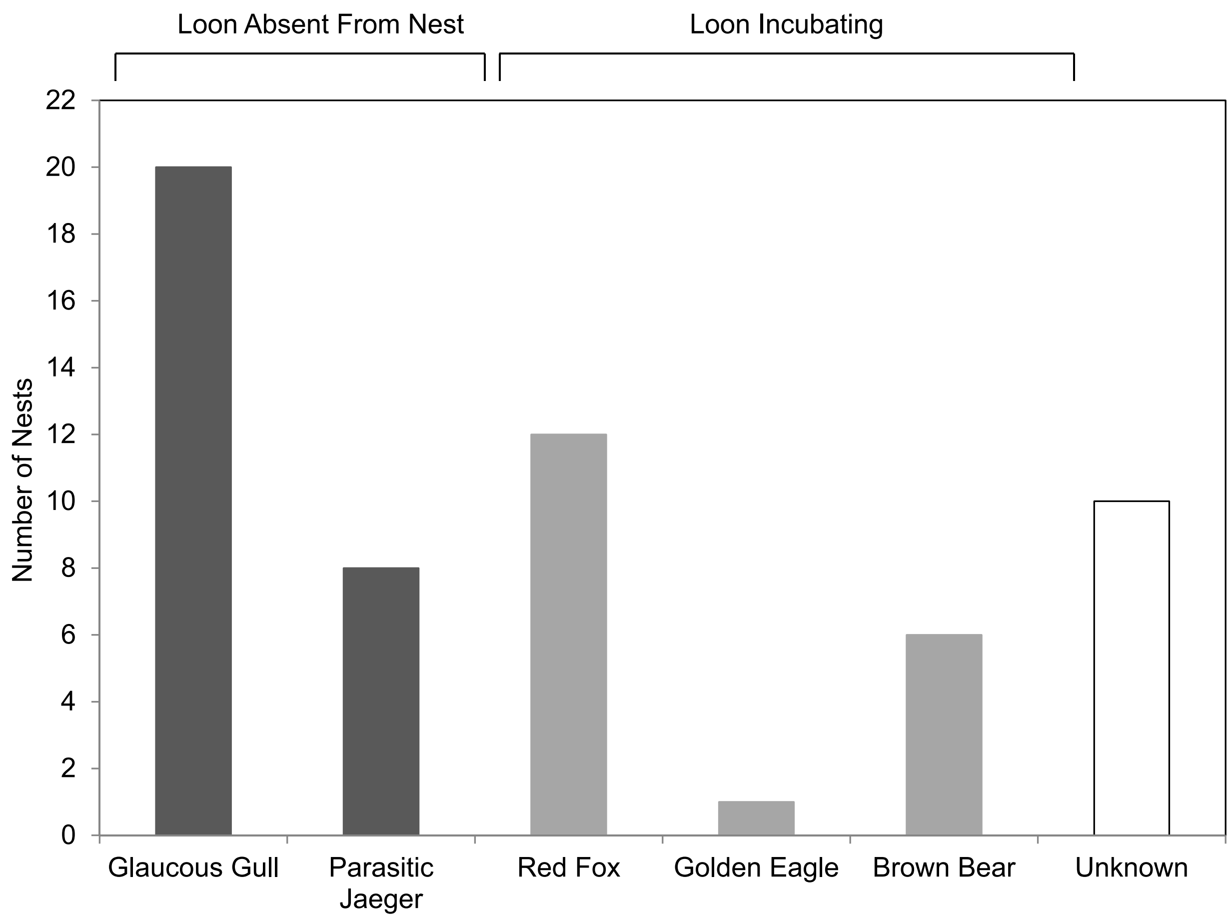


Figure 17. Predators seen taking eggs at camera-monitored Yellow-billed Loon nests (*n* = 99 nests), Colville Delta study area, Alaska, 2008–2014. Loons left nests 6–15 min prior to brown bear predation; we assume they were flushed into the water by the bears.

interaction, a gull landed at the nest ~20 min after the loon left. The gull was present for ~2 min before a loon chased it away. The gull landed 3 more times at the nest and after the fourth time, the loon did not chase the gull away, nor did it resume incubation. At the third nest, the incubating loon left the nest to interact with an intruder and ~25 min later a gull landed at the nest. The loon chased the gull off the nest, but the gull returned 2 more times, finally causing nest failure. At the fourth nest, images showed that a brown bear walking ~175 m from a nest caused the loon to leave. About 3 min later, a Glaucous Gull landed at the nest. The gull visited the nest 3 times, spending a total of 3–4 min at the nest, before the loon chased it away. The loon incubated for ~10 min before leaving to interact with an intruding loon. Although the pair returned to the nest, they did not resume incubation. At the fifth nest, the loon departed for an unknown reason. A Parasitic Jaeger landed at the nest ~8 min later but was immediately chased away by a Glaucous Gull. A maximum of 5 gulls were at the nest for ~ 4 min. The loon eventually returned to the nest but only incubated for ~60 min before ending nest attendance.

In contrast to the events leading to avian predation, incubating loons were likely flushed at 1 nest taken by a red fox and 3 nests taken by bears. A loon was incubating but quickly left the nest ~1 min before the appearance of the fox in the camera image. The loon unsuccessfully attempted to defend its nest by rising up on its legs and rushing (see descriptions in Sjölander and Ågren 1976) at the fox with its bill directed downward. At 1 nest taken by a bear, the loon quickly left the nest and camera view; a bear destroyed the nest ~6 min later (Figure 18). At 2 other nests taken by bears, the loons swam next to their nests for ~18 and 40 min before leaving camera view. The bears depredated the nests 4 and 6 min after the loons left camera view. Prior to bear predation loons were seen swimming partially submerged near nests which is a behavior that we also see during researcher disturbance, suggesting that the bears' presence caused the loons to flush. No loons attempted to defend their nests against bears. Mammalian predators depredated nests quickly; the fox and 2 bear predation events were recorded on single images, with encounters lasting ~30 sec. The third event, a sow with 2 cubs, was recorded on 3 images.

One nest failed after lake ice crushed it on day 9 of incubation. The event occurred after the wind, which had been blowing steadily from the east-northeast, began to blow out of the south. The nest site and eggs were destroyed and we did not detect any attempts by the pair to renest.

Partial predation was observed at 2 nests that hatched 1 egg. Yellow-billed Loons begin incubation after the first egg is laid (North 1994, this study). The second egg is laid ~2.5 d later, and as a result, eggs may hatch 1–3 d apart (this study). After the first chick emerges, some pairs decrease nest attendance as they alternate between incubating the second egg and swimming with the newly-hatched chick. This behavior exposes the unattended nest to predation. While adults were swimming with chicks at 2 different nests, a Parasitic Jaeger took 1 egg 1 d after the first chick hatched, whereas at another nest, a Glaucous Gull took 1 egg 2 d after the first chick hatched.

As mentioned above, Yellow-billed Loons intruding into occupied territories can lead to nest loss. Intruders were identified by the presence of >2 adults or by aggressive interactions between 2 Yellow-billed Loons. In most cases, the appearance of an intruding loon elicited defensive behaviors among the birds such as fencing, rushing, and physical contact (for descriptions see Sjölander and Ågren 1976). In 2014, intruders were seen at 58% of camera-monitored nests in the Colville Delta study area (n = 19 nests). In all cases, the incubating loon left the nest to interact with the intruder. The proportion of monitored nests with intruders on camera images in 2014 was similar to the mean detected since 2010 (57 ± 5.2%, n = 5 years); however, camera images likely under-estimate the frequency of occurrence of intruders because interactions with intruders can occur out of camera view. These interactions may reflect attempts at territorial takeover by the intruders. Territorial fights and subsequent takeovers have been observed in Common Loons (Piper et al. 2000), but it is unknown whether this behavior plays an important role in the establishment of Yellow-billed Loon territories (North 1994).

Brood Fate

During monitoring surveys following hatch, we observed broods of 2 chicks with 2 of 8 Yellow-billed Loon pairs (25%) that hatched young, and single chick broods with 5 pairs (Table 14). The remaining pair hatched at least 1 chick based on the presence of eggshell evidence at the nest but its brood did not survive to the next monitoring survey. Camera images confirmed that 1 chick hatched at that nest. Otherwise, no additional young were detected on camera images. We recorded 31 nests in the Colville Delta study area during the nesting, monitoring, and brood-rearing surveys in 2014. A minimum of 10 chicks were produced at 31 nests (0.32 chicks/nest; Table 13). Images from cameras deployed in May confirmed the presence of an additional nest that was only active between weekly surveys. Using all available sources of data (camera, eggshell evidence, and aerial surveys), a minimum of 10 chicks were produced by 32 nests (0.31 chicks/nest).

On the final survey on 24 September, chicks were 9.5 to 10.5 weeks old (Table 14). Although none were observed flying in 2014, chicks at 2 territories were observed flying at that age in 2013. The length of time from hatch to fledging is not known for Yellow-billed Loons, but may be similar to Common Loons, which fly after ~11 weeks of age (McIntyre and Barr 1997, North 1994). In the Colville Delta study area, all lakes with active Yellow-billed Loons were ice-free on the final survey in late September.

One goal of brood monitoring was to estimate juvenile recruitment, or how many chicks survived to fledging. Four of 8 Yellow-billed Loon pairs that

Figure 18. Digital time-lapse photos of a brown bear eating eggs from a Yellow-billed Loon nest in the Colville Delta study area (top) and a wolverine approaching a loon nest in the NE-NPRA study area (bottom), 2014. Both predators flushed the incubating loon from the nest and caused nest failure.

hatched at least 1 egg retained a chick on the final monitoring survey on 24 September; none retained both chicks (Table 14). Using data from the nesting, monitoring, and brood-rearing surveys, 4 chicks from 31 nests (0.13 chicks/nest) survived until the last survey on 24 September (Tables 13 and 14). Including the nest detected only on camera images, 4 chicks from 32 nests (0.12 chicks/nest) survived. Although we detected an above average number of nests in 2014 compared to the long-term mean, we observed record low nesting success, which produced the fewest chicks/nest at hatch since nest monitoring surveys began in 2005. Further, not all chicks survived to mid-September in 2014, resulting in an estimate of chicks/nest that was nearly 4 times lower than the long-term mean (0.49 ± .08, n = 7 years).

NE NPR-A Study Area

Distribution and Abundance

No nests were found during the 11 June survey, but 17 (65%) of 26 territories surveyed contained ≥1 Yellow-billed Loon. During the nesting survey on 19–22 June, we counted 47 Yellow-billed Loons and 18 nests in the 4 subareas surveyed: Alpine West, Fish Creek Delta, the eastern part of the Fish and Judy Creek Corridor, and the GMT Corridor (Figure 15, Table 9). Two additional nests were found during monitoring surveys on 25 June and 2 July. Of the 20 nests found in the NE NPR-A study area in 2014, 1 nest was located in the Alpine West subarea, 6 nests were in the Fish Creek Delta subarea, 9 nests were in the Fish and Judy Creek Corridor subarea, and 4 nests were in the GMT Corridor subarea (Appendix E).

All but 2 of the 20 Yellow-billed Loon nests recorded in the NE NPR-A study area in 2014 were on lakes where Yellow-billed Loons have nested previously (Figure 15) (Johnson et al. 2007b, 2010, 2011, 2012, 2013a, and 2014a). The 2 nests on newly discovered nesting lakes were on shallow lakes <2.0 ha in size and were adjacent to larger lakes previously used for both nesting and brood rearing. Seven of the 20 nests were located at the same nest sites used in previous years, 8 were very close to previous nest sites, and 3 were at new nest sites on lakes previously used for nesting.

The density of Yellow-billed Loon adults in the NE NPR-A study area during the nesting survey in 2014 was 0.09 birds/km², and the density of nests was 0.04 nests/km² (Appendices E and F). We cannot compare annual densities across the entire study area because survey areas have varied considerably in size among years; however, the Alpine West (surveyed 2002–2006 and 2008–2014) and Fish Creek Delta (surveyed 2005–2006 and 2008–2014) subareas have been surveyed in their entirety for 12 and 9 years, respectively. In the Alpine West subarea in 2014, density of adults (0.03 birds/km²) was similar to the 12-year mean (0.02 ± 0.003 birds/km²), whereas nest density was equal to the mean (0.01 ± 0.001 nests/km²). In the Fish Creek Delta subarea in 2014, density of adults (0.14 birds/km²) was similar to the 9-year mean (0.13 ± 0.007 birds/km²), and nest density was equal to the mean (0.05 ± 0.004 nests/km²). Only 1 Yellow-billed Loon territory has been identified in the Alpine West subarea during 12 years of surveys there.

We surveyed 26 territories in the NE NPR-A study area in 2014 and found 20 nests, resulting in a nest occupancy of 77%, which was the second highest nest occupancy recorded and higher than the long-term mean (66.2 ± 2.2%, n = 13 years; Table 9). Nesting surveys for Yellow-billed Loons in the NE NPR-A study area were most extensive in 2008–2010, when 51 territories were surveyed. During those 3 years, the highest number of Yellow-billed Loons recorded during nesting surveys was 82 adults in 2008 and the highest number of nests was 29 in 2010 (Table 9). The range of Yellow-billed Loon nest occupancy was 57–86% during 2008–2014.

During the brood-rearing survey on 21–22 August 2014, we recorded 29 adult Yellow-billed Loons (0.06 birds/km²) and 9 broods (0.02 broods/km²; Table 10, Appendix E). We inferred 2 additional broods hatched based on eggshell fragments at the nest but neither brood survived (Figure 15, Table 14). Of the 11 broods detected in the NE NPR-A study area, 1 was in the Alpine West subarea, 3 were in the Fish Creek Delta subarea, 5 were in the Fish and Judy Creek Corridor subarea, and 2 were in the GMT Corridor subarea. Similar to the nesting survey, yearly densities during brood-rearing in the NE NPR-A study area cannot be compared because the study area varied in size among years (Appendix F); however, Alpine West and Fish Creek Delta subareas, as described above, have been surveyed in their entirety for 12 and 9 years, respectively.

In the Alpine West subarea, only 1 Yellow-billed Loon territory has been identified so the densities of adults and broods during aerial surveys in 2014 (0 birds/km² and 0.01 broods/km²; Appendix E) were similar to the 12-year means (0.01 ± 0.005 birds/km² and 0.01 ± 0.002 broods/km²). The density of adults in the Fish Creek Delta subarea (0.05 birds/km²; Appendix E) was well below the 9-year mean for that area (0.09 ± 0.009 birds/km²), but the density of broods was the same as the mean (0.02 ± 0.003 broods/km broods).

In 2014, we surveyed 26 territories containing 11 broods, resulting in 35% brood occupancy, which was the fourth highest occupancy recorded for the NE NPR-A study area (mean = 27.8 ± 3.8%, *n* = 13 years; Table 10). Territory occupancy is standardized by the number of territories surveyed so the metric can be used to compare years with different survey areas; however, comparisons should be made cautiously because territory quality could vary among areas. During our most extensive brood-rearing surveys for Yellow-billed Loons in 2008–2010, 49–51 territories were surveyed each year and territory occupancy by broods was 29–38% (Table 10).

Habitat Use

Habitat selection was evaluated for nesting and brood-rearing Yellow-billed Loons in the 4 subareas of the NE NPR-A study area surveyed for loons in 2008–2014 (Alpine West, Fish Creek Delta, Fish and Judy Creek Corridor, and GMT Corridor subareas). Yellow-billed Loon nests were found in 13 of 26 available habitats in the NE NPR-A study area (Table 17). Five habitats supported 95 of 142 (67%) total nests and were preferred for nesting (Tapped Lake with High-water Connection, Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, Sedge Marsh, and Deep Polygon Complex). Within these areas, nests were built on peninsulas, shorelines, islands, or in emergent vegetation. Although all nests were on islands or shorelines of lakes, only nests on islands or in emergent vegetation were assigned to the aquatic habitat of the lake; otherwise nests were assigned to the terrestrial habitat on the lakeshore. Deep Open Water with Islands or Polygonized Margins was the most frequently used habitat for nesting (35% of all nests). Nesting Yellow-billed Loons avoided 8 habitats composing 59% of the loon survey area in the NE NPR-A study area.

Sixty-three Yellow-billed Loon broods were found in 3 habitats in the NE NPR-A study area, 2 of which were preferred: Tapped Lake with High-water Connection and Deep Open Water with Islands or Polygonized Margins (Table 17). Deep Open Water with Islands or Polygonized Margins also was the most frequently used habitat for brood-rearing (71% of all broods). No shallow-water habitats were used during brood-rearing. The selection analyses for loons in the NE NPR-A study area, like those conducted for the Colville Delta study area, highlight the reliance on large, deep waterbodies by breeding Yellow-billed Loons and their young.

Nest Monitoring and Nest Fate

We found 20 Yellow-billed Loon nests during nesting and monitoring surveys in the NE NPR-A study area in 2014. During the 7 years of monitoring surveys, the study area varied in size from 21 to 51 territories; however, the number of nests found in 2014 was above the mean (16.3 ± 1.4 nests) found during 4 years of surveys on lakes within the same survey area (2008–2010, and 2014). Apparent nesting success (55%) was well above the 7-year mean observed since monitoring surveys began in 2008 (46 ± 7.9%; Table 13). In 2014, 11 of 20 nests hatched and all but 2 did so by 16 July (Table 18).

Nine of 20 Yellow-billed Loon nests in the NE NPR-A study area failed to hatch (Table 18). Four nests (44%) failed by 2 July, 2 by 9 July and another by 16 July. The date of failure was unknown at 1 nest. The remaining nest failed by 13 August and was active for 49 to 56 d, which is longer than the 28 d incubation period reported for Yellow-billed Loons. We found 2 whole eggs abandoned next to the nest during the fate visit, suggesting that the pair was incubating nonviable eggs. A pair has incubated eggs >35 d at this same nest site since 2011, suggesting that the same pair of infertile loons may be returning to the nest site. Extended incubation for infertile eggs has been observed in Common Loons and Sutcliffe (1982)

Table 17. Habitat selection by nesting and brood-rearing Yellow-billed Loons, NE NPR-A study area, Alaska, 2008–2014.

SEASON Habitat	No. of Nests or Broods	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
NESTING					
Open Nearshore Water	0	0	6.3	avoid	
Brackish Water	0	0	2.7	avoid	low
Tapped Lake with Low-water Connection	0	0	1.8	ns	low
Tapped Lake with High-water Connection	21	14.8	1.4	prefer	low
Salt Marsh	0	0	4.8	avoid	
Tidal Flat Barrens	0	0	4.8	avoid	
Salt-killed Tundra	0	0	1.8	ns	low
Deep Open Water without Islands	5	3.5	5.8	ns	
Deep Open Water with Islands or Polygonized Margins	50	35.2	5.7	prefer	
Shallow Open Water without Islands	0	0	0.7	ns	low
Shallow Open Water with Islands or Polygonized Margins	6	4.2	1.5	prefer	low
River or Stream	0	0	2.0	ns	low
Sedge Marsh	14	9.9	1.5	prefer	low
Deep Polygon Complex	4	2.8	0.1	prefer	low
Grass Marsh	2	1.4	0.3	ns	low
Young Basin Wetland Complex	0	0	0.3	ns	low
Old Basin Wetland Complex	1	0.7	4.8	avoid	
Riverine Complex	0	0	0.1	ns	low
Dune Complex	3	2.1	1.2	ns	low
Nonpatterned Wet Meadow	5	3.5	3.2	ns	low
Patterned Wet Meadow	22	15.5	11.3	ns	
Moist Sedge-Shrub Meadow	6	4.2	15.9	avoid	
Moist Tussock Tundra	3	2.1	16.4	avoid	
Tall, Low, or Dwarf Shrub	0	0	3.7	avoid	
Barrens	0	0	1.7	ns	low
Human Modified	0	0	<0.1	ns	low
Total	142	100	100		
BROOD-REARING					
Open Nearshore Water	0	0	6.3	avoid	low
Brackish Water	0	0	2.7	ns	low
Tapped Lake with Low-water Connection	0	0	1.8	ns	low
Tapped Lake with High-water Connection	12	19.0	1.4	prefer	low
Salt Marsh	0	0	4.8	ns	low
Tidal Flat Barrens	0	0	4.8	ns	low
Salt-killed Tundra	0	0	1.8	ns	low
Deep Open Water without Islands	6	9.5	5.8	ns	low
Deep Open Water with Islands or Polygonized Margins	45	71.4	5.7	prefer	low
Shallow Open Water without Islands	0	0	0.7	ns	low
Shallow Open Water with Islands or Polygonized Margins	0	0	1.5	ns	low
River or Stream	0	0	2.0	ns	low
Sedge Marsh	0	0	1.5	ns	low
Deep Polygon Complex	0	0	0.1	ns	low
Grass Marsh	0	0	0.3	ns	low
Young Basin Wetland Complex	0	0	0.3	ns	low
Old Basin Wetland Complex	0	0	4.8	ns	low
Riverine Complex	0	0	0.1	ns	low
Dune Complex	0	0	1.2	ns	low
Nonpatterned Wet Meadow	0	0	3.2	ns	low
Patterned Wet Meadow	0	0	11.3	avoid	
Moist Sedge-Shrub Meadow	0	0	15.9	avoid	
Moist Tussock Tundra	0	0	16.4	avoid	
Tall, Low, or Dwarf Shrub	0	0	3.7	ns	low
Barrens	0	0	1.7	ns	low
Human Modified	0	0	<0.1	ns	low
Total	63	100	100		

[a] use = (groups / total groups) × 100

[b] 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

[c] Expected number < 5

Table 18. Weekly status (A = active, I = inactive) and fate of Yellow-billed Loon nests monitored by aerial surveys, NE NPR-A study area, Alaska, 2014.

	June			July					August		
Territory	11	20–22	25[a]	2[a]	9[a]	16	23	30	6	13	Fate/Total
51	I	A	A	A	A	I	–	–	–	–	Hatched
53	I	A	A	A	A	I	–	–	–	–	Hatched
54	I	A	A	A	A	I	–	–	–	–	Hatched
55	I	A	A	I	–	–	–	–	–	–	Failed
56[b]	I	A	A	A	I	–	–	–	–	–	Failed
58[b]	I	A	A	A	A	I	–	–	–	–	Hatched
59[b]	I	A	A	A	A	I	–	–	–	–	Hatched
61[b]	I	A	A	A	A	I	–	–	–	–	Hatched
68[b]	I	A	A	I	–	–	–	–	–	–	Failed
78[b]	I	A	–	–	I	–	–	–	–	–	Failed
79[b]	I	A	A[c]	A[c]	A	I	–	–	–	–	Hatched
88[b]	I	A	A	A	A[f]	I	–	–	–	–	Hatched
90	I	I	I	A	A	A	A	I	–	–	Hatched
91	I	A	A	A	A	A	A	A	A	I	Failed
93[b]	I	A	A	A	I	–	–	–	–	–	Failed
94[b]	I	A	A	A	A	A	I	–	–	–	Hatched
95[b]	I	A	A	A	A	I	–	–	–	–	Hatched
97	I	A	A	I	–	–	–	–	–	–	Failed
99[b]	I	I	A	A	A	I	–	–	–	–	Failed
100[b]	I	A	A	I	–	–	–	–	–	–	Failed
No. Active	0	18	18	15	13	3	2	1	1	0	20
No. Hatched	0	0	0	0	0	9	1	1	0	0	11
No. Failed	0	0	0	4	2	1	0	0	0	1	9

[a] Camera-monitored nest(s) was not surveyed by helicopter; nest status determined from camera images
[b] Nest monitored by camera
[c] No images collected by camera due to operator error
[d] No data; date of failure unknown and nest not included in totals by week
[e] No data; nest assumed active based on survey history
[f] No data because camera lens fogged up on 3 July; nest assumed active based on float data

suggested that loons may remain faithful to unhatched eggs to provide a safety margin for eggs taking longer to hatch, which is beneficial in northern environments where opportunities to renest are limited.

The contents all 20 Yellow-billed Loon nests were examined after nests were no longer active. Nine were classified as successful based on the presence of eggshell fragments in nests and broods and 2 were classified as successful based only on eggs fragments in nests. Successful nests contained 51–104 eggshell fragments and 2 nests contained entire egg membranes in addition to fragments. The vast majority (93%) of >800 fragments were found in nests. Furthermore, fragments at hatched nests were small; nearly 60% were ≤10 mm in length. Nine failed nests were examined for fate evidence. Four nests were empty. Two nests had 5–20 pieces of eggshell in or near the nest; both also contained a few pieces of thickened membrane loosely attached to egg fragments. Camera images at both nests confirmed nest failure (see *Time-Lapse Cameras* below). The presence of membrane pieces alone are not necessarily indicative of hatch because nests that fail close to hatching may contain some membrane pieces

(Johnson et al. 2013a). Two nests contained a broken egg, one of which was associated with ~40 egg fragments that mostly were in a single pile next to the nest. The remaining failed nest was abandoned with 2 intact eggs.

Time-lapse Cameras

We monitored 13 of 20 Yellow-billed Loon nests in the NE NPR-A study area with time-lapse cameras in 2014 (Table 19). Eight-power telephoto cameras were placed 66–92 m from nests (mean = 76 ± 3.8 m, *n* = 6 nests) and 2× and 2.5× telephoto cameras were placed 40–54 m from nests (mean = 46 ± 2.2 m, *n* = 7 nests). Two researchers were transported to and from nesting areas by helicopter for camera setup and were at nests an average of 39 min (range = 22–81 min, *n* = 13 nests). All 13 loons left their nest during camera setup (3 left as the helicopter landed, 6 swam away as researchers exited the helicopter, 3 left as researchers approached the nest, and 1 swam away while researchers were setting up the camera).

At least 12 of 13 loons returned to incubate after camera installation. Ten loons returned to their nests an average of 13 min after we departed in the helicopter (SE = 3 min, range = 2–71 min, *n* = 10 nests) and 1 loon returned before we left. Cameras did not collect images at 1 hatched and 1 failed nest so the length of time those loons were absent from nests was unknown. It also was unknown whether the loon from the failed nest returned to incubate since we did not have camera images as verification. Loons were absent from nests during camera installation for a mean of 50 min (SE = 6 min, range = 28–85 min, *n* = 11 nests).

Cameras successfully recorded daily nest survival, and we were able to use images to identify the day of hatch or failure at 10 of 13 camera-monitored nests. The cameras at 2 nests did not collect images due to operator error and moisture leaked into the camera at another nest causing the lens to fog over after ~8 d of monitoring. Seven nests hatched and 6 failed for an apparent nesting success of 54% (Table 19). The median initiation date of camera-monitored nests was 16 June (range = 13–21 June, *n* = 13 nests) and the median hatch date was 13 July (range = 11–19 July, *n* = 7 nests).

Incubation constancy by loons in the NE NPR-A study area in 2014 (Table 19) was similar to previous years, except for 2013, which was a year with fairly low nest attendance (Appendix G). In 2014, loons nests at hatched and failed nests spent 98.0% (SE = 0.5, *n* = 6 nests) and 93.6% (SE = 1.0, *n* = 5 nests) of the time incubating, respectively.

Since camera monitoring began in 2010 in the NE NPR-A study area, we have documented predation at 29 of 49 (59%) monitored nests. Glaucous Gulls, Parasitic Jaegers, and Common Ravens took eggs while nests where unattended, whereas brown bears, wolverine, Bald Eagles, and Golden Eagles appeared to flush incubating birds to steal eggs (Figure 19). Over half (59%) of the 29 events occurred while loons were absent from nests. Predators were not captured on images at 5 nests and the timing of predation could not be determined with certainty. In 2014, 3 failures were attributed to Glaucous Gulls, 1 to a Parasitic Jaeger, and 1 to a wolverine; the predator at 1 nest was unknown because the camera did not collect images (Table 19).

All 4 nests that failed due to avian predation were unattended at the time of predation. Two suffered predation while the incubating loon took a recess during hot weather and 1 failed while the incubating loon was interacting with an intruding loon. The camera at the remaining nest malfunctioned and collected images sporadically on the day of failure, so the reason why the loon was not incubating was unknown. During warm temperatures (>15 °C), incubating loons were seen gular fluttering (a primary means of evaporative cooling in birds) and rubbing their heads on their backs, presumably in response to mosquito harassment. Loons may be attempting to increase heat dissipation by leaving their nests and entering the water. One loon left its nest while the ambient temperature was ~20 °C. That nest was unattended for ~19 min before 3 Parasitic Jaegers arrived at the nest. The jaegers were at the nest for ~6 min before a loon displaced them. The loon incubated for almost 90 min before leaving the nest again, possibly to interact with an intruding loon. A loon returned ~6 h later and incubated for <1 h before ending nest attendance. At another nest, the loon swam away while the ambient temperature was ~18 °C. A gull landed at the nest ~35 min later and ate egg(s) at the nest for 11 min before departing. The loon did not return to incubate. At the third

Table 19. Nest history and incubation activity at Yellow-billed Loon nests monitored by time-lapse digital cameras, NE NPR-A study area, Alaska, 2014.

Territory	Fate[a]	Incubation Start Date[b]	Predator	No. Eggs[c]	Date Camera Setup	Date of Hatch or Failure	No. Days Monitored[d]	Incubation Constancy[d] (%)	Exchange Frequency[d] (no/d)	Recess Frequency[d] (no/d)	Recess Length[d] (min/recess)
58	S	13 June	Glaucous Gull[e]	2	25 June	11 July	13.5	99.5	1.2	1.0	5.4
59	S	13 June		2	25 June	11 July	14.7	98.9	1.6	1.8	7.5
61	S	15 June		2	24 June	13 July	18.2	98.8	2.3	1.9	7.3
79	S	15 June		2	24 June	13 July[f]	0	–	–	–	–
88	S	17 June		2	23 June	15 July[f]	8.7	97.9	0.6	2.9	10.9
94	S	21 June		2	25 June	19 July	23.4	95.9	0.7	5.0	11.9
95	S	15 June		2	24 June	13 July	18.2	97.2	1.7	2.7	13.7
Median/Average		15 July				13 July		98.0	1.3	2.5	9.4
SE		–				–		0.5	0.3	0.6	1.3
56	F	16 June	Wolverine	2	25 June	4 July	9.3	90.8	0.9	8.3	17.0
68	F	21 June	Parasitic Jaeger	1	24 June	30 June	5.4	96.5	0.8	3.9	11.1
78	F	17 June	Unknown	2	24 June	–	0	–	–	–	–
93	F	18 June	Glaucous Gull	2	23 June	9 July	14.4	92.5	1.0	4.3	44.5
99	F	13 June	Glaucous Gull	2	26 June	10 July	11.5	93.5	0.8	4.5	31.0
100	F	20 June	Glaucous Gull	2	25 June	1 July	3.3	94.5	1.5	2.1	9.8
Median/Average		17 July				6 July		93.6	1.0	4.6	22.7
SE		–				–		1.0	0.1	1.0	6.6

[a] S = hatched, F = failed to hatch
[b] Incubation start dates for successful nests estimated by subtracting 28 d from date chick first observed on camera images; for failed nests, nest age estimated using egg flotation schedule
[c] Recorded on aerial surveys, during camera setup, or maximum seen on camera images
[d] Summarized from time loon returns to nest after camera installation to day before hatch, or to time of nest failure; excludes period of time when photo images could not be interpreted because of poor weather conditions
[e] Predation occurred on the second egg while the adults were swimming with the first-hatched chick
[f] Hatch date estimated using egg floatation

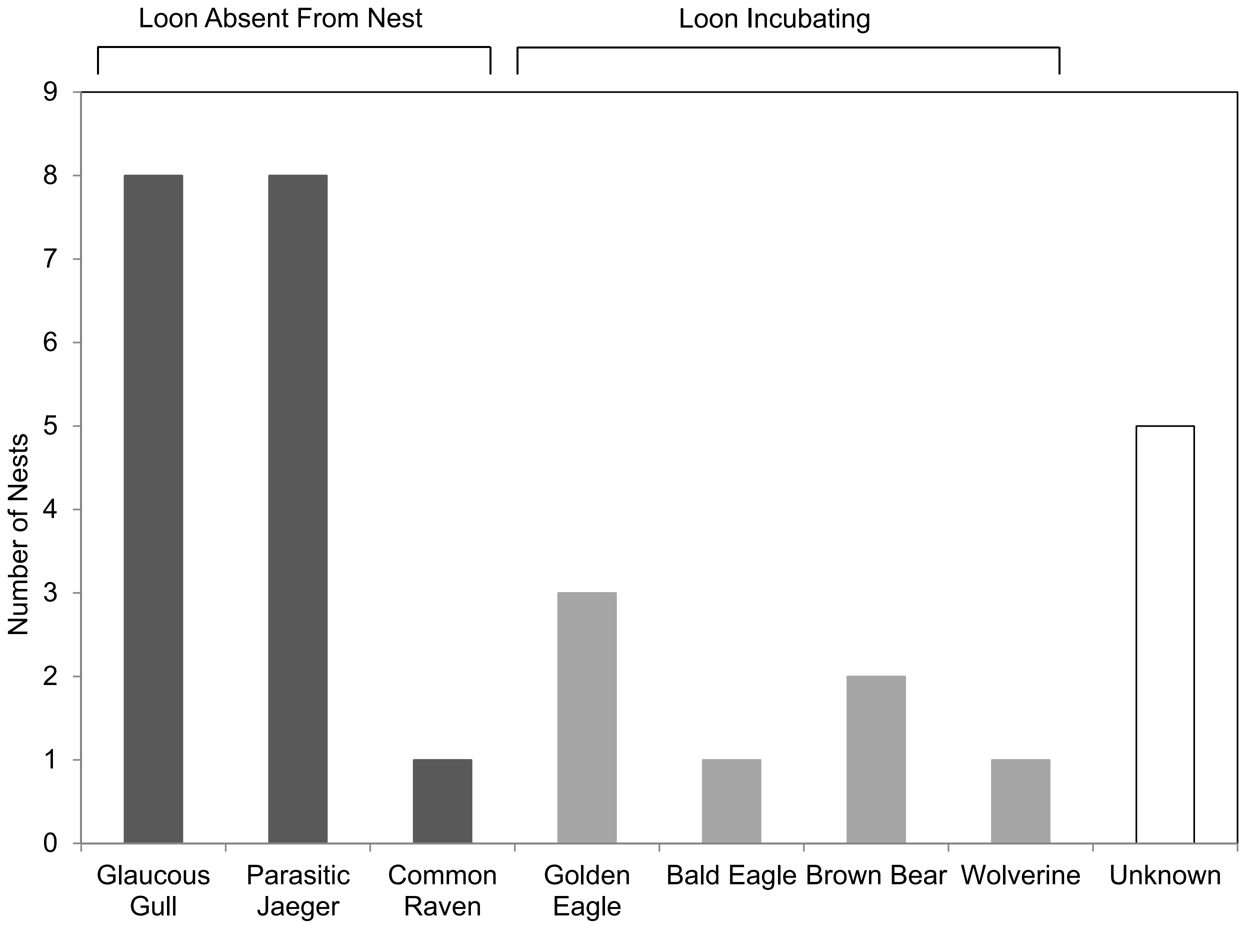


Figure 19. Predators seen taking eggs at camera-monitored Yellow-billed Loon nests (*n* = 36 nests), NE NPR-A study area, Alaska, 2010–2014. Loons left nests 3–33 min prior to brown bear predation; we assume they were flushed into the water by the bears.

nest, the loon concealed for ~10 min before leaving its nest to interact with an intruding loon. About an hour later, a gull landed at the nest and was immediately chased away by a loon; this occurred twice. The third time, however, the gull stayed at the nest for ~16 min and the loon did not return.

Although difficult to ascertain with certainty, the loon at the nest preyed on by the wolverine likely was incubating and flushed by the wolverine prior to nest predation (Figure 18). Before leaving its nest, the incubating loon became alert and looked in the direction from which the wolverine eventually approached the nest. The loon then quickly swam away from its nest. The wolverine appeared ~7 min later and was at the nest for ~30 sec. Images showed the loon swimming ~125 m from the nest during the predation event. Although the loon returned briefly to look in the nest, it did not resume incubation.

Partial predation (loss of 1 egg) also was observed at a nest that hatched 1 chick. While the adults were swimming with the chick that hatched, a Glaucous Gull landed at the nest and took the other egg. The predation event occurred 1 d after the other egg hatched. Yellow-billed Loon eggs hatch 1–3 d apart and adults will leave the nest to swim with 1 chick before the second egg hatches, exposing the unattended egg to predation (this study). Predation of the second egg after the first hatched also was seen in the Colville Delta study area (see *Time-lapse Cameras* under Colville Delta Study Area, above).

Since camera-monitoring began in 2010, we have observed intruding loons on images at

0–80% (mean = 44 ± 9.2%, *n* = 36 nests) of camera-monitored territories in the NE NPR-A study area. In 2014, we saw intruders at 36% of camera-monitored nests in the NE NPR-A study area (*n* = 11 nests), less than the 5-year mean. We also documented intruding loons in the Colville Delta study area (see *Time-lapse Cameras* under Colville Delta Study Area, above) and theorize that these interactions may be attempts by intruding loons to takeover occupied territories.

Brood Fate

During the monitoring surveys after hatch, we observed broods of 2 chicks with 2 of 11 (18%) Yellow-billed Loon pairs that hatched young, and single chick broods with 7 (64%) pairs (Table 20). Two additional pairs hatched ≥1 chick based on the presence of eggshell fragments at the nest, but those chicks did not survive to the following monitoring survey. Camera images confirmed the presence of 1 chick at 1 of those nests. No other

Table 20. Number of Yellow-billed Loon chicks observed during weekly aerial surveys, NE NPR-A study area, Alaska, 2014. Age of chicks determined by camera-monitoring presented in parentheses where it differed from age determined from aerial surveys.

Territory	July			August				September				No. Chicks Hatched	Age (d) When Last Seen[c]	Brood Fate[c]
	16	23	30	6	13	20	27	3	10	19[a]	24[b]			
51	0[d]	–[e]	0	–	–	–	–	–	–	–	–	1	4	Failed
53	1	1	1	1	1	1	1	1	1	U	1	1	74	Active
54	1	1	1	1	1	1	1	1	1	U	U	1	60	Active
58[f]	1[g,h]	1	1	1	1[h]	1	1[h]	1	1	U	1	1	74 (75)	Active
59[f]	1	1	1	1	1[h]	1	1	1	1	U	U	1	60 (61)	Active
61[f]	1	1	1	1	1	1	1	0	0	–	–	1	50	Failed
79[f]	2	1	1	1[h]	1[h]	1	1	1[h]	1	U	U	2	60	Active
88[f]	1	1	1	1	1	1	1	1	0	U	U	1	53	Unknown
90	Inc[i]	Inc	Inc	1	1	1	1	1	1	U	1	1	53	Active
94[f]	0[d]	0	–	–	–	–	–	–	–	–	–	1	4	Failed
95[f]	2[g,h]	2	2	1	1	1	1	1[h]	1	1	1	2	74 (73)	Active
Totals														
Broods of 2	2	1	1	0	0	0	0	0	0	0	0	2	–	–
Broods of 1	5	7	7	9	9	9	9	8	7	1	4	9	–	–
Unknown	0	0	0	0	0	0	0	0	1	7	4	–		
Chick Loss	2	1	0	1	0	0	0	1	U	U	U	–	–	–

[a] U = Unknown on territories where no young were seen; visibility was poor during survey due to high winds; detection of young was extremely reduced
[b] U = Unknown on territories where no young were seen; chicks may have fledged
[c] Final brood fate and age last seen was determined on 10 September, unless chicks were seen on 24 September
[d] No chick observed; at least 1 egg hatched based on eggshell evidence at the nest; assumed 1 chick died
[e] Territory not surveyed due to proximity of occupied hunting camp
[f] Nest monitored by camera
[g] Adult brooding chick(s)
[h] No chick(s) observed; chick(s) assumed present based on subsequent aerial surveys
[i] Inc = loon incubating at the time of the survey

additional chicks were detected on camera images. We recorded 20 nests in the NE NPR-A study area during the nesting, monitoring, and brood-rearing surveys in 2014. A minimum of 13 chicks were produced at 20 nests (0.65 chicks/nest; Table 13).

One goal of brood monitoring was to estimate juvenile recruitment, or how many chicks survived to fledging. Juvenile recruitment in 2014 was difficult to estimate due to poor weather during the 19 September survey. Winds >32 km/h (20 mi/h) reduced detection of loons to the extent that only 1 brood was resighted in the NE NPR-A study area. Although 4 broods were found the following week on 24 September, another 4 were not found. Since chicks may fledge by late September (Johnson et al. 2014a) and given the poor sightability on 19 September, we could not determine if the missing broods failed to survive or fledged. The last reliable survey with good sightability was conducted on 10 September so we used data from that survey to estimate juvenile recruitment. On 10 September, 7 of 11 Yellow-billed Loon pairs that hatched young retained 1 chick; none retained both chicks (Table 20). The fate of the brood at 1 nest was unknown. The brood was not seen on 10 September, but poor survey conditions on its lake prevented us from verifying its absence. Excluding the brood and nest with the unknown brood fate, a minimum of 7 chicks were produced at 19 nests (0.37 chicks/nest) according to nesting, monitoring, and brood-rearing surveys (Table 13). The number of chicks that survived to fledging in 2014 was below the 6-year mean of 0.43 ± 0.10 chicks/nest.

PACIFIC AND RED-THROATED LOONS

Colville Delta Study Area

We counted 280 Pacific Loons and 31 nests, and 34 Red-throated Loons and 3 nests in the Colville Delta study area during the nesting survey for Yellow-billed Loons in 2014 (Figure 20, Appendix E). During the brood-rearing survey, we recorded 174 adult Pacific Loons and 26 broods, and 37 adult Red-throated Loons and 7 broods (Figure 20, Appendix E). Because these counts of Pacific and Red-throated loons were recorded incidentally during Yellow-billed Loon surveys, they reflect the general distribution of these species in the Colville Delta study area but are not accurate estimates of the abundance of these species. Nests of Red-throated Loons are not easily detected from the air and are found on small ponds, which were not surveyed systematically in this study. Pacific Loons breed on small and large lakes and were clearly the most abundant loon on the delta in 2014 and in previous years. Because the survey focused on lakes larger than those typically occupied by Pacific and Red-throated loons for nesting and brood-rearing, densities have not been calculated for these 2 species.

NE NPR-A Study Area

Pacific Loons also were the most abundant and widespread loon species breeding in the NE NPR-A study area in 2014. On the loon nesting survey, we recorded 369 adult Pacific Loons and 50 nests, and 15 Red-throated Loons and 1 nest (Figure 20, Appendix E). During the brood-rearing survey, 358 adult Pacific Loons and 53 broods were found (Figure 20, Appendix E). Twenty-four Red-throated Loons and 1 brood were found in the NE NPR-A study area during the brood-rearing survey.

DISCUSSION

The numbers of Yellow-billed Loon adults on the Colville Delta study area has been increasing over the last 15 years (Figure 16). Over the same period, nests and young have been highly variable (Figure 16). Because of variation in annual survey areas, we lack consistent data to evaluate trends in the NE NPR-A study area. The extent of flooding during spring breakup on the Colville River delta appears to strongly influence nesting and chick production (Johnson et al. 2014a). Since 2000, 3 of the 5 years with the lowest numbers of nests and broods occurred during years when the Colville River flooded substantial portions of the delta during spring breakup (2000, 2001, and 2013). The arrival of loons on territories is closely associated with the formation of moats around thawing ice on lakes (North 1986), but pairs also must wait until water levels on lakes drop to allow use of nest sites (this study). Water levels on lakes during spring may be elevated from local runoff due to snowmelt or from the Colville River spilling over its banks. During years with high water levels, nesting can be delayed or prohibited at some territories, either of which can affect production of young (Johnson et

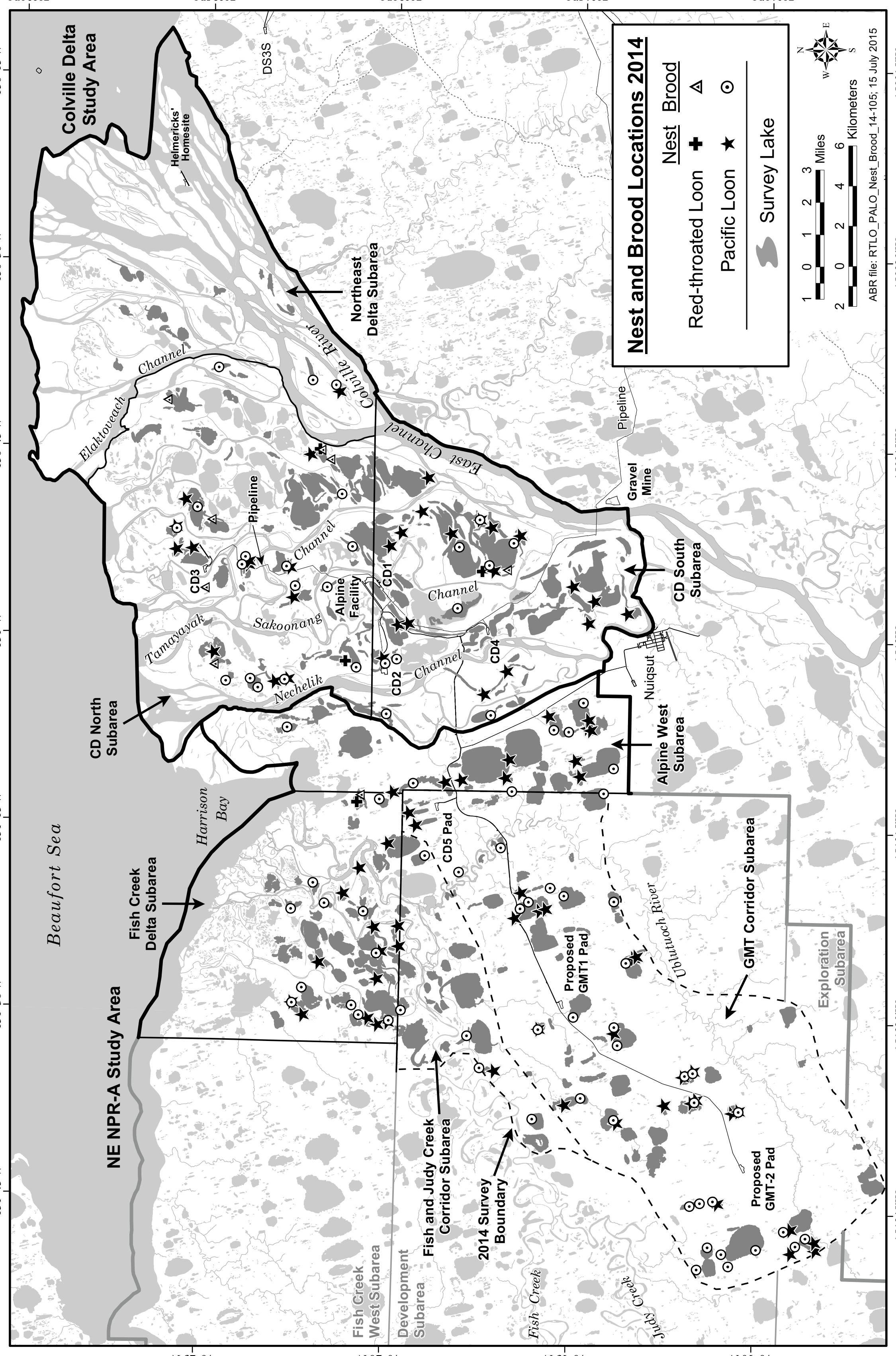


Figure 20. Red-throated and Pacific loon nests and broods, Colville Delta and NE NPR-A study areas, Alaska, 2014.

al. 2013a). The population trend for adults in the Colville Delta study area exhibits a positive growth rate of 1.019 (2% annual growth) (ln(y) = 0.019x – 34.63, R^2 = 0.31. P = 0.03; Table 21), which is significantly different from equilibrium. When 3 extreme flood years are excluded, the growth rate of adults increases to 1.032 (ln(y) = 0.032x – 61.04), which is similar to that estimated across the ACP during 2003–2012 (1.050, 90% CI = 1.006–1.096; Stehn et al. 2013). In contrast, annual numbers of nests and young are highly variable with depressed levels in 3 years of major flooding, and show no significant trends whether flood years were included or excluded from the analysis.

The positive growth in number of adults and relative unchanging number of breeding territories, nests, and young suggest a population that is habitat-limited for nesting. Yellow-billed Loons show clear preferences for habitats that are not uniformly distributed across the Colville River delta (Earnst et al. 2006, this study). Time-lapse cameras have documented intense physical interactions between territory holders and intruding loons, which likely are attempts by intruders to usurp occupied territories. Territorial fights also have been observed in Common and Pacific loons and appear to be a high-risk activity that may result in injury, such as sternal punctures, or death caused by drowning or internal organ damage (McIntyre and Barr 1997, Sjölander 1978). Territory takeover through aggressive usurpation has been documented in Common Loons and is thought to be an important means of territory acquisition in that species (McIntyre and Barr 1997, Piper et al. 2000). The high frequency of aggressive interactions we have observed in the last 5 years (some leading to nest failure when loons left their nests unattended; see below) in concert with an increasing adult population in the breeding area and static productivity suggest a possible density-dependent effect on reproduction. Within the Colville Delta and NE NPR-A study areas, we suspect suitable breeding lakes have become limiting under pressure from a growing Yellow-billed Loon population.

Yellow-billed Loons arrive on the Colville River delta in slowly growing numbers each year but productivity (as measured by the number of young) has not kept pace. Productivity does not appear to be limited by the number of returning adults, rather it is affected by how many of those adults initiate nests (territory occupancy by nests), how many nests hatch (nesting success), and, lastly, how many chicks fledge (fledging success). A fraction of loons that arrive on the delta initiate nests and, as a result, territory occupancy by nests has ranged from 40 to 90% (mean = 66 ± 3.5%, n = 15 years). Apparent nesting success has been quite variable but, on average, slightly more than half of the nests hatch, (mean = 54 ± 4.7%, range = 26–74%, n = 10 years). The percentage of chicks that survive to fledging (mid-September) in most years is relatively high (mean = 70%, SE = 6.3%, range = 40–90%, n = 7 years), although, 2014 had

Table 21. Population growth rate regressions of Yellow-billed Loon adults, nests, and young, Colville Delta study area, Alaska. Separate regressions run with data from all years (2000–2014) and with flood years excluded (non-flood years = 2002–2012, 2014).

VARIABLE Time Period	Growth Rate	90% CI	R^2	P-value	Regression
ADULTS					
All Years	1.019	1.006–1.034	0.306	0.03	In(y) = 0.019x – 34.63
Non-flood Years	1.032	1.013–1.052	0.486	0.01	ln(y) = 0.032x – 61.04
NESTS					
All Years	0.998	0.970–1.026	0.001	0.90	In(y) = -0.002x + 7.26
Non-flood Years	1.006	0.982–1.031	0.020	0.66	ln(y) = 0.006x – 9.104
YOUNG					
All Years	1.044	0.965–1.123	0.068	0.35	In(y) = 0.044x – 85.06
Non-flood Years	0.964	0.887–1.040	0.070	0.41	In(y) = -0.036x + 75.86

the lowest chicks/nest to date. Our results suggest that chick production (numbers surviving to or near fledging) in most years is limited by events during the nesting period.

Camera monitoring and weekly aerial surveys have increased our understanding of how breeding season dynamics affect annual outcomes. For example, the number of chicks produced has been very low during the last 2 years but for different reasons. In 2013, few Yellow-billed Loons nested because water levels were high on nesting lakes due to extreme flooding from the Colville River. Although nesting success and brood survival were high that year, chick production (total chicks) was limited by the low number of nests established. In contrast, in 2014 the number of nests was well above average, but nesting success was less than half the long-term mean, resulting in low chick production. Furthermore, only 40% of the young that hatched in 2014 survived until fledging, reducing chick production at fledging to the lowest since brood monitoring surveys began in 2008.

Images from time-lapse cameras revealed that nest predation was the primary cause of the extremely low nesting success in the Colville Delta study area in 2014. Most predation occurred either while nesting pairs were off nests interacting with intruding loons or after brown bears flushed loons from nests to eat eggs. Over all years, Glaucous Gulls and Parasitic Jaegers were the most commonly recorded nest predators, taking eggs at 51% of the camera monitored nests that lost eggs (n = 86 nests). Those avian predators, along with Common Ravens, preyed exclusively on unattended nests. In the Colville Delta study area in 2014, 5 loon pairs were not incubating at the time of predation, 4 of which were seen fighting intruding loons. Since 2010, intruders have been identified at 52% of camera-monitored nests (n = 136 nests) on the Colville Delta and NE NPR-A study areas. Incubating loons almost always leave nests to interact with intruders and, as a result, have significantly lower mean incubation constancies on days with intruders (91.2 ± 1.5%) compared to days without intruders (95.6 ± 0.5%; Wilcoxon Signed Rank Test, $P < 0.001$, n = 61 nests), which provides avian predators with increased opportunities to attack unattended nests. Decreased nesting success and low chick production may be density-dependent effects of population growth, if incidences of intruding loons are increasing at the same time.

Density-dependence, however, likely has no influence on the frequency of nest predation by mammals, particularly, brown bears, wolverines, and red foxes, which are able to displace Yellow-billed Loons from their nests. Brown bears are becoming important predators of Yellow-billed Loon nests on the Colville River delta and appear to be either increasing in abundance, or increasing their activity on the delta. We documented bear predation at 1 nest in 2009, 2 nests in 2013, and ≥3 nests in 2014 (the predators at 3 other nests were not captured on images). We saw bears in images at 11 territories in 2014, which represents a 4- to 5-fold increase over previous years when bears where seen. We have no data to suggest that the brown bear population on the Colville River delta is increasing, but images from time-lapse cameras suggest that individual bears may be spending more time seasonally on the delta. In 2014, the vast majority of bear sightings on images were of a sow with 2 medium-sized cubs. A single adult bear also was seen. Loons do not defend nests against bears; if a nest is detected by a bear, it likely fails. Bears also can be indirectly responsible for predation. Images showed that loons typically flushed from nests when bears were within 400 m, which exposed nests to other predators until the bear left the area. In 2014, a bear flushed a Yellow-billed Loon, allowing a Glaucous Gull to eat the eggs. We suspect that bears are attracted to the delta by the Snow Goose colonies, which apparently are growing rapidly in the CD North and Northeast subareas (see BROOD-REARING GEESE, Colville Delta Study Area, below). Bears were seen at almost twice as many loon territories in the CD North and Northeast Delta subareas compared with CD South where there are no colonies. Relatively low numbers of Snow Goose nests in the NE NPR-A study area (1 colony of ~100 nests in the Fish Creek Delta subarea) may also explain why brown bears were not recorded on time-lapse images at loon nests in the NE-NRPA study area in 2014.

A study conducted in 1983 and 1984 on the Colville River delta found that Yellow-billed Loons had high reproductive success compared to other loon species, as a result of low egg loss and high chick survival (North 1986). In both 1983 and

1984, apparent nesting success was 94% because nest predation was almost non-existent. An increase in the number of Glaucous Gulls, red foxes, and brown bears (described above) may be partly responsible for the increase in nest predation rates on the Colville River delta since the 1983 and 1984 studies. In the current study, gulls took eggs in 35% of the predation events. Gull numbers across the Arctic Coastal Plain have been increasing annually at 2% over the last 21 years (Stehn et al. 2013), and at 5% annually in the Colville Delta study area, since 2002 (see GLAUCOUS AND SABINE'S GULLS, below). An increase in gull abundance could reduce nest or chick survival, because gulls prey on eggs as well as young loon chicks (Johnson et al. 2010).

The number of red foxes potentially has increased on the Colville River delta since the 1980s as they have in Prudhoe Bay (Stickney et al. 2014). In our Colville Delta study area, red foxes caused nest failure at 21% of the failed nests since camera monitoring began in 2008 (n = 57 nest failures). North (1986) did not observe predation by red foxes and only mentions that they were uncommon on the delta. During the Alpine Avian Monitoring Program (1998–2001), arctic foxes were seen almost daily, whereas red foxes were uncommon and first observed in 1999 (Johnson et al. 2003a). During that study, video cameras deployed on swan and goose nests recorded that 72% of foxes seen on camera were arctic foxes, only 16% were red foxes, and 12% were unidentified. The percentage of red foxes increased to 58% of the foxes seen on cameras monitoring loon nests in the Colville Delta study area in 2010–2014 (n = 72 fox occurrences). At the same time, the red fox population has grown in the Prudhoe Bay area, where red fox dens began to outnumber arctic fox dens in 2010 (Stickney et al. 2014). An increase in the number of red foxes would have a negative effect on nest productivity because red foxes are more effective predators of Yellow-billed Loon nests than arctic foxes. Camera images from this study show arctic foxes passing by Yellow-billed Loon nests and, less frequently, trying (unsuccessfully) to flush loons from nests; we have not seen arctic foxes taking loon eggs on camera images or otherwise. In contrast, red foxes frequently have flushed loons from nests to steal eggs.

TUNDRA SWAN

COLVILLE DELTA STUDY AREA

Distribution and Abundance

Tundra Swan abundance matched long-term mean values on the Colville Delta study area in 2014; however, productivity was the second lowest since we began surveys in 1992. During the swan nesting survey, 413 swans, including 99 pairs, were counted in the Colville Delta study area. The total swan count in 2014 was somewhat greater than the 21-year mean of 382 swans found in the study area, but well within the range of counts previously recorded (range = 208–749, SE = 159). Twenty-three swan nests were found in the Colville Delta study area in 2014 (Figures 21 and 22, Table 22), a greatly reduced number from the annual mean of 34 nests (range = 14–55, SE = 2.1, n = 21 years). Five nests were located in the CD North subarea, 7 were in the CD South subarea, and 11 were in the Northeast Delta subarea. Twenty-two additional swan nests were discovered during helicopter-based loon surveys of portions of the Colville Delta study area, but are not included in the nest count from the swan survey (Table 22) for consistency with data presentations from previous years.

For the second consecutive year, productivity of Tundra Swans on the Colville Delta study area was very low. During the 2014 brood-rearing survey, only 14 Tundra Swan broods were observed in the Colville Delta study area (Figure 21), far fewer than the 21-year mean of 24 broods. The smallest number of broods counted since surveys were initiated in 1992 was 13, in 2013. Apparent nesting success was 61% (14 broods/23 nests), in contrast to the long-term mean of 71% (Table 22). The mean brood size in the Colville Delta study area of 2.1 young/brood in 2014 was less than the long-term mean of 2.5; the total of 29 young counted in 2014 was only half that of the mean of 58 young per year. Nesting success in the adjacent Kuparuk Oilfield also was much lower during 2014 (57%, 83 broods/145 nests) than the 26-year mean for that study area (77%; Stickney et al. 2015). In contrast to the mean brood size on the Colville Delta study area in 2014, mean brood size in the Kuparuk study area (2.3 young/brood) was equal to its long-term mean.

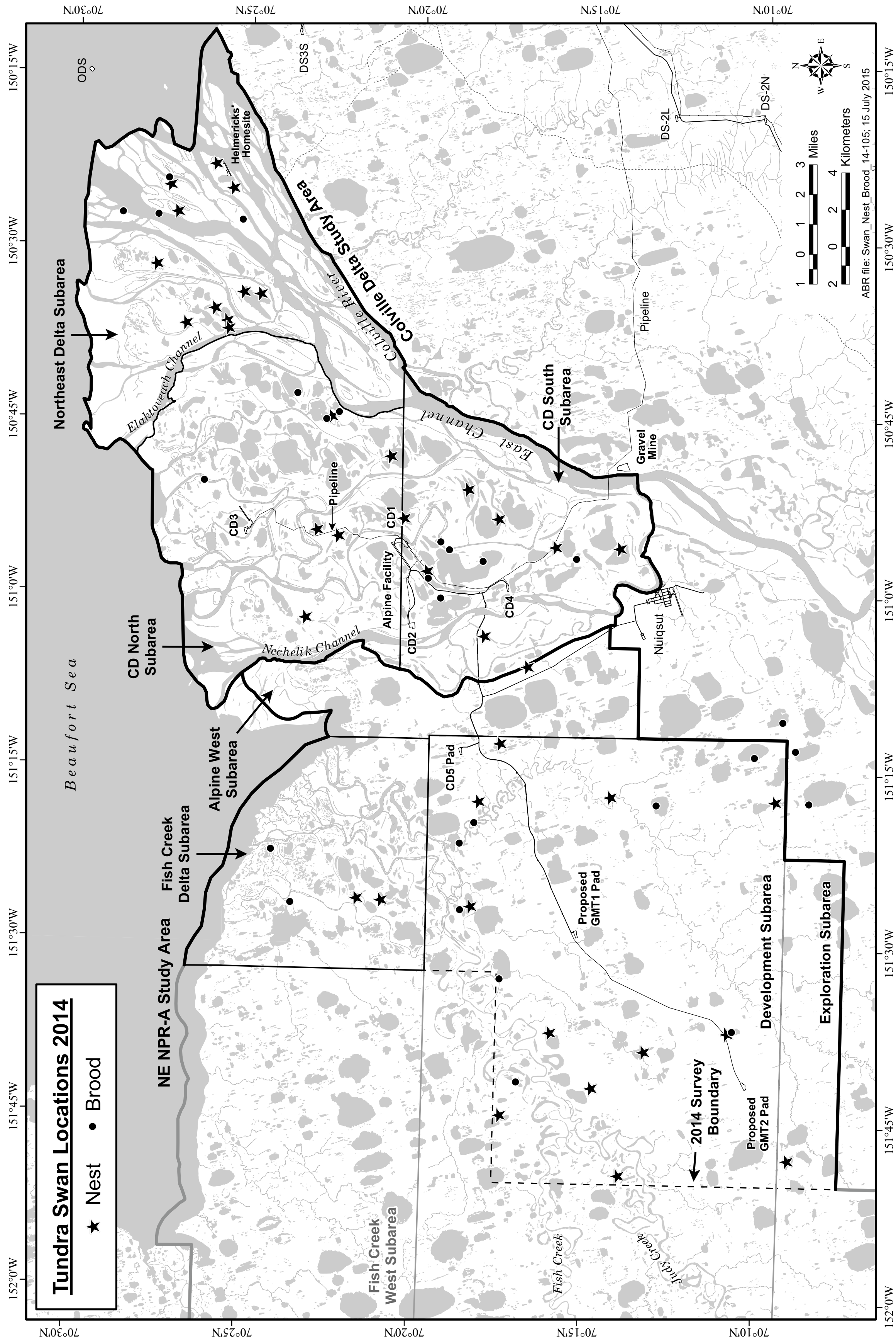


Figure 21. Tundra Swan nests and broods, Colville Delta and NE NPR-A study areas, Alaska, 2014.

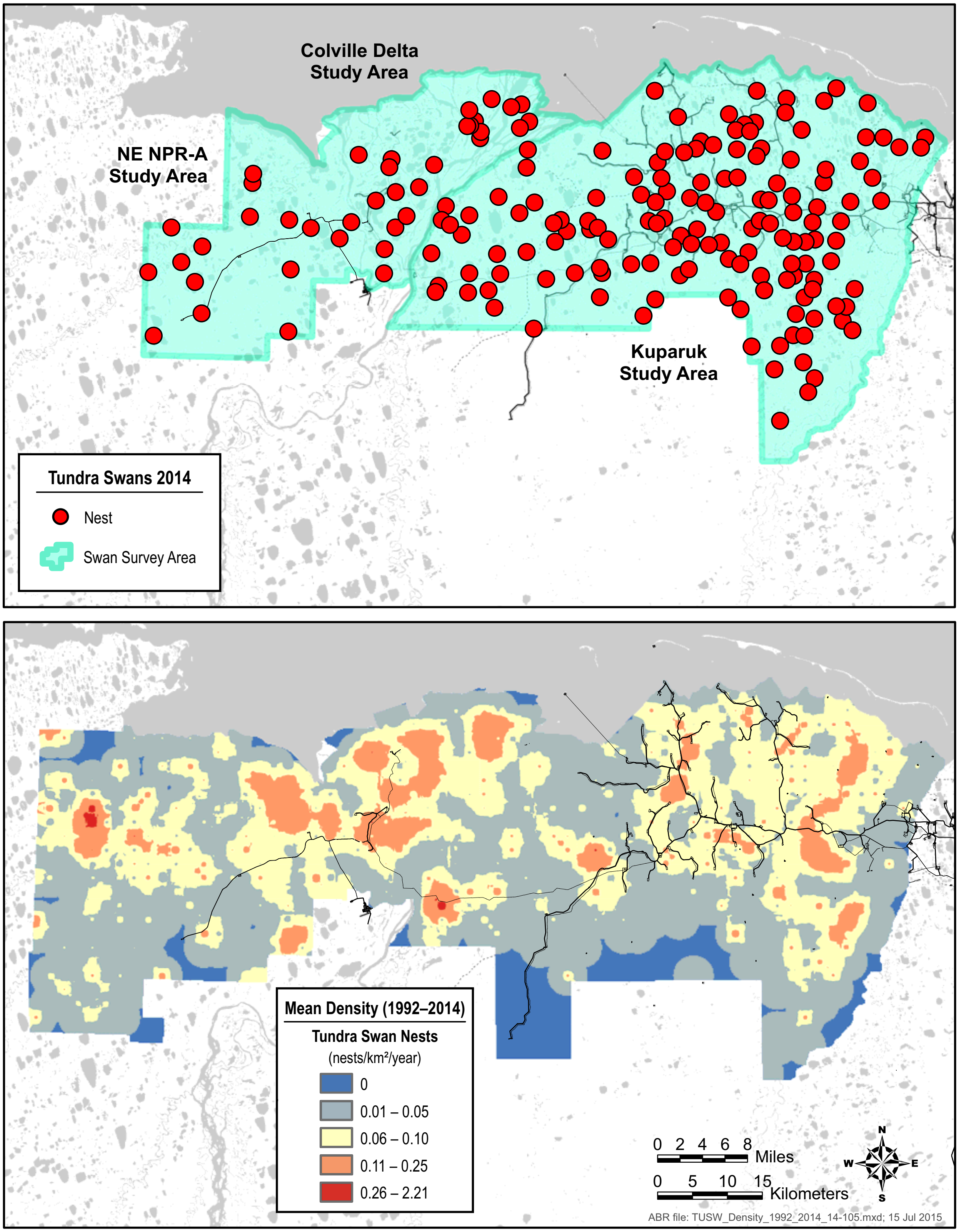


Figure 22. Tundra Swan nest locations in 2014 (top) and mean density distribution of nests in the Kuparuk, Colville Delta, and NE NPR-A study areas, 1992–2014 (bottom). Kuparuk data from Stickney et al. 2015.

Table 22. Number and density of Tundra Swan nests and broods during aerial surveys, Colville Delta study area, Alaska, 1992–2014.

Year	No. Nests	Density (nests/km²)[a]	No. Broods	Density (broods/km²)[a]	Mean Brood Size	Nesting Success (%)
1992	14	0.03	15	0.03	2.5	100
1993	17	0.04	14	0.03	2.6	82
1995	38	0.07	25	0.05	3.7	66
1996	45	0.08	32	0.06	3.4	71
1997	32	0.06	24	0.04	2.5	75
1998	31	0.06	22	0.04	2.4	71
2000	32	0.06	20	0.04	1.9	63
2001	27	0.05	22	0.04	1.7	81
2002	55	0.10	17	0.03	3.2	31
2003	43	0.08	27	0.05	2.4	63
2004	37	0.07	42	0.08	2.1	100
2005	35	0.06	36	0.07	2.3	100
2006	29	0.05	35	0.06	2.0	100
2007	42	0.08	33	0.06	2.6	79
2008	36	0.07	23	0.04	2.5	64
2009	40	0.07	17	0.03	2.8	43
2010	25	0.04	15	0.03	2.5	60
2011	35	0.06	29	0.05	2.8	83
2012	40	0.07	23	0.04	2.2	58
2013	39	0.07	13	0.02	1.8	33
2014	23	0.04	14	0.03	2.1	61
Mean	34	0.06	24	0.04	2.5	71
SE	2.1	<0.01	1.9	<0.01	0.1	4.7

[a] Area surveyed = 552.2 km²

Habitat Use

Habitat selection was evaluated for 717 Tundra Swan nests recorded on the Colville Delta study area since 1992 (Table 23). Although some nest sites were used in multiple years (and thus not annually independent locations), we were not able to distinguish these sites objectively from others where nests were close, but not in exactly the same location, in consecutive years. None of the nest sites were used in all the years that surveys were conducted. Previous investigations have reported that 21–49% of swan nests are located on mounds used during the previous year (Hawkins 1986, Monda et al. 1994) and that nest sites reused from previous years were slightly more successful than new nest sites (Monda et al. 1994). Therefore, deletion of multi-year nest sites from selection analysis could bias the results towards habitats used by less experienced or less successful pairs. Instead, we have chosen to include all nest sites, while recognizing that all locations may not be annually independent.

Tundra Swans on the Colville Delta study area used a wide range of habitats for nesting. Over 21 years of surveys, Tundra Swans nested in 20 of 24 available habitats, of which 9 habitats were preferred and 7 were avoided (Table 23). Eighty percent of the nests were found in the preferred habitats: Salt Marsh, Salt-killed Tundra, Deep Open Water with Islands or Polygonized Margins,

Table 23. Habitat selection by nesting and brood-rearing Tundra Swans, Colville Delta study area, Alaska, 1992, 1993, 1995–1998, and 2000–2014.

SEASON Habitat	No. of Nests/Broods	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
NESTING					
Open Nearshore Water	0	0	1.8	avoid	
Brackish Water	10	1.4	1.2	ns	
Tapped Lake with Low-water Connection	2	0.3	4.0	avoid	
Tapped Lake with High-water Connection	7	1.0	3.7	avoid	
Salt Marsh	41	5.7	3.0	prefer	
Tidal Flat Barrens	7	1.0	10.6	avoid	
Salt-killed Tundra	76	10.6	4.6	prefer	
Deep Open Water without Islands	19	2.6	3.3	ns	
Deep Open Water with Islands or Polygonized Margins	45	6.3	1.8	prefer	
Shallow Open Water without Islands	5	0.7	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	0.3	0.1	ns	low
River or Stream	1	0.1	15.0	avoid	
Sedge Marsh	2	0.3	<0.1	prefer	low
Deep Polygon Complex	95	13.2	2.4	prefer	
Grass Marsh	15	2.1	0.3	prefer	low
Young Basin Wetland Complex	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	53	7.4	7.2	ns	
Patterned Wet Meadow	268	37.4	17.7	prefer	
Moist Sedge-Shrub Meadow	33	4.6	2.2	prefer	
Moist Tussock Tundra	9	1.3	0.6	prefer	low
Tall, Low, or Dwarf Shrub	11	1.5	5.0	avoid	
Barrens	16	2.2	13.8	avoid	
Human Modified	0	0	0.1	ns	low
Total	717	100	100		
BROOD-REARING					
Open Nearshore Water	1	0.2	1.8	avoid	
Brackish Water	28	5.6	1.2	prefer	
Tapped Lake with Low-water Connection	67	13.5	4.0	prefer	
Tapped Lake with High-water Connection	57	11.4	3.7	prefer	
Salt Marsh	32	6.4	3.0	prefer	
Tidal Flat Barrens	4	0.8	10.6	avoid	
Salt-killed Tundra	35	7.0	4.6	prefer	
Deep Open Water without Islands	41	8.2	3.3	prefer	
Deep Open Water with Islands or Polygonized Margins	16	3.2	1.8	prefer	
Shallow Open Water without Islands	6	1.2	0.4	prefer	low
Shallow Open Water with Islands or Polygonized Margins	2	0.4	0.1	ns	low
River or Stream	32	6.4	15.0	avoid	
Sedge Marsh	0	0	<0.1	ns	low
Deep Polygon Complex	14	2.8	2.4	ns	
Grass Marsh	12	2.4	0.3	prefer	low
Young Basin Wetland Complex	0	0	<0.1	ns	low
Old Basin Wetland Complex	0	0	<0.1	ns	low
Nonpatterned Wet Meadow	28	5.6	7.5	ns	
Patterned Wet Meadow	63	12.7	18.5	avoid	
Moist Sedge-Shrub Meadow	7	1.4	2.2	ns	
Moist Tussock Tundra	1	0.2	0.6	ns	low
Tall, Low, or Dwarf Shrub	8	1.6	5.0	avoid	
Barrens	44	8.8	13.8	avoid	
Human Modified	0	0	0.1	ns	low
Total	498	100	100		

[a] Use = (groups / total groups) × 100
[b] 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
[c] Expected number < 5

Sedge Marsh, Deep Polygon Complex, Grass Marsh, Patterned Wet Meadow, Moist Sedge-Shrub Meadow, and Moist Tussock Tundra. Nests occurred most frequently in Patterned Wet Meadow (37% of all nests), Deep Polygon Complex (13%), and Salt-killed Tundra (11%).

Habitat selection also was evaluated for 498 Tundra Swan broods recorded on the Colville Delta study area since 1992 (Table 23). Nine habitats were preferred: Brackish Water, both types of Tapped Lakes, both types of Deep Open Water, Salt Marsh, Salt-killed Tundra, Shallow Open Water without Islands, and Grass Marsh. Broods were seen most frequently in Tapped Lake with Low-water Connections (13% of all broods), Patterned Wet Meadow (13%), and Tapped Lake with High-water Connections (11%).

The high use of salt-affected or coastal habitats (e.g., Brackish Water, Salt Marsh, Salt-killed Tundra, Tidal Flat Barrens, and Tapped Lake with Low-water Connection) by brood-rearing swans reflects an apparent seasonal change in distribution or habitat preference, in that approximately 34% of all swan broods on the delta were in salt-affected habitats, compared with only 19% of all nests (Table 23). Similar patterns have been reported by previous investigators (Spindler and Hall 1991, Monda et al. 1994).

NE NPR-A STUDY AREA

Distribution and Abundance

Apparent nesting success was similar in the NE NPR-A and Colville Delta study areas in 2014. During the 2014 nesting survey, 266 swans were counted in the NE NPR-A study area, including 81 pairs, of which 15 pairs were nesting (Table 24). Most nests (11) and broods (8) were found in the Development subarea (Figure 21, Appendix H). An additional 7 nests were discovered during helicopter-based loon surveys of limited portions of the NE NPR-A study area. Nesting success in 2014 was 67% (10 broods/15 nests), only slightly higher than on the Colville Delta study area (61%) but 10% higher than the Kuparuk area in 2014 (57%, Stickney et al. 2015). Mean brood size in the NE NPR-A study area in 2014 was 2.0 young, slightly less than the mean brood size in the Colville Delta study area. Both these study areas produced smaller average brood sizes than in Kuparuk (mean = 2.3 young/brood).

Table 24. Number and density of Tundra Swan nests and broods during aerial surveys, NE NPR-A study area, Alaska, 2001–2014.

	Nests		Broods			
Year[a]	No.	Density (nests/km²)	No.	Density (broods/km²)	Mean Brood Size	Nesting Success (%)
2001	32	0.03	21	0.02	2.5	66
2002	43	0.04	27	0.02	2.0	63
2003	43	0.04	18	0.02	2.3	42
2004	63	0.06	37	0.03	2.1	59
2005	48	0.03	37	0.02	2.1	77
2006	72	0.05	50	0.03	2.0	69
2008	69	0.04	34	0.02	2.6	49
2009	73	0.05	52	0.03	2.3	71
2011	12	0.04	10	0.03	1.9	83
2012	19	0.06	12	0.04	2.0	63
2013	15	0.05	13	0.04	1.9	87
2014	15	0.02	10	0.01	2.0	67

[a] Survey area differed among years: 2001–2003 = 1091.6 km², 2004–2009, 1571.1 km², 2011–2013 = 322.1 km², and 2014 = 667.65 km²

Habitat Use

We evaluated habitat selection for 347 Tundra Swan nests recorded in the NE NPR-A study area since 2001 (Table 25). Tundra Swans nested in 21 of 26 available habitats, but preferred only 4 habitats—Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, Grass Marsh, and Young Basin Wetland Complex—in which 63 nests were located.

Swan broods in NE NPR-A study area were attracted to large, deep waterbodies, similar to the habitats where swan broods were found on the Colville Delta study area. Habitat selection was evaluated for 220 Tundra Swan broods recorded in the NE NPR-A study area since 2001 (Table 25). Tundra Swan broods used 22 of 26 available habitats. We recorded 138 broods (63%) in the 5 preferred habitats: Tapped Lake with Low-water Connection, both types of Deep Open Water, River or Stream, and Grass Marsh.

DISCUSSION

Aerial surveys for nesting Tundra Swans have been conducted in the portion of the central Beaufort Sea coastal plain lying between the Kuparuk River on the east and the NE NPR-A on the west since 1989. The distribution of nests across this area is far from uniform, with concentrations of nests in more favorable habitat, near large lakes (Stickney et al. 2002), and on river deltas and near streams such Fish and Judy creeks (Figure 22). Long-term, the Colville River delta study area supports larger areas of concentrated nesting by Tundra Swans compared to the NE NPR-A and Kuparuk Oilfield study areas, although nest densities in 2014 did not entirely follow this pattern.

Since we began aerial surveys for Tundra Swans on the Colville River delta in 1992, counts of pairs, nests, and brood numbers have shown a fair degree of variability, but the overall trend has been one of slow increase. The lowest count of nests was 14 in 1992, the first year of surveys and the highest count of nests was 55 in 2002, producing a growth rate of 1.013, which was not significantly different from 1.0 ($\ln(y) = 0.013x - 23.12$, $R^2 = 0.085$, $P = 0.20$, $n = 21$ years). The total number of pairs counted during nesting surveys has increased more strongly, from a low of 42 in 1992 to a high of 118 pairs in 2011. The number of pairs has grown significantly at an annual rate of 1.030 ($\ln(y) = 0.030x - 81.47$, $R^2 = 0.548$, $P < 0.001$, $n = 21$). The growth rate in number of adults is slightly positive (1.01), whereas broods and young have slightly negative growth rates (0.998 and 0.985, respectively), but none of these rates differs significantly from equilibrium (1.0; $P \geq 0.269$), probably because of high annual variation in the number of non-breeding adults in the Colville Delta study area and in reproductive success in the cases of broods and young. The increase in Tundra Swans appears to be widespread; the growth observed on the Colville Delta study area generally matches the growth seen to the east in the Kuparuk Oilfield (Stickney et al. 2013). Moreover, the growth rate for adult Tundra Swans across the Arctic Coastal Plain (1.046) also is statistically significant (Stehn et al. 2013). The trend in these several areas probably tracks the population status of Tundra Swans wintering on the East Coast of the United States, which is where swans from the Arctic Coastal Plain return after breeding and where long-term growth has been recorded from 1955 to 2000 (Serie and Bartonek. 1991, Serie et al. 2002).

Aerial surveys for nesting and brood-rearing Tundra Swans in the NE NPR-A study area have been flown during 13 years since 2001; no surveys were flown in 2007 and 2010. The area surveyed has varied widely during that period. Out of the 5 subareas of the NE NPR-A study area, only Alpine West has been flown every survey year (Appendix H). Swan surveys in 2011–2014 were flown over a much smaller area than in previous years, although the 2014 study area was expanded slightly from that of 2011–2013. Thus, comparisons of nest and brood counts in the NE NPR-A study area among years are not very meaningful because of differing survey areas.

The low productivity of swans on the Colville Delta study area in 2014 was in contrast to that observed in NE NPR-A study area and the Kuparuk Oilfield. Poor nesting success and relatively low brood sizes produced the second smallest number of young ever recorded on the Colville Delta study area, after the smallest number in 2013. Direct evidence of the cause or causes of nest failures is lacking. Higher predation rates in the Colville Delta study area could produce the

Table 25. Habitat selection by nesting and brood-rearing Tundra Swans, NE NPR-A study area, Alaska, 2001–2006, 2008– 2009, and 2011–2014.

SEASON Habitat	No. of Nests/Broods	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
NESTING					
Open Nearshore Water	0	0	1.1	avoid	low
Brackish Water	8	2.3	1.2	ns	low
Tapped Lake with Low-water Connection	1	0.3	0.8	ns	low
Tapped Lake with High-water Connection	3	0.9	0.6	ns	low
Salt Marsh	13	3.7	2.1	ns	
Tidal Flat Barrens	1	0.3	1.5	ns	
Salt-killed Tundra	3	0.9	0.8	ns	low
Deep Open Water without Islands	13	3.7	6.5	avoid	
Deep Open Water with Islands or Polygonized Margins	29	8.4	5.1	prefer	
Shallow Open Water without Islands	3	0.9	1.0	ns	low
Shallow Open Water with Islands or Polygonized Margins	19	5.5	1.6	prefer	
River or Stream	0	0	1.2	avoid	low
Sedge Marsh	6	1.7	1.7	ns	
Deep Polygon Complex	0	0	0.1	ns	low
Grass Marsh	8	2.3	0.3	prefer	low
Young Basin Wetland Complex	7	2.0	0.3	prefer	low
Old Basin Wetland Complex	27	7.8	8.0	ns	
Riverine Complex	1	0.3	0.3	ns	low
Dune Complex	1	0.3	0.9	ns	low
Nonpatterned Wet Meadow	15	4.3	3.0	ns	
Patterned Wet Meadow	40	11.5	11.2	ns	
Moist Sedge-Shrub Meadow	58	16.7	21.5	avoid	
Moist Tussock Tundra	86	24.8	25.1	ns	
Tall, Low, or Dwarf Shrub	5	1.4	3.1	ns	
Barrens	0	0	1.1	avoid	low
Human Modified	0	0	<0.1	ns	low
Total	347	100	100		
BROOD-REARING					
Open Nearshore Water	1	0.5	1.1	ns	low
Brackish Water	6	2.7	1.2	ns	low
Tapped Lake with Low-water Connection	7	3.2	0.8	prefer	low
Tapped Lake with High-water Connection	0	0	0.6	ns	low
Salt Marsh	3	1.4	2.1	ns	low
Tidal Flat Barrens	1	0.5	1.5	ns	low
Salt-killed Tundra	0	0	0.8	ns	low
Deep Open Water without Islands	60	27.3	6.5	prefer	
Deep Open Water with Islands or Polygonized Margins	47	21.4	5.1	prefer	
Shallow Open Water without Islands	2	0.9	1.0	ns	low
Shallow Open Water with Islands or Polygonized Margins	3	1.4	1.6	ns	low
River or Stream	19	8.6	1.2	prefer	low
Sedge Marsh	3	1.4	1.7	ns	low
Deep Polygon Complex	0	0	0.1	ns	low
Grass Marsh	5	2.3	0.3	prefer	low
Young Basin Wetland Complex	1	0.5	0.3	ns	low
Old Basin Wetland Complex	7	3.2	8.0	avoid	
Riverine Complex	1	0.5	0.3	ns	low
Dune Complex	1	0.5	0.9	ns	low
Nonpatterned Wet Meadow	10	4.5	3.0	ns	
Patterned Wet Meadow	11	5.0	11.2	avoid	
Moist Sedge-Shrub Meadow	20	9.1	21.5	avoid	
Moist Tussock Tundra	6	2.7	25.1	avoid	
Tall, Low, or Dwarf Shrub	5	2.3	3.1	ns	
Barrens	1	0.5	1.1	ns	low
Human Modified	0	0	<0.1	ns	low sample
Total	220	100	100		

[a] Use = (groups / total groups) × 100

[b] 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

[c] Expected number < 5

geographic differences observed among study areas in 2014. Red foxes are more common on large river systems (Jones and Theberge 1982) such as the Colville River delta than in NE NPR-A. In 2013, the frequency of red foxes on camera images from Yellow-billed Loon nests in the Colville Delta study area was >6 times the frequency at nests in the NE NPR-A study area (ABR, unpublished data). The density of identified red fox dens on the Colville Delta study area was >5 times higher (1 den/61 km²) than in the NE NPR-A study area (1 den/340 km²; Johnson et al. 2005). Brown bears are known to take eggs and nestlings (Hechtel 1985) and tend to frequent riparian areas (Shideler and Hechtel 2000), which are extensive in the Colville Delta study area but also abundant along Fish and Judy creeks and the Ublutuoch River in NE NPR-A study area.

During annual eider pre-nesting aerial surveys of the Colville Delta and adjacent NE NPR-A study areas (12–14 June 2014), as many as 5 individual brown bears were observed, including a female bear with 2 yearlings and two single adult-size bears. The increase in the population of Snow Geese nesting on the outer Colville River delta may be attracting brown bears, as the eggs of these colonial nesters can be a substantial seasonal food source. Snow Goose colonies on Howe Island on the Sagavanirktok River delta and on the Ikpikpuk River delta became targeted by brown bears once the colonies became large enough to offer a consistent, easily exploited food source (Burgess, et al, 2012, Johnson 2000). Results from the 2014 nest survey of the Colville Delta study area indicated a near absence of swan nests in the northern portion (CD North subarea) of the study area. However, during loon surveys on 19 June, at least 10 swan nests were observed in the CD North subarea; all were missing by 24 June. Similarly, in 2013 the CD North subarea was populated by swan nests during the nesting survey in June, but was nearly devoid of broods in August, suggesting nest depredation occurred subsequent to the nesting survey.

Brown bears and red foxes depredated Yellow-billed Loon nests in 2013 and 2014, and both are likely predators of swan nests. Brown bears took at least 3 camera-monitored Yellow-billed Loon nests in the Colville Delta study area in 2014 and appear to be more active in the Colville Delta and NE NPR-A study areas in recent years (see predation accounts in YELLOW-BILLED LOON section above). Brown bears may have taken a number of swan nests as well. However, we can only speculate on causes of low productivity in the Colville Delta study area in 2014 as we lack direct observations of swan nest predation or nest failures.

GEESE

NESTING GEESE

Distribution and Abundance

Three species of geese nested on the 40 10-ha plots in the CD5 area in 2014, and their combined nests accounted for 90% of all nests recorded (Figure 23, Table 26). White-fronted Geese were the most abundant nesting waterfowl (28.7 nests/km^2), followed by Cackling/Canada Geese (5.8 nests/km^2), and 1 Snow Goose nest. White-fronted and Cackling/Canada Goose nests were widely distributed among the plots. We found the greatest number of White-fronted Goose nests on plots 20 (8 nests), 11 (7 nests), and 16 (7 nests; Table 27). Three plots contained no White-fronted Goose nests. The mean number of White-fronted Goose nests found per plot was 2.85 ± SE 0.33.

Habitat Use

Geese nested in 6 of the 16 habitats found on the nest plots (Table 28). White-fronted Geese nested in 6 habitats, though 83% of these nests were in just 3 habitats: Old Basin Wetland Complex, Patterned Wet Meadow, and Moist Sedge-Shrub Meadow. White-fronted Goose nests were the only nests for which sample size was adequate to test for habitat selection. Nesting White-fronted Geese used all habitats in proportion to availability and no habitat types were preferred or avoided by White-fronted Geese (Table 29). Cackling/Canada Geese nested in 4 habitats, with most nests located in close proximity to waterbodies in the wetter habitats available (Figure 23; Table 28).

Nest Initiation and Incubation

Data collected from temperature-sensing eggs, along with egg floatation data provided histories used for survival analyses (below) and activity budgets for incubating White-fronted

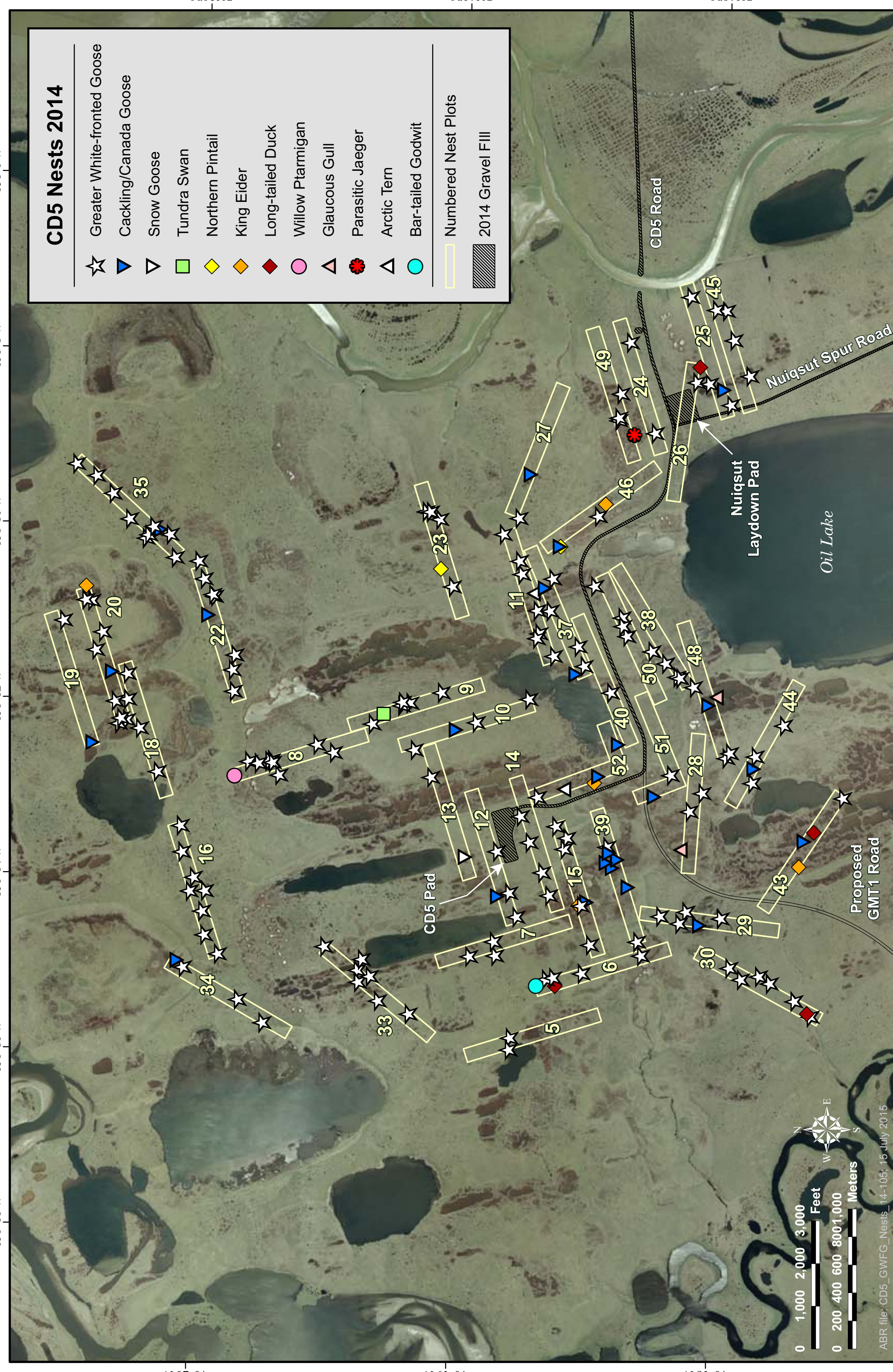


Figure 23. Nest locations of Greater White-fronted Geese and other species on nest plots at CD5, NE NPR-A study area, Alaska, 2014.

Table 26. Number and density of nests and apparent nesting success for birds at CD5, NE NPR-A study area, Alaska, 2014.

	Nests on Plot		All Nests[a]				
Species	Total	Density[b] (nests/km²)	Total	Successful	Failed	Unknown	Nesting Success[c] (%)
Greater White-fronted Goose	114	28.7	147	84	62	1	58
Snow Goose	1	0.3	1	-	1	-	0
Cackling/Canada Goose[d]	23	5.8	26	10	14	2	42
Tundra Swan	1	0.3	1	-	1	-	0
Northern Pintail	1	0.3	2	-	2	-	0
King Eider	3	0.8	5	4	1	-	80
Long-tailed Duck	3	0.8	4	1	2	1	33
Willow Ptarmigan	1	0.3	1	–	–	–	–
Bar-tailed Godwit	1	0.3	1	–	–	–	–
Glaucous Gull	–	–	2	–	–	–	–
Arctic Tern	2	0.5	2	–	–	–	–
Parasitic Jaeger	–	–	1	–	–	–	–
Total	150	38.1	193				

[a] Includes nests located outside plot boundaries
[b] Density calculations based on 3.97 km² search area
[c] Apparent nesting success = no. nests successful [hatching ≥1 egg] / (no. successful + no. failed) × 100
[d.] Nest belonging to either Cackling or Canada goose

Geese (Tables 30 and 31). We floated eggs from 132 White-fronted Goose nests and 14 Cackling/Canada Goose nests in 2014 to estimate nest age and the start of incubation. The median date of nest initiation (first egg laid) for White-fronted Geese in 2014 was 5 June (range = 25 May–12 June, n =132 nests), 5 d earlier than in 2013 (median = 10 June, range = 31 May–16 June, n = 106 nests). Twenty-two nests (17%) were estimated to have been initiated on 5 June 2014. By the time we began nest searching on 9 June, 98% of the White-fronted Geese had initiated nesting. Average clutch size for nests with complete clutches (eggs > 3 d old) was 3.8 eggs (SE = 0.17, n = 88 nests). The median start date of incubation for White-fronted Geese was 9 June (range = 30 May–15 June), 5 d earlier than in 2013 (range = 6–18 June; Figure 24).

The dates of nest initiation for Cackling/Canada Geese ranged from 25 May to 11 June, and the median date was 2 June (n = 14), earlier than the median date in 2013 (8 June, n = 6 nests). Clutch size was 4.3 eggs (SE = 0.36, n = 12 nests) for nests with complete clutches, an increase from 3.0 eggs in 2013, but only a few nests had complete clutches that year (n = 4). The median date that incubation started for Cackling/Canada Geese was 9 June (range = 27 May–14 June), the same as for White-fronted Geese.

Temperature-Sensing Eggs

Of the 40 thermistors installed in White-fronted Goose nests, 25 produced usable temperature data (Tables 30 and 31). Eighteen nests were monitored to day of hatch and brood departure and 6 nests were monitored to day of failure, including 1 nest that failed the same day it was found. Fifteen data-loggers failed to provide data for a number of reasons. Eight data loggers had programming errors, 4 had thermistor cords that became disconnected, 2 were not activated, and 1 was damaged by water (Tables 30 and 31). In 2014, no data loggers were lost to predators. A total of 27 (68%) nests instrumented with thermistors were successful and 13 nests failed.

Table 27. Number of nests and apparent nesting success of Greater White-fronted Geese by nest plot at CD5, NE NPR-A study area, Alaska, 2014.

	Number of Nests				Nesting Success[a] (%)
Plot	Total	Successful	Failed	Unknown	
5	1	0	1	0	0
6	4	2	2	0	50
7	2	2	0	0	100
8	5	1	4	0	20
9	5	4	1	0	80
10	2	1	1	0	50
11	7	6	1	0	86
12	3	1	2	0	33
13	0	–	–	–	–
14	2	2	0	0	100
15	5	4	1	0	80
16	7	2	4	1	33
18	3	2	1	0	67
19	0	–	–	–	–
20	8	5	3	0	63
22	5	0	5	0	0
23	4	4	0	0	100
24	2	1	1	0	50
25	2	1	1	0	50
26	1	1	0	0	100
27	0	–	–	–	–
28	1	1	0	0	100
29	4	1	3	0	25
30	5	4	1	0	80
33	5	2	3	0	40
34	3	1	2	0	33
35	6	4	2	0	67
37	2	2	0	0	100
38	2	0	2	0	0
39	2	0	2	0	0
40	1	1	0	0	100
43	1	0	1	0	0
44	1	0	1	0	0
45	3	2	1	0	67
46	1	1	0	0	100
48	1	1	0	0	100
49	3	3	0	0	100
50	3	3	0	0	100
51	1	0	1	0	0
52	1	1	0	0	100
Total	114	66	47	1	
Mean	2.85				59
SE	0.33				6
n (plots)	40				37

[a] Apparent nesting success = no. nests successful [hatching ≥1 egg] / (no. successful + no. failed) × 100

Table 28. Habitat use (%) by nesting birds on nest plots at CD5, NE NPR-A study area, Alaska, 2014.

Habitat	Greater White-fronted Goose[a]	Cackling/Canada Goose[b]	Snow Goose	Tundra Swan	Northern Pintail	King Eider[a]	Long-tailed Duck	Willow Ptarmigan	Arctic Tern	Bar-tailed Godwit	Total Nests	Habitat Use (%)
Shallow Open Water with Islands or Polygonized Margins	2	35	0	0	0	33	0	0	0	0	11	7
Sedge Marsh	3	9	0	0	0	0	0	0	0	0	6	4
Old Basin Wetland Complex	25	30	0	0	0	67	33	0	100	0	40	27
Patterned Wet Meadow	35	26	100	100	100	0	67	100	0	0	52	35
Moist Sedge-Shrub Meadow	23	0	0	0	0	0	0	0	0	100	27	18
Moist Tussock Tundra	12	0	0	0	0	0	0	0	0	0	14	9
Total Nests	114	23	1	1	1	3	3	1	2	1	150	100

[a] Includes nests identified to species from feather and down samples
[b] Nest belonging to either Cackling or Canada goose

Table 29. Habitat selection by nesting Greater White-fronted Geese on nest plots at CD5, NE NPR-A study area, Alaska, 2014.

Habitat	Area (km^2)	No. of Nests	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
Deep Open Water without Islands	0.01	0	0	0.2	ns	low
Deep Open Water with Islands or Polygonized Margins	0.02	0	0	0.5	ns	low
Shallow Open Water without Islands	0.03	0	0	0.7	ns	low
Shallow Open Water with Islands or Polygonized Margins	0.21	2	1.8	5.3	ns	
River or Stream	<0.01	0	0	<0.01	ns	low
Sedge Marsh	0.08	4	3.5	2.0	ns	
Grass Marsh	<0.01	0	0	<0.01	ns	
Old Basin Wetland Complex	0.93	28	24.6	23.3	ns	
Riverine Complex	<0.01	0	0	0.1	ns	low
Nonpatterned Wet Meadow	0.01	0	0	0.2	ns	
Patterned Wet Meadow	1.13	40	35.1	28.2	ns	
Moist Sedge-Shrub Meadow	1.02	26	22.8	25.5	ns	
Moist Tussock Tundra	0.52	14	12.3	13.0	ns	
Tall, Low, Dwarf Shrub	0.01	0	0	0.2	ns	low
Barrens	<0.01	0	0	<0.01	ns	
Human Modified	0.03	0	0	0.7	ns	
Total	4.00	114	100	100		

[a] Use (%) = (nests / total nests) × 100
[b] Significance calculated from 1,000 simulations at $\alpha = 0.05$; ns = not significant, prefer = significantly greater use than availability, and avoid = significantly less use than availability
[c] Expected number <5

Incubation behavior

Excluding the day of instrumentation, hatch, and failure, temperature-sensing eggs monitored nest temperature in 25 nests for <1–23 d (mean = 14.2 [± 1.5] d). When egg thermistors were deployed in White-fronted Goose nests, the incubating birds were flushed from their nests. The length of time females at successful nests took to return to incubate after installing an egg thermistor averaged 152.8 ± 31.6 min (range = 35–630 min, n = 18 nests; Table 30). Contrary to expectations, females from nests that later failed took less time to return to nests (mean = 80 ± 13.8 min, range = 35–135 min, n = 7 nests; Table 31). Incubation constancy was high, with females spending 99.3 ± 0.2% (n = 17) of the time incubating at hatched nests and 99.0 ± 0.3% (n = 4) at failed nests. Only 4 nests had incubation constancies <99% and 2 of those failed. At both hatched and failed nests, White-fronted Goose females took an average of 1.5 (± 0.1) incubation recesses each day (n = 17 nests), with only 2 females leaving the nest more than twice/day. Recess durations ranged from 8.6 to 26.7 min (mean= 14.8 ± 1.2 min), and the longest recess intervals were taken by females with successful nests (Table 30). Because the exact time of failure could not be discerned from temperature records, the day of nest failure was not included in summaries. Females at failed nest might have lower nest attendance on the day of failure, but we could not measure attendance on the day of failure without data on the time of nest failure.

Nesting Success

In 2014, 90% of the 147 White-fronted Goose nests were active when found. Our methods do not account for egg loss but we did find evidence of egg loss at 5 active nests during the nest search. Apparent nesting success (the percentage of nests hatching ≥1 egg) for all White-fronted Goose nests, including those outside plots, was 58% (Table 26), which was slightly higher than the apparent nesting success in 2013 (53%, n = 110 nests). Among the other geese nesting in the CD5 nest search area in 2014, 42% of Cackling/Canada Goose nests hatched (10 of 24 nests), and the single Snow Goose nest failed (Table 26).

We compared 6 models of DSR for monitored White-fronted Goose nests (probability of a nest surviving 1 d), including the constant model (no covariates), year, date, clutch age, and the additive models of year + date, and year + clutch age. Each of the models was plausible given the data with none clearly superior (AICc weights = 0.09–0.31), thus the date of failure and clutch age of nests did not improve the model predictions over that of the model with year (AICc weight = 0.31) or the second best model (AICc weight = 0.26), which was the constant model. Here, we report on the highest ranked model, which included year as a covariate. The DSR for monitored nests in 2014 was 0.984 ± 0.006, compared with 0.969 ± 0.008 in 2013. The estimated probability a nest would survive a 24 d incubation period in 2014 was 0.682 (95% CI = 0.423–0.891) and in 2013 it was 0.46 (95% CI = 0.276–0.638). The apparent nesting success for nests with temperature sensors in 2014 (68%, n = 40 nests) was the same as the estimate from DSR based on a 24-d incubation period. We did not calculate DSR for other species of geese or waterfowl.

OTHER NESTING BIRDS

Distribution and Abundance

We found a total of 193 nests belonging to 12 identified species of birds on and near nest plots in 2014 (Figure 23; Table 26). Only 10% of these nests belonged to species other than geese. Among the large waterbirds nesting on plot, we found 3 nests of King Eiders, 3 nests of Long-tailed Ducks, 1 nest of Northern Pintails, and 1 Tundra Swan nest. Other species nesting on or off plot included Glaucous Gull (2 nests), Arctic Tern (2 nests), Parasitic Jaeger (1 nest), Willow Ptarmigan (1 nest), and Bar-tailed Godwit (1 nest).

King Eider (0.8 nests/km²) was the only species of eider found nesting and the third most common large waterbird nesting on plot, tied with Long-tailed Duck (Figure 23; Table 26). Only 1 eider nest failed to hatch young of 5 nests found on and off plot (apparent nesting success = 80%). Several Red-throated Loons were observed in lakes near study plots or flying overhead, but we did not locate any nests for this species. No Yellow-billed Loons or Spectacled Eiders or their nests were seen in or near study plots.

Habitat Use

Nests of species other than geese were located in 4 of 6 habitats that were used by geese (Table 28). King Eider nests were found in Old Basin Wetland complex and Shallow Open Water with Island. Bar-tailed Godwit was the only species other than White-fronted Goose to nest in Moist Tussock Tundra, and all of the other waterfowl nests but 1 (Long-tailed Duck in Old Basin Wetland Complex) were found in Patterned Wet Meadow. The greatest species diversity was found in Patterned Wet Meadow (4 species, including goose species), followed by Old Basin Wetland Complex (3 species).

NEST PREDATORS

Jaegers and gulls were the most abundant and widespread nest predators observed during predator scans and incidental observations on nest plots (Appendix I). Potential nest predators seen on plots during predator scans included jaegers (53% of 226 sightings; 1.50 ± 0.43 jaegers/scan), Glaucous Gulls (45%; 1.26 ± 0.36/ scan), Common Ravens (3%; 0.05 ± 0.08/scan), and owls (<1%; Short-eared Owl; 0.01 ± 0.03 per scan). Parasitic Jaegers accounted for 78% of the jaeger observations (n = 120), followed by Pomarine (14%) and Long-tailed jaegers (8%). Similar proportions of the avian predators also were observed outside plots (within 300m of plot boundaries) as were observed on plots during predator scans. No mammal predators recorded were on plot. During predator scans we observed only 1 arctic fox and 1 brown bear sow with 2 cubs off plot (Appendix I). During predator scans, jaegers were seen on 33 of 40 plots and Glaucous Gulls were seen on 32 of 40 plots (Appendix I).

Table 30. Nest history and incubation activity of Greater White-fronted Geese at successful nests monitored by thermistors on nest plots at CD5, NE NPR-A study area, Alaska, 2014.

Nest	Date Instrumented	Incubation Start Date	No. Eggs	Date of Hatch	No. Days Monitored[a]	Initial Time Off Nest[b] (min)	Incubation Constancy[a] (%)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)
101	10 June	9 June	2	30 June	19	140	99.7	1.0	26.7
102[c,d]	10 June	9 June	3	3 July	0	–	–	–	–
113	12 June	8 June	2	30 June	17	120	98.9	1.7	13.0
119	13 June	9 June	5	5 July	19	85	99.6	1.5	12.8
122	14 June	13 June	2	8 July	23	90	99.5	1.2	11.0
127	14 June	8 June	3	1 July	16	160	99.5	1.0	24.0
130	14 June	6 June	2	24 June	9	100	99.0	1.4	13.0
132	15 June	9 June	5	27 June	11	235	99.3	1.7	11.5
138	15 June	11 June	3	6 July	21	150	99.7	1.0	19.0
143[c,d]	16 June	12 June	4	6 July	0	–	–	–	–
202[c]	10 June	9 June	6	3 July	0	–	–	–	–
216	13 June	9 June	4	3 July	19	40	99.3	1.8	8.6
217	14 June	10 June	3	2 July	17	630	96.2	3.5	15.6
220	14 June	10 June	4	3 July	18	35	99.6	1.3	13.1
313	12 June	11 June	5	6 July	23	265	99.6	2.0	17.5
315[c,d]	12 June	8 June	3	2 July	0	–	–	–	–
317	13 June	12 June	5	3 July	19	150	99.3	1.6	13.9
321[c,d]	15 June	7 June	5	1 July	0	–	–	–	–
413[c,d]	10 June	9 June	3	3 July	0	–	–	–	–
417	11 June	7 June	3	1 July	19	150	99.5	1.1	16.1
423	11 June	10 June	3	4 July	<1	180	–	–	–
425[c,d]	12 June	11 June	4	5 July	0	–	–	–	–
434[c,d]	13 June	5 June	3	28 June	14	–	–	–	–
442	15 June	11 June	3	3 July	17	75	99.6	1.2	10.0
501	11 June	5 June	2	27 June	15	80	99.5	1.5	16.7
504	11 June	10 June	4	5 July	23	65	99.6	1.1	9.7
505[c,d]	11 June	10 June	2	4 July	0	–	–	–	–
Median/ Average	13 June	9 June	3.4	3 July	12.3	152.8	99.3	1.5	14.8
SE	–	–	0.2	–	1.7	31.6	0.2	0.1	1.2
n	27	27	27	27	18	18	17	17	17

[a] Excludes day of instrumentation, hatch, or fledging
[b] Amount of time female was off nest following flush and instrumentation
[c] Thermistor data could not be used because data-logger was damaged, thermistor detached from data-logger, or data was otherwise erroneous
[d] Hatch date from egg-float data

Table 31. Nest history and incubation activity of Greater White-fronted Geese at failed nests monitored by thermistors on nest plots at CD5, NE NPR-A study area, Alaska, 2014.

Nest	Date Instrumented	Incubation Start Date	No. Eggs	Date of Failure	No. Days Monitored[a]	Initial Time Off Nest[b] (min)	Incubation Constancy[a] (%)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)
108[c]	12 June	11 June	3	–	0	–	–	–	–
110	12 June	8 June	3	14 June	1	65	100	0	0
112[c]	12 June	11 June	3	–	0	–	–	–	–
137	15 June	9 June	4	27 June	11	135	98.9	1.7	13.8
140[c]	16 June	10 June	5	–	0	–	–	–	–
205	10 June	9 June	5	18 June	7	35	99.9	1.0	10.0
213[c]	13 June	7 June	2	–	0	–	–	–	–
302[c]	10 June	9 June	2	–	0	–	–	–	–
324	16 June	10 June	5	16 June	<1	65	–	–	–
326	16 June	12 June	4	8 July	21	90	97.3	3.3	11.9
432[c]	13 June	9 June	4	–	0	–	–	–	–
448	16 June	15 June	4	16 June	<1	90	–	–	–
453[c]	17 June	11 June	3	–	0	–	–	–	–
Median/ Average	13 June	10 June	3.6	17 June	3.1	80	99.0	1.5	8.9
SE	–	–	0.3	–	1.8	13.8	0.3	0.4	1.7
n	13	13	13	7	4	7	4	3	3

[a] Excludes day of instrumentation and failure
[b] Amount of time female was off nest following flush and instrumentation
[c] Thermistor data could not be used because data-logger was damaged, thermistor detached from data-logger, or data was otherwise erroneous

From incidental observations during nest searching, jaegers were the most common predators (59% of 78 sightings) on plot, followed by Glaucous Gulls (35%; Appendix I). Besides jaegers and gulls, other avian predators were seen most often flying over plots and only occasionally landing on plot. The only mammals observed during nest searching were a brown bear sow and cub. Fewer predators were seen incidentally during nest searching than during predator scans. Observers were focused on detecting predators during predator scans, whereas observers recording incidental counts were focused on nest searching. Despite the differences in methods, we recorded a similar species composition of predators during scans and nest searching (Appendix I).

Short-eared Owl was the only raptor observed in 2014. In 2013, in addition to Short-eared Owls we recorded Northern Harriers, and Bald Eagles were reported depredating loon nests during camera monitoring.

Notably absent from predator observations were red foxes, which were observed at camera monitored loon nests in the NE NPR-A study area. Mammalian predators are likely less abundant than avian predators, but some species such as arctic foxes may be more active at night, when we are not on nesting plots, or they may avoid humans. Daytime predator scans likely are biased against observing mammalian predators, therefore the mammalian component of nest predators was under-represented using this technique.

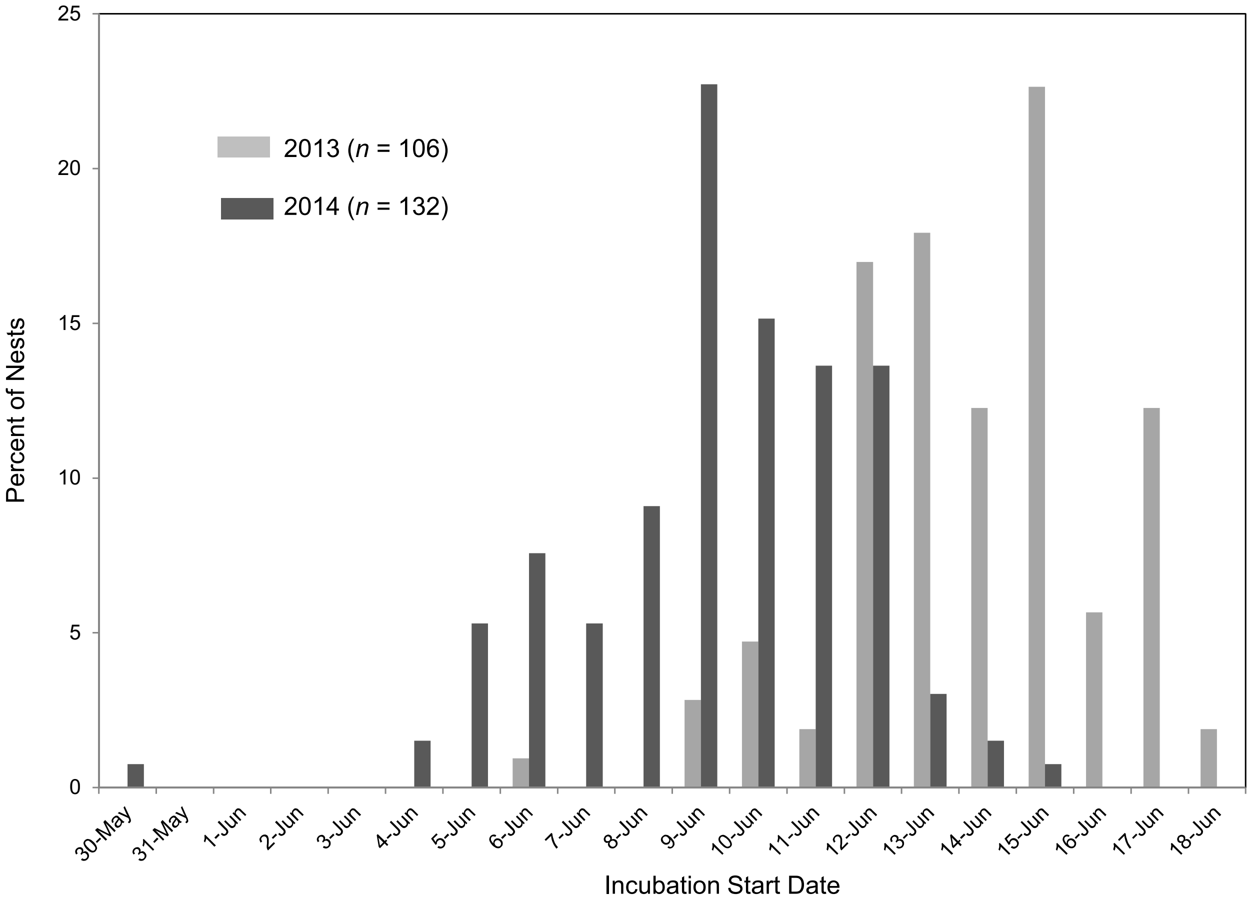


Figure 24. Incubation start dates estimated by egg-flotation for Greater White-fronted Goose nests (%) at CD5, NE NPR-A study area, Alaska, 2013–2014.

BROOD-REARING GEESE

Colville Delta Study Area

Distribution and Abundance

Brant production in the Colville Delta study area, as measured by numbers of adults and young on brood surveys, was high in 2014. During the goose brood-rearing aerial survey in 2014, we counted 2,067 Brant (1,049 adults and 1,018 young) in 13 groups in the Colville Delta study area (Figure 25, Table 32). All Brant groups included broods, and goslings comprised 49% of the total number of birds. Surveys producing comparable data on the total number of Brant (adults + goslings) have been conducted in the area as far back as 1989 (this study, Bayha et al. 1992) and the total count in 2014 was well above the 18-year mean of combined adults and goslings (1,385 ± 252 [mean ± SE]) (Table 32). Adults were enumerated separately from goslings in 16 years, and the total count of adult Brant in 2014 was the fourth highest on record (Figure 26, Table 32). The percentage of goslings in 2014 was above average, and the total count of goslings was the fourth highest in 15 years that goslings were recorded. Five groups containing 780 Brant (440 adults and 340 goslings) were located in the Northeast Delta subarea, and 8 groups totaling 1,287 Brant (609 adults and 678 goslings) were located in the CD North subarea. The largest group in the study area (198 adults and 262 goslings) was found in the CD North subarea, and was in captivity during a banding operation during the time of the survey (D. Ward, USGS, personal communication).

Snow Geese rebounded slightly following sharp declines in 2013. A total of 2,545 Snow

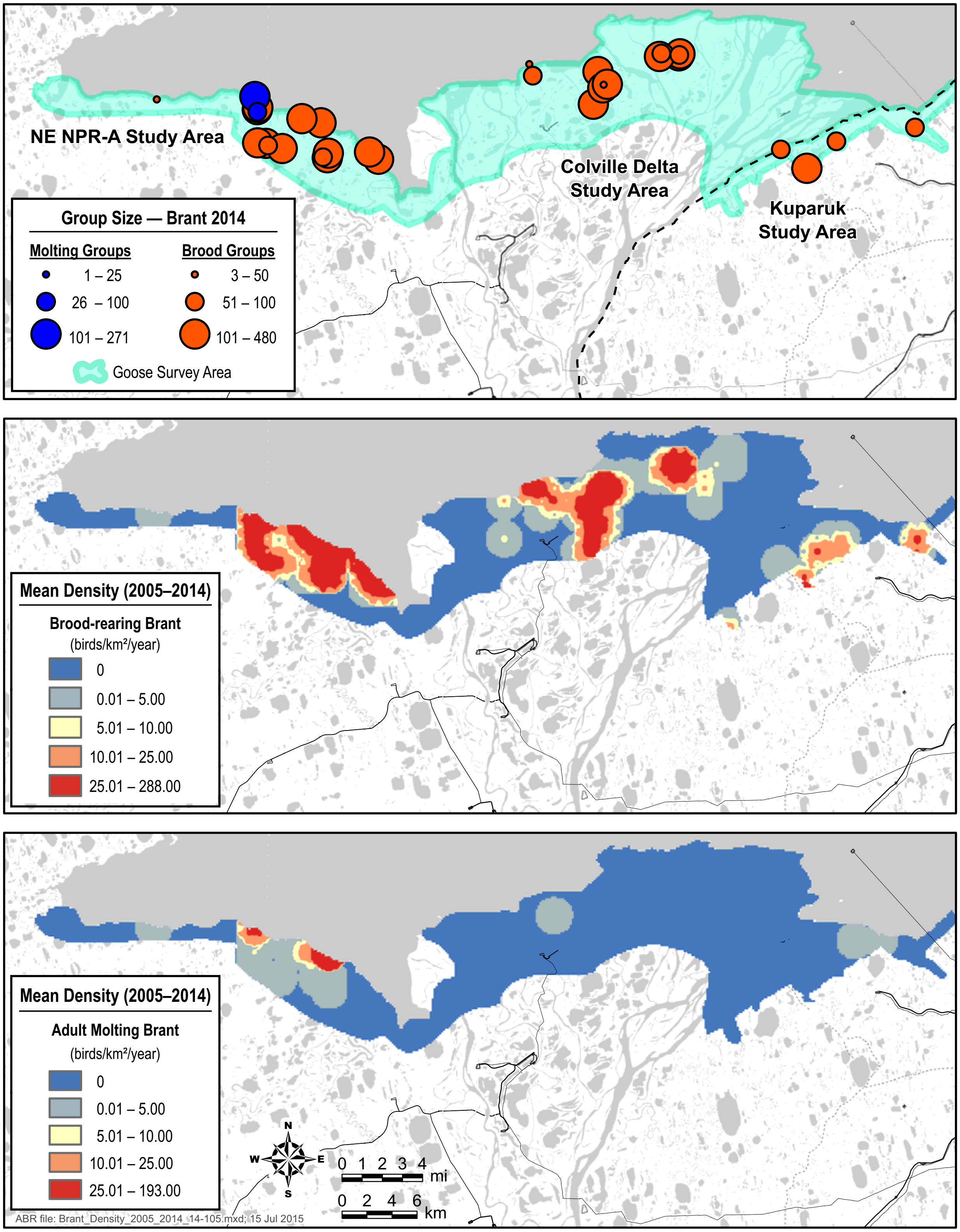


Figure 25. Brant brood-rearing and molting locations in 2014 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE NPR-A study areas, Alaska, 2005–2014 (middle and bottom). Kuparuk data from Stickney et al. 2015.

Table 32. Number of Brant adults and goslings during aerial surveys, Colville Delta study area, Alaska, 1998–2014. Data for 1988–1991 from Bayha et al. 1992; subsequent data from this study.

Year	Total Birds	Adults	Goslings	% Goslings	No. Groups	Survey Date(s)
1988[a]	no data[b]	173[b]	no data[b]	no data[b]	no data	25, 26 July
1989[a]	197[c,d]	no data[c,d]	no data[c,d]	no data[c,d]	no data	12, 13 August
1990[a]	628[c]	no data[c]	no data[c]	no data[c]	no data	2, 9 August
1991[a]	460[c,d]	no data[c,d]	no data[c,d]	no data[c,d]	no data	1, 7 August
1992	0	0	0	-	0	27 July
1993	720	347	373	51	5	27 July
1995	1,480	768	712	48	6	4 August
1996	993	478	515	52	7	25 July
1998	1,974	836	1,138	58	13	27 July
2005	3,847	2,360	1,487	39	16	30 July
2006	438	296	142	32	4	29 July
2007	980	446	534	54	6	30 July
2008	3,637	1,839	1,798	49	22	29 July
2009	679	501	178	26	6	29 July
2010	1,474	746	728	49	11	28 July
2011	1,986	1,221	765	39	10	28 July
2012	1,145	776	369	32	7	26 July
2013	795	439	356	45	9	26 July
2014	2,067	1,049	1,018	49	13	31 July
Mean	1,385	857	708	44.5	9.3	
SE	252	157	127	2.4	1.3	

[a] Data are from an average of 2 surveys (Bayha et al. 1992)
[b] Only adults were counted. Goslings were observed but were not enumerated
[c] Adults and goslings were not differentiated by the observer
[d] Includes birds in flight (90 on 12 August 1989, and 50 on 7 August 1991)

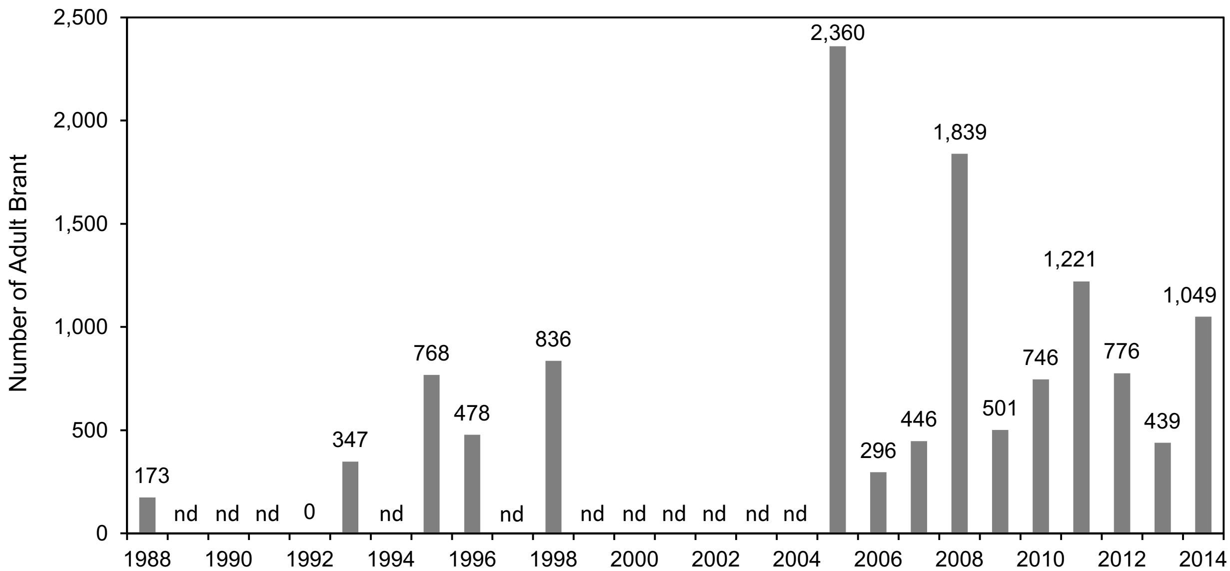


Figure 26. Number of adult Brant during the brood-rearing period, Colville Delta study area, Alaska, 1988–2014. Data for 1988–1991 are from Bayha et al. 1992; subsequent data from this study.

Geese (1,524 adults and 1,021 goslings) were counted in 26 groups in the Colville Delta study area (Figure 27, Table 33). The number of goslings was equal to the 10-year mean since 2005 and the number of adults was above average, but totals of each remained well below the maximal numbers observed prior to 2013. In 2014, 20 groups (77%) contained broods, but goslings comprised only 40% of the total number of birds, which was the third lowest gosling percentage since Snow Geese were added to the survey in 2005. Fourteen groups containing 1,370 Snow Geese (813 adults and 557 goslings) were found in the Northeast Delta subarea, and 12 groups totaling 1,175 Snow Geese (711 adults and 464 goslings) were found in the CD North subarea.

Habitat Use

Brant brood groups primarily occupied coastal salt-affected habitats in the Colville Delta study area (Table 34). All 13 Brant groups recorded during aerial surveys were distributed among 5 salt-affected habitats: Salt Marsh (5 groups), Brackish Water (3 groups), Open Nearshore Water (2 groups), Salt-killed Tundra (2 groups), and Tapped Lake with Low-water Connection (1 group; this habitat typically contains brackish water and has salt marsh vegetation along the shoreline; Appendix B).

Snow Geese were found in a wider range of habitats than Brant, but they also favored coastal salt-affected habitats for brood-rearing and molting in the Colville Delta study area (Table 34). Of 26 Snow Goose groups observed, 20 groups (77%) were found in salt-affected habitats, including Salt Marsh (7 groups), Brackish Water (4 groups), Salt-killed Tundra (4 groups), Open Nearshore Water (2 groups), Tidal Flat Barrens (2 groups), and Tapped Lake with Low-water Connection (1 group). The 6 Snow Goose groups not found in salt-affected sites were distributed among 6 different habitats (Table 34).

NE NPR-A Study Area

Distribution and Abundance

As was the case for the Colville Delta study area, Brant numbers were high in the NE NPR-A study area in 2014. During the aerial brood-rearing survey, we counted 3,882 Brant (2,741 adults and 1,141 goslings) in 17 groups in the NE NPR-A study area (Figure 25, Table 35). The number of adult Brant was the highest recorded in the area since 2005, and the number of goslings was the second highest. Fifteen of 17 Brant groups contained young, but goslings comprised only 29% of the total number of birds in all groups, which is near the 10-year mean for the NE NPR-A study

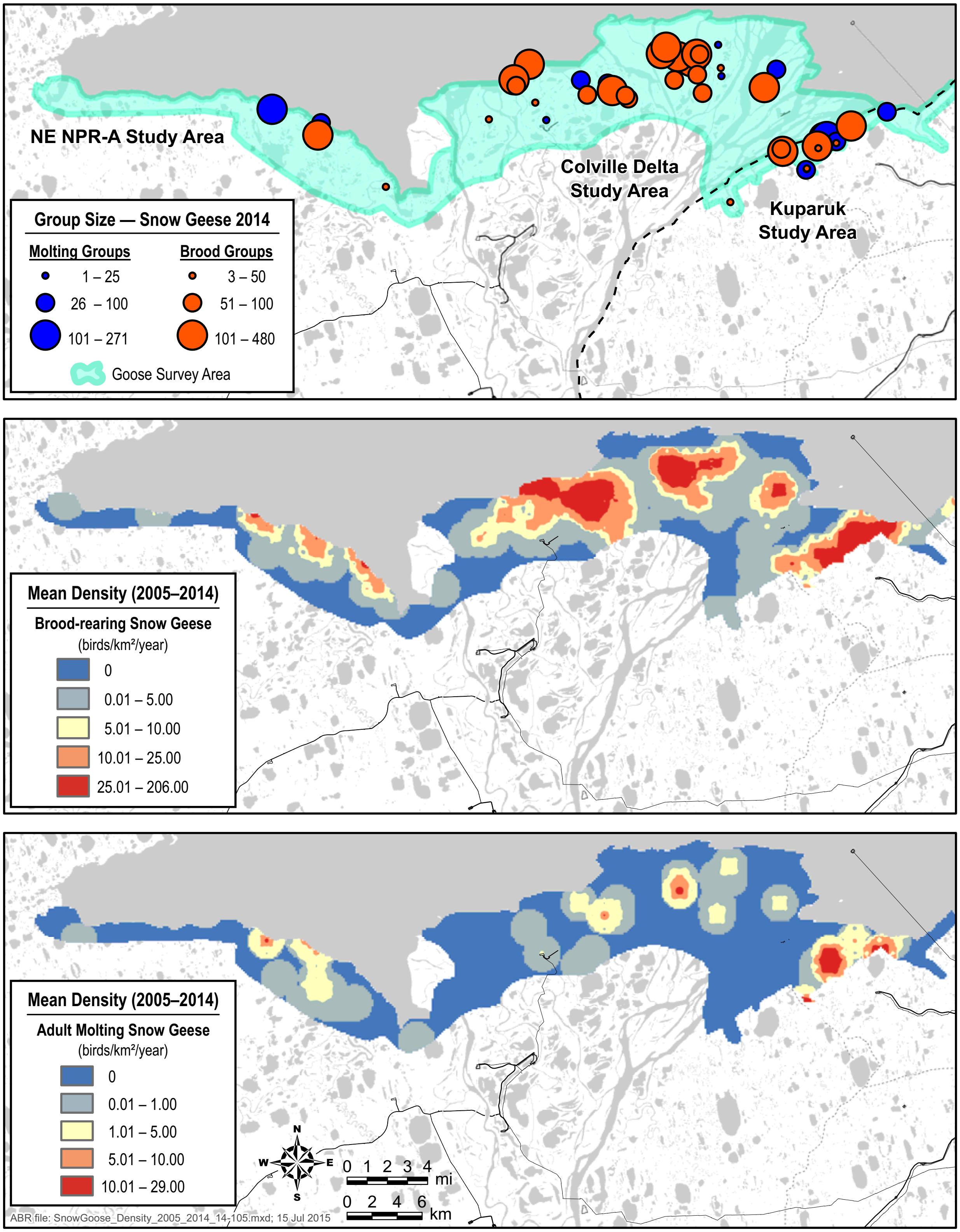


Figure 27. Snow Goose brood-rearing and molting locations in 2014 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE NPR-A study areas, Alaska, 2005–2014 (middle and bottom). Kuparuk data from Stickney et al. 2015.

Table 33. Number of Snow Goose adults and goslings during aerial surveys, Colville Delta study area, Alaska, 2005–2014.

Year	Total Birds	Adults	Goslings	% Goslings	No. Groups	Survey Date(s)
2005	972	412	560	58	11	30 July
2006	997	421	576	58	9	29 July
2007	1,154	596	558	48	13	30 July
2008	1,967	834	1,133	58	22	29 July
2009	678	463	215	32	15	29 July
2010	1,873	883	990	53	19	28 July
2011	4,023	1,745	2,278	57	36	28 July
2012	4,035	2,009	2,026	50	57	26 July
2013	2,454	1,568	886	36	31	26 July
2014	2,545	1,524	1,021	40	26	31 July
Mean	2,070	1046	1,024	49	23.9	
SE	383	192	208	3.1	4.6	

Table 34. Habitat use by brood-rearing/molting Brant and Snow Geese, Colville Delta and NE NPR-A study areas, Alaska, 2014.

	Colville Delta				NE NPR-A			
	Brant		Snow Geese		Brant		Snow Geese	
Habitat	No. of Groups	Use (%)	No. of Groups	Use (%)	No. of Groups	Use (%)	No. of Groups	Use (%)
Open Nearshore Water	2	15.4	2	7.7	7	43.8	2	50.0
Brackish Water	3	23.1	4	15.4	2	12.5	1	25.0
Tapped Lake with Low-water Connection	1	7.7	1	3.8	3	18.8	0	0
Tapped Lake with High-water Connection	0	0	1	3.8	0	0	0	0
Salt Marsh	5	38.5	7	26.9	2	12.5	1	25.0
Tidal Flat Barrens	0	0	2	7.7	1	6.3	0	0
Salt-killed Tundra	2	15.4	4	15.4	0	0	0	0
Deep Open Water with Islands or Polygonized Margins	0	0	1	3.8	0	0	0	0
River or Stream	0	0	1	3.8	0	0	0	0
Deep Polygon Complex	0	0	1	3.8	0	0	0	0
Old Basin Wetland Complex	0	0	1	3.8	0	0	0	0
Nonpatterned Wet Meadow	0	0	1	3.8	0	0	0	0
Barrens	0	0	0	0	1	6.3	0	0
Total	13	100	26	100	16[a]	100	4	100

[a] Excludes 1 group that occurred outside the area mapped for habitat

Table 35. Numbers of Brant and Snow Goose adults and goslings during aerial surveys, NE NPR-A study area, Alaska, 2005–2014.

SPECIES Year	Total Birds	Adults	Goslings	% Goslings	No. of Groups
BRANT					
2005	1,634	1,003	631	39	11
2006	2,235	1,350	885	40	17
2007[a]	1,512	1,185	327	22	8
2008	4,012	2,617	1,395	35	36
2009	2,628	2,161	467	18	12
2010[a]	1,565	1,073	492	31	8
2011	1,756	906	850	48	14
2012	1,684	1,410	274	16	15
2013	1,749	1,346	403	23	15
2014	3,882	2,741	1,141	29	17
Mean	2,266	1,579	687	30.1	15.3
SE	300	213	118	3.3	2.5
SNOW GEESE					
2005	32	13	19	59	1
2006	713	270	443	62	9
2007[a]	145	78	67	46	5
2008	234	107	127	54	5
2009	102	60	42	41	4
2010[a]	105	85	20	19	3
2011	388	142	246	63	8
2012	626	289	337	54	12
2013	312	182	130	42	4
2014	392	299	93	24	4
Mean	305	153	152	46.4	5.5
SE	72	33	46	4.8	1.0

[a] Surveys in 2007 and 2010 were conducted by ABR for the North Slope Borough Department of Wildlife Management (Ritchie et al. 2008, Appendix H; Burgess et al. 2011, Appendix G)

area. Sixteen Brant brood-rearing and molting groups were located in the Fish Creek Delta subarea, and 1 group was in the Fish Creek West subarea.

Snow Goose productivity was low in the NE NPR-A study area in 2014. A total of 392 Snow Geese (299 adults and 93 goslings) were counted in 4 groups (Figure 27, Table 35). Although the number of adults was the highest ever recorded, the count of goslings was 39% below the 10-year mean, and goslings comprised only 24% of the total number of birds in all groups, which was the second lowest gosling percentage on record (Table 35). All 4 Snow Goose groups were located in the Fish Creek Delta subarea.

Habitat Use

Brant and Snow Goose brood groups used salt-affected habitats almost exclusively in the NE NPR-A study area (Table 34). Sixteen out of 17 Brant groups occupied locations that were mapped for habitat, and all but 1 of these were found in salt-affected habitats: Open Nearshore Water (7 groups), Tapped Lake with Low-water Connection (3 groups), Brackish Water (2 groups), Salt Marsh (2 groups) and Tidal Flat Barrens (1 group). The 1 group not in a salt-affected habitat was found in Barrens. The 4 Snow Goose groups observed during aerial surveys occupied 3 salt-affected habitats: Open Nearshore Water (2 groups), Brackish Water (1 group) and Salt Marsh (1 group).

DISCUSSION

Nesting

In 2014, the nesting density of White-fronted Geese was 30% higher in 2014 (28.7 nests/km²) compared to 2013 (21.8 nests/km²). Spring conditions on the breeding grounds in 2014 were warmer than in 2013 (the first year of the White-fronted Goose study), when mid-May temperatures were colder and snow depth was deeper than average (Johnson et al. 2014a). Temperatures and availability of snow-free nesting habitat at the time of nest initiation may explain some of the annual difference observed in nesting densities of White-fronted Geese. When we began nest-searching in 2013, we estimated that 86% of White-fronted Geese had initiated nesting compared to 98% in 2014. Densities of nesting White-fronted Geese from studies conducted in the last decade on Colville River delta and NE NPR-A were highly variable. On the northern Colville River delta densities of White-fronted Geese were between 9.8 and 18.0 nests/km² (Johnson et al. 2003a, 2004, 2005), on the central delta densities were between 2.4 and 5.0 nests/km² (Johnson et al.2003a), and just east of the Colville River it was 14.8 nests/km² (Burgess et al. 2013). Nesting densities for White-fronted Geese on combined search areas in the NE NPR-A ranged from 0.9 to 17.9 nests/km² annually (Murphy and Stickney 2000, Burgess et al. 2002b, Burgess et al. 2003b, Johnson et al. 2004, 2005, 2010). The elevated densities of nests at CD5 in 2013 and 2014 may not be surprising considering that numbers of breeding White-fronted Geese have increased steadily on the North Slope at an annual rate of 4% over the last 27 years, increasing to 14% annual growth over the last 10 years (Stehn et al. 2013).

The median date of nest initiation for White-fronted Geese was earlier in 2014 than in 2013, most likely due to differences in early breeding season conditions described above. In 2013, the median nest initiation date was 10 June and the first nest was initiated on 2 June. In 2014, median nest initiation was 5 d earlier than in 2013 and the first nest was initiated on 25 May. In previous studies, nest initiation for White-fronted Geese on the Colville River delta ranged from 26 May to 14 June, with the peak of initiation ranging from 3 to 10 June (Simpson and Pogson 1982, Renken et al. 1983, Burgess et al. 2013, Hupp et al. 2012, Johnson et al. 2013b).

The apparent nesting success of all White-fronted Goose nests (58%) in 2014 was slightly higher than in 2013 (53%), but low compared with annual success rates calculated over multiple sites in NE NPR-A in 2002–2005 (66–81%) (Burgess et al. 2002b, 2003b; Johnson et al. 2004, 2005). In 2012, apparent nesting success of White-fronted Geese east of the Colville River was 77% (n = 112 nests; Burgess et al. 2013). High inter-annual variability in nesting success in White-fronted Geese is not uncommon and has been observed in many areas in Alaska (Johnson et. al. 2013b). Apparent nesting success of temperature-monitored White-fronted Goose nests in 2014 was 68% compared to 53% in 2013. That temperature monitored nests in 2014 had a higher nesting success than non-instrumented nests (60%, excluding nests that were failed at the first visit [11 nests]) of the same year is most likely coincidental. However, the high proportion of successful, temperature-monitored nests in 2014 suggests that temperature monitoring did not increase the susceptibility of a nest to predation or other causes of failure.

In 2014, the mean DSR of White-fronted Goose nests (includes temperature-monitored nests only) was higher than in 2013 (see RESULTS). The DSR in 2014 was also higher than reported for this species on plots in the NE NPR-A during 2003 and 2004 (0.946 ± 0.014, *n* = 12 nests and 0.917 ± 0.031, *n* = 10 nests, respectively; Johnson et al. 2004, Johnson et al. 2005), but the same as found for nests on the east side of the Colville River in 2012 (0.984 ± 0.011, *n* = 7 nests, Burgess et al. 2013). Nesting success calculated with DSR for a 24 d incubation period was 68% in 2014 compared to 47% in 2013. The average clutch size for White-fronted Geese at CD5 in 2014 (3.8 eggs/nest) was the same as in 2013, and falls within the reported range in previous years in the NE NPR-A study area. The clutch sizes reported for this and previous years, when active nests were checked only once, may have underestimated the number of eggs because some clutches might not have been complete. Studies with complete clutches reported an average 4.2 eggs/nest on the Colville River delta (Simpson and Pogson 1982, Rothe et al. 1983, Hupp et al. 2012).

In 2013, we were unable to examine nest attendance for monitored goose nests, because of erratic temperature records, probably caused by the use of “bare” thermistors in nests, which became buried in nest material. In 2014, we used an artificial egg to house the thermistor, and this greatly improved the quality of temperature records and our ability to quantify nesting behaviors. Despite the improvement in data collected from our temperature monitored nests in 2014, we still had instances of equipment failure. We will mitigate these issues in future years of this study by testing data loggers prior to deployment to insure they are working properly and insure that thermistor cords are fixed to data loggers during set-up to prevent disconnections.

Incubation constancy for White-fronted Goose nests at CD5 were consistent with other studies conducted on the North Slope. Temperature data from nests in 2014 indicated a high degree of nest attendance (99% incubation constancy for both successful and failed nests). In the Alpine study area during 1999–2001, incubation constancy in White-fronted Geese was 98.4–99% for successful nests (*n* = 43) and 96.1–97.8% for failed nests (*n* = 37; Johnson et. al 2000b, 2001, 2002). The mean duration females were away from nests following installation of egg thermistors was longer (mean = 134.6 ±24.7 min, *n* = 25) in this study than reported previously in the Alpine study area (mean = 118 min, *n* = 115 nests; Johnson et. al 2003a).

Jaegers and Glaucous Gulls were the most abundant predators observed during predator scans of the CD5 area. Time-lapse cameras at Yellow-billed Loon nests covering more extensive portions of the NE NPR-A study area recorded a similar predator composition. During 10 d of nest-searching in the CD5 area, we only observed 1 arctic fox near our nest plots. Liebezeit et al. (2009) used a similar method of sampling predators and concluded they also underestimated the occurrence of arctic and red foxes. It is possible that predator scans (2 10-min scans per plot) are too brief and limited (to line of sight) to have much opportunity for recording animals that occur in low densities, though incidental observations should provide more opportunity to observe the less abundant species. Foxes may avoid people on tundra, particularly in areas where they can be hunted. Both species of foxes are nocturnal (Ables 1969, Garrott 1980, Eberhardt et al. 1982), which biased our daytime predator scans against detecting their occurrence. We encountered 2 fox dens in and between plots that had been previously recorded (Burgess et al. 2003b), but neither showed any sign of recent activity. Evidence that foxes did occur in the area in 2014 came from fox scat and scent found at 38 waterbird nests checked for nest fate in July.

Brood-rearing

Nesting success in large Brant colonies is variable, and tends to be either high or very low (see Sedinger and Stickney 2000). The presence of predators in a breeding colony during nest initiation can result in very low nesting effort, as was seen in 1991 and 1992 when arctic foxes disrupted breeding on Howe Island in the Sagavanirktok Delta (Stickney and Ritchie 1996). During incubation, predators such as brown bears and arctic foxes can remove substantial numbers of nests (Smith et al. 1993). Furthermore, unfavorable weather conditions such as persistent snow and ice or cool temperatures can limit availability of nesting habitat or reduce nesting effort and success in some years (Barry 1962, Stickney and Ritchie 1996).

The number of adult Brant present in the Colville Delta study area during the brood-rearing period is not a reliable measure of the size of the local breeding population. Failed nesters typically depart the Colville River delta prior to the brood-rearing period and molt in other areas on the ACP, including the large molting area northeast of Teshekpuk Lake (Lewis et al. 2009). Additionally, some successful breeders from the Colville River delta rear their broods on coastal salt marshes outside the delta, at least as far east as Kavearak Point in the Kuparuk Oilfield (Sedinger and Stickney 2000) and likely to the west in the adjacent Fish Creek delta.

In 2014, Brant numbers were high in both the Colville Delta and NE NPR-A study areas. Brood groups were found in regions used historically, including multiple areas of relative high density in the outer Colville and Fish Creek deltas (Figure 25). Most molting adult Brant without broods were found in the Fish Creek delta during 2005–2013, as were the 2 adult molting groups observed in 2014. As mentioned above, many broods originating in the Colville River delta move eastward into the Kuparuk Oilfield, and this appeared to be the case again in 2014 (Figure 25). Results from our surveys show that the number of adult Brant in the Colville Delta study area during the brood-rearing period is highly variable (Figure 26), but numbers of adults have increased at a rate of 1.103 (10.3% annually) since 1988 ($\ln(y) = 0.103x - 200.5$, $R^2 = 0.250$, $P = 0.049$, $n = 16$ years). Numbers vary widely from year to year, probably due to factors discussed above, including variation in nesting effort and nesting success, and variable movements of broods out of the Colville Delta study area prior to our survey. These factors may make trends difficult to detect or interpret.

On the ACP, Brant can be found in large breeding colonies on deltaic islands, such as those on the Sagavanirktok, Colville, and Kuparuk river deltas, and in numerous smaller colonies in basin-wetland complexes primarily between the Sagavanirktok River and Barrow. Broad regional surveys conducted during early to mid-June show a statistically significant annual growth rate of 1.095 for Brant on the ACP between 1986 and 2012 (n = 27 years; Stehn et al. 2013). This increase may have been accompanied by increased total numbers of molting birds, expansion of the molting range, and growth of the breeding population of Brant on the ACP (Flint et al. 2014). Increases on the ACP have been concurrent with apparent long-term declines on the Yukon-Kuskokwim Delta (Wilson 2014). Trends are not uniform across the ACP. Nest numbers have dropped since 1993 on the Sagavanirktok River delta (Streever and Bishop 2014). In contrast, numbers of Brant nests appear to have remained stable or increased since 1995 in 23 small colonies between Fish Creek and Barrow (Ritchie et al. 2014). The molting range of Brant on the ACP may have expanded in response to climate-related changes in molting habitat (Tape et al. 2013).

Snow Goose nests have been found in small numbers on the Colville River delta at least as far back as 1994, and brood-rearing Snow Geese have been observed in small numbers at least as far back as 1996 (Johnson et al. 2003b). In 2014, Snow Goose brood rearing and molting groups were found at multiple sites throughout the study area (and in the Kuparuk Oilfield to the east of the delta) at locations that have been occupied historically (Figure 27). Numbers of brood-rearing Snow Geese in the study area have steadily increased in recent years, reaching record numbers in 2012. Brown bears were likely responsible for substantial nest losses in 2013, and may also be implicated in losses in 2014. Snow Goose nests are conspicuous from the air, and nest numbers in early June 2014 appeared to equal or exceed those from 2012 and 2013. Combined with relatively low brood-rearing numbers, these observations suggest that nest and/or brood losses were high in 2014. As in 2013, Yellow-billed Loon cameras captured multiple images of brown bears in 2014, including apparent foraging activity in a large Snow Goose colony west of CD3 in the CD North subarea. Similar patterns of colony growth and predation by bears has been observed elsewhere. Snow Goose numbers have increased sharply on the Ikpikpuk River delta (to the west of the Colville River) since surveys began there in 1994 (Ritchie et al. 2014), and that colony suffered near-total nest failure due to brown bear predation in 2009 and 2010 (Ritchie et al. 2010, Burgess et al. 2011).

Snow Goose breeding populations have been expanding in North America since at least the 1960s (Kerbes 1983, Kerbes et al. 1983, McCormick and Poston 1988, Alisauskas and Boyd 1994) perhaps due to increased availability of agricultural resources in wintering areas (Davis et al. 1989). Snow Geese forage by grubbing for roots and rhizomes during spring prior to emergence of above-ground vegetation (Kerbes et al. 1990). This behavior, coupled with high fidelity to breeding areas (Ganter and Cooke 1998) has resulted in long-term degradation of some nesting areas and arctic coastal salt marshes used for brood-rearing (Kerbes et al. 1990, Ganter et al. 1995, Srivastava and Jefferies 1996). Over-population of breeding colonies has led to decreased growth and survival of goslings (Cooch et al. 1991, Williams et al. 1993, Gadallah and Jefferies 1995), and eventual dispersal of young breeders to higher quality breeding areas (Ganter and Cooke 1998). In the long term, one might predict a negative impact on Brant from a substantial increase in Snow Goose numbers due to degradation of salt marsh habitats used by both species during brood-rearing. Intense grazing by Brant, focusing exclusively on above-ground biomass, appears to have no lasting deleterious effects on salt marsh grazing lawns (Person et al. 1998). Snow Geese, however, can cause long-term declines of these plant communities in the vicinity of nesting colonies (e.g., Kerbes et al. 1990, Abraham and Jefferies 1997).

GLAUCOUS AND SABINE’S GULLS

COLVILLE DELTA STUDY AREA

Distribution and Abundance

The count of Glaucous Gull nests on the Colville Delta study area in 2014 was relatively high. We recorded 84 Glaucous Gull nests during the aerial survey for nesting loons (Figure 28, Table 36). Forty-five of those nests were in the CD North subarea, 36 in the CD South subarea, and 3 in the Northeast Delta subarea. Glaucous Gull colonies are not common; the 5 colonies we recorded in 2014 were on only 12% of the 42 waterbodies occupied by nesting gulls. The largest of the 5 colonies in 2014 contained 18 nests and was located in CD South subarea ~5 km southeast of Alpine (Figure 28). The maximum number of nests we have seen at this colony over 13 years of monitoring was 23 nests in 2013 (Table 37). Other colonies in the Colville Delta study area include 1 with 6 nests in the northeastern part of the CD North subarea, 1 with 5 nests ~1.7 km north of the CD3 drill pad, and 1 with 3 nests ~3 km NE of Nuiqsut (Figure 28). While in transit between survey lakes we discovered a colony of 6 nests in the CD North subarea on a 4.9 ha lake, ~9.6 km NE of Alpine. We do not know the history of this colony because typically we do not survey lakes that size on the loon nesting survey.

For the past 13 years, 50 index lakes in the Colville Delta study area have been monitored annually for Glaucous Gull nests during the aerial survey for nesting loons. In 2014, 63 nests were found on 27 of those lakes (54%; Table 37). Gull nests were not evenly distributed among lakes. In 2014, 59% of nests (38 nests) were located on 10% of the lakes (5 lakes). Even so, the number of lakes occupied by nesting gulls has increased over time, suggesting that gulls are colonizing new lakes.

In 2014, 19 groups of Glaucous Gulls with young were recorded on 18 waterbodies in the Colville Delta study area during the survey for brood-rearing loons (Figure 28). Broods totaled 27 adults and 34 young, of which 17 adults and 21 young were in the CD North subarea, 8 adults and 12 young were in the CD South subarea, and 2 adults and 1 young were in the Northeast Delta subarea. Eight young were observed at the colony site in the northeastern part of the CD North subarea, 3 young at the colony site north of the CD3 drill pad, and 2 young at the colony site in the CD South subarea. Young from some nests were flight capable at the time of the loon survey and may have moved away from nest sites. No broods were observed at the largest colony in CD South yet 14 adults still occupied the site. A brown bear was detected on time-lapse images eating eggs at a Yellow-billed Loon nest adjacent to the CD South gull colony, and we suspect the bear was the cause of the colony failure.

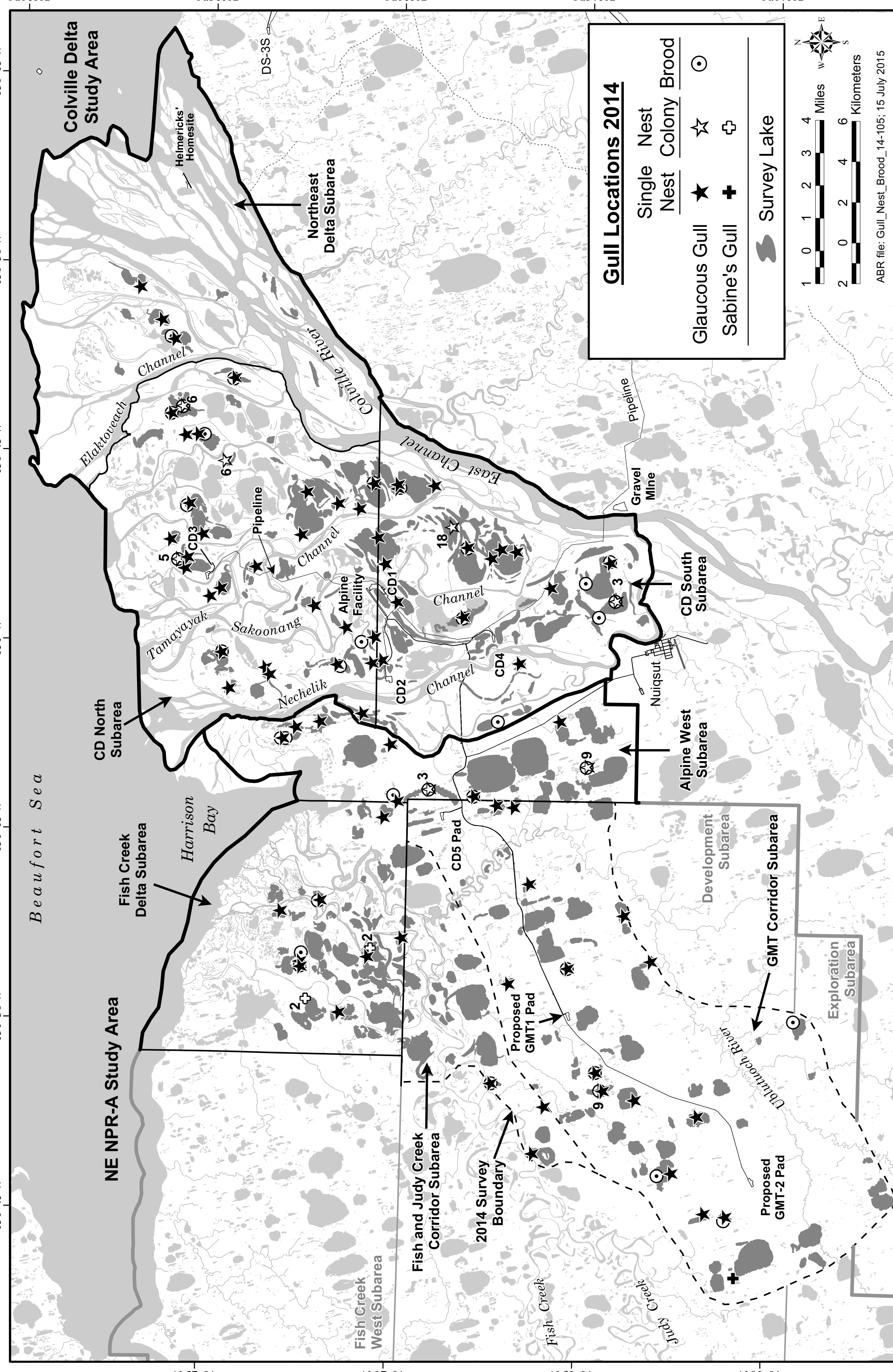


Figure 28. Glaucous and Sabine's gull nests and broods, Colville Delta and NE NPR-A study areas, Alaska, 2014. Numbers of nests are listed for colony locations.

Table 36. Number of Glaucous Gull nests observed during aerial surveys for nesting loons, Colville Delta and NE NPR-A study areas, Alaska, 2014.

STUDY AREA Subarea	Nests
COLVILLE DELTA	
CD North	45
CD South	36
Northeast Delta	3
Total	84
NE NPR-A	
Alpine West	18
Fish Creek Delta	9
Fish and Judy Creek Corridor	3
GMT Corridor	23
Total	53

No nests or broods belonging to Sabine's Gulls were observed in 2014 in the Colville Delta study area during the aerial survey for nesting loons. The absence of Sabine's Gull nests is not unusual for the loon surveys. Sabine's Gull nests are difficult to detect from aerial surveys. We have recorded Sabine's Gull nests in only 4 of the last 13 years and the distribution of these nests was limited to a cluster of 3 lakes in the northwestern portion of the delta. In years when Sabine's Gull nests were detected (2006–2010), numbers ranged from 1 to 16 nests.

Habitat Use

Glaucous Gull nests and colonies were found in 12 different habitats in the Colville Delta study area (Table 38). The 4 most commonly used habitats also contained colonies: Deep Open Water with Islands or Polygonized Margins (36% of nests), Patterned Wet Meadow (24%), Tapped Lake with High-water Connection (15%), and Grass Marsh (8%). The largest Glaucous Gull colony (18 nests) was located on a large island classified as Patterned Wet Meadow. The remaining 14% of nests were found on islands or complex shorelines in 8 other habitats. Glaucous Gull broods were found in aquatic and terrestrial habitats near nest locations, often in the same habitat as the nest.

NE NPR-A STUDY AREA

Distribution and Abundance

Glaucous Gull nests were numerous in the NE NPR-A study area during 2014. We counted 53 nests during aerial surveys for loons (Figure 28). We recorded 18 nests in the Alpine West subarea, 9 in the Fish Creek Delta subarea, 3 in the Fish and Judy Creek Corridor subarea (Table 39) and 23 in the GMT Corridor subarea. Three colonies accounted for 40% of Glaucous Gull nests (21 of 53 total nests); the remaining 32 were solitary nests. Two colonies were in the Alpine West subarea; 1 near the CD5 drill pad had 3 nests and the other in the southern part of Alpine West had 9 nests (Figure 28, Table 39). Annual counts have ranged from 0 to 7 nests at the CD5 colony and from 4 to 11 nests at the other colony site (Table 39). The third colony was located in the GMT subarea, ~3.8 km southeast of the proposed GMT1 pad, and contained 9 Glaucous Gull nests. This last colony has not been monitored annually.

In the NE NPR-A study area, we had consistent annual coverage (2005–2014) for only 2 subareas, Alpine West and Fish Creek Delta. Nest counts for the 2 combined subareas have ranged over the 9 years, from 12 to 28 nests (Table 39). The lowest count occurred in 2009 and was attributed to the predation of all nests at the CD5 colony by a brown bear (Johnson et al. 2010). In most years we have no information on nest losses due to predation; nests that fail prior to the aerial survey complicate detecting trends in nesting Glaucous Gulls.

Sixteen groups of Glaucous Gull broods were observed in the NE NPR-A study area in 2014 (Figure 28). Of the 17 adults and 44 young, 6 adults and 23 young were in Alpine West subarea, 3 adults and 4 young were in the Fish Creek subarea, 2 adults with 1 young were in the Fish and Judy Creek Corridor subarea, and 6 adults and 16 young were found in the GMT Corridor subarea. Within the Alpine West subarea the southern Alpine West colony had 12 young and the CD5 colony had 3 young. The colony in the GMT Corridor subarea area produced 8 young. Young from some nests probably were flight capable at the time of the survey, and consequently may have been undercounted if they moved away from nest areas.

Table 37. Number of Glaucous Gull nests recorded during aerial surveys for nesting loons on 50 index lakes, Colville Delta study area, Alaska, 2002–2014.

	Number of Nests				
Year	CD North Subarea[a]	CD South Subarea[b]	Northeast Delta Subarea	Total	No. of Lakes with Nests[c]
2002	11 (2, 1)	24 (18)	1	36	15
2003	11 (1, 1)	17 (14)	0	28	14
2004	19 (7, 1)	17 (13)	0	36	16
2005	18 (5, 1)	22 (15)	0	40	19
2006	15 (4, 1)	21 (16)	1	37	19
2007	16 (5, 1)	21 (13)	2	39	19
2008	19 (5, 1)	26 (18)	2	47	22
2009	17 (6, 1)	27 (19)	2	46	21
2010	17 (5, 2)	16 (6)	2	35	21
2011	17 (5, 2)	36 (17)	2	55	24
2012	26 (7, 5)	34 (17)	2	62	28
2013	19 (5, 4)	35 (23)	3	57	22
2014	27 (6, 5)	34 (18)	2	63	27
Mean	17.8 (4.8, 1.9)	25.4 (15.9)	1.5	44.7	20.5
SE	1.3 (0.5, 0.4)	2.0 (1.1)	0.3	3.1	1.2

[a] First number in parentheses is the number of nests at the colony site in the northeastern part of the CD North subarea and second number is the number of nests at the site north of the CD3 drill pad (see Figure 28)

[b] Number in parentheses is the number of nests at the colony site in the CD South subarea (see Figure 28)

[c] Of 50 lakes monitored annually for the presence of Glaucous Gull nests, 2 occur in the Northeast Delta subarea, 20 in the CD South subarea, and 28 in the CD North subarea

Table 38. Habitat use by nesting Glaucous Gulls, Colville Delta and NE NPR-A study areas, Alaska, 2014.

	Colville Delta		NE NPR-A	
Habitat	Nests	Use (%)	Nests	Use (%)
Brackish Water	1	1.2	3	5.7
Tapped Lake with High-water Connection	15	17.9	1	1.9
Deep Open Water without Islands	3	3.6	–	–
Deep Open Water with Islands or Polygonized Margins	30	35.7	9	17.0
Shallow Open Water without Islands	1	1.2	–	–
Shallow Open Water with Islands or Polygonized Margins	1	1.2	28	52.8
Sedge Marsh	1	1.2	3	5.7
Deep Polygon Complex	2	2.4	–	–
Grass Marsh	7	8.3	2	3.8
Young Basin Wetland Complex	–	–	1	1.9
Old Basin Wetland Complex	–	–	4	7.5
Nonpatterned Wet Meadow	2	2.4	1	1.9
Patterned Wet Meadow	20	23.8	–	–
Moist Sedge-Shrub Meadow	1	1.2	1	1.9
Total	84	100	53	100

Table 39. Number of Glaucous Gull nests recorded during aerial surveys for nesting loons in the Alpine West and Fish Creek Delta subareas, NE NPR-A study area, Alaska, 2002–2014.

Year	Alpine West Subarea[a]	Fish Creek Delta Subarea[b]	Total
2002	13 (4, –)	–	–
2003	16 (4, 7)	–	–
2004	15 (5, 6)	–	–
2005	13 (5, 6)	4	17
2006	17 (7, 6)	11	28
2008	19 (7, 6)	7	26
2009	9 (0, 5)	3	12
2010	12 (5, 4)	2	14
2011	19 (5, 11)	4	23
2012	17 (5, 9)	5	22
2013	13 (5, 6)	4	17
2014	18 (3, 9)	9	27

[a] First number in parentheses is the number of nests at the colony site near the CD5 Pad and second number is the number of nests at the site in the southern part of the subarea (see Figure 28). The colony in southern part of the subarea was first counted in 2003

[b] The Fish Creek Delta subarea was not surveyed in 2002–2004

A total of 5 Sabine's Gull nests were located in the NE NPR-A study area in 2014 during the loon nesting survey. Two small colonies of at least 2 nests (adults were not counted, and colony size is likely under-estimated) were located in the Fish Creek Delta subarea, and a single nest was located in the GMT Corridor subarea. Nest counts for Sabine's Gulls have ranged from 0 to 29 nests in the combined Alpine West and Fish Creek Delta subareas during 9 years of surveys, and nesting has been confirmed at only 6 survey lakes. The highest count of Sabine's Gull nests in the NE NPR-A study area occurred in 2008, a year noted for an early break-up and low peak-stage levels on the Colville River.

Habitat Use

Glaucous Gulls nested in 10 different habitats in the NE NPR-A study area in 2014 (Table 38). Twenty-eight (53%) of 53 nests, including 3 colonies, were in Shallow Open Water with Islands or Polygonized Margins. Another 17% of the nests were located in Deep Open Water with Islands or Polygonized Margins. The remaining 20% were found on islands or complex shorelines of 6 other aquatic habitats and 2 terrestrial habitats. Glaucous Gull broods observed during aerial surveys were located near nests and in the same habitats as were the nests.

DISCUSSION

The number of Glaucous Gull nests in the Colville Delta study area has increased steadily from 2002 to 2014. Over this 13-year period, counts of Glaucous Gulls nests at the index lakes have ranged from 28 to 64 nests. The population growth rate for nests at the 50 index lakes was 1.055, significantly higher than 1.0 (ln(y) = 0.055x – 107.62, R^2 = 0.739, P = <0.001, n = 13 years). Glaucous Gulls also have been increasing across the entire ACP during 1992–2012 (annual growth rate = 1.020, 90% CI = 1.007–1.033, n = 21 years) and during the last 10 years of that period, have increased at a similar rate as in the Colville Delta study area (annual growth rate = 1.058%, 90% CI = 1.023–1.095; Stehn et al. 2013). The increase in the Colville Delta study area occurred both in the number of nests associated with colonies and solitary nest sites. The number of colonies in the 50 index lakes increased from 1 to 4 over 13 years. In 2014, colonies accounted for 48% of the total nests, and in most years colonies accounted for roughly half of the total nests. The percentage of index lakes occupied by gull nests also has increased from 28 to 54% from 2002 to 2014. Once gulls colonize a lake, that lake tends to remain occupied. Of the 15 lakes with nests in 2002, 79% have been occupied by nests annually the following 12 breeding seasons.

The total number of lakes occupied by breeding Sabine's Gulls during surveys for nesting loons has been low during the 13 years of surveys on the Colville Delta study area and 9 years of surveys in the NE NPR-A study area. Nest counts at these lakes have been variable, possibly because spring conditions have influenced nesting or because nests were not detected consistently. Because Sabine's Gulls are recorded incidentally on loon surveys and nests are difficult to detect, these data are not adequate for estimating population trends. Sabine's Gulls do appear to be increasing across the ACP; during 2003–2012 Sabine's Gulls increased at an annual rate of 1.098 (90% CI = 1.080–1.115; Stehn et al. 2013).

LITERATURE CITED

Ables, E. D. 1969. Activity studies of red foxes in southwestern Wisconsin. Journal of Wildlife Management 33: 145–153.

Abraham, K. F., and R. L. Jefferies. 1997. High goose populations: causes, impacts and complications. Pages 7–72 *in* B. D. J. Batt, editor. Arctic Ecosystems in Peril: Report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture Special Publication. U.S. Fish and Wildlife Service, Washington, D.C. and Canadian Wildlife Service, Ottawa, Ontario. 120 pp.

Alisauskas, R. T., and H. Boyd. 1994. Previously unrecorded colonies of Ross' and Lesser Snow Geese in the Queen Maud Gulf Bird Sanctuary. Arctic 47: 69–73.

Anderson, B. A., and B. A. Cooper. 1994. Distribution and abundance of Spectacled Eiders in the Kuparuk and Milne Point oilfields, Alaska, 1993. Final report for ARCO Alaska, Inc., and the Kuparuk River Unit, Anchorage, AK, by Alaska Biological Research, Inc., Fairbanks, AK. 71 pp.

Anderson, B. A., and C. B. Johnson. 1999. Baseline avian surveys in four lease blocks within the National Petroleum Reserve–Alaska, 1999. Report for ARCO Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 18 pp.

Anderson, B. A., A. A. Stickney, T. Obritschkewitsch, and J. E. Shook. 2008. Avian studies in the Kuparuk Oilfield, Alaska, 2007. Data summary report for ConocoPhillips Alaska, Inc., and the Kuparuk River Unit, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Barr, J. F. 1997. Status report on the Yellow-billed Loon *Gavia adamsii* in arctic Canada. Report to Committee on Status of Endangered Wildlife in Canada. Guelph, ON.

Barry, T. W. 1962. Effect of late seasons on Atlantic Brant reproduction. Journal of Wildlife Management 26: 19–26.

Bayha, K., R. Meehan, and T. Jennings. 1992. Synthesis of Brant data for the Colville delta. Unpublished draft report by U.S. Fish and Wildlife Service, Anchorage, AK.

Bowman, T. D. 2004. Field guide to bird nests and eggs of Alaska's coastal tundra. Alaska Sea Grant College Program, University of Alaska Fairbanks. 81 pp.

BLM (Bureau of Land Management). 2004. Alpine Satellite Development Plan Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Land Management, with assistance from Minerals Management Service, Anchorage, AK.

BLM. 2008. Northeast National Petroleum Reserve–Alaska Supplemental Integrated Activity Plan Record of Decision. U.S. Department of the Interior, Bureau of Land Management, Anchorage, AK.

Burgess, R. M., C. B. Johnson, B. E. Lawhead, A. M. Wildman, A. A. Stickney, and J. R. Rose. 2000. Wildlife studies in the CD South study area, 2000. Report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 84 pp.

Burgess, R. M., C. B. Johnson, B. E. Lawhead, A. M. Wildman, P. E. Seiser, A. A. Stickney, and J. R. Rose. 2002a. Wildlife studies in the CD South study area, 2001. Second annual report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 98 pp.

Burgess, R. M., C. B. Johnson, P. E. Seiser, A. A. Stickney, A. M. Wildman, and B. E. Lawhead. 2002b. Wildlife studies in the Northeast Planning Area of the National Petroleum Reserve–Alaska, 2001. Report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 71 pp.

Burgess, R. M., C. B. Johnson, B. E. Lawhead, A. M. Wildman, P. E. Seiser, A. A. Stickney, and J. R. Rose. 2003a. Wildlife studies in the CD South study area, 2002. Third annual report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 126 pp.

Burgess, R. M., C. B. Johnson, A. M. Wildman, P. E. Seiser, J. R. Rose, A.K. Prichard, T. J. Mabee, A. A. Stickney, and B. E. Lawhead. 2003b. Wildlife studies in the Northeast Planning Area of the National Petroleum Reserve–Alaska, 2002. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 126 pp.

Burgess, R. M., T. Obritschkewitsch, R. J. Ritchie, J. E. Shook, and L. B. Attanas. 2011. Surveys for nesting and brood-rearing Brant and Lesser Snow Geese, Barrow to Fish Creek delta, Alaska, 2010. Report for North Slope Borough Department of Wildlife Management, Barrow, AK, by ABR, Inc., Fairbanks, AK. 58 pp.

Burgess, R. M., T. Obritschkewitsch, R. J. Ritchie, J. E. Shook, and L. B. Attanas. 2012. Surveys for nesting and brood-rearing Brant and Lesser Snow Geese, Barrow to Fish Creek delta, Alaska, 2011. Draft Report for North Slope Borough Department of Wildlife Management, Barrow, AK, by ABR, Inc., Fairbanks, AK. 89 pp.

Burgess, R. M., C. B. Johnson, T. Obritschkewitsch, A. K. Prichard, J. P. Parrett, N. A. Schwab, and P. E. Seiser. 2013. Wildlife studies for the Nuna development project, 2012. Report for Pioneer Natural Resources Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 55 pp.

CPAI (ConocoPhillips Alaska, Inc.). 2014. Data Management Protocols North Slope Field Surveys, Version 8.14.

Cooch, E. G., D. B. Lank, R. F. Rockwell, and F. Cooke. 1991. Long-term decline in body size in a Snow Goose population: evidence of environmental degradation? Journal of Animal Ecology 60: 483–496.

Davis, S. E., E. E. Klaas, and K. J. Koehler. 1989. Diurnal time-activity budgets and habitat use of Lesser Snow Geese *Anser caerulescens* in the middle Missouri River Valley during winter and spring. Wildfowl 40: 45–54.

Earnst, S. L., R. Platte, and L. Bond. 2006. A landscape-scale model of Yellow-billed Loon (*Gavia adamsii*) habitat preferences in northern Alaska. Hydrobiologia 567: 227–236.

Eberhardt, L. E., W. C. Hanson, J. L. Bengtson, R. A. Garrott, and E. E. Hanson. 1982. Arctic fox home range characteristics in an oil-study area. Journal of Wildlife Management 46: 183–190.

Ely, C. R., and A. X. Dzubin. 1994. Greater White-fronted Goose (*Anser albifrons*). No. 131 *in* A. Poole and F. Gill, editors. The birds of North America. The Birds of North America, Inc., Philadelphia, PA. 32 pp.

Flint, P. L., B. W. Meixell, and E. J. Mallek. 2014. High fidelity does not preclude colonization: range expansion of molting Black Brant on the Arctic coast of Alaska. Journal of Field Ornithology 85: 75–83.

Gadallah, F. L., and R. L. Jefferies. 1995. Forage quality in brood rearing areas of the Lesser Snow Goose and the growth of captive goslings. Journal of Applied Ecology 32: 276–287.

Ganter, B., and F. Cooke. 1998. Colonial nesters in deteriorating habitat: site fidelity and colony dynamics of Lesser Snow Geese. Auk 115: 642–652.

Ganter, B., F. Cooke, and P. Mineau. 1995. Long-term vegetation changes in a Snow Goose nesting habitat. Canadian Journal of Zoology 74: 965–969.

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

Haefner, J. W. 1996. Modeling Biological Systems: Principles and Applications. Chapman and Hall, New York, NY. 473 pp.

Hawkins, L.L. 1986. Nesting behaviour of male and female Whistling Swans and implications of male incubation. Wildfowl 37: 5–27.

Hechtel, J. L. 1985. Activity and food habits of barren-ground grizzly bears in arctic Alaska. M.S. Thesis, University of Montana, Missoula.

Hupp, J., D. Ward, E. Palm, T. Donnelly, K. Hogrefe, D. Pavlik, and B. Wilkinson. 2012. Comparative productivity of Lesser Snow Geese, Black Brant, and White-Fronted Geese on the Colville River delta, Alaska, 2011. U.S. Geological Survey, Alaska Science Center, Fairbanks. 10 pp.

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

Johnson, C. B., and A. A. Stickney. 2001. Avian surveys of exploration sites within the National Petroleum Reserve–Alaska, 2001. Report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 24 pp.

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

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

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

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

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

Johnson, C. B., R. M. Burgess, B. E. Lawhead, J. R. Rose, A. A. Stickney, and A. M. Wildman. 2000a. Wildlife studies in the CD North study area, 2000. Report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 96 pp.

Johnson, C. B., B. E. Lawhead, J. R. Rose, J. E. Roth, S. F. Schlentner, A. A. Stickney, and A. M. Wildman. 2000b. Alpine Avian Monitoring Program, 1999. Second annual report for PHILLIPS Alaska, Inc. and Anadarko Petroleum Corporation, Anchorage, by ABR, Inc., Fairbanks, AK. 86 pp.

Johnson, C. B., B. E. Lawhead, D. C. Payer, J. L. Petersen, J. R. Rose, A. A. Stickney, and A. M Wildman. 2001. Alpine Avian Monitoring Program, 2000. Third annual report for PHILLIPS Alaska, Inc., and Kuukpik Unit Owners, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 92 pp.

Johnson, C. B., R. M. Burgess, B. E. Lawhead, J. R. Rose, A. A. Stickney, and A. M. Wildman. 2002. Wildlife studies in the CD North study area, 2001. Second annual report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 114 pp.

Johnson, C. B., R. M. Burgess, B. E. Lawhead, J. Neville, J. P. Parrett, A. K. Prichard, J. R. Rose, A. A. Stickney, and A. M. Wildman. 2003a. Alpine Avian Monitoring Program, 2001. Fourth annual and synthesis report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 194 pp.

Johnson, C. B., R. M. Burgess, B. E. Lawhead, J. P. Parrett, J. R. Rose, A. A. Stickney, and A. M. Wildman. 2003b. Wildlife studies in the CD North study area, 2002. Third annual report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 104 pp.

Johnson, C. B., R. M. Burgess, A. M. Wildman, A. A. Stickney, P. E. Seiser, B. E. Lawhead, T. J. Mabee, J. R. Rose, and J. E. Shook. 2004. Wildlife studies for the Alpine Satellite Development Project, 2003. Annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 155 pp.

Johnson, C. B., R. M. Burgess, A. M. Wildman, A. A. Stickney, P.E. Seiser, B. E. Lawhead, T. J Mabee, A. K. Prichard, and J. R. Rose. 2005. Wildlife studies for the Alpine Satellite Development Project, 2004. Second annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 129 pp.

Johnson, C. B., J. P. Parrett, and P. E. Seiser. 2006a. Spectacled Eider monitoring at the CD-3 development, 2005. Annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, and J. E. Shook. 2006b. Avian studies for the Alpine Satellite Development Project, 2005. Third annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 30 pp.

Johnson, C. B., J. P. Parrett, and P. E. Seiser. 2007a. Spectacled Eider monitoring at the CD-3 development, 2006. Annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, and T. Obritschkewitsch. 2007b. Avian studies for the Alpine Satellite Development Project, 2006. Fourth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 31 pp.

Johnson, C. B., J. P. Parrett, and P. E. Seiser. 2008a. Spectacled Eider monitoring at the CD-3 development, 2007. Annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, T. Obritschkewitsch, and J. E. Shook. 2008b. Avian studies for the Alpine Satellite Development Project, 2007. Fifth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, T. Obritschkewitsch, and A. A. Stickney. 2009. Avian studies for the Alpine Satellite Development Project, 2008. Sixth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, and T. Obritschkewitsch. 2010. Avian studies for the Alpine Satellite Development Project, 2009. Seventh annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 71 pp.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, T. Obritschkewitsch, and P.E. Seiser. 2011. Avian studies for the Alpine Satellite Development Project, 2010. Eighth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 69 pp.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, T. Obritschkewitsch, and P.E. Seiser. 2012. Avian studies for the Alpine Satellite Development Project, 2011. Ninth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 91 pp.

Johnson, C. B., A. M. Wildman, J. P. Parrett, J. R. Rose, T. Obritschkewitsch, and P.E. Seiser. 2013a. Avian studies for the Alpine Satellite Development Project, 2012. Tenth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 92 pp.

Johnson, C. B., P. E. Seiser, J. P. Parrett. 2013b. Literature review of the Greater White-fronted Goose with emphasis on the Northeast National Petroleum Reserve–Alaska and the Colville River delta. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK.

Johnson, C. B., J. P. Parrett, T. Obritschkewitsch, J. R. Rose, K. B. Rozell, P. E. Seiser, and A. M. Wildman. 2014a. Avian studies for the Alpine Satellite Development Project, 2013. Eleventh annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 115 pp.

Johnson, C. B., A. M. Wildman, A. K. Prichard, C. L. Rea. 2014b. Yellow-billed Loon territory occupancy near a new oil development. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 27 pp.

Johnson, S. R. 2000. Lesser Snow Geese. Chapter 21 *in* J. Truett and S. Johnson, editors. The natural history of an Arctic oil field. Academic Press, San Diego, CA.

Jones D. B., and J. B. Theberge. 1982. Summer home range and habitat utilization of the red fox (*Vulpes vulpes*) in a tundra habitat, northwest British Columbia. Canadian Journal of Zoology 60: 807–812.

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

Jorgenson, M. T., J. E. Roth, M. Emers, S. Schlentner, D. K. Swanson, E.R. Pullman, J. Mitchell, and A. A. Stickney. 2003. An ecological land survey for the Northeast Planning Area of the National Petroleum Reserve–Alaska, 2002. Report for ConocoPhillips Alaska, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 84 pp.

Jorgenson, M. T., J. E. Roth, M. Emers, W. Davis, E.R. Pullman, and G. J. Frost. 2004. An ecological land survey for the Northeast Planning Area of the National Petroleum Reserve–Alaska, 2003. Addendum to 2002 report for ConocoPhillips Alaska and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 40 pp.

Kerbes, R. H. 1983. Lesser Snow Goose colonies in the western Canadian Arctic. Journal of Wildlife Management 47: 523–526.

Kerbes, R. H., M. R. McLandress, G. E. J. Smith, G. W. Beyersbergen, and B. Godwin. 1983. Ross' Goose and Lesser Snow Goose colonies in the central Canadian Arctic. Canadian Journal of Zoology 61: 168–173.

Kerbes, R. H., P. M. Kotanen, and R. L. Jefferies. 1990. Destruction of wetland habitats by Lesser Snow Geese: a keystone species on the west coast of Hudson Bay. Journal of Applied Ecology 27: 242–258.

Larned, W., R. Stehn, and R. Platte. 2006. Eider breeding population survey, Arctic Coastal Plain, Alaska, 2006. U.S. Fish and Wildlife Service, Migratory Bird Management–Waterfowl Management Branch, Soldotna, AK. 53 pp.

Larned, W., R. Stehn, and R. Platte. 2011. Waterfowl breeding population survey, Arctic Coastal Plain, Alaska, 2010. Unpublished report, U.S. Fish and Wildlife Service, Division of Migratory Bird Management, Anchorage, AK.

Lawhead, B. E., A. K. Prichard, and J. H. Welch. 2013. Mammal surveys in the Greater Kuparuk Area, Northern Alaska, 2012. Report for ConocoPhillips Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK.

Lewis, T. L., P. L. Flint, J. A. Schmutz, and D. V. Derksen. 2009. Temporal distributions and patterns of habitat use by Black Brant molting in the Teshekpuk Lake Special Area, Alaska. Interagency Report by U.S. Geological Survey, Alaska Science Center, Anchorage, AK. 113 pp.

Liebezeit, J., S. Kendall, S. Brown, C. Johnson, P. Martin, T. McDonald, D. Payer, C. Rea, B. Streever, and A. Wildman. 2009. Influence of human development and predators on nest survival of tundra birds, Arctic Coastal Plain, Alaska. Ecological Applications 19: 1,628–1,644.

Mabee, T. J., A. M. Wildman, and C. B. Johnson. 2006. Using egg flotation and eggshell evidence to determine age and fate of arctic shorebird nests. Journal of Field Ornithology 77: 163–172.

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

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 72: 255–261.

McCormick, K. J., and B. Poston. 1988. Lesser Snow Geese, *Anser c. caerulescens*, nesting on Jenny Lind Island, Northwest Territories. Canadian Field-Naturalist 102: 530–532.

McIntyre, J. W., and J. F. Barr. 1997. Common Loon (*Gavia immer*). No. 313 *in* A. Poole and F. Gill, editors. The birds of North America. The Birds of North America, Inc., Philadelphia, PA. 32 pp.

Michael Baker Jr., Inc. 2014. 2014 Colville River delta spring breakup monitoring and hydrological assessment. Report for ConocoPhillips Alaska, Inc., Anchorage, by Michael Baker, Jr., Inc., Anchorage, AK.

Monda, M. J., J. T. Ratti, and T. R. McCabe. 1994. Reproductive ecology of Tundra Swans on the Arctic National Wildlife Refuge, Alaska. Journal of Wildlife Management 58(4): 757–773.

Mowbray, T. B., C. R. Ely, J. S. Sedinger, and R. E.Trost. 2002. Canada Goose (*Branta canadensis*). No. 682 *in* A. Poole and F. Gill, editors. The birds of North America. The Birds of North America, Inc., Philadelphia, PA. 44 pp.

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

Murphy, S. M., and A. A. Stickney. 2000. Baseline avian surveys within the National Petroleum Reserve–Alaska, 2000. Report for PHILLIPS Alaska, Inc., Anchorage, by ABR, Inc., Fairbanks, AK. 28 pp.

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

North, M. R. 1994. Yellow-billed Loon (*Gavia adamsii*). No. 121 *in* A. Poole and F. Gill, editors. The birds of North America. The Birds of North America, Inc., Philadelphia, PA. 24 pp.

North, M. R., and M. R. Ryan. 1989. Characteristics of lakes and nest sites used by Yellow-billed Loons in arctic Alaska. Journal of Field Ornithology 60: 296–304.

Parrett, J., A. Wildman, and C. Johnson. 2008. Using evidence found at the nest to judge nest fate for Yellow-billed Loons (*Gavia adamsii*). Page 35 *in* Proceedings of the 2008 Alaska Bird Conference, 3–7 March 2008, Fairbanks, AK. [abstract only]

Piper, W. H., K. B. Tischler, M. Klich. 2000. Territory acquisition in loons: the importance of take-over. Animal Behaviour 59: 385–394.

Person, B. T., C. A. Babcock, and R. W. Ruess. 1998. Forage variation in brood-rearing areas used by Pacific Black Brant geese on the Yukon-Kuskokwim Delta, Alaska. Journal of Ecology 86: 243–259.

Renken, R., M. North, and S. G. Simpson. 1983. Waterbird studies on the Colville River delta, Alaska. U.S. Fish and Wildlife Service, Special Studies, Anchorage, AK.

Ritchie, R. J., R. M. Burgess, J. E. Shook, and T. Obritschkewitsch. 2010. Surveys for nesting and brood-rearing Brant and Lesser Snow Geese, Barrow to Fish Creek delta, Alaska, 2009. Report for North Slope Borough Department of Wildlife Management, Barrow, AK, by ABR, Inc., Fairbanks, AK. 75 pp.

Ritchie, R. J., R. M. Burgess, T. Obritschkewitsch, A. K. Prichard, and L. B. Attanas. 2014. Surveys for nesting and brood-rearing Brant and Lesser Snow Geese, Barrow to Fish Creek delta, Alaska, 2013. Report for North Slope Borough Department of Wildlife Management, Barrow, AK, by ABR, Inc., Fairbanks, AK. 70 pp.

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

Sedinger, J. S., and A. A. Stickney. 2000. Black Brant. Chapter 11 *in* J. C. Truett and S. R. Johnson, editors. The natural history of an Arctic oil field. Academic Press, San Diego, CA.

Seiser, P. E., and C. B. Johnson. 2010. Eider nest searches at the CD-3 Pad, ice road, and spill-response sites on the Colville delta, 2009. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Seiser. P. E., and C. B. Johnson. 2011a. Eider nest searches at the CD-3 Pad, ice road, spill-response sites, and pipeline bridges on the Colville River delta, 2010. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Seiser. P. E., and C. B. Johnson. 2011b. Eider nest searches at the CD-3 Pad, ice road, and spill-response sites on the Colville River delta, 2011. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 14 pp.

Seiser. P. E., and C. B. Johnson. 2012. Eider nest searches at the CD-3 Pad, ice road, and spill-response sites on the Colville River delta, 2012. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 14 pp.

Seiser. P. E., and C. B. Johnson. 2014a. Eider nest searches at the CD-3 Pad, ice road, and spill-response sites on the Colville River delta, 2013. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 13 pp.

Seiser. P. E., and C. B. Johnson. 2014b. Eider nest searches at CD3, spill-response sites, and the CD3 and CD5 ice roads, in the Alpine Oilfield, 2014. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 16 pp.

Serie, J. R, and J. C. Bartonek. 1991. Population status and productivity of tundra swans *Cyngus columbianus columbianus* in North America. Pp 172–177 *in* J. Sears and P. J. Bacon, editors. Proceedings of the Third International Swan Symposium, Oxford, 1989. Wildfowl, Supplement No. 1.

Serie, J. R., D. Luszcz, and R. V. Raftovich. 2002. Population trends, productivity and harvest of eastern population Tundra Swans. Pp 32–36 *in* E. C. Rees, S. L. Earnst, and J. Coulson, editors. Proceedings of the Fourth International Swan Symposium, 2001. Waterbirds 25, Special Publication 1.

Shideler, R., and J. Hechtel. 2000. Grizzly bear. Chapter 7 *in* J. Truett and S. R. Johnson, editors. The natural history of an Arctic oil field. Academic Press, San Diego, CA.

Simpson, S. G., and T. Pogson. 1982. White-fronted Geese on the Colville River delta, Alaska: 1982 progress report. U.S. Fish and Wildlife Service, Anchorage, AK. 5 pp.

Sjölander, S. 1978. Reproductive behaviour of the Black-throated Diver *Gavia arctica*. Ornis Scandinavica 9(1): 51–65.

Sjölander, S., and G. Ågren. 1976. Reproductive behavior of the Yellow-billed Loon, *Gavia adamsii*. Condor 78: 454–463.

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

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

Spindler. M. A., and K. F. Hall. 1991. Local movements and habitat use of Tundra or Whistling Swans *Cygnus columbianus* in the Kobuk-Selawik Lowlands of northwest Alaska. Wildfowl 42: 17–32.

Srivastava, D. S., and R. L. Jefferies. 1996. A positive feedback: herbivory, plant growth, salinity and the desertification of an Arctic salt-marsh. Journal of Ecology 84: 31–42.

Stehn, R. A., W. W. Larned, and R. M. Platte. 2013. Analysis of aerial survey indices monitoring waterbird populations of the Arctic Coastal Plain, Alaska, 1986–2012. Unpublished report by Migratory Bird Management, U.S. Fish and Wildlife Service, Anchorage and Soldotna, AK. 56 pp.

Stickney, A. A., and R. J. Ritchie. 1996. Distribution and abundance of Brant (*Branta bernicla*) on the central Arctic Coastal Plain of Alaska. Arctic 49: 44–52.

Stickney, A. A., R. J. Ritchie, B. A. Anderson, and D. A. Flint. 1993. Tundra Swan and Brant surveys on the Arctic Coastal Plain, Colville River to Sagavanirktok River, 1993. Report for ARCO Alaska, Inc., Anchorage, by Alaska Biological Research, Inc., Fairbanks, AK. 83 pp.

Stickney, A. A., B. A. Anderson, R. J. Ritchie, and J. G. King. 2002. Spatial distribution, habitat characteristics, and nest-site selection by Tundra Swans on the central Arctic Coastal Plain. Waterfowl 25 (Special Publication 1): 227–235.

Stickney, A. A., L. Attanas, and T. Obritschkewitsch. 2013. Avian studies in the Kuparuk Oilfield, 2012. Report for ConocoPhillips Alaska, Inc., and the Kuparuk River Unit, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 47 pp.

Stickney, A. A., T. Obritschkewitsch, and R. M. Burgess. 2014. Shifts in fox den occupancy in the greater Prudhoe Bay area, Alaska. Arctic 67: 196–202.

Stickney, A. A., L. Attanas, and T. Obritschkewitsch. 2015. Avian studies in the Kuparuk Oilfield, 2014. Draft report for ConocoPhillips Alaska, Inc., and the Kuparuk River Unit, Anchorage, AK, by ABR, Inc., Fairbanks, AK.

Streever, B., and S. C. Bishop, editors. 2014. Long-term ecological monitoring in BP's North Slope Oil Fields through 2013. BP Exploration (Alaska) Inc., Anchorage, AK. 97 pp.

Sutcliffe, S. 1982. Prolonged incubation behavior in Common Loons. Wilson Bulletin 94(3): 361–362.

Tape, K. D., P. L. Flint, B. W. Meixell, and B. J. Gaglioti. 2013. Inundation, sedimentation, and subsidence creates goose habitat along the Arctic coast of Alaska. Environmental Research Letters 8: 045031. 9 pp.

USFWS (U.S. Fish and Wildlife Service). 1987a. Standard operating procedures for aerial waterfowl breeding ground population and habitat surveys in North America. Unpublished report, Migratory Bird and Habitat Research Laboratory, Patuxent Wildlife Research Center, Laurel, MD. 96 pp.

USFWS. 1987b. Trumpeter and Tundra swan survey protocol update. Unpublished memorandum, Office of Migratory Bird Management, Juneau, AK. 8 pp.

USFWS. 1991. Trumpeter and Tundra swan survey protocol. Unpublished memorandum, Office of Migratory Bird Management, Juneau, AK. 4 pp.

Walker, H. J. 1978. Lake tapping in the Colville River delta, Alaska. Pages 233–238 *in* Proceedings of the 3rd International Conference on Permafrost, Vol. 1. Natural Research Council of Canada, Edmonton, AB.

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

Westerkov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14: 56–67.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement): 12–138.

Williams, T. D., E. G. Cooch, R. L. Jefferies, and F. Cooke. 1993. Environmental degradation, food limitation and reproductive output: juvenile survival in Lesser Snow Geese. Journal of Animal Ecology 62: 766–777.

Wilson, H. M. 2014. Aerial photographic surveys of Brant colonies on the Yukon-Kuskokwim Delta, Alaska, 2014. Unpublished report, U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK. 11 pp.

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Appendix A. Common, Iñupiaq, and scientific names of birds and mammals commonly observed in the Colville Delta and NE NPR-A study areas.

Common Name	Inupiaq Name	Scientific Name
Birds		
Snow Goose	Kaŋuq	*Chen caerulescens*
Brant	Niġlinġaq	*Branta bernicla*
Cackling Goose/Canada Goose	Iqsraġutilik	*Branta hutchinsii/B. canadensis*
Greater White-fronted Goose	Niġliviq	*Anser albifrons*
Tundra Swan	Qugruk	*Cygnus columbianus*
Northern Pintail	Kurugaq	*Anas Acuta*
Green-winged Teal	Qaiŋŋiq	*Anas crecca*
Steller's Eider	Igniqauqtuq	*Polysticta stelleri*
Spectacled Eider	Qavaasuk	*Somateria fischeri*
King Eider	Qiŋalik	*Somateria spectabilis*
Common Eider	Amauligruaq	*Somateria mollissima*
Willow Ptarmigan	Aqargiq, Nasaullik	*Lagopus lagopus*
Red-throated Loon	Qaqsrauq	*Gavia stellata*
Pacific Loon	Malġi	*Gavia pacifica*
Yellow-billed Loon	Tuullik	*Gavia adamsii*
Common Loon		*Gavia immer*
Bald Eagle	Tiŋmiaqpak	*Haliaeetus leucocephalus*
Northern Harrier	Papiktuuq	*Circus cyaneus*
Golden Eagle	Tiŋmiaqpak	*Aquila chrysaetos*
Glaucous Gull	Nauyavasrugruk	*Larus hyperboreus*
Bar-tailed Godwit	Turraaturaq	*Limosa lapponica*
Sabine's Gull	Iqirgagiak	*Xema sabini*
Arctic Tern	Mitqutailaq	*Sterna paradisaea*
Pomarine Jaeger	Isuŋŋaġluk	*Stercorarius pomarinus*
Parasitic Jaeger	Migiaqsaayuk	*Stercorarius parasiticus*
Long-tailed Jaeger	Isuŋŋaq	*Stercorarius longicaudus*
Short-eared Owl	Nipailuktaq	*Asio flammeus*
Common Raven	Tulugaq	*Corvus corax*
Mammals		
Arctic Fox	Tiġiganniaq	*Vulpes lagopus*
Red Fox	Kayuqtuq	*Vulpes vulpes*
Brown (Grizzly) Bear	Akłaq	*Ursus arctos*
Wolverine	Qavvik	*Gulo gulo*
Caribou	Tuttu	*Rangifer tarandus*

Appendix B. Classification and descriptions of wildlife habitat types found in the Colville Delta or NE NPR-A study areas, Alaska, 2012. Species associations of some habitats vary between the Colville Delta and the NE NPR-A study areas.

Habitat Class	Description
Open Nearshore Water (Estuarine Subtidal)	Shallow estuaries, lagoons, and embayments along the coast of the Beaufort Sea. Winds, tides, river discharge, and icing create dynamic changes in physical and chemical characteristics. Tidal range normally is small (< 0.2 m), but storm surges produced by winds may raise sea level as much as 2–3 m. Bottom sediments are mostly unconsolidated mud. Winter freezing generally begins in late September and is completed by late November. An important habitat for some species of waterfowl for molting during spring and fall staging.
Brackish Water (Tidal Ponds)	Coastal ponds and lakes that are flooded periodically with saltwater during storm surges. Salinity levels often are increased by subsequent evaporation of impounded saline water. Sediments may contain peat, reflecting a freshwater/terrestrial origin, but this peat is mixed with deposited silt and clay.
Tapped Lake with Low-water Connection	Waterbodies that have been partially drained by erosion of banks by adjacent river channels and are connected to rivers by distinct, permanently flooded channels. The water typically is brackish and the lakes are subject to flooding every year. Because water levels have dropped, the lakes generally have broad flat shorelines with silty clay sediments. Salt-marsh vegetation is common along the shorelines. Deeper lakes in this habitat do not freeze to the bottom during winter. Sediments are fine-grained silt and clay with some sand. These lakes form important over-wintering habitat for fish.
Tapped Lake with High-water Connection	Similar to Tapped Lake with Low-water Connection except that the connecting channels are dry during low water and the lakes are connected only during flooding events. Water tends to be fresh. Small deltaic fans are common near the connecting channel due to deposition during seasonal flooding. These lakes form important fish habitat.
Salt Marsh	On the Beaufort Sea coast, arctic Salt Marshes generally occur in small, widely dispersed patches, most frequently on fairly stable tidal flats associated with river deltas. The surface is flooded irregularly by brackish or marine water during high tides, storm surges, and river flooding events. Salt Marshes typically include a complex assemblage of small brackish ponds and Halophytic Sedge or Grass Wet Meadows. Moist Halophytic Dwarf Shrub and small barren areas also may occur in patches too small to map separately. Dominant plant species usually include *Carex subspathacea, C. ursina, C. ramenskii, Puccinellia phryganodes, Dupontia fisheri, P. andersonii, Salix ovalifolia, Cochlearia officinalis, Stellaria humifusa,* and *Sedum rosea*. Salt Marsh is important habitat for brood-rearing and molting waterfowl.
Moist Halophytic Dwarf Shrub	Tidal flats and regularly flooded riverbars of tidal rivers with vegetation dominated by dwarf willow and graminoids. Tide flat communities have brackish, loamy (with variable organic horizons), saturated soils, with ground water depths ~ 25 cm and active layer depths ~50 cm. Vegetation is dominated by *Salix ovalifolia, Carex subspathacea*, and *Calamagrostis deschampsioides*. On sandy sites *Elymus arenarius mollis* is a co-dominant. On active tidal river depostis, soils are loamy, less brackish, and vegetation is dominated by *Salix ovalifolia* with *Carex aquatilis* and *Dupontia fisheri*.

Appendix B. Continued.

Habitat Class	Description
Dry Halophytic Meadow	Somewhat poorly vegetated, well-drained meadows on regularly inundated tidal flats and riverbars of tidal rivers, characterized by the presence of *Elymus arenarius mollis*. Soils are brackish sands with little organic material and deep active layers. Commonly associated species include *Salix ovalifolia, Sedum rosea, Stellaria humifusa*, (on tide flats) and *Deschampsia caespitosa* (on tidal river deposits).
Tidal Flat Barrens	Areas of nearly flat, barren mud or sand that are periodically inundated by tidal waters. Tidal Flat Barrens occur on the seaward margins of deltaic estuaries, leeward portions of bays and inlets, and at mouths of rivers. Tidal Flat Barrens frequently are associated with lagoons and estuaries and may vary widely in actual salinity levels. Tidal Flat Barrens are considered separately from other barren habitats because of their importance to estuarine and marine invertebrates and shorebirds.
Salt-killed Tundra	Coastal areas where saltwater intrusions from storm surges have killed much of the original terrestrial vegetation and are being colonized by salt-tolerant plants. Colonizing plants include *Puccinellia andersonii, Dupontia fisheri, Braya purpurascens, B. pilosa, Cochlearia officinalis, Stellaria humifusa, Cerastium beeringianum,* and *Salix ovalifolia*. This habitat typically occurs either on low-lying areas that originally supported Patterned Wet Meadows and Basin Wetland Complexes or, less commonly, along drier coastal bluffs that originally supported Moist Sedge–Shrub Meadow and Dry Dwarf Shrub. Salt-killed Tundra differs from Salt Marshes in having abundant litter from dead tundra vegetation, a surface horizon of organic soil, and salt-tolerant colonizers.
Deep Open Water without Islands	Deep (≥1.5 m) waterbodies range in size from small ponds in ice-wedge polygons to large open lakes. Most have resulted from thawing of ice-rich sediments, although some are associated with old river channels. They do not freeze to the bottom during winter and usually are not connected to rivers. Sediments are fine-grained silt in centers with sandy margins. Deep Open Waters without Islands are differentiated from those with islands because of the lack of nest sites for waterbirds that prefer islands.
Deep Open Water with Islands or Polygonized Margins	Similar to above except that they have islands or complex shorelines formed by thermal erosion of low-center polygons. The complex shorelines and islands are important features of nesting habitat for many species of waterbirds.
Shallow Open Water without Islands	Ponds and small lakes <1.5 m deep with emergent vegetation covering <5% of the waterbody's surface. Due to the shallow depth, water freezes to the bottom during winter and thaws by early to mid-June. Maximal summer temperatures are higher than those in deep water. Sediments are loamy to sandy.
Shallow Open Water with Islands or Polygonized Margins	Shallow lakes and ponds with islands or complex low-center polygon shorelines, otherwise similar to Shallow Open Water without Islands. Distinguished from Shallow Open Water without Islands because shoreline complexity appears to be an important feature of nesting habitat for many species of waterbirds.
River or Stream	All permanently flooded channels large enough to be mapped as separate units. Rivers generally experience peak flooding during spring breakup and lowest water levels during mid-summer. The distributaries of Fish Creek are slightly saline, whereas other streams are non-saline.

Appendix B. Continued.

Habitat Class	Description
Sedge Marsh	Permanently flooded waterbodies dominated by *Carex aquatilis*. Typically, emergent sedges occur in water ≤0.5 m deep. Water and bottom sediments of this shallow habitat freeze completely during winter, but the ice melts in early June. The sediments generally consist of a peat layer (0.2–0.5 m deep) overlying loam or sand.
Deep Polygon Complex	A habitat associated with inactive and abandoned floodplains and deltas in which thermokarst of ice-rich soil has produced deep (>0.5 m), permanently flooded polygon centers. Emergent vegetation, mostly *Carex aquatilis,* usually is found around the margins of the polygon centers. Occasionally, centers will have the emergent grass *Arctophila fulva*. Polygon rims are moderately well drained and dominated by sedges and dwarf shrubs, including *Carex aquatilis, Eriophorum angustifolium, C. bigelowii, Dryas integrifolia, Salix reticulata,* and *S. ovalifolia*.
Grass Marsh	Ponds and lake margins with the emergent grass *Arctophila fulva*. Due to shallow water depths (<1 m), the water freezes to the bottom in the winter, and thaws by early June. *Arctophila fulva* stem densities and annual productivity can vary widely among sites. Sediments generally lack peat. This type usually occurs as an early successional stage in recently drained lake basins and is more productive than Sedge Marsh. This habitat tends to have abundant invertebrates and is important to many waterbirds.
Young Basin Wetland Complex (Ice-poor)	Complex habitat found in recently drained lake basins and characterized by a mosaic of open water, Sedge and Grass Marshes, Nonpatterned Wet Meadows, and Moist Sedge–Shrub Meadows in patches too small (<0.5 ha) to map individually. During spring breakup, basins may be entirely inundated, though water levels recede by early summer. Basins often have distinct banks marking the location of old shorelines, but these boundaries may be indistinct due to the coalescence of thaw basins and the presence of several thaw lake stages. Soils generally are loamy to sandy, moderately to richly organic, and ice-poor. Because there is little segregated ground ice the surface form is nonpatterned ground or disjunct polygons and the margins of waterbodies are indistinct and often interconnected. Ecological communities within young basins appear to be much more productive than are those in older basins: this was the primary rationale for differentiating these two types.
Old Basin Wetland Complex (Ice-rich)	Similar to above but characterized by well-developed low- and high-centered polygons resulting from ice-wedge development and aggradation of segregated ice. Complexes in basin margins generally include Sedge Marsh, Patterned Wet Meadow, Moist Sedge–Shrub Meadows, and small ponds (<0.25 ha). The waterbodies in old basins tend to have smoother, more rectangular shorelines and are not as interconnected as those in more recently drained basins. The vegetation types in basin centers generally include Moist Sedge–Shrub Meadow and Moist Tussock Tundra on high-centered polygons, and Patterned Wet Meadows. Grass Marsh generally is absent. Soils have a moderately thick (0.2–0.5 m) organic layer overlying loam or sand.

Appendix B. Continued.

Habitat Class	Description
Riverine Complex	Permanently flooded streams and floodplains characterized by a complex mosaic of water, Barrens, Dry Dwarf Shrub, Moist Tall Shrub and Moist Low Shrub, Sedge and Grass Marsh, Nonpatterned and Patterned Wet Meadow, and Moist Sedge–Shrub Meadow in patches too small (<0.5 ha) to map individually. Surface form varies from nonpatterned point bars and meadows to mixed high- and low-centered polygons and small, stabilized dunes. Small ponds tend to have smooth, rectangular shorelines resulting from the coalescing of low centered polygons. During spring flooding these areas may be entirely inundated, following breakup water levels gradually recede.
Dune Complex	Complex formed from the action of irregular flooding on inactive sand dunes, most commonly on river point bars. A series of narrow swale and ridge features develop in parallel with river flow that are too small to map separately. Swales are moist or saturated while ridges are moist to dry. Habitat classes in swales typically are Moist Low Shrub, Nonpatterned Wet Meadow, or Sedge Marsh, while ridges commonly are Dry Dwarf Shrub or Moist Low Shrub.
Nonpatterned Wet Meadow	Sedge-dominated meadows that occur within recently drained lake basins, as narrow margins of receding waterbodies, or along edges of small stream channels in areas that have not yet undergone extensive ice-wedge polygonization. Disjunct polygon rims and strang cover <5% of the ground surface. The surface generally is flooded during early summer (depth <0.3 m) and drains later, but water remains close to the surface throughout the growing season. The uninterrupted movement of water (and dissolved nutrients) in nonpatterned ground results in more robust growth of sedges than occurs in polygonized habitats. Usually dominated by *Carex aquatilis* and *Eriophorum angustifolium*, although other sedges may be present. Near the coast, the grass *Dupontia fisheri* may be present. Low and dwarf willows (*Salix lanata richardsonii, S. reticulata, S. planifolia pulchra*) occasionally are present. Soils generally have a moderately thick (10–30 cm) organic horizon overlying loam or sand.
Patterned Wet Meadow	Lowland areas with low-centered polygons or strang within drained lake basins, level floodplains, and flats and water tracks on terraces. Polygon centers are flooded in spring and water remains close to the surface throughout the growing season. Polygon rims or strang interrupt surface and groundwater flow, so only interconnected polygon troughs receive downslope flow and dissolved nutrients; in contrast, the input of water to polygon centers is limited to precipitation. As a result, vegetation growth typically is more robust in polygon troughs than in centers. Vegetation is dominated by sedges, usually *Carex aquatilis* and *Eriophorum angustifolium*, although other sedges may be present including *C. rotundata, C. saxatilis, C. membranacea, C. chordorrhiza,* and *E. russeolum*. On polygon rims, willows (e.g., *Salix lanata richardsonii, S. reticulata, S. planifolia pulchra*) and the dwarf shrubs *Dryas integrifolia* and *Cassiope tetragona* may be abundant along with other species typical of moist tundra.
Moist Sedge–Shrub Meadow	High-centered, low-relief polygons and mixed high- and low-centered polygons on gentle slopes of lowland, riverine, drained basin, and solifluction deposits. Soils are saturated at intermediate depths (>0.15 m) but generally are free of surface water during summer. Vegetation is dominated by *Dryas integrifolia*, and *Carex bigelowii*. Other common species include *C. aquatilis*, *Eriophorum angustifolium*, *Salix reticulata, S. lanata richardsonii,* and the moss *Tomentypnum nitens*. The active layer is relatively shallow and the organic horizon is moderate (0.1–0.2 m).

Appendix B. Continued.

Habitat Class	Description
Moist Tussock Tundra	Gentle slopes and ridges of coastal deposits and terraces, pingos, and the uplifted centers of older drained lake basins. Vegetation is dominated by tussock-forming plants, most commonly *Eriophorum vaginatum***.** High-centered polygons of low or high relief are associated with this habitat. Soils are loamy to sandy, somewhat well-drained, acidic to circumneutral, with moderately thick (0.1–0.3 m) organic horizons and shallow (<0.4 m) active layer depths. On acidic sites, associated species include *Ledum decumbens, Betula nana, Salix planifolia pulchra, Cassiope tetragona* and *Vaccinium vitis-idaea*. On circumneutral sites common species include *Dryas integrifolia, S. reticulata, Carex bigelowii,* and lichens. Mosses are common at most sites.
Tall, Low, or Dwarf Shrub	Includes all 5 shrub classifications— Moist Tall Shrub, Moist Low Shrub, Moist Dwarf Shrub, and Dry Tall Shrub.
Moist Tall Shrub	Most commonly found on actively flooded banks and bars of meander and tidal rivers dominated by tall (> 1.5 m) shrubs. Sites are nonpatterned and subject to variable flooding frequency, soils are well-drained, alkaline to circumneutral, and lack organic material. Vegetation is defined by an open canopy of *Salix alaxensis*. Understory species include *Equisetum arvense, Gentiana propinqua, Chrysanthemum bipinnatum, Festuca rubra* and *Aster sibiricus*. Moist Tall Shrub occasionally occurs on protected lowland sites where the dominant species may be *Salix* spp.or *Alnus crispa*.
Moist Low Shrub	Any community on moist soils dominated by willows < 1.5m tall. Upland sites are well-drained sands and loams characterized by *Salix glauca* (or infrequently, *Betula nana*), *Dryas integrifolia*, and *Arctostaphylos rubra*. Recently drained basins are somewhat poorly drained loams with moderate organic horizons dominated by either *S. lanata richardsonii* or *S. planifolia pulchra* with *Eriophorum angustifolium* and *Carex aquatilis*. Riverbank deposits also are dominated by either *S. lanata richardsonii* or *S. planifolia pulchra*, but with *Equisetum arvense*, *Arctagrostis latifolia*, or *Petasites frigidus*. Somewhat poorly-drained lowland flats and lower slopes have the greatest organic horizon development and are dominated by *S. planifolia pulchra*. Associated species are similar to those in drained basin communities. Thaw depths are deepest in riverine and upland communities and shallowest in lowland areas.
Moist Dwarf Shrub	Well-drained upland slopes and banks, and the margins of drained lake basins dominated by *Cassiope tetragona*. Soils are well-drained, loamy to sandy and circumneutral to acidic. Vegetation is species rich, associated species include *Dryas integrifolia, Salix phlebophylla, Vaccinium vitis-idaea, Carex bigelowii, Arctagrostis latifolia, Hierochloe alpina, Pyrola grandiflora,* and *Saussurea angustifolia*. Lichens and mosses also are common.
Dry Tall Shrub	Crests of active sand dunes with vegetation dominated by the tall willow *Salix alaxensis*. Soils are sandy, excessively drained, alkaline to circumneutral, with deep active layers (>1 m) and no surface organic horizons. The shrub canopy usually is open with dominant shrubs >1m tall. Other common species include *Chrysanthemum bipinnatum, Festuca rubra*, and *Equisetum arvense*.

Appendix B. Continued.

Habitat Class	Description
Dry Dwarf Shrub	Well-drained riverbank deposits and windswept, upper slopes and ridges dominated by the dwarf shrub *Dryas integrifolia*. Soils are sandy to loamy, alkaline to circumneutral, with deep active layers. Upland sites are lacking in organics, and in riverine sites organic accumulation is shallow. Riverbank communities have *Salix reticulata, Carex bigelowii, Arctagrostis latifolia, Equisetum variegatum, Oxytropis deflexa, Arctostaphylos rubra,* and lichens as common associates, while upland sites have *S. reticulata, S. glauca, S. arctica, C. bigelowii, Arctostaphylos alpina, Arctagrostis latifolia*, and lichens.
Barrens (Riverine, Eolian, or Lacustrine)	Includes barren and partially vegetated (<30% plant cover) areas related to riverine, eolian, or thaw basin processes. Riverine Barrens on river flats and bars are underlain by moist sands and are flooded seasonally. Early colonizers are *Deschampsia caespitosa, Poa hartzii, Festuca rubra, Salix alaxensis*, and *Equisetum arvense.* Eolian Barrens are active sand dunes that are too unstable to support more than a few pioneering plants (<5% cover). Typical species include *Salix alaxensis, Festuca rubra,* and *Chrysanthemum bipinnatum*. Lacustrine Barrens occur within recently drained lakes and ponds. These areas may be flooded seasonally or can be well drained. Typical colonizers are forbs, graminoids, and mosses including *Carex aquatilis, Dupontia fisheri, Scorpidium scorpioides*, and *Calliergon* sp. on wet sites and *Poa* spp.*, Festuca rubra, Deschampsia caespitosa, Stellaria humifusa, Senecio congestus,* and *Salix ovalifolia* on drier sites. Barrens may receive intense use seasonally by caribou as mosquito-relief habitat.
Moist Herb Meadow	Active and Inactive Delta Channel deposits with sandy, moist, moderately well-drained soil. The ground surface is dominated by bare soil. *Chrysanthemum bipinnatum*, and *Equisetum arvense* are the dominant species. Other taxa characteristic taxa include *Artemisia tilesii*, *Astragalus alpinus*, *Deschampsia caespitosa*, *Festuca rubra*, *Pedicularis verticillata*, *Salix alaxensis*, and *Wilhelmsia physodes*
Human Modified (Water, Fill, Peat Road)	A variety of small disturbed areas, including impoundments, gravel fill, and a sewage lagoon at Nuiqsut. Gravel fill is present at Nuiqsut, the Alpine facilities, and at the Helmericks' residence near the mouth of the Colville River.

Appendix C. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 2014.

SPECIES Subarea Location	Observed				Indicated Total[a]	Observed Density[b]	Indicated Density[a, b]
	Males	Females	Total	Pairs			
SPECTACLED EIDER							
CD North							
On ground	30	22	52	22	60	0.25	0.29
In flight	4	0	4	0	–	0.02	–
All birds	34	22	56	22	–	0.27	–
Northeast Delta							
On ground	3	3	6	3	6	0.04	0.04
In flight	3	2	5	2	–	0.03	–
All birds	6	5	11	5	–	0.07	–
CD South							
On ground	1	1	2	1	2	0.01	0.01
In flight	0	0	0	0	–	0.00	–
All birds	1	1	2	1	–	0.01	–
Total (subareas combined)							
On ground	34	26	60	26	68	0.12	0.14
In flight	7	2	9	2	–	0.02	–
All birds	41	28	69	28	–	0.14	–
KING EIDER							
CD North							
On ground	8	8	16	8	16	0.08	0.08
In flight	1	1	2	1	–	0.01	–
All birds	9	9	18	9	–	0.09	–
Northeast Delta							
On ground	16	16	32	16	32	0.20	0.20
In flight	4	1	5	1	–	0.03	–
All birds	20	17	37	17	–	0.23	–
CD South							
On ground	9	7	16	7	18	0.12	0.13
In flight	0	0	0	0	0	0.00	–
All birds	9	7	16	7	–	0.12	–
Total (subareas combined)							
On ground	33	31	64	31	66	0.13	0.13
In flight	5	2	7	2	–	0.01	–
All birds	38	33	71	33	–	0.14	–

[a] Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a)

[b] Density based on 100% coverage of subareas: CD North = 206.7 km²; Northeast Delta = 157.6 km², CD South = 137.2 km², all subareas combined = 501.4 km²; numbers not corrected for sightability

Appendix D. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, NE NPR-A study area, Alaska, 2014.

SPECIES Subarea Location	Observed Males	Observed Females	Observed Total	Observed Pairs	Indicated Total[a]	Observed Density[b]	Indicated Density[a, b]
SPECTACLED EIDER							
Development & Exploration	0	0	0	0	0	0	0
All birds	0	0	0	0	–	0	–
Alpine West							
On ground	3	1	4	1	6	0.10	0.14
In flight	0	0	0	0	0	0	–
All birds	3	1	4	1	–	0.10	–
Fish Creek Delta							
On ground	2	1	3	1	4	0.05	0.07
In flight	1	0	1	0	–	0.02	–
All birds	3	1	4	1	–	0.07	–
Total (subareas combined)							
On ground	5	2	7	2	10	0.02	0.03
In flight	1	0	1	0	–	<0.01	–
All birds	6	2	8	2	–	0.02	–
KING EIDER							
Development							
On ground	27	20	47	20	54	0.23	0.26
In flight	11	2	13	2	–	0.06	–
All birds	38	22	60	22	–	0.29	–
Alpine West							
On ground	16	11	27	11	32	0.65	0.77
In flight	7	6	13	6	–	0.31	–
All birds	23	17	40	17	–	0.96	–
Fish Creek Delta							
On ground	16	13	29	13	32	0.51	0.56
In flight	8	4	12	4	–	0.21	–
All birds	24	17	41	17	–	0.72	–
Exploration							
On ground	1	0	1	0	2	0.04	0.07
In flight	0	0	0	0	–	0	–
All birds	1	0	1	0	–	0.04	–
Total (subareas combined)							
On ground	60	44	104	44	120	0.31	0.36
In flight	26	12	38	12	–	0.11	–
All birds	86	56	142	56	–	0.43	–

[a] Total indicated birds was calculated according to standard USFWS protocol (USFWS 1987a)
[b] Numbers not corrected for sightability. Surveys conducted at 50% coverage. Density based on area surveyed: Development subarea = 205.7 km², Exploration = 27.9 km², Alpine West = 41.8 km², Fish Creek Delta = 57.3 km², all subareas combined = 332.7 km². Fish Creek West, and the western portions of the Development and Exploration subareas were not surveyed in 2014 (see Figure 1)

Appendix E. Number and density of loons and their nests, broods, and young during aerial surveys, Colville Delta and NE NPR-A study areas, Alaska, 2014.

	Yellow-billed Loon					Pacific Loon[a]			Red-throated Loon[a]		
STUDY AREA	Number			Density (number/km²)		Number			Number		
Subarea[b] / Survey Type	Adults	Nests/ Broods	Young	Adults	Nests/ Broods	Adults	Nests/ Broods	Young	Adults	Nests/ Broods	Young
COLVILLE DELTA											
CD North											
Nesting	37	15[c,d]	–	0.18	0.07	146	12	–	20	2	–
Brood-rearing	19	2[e]	2	0.08	0.01	93	15	16	20	6	6
CD South											
Nesting	38	16[d]	–	0.24	0.10	106	18	–	12	1	–
Brood-rearing	28	6[e,f]	8	0.17	0.04	67	9	10	17	1	1
Northeast Delta[g]											
Nesting	3	1	–	–	–	28	1	–	2	0	–
Brood-rearing	1	0	0	–	–	14	2	2	0	0	0
Total (subareas combined)[f]											
Nesting	78	32[c,d]	–	0.22	0.09	280	31	–	34	3	–
Brood-rearing	48	8[e,f]	10	0.12	0.02	174	26	28	37	7	7
NE NPR-A											
Alpine West											
Nesting	2	1	–	0.03	0.01	90	11	–	1	0	–
Brood-rearing	0	1[f]	1	0	0.01	85	7	8	4	0	0
Fish Creek Delta											
Nesting	18	6[d]	–	0.14	0.05	116	14	–	14	1	–
Brood-rearing	7	3[f]	3	0.05	0.02	73	11	11	19	1	1
Fish and Judy Creek Corridor											
Nesting	17	9	–	0.34	0.18	19	1	–	0	0	–
Brood-rearing	13	5	5	0.26	0.10	22	5	5	0	0	0
GMT Corridor											
Nesting	10	4[d]	–	0.04	0.02	144	24	–	0	0	–
Brood-rearing	9	2	4[e]	0.03	0.01	178	30	33	1	0	0
Total (subareas combined)[h]											
Nesting	47	20[d]	–	0.09	0.04	369	50	–	15	1	–
Brood-rearing	29	11[f]	14[e]	0.06	0.02	358	53	57	24	1	1

[a] Densities of Pacific and Red-throated loons were not calculated because detectability differed from that of Yellow-billed Loons and surveys did not include smaller lakes (<5 ha) where those species commonly nest

[b] CD North = 206.7 km², CD South = 155.9 km², Alpine West = 79.7 km², Fish Creek Delta = 130.5 km²; eastern portion of Fish and Judy Creek Corridor = 49.5 km²; GMT Corridor = 265.5 km²; see Figure 5

[c] Number includes 1 nest documented in the CD North subarea on camera images only

[d] Number includes nests found during weekly monitoring surveys: 4 nests in the CD North subarea and 1 nest in the CD South subarea of the Colville Delta study area, and 1 nest in both the Fish Creek Delta and the GMT Corridor subareas of the NE NPR-A study area

[e] Number includes broods and young found during weekly monitoring surveys: 1 brood (1 young) in the CD North subarea and 2 in the CD South subarea (4 young) of the Colville Delta study area, and 2 young in the GMT Corridor Subarea of the NE NPR-A study area

[f] Number includes broods determined only by eggshell evidence: 1 brood in the CD South subarea of the Colville Delta study area, and 1 in the Alpine West and 1 in the Fish Creek Delta subareas of the NE NPR-A study area.

[g] Densities were not calculated for the Northeast Delta subarea because only a portion of the subarea was surveyed

[h] Total is the sum of all subareas but density calculations included only CD North and CD South for Colville Delta

Appendix F. Annual density (number/km²) of Yellow-billed Loons, nests, and broods, Colville Delta (1993–2014) and NE NPR-A (2001–2014) study areas, Alaska.

STUDY AREA Year	Nesting Survey Adults	Nests[a]	Brood-rearing Survey Adults	Broods[b]
COLVILLE DELTA[c]				
1993	0.14	0.02	0.08	0.02
1995	0.11	0.03	0.14	0.02
1996	0.12	0.03 (0.05)	0.17	0.02
1997	0.13	0.03 (0.04)	0.18	0.01
1998	0.09	0.04 (0.06)	0.14	0.03
2000	0.15	0.04 (0.04)	0.04	0.01
2001	0.15	0.05 (0.05)	0.07	0.01
2002	0.13	0.05 (0.05)	0.18	0.02
2003	0.14	0.07	0.13	0.04
2004	0.11	0.07	0.14	0.03
2005	0.15	0.08	0.10	0.04 (0.05)
2006	0.17	0.06 (0.07)	0.18	0.03 (0.04)
2007	0.17	0.07 (0.08)	0.14	0.05 (0.06)
2008	0.18	0.09 (0.10)	0.15	0.06 (0.07)
2009	0.17	0.07 (0.08)	0.15	0.02 (0.03)
2010	0.18	0.06 (0.09)	0.16	0.04 (0.04)
2011	0.19	0.06 (0.07)	0.12	0.03 (0.04)
2012	0.15	0.06 (0.08)	0.14	0.03 (0.04)
2013	0.18	0.03 (0.04)	0.11	0.02 (0.02)
2014	0.22	0.07 (0.09)	0.12	0.02 (0.01)
Mean	0.15	0.05 (0.08)[d]	0.13	0.03 (0.04)
SE	<0.01	<0.01 (<0.01)[d]	<0.01	<0.01 (<0.01)
NE NPR-A[e, f]				
2001	0.07	0.03	0.08	0.01
2002	0.07	0.03	0.05	0.01
2003	0.06	0.03	0.06	0.02
2004	0.07	0.03	0.08	0.01
2005	0.11	0.04	0.06	0.01
2006	0.11	0.04	0.07	0.01
2008	0.17	0.05 (0.06)	0.14	0.02 (0.04)
2009	0.13	0.05 (0.06)	0.16	0.03 (0.03)
2010	0.15	0.06 (0.06)	0.14	0.03 (0.03)
2011	0.12	0.03 (0.05)	0.12	0.02 (0.02)
2012	0.14	0.06 (0.07)	0.17	0.05 (0.05)
2013	0.16	0.05 (0.06)	0.08	0 (<0.01)
2014	0.09	0.03 (0.04)	0.06	0.02 (0.02)

[a] Density of nests found on the nesting survey and, in parentheses, cumulative density including additional nests found during revisit (1996–2002) and monitoring (2006–2013) surveys

[b] Density of broods found on the brood-rearing survey and, in parentheses, cumulative density including additional broods found during monitoring surveys (2005–2013) that did not survive to the time of the brood-rearing survey

[c] Colville Delta study area = 362.6 km² and includes CD North and CD South subareas combined

[d] Mean density and SE includes only years when monitoring surveys were conducted: 2006–2013

[e] Survey area included 5 subareas: Development (617.8 km²) surveyed in 2001–2004, Exploration (260.4 km²) in 2002–2004, Alpine West (79.7 km²) in 2002–2006 and 2008–2013, Fish Creek Delta (130.5 km²) in 2005–2006 and 2008–2013, and the Fish and Judy Creek Corridor (255.9 km²) in 2008–2010. In 2011–2013, the eastern one-quarter of the Fish and Judy Creek Corridor subarea (41.0 km²) was surveyed; area in 2014 was 525.2

[f] Mean densities not calculated for NE NPR-A because the study area differed among years

Appendix G. Nest history and incubation activity of Yellow-billed Loon nests monitored by time-lapse digital cameras, Colville Delta and NE NPR-A study areas, Alaska, 2008–2014.

STUDY AREA/ Year/ Fate	Median				Average				
	Start of Incubation	*n*	Hatch or Failure	*n*	Incubation Constancy[d] (%)	Exchange Frequency[a] (no/d)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)	*n*
COLVILLE DELTA									
2008									
Hatched	10 June	10	8 July	9	97.1 ± 0.7	1.1 ± 0.1	2.1 ± 0.3	17.1 ± 2.2	9
Failed	11 June	3	29 June	3	98.5 ± 1.0	2.1 ± 0.2	1.4 ± 0.4	13.0 ± 6.5	3
2009									
Hatched	11 June	9	9 July	9	98.2 ± 0.4	1.5 ± 0.2	1.7 ± 0.4	12.6 ± 1.6	9
Failed	10 June	6	29 June	7	95.7 ± 2.2	1.5 ± 0.5	2.5 ± 1.0	14.6 ± 5.9	4
2010									
Hatched	19 June	9	16 July	7	98.0 ± 0.2	1.8 ± 0.1	2.6 ± 0.2	10.0 ± 0.8	9
Failed	21 June	10	6 July	9	89.8 ± 3.9	1.6 ± 0.3	5.0 ± 0.7	34.9 ± 17.1	9
2011									
Hatched	15 June	13	13 July	13	98.0 ± 0.3	1.5 ± 0.1	2.6 ± 0.3	10.2 ± 1.0	13
Failed	19 June	7	4 July	7	93.1 ± 2.2	1.3 ± 0.2	5.0 ± 1.0	24.0 ± 8.1	6
2012									
Hatched	14 June	11	12 July	9	97.6 ± 0.5	1.6 ± 0.2	2.8 ± 0.3	10.6 ± 1.2	10
Failed	14 June	8	29 June	8	95.9 ± 1.8	1.7 ± 0.4	4.5 ± 1.6	12.0 ± 1.9	6
2013									
Hatched	17 June	4	16 July	3	92.8 ± 1.2	1.0 ± 0.2	4.5 ± 0.3	23.3 ± 5.0	4
Failed	17 June	8	27 June	8	87.2 ± 3.6	1.2 ± 0.3	4.4 ± 0.6	77.8 ± 18.7	9
2014									
Hatched	16 June	9	13 July	8	96.8 ± 0.7	1.6 ± 0.1	2.5 ± 0.3	12.8 ± 2.8	6
Failed	19 June	12	2 July	13	95.2 ± 0.6	1.8 ± 0.2	4.6 ± 0.5	14.7 ± 1.3	11
Total									
Hatched	15 June[b]	8	13 July[b]	8	97.4 ± 0.2	1.5 ± 0.1	2.5 ± 0.1	12.8 ± 0.8	60
Failed	17 June[b]	8	29 June[b]	8	92.8 ± 1.2	1.5 ± 0.1	4.3 ± 0.3	31.0 ± 5.8	48

Appendix G. Continued.

STUDY AREA/ Year/ Fate	Median				Average				
	Start of Incubation	n	Hatch or Failure	n	Incubation Constancy[d] (%)	Exchange Frequency[a] (no/d)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)	n
NE NPRA									
2010									
Hatched	19 June	6	18 July	5	97.2 ± 0.5	1.2 ± 0.2	3.5 ± 0.2	11.0 ± 1.3	6
Failed	18 June	2	5 July	4	94.4 ± 1.8	1.4 ± 0.2	3.6 ± 0.5	30.9 ± 9.6	4
2011									
Hatched	14 June	2	12 July	2	98.4 ± 0.2	1.3 ± 0.5	1.8 ± 0.1	12.4 ± 1.8	2
Failed	19 June	4	25 June	3	95.2 ± 0.4	1.6 ± 0.4	4.9 ± 0.4	20.5 ± 5.6	2
2012									
Hatched	14 June	9	12 July	8	97.9 ± 0.4	1.4 ± 0.2	2.4 ± 0.3	11.2 ± 1.2	9
Failed	16 June	2	4 July	2	95.8 ± 0.8	0.9 ± 0.9	4.0 ± 0.4	16.8 ± 1.8	2
2013									
Hatched	23 June	1	21 July	1	94.0	1.4	4.0	16.4	1
Failed	17 June	7	29 June	8	93.2 ± 0.9	1.1 ± 0.1	3.6 ± 0.3	58.6 ± 22.7	7
2014									
Hatched	15 June	7	13 July	7	98.0 ± 0.5	1.3 ± 0.3	2.5 ± 0.6	9.4 ± 1.3	6
Failed	17 June	6	6 July	5	93.6 ± 1.0	1.0 ± 0.1	4.6 ± 1.0	22.7 ± 6.6	5
Total									
Hatched	15 June[b]	5	13 July[b]	5	97.6 ± 0.3	1.3 ± 0.1	2.7 ± 0.2	11.0 ± 0.7	24
Failed	17 June[b]	5	4 July[b]	5	94.0 ± 0.5	1.2 ± 0.1	4.0 ± 0.3	36.1 ± 8.8	20

[a] Summarized from time loon returns to nest after camera installation to day before hatch, or to time of nest failure; excludes period of time when photo images could not be interpreted because of poor weather conditions

[b] Overall median calculated across yearly medians

Appendix H. Annual number of Tundra Swan nests and broods by subarea during aerial surveys, NE NPRA study area,[a] Alaska, 2001–2014.

SEASON Year	Alpine West	Development	Exploration	Fish Creek Delta	Fish Creek West
NESTS					
2001	1	20	11	–	–
2002	2	24	17	–	–
2003	3	27	13	–	–
2004	2	33	15	13	–
2005	3	25	9	4	7
2006	5	36	11	4	16
2008	5	32	18	4	10
2009	5	27	13	12	16
2011	4	1	–	7	–
2012	4	9	–	6	–
2013	3	5	–	7	–
2014	1	11	1	2	–
BROODS					
2001	2	16	5	–	–
2002	1	15	10	–	–
2003	3	12	5	–	–
2004	2	16	13	–	–
2005	2	18	6	3	8
2006	1	17	11	6	14
2008	2	16	4	4	9
2009	0	28	8	6	8
2011	0	5	–	5	–
2012	3	5	–	4	–
2013	5	4	–	4	–
2014	–	8	–	2	–

[a] Alpine West = 79.7 km^2, Development = 615.8 km^2, Exploration = 404.7 km^2, Fish Creek Delta = 130.5 km^2, Fish Creek West = 340.4 km^2. In 2011–2013, Development Subarea = 130.9 km^2. In 2014, sub-areas surveyed: Alpine West = 71.6 km^2, Development = 419.7 km^2, Exploration = 56.7 km^2, Fish Creek Delta = 119.7 km^2

Appendix I. Number of nest predators observed in and near 40 10-ha nest plots at CD5, NE NPR-A, Alaska, 2014. Predators include Long-tailed, Parasitic, and Pomarine jaegers (jaeger); Glaucous Gull (gull); Common Raven (raven); Short-eared Owl (owl); artic fox and brown bear (mammal).

	Predator Scans												Incidental Observations[a]											
	On Plot						Outside Plot[b]						On Plot						Outside Plot[b]					
Plot	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total
5	1	1	0	0	0	2	2	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
6	1	1	0	0	0	2	1	0	0	0	0	1	3	0	0	0	0	3	0	0	0	0	0	0
7	2	1	0	0	0	3	2	5	0	0	0	7	3	1	0	0	0	4	2	3	0	0	0	5
8	12	3	0	0	0	15	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
9	5	6	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	4	0	0	0	0	4	0	0	0	0	1	1	3	0	0	0	0	3	0	0	0	0	0	0
12	1	3	0	0	0	4	0	2	0	0	0	2	5	6	0	0	0	11	0	0	0	0	0	0
13	0	3	0	0	0	3	4	1	0	0	0	5	2	4	1	0	0	7	0	0	0	0	0	0
14	3	4	0	0	0	7	3	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
15	1	10	0	0	0	11	3	6	0	0	0	9	1	0	0	0	0	1	0	5	0	0	0	5
16	2	2	0	0	0	4	2	0	0	0	0	2	3	3	0	0	0	6	0	0	0	0	0	0
18	6	5	0	0	0	11	3	1	0	0	0	4	0	0	0	0	0	0	2	2	0	0	0	4
19	3	3	0	0	0	6	3	5	0	0	0	8	1	1	0	1	0	3	0	0	0	0	0	0
20	3	6	0	0	0	9	1	2	0	0	0	3	2	3	0	0	0	5	0	0	0	0	0	0
22	2	5	0	0	0	7	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
23	6	2	0	0	0	8	1	0	0	0	0	1	4	1	0	0	0	5	0	0	0	0	0	0
24	1	0	0	0	0	1	1	1	1	0	0	3	2	0	0	0	0	2	3	0	0	0	0	3
25	0	0	0	0	0	0	4	0	0	0	0	4	3	1	0	0	0	4	0	0	1	0	0	1
26	0	3	3	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	4	2	0	0	0	6	0	0	0	0	0	0	3	0	0	0	0	3	0	0	0	0	0	0
28	3	2	0	0	0	5	0	5	0	0	0	5	0	1	0	0	0	1	0	0	0	0	0	0
29	0	7	0	0	0	7	1	3	0	0	0	4	0	0	0	0	0	0	0	0	0	0	2	2
30	0	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1
33	0	0	0	1	0	1	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
34	1	3	0	0	0	4	0	0	0	0	3	3	3	0	3	0	0	6	0	0	0	0	0	0
35	1	1	0	0	0	2	7	11	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0

Appendix I. Continued.

Plot	Predator Scans												Incidental Observations[a]											
	On Plot						Outside Plot[b]						On Plot						Outside Plot[b]					
	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total	Jaeger	Gull	Raven	Owl	Mammal	Total
37	2	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	5	0	1	0	0	6	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
39	2	5	0	0	0	7	1	5	0	0	0	6	0	3	0	0	0	3	0	0	0	0	0	0
40	2	5	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	2	0	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
44	5	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	8	0	0	0	0	8	1	0	0	0	0	1	1	1	0	0	0	2	0	0	0	0	0	0
46	6	2	0	0	0	8	0	1	0	0	0	1	1	1	0	0	0	2	0	2	0	0	0	2
48	3	5	0	0	0	8	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0
49	2	2	0	0	0	4	0	1	0	0	0	1	4	1	0	0	0	5	0	0	0	0	0	0
50	8	3	0	0	0	11	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
51	7	1	0	0	0	8	3	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
52	5	1	0	0	0	6	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Total	120	101	4	1	0	226	52	59	2	0	4	117	46	27	4	1	0	78	7	13	1	0	2	23
Mean	1.50	1.26	0.05	0.01	0	2.83	0.65	0.74	0.03	0	0.05	1.46	0.58	0.34	0.05	0.01	0	0.98	0.09	0.16	0.01	0	0.03	0.29
SE	0.43	0.36	0.08	0.03	0	0.53	0.25	0.36	0.03	0	0.08	0.53	0.23	0.21	0.08	0.03	0	0.41	0.10	0.16	0.03	0	0.05	0.21
n [c]	80	80	80	80	80	80	80	80	80	80	80	80	40	40	40	40	40	40	40	40	40	40	40	40

[a] Predator scans included, 10-min scans per plot; incidental observations were made during nest-searching
[b] Predators observed outside plot but ≤300 m from plot boundary
[c] *n* = total number of 10-min scans for predators (predator scans) on and outside plots, and for incidental observations *n*= number of plots visited