EIGHTH ANNUAL REPORT

AVIAN STUDIES FOR THE ALPINE SATELLITE DEVELOPMENT PROJECT, 2010

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ANCHORAGE, ALASKA

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FAIRBANKS, ALASKA

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EXECUTIVE SUMMARY

Avian aerial surveys were conducted in the Colville Delta and in the northeastern National Petroleum Reserve–Alaska (NE NPRA) in 2010 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 Delta and in 1999 in the NE NPRA. Surveys focused on the abundance, distribution, and habitat use of 5 focal species: Spectacled Eider, King Eider, Tundra Swan, Yellow-billed Loon, and Brant. These 5 species 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 for development impacts. Monitoring a collection of focal species with differing habitat requirements provides both in-depth data on species trends and responses to a changing environment and a general view of ecosystem health. Aerial surveys for eiders, swans, and Brant were conducted from fixed-wing airplanes. Surveys for Yellow-Billed Loons were conducted from a helicopter; other loon species were recorded opportunistically.

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 (CD-1 and CD-2) began oil production on the Colville Delta in 2000. Two ASDP satellite drill sites were built in the winter of 2005: CD-3 was built 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 CD-4 was connected by a road on the south side of the Alpine Facility. The CD-3 site began producing oil in August 2006, and CD-4 began producing in November 2006. The NE NPRA study area (1,571 km²) abuts the western edge of the Colville Delta and encompasses 5 proposed development sites that are part of the ASDP: drill sites CD-5, Fiord West, GMT-1, and GMT-2, and the Clover A gravel mine site.

Each year, open houses are held in Nuiqsut to allow residents to visit with CPAI biologists and other scientists to discuss information and concerns about resources in the Colville Delta and NE NPRA areas. In October 2010, CPAI staff attended a science fair at the local school during the day, followed by a community meeting in the evening where they presented findings of recent monitoring efforts. During the summer field season in 2010, CPAI posted weekly updates on bulletin boards in the post office, store, and community center in Nuiqsut. Updates were also emailed to key representatives of the Kuukpik Subsistence Oversight Panel (KSOP), Kuukpik Corporation, the Department of Wildlife of the North Slope Borough, various state and federal agencies, and several environmental organizations. The updates reported on surveys conducted the previous week (for example, type of aircraft used, altitude of aircraft, and species enumerated) and the schedule of surveys for the upcoming week. The open house meetings and weekly updates kept local residents informed on the progress and results of studies conducted by CPAI in the area near Nuiqsut.

Results of aerial surveys in the Colville Delta study area indicated that 2010 was an above-average year in terms of abundance for Spectacled Eiders, Yellow-billed Loons, and Snow Geese, an average year for King Eiders and Brant, and a below-average year for Tundra Swans. Productivity was generally high for geese and low for loons and swans in the Colville Delta study area. In the NE NPRA study area, 2010 was an above-average year in terms of abundance for Spectacled Eiders and Yellow-billed Loons and an average year for King Eiders. Surveys for Tundra Swans and geese were not conducted in the NE NPRA study area in 2010.

Spring conditions appeared to be close to average. The mean monthly temperature for May 2010 on the Colville Delta was 0.4° C colder than the 14-year mean temperature and June was 1.2° C colder than the long-term mean. Cumulative thawing degree-days (an index to days with temperatures above freezing) for the first half of June were similar to the long-term average. Peak breakup of the Colville River occurred on 1 June 2010 and snow disappeared from the tundra on 7 June. Ice was gone from most deep lakes on 6 July and from all lakes by 13 July. Temperatures were colder than average for the last half of June.

The number of pre-nesting Spectacled Eiders on the Colville Delta in 2010 was the second-

highest recorded in 17 years. As in previous years, Spectacled Eiders were found primarily in the CD North subarea. Spectacled Eiders in the NE NPRA occurred at ≤25% of the densities found on the Colville Delta study area, with the highest densities of eiders in NE NPRA occurring in the Alpine West subarea.

During pre-nesting on the Colville Delta in 2010, King Eiders were half as numerous as Spectacled Eiders and most of the King Eiders were in the Northeast Delta subarea. The density of King Eiders on the Colville Delta study area in 2010 was the same as the long-term average. King Eiders were 20 times more abundant in NE NPRA than on the Colville Delta; their density in NE NPRA in 2010 was the same as the long-term average.

In 2010, we found the second highest number of Yellow-billed Loon nests (35) in the Colville Delta study area since aerial surveys began in 1993, but less than half of those nests (15) hatched young. In the NE NPRA study area, we counted 36 Yellow-billed Loon nests and 17 broods, which were the highest count of nests and the second highest count of broods during 3 years of surveys. Overall, 15 of 35 Yellow-billed Loon nests in the Colville Delta study area hatched young in 2010 for an apparent nesting success of 43%, which was the same as in 2009 and the lowest since nest monitoring surveys began in 2005. Similarly, in the NE NPRA study area, 17 of 36 nests hatched young for apparent nesting success of 47%, which was the lowest since nest monitoring surveys began in that area in 2008. In the Colville Delta study area, most nests hatched between surveys on 20 and 27 July, whereas in the NE NPRA study area, most nests hatched during the previous week. One of the 15 broods in the Colville Delta study area and 2 of the 17 broods in the NE NPRA study area disappeared between hatch and the next weekly survey. The presence of numerous (≥20) eggshell fragments indicated hatch occurred at those 3 nests; camera images at the nest in the Colville Delta study area also verified the presence of a chick. Those 3 broods were the only ones that failed to survive to the brood-rearing aerial survey on 16–17 August. An additional 2 broods disappeared by the last monitoring survey on 13 September.

During the first monitoring survey after hatch in 2010, 14 Yellow-billed Loon pairs were observed with 21 chicks (0.63 chicks/nest) in the Colville Delta study area; half of those pairs had 2 chicks. In the NE NPRA study area, 15 pairs were observed with 20 chicks (0.61 chicks/nest); 5 of those pairs had broods of 2. The remaining pairs either hatched only 1 egg or lost 1 of their chicks between hatching and the next weekly survey. One pair in the Colville Delta study area and 2 pairs in the NE NPRA study area were not observed with young during monitoring surveys but were determined to have hatched young based on egg fragments at the nest. On the last brood monitoring survey on 13 September, 4 pairs in the Colville Delta study area had 2 chicks and 9 pairs had 1 chick (0.49 chicks/nest). In the NE NPRA study area, 3 pairs retained 2 chicks and 11 pairs had 1 chick (0.47 chicks/nest). Loon chicks in both study areas were approximately 7–8 weeks old during the last monitoring survey and none were observed flying.

Nineteen Yellow-billed Loon nests on the Colville Delta were monitored with time-lapse cameras. Seventeen loons left nests during camera installation. Ten nests were monitored with cameras in the NE NPRA study area and 8 loons left nests during camera installation. All loons returned to their nest after camera installation (Colville Delta mean = 62 min off nest; NE NPRA mean = 49 min). Apparent nesting success for camera-monitored nests on the Colville Delta and NE NPRA was 47% and 60%, respectively, or slightly higher than for all Yellow-billed Loon nests in those areas monitored by weekly surveys. Of the 10 nests that failed, 3 failures were attributed to predation by red foxes, 2 to Glaucous Gulls, 2 to Parasitic Jaegers, 1 to a Golden Eagle and 1 to nest abandonment; the camera at the remaining nest malfunctioned before nest failure. Loons at hatched nests exhibited higher nest attendance than those at failed nests, spending 98.1% and 91.2% of monitored time on nests, respectively. Of the 4 nests that failed, 1 failure was attributed to a pair of Common Ravens, 1 to a pair of Parasitic Jaegers and a Glaucous Gull, and 1 to a Golden Eagle; the predator at the remaining nest was not captured on camera images because predation occurred during the time interval between when images were taken. Loons at both hatched and failed nests in the NE NPRA study area exhibited high nest attendance, spending 97.1% and 94.3% of the time incubating, respectively. The cameras also documented partial predation at 6 nests and verified that chicks were present at 1 nest where the presence of egg fragments indicated hatch, but where no chicks were seen during weekly monitoring surveys.

Fifteen nests and 5 broods of Pacific Loons were counted opportunistically during Yellow-billed Loon surveys in the Colville Delta study area in 2010. Two broods of Red-throated Loons but no nests were seen during the same aerial surveys. In the NE NPRA study area, we counted 32 nests and 2 broods of Pacific Loons. No Red-throated Loons were seen during the same aerial surveys. Opportunistic counts of Pacific and Red-throated loons reflect their general distribution in these study areas but are not indicative of relative abundance, because the loon survey focused mostly on large lakes and not smaller lakes that are typical nesting and brood-rearing habitat for Pacific and Red-throated loons.

Twenty-four Tundra Swan nests were found in the Colville Delta study area in 2010, which is well below the average of 34 nests/year for 17 years of aerial surveys. The count of 15 swan broods in the Colville Delta study area in 2010 also was lower than the long-term average of 25 broods. Apparent nesting success was fairly poor, at 60%. The mean brood size of 2.5 young in 2010 was average, but the 37 swan young counted on the delta was only about half of the long-term average production of 64 young/year.

Brant and Snow Goose productivity appeared to be high in the Colville Delta study area in 2010. The total count for Brant during brood-rearing (1,474) was near average, but the gosling count (728) was the fourth highest ever recorded along the survey route. Snow Goose numbers increased sharply from 2009, and the total number of Snow Geese (883 adults and 990 young) was just below the record high set in 2008. Brant and Snow Geese favored coastal salt-affected habitats for brood-rearing and molting in the Colville Delta study area.

Forty-five Glaucous Gull nests and at least 8 broods were counted incidentally during loon aerial surveys in the Colville Delta study area in 2010. The number of Glaucous Gull nests in the Colville Delta study area in 2010 is similar to the 8-year mean of 44 nests. In the NE NPRA, we found 23 Glaucous Gull nests and 8 broods in 2010, which is fewer nests and more broods than are usually recorded within the survey area. The largest number of nests was in the Alpine West subarea. The count of broods is partly dependent on whether gull chicks are flight capable by the time of the loon brood-rearing survey. In years when hatch is late, more broods are observed because chicks are not flight capable. Two Sabine's Gull nests were found in the Colville Delta study area during the loon nesting survey. Numbers of Sabine's Gull nests have ranged from 1 to 16 in the study area during the years when Sabine's Gulls were recorded on aerial surveys (2003–2010). Twelve nests were found in the NE NPRA study area.

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INTRODUCTION

During 2010, ABR, Inc., conducted wildlife surveys for selected birds and mammals in the Colville River Delta and Northeast Planning Area of the National Petroleum Reserve–Alaska (NE NPRA) in support of the Alpine Satellite Development Project (ASDP) of ConocoPhillips Alaska, Inc., (CPAI) and Anadarko Petroleum Corporation (APC). The wildlife studies in 2010 were a continuation of work initiated by CPAI's predecessors, ARCO Alaska, Inc., and Phillips Alaska, Inc., in 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, 2008b, 2009, 2010; Burgess et al. 2000, 2002a, 2003a) and in the NE NPRA 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). Avian surveys in the NE NPRA were interrupted in 2007 due to delays in permitting for the CD-5 drill site. Permits for CD-5 were held up again in 2010; consequently, surveys were conducted in NE NPRA only for Spectacled Eiders and Yellow-billed Loons, because of their sensitive status under the Endangered Species Act of 1993, as amended.

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, Anderson et al. 2009, Lawhead et al. 2010). 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 CD-1 and CD-2 drill sites. Production was augmented in 2006 with construction of the CD-3 and CD-4 drill sites. CPAI has proposed additional oil and gas development sites in NE NPRA as part of the Alpine Satellite Development Project (BLM 2004): CD-5 (Alpine West), GMT-1 (formerly CD-6 or Lookout), and GMT-2 (formerly CD-7 or Spark), and a newly proposed site named Fiord West (Figure 1). Readers are directed to prior reports for wildlife information from previous years.

We report here the results of avian surveys in 2010 that were conducted in the Colville River Delta and NE NPRA. Surveys in 2010 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 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. Monitoring a collection of focal species provides in-depth data on individual species trends and responses to a changing environment, as well as a general overview of ecosystem health. Data collection for a suite of indicator species with diverse life histories and habitat needs is an efficient way to monitor a multi-species system, obviating the need to study all species that breed in the study area. Ground-based surveys for nesting birds were conducted in select areas on the Colville River Delta in 2010 as part of other studies (Seiser and Johnson 2011). Required state and federal permits were obtained for authorized survey activities, including a Scientific or Educational Permit (Permit No. 10-028) from the State of Alaska and a Federal Fish and Wildlife Permit—Threatened and Endangered Species [Permit No. TE012155-0 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 2010 (Stickney et al. 2011). CPAI supported other avian research on the Arctic Coastal Plain in 2010 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; a study of Spectacled Eider movements by USGS; and a study of Long-tailed Duck migration on the

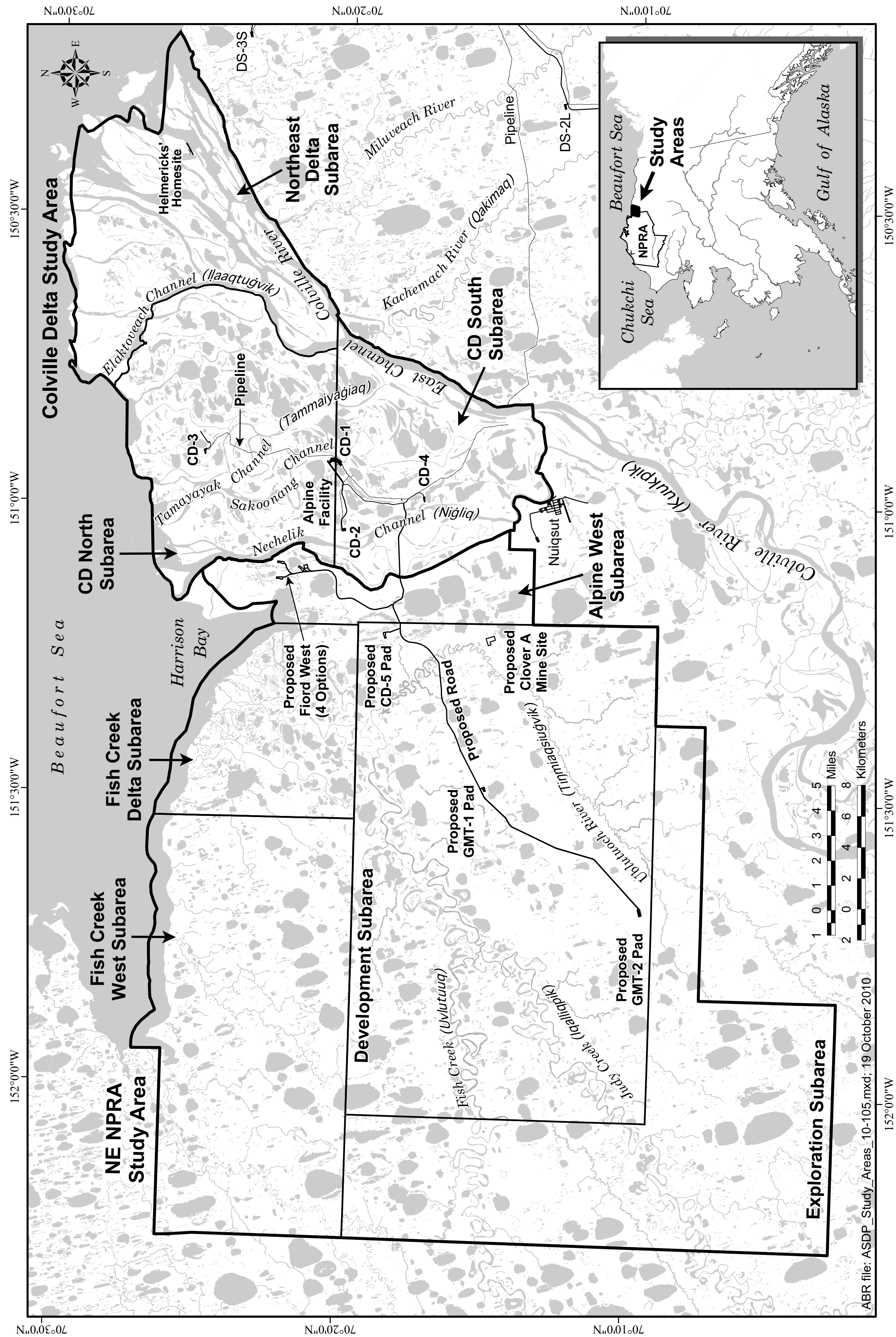

Figure 1. Wildlife study areas and subareas for the Alpine Satellite Development Project, northern Alaska, 2010.

Mackenzie River Delta with the Canadian Wildlife Service.

Wildlife study objectives were developed and study progress was reported through a series of agency and community scoping and planning meetings, beginning in 2001. Annual informational meetings are held in Nuiqsut to allow residents to visit with CPAI biologists and other scientists to discuss information and concerns about resources in the Colville Delta and NE NPRA areas. In October 2010, CPAI staff attended a science fair at the local school during the day, followed by an open community meeting in the evening where they presented findings of recent monitoring efforts. The open house was attended by approximately 35 people from the village of Nuiqsut. In 2009, CPAI flew the late Joeb Woods, Sr., and Lydia Sovalik, 2 elders from Nuiqsut, and James Taallak as facilitator, to meet with biologists in the study site near Fiord West on 3 July. The elders reviewed the boundaries of their native allotments and described their family's history in the area. The locations of 2 grave sites in the area were discussed, and our study plans were adjusted to stay a respectful distance away from those locations. During the summer field season in 2010, CPAI posted weekly updates on bulletin boards in the post office, store, and community center in Nuiqsut. Updates were also emailed to key representatives of the Kuukpik Subsistence Oversight Panel (KSOP), Kuukpik Corporation, the Department of Wildlife of the North Slope Borough, various state and federal agencies, and several environmental organizations. The updates reported on surveys conducted the previous week (for example, type of aircraft used, altitude of aircraft, and species enumerated) and the schedule of surveys for the upcoming week. The open house meetings and weekly updates kept local residents informed on the progress and results of studies conducted by CPAI in the area near Nuiqsut.

STUDY AREA

The place names used throughout this report are those depicted on U.S. Geological Survey (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 understand that the published USGS names for some streams (notably the Ublutuoch and Tingmeachsiovik rivers) do not correctly reflect local usage. The Iñupiaq names we use for Fish and Judy creeks in NE NPRA 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 other channels on the Colville River Delta (E. Wilson, ANLC, pers. comm.).

COLVILLE DELTA

The Colville River Delta (henceforth, Colville 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 Colville 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 Delta began in 1998 with construction of the Alpine Facility (a full-production facility including a processing plant, camp, airstrip, and the CD-1 and CD-2 drill sites) (Figure 1). In 2005, construction began on 2 satellite drill sites, whose oil is also processed at Alpine. The CD-3 satellite is a roadless drill site accessible by aircraft and boat during the summer and fall and by ice roads during winter. Drilling at this satellite is conducted only during the winter months when ice roads are used for access. The CD-4 satellite is connected to Alpine by an all-season road. Both the CD-3 and CD-4 drill sites began producing oil in 2006.

Landforms, vegetation, and wildlife habitats in the Colville 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).

Coastal and riverine landforms dominate the delta. Fluvial processes predominate, 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 (19% 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 33% of the total delta. Coastal salt-affected habitats—Tidal Flat Barrens, Salt-killed Tundra, Salt Marsh, Moist Halophytic Dwarf Shrub, Open Nearshore Water, and Brackish Water—together comprise 21% of the total area and contribute greatly to avian biodiversity. Tapped lakes (Tapped Lake with Low-water Connection and Tapped Lake with High-water Connection) are unique to the delta environment and also are important 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, and Sedge Marsh) and waterbodies with islands and polygonized margins (Deep Open Water with Islands or Polygonized Margins and Shallow Open Water with Islands or Polygonized Margins), which account for a combined total of <5% of the delta. The definition and composition of each habitat are provided in Appendix B. A strong north–south gradient occurs across the delta in the distribution of many of these habitats, with coastal habitats—Tapped Lakes with Low-water Connections, Deep Polygon Complex, and Nonpatterned Wet Meadow—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 in the delta.

As mentioned above, lakes and ponds are dominant physical features of the Colville Delta. The most abundant waterbodies on the delta are polygon ponds, which generally are 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 until 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 thermokarst 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. Because tapped lakes and river channels are the first areas of the delta to become flooded in spring, they constitute important staging habitat for migrating waterfowl in that season (Rothe et al. 1983).

As used in this report, 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 NPRA

The NE NPRA study area (1,571 km²) abuts the western edge of the Colville Delta and

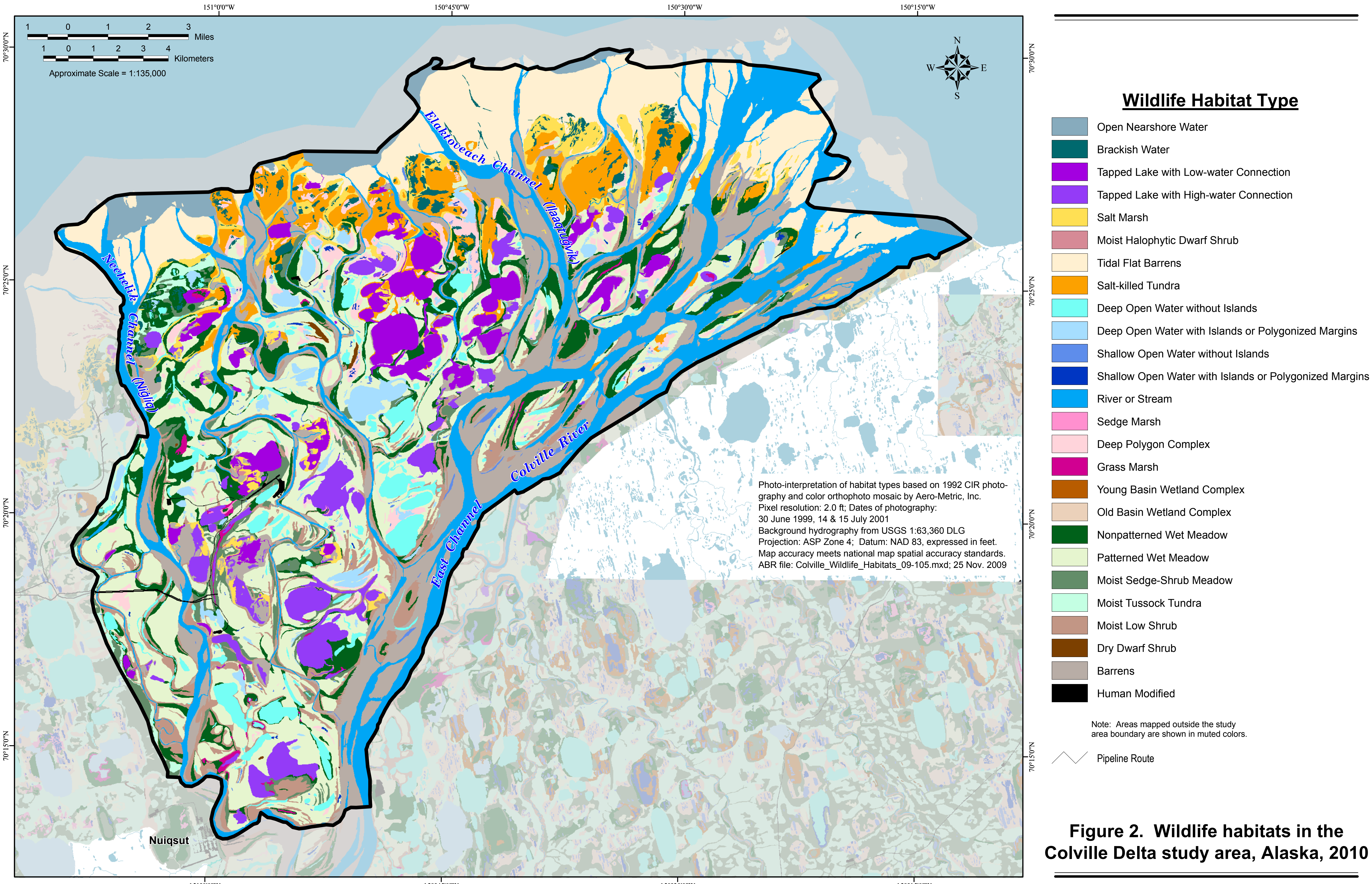

Figure 2. Wildlife habitats in the Colville Delta study area, Alaska, 2010

Table 1. Habitat availability in the Colville Delta and the NE NPRA study areas, Alaska, 2010.

Habitat	Colville Delta Area (km²)	Colville Delta Availability (%)	NE NPRA Area (km²)	NE NPRA Availability (%)
Open Nearshore Water	10.12	1.8	22.49	2.7
Brackish Water	6.55	1.2	9.50	1.1
Tapped Lake with Low-water Connection	22.28	4.0	6.20	0.7
Tapped Lake with High-water Connection	20.77	3.8	4.87	0.6
Salt Marsh	16.31	3.0	16.51	2.0
Moist Halophytic Dwarf Shrub	0.14	<0.1	0.44	0.1
Dry Halophytic Meadow	0	0	0.21	<0.1
Tidal Flat Barrens	58.42	10.6	16.63	2.0
Salt-killed Tundra	25.63	4.6	6.49	0.8
Deep Open Water without Islands	18.42	3.3	50.71	6.1
Deep Open Water with Islands or Polygonized Margins	9.55	1.7	42.49	5.1
Shallow Open Water without Islands	2.01	0.4	7.77	0.9
Shallow Open Water with Islands or Polygonized Margins	0.54	0.1	13.37	1.6
River or Stream	82.79	15.0	10.28	1.2
Sedge Marsh	0.13	<0.1	13.64	1.6
Deep Polygon Complex	13.17	2.4	0.35	<0.1
Grass Marsh	1.44	0.3	2.38	0.3
Young Basin Wetland Complex	<0.01	<0.1	2.67	0.3
Old Basin Wetland Complex	0.14	<0.1	64.76	7.8
Riverine Complex	0	0	2.81	0.3
Dune Complex	0	0	8.07	1.0
Nonpatterned Wet Meadow	41.50	7.5	24.33	2.9
Patterned Wet Meadow	102.45	18.6	90.44	10.9
Moist Sedge–Shrub Meadow	12.25	2.2	173.74	20.9
Moist Tussock Tundra	3.24	0.6	205.17	24.7
Moist Tall Shrub	0	0	1.02	0.1
Moist Low Shrub	27.10	4.9	10.68	1.3
Moist Dwarf Shrub	0	0	4.83	0.6
Dry Tall Shrub	0	0	1.71	0.2
Dry Dwarf Shrub	0.47	0.1	7.25	0.9
Barrens	76.11	13.8	8.66	1.0
Human Modified	0.66	0.1	0	0
Subtotal (total mapped area)	552.19	100	830.50	100.0
Unknown (unmapped areas)	0		740.65	
Total	552.19		1,571.15	

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 NPRA study area is located 6–39 km west of the village of Nuiqsut and 1–43 km west of the Alpine Facility. The NE NPRA study area encompasses 5 proposed development sites that are part of the ASDP: CD-5, Greater Moose's Tooth-1 (GMT-1), GMT-2, Fiord West, and the Clover A gravel mine site. The 2 GMT sites reside in a new (January 2008) unit—the Greater Moose's Tooth Development Area. Proposed roads would connect the 4 well pads and also would connect the CD-5 pad to the Alpine Facility near CD-4 (Figure 1).

Three major streams flow through the NE NPRA study area (Figure 1). On USGS topographic maps (Harrison Bay 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 NPRA were described in the Environmental Impact Statement for the lease area and the Alpine Satellite Development Project (BLM 1998, 2004) and in Jorgenson et al. (2003, 2004). Coastal plain and riverine landforms dominate the NE NPRA. 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 NPRA study area are not present on the Colville Delta study area (Figure 3, Table 1). Three habitats dominate the NE NPRA landscape: Moist Tussock Tundra (25% of area), Moist Sedge–Shrub Meadow (21%), and Patterned Wet Meadow (11%; Table 1). Aquatic habitats comprise 29% of the study area. Although the NE NPRA study area includes some coastal habitats in the Fish Creek Delta, they are much less abundant than in the adjacent Colville Delta (Table 1). Riparian habitats also are much less common in the NE NPRA than they are on the Colville Delta.

Like the Colville Delta, the NE NPRA is an important area for wildlife and for subsistence harvest activities. The NE NPRA 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 NPRA 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 (Burgess et al. 2003b, Johnson et al. 2004, Johnson et al. 2009, 2010).

METHODS

Aerial surveys are the primary means for collecting data on bird species using the Colville Delta and NE NPRA 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 2010, 4 aerial surveys were conducted using fixed-wing aircraft for Spectacled Eiders (pre-nesting), Tundra Swans (nesting and brood-rearing), and geese (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). Thirteen aerial surveys (1 per week) for loons were conducted from a helicopter, targeting specific lakes suitable to Yellow-billed Loons. In 2010, the NE NPRA study area was surveyed for eiders and loons, but not for swans or geese. 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. 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 posted in Nuiqsut.

During the surveys, locations of eiders, loons, and swans were recorded on photomosaics of 1-ft pixel imagery taken in 2004, 2006, or 2008 (Colville Delta and Alpine West subarea in NE NPRA, by Aeromap U.S.), 2 ft pixel imagery taken in 1999–2004 (Development Area and Fish Creek Delta subareas in NE NPRA, by Aeromap U.S.), or 8-ft pixel imagery taken in 2002 (Fish Creek West and Exploration subareas in NE NPRA, by USGS). Plotted bird locations on maps were reviewed in the field and later in the office before they were entered into a GIS database. See Data Management, below, for data management protocols.

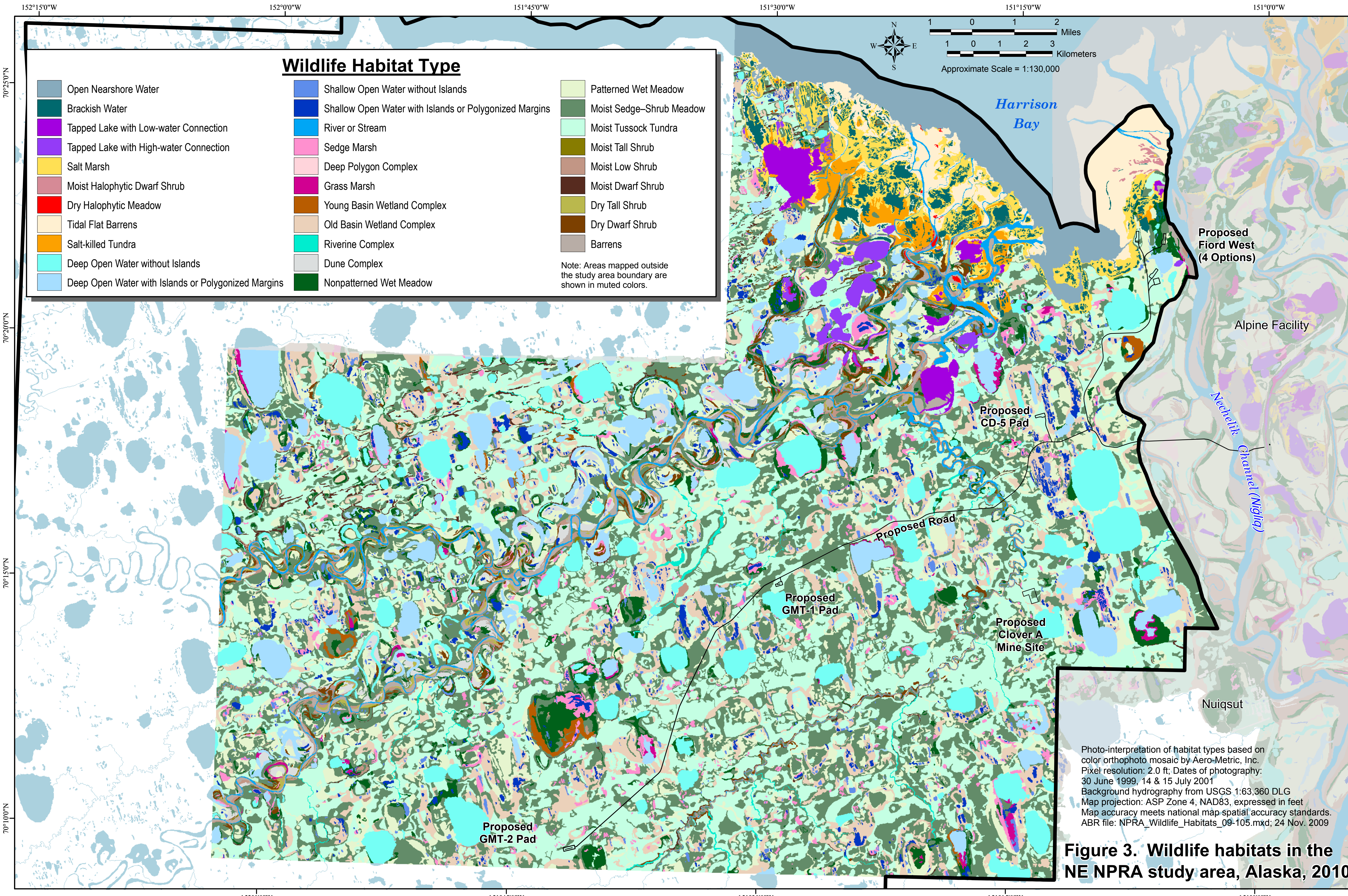

Figure 3. Wildlife habitats in the NE NPRA study area, Alaska, 2010.

EIDER SURVEYS

Regional abundance and distribution of Spectacled and King eiders (other eider species are seen infrequently), were evaluated with data collected on 1 aerial survey flown 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. The pre-nesting survey in 2010 covered the same areas surveyed in 2009 and other prior years in the Colville Delta and NE NPRA study areas (Figure 4). The pre-nesting survey was conducted 10–14 June using the same methods that were used on the Colville Delta in 1993–1998 and 2000–2009 and in the NE NPRA study area in 1999–2006, 2008, and 2009 although the survey areas and survey coverage differed among years (see Anderson and Johnson 1999; Murphy and Stickney 2000; Johnson and Stickney 2001; Smith et al. 1993, 1994; Johnson 1995; Johnson et al. 1996, 1997, 1998, 1999a, 2000a, 2002, 2003b, 2004, 2005, 2006b, 2007b, 2008b, 2009, 2010; Burgess et al. 2000, 2002a, 2003a). The survey was flown in a Cessna 185 airplane at 30–35 m above ground level (agl) and approximately 145 km/h. A Global Positioning System (GPS) receiver was used to navigate pre-determined east–west transect lines that were spaced 800 m apart (50% coverage) in the NE NPRA study area and 400 m apart (100% coverage) over the Colville Delta study area (Figure 4). The lower coverage in the NE NPRA is intended to sample the 3x larger area with its lower densities of Spectacled Eiders relative to the Colville Delta study area. An observer on each side of the airplane (in addition to the pilot) counted eiders in a 200-m-wide transect. Two areas were not surveyed on the Colville Delta: the extensive tidal flats and marine waters on the northernmost delta were not included (because Spectacled and King eiders rarely use those habitats during the survey time period; Johnson et al. 1996), and the extreme southern delta was avoided to limit disturbance to Nuiqsut residents (Figure 4). Eider locations were recorded on color photomosaic maps (1:63,360-scale) and tape recorders were used to record species, number of identifiable pairs and individuals of each sex, and activity (flying or on the ground).

We recorded the observed number of birds and pairs and calculated the "indicated" number of birds and densities (number/km²). Following the USFWS (1987a) protocol, the total indicated number of birds excludes flying birds and is twice the number of males not in groups (groups are defined as >3 birds of mixed sex that cannot be separated into singles or pairs) plus the number of birds in groups (see USFWS 1987a for exceptions to the rule).

LOON SURVEYS

One aerial survey for nesting Yellow-billed Loons was conducted on 20–24 June 2010 and a single survey for brood-rearing loons was conducted on 16–17 August 2010 (Table 2). In the Colville Delta, surveys were flown of selected lakes in the CD North, CD South, and Northeast Delta subareas (Figure 5). The CD North and CD South subareas have been surveyed consistently since 1993. The 6 large lakes in the Northeast Delta subarea have been surveyed occasionally in past years. In the NE NPRA study area in 2010, loon surveys were conducted in the Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas. Alpine West was surveyed previously in 2002–2006 and 2008–2009, and the Fish Creek Delta was surveyed previously in 2005–2006 and 2008–2009. The Fish and Judy Creek Corridor subarea was created in 2008 and comprises a series of deep lakes adjacent to the stream channels. The Fish and Judy Creek Corridor subarea was surveyed in 2008–2009 and as part of the Development and Exploration subareas in 2001–2004. Ten lakes outside the Fish and Judy Creek Corridor subarea also were surveyed in 2008–2010 because Yellow-billed Loons were observed there in previous years (Figure 5). The remainder of the Development and Exploration subareas were excised from the loon survey in 2008–2010 to focus on areas most likely to be proposed for development.

Both nesting and brood-rearing surveys were conducted in a helicopter flying at ~60 m agl in a pre-determined lake-to-lake pattern, searching most lakes ≥5 ha in size and immediately adjacent smaller lakes and aquatic habitats that are typical breeding habitats for nesting Yellow-billed Loons (Sjölander and Ågren 1976, North and Ryan 1989).

Table 2. Avian surveys conducted in the Colville Delta and the NE NPRA study areas, Alaska, 2010.

Survey Type / Season / Survey 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	10–14 June	C185	0.4	0.4	30–35	100% coverage
NE NPRA	1	11–13 June	C185	0.4	0.8	30–35	50% coverage
Yellow-billed Loon surveys[bc]							
Nesting	1	20–24 June	206L	–	–	60-75	All lakes ≥5 ha and adjacent lakes
Brood-rearing	1	16–17 Aug.	206L	–	–	60–90	Yellow-billed Loon territory lakes
Nest and brood monitoring	12 (1/week)	28 June–13 Sept.	206L	–	–	60–90	Lakes with active nests and broods
Tundra Swan surveys[d]							
Nesting	1	24–25 June	C185	1.6	1.6	150	100% coverage
Brood-rearing	1	17–18 Aug.	C185	1.6	1.6	150	100% coverage
Goose surveys[d]							
Brood-rearing	1	28 July	PA-18	–	–	75–150	Coastal and lake-to-lake pattern

[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] Study areas included the Colville Delta and NE NPRA (see Figure 5)
[d] Study area included the Colville Delta only

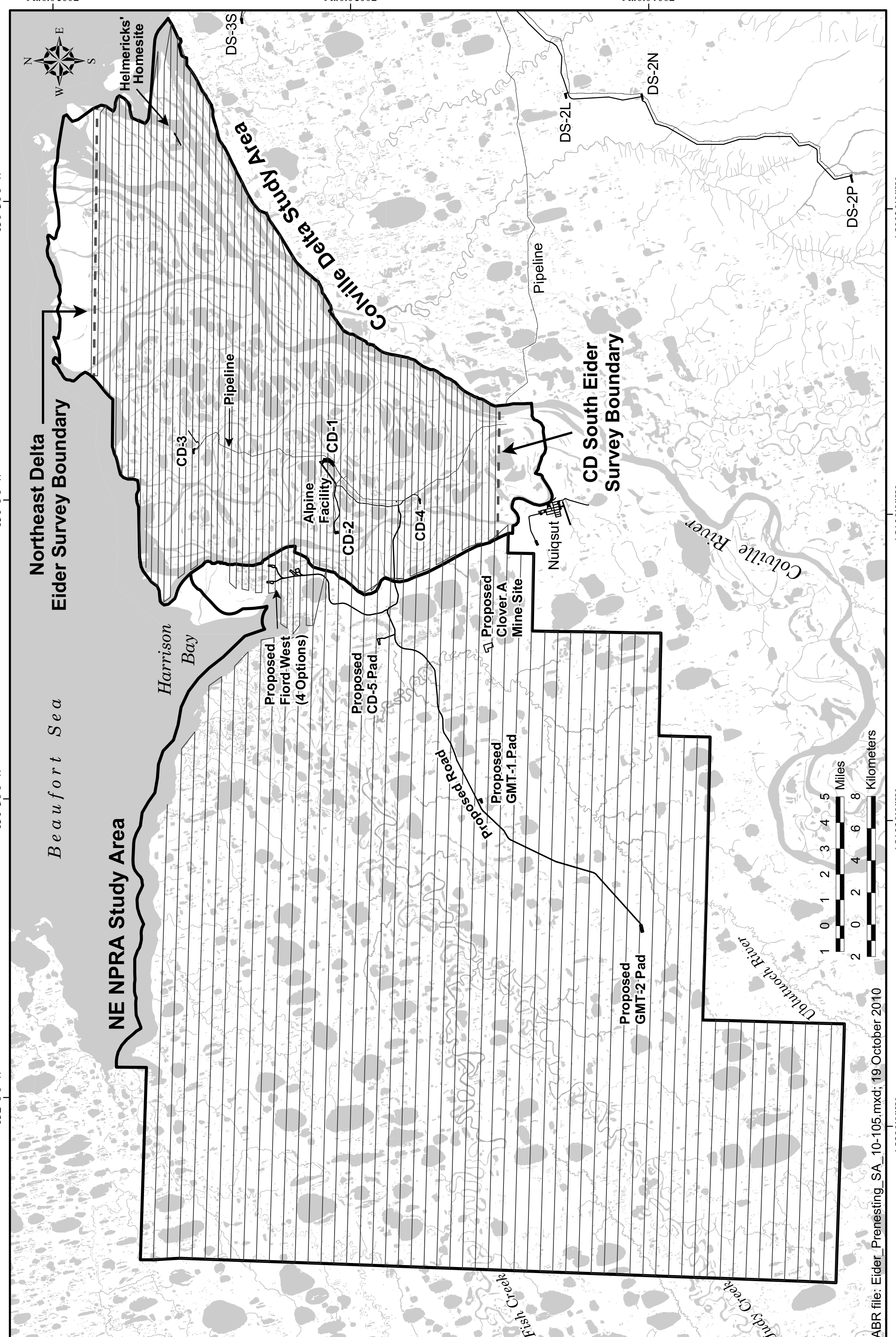

Figure 4. Transect lines for aerial surveys of pre-nesting eiders, Colville Delta and NE NPRA study areas, Alaska, 2010.

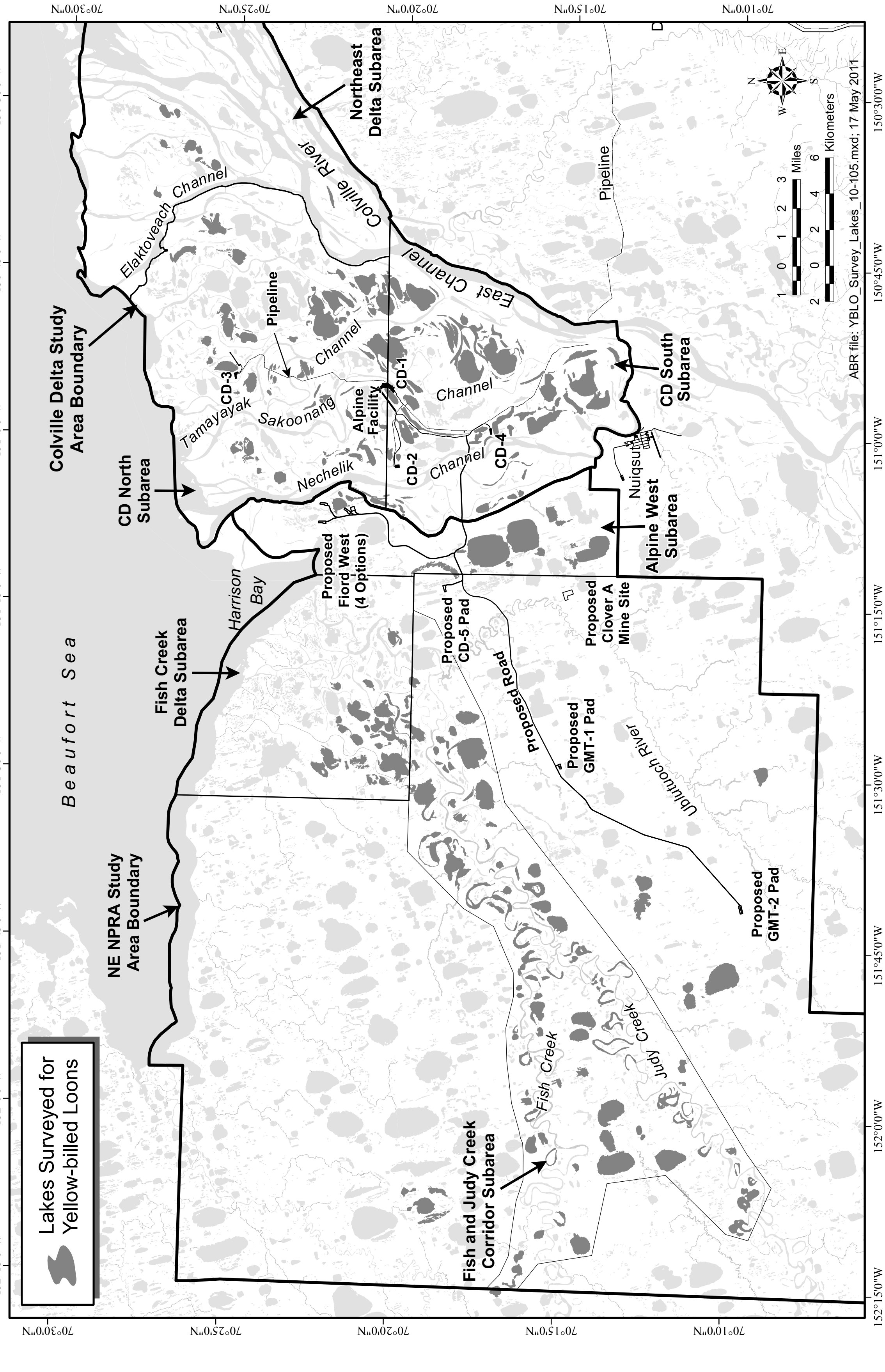

Figure 5. Lakes included in aerial surveys for Yellow-billed Loons, Colville Delta and NE NPRA study areas, Alaska, 2010.

We targeted lakes 5 ha and larger for nest surveys to increase survey efficiency, and we included adjacent smaller lakes to ensure we searched most if not all of the potential nesting habitat. North and Ryan (1989) found only 3 nests on lakes <2 ha, and all were within 70 m of larger lakes that were used for rearing broods. The smallest brood-rearing lake was 13 ha (North and Ryan 1989). Tapped Lakes with Low-water Connections (lakes whose levels fluctuate with changing river levels) were excluded from surveys because Yellow-billed Loons do not use such lakes for nesting (North 1986, Johnson et al. 2003b). Observations of Pacific (Malġi) and Red-throated loons (Qaqsrauq) were recorded incidentally. All locations of loons and their nests were recorded on color photomosaics (~1:1,500 or 1:30,000 scale) and later entered into a GIS database.

The total numbers of adults, nests, broods, and young counted on aerial surveys were summarized for each species of loon. Densities of adults, nests, and broods were calculated only for Yellow-billed Loons because smaller lakes that typically are used by Pacific and Red-throated loons were not included in the survey.

NEST MONITORING AND NEST FATE

In addition to the nesting and brood-rearing surveys described above, weekly surveys were conducted in the Colville Delta and NE NPRA study areas to monitor the status of Yellow-billed Loon nests found during the nesting survey. Traditional nest lakes without an active nest were revisited for 2 weeks after the nesting survey to look for nests that may have been missed on the nesting survey or that were initiated after the nesting survey. After 2 weeks, we only surveyed lakes with confirmed nests and no attempt was made to search for additional nests.

Each nest was surveyed weekly from a helicopter until the nest was noted as inactive. Active nests had an incubating adult or an adult swimming near a nest with eggs. Nests were assumed inactive when adults were no longer incubating for 2 or more consecutive visits. When a nest appeared inactive, the nesting lake was immediately searched for a brood by flying along the shoreline and scanning across the lake. Adjacent lakes known from previous surveys to be brood-rearing lakes or part of a pair's territory also were surveyed.

Camera-monitored nests (see below) were not included in weekly monitoring surveys, but camera images on survey dates were used to summarize data from all nests each week. In the weekly tallies, the nest status of camera-monitored nests was determined from the camera images taken at 14:00 on the day of the survey. That time approximated the middle of the period when we typically flew our aerial surveys. For surveys that spanned multiple days, we used camera data from the first survey day. We resumed visiting camera-monitored nests during the week of hatch, which was estimated from egg floatation data.

Inactive nests were visited on the ground to inspect their contents and to confirm nest fate. The nest and the surrounding area within 5 m, including the water around the nest, were examined closely for the presence of 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. Nests were assumed failed if they contained <20 egg fragments, eggshells had signs of predation (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. Egg fragments were used in addition to the presence of broods to classify nest fate because some broods may not survive the period between hatch and the following aerial survey. 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, 21–30 mm. Egg membranes or pieces of membranes also were counted and measured.

TIME-LAPSE CAMERAS

We deployed digital time-lapse cameras at 19 Yellow-billed Loon nests in the Colville Delta study area and 10 in the NE NPRA study area, primarily to monitor nest survival and, secondarily, to summarize nest attendance patterns and identify causes of nest failures. We used 3 models of Silent Image® Professional cameras: 9 PM35 cameras with custom 8× zoom lens and 640 × 480 pixel photos, and 10 each of PC85 and PC800 cameras with custom 2.5× and 2× zoom lens and 3.1 megapixel photos (Reconyx, Lacrosse, WI). We randomly selected nests to monitor from those that were found during the June nesting survey. Cameras were installed within 3–9 d of nest discovery. 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 picture every 60 sec. The PC85 and PC800 cameras were equipped with 32-GB memory cards and programmed to take 1 picture every 30 sec. All cameras were run on 12V external sealed lead acid batteries. Settings, memory cards, and power were chosen so that we could take the maximum number of photos possible for 23–27 d without requiring maintenance (e.g., battery or memory changes). Cameras were removed when nests were no longer active.

We reviewed digital images on personal computers with Irfanview software (version 4.1.0). Loon activity was classified into 4 major classes of activity: incubation, break, incubation exchange, 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), preening on the nest, 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, sitting beside the nest, standing over the nest, rolling eggs, and standing while preening. Recess activities were absences from the nest and those activities immediately preceding and following the recess, including egg moving, swimming beside the nest, flying, and gone from view. We identified predators in camera views 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. The day of nest failure was the last date on which adults were observed attending a nest at which chicks were not seen.

Nest initiation dates were estimated for successful nests by subtracting 28 d from the day of hatch. Twenty-eight days is the reported incubation period for Yellow-billed Loons (North 1994), which begins with laying of the first egg. For failed nests, we estimated nest initiation dates using an egg-floatation schedule that we developed from known-age Yellow-billed Loon nests in 2008–2010 (using a method developed for Semipalmated Sandpipers by Mabee et al. 2006). During visits to Yellow-billed Loon nests to set up cameras in 2008–2010, we floated eggs in water and recorded the position of the egg in the water column (on the bottom [all eggs in this study], suspended in the water column, or on the surface), measured the angle between the central axis of the egg and the water surface (from 0° when egg is first laid to a maximum of 90° when the egg is upright in the water column), and estimated the percent volume of the egg above the surface (none in this study). For nests that were observed hatching on camera images (known-age nests; n = 19 nests), the clutch age on the day of egg floating was determined by backdating from hatch date to the day the eggs were floated. The relationship between the float angle and clutch age was plotted, and the correlation provided an egg-floatation schedule that could be used to estimate nest initiation date ± 2 days for failed nests or successful nests with an unknown hatch date. For nests with 2 eggs, an average of the float angle of the 2 eggs was used for dating.

The number of days or minutes of monitoring and incubation statistics (constancy, recess and exchange frequency, and recess length) were calculated for each nest. The days of camera set-up, hatch, and periods of poor visibility were excluded. Incubation constancy was calculated as the percentage of time the bird was observed incubating out of the number of minutes monitored. Mean daily number of recesses and exchanges were calculated as the sum of that activity divided by number of days monitored.

BROOD MONITORING

In the Colville Delta and NE NPRA study areas, weekly brood monitoring surveys were conducted after hatch to estimate chick survival and document juvenile recruitment of Yellow-billed Loons. Brood-monitoring surveys were flown in a manner similar to the brood-rearing survey described above. We surveyed all lakes known to have pairs with nests and broods by flying the shoreline and scanning for loons. If no young were seen, 2–3 additional flights were conducted around the lakes and for some large lakes, a flight line 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 waves on the lake obscured the view (i.e., waves were breaking with whitecaps during 1 or both of the surveys). If these conditions occurred, we felt that brood detection was reduced, and any lake with such conditions was resurveyed the following week, regardless of observation history. Brood locations were hand-mapped and the number of adults and young was recorded.

We aged each brood from the date of initial observation of the first chick. To account for the unknown number of days the brood was alive before that period, we added one-half of the interval between the date of first observation of a brood and the previous nest-monitoring survey. In the same manner, we estimated age at death as the number of days from first observation of a chick to the last day of observation of that chick, plus one-half the interval between when the chick was last seen and when was it was absent. For example, given a 7-day interval between surveys, each chick was assumed to be 4 days old when first observed and the date of death was 4 days after the last observation.

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 number of nests detected. 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 a camera and because the photos often revealed additional chicks at hatching that were not subsequently 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 detected.

TUNDRA SWAN SURVEYS

One aerial survey for nesting Tundra Swans was flown 24–25 June and 1 aerial survey for brood-rearing Tundra Swans was flown 17–18 August 2010 (Table 2). Each aerial survey covered the entire Colville Delta (Figure 6). The surveys were conducted in accordance with USFWS protocols (USFWS 1987b, 1991). East–west transects spaced 1.6 km apart were flown 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 on the Colville Delta was photographed using a Canon PowerShot SX10 IS (10 megapixel) or a Canon PowerShot SD850 IS (8 megapixel) for site verification.

Numbers of swans, nests, and broods were summarized and densities calculated for each subarea. Apparent nesting success was estimated from the ratio of broods to nests counted 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.

GOOSE SURVEYS

One survey for brood-rearing and molting Brant and Snow Geese was conducted on 28 July 2010 in the coastal zone of the Colville Delta study area (Table 2). 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 in a lake-to-lake pattern (Figure 7). One pilot and 1 observer searched appropriate habitats (coastal salt-affected vegetation and water) along the coast, rivers, channels, and lakes. The numbers of adults and young Brant and Snow Geese were recorded

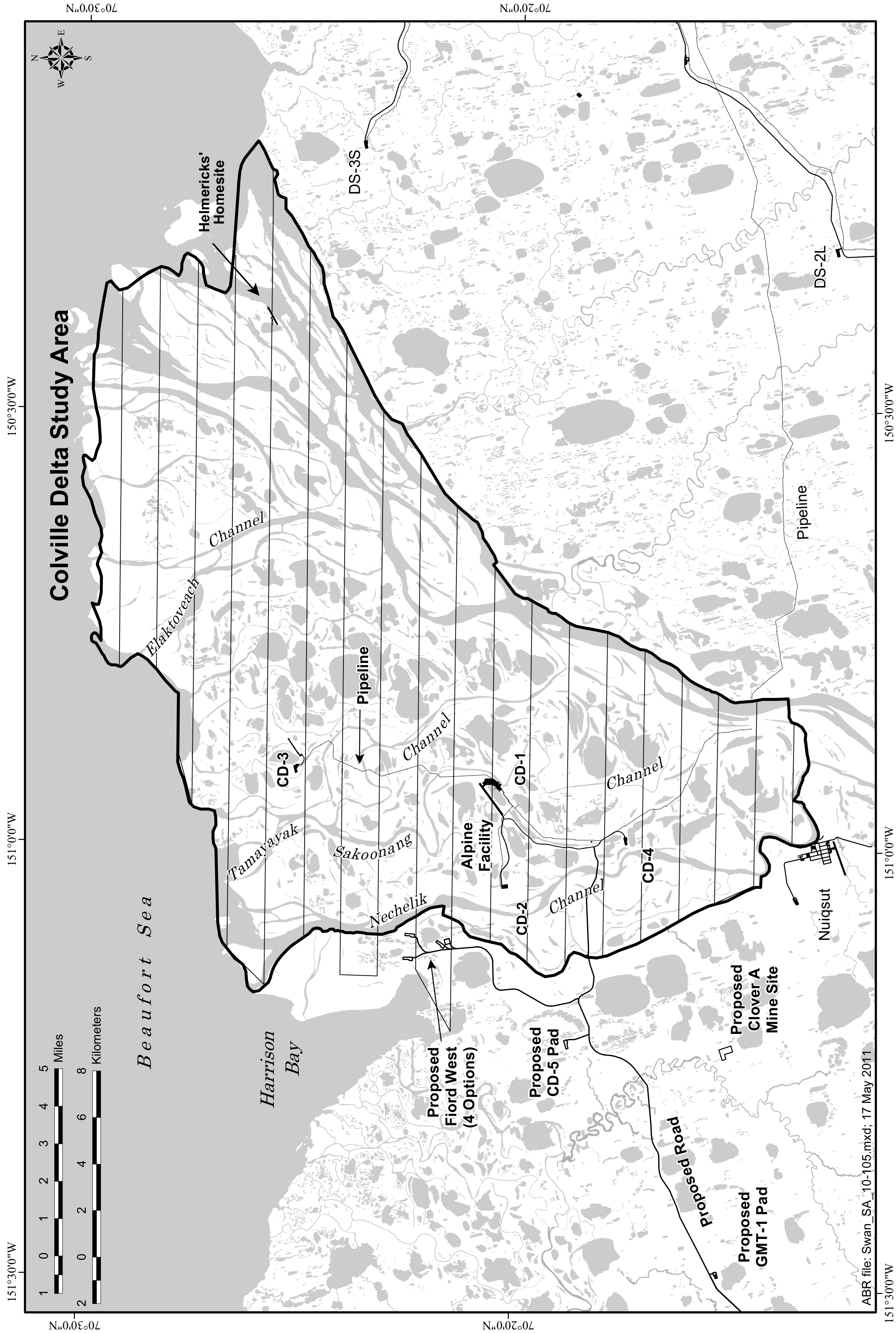

Figure 6. Transect lines for aerial surveys of nesting and brood-rearing Tundra Swans, Colville Delta study area, Alaska, 2010.

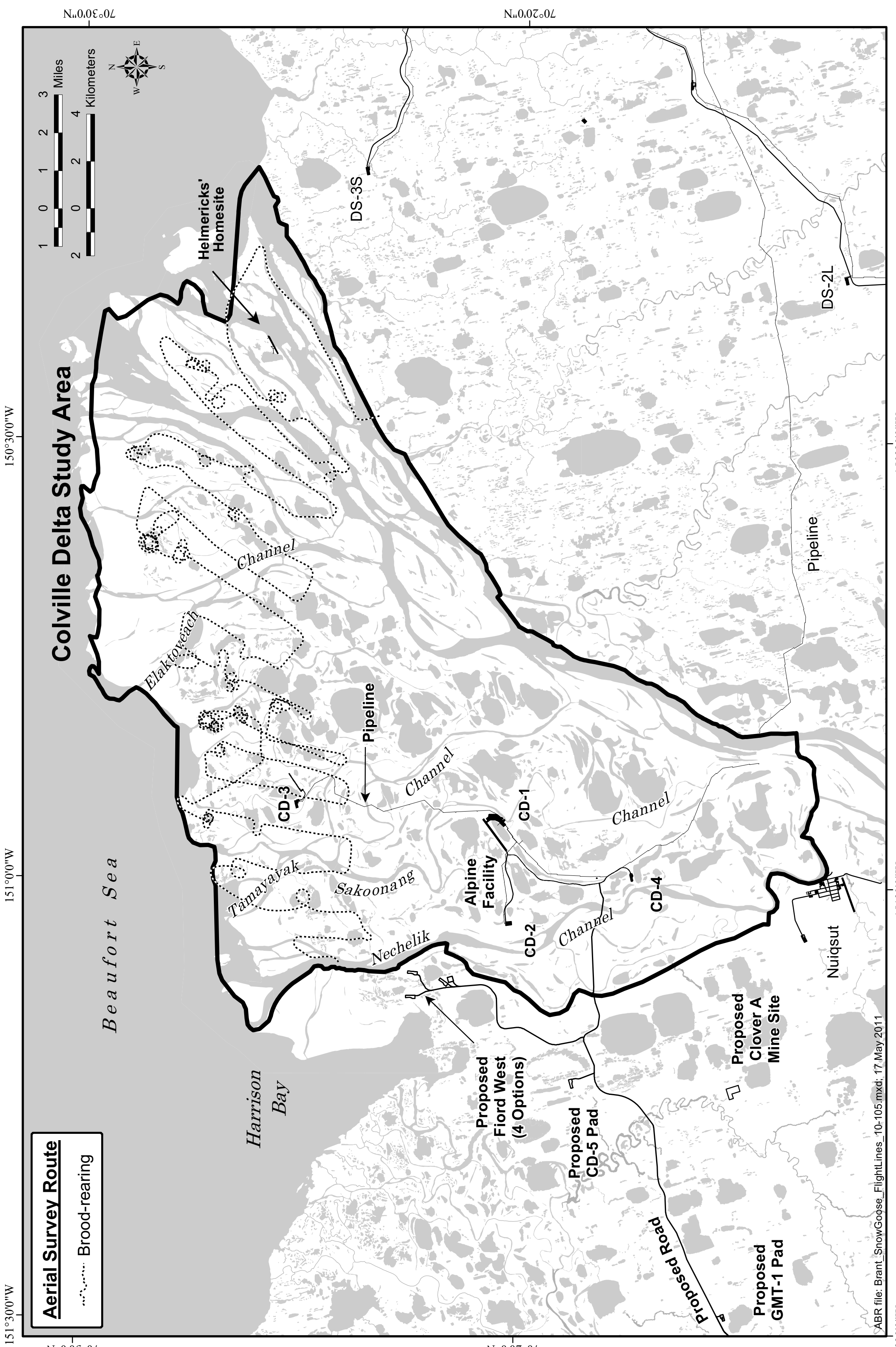

Figure 7. Flight lines for aerial surveys of brood-rearing geese, Colville Delta study area, Alaska, 2010.

and their locations were saved on a GPS receiver. Geese in small groups (<50) were counted visually from the airplane, whereas larger groups were counted on photographs taken with a Canon EOS 40D digital SLR camera (10.1 megapixel) and a 17–85-mm image-stabilizing lens.

GULL SURVEYS

Glaucous Gulls nests and broods were recorded incidentally during the nesting and brood surveys conducted for Yellow-billed Loons in the Colville Delta and NE NPRA study areas (see Loon Surveys, above, for methods). Colonies of nesting Sabine's Gulls (Iqirgagiak) also were recorded opportunistically on the loon nesting survey. Sabine's Gull nests are hard to detect during aerial surveys because of their relatively small size compared to Glaucous Gulls, therefore incidental observations of Sabine's Gulls may be biased towards larger colonies. Nest counts were estimated by dividing the number of Sabine's Gulls associated with the colony site by 2. All nest and brood observations were recorded on color photomosaics (1:30,000 scale) and later entered into a GIS database.

HABITAT MAPPING AND ANALYSIS

A wildlife habitat was assigned to each observation by plotting its coordinates on the wildlife habitat maps (Figures 2 and 3). For each species, habitat use (% of 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, young, 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 we could not assume independence of location, habitat use, or habitat selection among individuals in these groups (i.e., a few large groups could bias results).

For a subset of species/surveys, a statistical evaluation of habitat selection was used to evaluate whether habitats were used in proportion to their availability. (Note that habitat availability [the percent availability of each habitat in the survey area] often differed among species, because survey areas often differed, as described below). When multiple years of survey data were available, all comparable data were used in statistical evaluation of habitat selection. For this purpose, annual surveys were considered comparable only when the survey areas were similar in habitat composition, because habitat availability was calculated by summing annual habitat availability over years.

Habitat selection was evaluated for the following species and seasons:

- pre-nesting Spectacled Eiders and King Eiders (Colville Delta 1993–1998 and 2000–2010 and NE NPRA study area 2001–2006 and 2008–2010)
- nesting and brood-rearing Tundra Swans (Colville Delta 1992–1998 and 2000–2010)
- nesting and brood-rearing Yellow-billed Loons (Colville Delta 1993–1998 and 2000–2010 [nests] and 1995–1998 and 2000–2010 [broods] and NE NPRA study area 2008–2010).

For other species, the number of observations from comparable annual surveys was inadequate for statistical analysis. Several habitats were merged, 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 with Salt Marsh, Dry Halophytic Meadow (<0.1% of NE NPRA) was merged with Tidal Flat Barrens, and all non-halophytic shrub types (all but one occupied <1% of each study area) were merged into Tall, Low, or Dwarf Shrub.

Habitat selection was inferred 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 GPS/GIS Data Management Protocols, North Slope, Alaska, Version 6.7 (CPAI 2011). 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

CONDITIONS IN THE STUDY AREAS

In late May and early June 2010, breeding birds returning to the Colville River Delta and NE NPRA found moderate temperatures, and breakup and snow melt were only slightly delayed from long-term means. Break-up (peak water level) of the Colville River occurred on 1 June 2010, 1 day behind the mean date of peak water level (24-year mean, Michael Baker, Jr. Inc. 2010). Accumulated snow disappeared 7 June 2010 at Colville Village, 2 days after the mean snow-free date (5 June ± 2 days [mean ± SE]). The mean monthly temperature in May 2010 (–6.1 ± 0.9° C [mean ± SE]) was similar to the 14-year mean (–5.7 ± 0.7° C) and the mean monthly temperature in June 2010 (2.3 ± 0.4° C) was 1.2° C colder than the 14-year mean (3.5 ± 0.4° C).

During the period of waterfowl arrival and peak nest initiation (15 May–15 June), 38 cumulative thawing degree-days were recorded in 2010, similar to the 14-year average of 39 cumulative thawing degree-days. Most of the warming was during June (Figure 8). From 15–31 May in 2010, only 3 cumulative thawing degree-days were gained, which is below the average of 7 cumulative thawing degree-days for this period (Figure 8). In early June 2010, 35 cumulative thawing degree-days were recorded compared to the long-term average of 32 cumulative thawing degree-days. However, temperatures in the last half of June were colder than average (Lawhead and Prichard 2011).

During the eider pre-nesting surveys on 10–11 June 2010, polygon ponds and small shallow lakes were ice-free, while deep lakes were mostly ice-covered except for small areas of shallow open water. Deep lakes in the Colville Delta study area retained ~95% of their ice cover on 11 June, ~85% ice cover through 23 June, and ~75% ice cover through 29 June. Deep lakes in the NPRA study area retained ~90% of their ice cover on 11 June, ~75% ice cover through 23 June, and ~50% ice cover through 29 June. On 6 July, 12 lakes in the Colville Delta study area (range = 5–60%) and 3 lakes in the NPRA study area (range = 5–20%) still had some ice cover. All lakes were ice-free by 13 July. Mosquitoes were first noticeable in small numbers on 29 June and at severe levels during the first days of July. We do not have dates of first hatch for tundra birds in 2010 to compare with past dates. Hatch dates for Yellow-billed Loons were about a week later in 2010 than during the previous 5 years (2005–2009) when nests were monitored.

EIDERS

Of the 2 species of eiders that commonly occur in the Colville Delta and NE NPRA 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 Spectacled Eider nests at low densities across the outer Colville Delta and nests in even lower numbers in inland parts of the delta and in scattered wetland basins in the NE NPRA 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. Steller's

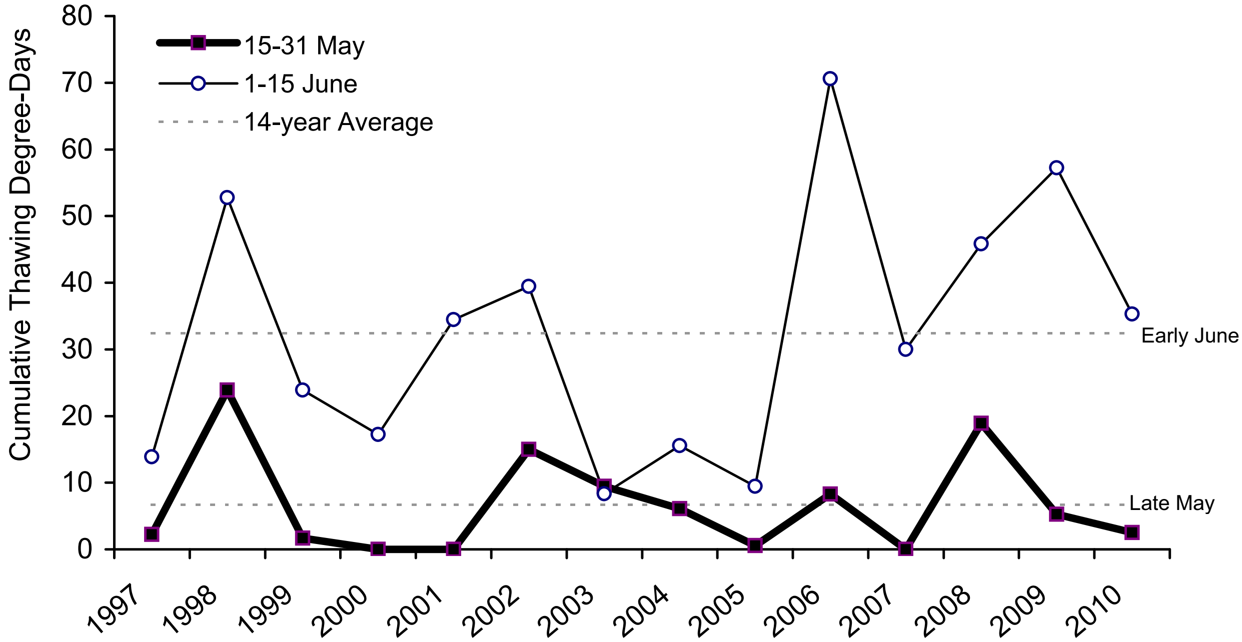

Figure 8. Cumulative number of thawing degree-days recorded 15 May–15 June at Colville Village, Colville River Delta, Alaska, 1997–2010.

Eiders (also a threatened species, listed in 1997) and Common Eiders occur infrequently in the Colville Delta and NE NPRA study areas.

SPECTACLED EIDER

Colville Delta

Distribution and Abundance

The number of Spectacled Eiders on the Colville Delta during pre-nesting in 2010 was the second highest recorded in 17 years (Figure 9). We counted 103 Spectacled Eiders, of which 68 were observed on the ground and 35 were in flight (Table 3). All sightings of Spectacled Eiders in the Colville Delta study area during the pre-nesting survey in 2010 were in groups of 1–4 birds, and approximately 80% of those counted were found in the CD North subarea (Figure 10, Table 3). The density of observed birds in the CD North subarea was 0.39 birds/km² (birds on ground and in flight), and the density of indicated birds (USFWS 1987a) was 0.29 birds/km². The density in the entire Colville Delta study area was 0.21 observed birds/km² and 0.16 indicated birds/km². These densities were nearly twice the densities seen in 2009 and approach the record densities on the Colville Delta in 2008.

Habitat Use

Pre-nesting Spectacled Eiders used 17 of 24 available habitats during 17 years of aerial surveys on the Colville Delta study area. Seven habitats were preferred (i.e., use significantly greater than availability) by pre-nesting Spectacled Eiders: 3 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) (Table 4). Patterned Wet Meadow had high use (15%, 50 groups of eiders) but was not preferred because of its higher availability (20%). All other habitats were avoided or used in proportion to their availabilities.

NE NPRA

Distribution and Abundance

Spectacled Eiders occurred in low numbers in all the subareas of the NE NPRA in 2010, with a

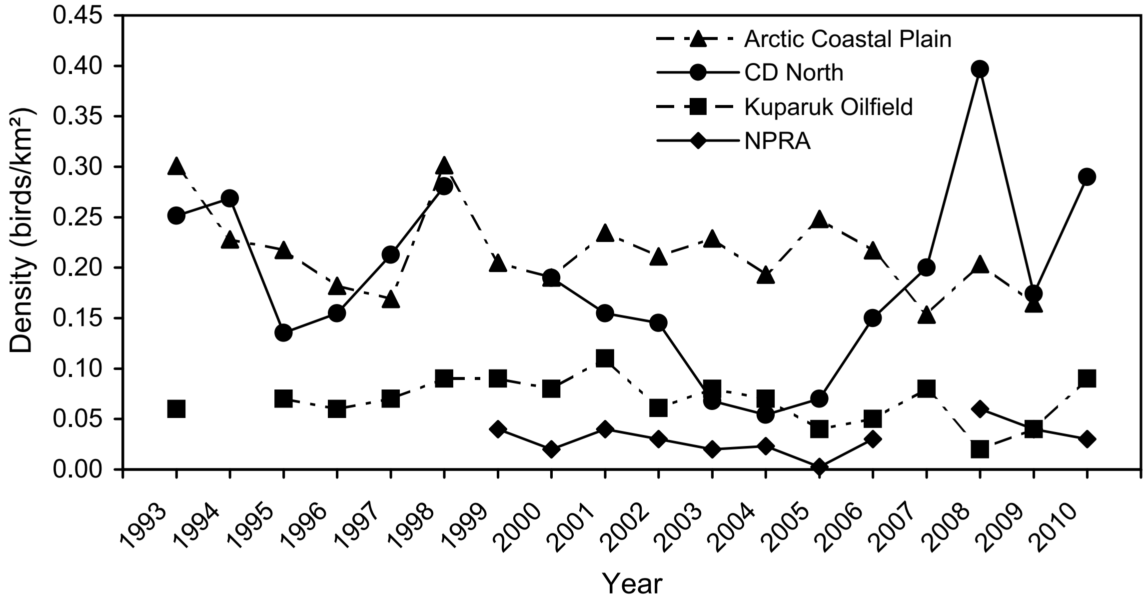

Figure 9. Density of indicated total Spectacled Eiders during pre-nesting aerial surveys in 4 study areas on the Arctic Coastal Plain, Alaska, 1993–2010. Arctic Coastal Plain data from Larned et al. 2010, Kuparuk data from Stickney et al. 2011, and CD North and NE NPRA data from this study.

slightly higher density of indicated birds (0.05 birds/km²) in Alpine West (Figure 10, Table 5). Over the entire NE NPRA study area, we counted 23 observed (on ground and in flight) and 24 indicated Spectacled Eiders resulting in a density of 0.03 observed birds/km² and 0.03 indicated birds/km², ≤25% of the densities on the Colville Delta study area in 2010.

Habitat Use

Pre-nesting Spectacled Eiders used 12 of 26 available habitats in the NE NPRA study area over 9 years of aerial surveys. Spectacled Eiders preferred 5 habitats in NE NPRA, 3 of which also were preferred in the Colville Delta survey area: Brackish Water, Shallow Open Water with Islands or Polygonized Margins, and Grass Marsh (Table 6). However, the sample size is low (44 groups total), resulting in low power in the selection analysis, and we will likely find that additional habitats are preferred as the sample size increases in the future.

OTHER EIDERS

Colville Delta

Distribution and Abundance

King Eiders (57 observed birds) were about half as numerous as Spectacled Eiders (103 observed birds) during the 2010 pre-nesting period in the Colville Delta study area (Table 3). The indicated density (0.07 birds/km²) was identical to the 17-year mean. Most King Eiders (59% of indicated birds) were seen in the Northeast Delta subarea (Figure 10), which is typical of the distribution in most years. Few King Eiders nest on the delta, so we assume most of those observed during pre-nesting are in transit to other breeding areas (Johnson et al. 2003b).

No Steller's or Common eiders were seen on the Colville Delta in 2010. Steller's Eiders rarely are seen in the vicinity of the Colville Delta, but a flying male Steller's Eider was seen on the Colville Delta in 2007 (Johnson et al. 2008b), and several sightings of single males or pairs were reported in the Colville Delta and the NE NPRA (Johnson and Stickney 2001) during 2001, and in the Kuparuk Oilfield during 1995, 2000, 2001, and 2007 (not all

Table 3. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 2010.

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	15	13	28	11	–	0.14	–
All birds	45	35	80	33	–	0.39	–
Northeast Delta							
On ground	6	5	11	5	12	0.07	0.08
In flight	3	2	5	2	–	0.03	–
All birds	9	7	16	7	–	0.10	–
CD South							
On ground	3	2	5	2	6	0.04	0.04
In flight	2	0	2	0	–	0.01	–
All birds	5	2	7	2	–	0.05	–
Total (subareas combined)							
On ground	39	29	68	29	78	0.14	0.16
In flight	20	15	35	13	–	0.07	–
All birds	59	44	103	42	–	0.21	–
KING EIDER							
CD North							
On ground	5	4	9	4	10	0.04	0.05
In flight	7	7	14	7	–	0.07	–
All birds	12	11	23	11	–	0.11	–
Northeast Delta							
On ground	10	8	18	8	20	0.11	0.13
In flight	6	5	11	5	–	0.07	–
All birds	16	13	29	13	–	0.18	–
CD South							
On ground	2	2	4	2	4	0.03	0.03
In flight	1	0	1	0	–	0.01	–
All birds	3	2	5	2	–	0.04	–
Total (subareas combined)							
On ground	17	14	31	14	34	0.06	0.07
In flight	14	12	26	12	–	0.05	–
All birds	31	26	57	26	–	0.11	–

[a] Total indicated 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

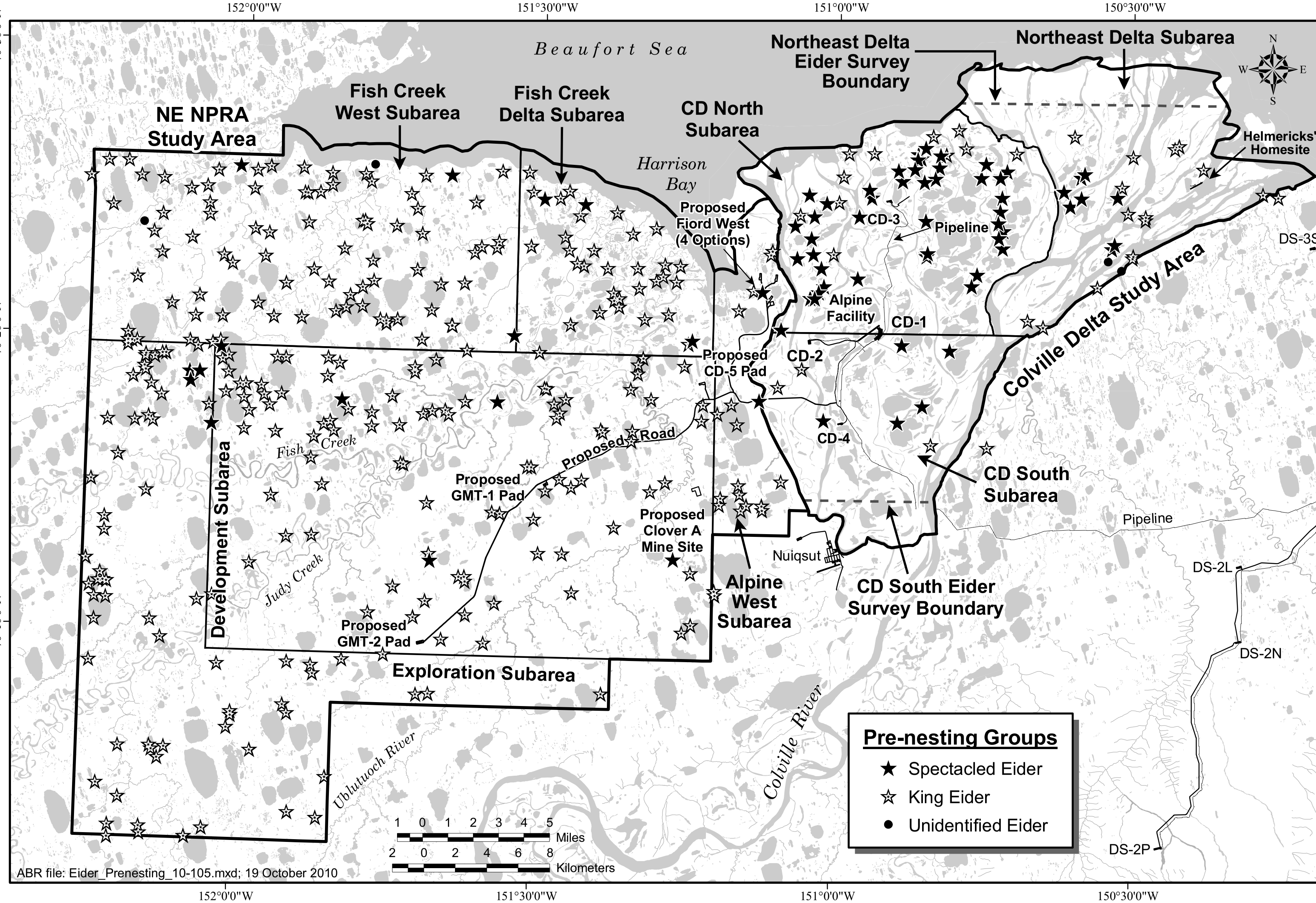

Figure 10. Spectacled and King eider groups during pre-nesting, Colville Delta and NE NPRA study areas, Alaska, 2010.

sightings in the Kuparuk Oilfield were confirmed; see Anderson et al. 2008).

Common Eiders are seen infrequently on the Colville 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 have been recorded during pre-nesting in 1992, 1998, and 2001, and a nest was found near the coastline in 1994 (Johnson 1995).

Habitat Use

Steller's and Common eiders have not been numerous enough to enable evaluation of habitat preferences on the Colville Delta. Pre-nesting King Eiders used 19 of 24 available habitats in the Colville Delta study area over 17 years of aerial surveys. King Eiders preferred 4 of the same habitats preferred by Spectacled Eiders on the Colville Delta: Brackish Water, Salt-killed Tundra, Deep Polygon Complex, and Grass Marsh (Table 4). King Eiders also preferred River or Stream, where the largest percentage (37%) of the groups was found. The high use of River or Stream, which includes river channels, suggests that many King Eiders were in transit to breeding areas farther east, because River or Stream is not potential breeding habitat, and because such large numbers of King Eiders are not found in the available breeding habitats on the delta. Moreover, King Eiders nest at very low densities on the Colville Delta in the several locations where intensive nest searches have been conducted (Burgess et al. 2003a, Johnson et al. 2003a, Johnson et al. 2008a, Seiser and Johnson 2010), affirming that most of the pre-nesting King Eiders seen on the delta are stopping over during migration.

NE NPRA

King Eiders were approximately 20 times more abundant than were Spectacled Eiders in the NE NPRA study area (Figure 10, Table 5). The highest number of King Eiders was seen in the Development subarea (166 indicated birds), whereas the highest density was found in the Fish Creek West subarea (0.78 indicated birds/km^2). The indicated total of King Eiders in the NE NPRA study area in 2010 was 457 birds, and the indicated density was 0.61 birds/km^2, a 27% increase from the 360 indicated King Eiders counted in 2009 (Johnson et al. 2010).

Habitat Use

King Eiders used 20 of 26 available habitats and preferred 11 habitats over 9 years of pre-nesting surveys in the NE NPRA study area (Table 6). 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, with the exceptions of Tapped Lake with Low-water Connection and River and Stream. These latter 2 habitats are likely being used by 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.

DISCUSSION

The annual number of pre-nesting Spectacled Eiders on the Colville Delta has been highly variable over the last 18 years (Figure 9). The current breeding season (2010) was the fourth year in a row of relatively high numbers of Spectacled Eiders on the Colville River Delta during pre-nesting. Our long-term records show 3 periods of high numbers, in the early 1990s, the late 1990s, and the recent period of 2007–2010 (Figure 9). Although we don't have an explanation for the oscillation of eider numbers on the Colville River Delta, the recent upswing in Spectacled Eiders is encouraging because numbers were quite low for the preceding 3 years (2003–2005). The slope of the overall trend is still negative, but not significantly different from 0 ($\ln(y) = -0.017x + 38.5$, $R^2 = 0.029$, $P = 0.51$, $n = 17$ years).

The density of Spectacled Eiders in the NE NPRA study area has been consistently low (mean = 0.03 birds/km^2, $n = 11$ years). The density in NE NPRA averages 32% ($n = 10$ years) of the density on the Colville River Delta. However, NE NPRA supports high densities of King Eiders (mean = 0.35 birds/km^2, $n = 11$ years), quite unlike the Colville River Delta (mean = 0.07 birds/km^2, $n = 17$ 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 (Tables 4 and 6), and nest farther from

Table 4. Habitat selection by Spectacled and King eider groups during pre-nesting, Colville Delta study area, Alaska, 1993–1998, and 2000–2010.

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	low
Brackish Water	69	30	9.2	1.3	prefer	low
Tapped Lake with Low-water Connection	29	12	3.7	4.5	ns	
Tapped Lake with High-water Connection	16	9	2.8	3.7	ns	
Salt Marsh	45	25	7.6	3.2	prefer	
Tidal Flat Barrens	2	1	0.3	7.0	avoid	
Salt-killed Tundra	57	31	9.5	5.1	prefer	
Deep Open Water without Islands	25	16	4.9	3.5	ns	
Deep Open Water with Islands or Polygonized Margins	25	13	4.0	2.1	prefer	low
Shallow Open Water without Islands	5	3	0.9	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	5	4	1.2	0.1	prefer	low
River or Stream	18	9	2.8	14.3	avoid	
Sedge Marsh	0	0	0	<0.1	ns	low
Deep Polygon Complex	151	85	26.0	2.7	prefer	
Grass Marsh	8	5	1.5	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	65	32	9.8	8.2	ns	
Patterned Wet Meadow	96	50	15.3	19.5	ns	
Moist Sedge-Shrub Meadow	0	0	0	2.3	avoid	
Moist Tussock Tundra	1	1	0.3	0.6	ns	low
Tall, Low, or Dwarf Shrub	0	0	0	4.9	avoid	
Barrens	2	1	0.3	14.8	avoid	
Human Modified	0	0	0	<0.1	ns	low
Total	619	327	100	100		
KING EIDER						
Open Nearshore Water	11	3	1.4	1.6	ns	low
Brackish Water	27	15	7.1	1.3	prefer	low
Tapped Lake with Low-water Connection	25	12	5.7	4.5	ns	
Tapped Lake with High-water Connection	8	3	1.4	3.7	ns	
Salt Marsh	18	8	3.8	3.2	ns	
Tidal Flat Barrens	4	2	1.0	7.0	avoid	
Salt-killed Tundra	41	21	10.0	5.1	prefer	
Deep Open Water without Islands	16	7	3.3	3.5	ns	
Deep Open Water with Islands or Polygonized Margins	11	5	2.4	2.1	ns	low
Shallow Open Water without Islands	4	2	1.0	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	1	0.5	0.1	ns	low
River or Stream	222	78	37.1	14.3	prefer	
Sedge Marsh	0	0	0	<0.1	ns	low
Deep Polygon Complex	33	18	8.6	2.7	prefer	low
Grass Marsh	8	3	1.4	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	7	5	2.4	8.2	avoid	
Patterned Wet Meadow	34	20	9.5	19.5	avoid	
Moist Sedge-Shrub Meadow	2	1	0.5	2.3	ns	low
Moist Tussock Tundra	0	0	0	0.6	ns	low
Tall, Low, or Dwarf Shrub	2	1	0.5	4.9	avoid	
Barrens	13	5	2.4	14.8	avoid	
Human Modified	0	0	0	<0.1	ns	low
Total	488	210	100	100		

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

Table 5. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, NE NPRA study area, Alaska, 2010.

SPECIES Subarea Location	Observed Males	 Females	 Total	 Pairs	Indicated Total[a]	Observed Density[b]	Indicated Density[a,b]
SPECTACLED EIDER							
Development							
On ground	3	2	5	2	6	0.02	0.02
In flight	1	0	1	0	–	0	–
All birds	4	2	6	2	–	0.02	–
Alpine West							
On ground	1	1	2	1	2	0.05	0.05
In flight	0	0	0	0	–	0	–
All birds	1	1	2	1	–	0.05	–
Fish Creek Delta							
On ground	1	0	1	0	2	0.02	0.03
In flight	2	2	4	2	–	0.07	–
All birds	3	2	5	2	–	0.09	–
Fish Creek West							
On ground	3	0	3	0	6	0.02	0.04
In flight	0	0	0	0	–	0	–
All birds	3	0	3	0	–	0.02	–
Exploration							
On ground	4	3	7	3	8	0.03	0.04
In flight	0	0	0	0	–	0	–
All birds	4	3	7	3	–	0.03	–
Total (subareas combined)							
On ground	12	6	18	6	24	0.02	0.03
In flight	3	2	5	2	–	0.01	–
All birds	15	8	23	8	–	0.03	–
KING EIDER							
Development							
On ground	83	65	148	62	166	0.49	0.54
In flight	30	26	56	25	–	0.18	–
All birds	113	91	204	87	–	0.67	–
Alpine West							
On ground	12	12	24	12	24	0.57	0.57
In flight	7	4	11	3	–	0.26	–
All birds	19	16	35	15	–	0.84	–
Fish Creek Delta							
On ground	19	15	34	15	38	0.59	0.66
In flight	13	10	23	10	–	0.40	–
All birds	32	25	57	25	–	0.99	–
Fish Creek West							
On ground	59	45	104	43	118	0.69	0.78
In flight	37	32	69	31	–	0.46	–
All birds	96	77	173	74	–	1.14	–
Exploration							
On ground	55	47	102	35	111	0.51	0.55
In flight	27	19	46	14	–	0.23	–
All birds	82	66	148	49	–	0.74	–
Total (subareas combined)							
On ground	228	184	412	167	457	0.55	0.61
In flight	114	91	205	83	–	0.27	–
All birds	342	275	617	250	–	0.82	–

[a] Total indicated birds was calculated according to standard USFWS protocol (USFWS 1987a)

[b] Surveys conducted at 50% coverage. Density based on area surveyed: Development subarea = 304.6 km², Alpine West = 41.8 km², Fish Creek = 57.3 km², Fish Creek West = 151.2 km², Exploration = 200.2 km², all subareas combined = 755.1 km²; numbers not corrected for sightability

Table 6. Habitat selection by Spectacled and King eider groups during pre-nesting, NE NPRA study area, Alaska, 2001–2006 and 2008–2010.

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	0.6	ns	low
Brackish Water	10	5	11.6	1.0	prefer	low
Tapped Lake with Low-water Connection	0	0	0.0	0.7	ns	low
Tapped Lake with High-water Connection	0	0	0.0	0.4	ns	low
Salt Marsh	4	2	4.7	1.9	ns	low
Tidal Flat Barrens	0	0	0	1.1	ns	low
Salt-killed Tundra	0	0	0	0.6	ns	low
Deep Open Water without Islands	4	2	4.7	6.5	ns	low
Deep Open Water with Islands or Polygonized Margins	10	5	11.6	5.4	ns	low
Shallow Open Water without Islands	5	4	9.3	1.0	prefer	low
Shallow Open Water with Islands or Polygonized Margins	15	7	16.3	1.6	prefer	low
River or Stream	1	1	2.3	1.1	ns	low
Sedge Marsh	1	1	2.3	1.7	ns	low
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	3	2	4.7	0.3	prefer	low
Young Basin Wetland Complex	0	0	0.0	0.3	ns	low
Old Basin Wetland Complex	14	9	20.5	8.3	prefer	low
Riverine Complex	0	0	0	0.4	ns	low
Dune Complex	0	0	0	1.1	ns	low
Nonpatterned Wet Meadow	4	2	4.7	3.2	ns	low
Patterned Wet Meadow	8	4	9.3	11.1	ns	low
Moist Sedge-Shrub Meadow	0	0	0	21.8	avoid	
Moist Tussock Tundra	0	0	0	25.8	avoid	
Tall, Low, or Dwarf Shrub	0	0	0	3.1	ns	low
Barrens	0	0	0	1.1	ns	low
Human Modified	0	0	0	0	ns	
Total	78	44	100	100		
KING EIDER						
Open Nearshore Water	6	3	0.6	0.6	ns	low
Brackish Water	46	23	4.6	1.0	prefer	
Tapped Lake with Low-water Connection	42	13	2.6	0.7	prefer	low
Tapped Lake with High-water Connection	0	0	0	0.4	ns	low
Salt Marsh	56	25	5.0	1.9	prefer	
Tidal Flat Barrens	10	4	0.8	1.1	ns	
Salt-killed Tundra	4	2	0.4	0.6	ns	low
Deep Open Water without Islands	176	59	11.8	6.5	prefer	
Deep Open Water with Islands or Polygonized Margins	129	53	10.6	5.4	prefer	
Shallow Open Water without Islands	86	45	9.0	1.0	prefer	low
Shallow Open Water with Islands or Polygonized Margins	178	72	14.4	1.6	prefer	
River or Stream	80	32	6.4	1.1	prefer	
Sedge Marsh	46	21	4.2	1.7	prefer	
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	17	5	1.0	0.3	prefer	low
Young Basin Wetland Complex	0	0	0.0	0.3	ns	low
Old Basin Wetland Complex	175	83	16.6	8.3	prefer	
Riverine Complex	6	3	0.6	0.4	ns	low
Dune Complex	0	0	0	1.1	avoid	
Nonpatterned Wet Meadow	22	12	2.4	3.2	ns	
Patterned Wet Meadow	52	31	6.2	11.1	avoid	
Moist Sedge-Shrub Meadow	16	7	1.4	21.8	avoid	
Moist Tussock Tundra	9	5	1.0	25.8	avoid	
Tall, Low, or Dwarf Shrub	1	1	0.2	3.1	avoid	
Barrens	0	0	0	1.1	avoid	
Human Modified	0	0	0	0	ns	
Total	1157	499	100	100		

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

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

[c] Expected number < 5

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 and King Eiders most prevalent in more inland areas (see Figures 17 and 19 in Larned et al. 2006). The differences in species densities observed on eider surveys of the Colville River Delta and NE NPRA study areas are reflective of the regional patterns of distribution these 2 species exhibit on breeding pair surveys across the ACP (Larned et al. 2006).

LOONS

YELLOW-BILLED LOON

Colville Delta

Distribution and Abundance

During the nesting survey on 20–22 June 2010, 69 Yellow-billed Loons and 23 nests were observed in the Colville Delta study area (Table 7, Figure 11). An additional 12 nests were found on monitoring surveys, resulting in a total of 35 nests, and the second highest number of nests recorded in the study area during 16 years of surveys (Burgess et al. 2003a; Johnson et al. 2003b, 2004, 2005, 2006b, 2007b, 2008b, 2009, 2010). Eighteen of the 35 nests were found in the CD North subarea, 15 nests in the CD South subarea, and 2 nests in the Northeast Delta subarea. Eleven of the 35 nests were found during the weekly monitoring survey on 29 June and 1 nest was found on the 16 July monitoring survey. Most of these 12 nests probably were inactive (not yet initiated) or in the early initiation phase at the time of the nesting survey because pairs were seen on lakes at 7 territories near locations where nests were found later. Also, a few nests may have been missed on the nesting survey. Late ice melt on lakes may have prevented access to traditional nest locations at some territories and delayed nest initiation.

The density of Yellow-billed Loon adults in the Colville Delta study area was 0.18 birds/km² in 2010 (Table 7), which was higher than the average of 16 years of surveys between 1993 and 2010 (0.14 birds/km²). In 2010, the density of loons and the density of nests was higher in the CD South subarea (0.21 birds/km² and 0.10 nests/km²) than in the CD North subarea (0.15 birds/km² and 0.09 nests/km²). The average density of nests for the CD North and CD South subareas combined during 16 years of surveys was 0.06 nests/km². The 2 nests found in the Northeast Delta subarea were not included in density calculations to be consistent with data presentations from previous years.

As in previous years, Yellow-billed Loon nests in 2010 were concentrated in the central part of the delta (Figure 11), and all nests were on lakes where Yellow-billed Loons have nested previously (Rothe et al. 1983; North 1986; Burgess et al. 2003a; Johnson et al. 2003b, 2004, 2005, 2006b, 2007b, 2008b, 2009). However, nests at 13 territories were in locations previously undocumented for those territories and 3 territories had active nests where nesting has been documented <4 times during our 16 years of surveys. The water level of some lakes in the Colville Delta study area was higher than previous years and traditional nesting sites may not have been available to some loons during nest initiation. Alternatively, higher water levels may have created nesting sites by forming islands and emergent vegetation along terrestrial shorelines, both habitat site characteristics that are used by Yellow-billed Loons.

During the brood-rearing survey on 17 August 2010, 59 Yellow-billed Loons and 14 broods were recorded in the Colville Delta study area (Figure 11, Table 7). Nine broods were found in the CD North subarea and 5 in the CD South subarea. An additional brood was documented in the Northeast Delta subarea based on its occurrence in camera images and evidence of hatch from eggshell fragments in the nest, but the brood did not survive to the brood-rearing survey in August (see *Nest Fate*, below). The total of 15 broods for the entire Colville Delta study area was the fifth highest number of broods recorded during 16 years of surveys. The density of broods in the CD North and CD South study areas was similar, 0.04 broods/km² and 0.03 broods/km², respectively.

Habitat Use

During 16 years of nesting aerial surveys in the CD North and CD South subareas, 352 Yellow-billed Loon nests were found in 11 of 24 available habitats on the Colville Delta (Table 8). Four habitats were preferred for nesting (Patterned

Table 7. Number and density of loons and their nests, broods, and young during aerial surveys, Colville Delta and NE NPRA study areas, Alaska, 2010.

STUDY AREA / Subarea[b] / Survey Type	Yellow-billed Loon					Pacific Loon[a]			Red-throated Loon[a]		
	Number			Density (number/km²)		Number			Number		
	Adults	Nests/ Brood	Young	Adults	Nests/ Broods	Adults	Nests/ Broods	Young	Adults	Nests/ Broods	Young
COLVILLE DELTA											
CD North											
Nesting	32	18[e]	–	0.15	0.09	69	4	–	4	0	–
Brood-rearing	20	9	13	0.10	0.04	17	3	5	0	0	0
CD South											
Nesting	33	15[e]	–	0.21	0.10	63	9	–	6	0	–
Brood-rearing	37	5	7	0.24	0.03	8	1	2	3	2	2
Northeast Delta[c]											
Nesting	4	2	–	–	–	19	2	–	0	0	–
Brood-rearing	2	1[f]	0	–	–	4	1	1	0	0	0
Total (subareas combined)[d]											
Nesting	69	35[e]	–	0.18	0.09	151	15	–	10	0	–
Brood-rearing	59	15[f]	20	0.16	0.04	29	5	8	0	0	0
NE NPRA											
Alpine West[g]											
Nesting	1	1	–	0.01	0.01	5	0	–	0	0	–
Brood-rearing	1	1	1	0.01	0.01	32	1	1	0	0	0
Fish Creek Delta[g]											
Nesting	12	6[e]	–	0.09	0.05	46	14	–	0	0	–
Brood-rearing	15	4	5	0.11	0.03	16	2	2	0	0	0
Fish and Judy Creek Corridor											
Nesting	56	25[e]	–	0.22	0.10	150	16	–	0	0	–
Brood-rearing	48	11[f]	10	0.19	0.04	79	15	18	0	0	0
Outside of Survey Subareas[c]											
Nesting	7	4[e]	–	–	–	57	2	–	0	0	–
Brood-rearing	6	1	2	–	–	28	4	5	0	0	0
Total (subareas combined)[d]											
Nesting	76	36[e]	–	0.15	0.07	258	32	–	0	0	–
Brood-rearing	70	17[f]	18	0.14	0.03	155	22	26	0	0	0

[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, Fish and Judy Creek Corridor = 255.9 km²; see Figure 5

[c] Densities were not calculated for the Northeast Delta subarea and the survey area outside of the Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas because only portions of each subarea were surveyed

[d] Total is the sum of all subareas but density calculations included only CD North and CD South for Colville Delta (362.6 km² total), and Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor for NE NPRA (466.1 km² total)

[e] Number includes nests found only during monitoring surveys: 7 nests in the CD North subarea and 5 nests in the CD South subarea of the Colville Delta study area, and 2 nests in the Fish Creek Delta subarea, 4 nests in the Fish and Judy Creek Corridor subarea, and 1 nest outside of the survey subareas of the NE NPRA study area

[f] Number includes broods determined by eggshell evidence: 1 brood in the Northeast Delta subarea of the Colville Delta study area, and 2 broods in the Fish and Judy Creek Corridor subarea of the NE NPRA study area

[g] Only some lakes were surveyed in the Alpine West and Fish Creek Delta subareas during the nesting survey because helicopter mechanical problems prevented all lakes to be surveyed

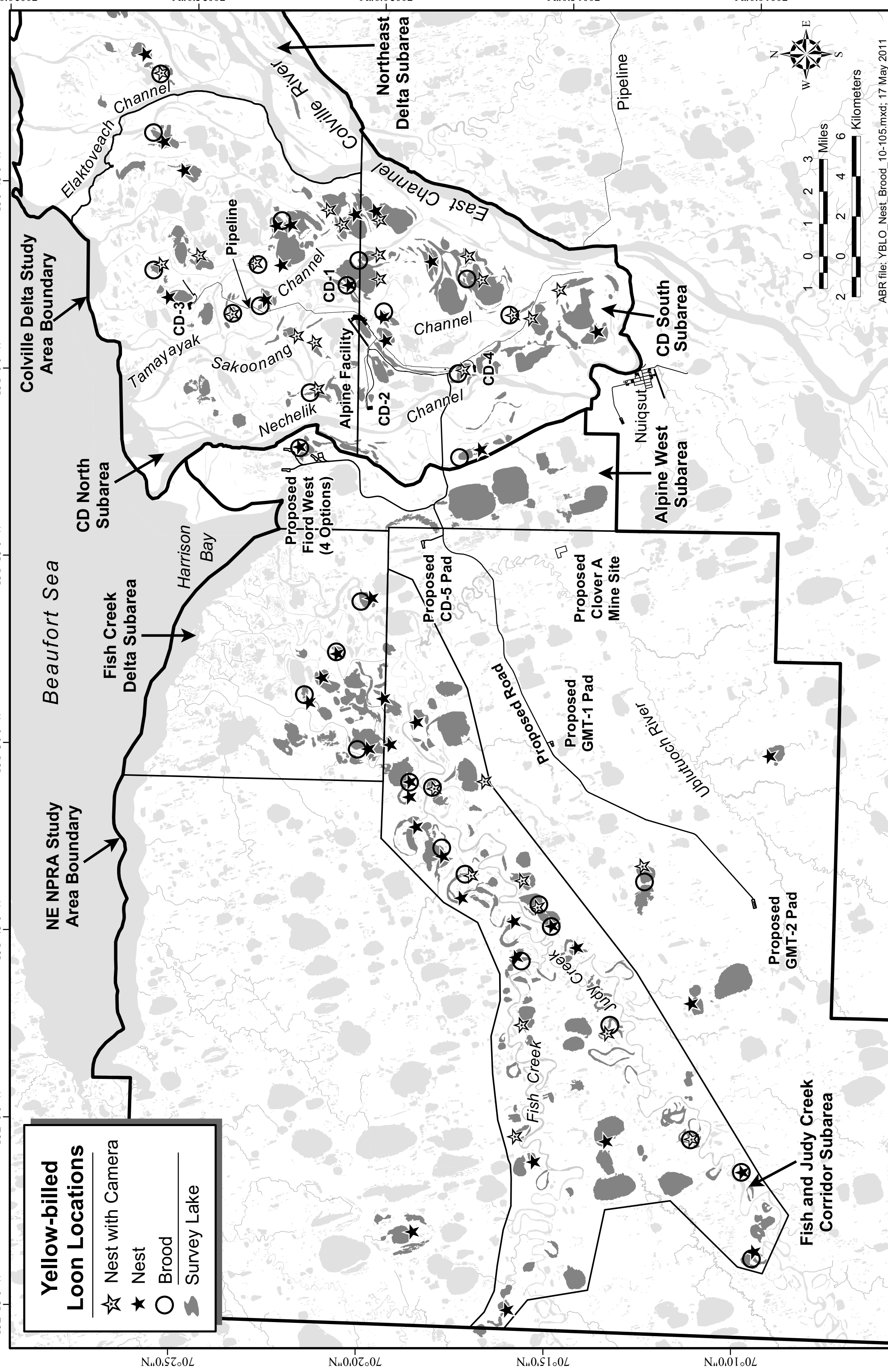

Figure 11. Yellow-billed Loon nests and broods, Colville Delta and NE NPRA study areas, Alaska, 2010.

Table 8. Habitat selection by nesting (1993–2010) and brood-rearing (1995–2010) 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	low
Tapped Lake with Low-water Connection	0	0	5.4	avoid	
Tapped Lake with High-water Connection	21	6.0	5.4	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	29	8.2	4.9	prefer	
Deep Open Water with Islands or Polygonized Margins	105	29.8	2.5	prefer	
Shallow Open Water without Islands	0	0	0.3	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	0.6	0.1	ns	low
River or Stream	0	0	8.8	avoid	
Sedge Marsh	5	1.4	<0.1	prefer	low
Deep Polygon Complex	15	4.3	2.8	ns	
Grass Marsh	4	01.1	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	37	10.5	8.7	ns	
Patterned Wet Meadow	129	36.6	24.6	prefer	
Moist Sedge–Shrub Meadow	4	1.1	3.2	avoid	
Moist Tussock Tundra	0	0	0.9	ns	low
Tall, Low, or Dwarf Shrub	1	0.3	6.5	avoid	
Barrens	0	0	12.1	avoid	
Human Modified	0	0	0.1	ns	low
Total	352	100	100		
BROOD-REARING					
Open Nearshore Water	0	0	2.0	avoid	low
Brackish Water	1	0.6	1.1	ns	low
Tapped Lake with Low-water Connection	0	0	5.4	avoid	
Tapped Lake with High-water Connection	35	20.5	5.4	prefer	
Salt Marsh	0	0	2.6	avoid	low
Tidal Flat Barrens	0	0	3.5	avoid	
Salt-killed Tundra	0	0	4.2	avoid	
Deep Open Water without Islands	77	45.0	4.9	prefer	
Deep Open Water with Islands or Polygonized Margins	58	33.9	2.5	prefer	low
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	2.8	avoid	low
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	24.6	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	171	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

Wet Meadow, Sedge Marsh, Deep Open Water with Islands or Polygonized Margins, and Deep Open Water without Islands), altogether supporting 268 of 352 total nests. Within these areas, 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 (37% of all nests), and it also was the most abundant habitat on the delta (25% of the loon survey area; Table 8). Nesting Yellow-billed Loons avoided 10 habitats, which together occupied 49% of the CD North and CD South study areas. In August 2009, a 0.55-km² lake (Deep Open Water with Islands or Polygonized Margins) began to drain into a nearby river channel. By September 2009, the connection between the lake and the river channel was ~10 m wide and the lake level had dropped to the water level of the channel, leaving a wide margin of barren mud along the lake's shorelines where loons previously nested adjacent to deep water. Yellow-billed Loons nested on that lake during 10 years since 1993, including 2009, but not in 2010. The habitat of the lake was reclassified after it drained to Tapped Lake with Low-water Connection, which is a habitat avoided by nesting Yellow-billed Loons.

One hundred seventy-one Yellow-billed Loon broods were found in 4 habitats, 3 of which were preferred: Deep Open Water without Islands, Deep Open Water with Islands or Polygonized Margins, and Tapped Lake with High-water Connection (Table 8). 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.

Nest Monitoring and Nest Fate

Overall, 15 of 35 Yellow-billed Loon nests hatched in the Colville Delta study area in 2010 for an apparent nesting success of 43% (Table 9). Young loons were observed during aerial surveys at all but 1 hatched nest. At that nest hatching was confirmed by eggshell fragments and by a chick seen on camera images, but the chick did not survive the period between hatch and the following monitoring survey. Of the 15 successful nests, 6 (40%) hatched between 13 July and 20 July and 9 (60%) hatched between 20 and 27 July.

Twenty of 35 Yellow-billed Loon nests on the Colville Delta failed to hatch (Table 9). Four of 20 nests (20%) failed by 29 June, the week after the nest survey, and 2 more nests failed by 6 July. Most nests (12; 60%) failed between that visit and 16 July, including 1 nest that may have failed earlier but the date of failure was unknown due to a camera malfunction. One more nest failed by 20 July. By 26 July, only 1 nest, which was first found on 16 July, remained active and it failed in late August. That nest was active for a minimum of 42 d, or ~14 days longer than the reported incubation period for Yellow-billed Loons (North 1994). Reasons for the extended incubation are unknown but may be attributed to infertile or damaged eggs or this loon may have suffered egg predation and renested between monitoring surveys.

The contents of 33 of 35 Yellow-billed Loon nests were examined after nests were no longer active. Two nests on islands and inaccessible by helicopter were not inspected; 1 hatched and 1 failed based on presence or absence of a brood. In addition to those 2 nests, 14 nests were classified as successful based on the presence of many eggshell fragments and at some nests, egg membranes, and 19 failed based on the absence or presence of only a few eggshell fragments and at some nests, the presence of broken eggshells. Successful nests contained 20–92 eggshell fragments, and broods were observed at all of these nests, including 1 nest where a chick was seen only on camera images. Of >880 eggshell fragments found within 5 m of successful nests, 76% were ≤10 mm in length. None of the nests contained whole membranes but 7 nests 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; only 68 fragments were found in the water or on shore adjacent to successful nests. Seven of the 19 failed nests that were inspected had egg remains in the nest or nearby: eggs broken in half or eggs with holes in them were found within 4 m of 2 nests, and 5 nests contained egg fragments (range = 2–15 fragments). The remaining 12 nests were empty.

Table 9. Weekly status (A = active, I = inactive) and fate of Yellow-billed Loon nests monitored by aerial surveys, Colville Delta study area, Alaska, 2010. Status determined from camera-monitored nests is presented in parentheses where it differed from status determined from aerial surveys.

	June		July				August					
Territory	20–24	28–29[a]	5–6[a]	13, 15–16	19–20	26–27	3	10	16–17	23	30	Fate/Total
1	A	I	–	–	–	–	–	–	–	–	–	Fail
2[b]	A	A	A	A	I	–	–	–	–	–	–	Hatched[c]
3	I	A	A	A	A	I	–	–	–	–	–	Hatched
4	I	A	A	I	–	–	–	–	–	–	–	Fail
6[b]	A	I	–	–	–	–	–	–	–	–	–	Fail
7[b]	A	A	A	A	A (I[d])	I	–	–	–	–	–	Hatched
8	I	A	A	I	–	–	–	–	–	–	–	Fail
10[b]	A	A	A	A	A	I	–	–	–	–	–	Hatched
11[b]	A	A	A	A (I[d])	I	–	–	–	–	–	–	Hatched
12	I	A	A	A	A	I	–	–	–	–	–	Hatched
13[b]	A	–[e]	–[e]	I[e]	–	–	–	–	–	–	–	Fail
14[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
15	I	I	A	A	I	–	–	–	–	–	–	Fail
16	I	A	A	A	A	I	–	–	–	–	–	Hatched
17[b]	A	A	A	A (I[d])	I	–	–	–	–	–	–	Hatched
18[b]	A	A	A	A	A	I	–	–	–	–	–	Hatched
19[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
20[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
21	A	A	I	–	–	–	–	–	–	–	–	Fail
22[b]	A	A	A	A (I[f])	I	–	–	–	–	–	–	Hatched
23[b]	A	I	–	–	–	–	–	–	–	–	–	Fail
25	I	I	I	A	A	A	A	A	A	A	I	Fail
26[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
27[b]	A	A	A	A (I[d])	I	–	–	–	–	–	–	Hatched
29	I	A	A	A	A	I	–	–	–	–	–	Hatched
30[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
31	I	A	A	I	–	–	–	–	–	–	–	Fail
32[b]	A	A	A	I	–	–	–	–	–	–	–	Fail
33[b]	A	I	–	–	–	–	–	–	–	–	–	Fail
35	I	A	A	I	–	–	–	–	–	–	–	Fail
36	A	A	A	I	–	–	–	–	–	–	–	Fail
38	I	A	I	–	–	–	–	–	–	–	–	Fail
39	A	A	A	A	A	I	–	–	–	–	–	Hatched
45	I	A	A	A	I	–	–	–	–	–	–	Hatched
46[b]	A	A	A	A	A (I[f])	I	–	–	–	–	–	Hatched
No. Active	23	28	27	17 (13)	10 (8)	1	1	1	1	1	0	35
No. Hatched	0	0	0	0 (4)	6 (4)	9 (7)	0	0	0	0	0	15
No. Failed	0	4	2	12	1	0	0	0	0	0	1	20

[a] Camera-monitored nests were not surveyed by helicopter; nest status determined from camera images
[b] Nest monitored by camera
[c] No brood was seen but nest classified as hatched based on eggshell evidence at the nest and chicks detected on camera images
[d] Camera images showed hatch occurred during this survey period but after the aerial survey was conducted
[e] Camera malfunctioned on 22 June and nest status checked by aerial survey on 15 July found nest inactive; date of failure unknown but counted as failed on 15 July
[f] Camera images show young were being brooded in nest at the time of this survey

Time-lapse Cameras

We monitored 19 of 35 Yellow-billed Loon nests in the Colville Delta study area with time-lapse cameras in 2010 (Table 10). Eight-power zoom cameras were placed 37–170 m from nests (mean = 88 m, n = 6) and 2× and 2.5× zoom cameras were placed 30–77 m from nests (mean = 50 m, n = 13). Researchers were transported to and from nesting areas by helicopter for camera setup and were at nests an average of 37 min (range = 26–54 min, n = 19 nests). No loons remained on their nests during camera setup. At 17 of 19 nests, the attendant loon left the nest during camera setup: 7 swam away from the nest as the helicopter landed, 7 left as researchers exited the helicopter, and 3 left as researchers approached the camera setup location. At the remaining 2 nests, the attendant loon was swimming next to the nest upon our arrival and swam away as the helicopter approached; both remained off the nest during camera setup.

All 19 of the loons returned to incubate after camera installation. One returned before we departed in the helicopter, whereas the remaining 18 returned an average of 31 min (median = 22 min, range = 1–120 min) after we departed in the helicopter. Excluding the 2 loons already off their nests when we arrived, loons were absent from nests an average of 62 min during camera installation (median = 54 min, range = 24–157 min, n = 17 nests).

Cameras successfully recorded daily nest survival data, and we were able to identify the day of hatch or failure from 16 of 19 camera-monitored nests. At 2 nests, memory cards filled to capacity before hatch occurred. At the remaining nest, the camera became disconnected from the battery prior to nest failure. Of the 19 nests that were monitored, 9 hatched and 10 failed for an apparent nesting success of 47%. The median initiation date of camera-monitored nests was 19 June (range = 17–22 June, n = 19), and the median hatch date for successful nests was 17 July (range = 15–20 July, n = 9; Table 10). That hatch date was slightly earlier than the hatch date determined from monitoring surveys, which indicated that most nests hatched between visits on 19 and 27 July. Camera images indicated that hatch had occurred at 4 nests but that young were being brooded in the nest during the monitoring survey conducted on 13–16 July. Brooding of young cannot always be distinguished from the incubation of eggs during aerial surveys, so nests with brooding loons are often judged as active. Excluding the day of hatch or failure, loons at hatched nests exhibited higher nest attendance than those at failed nests, spending 98.1% (SE = 0.1, n = 9) and 91.2% (SE = 4.1, n = 9) of the time incubating, respectively. Reasons for poor nest attendance at failed nests is unknown.

Of the 10 nests that failed to hatch, 3 failures were attributed to predation by red foxes, 2 to Glaucous Gulls, 2 to Parasitic Jaegers, 1 to a Golden Eagle and 1 failure was attributed to nest abandonment (Table 10). The predator at 1 nest was not captured on camera images because the camera became disconnected from the battery after taking photos for only ~1 d, which was prior to nest failure. All 4 nests that failed because of gull or jaeger predation were unattended at the time of predation. At 2 of those nests, the nesting pair of Yellow-billed Loons was seen fighting with an intruding Yellow-billed Loon prior to leaving the camera field of view. At the nest taken by an eagle, the loon was incubating normally before the eagle appeared at the nest, suggesting that the eagle flushed the loon off its nest. The loon was not in the camera field of view during the predation event. At 2 of the 3 nests taken by foxes, an adult loon was incubating <1 min prior to the appearance of the fox and the loons from both nests were observed swimming near their nests during the predation event. The loon at the third nest left the camera view ~4 min prior to the image containing the fox. Each fox predation event lasted 0.5–1.5 min.

Yellow-billed Loon eggs hatch asynchronously. Adults brood and swim with the first hatched chick while the second egg is hatching, which can take 1–3 d. At 3 Yellow-billed Loon nests which hatched successfully, cameras documented predation by Glaucous Gulls of a chick or the second egg during hatch. At territory 7, the nest suffered predation of the second egg when both adults left the nest to swim with their ~3-d old chick. A gull carried away the entire egg from the unattended nest in <30 sec. A Glaucous Gull also caused partial brood loss at territory 11. A gull flew in and grabbed a ~1-d old chick that

Table 10. Nest history and incubation activity at Yellow-billed Loon nests monitored by time-lapse digital cameras, Colville Delta study area, Alaska, 2010.

Territory	Fate[a]	Nest initiation 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)
2	S	19 June	Glaucous Gull[e]	2	21 Jun	17 July	25.0	98.5	2.0	3.0	6.3
6	F	19 June	Red Fox	2	21 Jun	26 June	4.0	94.3	2.3	6.0	13.1
7	S	22 June	Glaucous Gull[e]	2	23 Jun	20 July	26.0	98.5	1.8	2.0	9.8
10	S	19 June		2	21 Jun	17 July[f]	24.9	98.3	2.0	2.9	7.9
11	S	17 June	Glaucous Gull[e]	2	22 Jun	15 July	22.0	98.3	2.3	2.7	8.2
13[g]	F	19 June	Unknown	1	21 Jun	–	0.3	–	–	–	–
14	F	20 June	Parasitic Jaeger	1	22 Jun	14 July	20.8	97.1	1.2	3.1	12.8
17	S	17 June		2	22 Jun	15 July	21.6	98.3	1.2	2.4	9.6
18	S	20 June		1	22 Jun	18 July[f]	19.6	98.3	2.4	2.3	9.0
19	F	20 June	Red Fox	1	22 Jun	8 July	14.8	96.3	1.7	5.1	9.9
20	F	20 June	Glaucous Gull	2	22 Jun	6 July	13.0	94.0	1.6	4.7	17.9
22	S	17 June		2	22 Jun	15 July	21.5	97.4	1.7	3.4	9.9
23	F	19 June	None, nest abandoned	2	22 Jun	30 June	7.0	58.6	0.1	3.9	156.1
26	F	19 June	Golden Eagle	1	21 Jun	11 July	17.9	94.4	1.1	3.5	15.5
27	S	19 June		2	22 Jun	16 July[h]	18.5	97.9	1.5	2.2	13.2
30	F	20 June	Glaucous Gull	2	22 Jun	9 July	15.6	97.7	1.2	3.2	10.0
32	F	20 June	Parasitic Jaeger	1	22 Jun	6 July	13.0	96.4	1.7	4.4	11.3
33	F	20 June	Red Fox	2	22 Jun	24 June	1.0	91.6	4.0	9.0	13.0
46	S	19 June		2	22 Jun	17 July	23.3	97.7	1.8	2.0	15.1

[a] S = successfully hatched, F = failed to hatch
[b] Nest initiation dates for successful nests estimated by subtracting 28 d from hatch date; for failed nests, nest age estimated using egg floatation (see Methods: Loon Surveys)
[c] As known on day of camera setup or maximum seen on camera images
[d] Excludes day of camera installation and periods of time when photo images could not be interpreted because of poor weather conditions
[e] Predation occurred during hatch on 1 chick and/or 1 egg.
[f] Memory card in camera reached capacity before the day of hatch; day of hatch estimated using egg floatation
[g] Camera malfunctioned on 22 June; cause and day of nest failure are unknown
[h] Camera was placed too far from nest to detect chicks on images; day of hatch determined by non-incubating adult's increased presence at the nest

was swimming with an adult loon while the other adult was incubating. The second egg hatched and no further predation was observed. Complete brood loss occurred on the day of hatch at territory 2. An adult was incubating in a concealed posture before leaving the camera field of view with its mate. During the next few minutes, a single chick was seen swimming by itself. The chick disappeared in the same photo that a loon was seen rushing across the water towards the nest. No chicks were seen after this point. A loon returned to incubate for ~8 min before leaving again. A gull appeared at the nest 12 min later and ate what was assumed to be the second egg, likely in the process of hatching.

In addition to documenting nest fate, cameras also recorded other Yellow-billed Loons intruding into occupied territories, a behavior previously undetected by cameras. Intruding loons were seen at 12 of 19 camera-monitored nests. Intruders were identified by the presence of >2 adults on images or, less frequently, by seeing aggressive interactions between 2 Yellow-billed Loons. In nearly all cases, the incubating loon left the nest to interact with the intruder. Aggressive behaviors included fencing, rushing, and physical contact (Sjölander and Ågren 1976). Yellow-billed loons reach maturity during their third summer and, although there is no information on whether Yellow-billed Loons return to natal sites, Common Loons have been documented doing so (McIntyre and Barr 1997, North 1994). In 2007, Yellow-billed Loons on the Colville Delta produced the highest number of chicks at hatch since monitoring surveys began. Chicks hatched in 2007 would be reaching sexual maturity in 2010, and the return of this cohort could possibly explain the territory intrusions observed on cameras.

We also documented a Yellow-billed Loon removing part of a successfully hatched egg from its nest. The loon removed the egg remains after the first chick hatched but prior to the second chick hatching. We rarely find entire membranes in successful loon nests during nest fate visits and documenting this behavior further suggests that relying solely on the presence of membranes as an indicator of hatch in Yellow-billed Loons is not reliable. We also saw loons removing pieces of depredated eggs (see Results, NPRA, Time-lapse Cameras).

Brood Fate

During the monitoring survey following hatch, 7 of 15 (47%) Yellow-billed Loon pairs that hatched young were observed with a single chick, and 7 (47%) were observed with 2 chicks (Table 11). One pair hatched at least 1 chick based on the presence of eggshell fragments at the nest but the chick did not survive to the next monitoring survey. According to monitoring surveys and nest fate data, a minimum of 22 chicks were produced at 35 nests (0.63 chicks/nest). Images from 19 camera-monitored nests confirmed the presence of 1 chick at the nest judged successful based on eggshell fragments and documented 1 additional chick that suffered predation prior to the next monitoring survey. Based on camera, nest fate, and brood-monitoring data, a minimum of 23 chicks were produced by 35 nests (0.66 chicks/nest).

Thirteen of 15 (87%) Yellow-billed Loon pairs that hatched at least 1 egg retained 1 chick on the final monitoring survey on 13 September. Four of those pairs retained both chicks. Only 2 pairs suffered complete brood loss; 1 pair lost their chick on the day of hatch and the other lost 1 chick ~18 d after hatch and their other chick ~45 d after hatch.

One goal of brood monitoring was to estimate juvenile recruitment, or how many chicks survived to fledging. From the 35 known Yellow-billed Loon nests, 17 chicks survived until the last survey on 13 September (0.49 chicks/nest). Most loon chicks were ~7 weeks old (range = 7–8 weeks) and none were observed flying by that time (Table 11). The period from hatching to fledging is unknown in Yellow-billed Loons, but is assumed to be similar to Common Loons, which make their first flights at ~11 weeks (McIntyre and Barr 1997, North 1994). Chicks in this study were observed exercising their wings by mid-September but were likely 3–4 wks from becoming flight capable.

NE NPRA

Distribution and Abundance

During the nesting survey in 2010, 76 Yellow-billed Loons and 29 nests were recorded in the NE NPRA study area (Figure 11, Table 7). Six additional nests were found during the weekly monitoring survey on 29 June and 1 additional nest was found on the 5 July monitoring survey. At 4 of these territories, pairs were seen prior to nest discovery on the breeding lake near the eventual

Table 11. Number of Yellow-billed Loon chicks observed during weekly aerial surveys, Colville Delta study area, Alaska, 2010. Status and number of chicks determined by camera-monitoring presented in parentheses where it differed from counts determined during aerial surveys.

	July			August					September				
Territory	13–16	19–20	26–27	3	10	16–17	23	30	6	13	No. chicks hatched	Age (d) when last seen	Brood fate[a]
2[b]	Inc[c]	0[d]	0								1 (1)	2.0	F
3	Inc	Inc	1	1	1	1[e]	1	1	1	1	1	52.5	A
7[b]	Inc	Inc (1[f])	1	1	1	1	1	1	1	1	1	52.5	A
10[b]	Inc	Inc	1	1	1	1	1	1	1	1	1	52.5	A
11[b]	Inc (2[f])	1[e,f] (1)	1	1	1	1	1	1	1	1	1 (2)	58.0	A
12	Inc	Inc	2	2	2[f,g]	2	1	1	1	1	2	52.5	A
16	Inc	Inc	2	2	2	2	2	2	2	2	2	52.5	A
17[b]	Inc (2[f])	2	2	2	2	2	2	2	2	2	2	59.0	A
18[b]	Inc	Inc	1	1	1	1	1	1	1	1	1	52.5	A
22[b]	Inc (1[f])	1[e,f]	1[e]	1	1	1	1	1	1	1	1	59.0	A
27[b]	Inc	2	2	2	2	2	2	2	2	1	2	58.0	A
29	Inc	Inc	2	2	2	2	2	2	2	2	2	52.5	A
39	Inc	Inc	2	2[f,g]	1[e]	1	1	1	0	0	2	45.5	F
45	Inc	Inc	1	1	1	1	1	1	1	1	1	59.0	A
46[b]	Inc	Inc (2[f,g])	2	2	2	2	2	2	2	2	2	52.5	A
Totals													
Broods of 2	0 (2)	2 (3)	7	7	6	6	5	5	5	4	7 (8)	–	–
Broods of 1	0 (1)	2 (3)	7	7	8	8	9	9	8	9	8 (7)	–	–
Chick loss	0	1 (2)	0	0	1	0	1	0	1	1	5 (6)	–	–

[a] A = active, young present on 13 September, F = failed
[b] Nest monitored by camera
[c] Inc = loon incubating at the time of the survey
[d] No chick observed; at least 1 egg hatched since previous aerial survey based on eggshell evidence at the nest. Camera images confirmed that 1 chick hatched on 17 July and suffered predation by a Glaucous Gull on that day
[e] No chick observed; 1 chick assumed present based on subsequent or previous aerial surveys
[f] Adult brooding chick(s)
[g] No chicks observed; 2 chicks assumed present based on subsequent aerial surveys

nest location, suggesting that most of these 7 nests probably were inactive (not yet initiated) or in the early initiation phase at the time of the nesting survey. Some lakes in the Fish Creek Delta and Alpine West subareas, including lakes of 2 Yellow-billed Loon territories, were not surveyed during the nesting survey because helicopter mechanical problems prevented completion of the survey. These Yellow-billed Loon territories were surveyed during the next monitoring survey on 29 June and a nest was found at 1 of the territories. In the NE NPRA survey area, most nests were found in the Fish and Judy Creek Corridor subarea (25 nests), followed by the Fish Creek Delta subarea (6 nests), and the Alpine West subarea (1 nest). Nest density was 0.07 nests/km² for the entire NE NPRA survey area in 2010 and ranged from 0.01 to 0.10 nests/km² for the 3 subareas surveyed. Four of the 36 nests were found outside of the survey subareas and were not included in density calculations to be consistent with data presentations from previous years.

Two nests found in the Fish and Judy Creek Corridor subarea and 1 nest outside of the subareas were on lakes without a previous history of nesting by Yellow-billed Loons, but Yellow-billed Loons had been recorded on these 3 lakes during nesting and brood-rearing surveys in previous years. An additional nest found in the Fish and Judy Creek Corridor subarea was at an alternate nest site of a territory that already contained a nesting Yellow-billed Loon, resulting in 2 Yellow-billed Loon nests in an area that was considered to be only 1 territory. The nest at the alternate site was active for 2 weeks before it failed, after which it was occupied by a nesting Pacific Loon. All other Yellow-billed Loon nests found in NE NPRA in 2010 were on lakes where nesting was recorded during surveys in previous years (Johnson et al. 2005, 2006b, 2007b, 2009, 2010).

During the brood-rearing survey on 16–17 August 2010, 70 adult Yellow-billed Loons and 15 broods were observed in the NE NPRA study area (Figure 11, Table 7). Nine broods were found in the Fish and Judy Creek Corridor subarea, 4 broods in the Fish Creek Delta subarea, 1 brood in the Alpine West subarea, and 1 brood was outside the survey subareas. At 2 nests in the Fish and Judy Creek Corridor subarea where broods were not observed on aerial surveys, hatching was confirmed by eggshell evidence at the nest. The density of Yellow-billed Loon broods in the NE NPRA study area in 2010 was 0.03 broods/km², and ranged from 0.01 to 0.04 broods/km² for the 3 subareas surveyed.

Habitat Use

Habitat selection was evaluated for nesting and brood-rearing Yellow-billed Loons in 2008–2010 in the 3 subareas surveyed for loons (Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas) in the NE NPRA study area. Yellow-billed Loon nests were found in 12 of 26 available habitats in the NE NPRA study area (Table 12). Three habitats were preferred for nesting (Deep Open Water with Islands or Polygonized Margins, Tapped Lake with High-water Connection, and Sedge Marsh), altogether supporting 46 of 77 total nests. Within these areas, 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. Deep Open Water with Islands or Polygonized Margins was the most frequently used habitat for nesting (39% of all nests), and it also was the most abundant waterbody habitat in the loon survey area (6%). Nesting Yellow-billed Loons avoided 4 habitats (Open-Nearshore Water, Moist Sedge–Shrub Meadow, Moist Tussock Tundra, and Tall, Low, or Dwarf Shrub), which together occupied 43% of the loon survey area in the NE NPRA study area.

Thirty-seven Yellow-billed Loon broods were found in 3 habitats in the NE NPRA study area, 2 of which were preferred: Deep Open Water with Islands or Polygonized Margins and Tapped Lake with High-water Connection (Table 12). Deep Open Water with Islands or Polygonized Margins also was the most frequently used habitat for brood-rearing (81% of all broods). No shallow-water habitats were used during brood-rearing. The selection analyses for loon in the NE NPRA, like those conducted for the Colville Delta, highlight the reliance on large, deep waterbodies by breeding Yellow-billed Loons.

Table 12. Habitat selection by nesting and brood-rearing Yellow-billed Loons, NE NPRA study area, Alaska, 2008–2010.

SEASON Habitat	No. of Nests or Broods	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
NESTING					
Open Nearshore Water	0	0	5.5	avoid	low
Brackish Water	0	0	2.3	ns	low
Tapped Lake with Low-water Connection	0	0	1.5	ns	low
Tapped Lake with High-water Connection	8	10.4	1.2	prefer	low
Salt Marsh	0	0	4.1	ns	low
Tidal Flat Barrens	0	0	4.1	ns	low
Salt-killed Tundra	0	0	1.6	ns	low
Deep Open Water without Islands	3	3.9	5.5	ns	low
Deep Open Water with Islands or Polygonized Margins	30	39.0	6.5	prefer	low
Shallow Open Water without Islands	0	0	0.8	ns	low
Shallow Open Water with Islands or Polygonized Margins	4	5.2	1.5	ns	low
River or Stream	0	0	2.2	ns	low
Sedge Marsh	8	10.4	1.5	prefer	low
Deep Polygon Complex	1	1.3	<0.1	ns	low
Grass Marsh	2	2.6	0.4	ns	low
Young Basin Wetland Complex	0	0	0.3	ns	low
Old Basin Wetland Complex	0	0	4.0	ns	low
Riverine Complex	0	0	0.1	ns	low
Dune Complex	3	3.9	2.0	ns	low
Nonpatterned Wet Meadow	4	5.2	3.3	ns	low
Patterned Wet Meadow	10	13.0	12.3	ns	
Moist Sedge-Shrub Meadow	3	3.9	16.7	avoid	
Moist Tussock Tundra	1	1.3	16.0	avoid	
Tall, Low, or Dwarf Shrub	0	0	4.6	avoid	low
Barrens	0	0	2.1	ns	low
Human Modified	0	0	0	ns	
Total	77	100	100.0		
BROOD-REARING					
Open Nearshore Water	0	0	5.5	ns	low
Brackish Water	0	0	2.3	ns	low
Tapped Lake with Low-water Connection	0	0	1.5	ns	low
Tapped Lake with High-water Connection	5	13.5	1.2	prefer	low
Salt Marsh	0	0	4.1	ns	low
Tidal Flat Barrens	0	0	4.1	ns	low
Salt-killed Tundra	0	0	1.6	ns	low
Deep Open Water without Islands	2	5.4	5.5	ns	low
Deep Open Water with Islands or Polygonized Margins	30	81.1	6.5	prefer	low
Shallow Open Water without Islands	0	0	0.8	ns	low
Shallow Open Water with Islands or Polygonized Margins	0	0	1.5	ns	low
River or Stream	0	0	2.2	ns	low
Sedge Marsh	0	0	1.5	ns	low
Deep Polygon Complex	0	0	<0.1	ns	low
Grass Marsh	0	0	0.4	ns	low
Young Basin Wetland Complex	0	0	0.3	ns	low
Old Basin Wetland Complex	0	0	4.0	ns	low
Riverine Complex	0	0	0.1	ns	low
Dune Complex	0	0	2.0	ns	low
Nonpatterned Wet Meadow	0	0	3.3	ns	low
Patterned Wet Meadow	0	0	12.3	avoid	low
Moist Sedge-Shrub Meadow	0	0	16.7	avoid	
Moist Tussock Tundra	0	0	16.0	avoid	
Tall, Low, or Dwarf Shrub	0	0	4.6	ns	low
Barrens	0	0	2.1	ns	low
Human Modified	0	0	0	ns	
Total	37	100	100		

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

[b] Significance calculated from 1,000 simulations at = 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

Overall, 17 of 36 Yellow-billed Loon nests in the NE NPRA study area in 2010 hatched for an apparent nesting success of 47% (Table 13). Young loons were observed during aerial surveys at all but 2 nests, which were determined to have hatched based on eggshell evidence. Of the 17 successful nests, most hatched during the last 2 weeks of July: 8 nests (47%) hatched between visits on 15 and 20 July and 6 (35%) hatched between 20 and 27 July. Two nests hatched before 15 July and an additional nest probably hatched by 27 July, but we could not check its status until 3 August because of a large caribou herd in the area on 27 July (to reduce potential disturbance, we avoid helicopter flights over groups of caribou during June–August).

Nineteen of 36 Yellow-billed Loon nests in the NE NPRA study area failed to hatch (Table 13). One of 19 (5%) nests failed between the nesting survey and the first monitoring survey on 29 June. Most failed nests were found inactive during the first 2 weeks of July. Eight (42%) nests failed between 29 June–6 July and 9 (47%) failed between 6 and 15 July. The remaining nest (5%) failed between visits on 3 and 16 August; fog prevented us from surveying this nest on 10 August. The nest was active for a minimum of 42 days, or ~14 d longer than the reported incubation period for Yellow-billed Loons (North 1994). Reasons for the extended incubation are unknown but may be caused by infertile or damaged eggs or this loon may have renested after its nest was depredated between monitoring surveys.

The contents of 34 of 36 Yellow-billed Loon nests were examined after nests were no longer active. Two nests on islands were not examined because they were inaccessible by helicopter, but both nests hatched based on the presence of broods. In addition to those 2 nests, 13 nests were classified as successful based on the presence of a brood and eggshell fragments in the nest, and 2 nests were classified as successful based only on eggshell fragments in the nest. These nests contained 21–119 small eggshell fragments within 5m of the nest. Of >1,000 eggshell fragments found in successful nests, 67% were ≤10 mm in length. Eleven of 15 successful nests examined also contained pieces of thickened egg membrane. Membranes were whole at 3 nests while the remainder had pieces mostly <30 mm in length. The majority of egg membranes and eggshell fragments were found in nest bowls and only ~110 fragments were found in the water or on shore adjacent to successful nests. Six of the 19 failed nests had egg remains in or near the nest. One nest had broken eggs within 5 m and 4 nests contained 3–15 egg fragments, both with and without adhered membranes. One failed nest (confirmed by predation seen on camera images) contained 17 fragments, including 6 pieces of membrane. The remaining 13 nests were empty.

Time-lapse Cameras

We monitored 10 of 36 Yellow-billed Loon nests in the NE NPRA study area with time-lapse cameras in 2010 (Table 14). Eight-power zoom cameras were placed 36–120 m from nests (mean = 82 m, n = 3) and 2× and 2.5× zoom cameras were placed 24–56 m from nests (mean = 43 m, n = 7). Researchers were transported to and from nesting areas by helicopter for camera setup and were at nests an average of 40 min (range = 26–83 min, n = 10 nests). One of 10 loons remained on its nest during camera setup and 8 left their nest (6 swam away as the helicopter landed and 2 left as researchers approached the camera setup location). The remaining loon was swimming next to its nest upon our arrival and swam away as the helicopter approached; it remained off the nest during camera setup.

All 9 loons that left their nests returned to incubate after camera installation. Excluding the loon that was swimming next to its nest upon our arrival and another that returned before we departed in the helicopter, the remaining 7 loons returned to their nests an average of 18 min after we departed in the helicopter (median = 15 min, range = 2–55 min). In total, loons were absent from nests an average of 49 min during camera installation (median = 49 min, range = 36–63 min, n = 8 nests).

We were able to identify the day of hatch or failure from 9 of 10 camera-monitored nests. At 1 nest, the memory card filled to capacity before hatch occurred. Of the 10 nests that were monitored, 6 hatched and 4 failed for an apparent nesting success of 60%. The median initiation date of camera-monitored nests was 19 June (range = 13–22 June, n = 8), and the median hatch date for

Table 13. Weekly status (A = active, I = inactive) and fate of Yellow-billed Loon nests monitored by aerial surveys, NE NPRA study area, Alaska, 2010. Status determined from camera-monitored nests is presented in parentheses where it differed from status determined from aerial surveys.

	June		July				August			
Territory	20–24	29[a]	5–6[a]	14–15	20	26–27	3	10	16	Fate/total
51	A	A	A	A	I	–	–	–	–	Hatched
53	I	A	–[b]	I	–	–	–	–	–	Failed
55	A	A	A	I	–	–	–	–	–	Failed
58	A	A	A	A	A	I	–	–	–	Hatched[c]
59[d]	A	A	A	A	I	–	–	–	–	Hatched
61[d]	A	A	I	–	–	–	–	–	–	Failed
62	I	A	A	I	–	–	–	–	–	Failed
63	A	A	A	A	I	–	–	–	–	Hatched
65[d]	A	A	A	I	–	–	–	–	–	Hatched
66	A	A	I	–		–	–	–	–	Failed
68[d]	A	A	I	–	–	–	–	–	–	Failed
69[d]	A	A	A	A	A	I	–	–	–	Hatched
70	A	A	I	–	–	–	–	–	–	Hatched[c]
71	–	A	A	I	–	–	–	–	–	Failed
72	I	A	I	–		–	–	–	–	Failed
73	A	A	A	A	I	–	–	–	–	Hatched
75[d]	A	A	A	I	–	–	–	–	–	Failed
77[d]	A	A	A	A	A (I[e])	I	–	–	–	Hatched
78[d]	A	A	A	A	I	–	–	–	–	Hatched
80	I	I	A	A	A	I	–	–	–	Hatched
81[d]	A	A	A	A	A (I[e])	I	–	–	–	Hatched
82	A	I	–	–	–	–	–	–	–	Failed
83	A	A	A	I	–	–	–	–	–	Failed
85	A	A	A	A	I	–	–	–	–	Hatched
86	A	A	A	A	A	A	A	–[b]	I	Failed
87	I	A	I	–	–	–	–	–	–	Failed
88	A	A	A	A	A	I	–	–	–	Hatched
89	–	A	A	A	I	–	–	–	–	Hatched
91	A	A	I	–	–	–	–	–	–	Failed
92	A	A	A	A	A	–[f]	I	–	–	Hatched
94	A	A	A	A	I	–	–	–	–	Hatched
95	A	A	A	I	–	–	–	–	–	Failed
99	A	A	A	I	–	–	–	–	–	Failed
100	A	A	I	–	–	–	–	–	–	Failed
101[d]	I	A	A	I	–	–	–	–	–	Failed
102	A	A	I	–	–	–	–	–	–	Failed
No. Active	28	34	25	16	8 (6)	1	1	–	0	36
No. Hatched	0	0	1	1	8 (10)	6 (4)	1	0	0	17
No. Failed	0	1	8	9	0	0	0	–	1	19

[a] Camera-monitored nests were not surveyed by helicopter; nest status determined from camera images
[b] Nest not surveyed due to fog and/or limited time
[c] No brood was seen but nest classified as hatched based on eggshell evidence at the nest
[d] Nest monitored by camera
[e] Camera images show young were being brooded in nest during this survey
[f] Nest not surveyed due to the proximity of a large caribou herd

Table 14. Nest history and incubation activity at Yellow-billed Loon nests monitored by time-lapse digital cameras, NE NPRA study area, Alaska, 2010.

Territory	Fate[a]	Nest initiation 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)
59	S	18 June		2	23 Jun	16 July	22.0	98.1	1.7	3.1	8.3
61	F	20 June	Common Raven	2	23 Jun	30 June	5.9	92.0	1.5	4.2	28.0
65	S	13 June		2	23 Jun	11 July	16.8	97.9	1.5	3.1	9.1
68	F	16 June	Glaucous Gull, Parasitic Jaeger	2	23 Jun	2 July	8.0	97.4	1.4	3.3	11.1
69	S	17 June	Golden Eagle[e]	2	23 Jun	15 July[f]	23.3	96.2	1.5	4.0	13.2
75	F	–[g]	Unknown	U	23 Jun	8 July	13.1	98.9	1.7	1.9	7.0
77	S	22 June	Glaucous Gull[e]	2	29 Jun	20 July	20.0	94.9	1.6	4.3	16.6
78	S	22 June		2	29 Jun	20 July	20.0	97.9	0.5	3.1	9.7
81	S	20 June	Parasitic Jaeger[e]	2	29 Jun	18 July	18.0	97.5	0.6	3.5	10.1
101	F	–[g]	Golden Eagle	U	29 Jun	12 July	11.6	88.8	0.8	4.3	37.3

[a] S = successfully hatched, F = failed to hatch
[b] Nest initiation dates for successful nests estimated by subtracting 28 d from hatch date; for failed nests, nest age estimated using egg floatation (see Methods: Loon Surveys)
[c] As known on day of camera setup or maximum seen on camera images; U = unknown
[d] Excludes day of camera installation and periods of time when photo images could not be interpreted because of poor weather conditions
[e] Predator was recorded at the nest; egg predation was not observed but assumed to have occurred
[f] Memory card in camera reached capacity before the day of hatch; day of hatch estimated using egg floatation
[g] Eggs not floated

successful nests was 17 July (range = 11–20 July; Table 14). Hatch dates determined from camera images agree with the hatch dates determined from monitoring surveys, which indicate that most nests hatched between visits on 15 and 20 July. Excluding the day of hatch or failure, loons at both hatched and failed nests exhibited high nest attendance, spending 97.1% ($n = 9$) and 94.3% ($n = 5$) of the time incubating, respectively.

Of the 4 nests that failed to hatch, 1 failure was attributed to a pair of Common Ravens, 1 to a pair of Parasitic Jaegers and a Glaucous Gull, and 1 to a Golden Eagle. The predator at the fourth nest was not captured on camera images because the predation event occurred during the time between camera images, which was set to record at 1 minute intervals, indicating that the predation event occurred in <1 min. All 3 nests that failed due to avian predation were unattended prior to the predation event; the ravens, gull, and jaegers opportunistically took eggs while loons were away from their nests. The ravens destroyed a nest ~7 min after the incubating loon left. One nest suffered predation by a gull within ~3 min of being unattended. The gull was at the nest for 1 min before the loon returned to incubate. Although there was an egg visible in the nest, the loon left after ~1 h and did not return for nearly 6 h. During that time a pair of jaegers took the egg. Several hours after that, a gull landed at the nest but was chased off by the loon. The loon removed a broken egg from the nest but complete nest failure had occurred and the loon did not resume incubation. At the nest that failed due to predation by a Golden Eagle, the eagle may have flushed the incubating bird off the nest. The loon was seen swimming next to its nest 1–2 min prior to the image with the eagle. The eagle ate 1 of the eggs a few meters from the nest during which time the loon returned to incubate; however, the eagle flushed the loon to take the second egg.

Partial egg predation was documented at 3 nests that subsequently were successful in hatching 1 chick. A Glaucous Gull, a Parasitic Jaeger, and a Golden Eagle each took an egg at 3 different nests. Those predators were seen standing at a nest for <1 min, and although we did not see them with an egg in their bill, we assumed that either an egg was damaged or that it was carried away from the nest. At the 2 nests that suffered gull and jaeger predation, the loon was on a recess from the nest, giving those predators an opportunity to land at the unattended nest. One of those loons was seen removing a bloody egg or chick from the nest after returning to incubate. The Golden Eagle may have flushed the incubating loon off its nest. That loon was incubating in a concealed posture prior to leaving the nest. The eagle appeared ~30 sec after the loon left. We did not record any chick or egg predation during hatch.

In addition to documenting nest fate, cameras also recorded other Yellow-billed Loons intruding into occupied territories. Intruding loons were seen at 8 of 10 camera-monitored territories. Intruding loons also were seen on images at nests in the Colville Delta study area and may reflect young loons returning to natal areas to setup breeding territories (see Results, Colville Delta, Time-lapse Cameras). Three-year old Common Loons have been documented returning to natal sites but it is unknown whether Yellow-billed Loons do so (McIntyre and Barr 1997, North 1994).

We also documented a loon removing part of a successfully hatched egg from its nest. This loon was part of the same pair that removed a depredated egg during incubation. We typically do not find entire membranes in loon nests during nest fate visits and documenting this behavior further suggests that relying solely on the presence of membranes as an indicator of hatch is not reliable in Yellow-billed Loons.

Brood Fate

During the monitoring surveys following hatch, 5 of 17 (29%) successful Yellow-billed Loon pairs in the NE NPRA study area were observed with 2 chicks, 10 (59%) had 1 chick, and 2 pairs lost their brood (unknown number of chicks) between hatching and the next weekly survey (Table 15). Assuming a minimum of 1 chick for each of these nests with an unknown number of chicks, a minimum of 22 chicks were produced at 36 detected nests (0.61 chicks/nest). All chicks seen on images at camera-monitored nests ($n = 10$) were seen during monitoring surveys.

Fourteen of 17 (82%) Yellow-billed Loon pairs that hatched at least 1 egg retained 1 chick on the final monitoring survey on 13 September. Of the 5 pairs that hatched 2 chicks, 3 retained both chicks. During our final survey, we recorded 17

Table 15. Number of Yellow-billed Loon chicks observed during weekly aerial surveys, NE NPRA study area, Alaska, 2010. Status and number of chicks determined by camera-monitoring presented in parentheses where it differed from counts determined during aerial surveys.

	July				August					September				
Territory	5–6	14–15	20	26–27	3	10	16	23	30	6	13	No. chicks hatched	Age (d) when last seen	Brood fate[a]
51	Inc[b]	Inc	1	1	1	1[c]	1	1	1	1	1	1	58.0	A
58	Inc	Inc	0[d]	0	–	–	–	–	–	–	–	1	3.5	F
59[e]	Inc	Inc	2	1	1	1	1	1	0	0	0	2	58.0	F
63	Inc	Inc	1	1[c]	1	1[c]	1[c]	1[c]	1	1	1	1	58.0	A
65[e]	Inc	2	2	1	1	1	1	1	1	1	1	2 (1)	64.5	A
69[e]	Inc	Inc	Inc	1	1	1	1	1	1	1	1	1	51.5	A
70	0[d]	0	–	–	–	–	–	–	–	–	–	1	3.5	F
73	Inc	Inc	2	2	2	2	2	2	2	2	2	2	58.0	A
77[e]	Inc	Inc	Inc (1[f])	1	1	1	1	1	1[c]	1	1	1	51.5	A
78[e]	Inc	Inc	1	2[g]	2	2	2	2	2	2	2	2	57.5	A
80	Inc	Inc	Inc	1	1	1	1	1	1	1	1	1	51.5	A
81[e]	Inc	Inc	Inc (1[f])	1	1	1	1	1	1	1	1	1	54.5	A
85	Inc	Inc	1	1	1	1[c]	1	1	1	1	1	1	58.0	A
88	Inc	Inc	Inc	1	2	2[g]	2	2	2	2	2	2	52.0	A
89	Inc	Inc	1	1[h]	1	1	1	1	1	1	1	1	58.0	A
92	Inc	Inc	Inc	1[h]	1[c]	1	1	1	1	1	1	1	41.0	A
94	Inc	Inc	1[c, f]	1[c]	1	1	1	1	1	1	1	1	58.0	A
Totals														
Broods of 2	0	1	3	2	3	3	3	3	3	3	3	5 (4)	–	–
Broods of 1	0	0	6 (8)	13	12	12	12	12	11	11	11	12 (13)	–	–
Chick loss	1	0	1	2	0	0	0	0	1	0	0		–	–

[a] A = active, young present on 13 September, F = failed
[b] Inc = loon incubating at the time of the survey
[c] No chick observed; 1 chick assumed present based on subsequent aerial surveys
[d] No chick observed; at least 1 egg hatched since previous aerial survey based on eggshell evidence at the nest and chick did not survive to this aerial survey; assumed 1 chick died

chicks from 36 nests (0.47 chicks/nest). Most loon chicks were ~8 weeks old (range = 6–9 weeks) and none were observed flying by that time (Table 15). Assuming the fledging period is similar to that of Common Loons, which is ~11 weeks (McIntyre and Barr 1997, North 1994), the chicks in this study were 2–5 weeks from fledging. Chicks 6–7 weeks old were observed exercising their wings by wing stretching or flapping and by running across the water while wing-flapping.

PACIFIC AND RED-THROATED LOONS

Colville Delta

We counted 151 Pacific Loons and 15 Pacific Loon nests and 10 Red-throated Loons (and no Red-throated Loon nests) in the Colville Delta study area during the nesting survey for Yellow-billed Loons in 2010 (Figure 12, Table 7). During the brood-rearing survey, 29 adult Pacific Loons with 5 broods were observed in the Colville Delta study area. No Red-throated adults or broods were found. Opportunistic counts of Pacific and Red-throated loons reflect their general distribution on the Colville Delta but are not indicative of the relative abundance of these species (due to differences in species detectability). Nests of Red-throated Loons are not easily detected from the air and are found on small ponds, which were not surveyed in this study. 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. Nonetheless, Pacific Loons were clearly the most abundant loon on the delta in 2010 and in previous years.

NE NPRA

Pacific Loons also were the most abundant and widespread loon species breeding in the NE NPRA study area in 2010 (Figure 12, Table 7). On the loon nesting survey, we recorded 258 adult Pacific Loons with 32 nests. During the brood-rearing survey, 155 adult Pacific Loons were found with 22 broods. No Red-throated Loons, nests, or broods were observed during the nesting and brood-rearing surveys.

DISCUSSION

Annually, the number of Yellow-billed Loons recorded on the aerial nesting survey of the Colville Delta study area has ranged from 36 to 69 loons (mean = 54 loons) during 16 years of surveys (1993, 1995–1998, 2000–2010). The number of nests counted on the same surveys ranged from 10 to 33 nests (mean = 20 nests). Up to 12 additional nests were found after the nesting survey during those years (11 of the 16 survey years) when searches for nests were repeated during subsequent monitoring surveys at traditional Yellow-billed Loon nesting lakes and at lakes where Yellow-billed Loons were seen but no nest was found on the nesting survey. The high count of 69 loons occurred in 2008 and 2010, which also are the years when the highest number of nests were found: 38 and 35 nests, respectively. We have identified 46 Yellow-billed Loon nesting territories in the Colville Delta study area, of which 33 territories have had a nesting pair of loons in at least half of the 16 survey years.

A similar number of nesting Yellow-billed Loons occurs in the Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas of the NE NPRA study area. Although surveys for Yellow-billed Loons started in 2001 in NE NPRA, the 3 subareas have been surveyed in the same year only since 2008. The number of Yellow-billed Loons and nests found in these 3 subareas during the aerial nesting survey has ranged from 61 to 78 loons and 26 to 32 nests, with the highest number of loons recorded in 2008 and the highest number of nests in 2010. These nest counts include 2 to 6 nests found per year after the nesting survey during weekly monitoring surveys. An additional 2 to 4 nests were found each year in lakes outside of the current study area but the nests were in Yellow-billed Loon territories identified during surveys of the Development and Exploration subareas in 2002–2004. We have identified 52 Yellow-billed Loon nesting territories in the NE NPRA study area, which includes 5 territories outside of the survey subareas. At 4 of the 52 territories, the first record of nesting by Yellow-billed Loons occurred in 2010, although adults were recorded at those lakes in previous years.

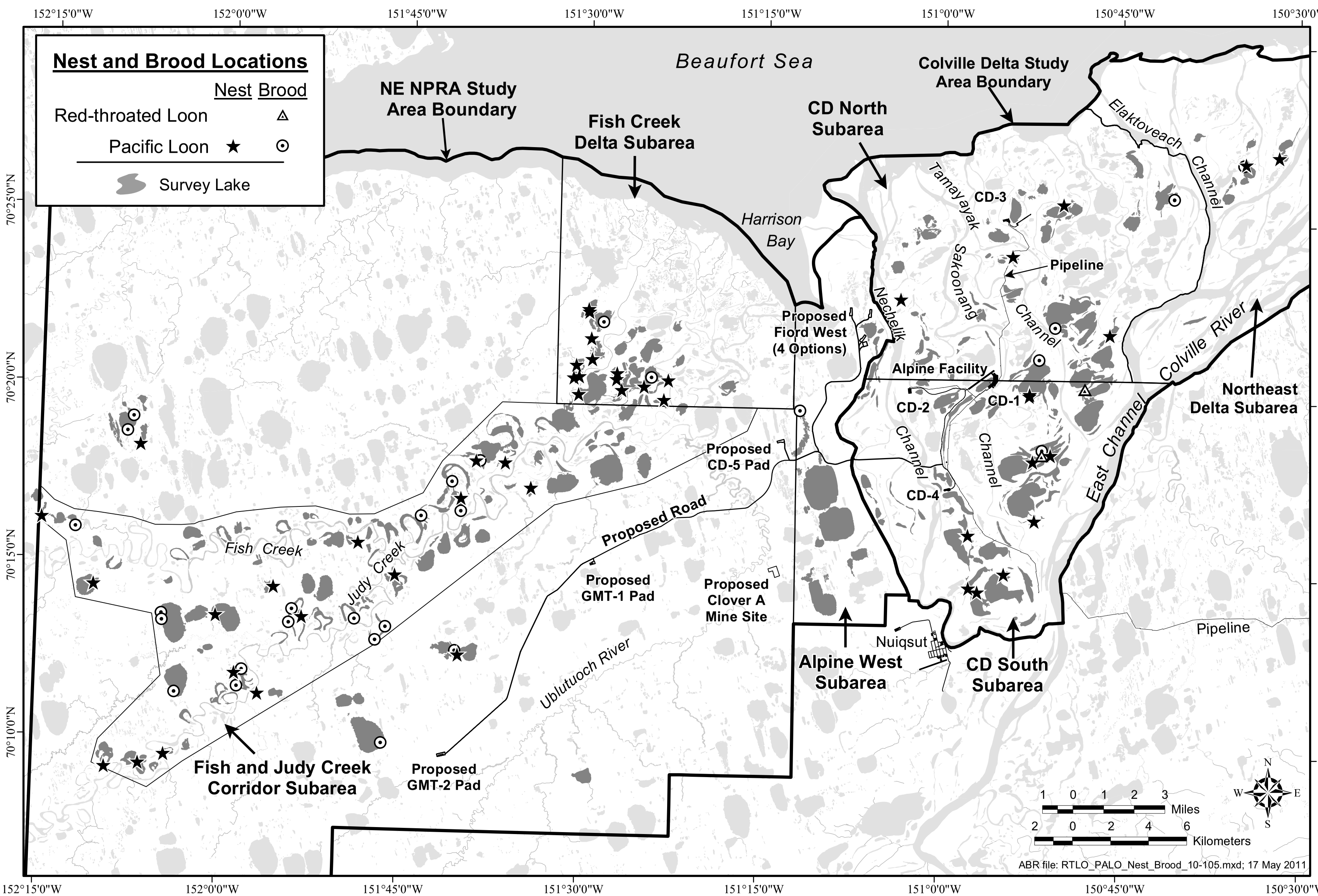

Figure 12. Pacific and Red-throated loon nests and broods, Colville Delta and NE NPRA study areas, Alaska, 2010.

The density of Yellow-billed Loons and nests was slightly higher each year in the Colville Delta study area (CD North and CD South subareas only) compared to the NE NPRA study area (Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas only) for the years 2008–2010. The 3-year mean of loons and nests for the Colville Delta study area was 0.18 birds/ km^2 and 0.09 nests/ km^2 compared to 0.15 birds/ km^2 and 0.06 nests/ km^2 for the NE NPRA study area. The 16-year mean for Yellow-billed Loons and nests in the Colville Delta study area was 0.14 birds/ km^2 (SE = 0.007) and 0.05 nests/ km^2 (SE = 0.005). In both study areas, the 2 habitats most commonly used by Yellow-billed Loons for nesting were Deep Open Water with Islands or Polygonized Margins and Patterned Wet Meadow.

The number of broods found in the Colville Delta study area during the 16 years of brood-rearing surveys in August was highly variable. The lowest number recorded was 2 broods in 2000 and the highest number was 22 broods in 2008. The 14 Yellow-billed Loon broods found in the Colville Delta study area in 2010 was greater than the 16-year mean (11 broods). Fourteen broods also were found in the 3 survey subareas of the NE NPRA study area in 2010, slightly more than the number found in 2008 and 2009 (11 and 12 broods, respectively). An additional 2 to 5 broods were found each year during monitoring surveys that were gone by the time of the August brood-rearing survey

In 2010, we found the second-highest number of Yellow-billed Loon nests (35) in the Colville Delta since nest monitoring surveys began in 2005 (mean = 32); however, apparent nesting success (43%) was lower in 2010 than the previous 5 years (mean = 62%). Similarly, the number of nests (36) in the NE NPRA study area in 2010 was the highest since monitoring surveys began in 2008 (mean = 29), but nesting success was lower in 2010 (47%) than the 2 previous years (mean = 59%).

Hatch occurred later in both study areas in 2010 than in previous years when nest monitoring occurred. Based on monitoring surveys of previous years, most nests hatched during the second week of July (*n* = 5 years for Colville Delta; *n* = 2 years for NE NPRA). In 2010, most nests in the NE NPRA study area hatched during the third week of July and in the Colville Delta study area during the fourth week of July. The timing of moat formation on nesting lakes has been shown to influence nest initiation (North 1994) and likely contributed to the late nesting phenology observed in 2010 in this study. Incidental observations on 10–11 June 2010 showed that nesting lakes in the Colville Delta study area lacked appreciable moats and the area around most nest sites was ice covered. In NE NPRA, large lakes were starting to acquire moats on 10–11 June 2010. Later nest initiation in 2010 compared with other nest monitoring years may have contributed to the high number of nests found in 2010 because in years of earlier nest initiation, we may miss some nests that fail prior to the nesting survey. The documentation of early nest failures also may explain the lower nesting success observed in 2010 compared with previous years.

During the weekly monitoring survey following hatch, excluding chicks detected only on camera images, we saw 14 broods in the Colville Delta study area in 2010, comprising 0.63 chicks/nest (*n* = 35 nests), which is the second-lowest number since nest monitoring began in 2005 (mean = 0.89 chicks/nest). Half of those broods contained 2 chicks, which is within the range of variation seen in 2005–2009. In the NE NPRA study area in 2010, we found 15 broods during the weekly monitoring survey after hatch, comprising 0.61 chicks/nest (*n* = 36 nests), which is lower than the 2-year mean of 0.88 chicks/nest. Fewer (33%) of those broods had 2 chicks compared to previous years. Since we began monitoring nests with cameras, 5 broods of 2 chicks have been detected where only 1-chick broods were seen during weekly aerial surveys because the second chick of each brood died between hatch and the weekly survey.

Although Yellow-billed Loons in both study areas had fairly low nesting success and hatched few chicks per nest in 2010, the number of chicks per nest was high in mid-September compared to previous years. In the Colville Delta study area in 2010, we observed the highest chick production during the mid-September survey (0.49 chicks/ nest) since brood monitoring began in 2008 (mean = 0.41 chicks/nest). Chick production in the NE NPRA study area in 2010 (0.47 chicks/nest) was similar to the Colville Delta study area in 2010 and only slightly lower than that found in the NE NPRA study area in 2009 (0.52 chicks/nest) when brood monitoring began.

We began monitoring a sample of Yellow-billed Loon nests with cameras in the Colville Delta (n = 48 nests) and NE NPRA (n = 10 nests) study areas starting in 2008 and 2010, respectively. Predators caused nest failure at 23 of 24 failed nests and were seen taking an egg or chick from 9 successful nests. Glaucous Gulls were the most commonly recorded predator, preying on both eggs (9 nests) and chicks (2 nests). Other avian predators included Parasitic Jaegers (7 nests); Golden Eagles (4 nests), including 1 that was observed taking a chick; and Common Ravens (1 nest). Red fox (5 nests) were the most commonly recorded mammalian predator, followed by brown bear (1 nest). Although camera images have shown arctic foxes traveling past nests and, less frequently, trying to flush loons from nests, they have not been documented taking eggs. A predator was not captured on camera images at 4 nests that failed and 1 pair of loons appeared to abandon their nest.

TUNDRA SWAN

COLVILLE DELTA

Distribution and Abundance

During the 2010 swan nesting survey, 373 swans, including 91 pairs, were counted in the Colville Delta study area (Figure 13). The number of swans counted in 2010 was about the same as the 17-year mean of 379 swans found in the study area; and the number of pairs of swans was well above the 17-year average of 73 pairs. Twenty-four swan nests were found in the Colville Delta study area in 2010 (Table 16), fewer than the annual mean of 34 nests. Nine nests were located in the CD North subarea, 5 were in the CD South subarea, and 10 were in the Northeast Delta subarea. Ten additional swan nests were discovered during helicopter-based loon surveys of portions of the Colville Delta and are not included in the aerial swan survey total (Table 16) for consistency with data presentations from previous years; however, all swan nests are shown in Figure 13.

Productivity of Tundra Swans was poor on the Colville Delta in 2010. During the brood-rearing survey, 15 Tundra Swan broods were observed in the Colville Delta study area, well below the 17-year mean of 25 broods per year. Apparent overall nesting success was moderate, at 60% (Table 16). The mean brood size of 2.5 young in 2010 was equivalent to the 17-year mean of 2.5; however, the total of 37 young counted on the delta was below the 17-year mean of 62 young per year. Fewer than average nests, and a lower nesting success (50%), also were found in the adjacent Kuparuk oilfield in 2010 (Stickney et al. 2011).

Habitat Use

Habitat selection was evaluated for 580 Tundra Swan nests recorded on the Colville Delta since 1992 (Table 17). 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 1983, 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 used a wide range of habitats for nesting. Over 17 years of surveys, Tundra Swans nested in 19 of 24 available habitats, of which 8 habitats were preferred and 7 were avoided (Table 17). Eighty percent of the nests were found in the 8 preferred habitats: Salt Marsh, Salt-killed Tundra, Deep Open Water with Islands or Polygonized Margins, Sedge Marsh, Deep Polygon Complex, Grass Marsh, Patterned Wet Meadow, and Moist Sedge–Shrub Meadow. Nests occurred most frequently in Patterned Wet Meadow (37% of all nests), Deep Polygon Complex (13%), and Salt-killed Tundra (11%).

Habitat selection was evaluated for 419 Tundra Swan broods recorded on the Colville Delta since 1992 (Table 17). Eight habitats were preferred: Brackish Water, both types of Tapped

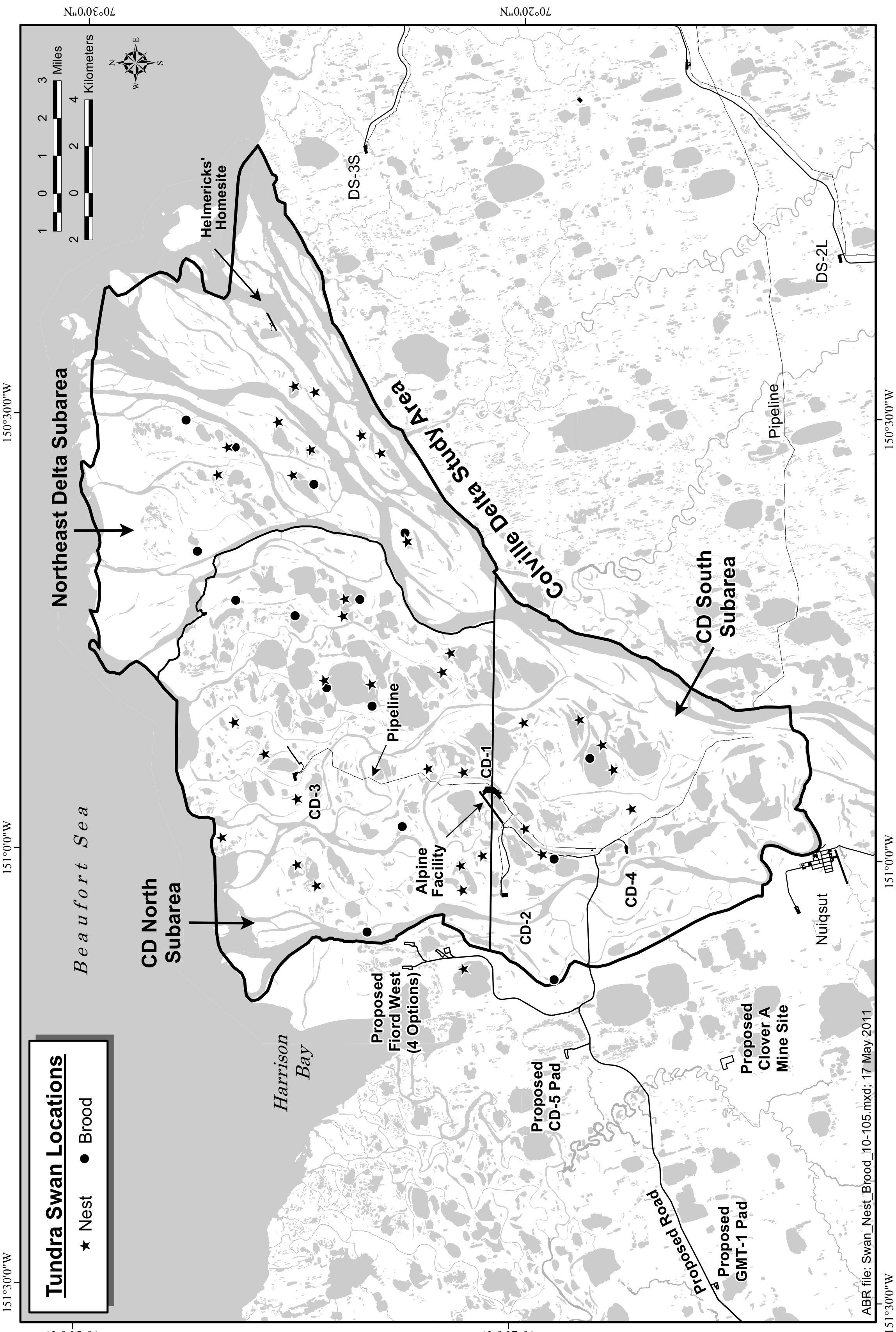

Figure 13. Tundra Swan nests and broods, Colville Delta study area, Alaska, 2010.

Table 16. Number and density of Tundra Swan nests and broods during aerial surveys of the Colville Delta, Alaska, 2010.

STUDY AREA Subarea	Nests Number	Nests Density (nests/km²)	Apparent Nesting Success[a] (%)	Broods Number	Broods Density (broods/km²)	Mean Brood Size
COLVILLE DELTA[b]						
CD North	9	0.4	78	7	0.3	2.4
CD South	5	0.3	60	3	0.2	3.0
Northeast Delta	10	0.5	50	5	0.3	2.2
Total (subareas combined)	24	0.4	60	15	0.3	2.5

[a] Apparent nesting success = (broods / nests) × 100
[b] CD North subarea = 206.7 km², CD South subarea = 155.9 km², Northeast Delta subarea = 189.6 km², and Colville Delta study area (subareas combined) = 552.2 km²

Lakes, Deep Open Water without islands, 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 (15% 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 37% of all swan broods on the delta were in salt-affected habitats, compared with only 20% of all nests (Table 16). Similar patterns have been reported by previous investigations (Spindler and Hall 1991, Monda et al. 1994).

DISCUSSION

Since we began aerial surveys for Tundra Swans on the Colville Delta, counts of pairs, nests, and brood numbers have shown a fair degree of variability. The lowest count of nests, 14, occurred in 1992, our first year of surveys; the highest count was 55 nests in 2002. The 17-year mean is 34 nests. Although the number of nests has fluctuated considerably over the 17 years of surveys, the overall trend has been an increase in nests. The total number of pairs counted during the nesting surveys has shown a more distinct increase, from a low of 42 in 1992 to a high of 97 pairs in 2002 and again in 2009. The mean number of pairs counted during the nesting surveys to date is 73. The increase in Tundra Swans observed on the Colville Delta is similar to the increase in the Kuparuk Oilfield and the increase (3.6 %) on the Arctic Coastal Plain (Larned et al. 2010). This growth trend appears to be widespread, probably related to the steady growth of the population of Tundra Swans wintering on the East Coast of the United States from 1955 to 2000 (Serie and Bartonek. 1991, Serie et al. 2002).

As with nests, brood counts have fluctuated considerably over the years, ranging from a low of 14 in 1993 to a high of 42 in 2004. The 2010 count of only 15 broods is well below the mean of 25 for the survey area, and reflects the low number of nests counted in June. A similarly low number of broods was recorded in the Kuparuk Oilfield. Taken together with the poor nesting success of Yellow-billed Loons, these events suggest a widespread factor such as weather may have affected Tundra Swan nesting in 2010. Although May and early June temperatures were near the norm, temperatures in the Kuparuk Oilfield during the last half of June were cooler than the long-term mean by 2–5° C (Appendix B in Lawhead and Prichard 2011). Despite the low number of broods counted in 2010, the trend over the past 17 years has also been one of slow increase.

Table 17. Habitat selection by nesting and brood-rearing Tundra Swans, Colville Delta study area, Alaska, 1992–1998 and 2000–2010.

SPECIES 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	8	1.4	1.2	ns	
Tapped Lake with Low-water Connection	2	0.3	3.9	avoid	
Tapped Lake with High-water Connection	5	0.9	3.8	avoid	
Salt Marsh	37	6.4	3.0	prefer	
Tidal Flat Barrens	5	0.9	10.6	avoid	
Salt-killed Tundra	64	11.0	4.6	prefer	
Deep Open Water without Islands	15	2.6	3.3	ns	
Deep Open Water with Islands or Polygonized Margins	35	6.0	1.8	prefer	
Shallow Open Water without Islands	3	0.5	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	1	0.2	0.1	ns	low
River or Stream	0	0	15.0	avoid	
Sedge Marsh	2	0.3	<0.1	prefer	low
Deep Polygon Complex	77	13.3	2.4	prefer	
Grass Marsh	12	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	42	7.2	7.5	ns	
Patterned Wet Meadow	214	36.9	18.6	prefer	
Moist Sedge-Shrub Meadow	27	4.7	2.2	prefer	
Moist Tussock Tundra	8	1.4	0.6	ns	low
Tall, Low, or Dwarf Shrub	10	1.7	5.0	avoid	
Barrens	13	2.2	13.8	avoid	
Human Modified	0	0	0.1	ns	low
Total	580	100	100		
BROOD-REARING					
Open Nearshore Water	1	0.2	1.8	avoid	
Brackish Water	27	6.4	1.2	prefer	low
Tapped Lake with Low-water Connection	62	14.8	3.9	prefer	
Tapped Lake with High-water Connection	45	10.7	3.8	prefer	
Salt Marsh	30	7.2	3.0	prefer	
Tidal Flat Barrens	3	0.7	10.6	avoid	
Salt-killed Tundra	31	7.4	4.6	prefer	
Deep Open Water without Islands	36	8.6	3.3	prefer	
Deep Open Water with Islands or Polygonized Margins	14	3.3	1.8	ns	
Shallow Open Water without Islands	6	1.4	0.4	prefer	low
Shallow Open Water with Islands or Polygonized Margins	2	0.5	0.1	ns	low
River or Stream	22	5.3	15.0	avoid	
Sedge Marsh	0	0	<0.1	ns	low
Deep Polygon Complex	10	2.4	2.4	ns	
Grass Marsh	9	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	22	5.3	7.5	ns	
Patterned Wet Meadow	54	12.9	18.6	avoid	
Moist Sedge-Shrub Meadow	7	1.7	2.2	ns	
Moist Tussock Tundra	1	0.2	0.6	ns	low
Tall, Low, or Dwarf Shrub	7	1.7	5.0	avoid	
Barrens	30	7.2	13.8	avoid	
Human Modified	0	0	0.1	ns	low
Total	419	100	100		

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

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

[c] Expected number < 5

GEESE

COLVILLE DELTA

Distribution and Abundance

During the goose brood-rearing aerial survey in 2010, we counted 1,474 Brant (746 adults and 728 young) in 11 groups in the Colville Delta study area (Figure 14, Table 18). All Brant groups included broods, and goslings comprised 49% of the total number of birds. Ten Brant brood-rearing groups were located in the CD North subarea (889 total birds), and 1 was located in the Northeast Delta subarea (585 total birds). Comparable surveys have been conducted in the area for 11 years and the total count in 2010 was near the average (mean = 1,313 Brant; range = 45–3,847; *n* = 11 years: 1990–1993, 1995, and 2005–2010; Bayha et al. 1992; Johnson et al. 1999a, 2006b, 2008b, 2009, 2010). The gosling count was the fourth highest and gosling percentage tied for the third highest in 9 years that goslings were recorded (1992–1993, 1995, and 2005–2010).

In 2010, 1,873 Snow Geese (883 adults and 990 goslings) in 19 groups were counted in the Colville Delta study area (Figure 14, Table 18). The 2010 count represented a sharp increase from the 678 Snow Geese (463 adults and 215 goslings) counted in 2009, and was slightly below the record high count of 1,967 Snow Geese (834 adults and 1,133 goslings) recorded in 2008 (Johnson et al. 2009, 2010). Eighteen (95%) groups contained broods, and goslings comprised 53% of the total number of birds. Twelve groups were located in the Northeast Delta subarea (915 total birds), and 7 were located in the CD North subarea (958 total birds).

Habitat Use

Brant brood groups favored coastal salt-affected habitats in the Colville Delta study area (Table 19). Ten of 11 Brant brood groups (91%) were found in 3 brackish habitats: Tapped Lakes with Low-water Connections (4 groups), Brackish Water (3) and Salt-killed Tundra (3).

Snow Geese also favored coastal salt-affected habitats for brood-rearing and molting in the Colville Delta study area. Of 19 Snow Goose groups observed, 12 groups (63%) were in salt-affected habitats, including Brackish Water (7 groups), Salt-killed Tundra (2), Salt Marsh (1), Tidal Flat Barrens (1), and Barrens (1). Five groups (26%) were found in River or Stream.

DISCUSSION

Surveys for Brant in the Colville River Delta study area were conducted using comparable methods in 1992, 1993, 1995, and 2005–2010. Since 2005, numbers of goslings and brood-rearing adults have been highly variable and no clear trends are apparent; but numbers appear to have increased since the earlier set of surveys in 1992–1995.

In the neighboring Kuparuk Oilfield study area (extending from the east bank of the Colville River to the east side of Prudhoe Bay for goose brood surveys) numbers of Brant goslings and brood-rearing adults have decreased gradually since comparable surveys began in 1989 (Stickney et al. 2011). Many of the brood groups in the western half of the Kuparuk Oilfield (from the Colville River to Milne Point) originate from nests on the Colville River Delta, with some additional broods coming from smaller colonies in the Kuparuk Oilfield (A. Stickney, ABR, pers. comm.). In contrast, Brant brood groups from Milne Point to the east side of Prudhoe Bay originate in colonies to the east of the Colville River, such as the large colonies on Howe and Duck islands on the Saganavirktok River Delta. From the Kuparuk River to the east side of Prudhoe Bay in the Kuparuk Oilfield study area, numbers of brood rearing Brant and goslings have decreased substantially since 1989 (Stickney et al. 2011). This is consistent with observed declines in productivity east of the Kuparuk Oilfield, including colonies on Howe Island, Duck Island, Niakuk Islands, and Surfcote Island (A. Stickney, ABR, pers. comm.).

To the west of the Colville River Delta (from the west bank of the Colville River to Barrow) numbers of Brant goslings and brood-rearing adults have been variable, but survey results show a gradual increasing trend since 1995 (Ritchie et al. 2010). Brant broods in this area originate from numerous scattered colonies between Barrow and Fish Creek Delta. Numbers of adult molting Brant have also been increasing in this area, particularly in the molting area near Teshekpuk Lake, a region used by failed- and non-breeding Brant from colonies throughout Alaska, including the Colville

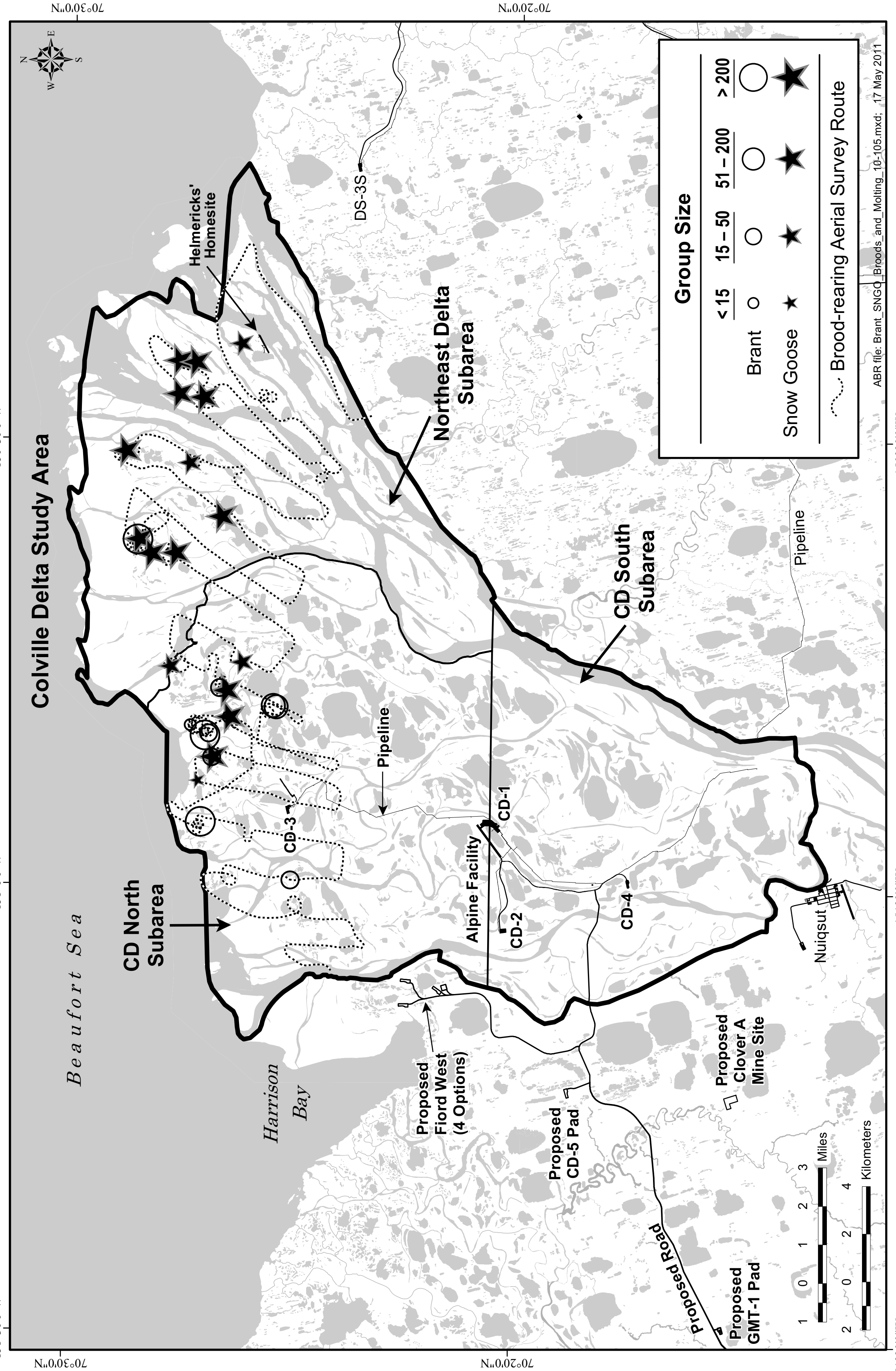

Figure 14. Brant and Snow Goose brood-rearing groups, Colville Delta study area, Alaska, 2010.

Table 18. Numbers of Brant and Snow Goose adults and young during brood-rearing aerial surveys, Colville Delta study area, Alaska, 2010.

SPECIES Study Area Subarea	Total Birds	Adults	Young	% Young	No. of Groups
BRANT					
Colville Delta[a]					
CD North	889	438	451	51	10
Northeast Delta	585	308	277	47	1
Total (subareas combined)	1,474	746	728	49	11
SNOW GEESE					
Colville Delta[a]					
CD North	958	451	507	53	7
Northeast Delta	915	432	483	53	12
Total (subareas combined)	1,873	883	990	53	19

[a] Only the CD North and Northeast Delta subareas were surveyed

Table 19. Habitat use by brood-rearing/molting Brant and Snow Geese, Colville Delta study area, Alaska, 2010.

	Brant		Snow Geese	
Habitat	No. of Groups	Use (%)	No. of Groups	Use (%)
Brackish Water	3	27.3	7	36.7
Tapped Lake with Low-water Connection	4	36.4	1	5.3
Salt Marsh	0	0	1	5.3
Tidal Flat Barrens	0	0	1	5.3
Salt-killed Tundra	3	27.3	2	10.5
River or Stream	1	9.1	5	26.3
Nonpatterned Wet Meadow	0	0	1	5.3
Barrens	0	0	1	5.3
Total	11	100	19	100

River Delta (Lewis et al. 2009) and particularly the large nesting colonies on the Yukon-Kuskokwim Delta (Derksen et al. 1979, King and Hodges 1979). Nest numbers have been decreasing on the Yukon-Kuskokwim Delta since 1992 (Wilson 2010), likely contributing to the increase of molting failed- and non-breeding Brant near Teshekpuk Lake (Ritchie et al. 2010).

Snow Goose nests have been found in small numbers on the Colville 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 2003 (Johnson et al. 2003b). Numbers of brood rearing Snow Geese have steadily increased in recent years, reaching record numbers in 2008, and near-record numbers in 2010. Similarly, numbers have been increasing sharply on the Ikpikpuk Delta Snow Goose colony, to the west of the Colville Delta, since surveys began there in 1994 (Ritchie et al. 2010). Numbers of nesting Snow Geese on the Saganavirktok River Delta have fluctuated widely since 1984, with nesting failures in some years attributed to mammalian nest predators (summarized in Ritchie et al. 2010). The Ikpikpuk Delta colony also suffered major nest predation by brown bears in 2009 and 2010 (Ritchie et al. 2010; ABR, unpubl. data).

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 as well as Snow Geese 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, focused exclusively on above-ground biomass, appears to have no lasting deleterious effects on salt marsh grazing lawns (Person et al. 1998). In contrast, Snow Geese remove rhizomes and meristematic tissue by grubbing in the spring, which can result in long-term degradation 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

Distribution and Abundance

Forty-five Glaucous Gull nests were counted in the Colville Delta study area during the aerial survey for nesting loons in 2010 (Figure 15, Table 20). Opportunistic counts of Glaucous Gull nests in the CD North and CD South subareas of the Colville Delta study area have ranged from 26 to 48 since 2001 (Burgess et al. 2002a, 2003a; Johnson et al. 2002, 2003b, 2004, 2005, 2006b, 2007b, 2008b, 2009, 2010). As in previous years, most nests were found in the CD North subarea. Five of the 28 nests in the CD North subarea in 2010 were located in 1 colony, a site that has been occupied since 2004 by 4–7 pairs of breeding gulls. Six out of 16 nests in the CD South subarea in 2009 were in a colony located ~5 km southeast of the Alpine Facility (Figure 15); that colony had the lowest number of nests in 11 years of monitoring the site, during which counts have ranged from 10 to 19 nests. A single nest was found in the Northeast Delta subarea, but it was not included in Colville Delta density calculations (Table 20) to be consistent with data presentations from previous years. Nest density was 0.12 nests/km² in 2010 for the CD North and CD South subareas combined, but because Glaucous Gulls were counted on aerial surveys targeting loons, this density estimate may be low as some nests were probably missed where they occur in lakes and wetlands not surveyed for loons.

Eight groups of Glaucous Gulls were recorded incidentally in 2010 during the aerial survey for brood-rearing loons. Twenty-four adults and 21 young were recorded in the Colville Delta study

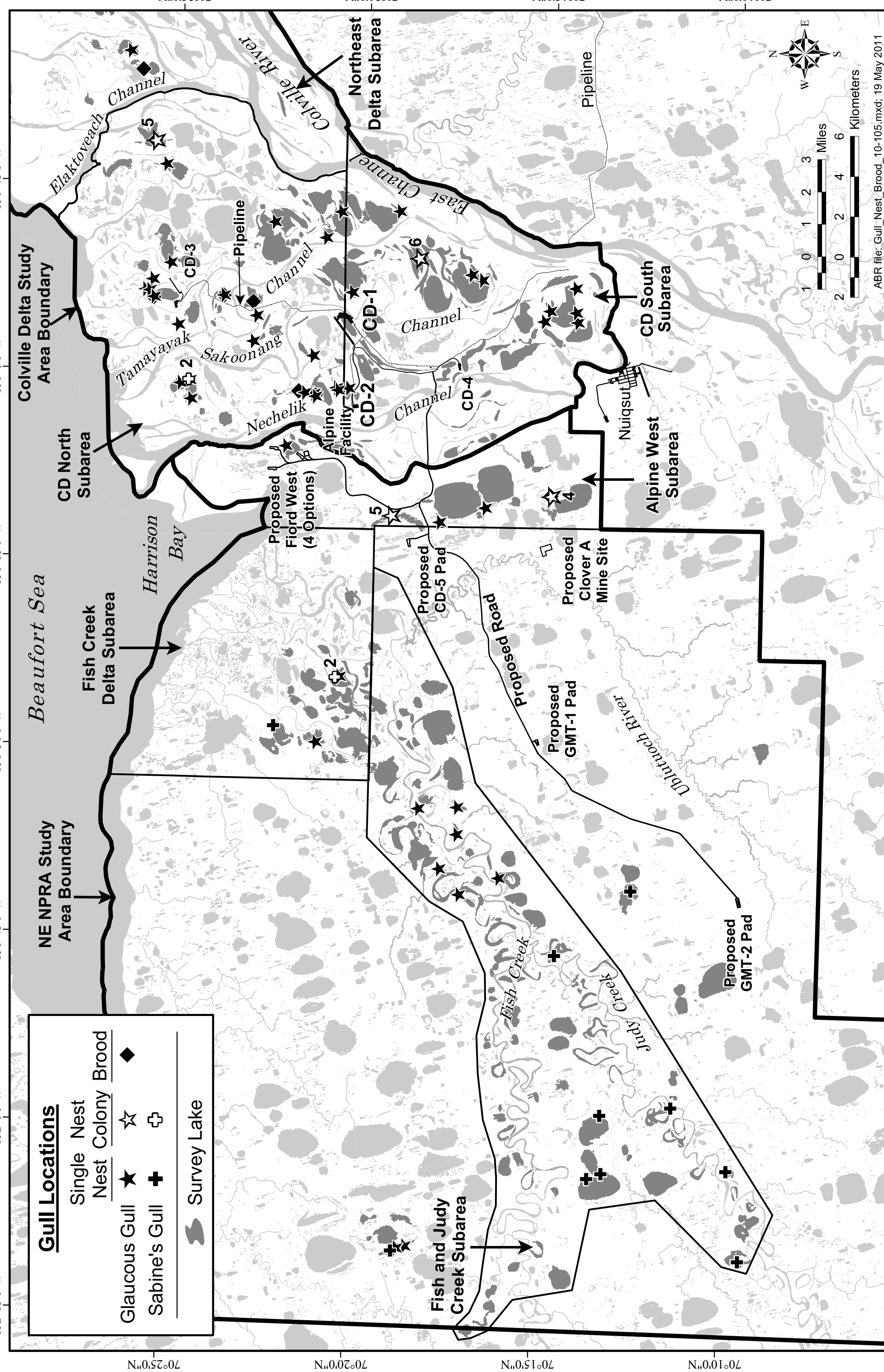

Figure 15. Glaucous and Sabine's gull nests and broods, Colville Delta and NE NPRA study areas, Alaska, 2010. Numbers of nests are listed for colony locations.

Table 20. Number and density of Glaucous and Sabine's gull nests, Colville Delta and NE NPRA study areas, Alaska, 2010.

STUDY AREA Subarea[b]	Sabine's Gull[a] Number of Nests[c]	Glaucous Gull Number of Nests[c]	Glaucous Gull Nest Density (nests/km²)
COLVILLE DELTA			
CD North	2	28	0.14
CD South	0	16	0.10
Northeast Delta[d]	0	1	–
Total (subareas combined)[e]	2	45	0.12
NE NPRA			
Alpine West	0	12	0.15
Fish Creek Delta	3	2	0.01
Fish and Judy Creek Corridor	7	6	0.02
Outside of Survey Subareas[d]	2	3	–
Total (subareas combined)[e]	12	23	0.04

[a] Nest density was not calculated for Sabine's Gull because detectability of nesting pairs on aerial surveys is low and surveys were not comprehensive
[b] CD North = 206.7 km², CD South = 155.9 km², Alpine West = 79.7 km², Fish Creek Delta = 130.5 km²; Fish and Judy Creek Corridor = 255.9 km²; see Figure 5
[c] Data for Colville Delta and NE NPRA study areas were collected during aerial surveys for nesting Yellow-billed Loons
[d] Densities were not calculated for the Northeast Delta subarea and the survey area outside of the Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor subareas because only portions of each subarea were surveyed
[e] Total is the sum of all subareas but density calculations included only CD North and CD South for Colville Delta (362.6 km² total), and Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor for NE NPRA (466.1 km² total)

area, of which 11 adults and 14 young were in the CD North subarea, 12 adults and 6 young were in the CD South subarea, and 1 adult and 1 young were in the Northeast Delta subarea (Figure 15). Six young were counted at the colony site in the CD North subarea and 6 young were also recorded at the colony site in the CD South subarea. Young from some nests were flight capable at the time of the loon brood-rearing survey and consequently some young may have been missed because they were no longer near their nest site.

Two Sabine's Gull nests were observed in the Colville Delta study area during the aerial survey for nesting loons in 2010 (Figure 15). The number of Sabine's Gull nests in the Colville Delta study area have ranged from 1 to 16 nests during the years (2003–2010) when Sabine's Gulls were recorded on aerial surveys for loons.

Habitat Use

Thirteen of the 44 Glaucous Gull nests (29%) found in the CD North and CD South subareas of the Colville Delta in 2010 were in Deep Open Water with Islands or Polygonized Margins (Table 21). Eleven nests (25%) were found in Tapped Lake with High-water Connection, including the colony of 5 nests located on 2 islands in the CD North subarea. All six nests (14%) in Patterned Wet Meadow belong to 1 colony nesting on an island within a lake classified as Deep Open Water with Islands and Polygonized Margins. The remaining 14 nests were found on islands or complex shorelines of 7 other habitats. Glaucous Gull broods observed during aerial surveys were located near nests and in the same habitats as were the nests. Both Sabine's Gull nests were located in Non-patterned Wet Meadow.

NE NPRA

Distribution and Abundance

Twenty-three Glaucous Gull nests were counted in the NE NPRA study area in 2010 during aerial surveys for loons (Figure 15, Table 20).

Table 21. Habitat use by nesting Glaucous Gulls, Colville Delta and NE NPRA study areas, Alaska, 2010.

Habitat	Colville Delta Nests	Colville Delta Use (%)	NE NPRA[b] Nests	NE NPRA[b] Use (%)
Brackish Water	2	4.5	0	0
Tapped Lake with High-water Connection	11	25.0	0	0
Deep Open Water without Islands	2	4.5	0	0
Deep Open Water with Islands or Polygonized Margins	13	29.5	3	15.0
Shallow Open Water without Islands	0	0	1	5.0
Shallow Open Water with Islands or Polygonized Margins	2	4.5	15	75.0
Sedge Marsh	0	0	1	5.0
Deep Polygon Complex	1	2.3	0	0
Grass Marsh	3	6.9	0	0
Old Basin Wetland Complex	0	0	0	0
Nonpatterned Wet Meadow	3	6.9	0	0
Patterned Wet Meadow	6	13.6	0	0
Moist Sedge-Shrub Meadow	1	2.3	0	0
Total	44[a]	100.0	20[b]	100.0

[a] Excludes 1 nest that occurred outside the 2010 study area.
[b] Excludes 3 nests that occurred outside the 2010 study area.

Twelve nests were counted in the Alpine West subarea, 2 in the Fish Creek Delta subarea, 6 in the Fish and Judy Creek subarea, and 3 nests were recorded outside of those subareas. The number of nests found in 2010 was higher than the number found in 2009 (17 nests) in the same survey area and less than in 2008 (40 nests). Of the 12 nests found in the Alpine West subarea, 9 nests were in 2 colonies—1 colony of 5 nests was found near the proposed CD-5 Pad and another colony of 4 nests was located in the southern part of the subarea. During 10 years of surveys, the annual count of nests at each colony has ranged from 4 to 7 nests. All other Glaucous Gull nests found in the NE NPRA study area in 2010 were individual nest locations. Nest density was 0.04 nests/km² in 2010 for all 3 subareas combined in the NE NPRA study area. Because Glaucous Gulls were counted on aerial surveys designed to survey loons, some nests undoubtedly were missed. Glaucous Gull broods (8 adults and 7 young) were observed at the southern colony in Alpine West during the brood-rearing aerial survey for loons in 2010. Young from some nests were flight capable at the time of the loon brood-rearing survey and consequently some young may have been missed because they were no longer near their nest site.

Twelve Sabine's Gull nests were found in the NE NPRA study area during the loon nesting survey in 2010 (Figure 15, Table 20). Three nests were counted in the Fish Creek Delta subarea, 7 in the Fish and Judy Creek subarea, and 2 nests were recorded outside of those subareas. There were no nests in the Alpine West subarea. The distribution of Sabine's Gull nests in the NE NPRA study area was different in 2009, when Alpine West was the only subarea where nests were found. Sabine's Gull densities were not calculated for the NE NPRA study area because sightings were opportunistic and not comprehensive for that area. The total number of Sabine's Gull nests counted in 2010 were below average (mean = 24, SE = 6, n = 8 years). The highest number of Sabine's Gull nests recorded on loon surveys was 53 nests in 2008.

Habitat Use

Glaucous Gulls nested in 4 different habitats in the NE NPRA study area (Table 21). Fifteen of the 20 nests were located on islands in Shallow Open Water with Islands or Polygonized Margins

(75% of all nests). The remaining 5 nests were found on islands or complex shorelines of 3 other habitats. Glaucous Gull broods were found in aquatic habitats near nest locations, often in the same habitat as the nest. The Sabine's Gull colony found in the Alpine West subarea was on a island of Nonpatterned Wet Meadow in Deep Open Water with Islands or Polygonized Margins.

DISCUSSION

Glaucous Gulls nests have been recorded during Yellow-billed Loon nesting surveys of the Colville Delta study area since 2001. Glaucous Gulls tend to reuse nest sites annually and the status of known nest sites near Yellow-billed Loon lakes have been monitored since 2004. The average number of Glaucous Gull nests in the CD North and CD South subareas between 2004–2010 was 44 nests (range = 43 to 48 nests). One nesting colony in the CD North subarea has supported 4– 7 nests annually (mean = 5, n = 7 years) and another colony in the CD South subarea, monitored 12 years since 1998, contained 6–19 nests annually (mean = 14).

Glaucous Gulls nests have been recorded in the NE NPRA study area when Yellow-billed Loon nesting surveys were conducted in 2001–2006 and 2008–2010, but only since 2008 have Alpine West, Fish Creek Delta, and Fish and Judy Creek Corridor all been surveyed in the same year. The count of nests in those 3 subareas combined has ranged from 17 to 40 nests, with the highest count in 2008. The low count of 17nests in 2009 was partly attributed to the failure of 1 of the Alpine West colonies prior to the loon nesting surveys. The 2 Glaucous Gull colonies in the Alpine West subarea have been surveyed in 7 years during Yellow-billed Loon surveys since 2003. One just northeast of the CD-5 Pad has had an average of 4 nests/year (range = 0–7 nests) and the other in the southern part of the subarea supported an average of 6 nests/year (range = 4–7 nests).

Sabine's Gulls are found as solitary nesting birds or in loose nesting colonies. Single nests are hard to detect during loon surveys and nesting colonies are usually only detected because some birds are flying near the colony site. Recorded observations are most often colony sites and single nesting birds are likely under reported. Counts of Sabine's Gull nests have varied from annually in both the Colville Delta and NE NPRA survey areas largely because of the variability in detection rates but also possibly because of the timing of their nesting relative to the loon survey. In 2010, groups of flying Sabine's Gulls were observed in both the Colville Delta and NE NPRA survey areas but they did not appear to be associated with a nesting site. Water levels at some lakes in both study areas appeared high at the time of the loon survey and, as a result, some nest sites traditionally used by Sabine's Gulls may have been unavailable for nesting.

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PERSONAL COMMUNICATIONS

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Appendix A. Common, Iñupiaq, and scientific names of birds and mammals referenced in this report.

COMMON NAME	IÑUPIAQ NAME	SCIENTIFIC NAME
BIRDS		
Snow Goose	Kaŋuq	*Chen caerulescens*
Brant	Niġlinġaq	*Branta bernicla*
Tundra Swan	Qugruk	*Cygnus columbianus*
Steller's Eider	Igniqauqtuq	*Polysticta stelleri*
Spectacled Eider	Qavaasuk	*Somateria fischeri*
King Eider	Qiŋalik	*Somateria spectabilis*
Common Eider	Amauligruaq	*Somateria mollissima*
Red-throated Loon	Qaqsrauq	*Gavia stellata*
Pacific Loon	Malġi	*Gavia pacifica*
Yellow-billed Loon	Tuullik	*Gavia adamsii*
Glaucous Gull	Nauyavasrugruk	*Larus hyperboreus*
Sabine's Gull	Iqirgagiak	*Xema sabini*
Parasitic Jaeger	Migiaqsaayuk	*Stercorarius parasiticus*
Golden Eagle	Tifmiaqpak	*Aquila chrysaetos*
Common Raven	Tulugaq	*Corvus corax*
MAMMALS		
Arctic Fox	Tiġiganniaq	*Vulpes lagopus*
Red Fox	Kayuqtuq	*Vulpes vulpes*
Brown (Grizzly) Bear	Akłaq	*Ursus arctos*
Caribou	Tuttu	*Rangifer tarandus*

Appendix B. Classification and descriptions of wildlife habitat types found on the Colville River delta or in the NPRA study area, Alaska, 2010. Species associations of some habitats vary between the Colville River delta and the NPRA study area.

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.
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.
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.