Avian Studies for the Alpine Satellite Development Project, 2015

THIRTEENTH ANNUAL REPORT

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Prepared for
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Anchorage, Alaska

and

Anadarko Petroleum Corporation
Anchorage, Alaska

Prepared by
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Fairbanks, Alaska

Cover:

Time-lapse digital photograph of Yellow-billed Loon nest at territory 39, with Snowy Owl in foreground and Greater White-fronted Geese in the background, Colville River delta, Alaska. Photo © ConocoPhillips Alaska, Inc.

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Avian surveys for the Alpine Satellite Development Project were performed with the assistance of many people, both in the field and in the office. Pathfinder Aviation pilots Dave McKnight and Colby Hamon skillfully piloted us to and from our nest lakes. On the ground, Ray Rush and Mary Lacey coordinated the helicopter flights and kept us on schedule. Callie Gates supported logistics and safety concerns from Anchorage. Tim Obritschkewitsch and John Rose spent long hours on aerial surveys. Arctic Air Alaska pilots Sandy Hamilton and Zachary Lyall safely piloted fixed-wing aircraft over the study area. In our Fairbanks office, Dorte Dissing and Pam Odom provided expert support in figure and report production. James Smith viewed time-lapse images of nesting Yellow-billed Loons. Tawna Morgan and Chris Swingley helped manage and analyze our data. Logistics were handled by Pam Odom and Tony LaCortiglia, and Will Lentz handled our electronic equipment needs. We thank all the ConocoPhillips Alaska staff and contractors at the Alpine Oilfield for providing a safe and welcoming work environment, especially field coordinators, Jessika Gonzalez and Jodi Smith. This study was funded by ConocoPhillips Alaska, Inc., and was administered by Robyn McGhee, Environmental Studies Coordinator for ConocoPhillips Alaska, Inc. We especially thank Robyn McGhee for supporting the continuation of these long-term monitoring studies, which have benefited other biological studies, past and future National Environmental Protection Act (NEPA) documents, species status reviews, Section 7 Consultations, and development permit applications. We appreciate the review and comments on this report made by Robyn McGhee and ABR's Bob Burgess. We thank all the above for making 2015 a successful year for avian studies on the Colville River delta.

INTRODUCTION

The Colville River delta and Northeast Planning Area of the National Petroleum Reserve in Alaska (NE NPR-A) have been focal points of exploration and development for oil and gas since at least the 1990s. During 2015, ABR, Inc., conducted wildlife surveys for selected birds and mammals in the Colville River delta in support of the Alpine Satellite Development Project (ASDP) of ConocoPhillips Alaska, Inc., (CPAI) and Anadarko Petroleum Corporation. Previous studies in the area are described by Johnson et al. (2015).

The primary goal of wildlife investigations in the ASDP 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. The CD-3 and CD-4 drill sites were constructed in 2005 and winter of 2006, and CD-5 in NE NPR-A was constructed in 2014 and 2015. Readers are directed to prior reports for wildlife information from previous years and for all these sites.

In this report, we present the results of avian surveys that were conducted on the Colville River delta in 2015 along with brief comparisons of results from previous years and other surveys. The surveys were designed initially to collect data on the distribution, abundance, and habitat use of 5 focal taxa (common names followed by Iñupiaq names): Spectacled Eider (Qavaasuk), King Eider (Qiŋalik), Tundra Swan (Qugruk), geese (Niġliq), and Yellow-billed Loon (Tuullik) (scientific names and Iñupiaq names are listed in Appendix A). These 5 taxa were selected in consultation with resource agencies and communities because of 1) threatened or sensitive status, 2) indications of declining populations, 3) restricted breeding range, 4) importance to subsistence hunting, and/or 5) concern by regulatory agencies for development impacts. Surveys for brood-rearing geese were not conducted on the Colville River delta in 2015, but a study of nesting Greater White-fronted Geese took place at CD-5 (see Rozell and Johnson [2016]).

Required state and federal permits were obtained for all survey activities, including a Scientific or Educational Permit (Permit No. 15-146) from the State of Alaska and a Federal Fish and Wildlife Permit—Native Threatened Species Recovery—Threatened Wildlife; Migratory Birds [Permit No. TE012155-4 issued under Section 10(a)(1)(A) of the Endangered Species Act (58 FR 27474-27480)] from the U.S. Fish and Wildlife Service Endangered Species Permit Office. Similar avian species were monitored in the Kuparuk Oilfield on the eastern border of the Colville River delta in 2015 (Morgan et al. 2016).

STUDY AREA

The ASDP study area comprises separate study areas on the Colville River delta and in the easternmost portion of the NE NPR-A (Johnson et al. 2015); in 2015, only the Colville Delta study area was included in surveys (Figure 1). Wildlife studies began in the Colville Delta study area in 1992 with interruptions in 1994 and 1999 (see Johnson et al. [2015] for description of study history and study area).

Oil development on the Colville River delta began in 1998 with construction of the Alpine Facility, a roadless oilfield 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. 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. Construction on the CD-5 drill site began in 2014. The road between CD-4 and CD-5, including a bridge crossing the Niġliq (Nechelik) Channel, was completed in 2015 and oil from CD-5 first was produced in October of that year.

Landforms, vegetation, and wildlife habitats in the Colville River delta were described in the Ecological Land Survey (Jorgenson et al. 1997), and the resulting habitat map has been updated several times to unify it with similar mapping of the surrounding Coastal Plain (see Johnson et al. [2015] for the current habitat map and descriptions).

The Colville Delta study area (552 km^2) comprises the CD North, CD South, and the Northeast Delta subareas (Figure 1). These

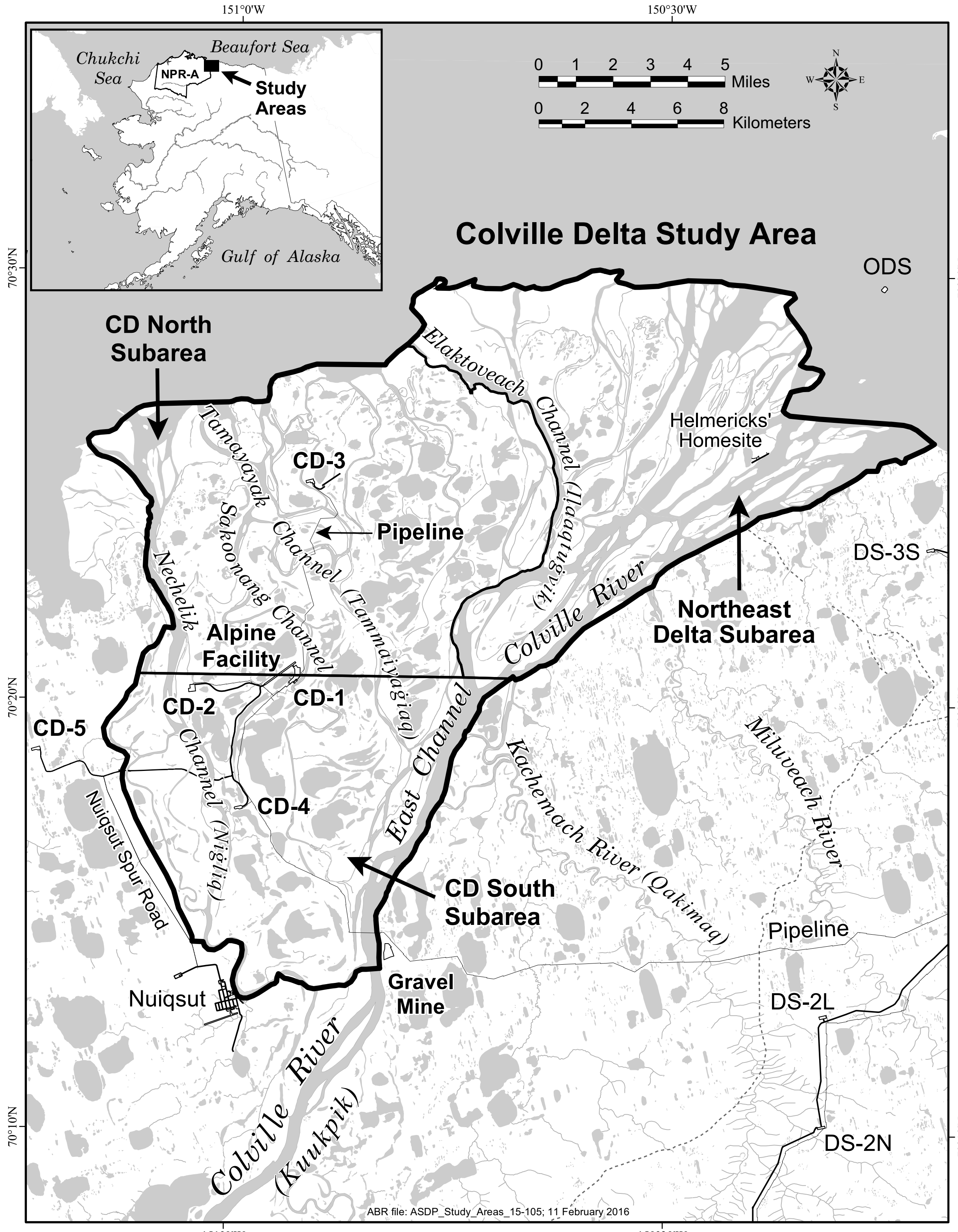

Figure 1. Wildlife study areas and subareas for the Alpine Satellite Development Project, northern Alaska, 2015.

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 Niġliq (Nechelik) Channel and inland to where the Colville River divides into these channels.

METHODS

Aerial surveys were the primary means for collecting data on eiders, loons, swans, and gulls using the Colville Delta study area because of the large size of the study area and the short periods of time that each species is at the optimal stage for data collection. In 2015, 2 aerial surveys were conducted using fixed-wing aircraft: 1 for eiders during pre-nesting and 1 for Tundra Swans during nesting. Two aerial surveys also were conducted from a helicopter for Yellow-billed Loons (one for nesting and one for brood-rearing). Nesting and brood-rearing gulls were recorded during loon surveys. Each of these surveys was scheduled specifically (see Table 2 for survey details) for the period when the species was most easily detected or when the species was at an important stage of its breeding cycle (nesting or raising broods).

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. Monitoring flights conducted for Yellow-billed Loons (up to 13/year) were discontinued in 2015. Flight altitudes were set at the maximum level at which the target species could be adequately detected and counted (see survey protocols for each species group below). Survey flights specifically avoid the areas around the village of Nuiqsut, the Helmericks' homesite, and any active hunting parties.

During the surveys, locations of eiders, loons, gulls, and swans were recorded on digital orthophoto mosaics of 1 foot resolution natural color imagery acquired in 2004–2012 by Quantum Spatial (Anchorage, AK). Bird locations plotted on maps were reviewed before they were entered into a geographical information system (GIS) database.

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

EIDER SURVEYS

We evaluated the regional abundance, distribution, and habitat selection of 2 species of eiders (Spectacled and King eiders) with data collected on 1 aerial survey flown annually during the pre-nesting period (Table 1), when male eiders (the more visible of the 2 sexes in breeding plumage) were still present on the breeding grounds. We conducted the pre-nesting survey during 9–12 June using the same methods that were used on the Colville Delta study area since 1993 (for details, see Johnson et al. [2015]). The survey was flown in a Cessna 185 airplane at 30–35 m above ground level (agl) and approximately 145 km/h. Two observers each counted eiders in a 200 m wide transect on each side of the airplane (400 m total transect width) and the pilot viewed the area ahead of the aircraft. A Global Positioning System (GPS) receiver was used to navigate pre-determined east–west transect lines that were spaced 400 m apart achieving 100% coverage. Three areas were not surveyed in the Colville Delta study area: the extensive tidal flats and marine waters on the northernmost delta (Spectacled and King eiders rarely use those habitats during the survey time period; Johnson et al. 1996), a ~1.6 km radius circle around the Helmericks' homesite, and the southernmost portion of the delta near Nuiqsut (Appendix B). The latter 2 areas were avoided to reduce disturbance to residents. Eider locations were recorded on color photomosaic maps (1:63,360 scale) and digital voice recorders were used to record species, number of identifiable pairs, the sex and activity (flying or on the ground) of each individual, and a brief habitat description for non-flying birds. Annual population growth rates for pre-nesting Spectacled and King eiders on the Colville Delta study area were calculated with log-linear regression for the period from 1993 to 2015 using density of birds expanded to a standard study area (501 km^2) as the dependent variable.

Table 1. Avian surveys conducted in the Colville Delta study area, Alaska, 2015.

SURVEY TYPE Season	Number of Surveys	Survey Dates	Aircraft[a]	Transect Width (km)	Transect Spacing (km)	Aircraft Altitude (m)	Notes
EIDER SURVEY							
Pre-nesting	1	9–12 June	C185	0.4	0.4	30–35	100% coverage
YELLOW-BILLED LOON SURVEYS[b]							
Nesting	1	18–20 June	206L	–	–	60–75	All lakes ≥5 ha and adjacent lakes
Brood-rearing	1	17, 19–20 Aug.	206L	–	–	60–90	Yellow-billed Loon territory lakes
Pre-nesting Camera Set up	1	1–3 June	–	–	–	–	13 sites
Nest Camera Setup	1	20, 21 June	–	–	–	–	12 sites
TUNDRA SWAN SURVEY							
Nesting	1	20–22 June	C185	1.6	1.6	150	100% coverage

[a] C185 = Cessna 185 fixed-wing airplane; 206L = Bell "Long Ranger" helicopter.
[b] Nests and broods of Pacific Loons, Red-throated Loons, Glaucous Gulls, and Sabine's Gulls were recorded incidentally.

LOON SURVEYS

In 2015, we conducted 1 aerial survey for nesting Yellow-billed Loons on 18–20 June and 1 aerial survey for brood-rearing Yellow-billed Loons on 17 and 19–20 August (Table 1). In the Colville Delta study area, we surveyed 221 lakes for nesting loons and 224 lakes for brood-rearing loons (Appendix C). Both nesting and brood-rearing surveys were conducted annually in the Colville Delta study area during 21 years from 1993 to 2015, with the exception of 1994 and 1999, when no surveys were conducted. The CD North and CD South subareas were surveyed each year and part of the Northeast Delta subarea was surveyed in all survey years except 2000.

Methods for the nesting and brood-rearing survey were the same as in previous years (for details, see Johnson et al. [2015]). Each year the nesting survey was conducted between 18 and 30 June and the brood-rearing survey between 15 and 27 August. Additional surveys were flown in 1996–1998, 2000–2002, and 2005–2014 (for details, see Johnson et al. [2015]). All surveys were flown in a lake-to-lake pattern at 60–90 m above ground level. Survey lakes were selected before each survey and included most lakes ≥10 ha in size in 1993–2007 and most lakes ≥5 ha in size in 2008–2015. During nesting surveys each year, we also surveyed small lakes (1–10 ha) and aquatic habitats adjacent to survey lakes because Yellow-billed Loons sometimes nest on small lakes next to larger lakes that are used for brood-rearing (North and Ryan 1989, Johnson et al. 2014b). Tapped Lakes with Low-water Connections (lakes whose levels fluctuate with changing river levels) were excluded from surveys during all years because Yellow-billed Loons do not use such lakes for nesting (North 1986, Johnson et al. 2003b).

We recorded incidental observations of Pacific Loons (Malġi) and Red-throated Loons (Qaqsrauq) during all nesting and brood-rearing surveys. All locations of loons and their nests and broods were recorded on color photomosaics (1:30,000 scale). In 2005–2015, Yellow-billed Loon nest locations also were marked on high resolution color images of nest site areas (~1:1,500 scale).

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

Population growth rates were calculated for Yellow-billed Loons with counts of adults, nests, and young adjusted for the number of territories surveyed; we divided those counts by the number of territories surveyed and multiplied by the highest number of territories surveyed in all years (44). Population growth rates were estimated with log-linear regression on adjusted counts for all years when helicopters were used for all surveys (2000–2015).

NEST FATE

We inspected the contents of inactive nests during the August brood-rearing survey to confirm nest fate years (for details, see Johnson et al. [2015]). The nest and the surrounding area within 5 m, including the water adjacent to the nest, were examined closely for egg remains, including eggshell fragments, egg membranes, and broken eggs. In general, nests were assumed failed if they contained <20 egg fragments, eggshells had signs of predation (i.e., holes, albumen, yolk, or blood), or if eggs were unattended and cold (Parrett et al. 2008). Nests were assumed successful if a brood was present, or if the nest contained >20 egg fragments. Nest fate was based on the number of fragments as long as there was no conflicting evidence (e.g., too many or too few days of incubation for a particular fate for eggs with egg-floatation data). Images from time-lapse cameras (see below) were used to confirm nest fate where possible.

TIME-LAPSE CAMERAS

We began using time-lapse digital cameras in the Colville Delta study area in 2008, primarily to reduce helicopter traffic while monitoring nest survival, and secondarily, to record nest attendance patterns and identify causes of nest failures. Cameras were installed at active nests within several days of the nesting survey. We used 2 models of Silent Image® Professional cameras: PC85 and PC800 cameras with custom 2.5× and 2× telephoto lenses taking 3.1-megapixel images (Reconyx, Lacrosse, WI). Cameras were installed using the same methods as previous years (for details, see Johnson et al. [2015]). Cameras were capable of taking images every 30 sec for 23–28 d without requiring maintenance (i.e., battery or memory card changes).

In early June 2015, before loons initiated nests, we deployed 13 cameras (10 PC800 and 3 PC85) at territories with regularly used nest sites to observe pre-nesting behavior and the start date of incubation. We originally planned to deploy cameras during late May, prior to breakup, but extensive flooding of the Colville River prevented access to the study area until June. Cameras deployed during early June were revisited after the nesting survey. If a nest was in camera view, we replaced the camera with one that contained a new memory card and a fresh battery; otherwise cameras were collected, serviced, and redeployed at territories with active nests found during the nesting survey. Four cameras deployed in early June captured the start of incubation; otherwise, cameras were installed within 1–3 d (median = 1.5 d, n = 8) of nest discovery. A total of 12 nests were monitored in the Colville Delta study area using 8 PC85 and 4 PC800 cameras. We removed cameras in mid-August during the brood-rearing survey.

We reviewed digital images on computers with Irfanview software (version 4.33) using the same methods as used in previous years (for details, see Johnson et al. [2015]). Loon behavior was classified into 3 major types of activity: incubation, break, and recess. The number of days monitored and incubation parameters (constancy, recess and exchange frequency, and recess length) were calculated for each nest from the time the loon returned to the nest after camera installation to the day before hatch, or to the time of nest failure. Periods of time when images could not be interpreted because of poor weather conditions were excluded. We identified predators in camera view to species, estimated their distance from the nest, and described their behavior.

Day of hatch was defined as occurring when the first chick was seen at the nest or when adults were seen removing egg membranes from the nest, whichever was observed first. If eggshell evidence and/or aerial surveys indicated hatch but no chicks were observable on images, the day of hatch was identified by the increased presence of the non-incubating loon at the nest as it began to feed the hatchlings. If the mate's presence also was obscured on images, then egg flotation data were used to estimate hatch date (described below). We judged a nest to be failed if the loons did not resume incubation after a predator was seen at the nest. The time of failure was taken from the first image containing the predator. Some predation events were not captured on images, and in those cases we assigned nest failure to the time when the loons stopped incubating the eggs.

The date incubation started was estimated for successful nests by backdating 28 d from the day of hatch. North (1994) reported 27 and 28 d for the incubation period of Yellow-billed Loons. For failed nests, we estimated the start of incubation by using ages derived from an egg-flotation schedule that we developed from eggs in known-age Yellow-billed Loon nests in 2008–2015 (modifying a method developed for Semipalmated Sandpipers by Mabee et al. [2006]). Methods for aging are presented in Johnson et al. (2015). For nests where the start of incubation was observed on camera images in 2013–2015 (n = 10 nests), we calculated the age of the oldest egg on the day of floating by backtracking to the date incubation started. For nests that were observed hatching on camera images in 2008–2015 (n = 59 nests), the clutch age on the day of egg floating was determined by backdating from the hatch date. These known-age nests were used to develop a regression to estimate egg ages from flotation data at nests without known hatch dates. If a known-age nest had 2 eggs, we used the maximum float angle in the clutch age regression because loons begin incubation as soon as the first egg is laid. The first egg hatches 1–3 days before the second egg, judging by when the second chick is seen on camera images (this study). The relationship between the float angle and clutch age for nests 1–14 d old was determined by linear regression (clutch age = 2.47 × float angle – 3.77, R^2 = 0.86, n = 59 nests). For nests with unknown clutch age, we used the regression equation to estimate clutch age at discovery and backdated to the incubation start date. For nests with 2 eggs, the older of the 2 eggs was used for determining clutch age. Because we did not revisit active nests after camera installation in June, eggs were floated only once and only in the early stages of incubation.

TUNDRA SWAN SURVEYS

We flew 1 aerial survey for nesting Tundra Swans on 20–22 June 2015 (Table 1). With the exception of areas within a ~1.6-km radius of the Helmericks' family homesite on Anachlik Island in the northeastern Colville River delta, and the southern Colville River delta around Nuiqsut, the aerial survey covered the entire Colville Delta study area (Appendix D). We conducted the survey in accordance with USFWS (1987b, 1991) protocols, using the same methods employed for 21 years during 1992–2014 in the Colville Delta study area (no surveys occurred in 1994 or 1999; for details see Johnson et al. [2015]). We followed east–west transects spaced 1.6 km apart in a Cessna 185 fixed-wing airplane that was navigated with the aid of a GPS receiver. Flight speed was 145 km/h and altitude was 150 m agl. Two observers each searched 800 m wide transects on opposite sides of the airplane while the pilot navigated and scanned for swans ahead of the airplane, providing 100% coverage of the surveyed area. Locations and counts of swans and their nests were recorded on color photomosaics (1:63,360 scale). Each nest was photographed for site verification using a Canon PowerShot SX10 IS (10 megapixel) or a Canon PowerShot SD850 IS (8 megapixel). Population growth rates for adults and nests on the Colville Delta study area were calculated with log-linear regression for the period from 1992 to 2015.

GULL SURVEYS

We recorded nests and broods of Glaucous Gulls during the nesting and brood surveys conducted for Yellow-billed Loons in the Colville Delta study area (see LOON SURVEYS, above). Glaucous Gulls nest singly and in loose aggregations or colonies. We considered a group of 3 or more nests occurring in proximity on the same lake or wetland complex to be a colony. Nests and broods of gulls were recorded incidentally as they were encountered, whereas traditional nest or colony locations within the study areas were checked systematically for activity. Once a Glaucous Gull colony was identified, we used 1 central location for all nests, even though some nests may be as far as 350 m apart. All nest and brood observations were recorded on color photomosaic field maps (1:30,000 scale) and later entered into a GIS database.

We monitored trends in nest numbers for Glaucous Gulls in the Colville Delta study area using a subset of 50 lakes annually surveyed for Yellow-billed Loons since 2002. At that time, index lakes included 15 lakes with at least 1 year of gull nesting history, and 35 lakes with no history of nesting gulls. Of the 50 lakes, 2 were in the Northeast Delta subarea, 20 in the CD South subarea, and 28 in the CD North subarea.

HABITAT MAPPING AND ANALYSIS

A wildlife habitat was assigned to each observation of birds, nests, or broods by plotting their coordinates on the wildlife habitat maps (see Figure 2 in Johnson et al. [2015]). For each bird species, habitat use (% of all observations in each identified habitat type) was determined separately for various seasons (e.g., pre-nesting, nesting, and brood-rearing), as appropriate. For each species and season, we calculated 1) the number of adults, flocks, nests, or broods in each habitat, and 2) the percent of total observations in each habitat (habitat use). Habitat use was calculated from group locations for species when birds were in pairs, flocks, or broods, because counts of individuals in large groups could bias results. Habitat availability was calculated as the percent of each habitat in the survey area.

For a subset of species and seasons, a statistical analysis of habitat selection was used to evaluate whether habitats were used in proportion to their availability. Habitat selection was evaluated for the following species, seasons, and years:

- pre-nesting Spectacled Eiders and King Eiders (1993–1998 and 2000–2015),
- nesting and brood-rearing Yellow-billed Loons (nests: 1993–1998 and 2000–2015, broods: 1995–1998 and 2000–2015), and
- nesting Tundra Swans (1992–1993, 1995–1998, and 2000–2015).

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

We inferred habitat selection from comparisons of observed habitat use with random habitat use, using Monte Carlo simulations (for methods, see Johnson et al. [2015]). We defined habitat preference (i.e., use > availability) as observed habitat use greater than the 95% confidence interval of simulated random use. Conversely, we defined habitat avoidance (i.e., use < availability) as observed habitat use below the 95% confidence interval.

DATA MANAGEMENT

All data collected during surveys for CPAI were compiled into a centralized database following CPAI's data management protocols (ver. 9.3, CPAI 2015). All 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 to CPAI in GIS-ready format with corresponding metadata.

RESULTS AND DISCUSSION

SEASONAL CONDITIONS IN THE STUDY AREAS

The second half of May in 2015 produced unseasonably warm weather and early flood conditions along major rivers. The 2015 breakup season was notable for its early arrival, high water levels, and the large areas flooded. On 18 May, melt water from the Brooks Range reached the head of the Colville River delta (Monument 1) at the same time high temperatures across the delta were causing local snow melt. The peak water level at Monument 1 occurred on 21 May at 7.15 m above mean sea level, 10 d earlier than average for peak, and was the highest peak water level on record (Michael Baker Jr. 2015). Peak discharge at Monument 1 was on 22 May and was the fourth highest in 19 years of records (Michael Baker Jr. 2015). Extreme peak water levels were caused by 2 large ice jams. On 20 May, an ice jam near Ocean Point released and reformed in the East Channel, which diverted water into the Niġliq Channel. A concurrent ice jam formed in the Niġliq Channel near Nuiqsut and obstructed the flow of water. As a result, widespread flooding occurred on 21 May along the Niġliq Channel, near the Alpine facilities, and across the southern delta. Most of the area was inundated with overflow water for 2 days or more, including the area around CD-2 and CD-4. The East Channel ice jams broke on the morning of 22 May, when the water level at Monument 1 dropped 2 m in 24 h and water levels on the outer delta rose. Colville Village (Monument 35) experienced extensive flooding on 22 May, when water peaked at 2.1 m above mean sea level (Michael Baker Jr. 2015). Of 50 lakes that comprise 44 Yellow-billed Loon territories, nearly 75% were obviously murky from flooding during loon nest surveys on 18 June.

Spring temperatures were warm on the Colville River delta in 2015. During the period of waterfowl arrival and peak nest initiation (15 May–15 June), 86 cumulative thawing degree-days were measured at Colville Village, more than double the long-term mean of 40 cumulative thawing degree-days (SE = 8 thawing degree-days, n = 19 years; Figure 2). The mean temperatures in May (–1.4 °C) and June (7.6 °C) were warmer than the 19-year means (–5.3 ± 0.6 °C and 3.8 ± 0.4 °C, respectively). Daily mean temperatures at Alpine (24 km southwest of Colville Village) averaged 1.8 °C warmer than at Colville Village on the outer delta, indicating an earlier thaw in the central and southern delta.

Snow depth for birds arriving in the spring of 2015 was near normal but snow cover disappeared early. On 15 May, snow depth was 30 cm compared with the 19-year mean of 24 ± 2 cm at Colville Village. At Alpine, snow depth was 86 cm on 15 May. Snow cover disappeared at both locations on 20 May, which was 12 d earlier than the long-term mean for Colville Village (2 June ± 1 d).

Ice coverage on large lakes (>5 ha) was estimated visually during aerial surveys for eiders and loons. On 8 June, shallow waterbodies were open, but ice cover was approximately 80% on deep waterbodies. On 18–20 June, mean ice cover was 69% on 45 lakes. Reduction in lake ice cover was roughly a week advanced over loss of lake ice

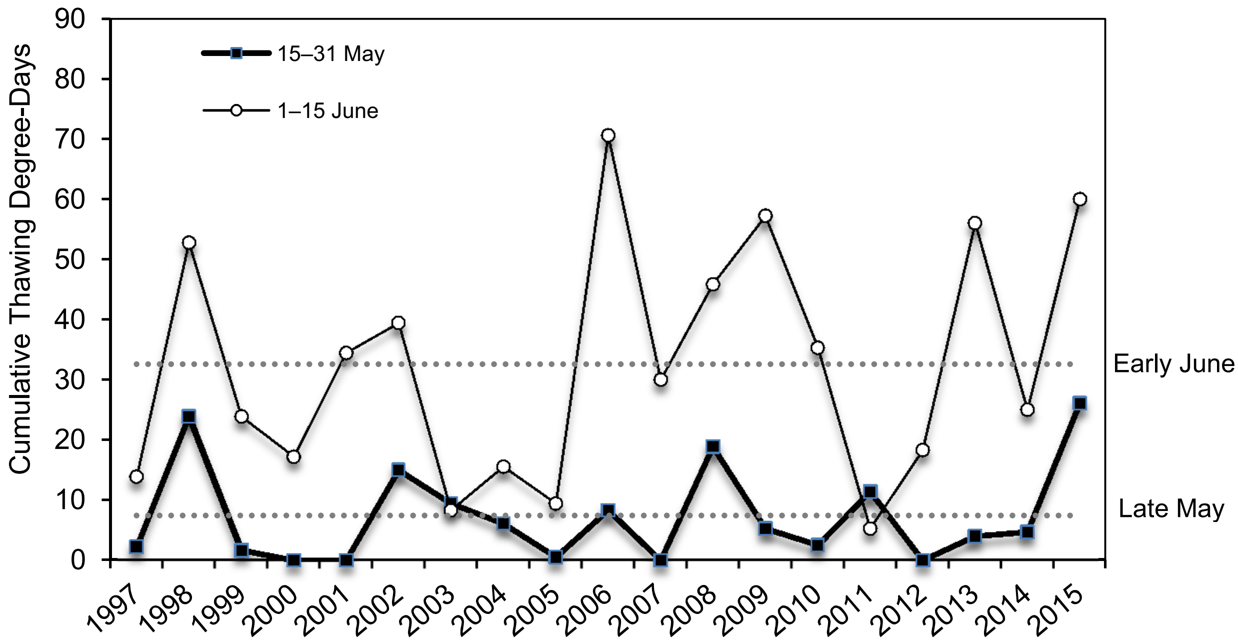

Figure 2. Cumulative number of thawing degree-days recorded 15 May–15 June at Colville Village, Colville River delta, Alaska, 1997–2015. Means indicated by dotted lines.

in 2014, with 18% less ice cover in 2015 compared with 2014 during the same time period.

Warm weather in June promoted early emergence of midges and mosquitoes. Mean daily temperatures reached 10 °C before mid-June. By 20 June, mosquitoes were at moderate to severe levels in the CD-5 area. In most years, mosquitoes do not emerge in great numbers before late June or early July.

Many birds nested early in 2015. Yellow-billed Loons were first observed nesting on 4 June, the earliest in 9 years that cameras have been used to monitor nesting on the Colville Delta. Nesting by Greater White-fronted Geese, as indicated by hatch and clutch ages, began 20 May, 6 days earlier than in 2014 and 11 days earlier than in 2013 (Rozell and Johnson 2016). Greater White-fronted Geese goslings were first seen 22 June (ABR, unpublished data).

EIDERS

Four species of eiders may occur in the ASDP area, but each occurs at different frequencies and widely varying numbers. Of the 2 species of eiders that commonly occur in the Colville Delta study area, the Spectacled Eider has received the most attention because it was listed as "threatened" in 1993 (58 FR 27474–27480) under the Endangered Species Act of 1973, as amended. The outer Colville River delta is a concentration area for breeding Spectacled Eiders relative to surrounding areas; nonetheless, Spectacled Eiders nest there at low densities and nest at even lower densities at inland portions of the Colville River delta (Burgess et al. 2002, 2003; Johnson et al. 2004, 2005). The King Eider, which is not protected under the Endangered Species Act, is more widespread and generally more numerous than the Spectacled Eider across the Arctic Coastal Plain, although their relative abundance varies geographically. The Steller's Eider was listed as a threatened species in 1997 (62 FR 31748–31757). Steller's Eiders are rare on the Colville River delta and immediate surroundings as these areas are east of their current Alaska breeding range centered around Barrow. The Colville Delta study area is within the range of Common Eiders, which nest primarily on barrier islands and coastlines but are seen rarely on surveys of the Colville Delta study area.

SPECTACLED EIDER

Distribution and Abundance

We recorded 59 Spectacled Eiders (on the ground and flying) and 54 indicated total

Spectacled Eiders during the pre-nesting aerial survey on the Colville Delta study area in 2015 (Table 2). Indicated total is a standardized method of counting ducks, which doubles the number of males in singles, pairs, and small groups (no flying birds are included) to compensate for the lower detectability of females (USFWS 1987a). Spectacled Eiders were near average in abundance on the Colville Delta study area in 2015, with densities of both total indicated and observed Spectacled Eiders (0.11 indicated total birds/km² and 0.12 observed birds/km²) similar to mean values recorded over 22 years (Table 2). All observations of Spectacled Eiders in the Colville Delta study area during the pre-nesting survey in 2015 were of small groups of 1–4 birds. The CD North subarea contained 96% of the Spectacled Eiders observed, whereas the CD South subarea contained none (Figure 3, Appendix E). The density of Spectacled Eiders in the CD North subarea during 2015 (0.25 indicated birds/km²) was about twice the density on the much larger Colville Delta study area. The distribution of Spectacled Eiders in 2015 was typical of previous years, when densities have been highest north of Alpine and low south and northeast of Alpine (Figure 3). Over the 22 years that ABR and others have monitored Spectacled Eiders, their population trend has been relatively stable (Figure 4). In the CD North subarea, the annual growth rate is 2% (logarithmic growth rate of 1.02; ln(adults) = 0.019 (year) – 33.44, $R^2 = 0.056$, $P = 0.29$). The growth rate for the entire Colville Delta study area is similar at 1% (ln(adults) = 0.012 (year) – 20.24, $R^2 = 0.024$, $P = 0.49$, $n = 22$ years). A recent reanalysis combining 2 separate datasets of pre-nesting Spectacled Eiders, the ACP breeding pair waterfowl survey conducted in late June with North Slope eider surveys conducted in early–mid June, estimated a slight decline (–1%) in Spectacled Eiders for the entire ACP (logarithmic growth rate = 0.99, $n = 21$ years; Stehn et al. 2013). However, none of the above growth rates differs significantly from 0% (a logarithmic growth rate of 1.0 equals 0% annual change or equilibrium). Similarly, Spectacled Eiders in the NE NPR-A, up through 2014, also had an annual growth rate not significantly different from equilibrium (Johnson et al. 2015).

Habitat Use

Pre-nesting Spectacled Eiders used 17 of 24 available habitats during 22 years of aerial surveys on the Colville Delta study area (Table 3). Seven habitats were preferred (i.e., use significantly greater than availability, $P \leq 0.05$) including 3 primarily coastal, salt-affected habitats (Brackish Water, Salt Marsh, and Salt-killed Tundra), 3 aquatic habitats (Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, and Grass Marsh), and 1 terrestrial habitat (Deep Polygon Complex). Deep Polygon Complex, which consists of a mosaic of small, deep, polygon ponds with relatively narrow vegetated rims and sometimes with islets, is notable because of its disproportionate use; Deep Polygon Complex was used by 29% of the Spectacled Eider groups, yet occurred on only 2.7% of the study area. Deep Polygon Complex also is a preferred habitat during the nesting season (Johnson et al. 2008a). Patterned Wet Meadow was second highest in use (19% of Spectacled Eider groups) during pre-nesting but was not preferred because its use and availability were essentially equal. Six habitats were avoided (use significantly less than availability), including Open Nearshore Water; Tidal Flat Barrens; River or Stream; Moist Sedge-Shrub Meadow; Tall, Low, or Dwarf Shrub; and Barrens. All other habitats were used in proportion to their availability.

OTHER EIDERS

Distribution and Abundance

In 2015, we recorded 57 observed (on the ground and flying) and 42 indicated total King Eiders on the pre-nesting aerial survey of the Colville Delta study area (Table 2). The number of King Eiders recorded in the Colville Delta study area in 2015 was just above average, whereas the density of indicated total King Eiders (0.08 birds/km²) was the same as the 22-year mean (Table 2). As for most years in the Colville Delta study area, King Eiders (42 indicated birds) were less numerous than Spectacled Eiders (54 indicated birds) (Table 2). Unlike the Kuparuk Oilfield, NE NPR-A, and the ACP where King Eiders have been increasing (Figure 5; Stehn et al. 2013, Johnson et al. 2015, Morgan et al. 2016), King Eiders on the Colville Delta study area, have an annual growth

Table 2. Annual number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 1993–2015.

		Spectacled Eider				King Eider			
		Total[a]		Density[b]		Total[a]		Density[b]	
Year	Surveyed Area (km²)	Observed	Indicated	Observed	Indicated	Observed	Indicated	Observed	Indicated
1993	248.8	31	32	0.12	0.13	39	30	0.16	0.12
1994	455.7	79	57	0.17	0.13	58	35	0.13	0.08
1995	501.4	61	40	0.12	0.08	34	23	0.07	0.05
1996	501.4	41	40	0.08	0.08	59	43	0.12	0.09
1997	501.4	59	58	0.12	0.12	49	54	0.10	0.11
1998	501.4	71	70	0.14	0.14	57	18	0.11	0.04
2000	300.0	40	38	0.13	0.13	22	24	0.07	0.08
2001	501.4	38	36	0.08	0.07	35	22	0.07	0.04
2002	501.4	26	30	0.05	0.06	61	42	0.12	0.08
2003	501.4	24	20	0.05	0.04	50	38	0.10	0.08
2004	353.0	12	10	0.03	0.03	17	14	0.05	0.04
2005	501.4	16	14	0.03	0.03	46	22	0.09	0.04
2006	501.4	31	30	0.06	0.06	63	60	0.13	0.12
2007	501.4	52	48	0.10	0.10	30	28	0.06	0.06
2008	501.4	80	89	0.16	0.18	33	40	0.07	0.08
2009	501.4	41	42	0.08	0.08	33	30	0.07	0.06
2010	501.4	103	78	0.21	0.16	57	34	0.11	0.07
2011	501.4	99	95	0.20	0.19	133	129	0.27	0.26
2012	501.4	59	60	0.12	0.12	25	20	0.05	0.04
2013	501.4	63	66	0.13	0.13	38	24	0.08	0.05
2014	501.4	69	68	0.14	0.14	71	66	0.14	0.13
2015	501.4	59	54	0.12	0.11	57	42	0.11	0.08
Mean		55.1	51.4	0.11	0.10	51.7	40.8	0.10	0.08
SE		5.73	5.38	0.01	0.01	5.73	6.15	0.01	0.01

[a] Observed total includes flying and non-flying eiders. Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a). Mean and standard error calculated for total observed or indicated when survey area = 501.4 km², *n* = 18 years.

[b] Numbers not corrected for sightability. Density (birds/km²) based on 100% coverage of surveyed area. Means calculated for all years, *n* = 22 years.

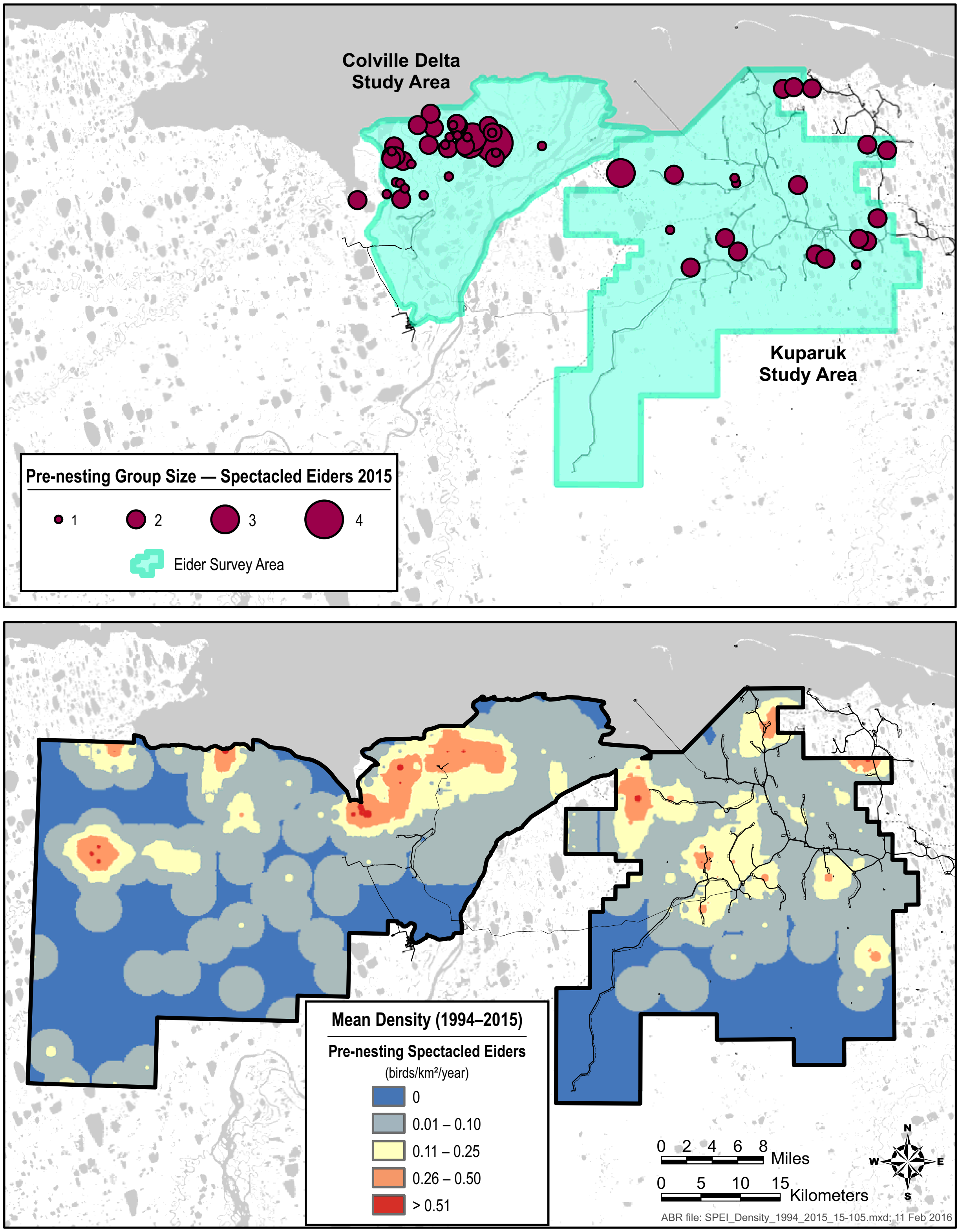

Figure 3. Spectacled Eider pre-nesting group locations in 2015 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE NPR-A study areas, 1994–2015 (bottom). Kuparuk data from Morgan et al. (2016). NE NPR-A data only through 2014.

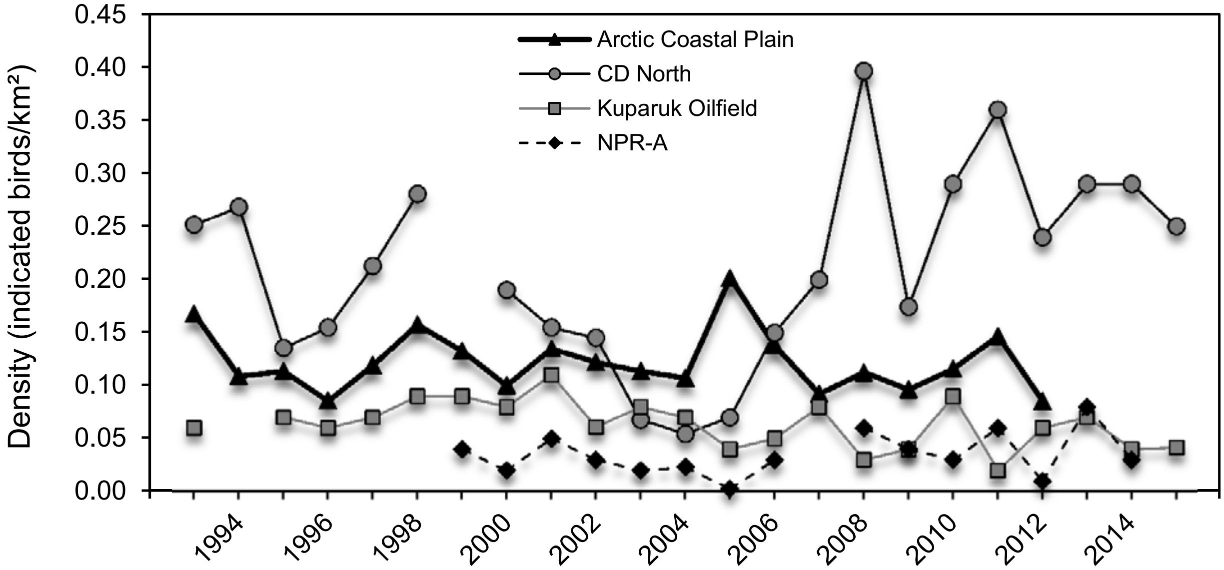

Figure 4. Annual densities of indicated total Spectacled Eiders during pre-nesting aerial surveys in 4 study areas on the Arctic Coastal Plain, Alaska, 1993–2015. Arctic Coastal Plain data from Stehn et al. (2013), Kuparuk data from Morgan et al. (2016), and CD North and NE NPR-A data from this study.

rate of only 0.6%, which is not significantly different from equilibrium (ln(adults) = 0.006 (year) – 8.55, $R^2 = 0.007$, $P = 0.711$, $n = 22$ years). King Eiders were seen in all 3 of the subareas, but they achieved their highest density (0.11 indicated birds/km²) in the Northeast Delta subarea in 2015 (Figure 6, Appendix E). The highest densities occur on the East Channel of the Colville River near the coast, where flocks of King Eiders collect in open water; negligible densities are seen elsewhere on the delta. Relatively few King Eiders nest on the Colville River delta, which leads us to surmise that 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 in the Colville Delta study area in 2015. Steller's Eiders rarely are seen in the vicinity of the Colville River delta, but over the years we have accumulated several records from the vicinity. Five flying birds were sighted there in 1995 (J. Bart, personal communication), a pair was spotted on the ground in the CD North subarea in 2001, single flying males were seen in the NE NPR-A study area in 2001 and in the Colville Delta study area in 2007 (Johnson and Stickney 2001, Johnson et al. 2008b), and several sightings of singles or pairs were reported in the Kuparuk Oilfield during 1995, 2000, 2001, 2007, and 2014 (not all sightings in the Kuparuk Oilfield were confirmed; Anderson et al. 2008; I. Helmericks, personal communication 2014). Since 1992, nest searches have been conducted in multiple locations on the Colville River delta, in the Kuparuk Oilfield, and in NE NPR-A; in over 2 decades of nest searches in those study areas, no nests or indications of breeding by Steller's Eiders have been observed.

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

Habitat Use

Steller's and Common eiders have not been numerous enough to warrant evaluations of habitat preferences on the Colville River delta. King

Table 3. Habitat selection by Spectacled and King eider groups during pre-nesting, Colville Delta study area, Alaska, 1993–1998 and 2000–2015.

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	1.6	avoid	
Brackish Water	83	38	7.8	1.3	prefer	
Tapped Lake with Low-water Connection	31	13	2.7	4.5	ns	
Tapped Lake with High-water Connection	19	11	2.3	3.7	ns	
Salt Marsh	62	34	7.0	3.2	prefer	
Tidal Flat Barrens	2	1	0.2	7.0	avoid	
Salt-killed Tundra	85	47	9.7	5.1	prefer	
Deep Open Water without Islands	31	19	3.9	3.4	ns	
Deep Open Water with Islands or Polygonized Margins	35	17	3.5	2.1	prefer	
Shallow Open Water without Islands	6	4	0.8	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	7	6	1.2	0.1	prefer	low
River or Stream	24	12	2.5	14.4	avoid	
Sedge Marsh	0	0	0.0	<0.1	ns	low
Deep Polygon Complex	250	142	29.2	2.7	prefer	
Grass Marsh	10	6	1.2	0.2	prefer	low
Young Basin Wetland Complex	0	0	0.0	<0.1	ns	low
Old Basin Wetland Complex	0	0	0.0	<0.1	ns	low
Nonpatterned Wet Meadow	83	41	8.4	8.2	ns	
Patterned Wet Meadow	172	93	19.1	19.3	ns	
Moist Sedge-Shrub Meadow	0	0	0.0	2.3	avoid	
Moist Tussock Tundra	1	1	0.2	0.6	ns	low
Tall, Low, or Dwarf Shrub	0	0	0.0	4.9	avoid	
Barrens	2	1	0.2	14.8	avoid	
Human Modified	0	0	0.0	0.1	ns	low
Total	903	486	100	100		
KING EIDER						
Open Nearshore Water	13	4	1.4	1.6	ns	low
Brackish Water	42	21	7.1	1.3	prefer	low
Tapped Lake with Low-water Connection	25	12	4.1	4.5	ns	
Tapped Lake with High-water Connection	10	4	1.4	3.7	avoid	
Salt Marsh	47	18	6.1	3.2	prefer	
Tidal Flat Barrens	4	2	0.7	7.0	avoid	
Salt-killed Tundra	51	27	9.1	5.1	prefer	
Deep Open Water without Islands	22	10	3.4	3.4	ns	
Deep Open Water with Islands or Polygonized Margins	19	9	3.0	2.1	ns	
Shallow Open Water without Islands	5	3	1.0	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	4	2	0.7	0.1	ns	low
River or Stream	371	106	35.8	14.4	prefer	
Sedge Marsh	0	0	0.0	<0.1	ns	low
Deep Polygon Complex	47	26	8.8	2.7	prefer	
Grass Marsh	8	3	1.0	0.2	ns	low
Young Basin Wetland Complex	0	0	0.0	<0.1	ns	low
Old Basin Wetland Complex	0	0	0.0	<0.1	ns	low
Nonpatterned Wet Meadow	17	11	3.7	8.2	avoid	
Patterned Wet Meadow	51	29	9.8	19.3	avoid	
Moist Sedge-Shrub Meadow	2	1	0.3	2.3	avoid	
Moist Tussock Tundra	1	1	0.3	0.6	ns	low
Tall, Low, or Dwarf Shrub	2	1	0.3	4.9	avoid	
Barrens	15	6	2.0	14.8	avoid	
Human Modified	0	0	0.0	0.1	ns	low
Total	756	296	100	100		

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

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

[c] Low = expected number < 5.

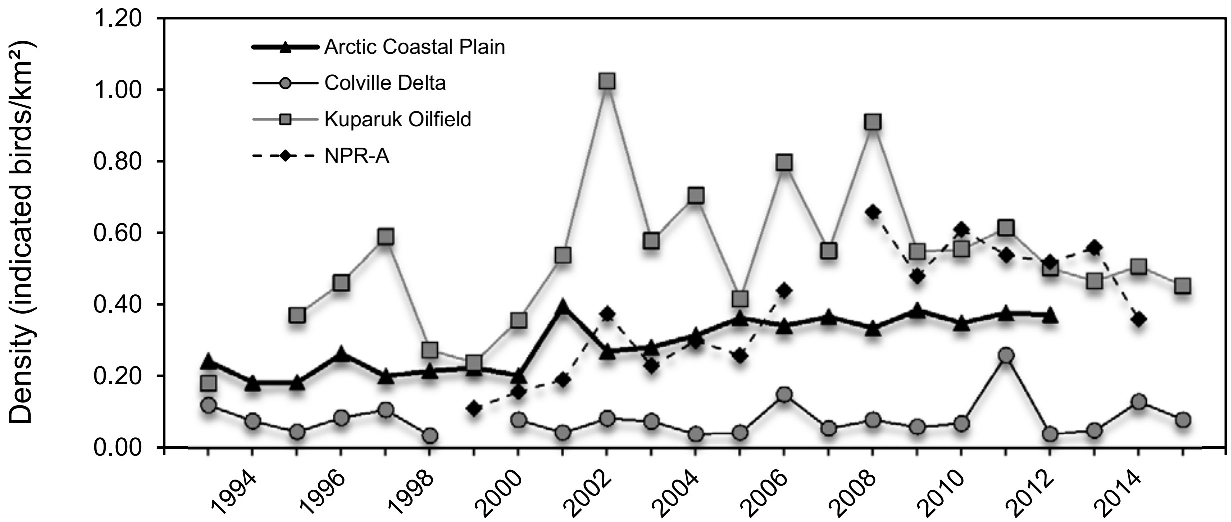

Figure 5. Annual densities of indicated total King Eiders during pre-nesting aerial surveys in 4 study areas on the Arctic Coastal Plain, Alaska, 1993–2015. Arctic Coastal Plain data from Stehn et al. (2013), Kuparuk data from Morgan et al. (2016). NE NPR-A data only through 2014.

Eiders used 20 of 24 available habitats in the Colville Delta study area over 22 years of pre-nesting aerial surveys (Table 3). King Eiders preferred 4 of the same habitats preferred by pre-nesting Spectacled Eiders in the Colville Delta study area: Brackish Water, Salt Marsh, Salt-killed Tundra, and Deep Polygon Complex. King Eiders also preferred River or Stream, where the largest percentage (36%) of groups was found. The high use of River or Stream, which includes the river channels primarily in the Northeast Delta subarea (Figure 6), suggests that many King Eiders were moving through to breeding areas farther east, because River or Stream is not potential breeding habitat. In contrast, Spectacled Eiders, which occur in high numbers during pre-nesting and nest in relatively high concentrations on the outer Colville River delta (0.8–1.0 nests/km²; ABR, unpublished data), avoid River or Stream. Moreover, King Eiders nest at very low densities on the Colville River delta in the several locations where intensive nest searches have been conducted (Burgess et al. 2003; Johnson et al. 2003a, 2008a; Seiser and Johnson 2010, 2011a, 2011b, 2012, 2014a, 2014b), affirming that most of the pre-nesting King Eiders seen on the delta are stopping over during migration.

YELLOW-BILLED LOON

DISTRIBUTION AND ABUNDANCE

Nesting in 2015 was affected by widespread flooding on the Colville River delta with the river flooding its banks 20–24 May (see CONDITIONS IN THE STUDY AREA). We deployed cameras from 1 to 3 June at 13 loon territories to document pre-nesting behavior and nest initiation (see *Time-Lapse Cameras*, below). Four of the 13 territories had nests recorded on camera and those nests were found subsequently during the nesting survey. During the nesting survey on 18–20 June, we counted 63 Yellow-billed Loons and 19 nests (Figure 7, Table 4). Six additional nests were found after the nesting survey. Two were found while visiting territories to collect time-lapse cameras. Both had 1 egg and had been initiated 1–2 d after the nesting survey. Another 2 were found during the brood-rearing survey, when broods were seen where no nests were found during June. The remaining 2 nests were from nesting pairs that were assumed to have failed and renested. One renesting location was found after observing a brood that was nearly half the size of other broods from nests started in the same time period (i.e., the chicks should be similar in age and size), and the other nest was inferred from the presence of a brood near a nest that failed during June. Of the 25

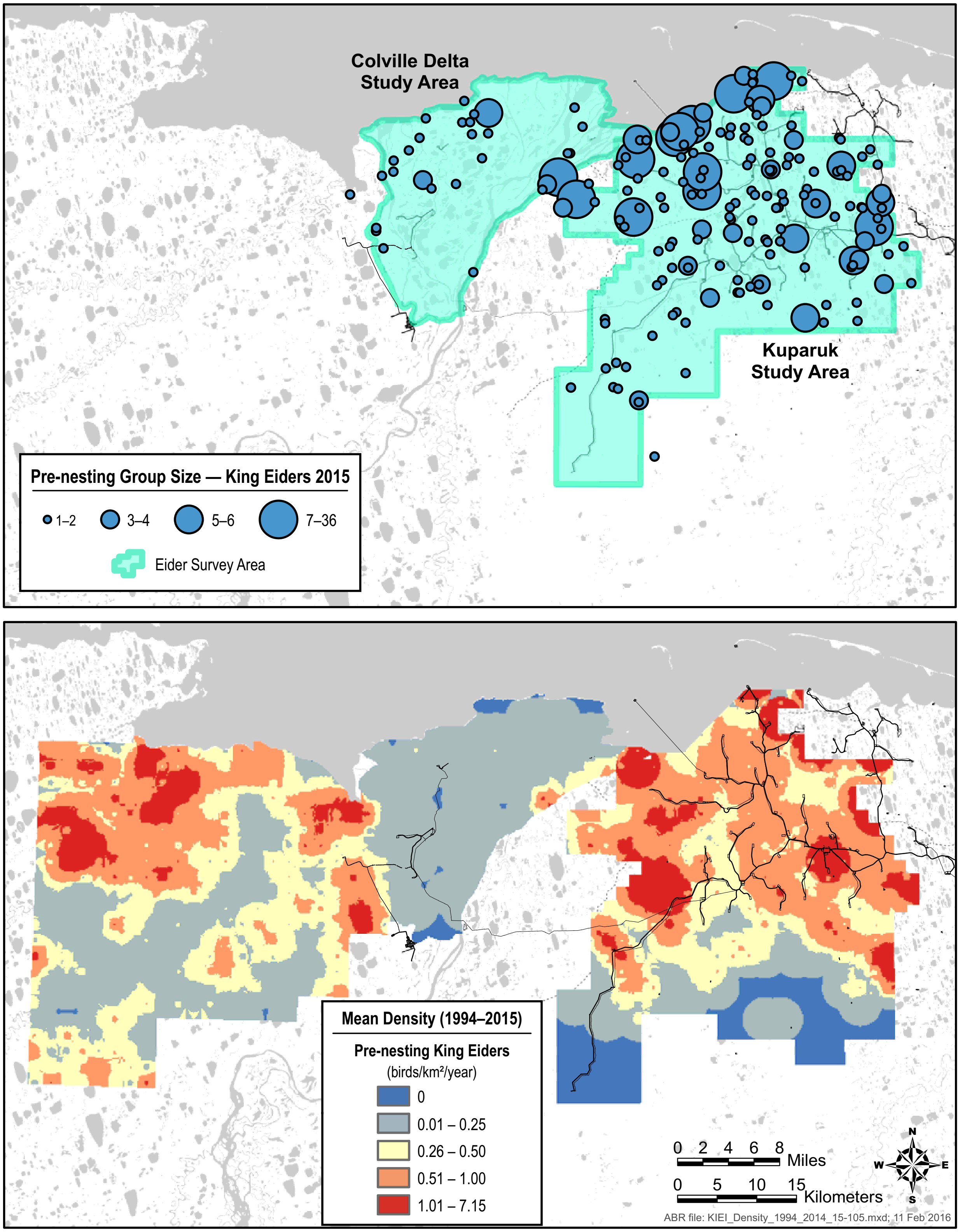

Figure 6. King Eider pre-nesting group locations in 2015 (top) and mean density distribution in the Kuparuk, Colville Delta, and NE NPR-A study areas, 1994–2015 (bottom). Kuparuk data from Morgan et al. (2016). NE NPR-A data only through 2014.

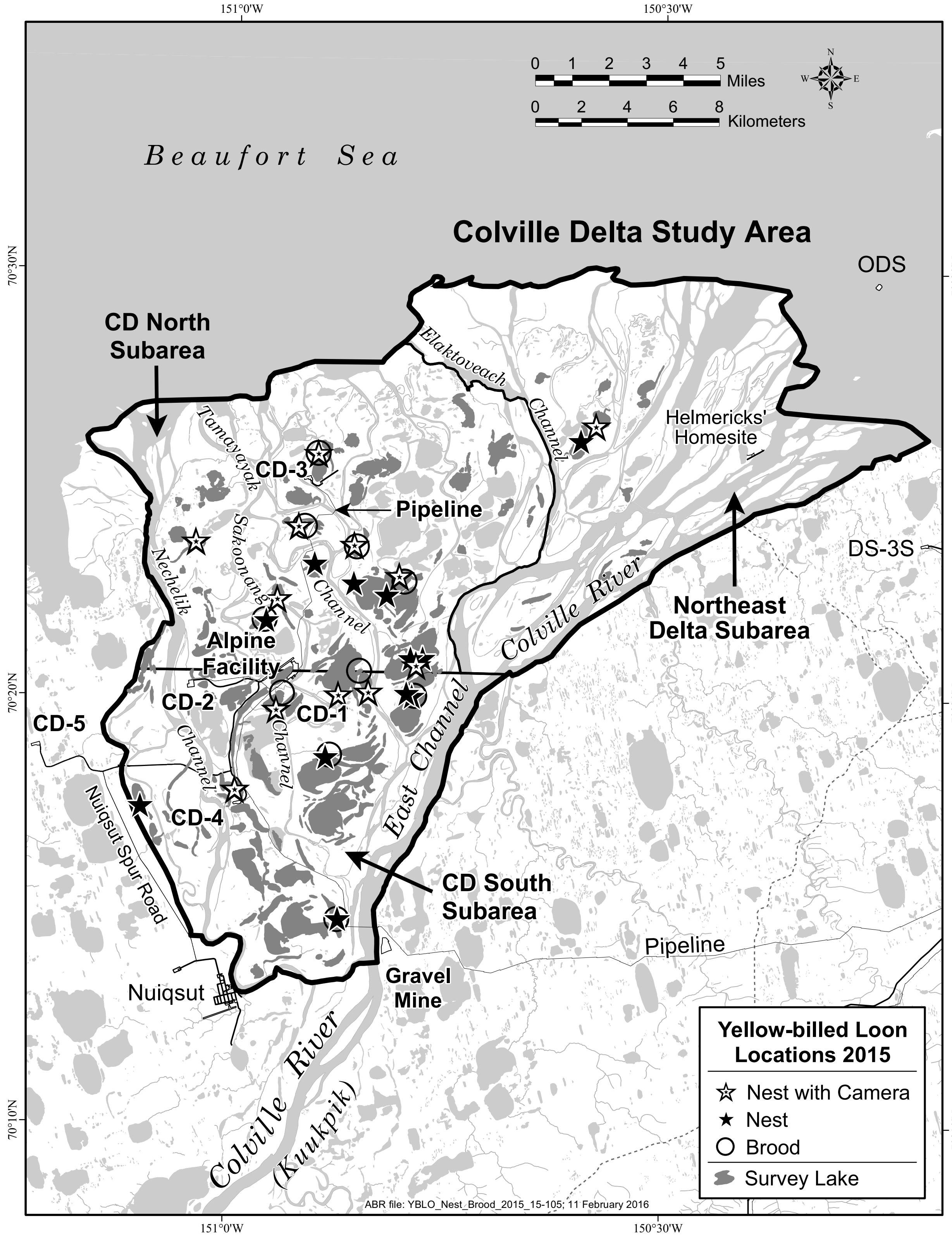

Figure 7. Yellow-billed Loon nest and brood locations, Colville Delta study area, Alaska, 2015.

Table 4. Number of Yellow-billed Loons and nests, and territory occupancy by nests, Colville Delta study area, Alaska, 1993–2015.

Year	Nesting Survey[a] No. Adults	Nesting Survey[a] No. Nests	All Surveys[b] No. Nests	No. Territories Surveyed	Nest Occupancy (%)[c]
1993	50	11	16[e,f]	41	39
1995	42	12	21[e,f]	39	54
1996	45	11	20[e,f,g]	35	46
1997	48	10	18[e,g]	38	39
1998	35	17	24[e,f,g]	40	60
2000	53	16	16	37	43
2001	54	19	20[e]	37	54
2002	46	17	22[e,f,g]	41	54
2003	53	25	27[f]	41	66
2004	41	24	26[f]	41	63
2005	56	30	31[f]	40	75
2006	63	24	28[g]	41	68
2007	66	27	31[g]	41	73
2008	69	33	38[g]	42	90
2009	67	27	30[g]	43	70
2010	69	23	35[g]	42	83
2011	70	23	29[g]	42	67
2012	57	25	32[g]	43	70
2013	67	12	17[f,g,h]	43	40
2014	78	26	32[g,h]	43	74
2015	63	19	25[f,h]	44	52
Mean	56.8	20.5	25.6	–	61.0
SE	2.5	1.5	1.4	–	3.2

[a] Nesting survey is limited to survey conducted between 18 and 30 June.
[b] Observation effort varied between years. Includes all nests found on loon aerial surveys, ground surveys, camera images or inferred by brood observations. Observation methods other than nesting survey are footnoted.
[c] Calculated as the number of nests from all surveys divided by the number of territories surveyed. Excludes 1 renesting in 2007 and 2011, and 2 renestings in 2012 and 2015.
[d] Survey area included CD North, CD South, and Northeast Delta subareas for all years except 2000, when only CD North and CD South were surveyed.
[e] Includes nest(s) found during ground surveys.
[f] Includes nest(s) inferred by the presence of a brood observed on a territory lake during ground or aerial surveys.
[g] Includes nest(s) found during revisit (1996–2002), monitoring (2006–2014), and early nesting (2011) surveys.
[h] Includes nest(s) documented on camera images only or nest(s) found after the nesting survey during camera setup.

nests found in 2015 (including 2 renesting attempts), 13 nests were located in the CD North subarea, 10 nests in the CD South subarea, and 2 nests in the Northeast Delta subarea (Appendix F). The total number of nests was nearly identical to the long-term mean (25.6 ± 1.4 nests; for densities see Appendix G). The count of 63 adults on the nesting survey was higher than the long-term mean (56.8 ± 2.5 adults) but was among the lowest counts in the last 10 years. The density of adults in the Colville Delta study area was slightly lower in the CD North subarea (0.15 birds/km²) than in the CD South subarea (0.17 birds/km²) but the density of nests was identical (0.06 nests/km²; Appendix F). Incidental records of Pacific and Red-throated Loon nests and broods are presented in Appendices F and H.

All but 2 of the 25 Yellow-billed Loon nests recorded in the Colville Delta study area in 2015 were on lakes where Yellow-billed Loons have nested previously (Figure 7; Johnson et al. 2009, 2010, 2011, 2012, 2013, 2014a, 2015). One pair nested on a lake where we had not documented breeding in previous years, which increases the number of known breeding territories from 43 to 44. The nest was on a Tapped Lake with a High-water Connection (8.8 ha) that we began surveying in 2014. The other newly-used lake was a small pond (~4.0 ha) near the margin of a lake previously used for nesting and brood rearing. Of the remaining 23 nests, 10 were located at the same nest sites used in previous years, 11 were very close to nest sites used in previous years, and 1 was at a new nest site on a lake previously used for nesting. The location of one nest was unknown.

Since 1993, the number of nests recorded during the nesting aerial survey in June ranged from 10 nests in 1997 to 33 nests in 2008 (Table 4). In most years, 1–12 additional nests were found during ground, revisit, and/or monitoring surveys, and in some years inferred from the presence of broods found during brood-rearing surveys on nest lakes where no nests were found. With the addition of these nests, the counts of nests ranged from 16–38; however, these nest counts are not directly comparable among years because survey coverage varied annually from 35 to 44 identified territories. To adjust for variable coverage, we used territory occupancy by nests, calculated as the total number of nests found on all surveys divided by the number of territories surveyed. Although the number of nests found in 2015 was near the long-term mean, only 52% of the territories surveyed were occupied by nests, which is well below the long-term mean (61.0 ± 3.2%, n = 21 years; Table 4).

During the brood-rearing survey on 17 and 19–20 August, 58 Yellow-billed Loons, 9 broods, and 10 young were recorded in the Colville Delta study area (Figure 7, Table 5). We inferred 1 additional brood based on eggshell fragments at the nest, which was confirmed by time-lapse camera images. Of the 10 broods recorded, 6 were found in the CD North subarea and 4 were found in the CD South subarea (Appendix F). The count of 58 adults recorded during the brood-rearing survey was higher than the long-term mean (50.5 ± 2.7 adults) and the number of broods detected (9) was slightly lower (mean = 10.4 ± 1.1 broods, n = 21 years; Table 5; for densities, see Appendix G). As with nests, the density of adults during the brood-rearing survey in the Colville Delta study area was slightly lower in the CD North subarea (0.13 birds/km^2) than in the CD South subarea (0.19 birds/km^2), but the density of broods was identical (0.03 broods/km^2; Appendix F).

During the 21 years of brood-rearing surveys in the Colville Delta study area, the lowest number of broods recorded was 2 broods in 2000 and the highest was 22 broods in 2008 (Table 5). In most years, an additional 1–6 broods were found during ground and/or monitoring surveys, or were determined by eggshell fragments at the nest indicating that hatching occurred (see *Nest Fate,* below). With the addition of these broods, the range of brood counts was 3–27. Like nest counts, these raw counts of broods are not directly comparable because survey coverage varied annually from 34 to 44 territories (Table 5). We calculated territory occupancy by broods (the number of broods seen on all surveys divided by the number of territories surveyed) to standardize for survey effort. In 2015 and for the third year in a row, brood occupancy (23%) was well below the long-term mean (30.9 ± 3.2%, n = 21 years). Only 5 of the 21 years had a lower brood occupancy.

Yellow-billed Loons on the Colville Delta study area have exhibited long-term population growth, but indices of productivity have not followed that trend. The number of adults (adjusted by the number of territories surveyed; Figure 8) has increased at 1.6% annually over 16 years (ln(adults) = 0.016 (year) – 28.60, R^2 = 0.257, P = 0.045). Reproductive output has been more variable; neither nests nor young (both adjusted for the number of territories surveyed) show significant change. The adjusted number of nests exhibited a slight decline that was not significantly different from 0% growth or equilibrium (ln(nests) = –0.006 (year) + 15.97, R^2 = 0.014, P = 0.659). Similarly, the adjusted number of young was not significantly different from equilibrium (ln(young) = 0.030 (year) – 57.04, R^2 = 0.041, P = 0.455).

HABITAT USE

Yellow-billed Loons nested in 12 of 24 available habitats during nesting surveys conducted in the Colville Delta study area over 21 years (Table 6). Seven habitats, supporting 435 of 481 total nests, were preferred for nesting (Deep Open Water with Islands or Polygonized Margins, Deep Open Water without Islands, Sedge Marsh, Grass Marsh, Deep Polygon Complex, Nonpatterned Wet Meadow, and Patterned Wet Meadow). Within

Table 5. Number of Yellow-billed Loons, broods, and territory occupancy by broods, Colville Delta study area, Alaska, 1993–2015.

Year	Brood-rearing Survey[a]			All Surveys[b]	No. Territories Surveyed[c]	Brood Occupancy (%)[d]
	No. Adults	No. Young	No. Broods	No. Broods		
1993	29	7	7	10[e]	34	29
1995	51	13	10	13[e]	42	31
1996	62	6	6	10[e]	36	25
1997	66	8	5	5	38	13
1998	55	15	12	12	41	29
2000	21	2	2	3[f]	36	8
2001	33	4	4	4	37	11
2002	66	9	8	9[e]	40	23
2003	47	16	14	14	40	35
2004	54	15	12	12	40	30
2005	39	21	17	21[f,g]	40	53
2006	66	13	13	16[f]	41	39
2007	53	20	17	23[f,g]	41	56
2008	57	29	22	27[f,g]	42	64
2009	56	12	11	13[g]	43	30
2010	59	19	13	15[f,g,h]	42	36
2011	45	20	12	15[f,g,h]	42	36
2012	52	19	14	17[g,h]	43	40
2013	43	9	7	7	43	16
2014	48	4	4	8[f,g]	43	19
2015	58	10	9	10[h]	44	23
Mean	50.5	12.9	10.4	12.6		30.9
SE	2.7	1.5	1.1	1.3		3.1

[a] Brood-rearing surveys were conducted sometime between 15 and 27 August.
[b] Includes all broods found on brood-rearing survey and any additional broods found during other types of surveys as footnoted.
[c] Survey area included CD North, CD South, and Northeast Delta subareas for all years except 2000, when only CD North and CD South were surveyed.
[d] Calculated as the number of broods from all surveys divided by the number of territories surveyed.
[e] Includes brood(s) found during ground surveys.
[f] Includes brood(s) found during monitoring surveys.
[g] Includes broods from territories where no brood was seen but presence of a brood was determined from eggshell evidence.
[h] Includes broods from territories where broods were seen only on camera images.

these habitats, nests were built on peninsulas, shorelines, islands, or in emergent vegetation. All nests were on shorelines of lakes, but were assigned to the terrestrial habitat on the lakeshore except where nests were on islands or in emergent vegetation, in which case they were assigned to the aquatic habitat of the lake. Patterned Wet Meadow was the habitat used most frequently for nesting (35% of all nests), and it also was the most abundant habitat on the delta (24% of the loon survey area; Table 6). Nesting Yellow-billed Loons avoided 11 habitats, which together occupied 50% of the Colville Delta study area.

Yellow-billed Loons were highly selective in their use of brood-rearing habitat. All Yellow-billed Loon broods (219 broods over 21 years) were found in 4 lake habitats, only 3 of which were preferred: Tapped Lake with High-water Connection, Deep Open Water without Islands, and Deep Open Water with Islands or Polygonized Margins (Table 6). The preferred habitats occupied only 13% of the delta. Brackish Water was the only shallow-water habitat used during brood-rearing and was used by 1 brood. The selection analyses for nesting and brood-rearing highlight the importance of large, deep waterbodies to breeding Yellow-billed Loons.

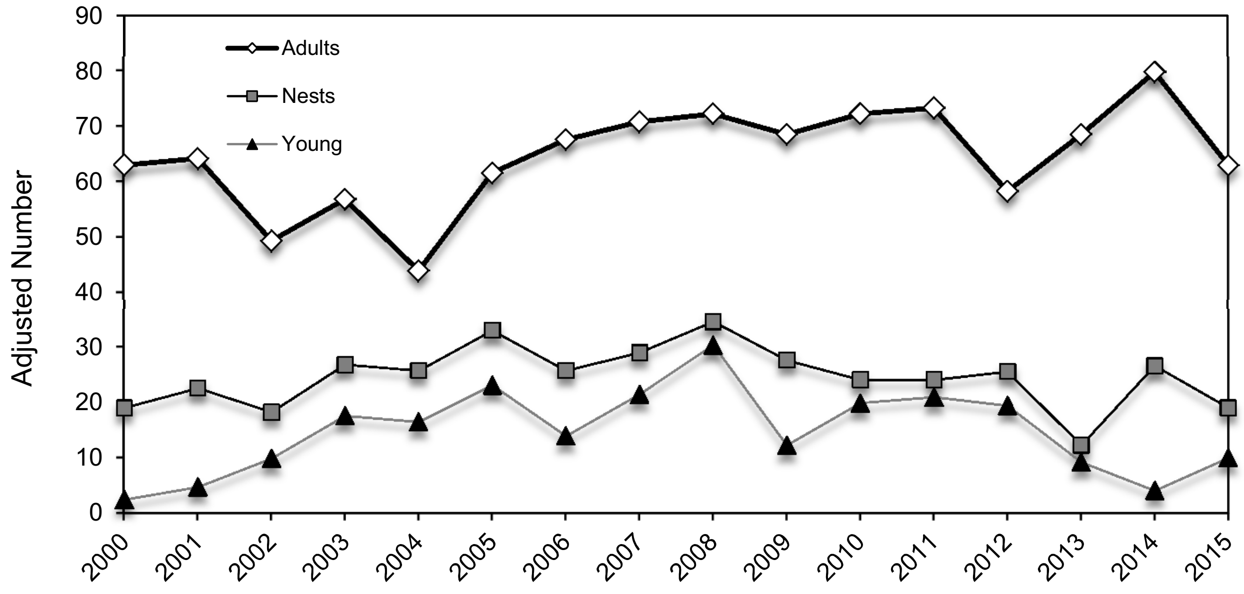

Figure 8. Annual numbers of Yellow-billed Loon adults and nests during the nesting survey and young during the brood-rearing survey, Colville Delta study area, 2000–2015. Adjusted numbers were standardized for the number of territories surveyed each year (number observed/number of territories surveyed × 44 territories [maximum number of territories surveyed]).

NEST FATE

The contents of 24 of 25 Yellow-billed Loon nests were examined during the brood-rearing survey to determine nest fate. Nine nests were classified as successful based on the presence of a brood and 1 nest was classified as successful based only on eggshell fragments in the nest. All but 1 successful nest contained >20 eggshell fragments (range 21–68 fragments). One nest associated with a brood only contained ~3 fragments but the nest was extremely degraded. Of ~270 eggshell fragments found within 5 m of successful nests, 80% were ≤10 mm in length. Four successful nests also contained pieces of membrane that were either separate or loosely attached to fragments. The majority of egg membranes and eggshell fragments were found in nest bowls; <50 fragments were found in the water or on shore adjacent to successful nests. Fourteen nests were judged failed by the absence of a brood and eggshell fragments, or by the presence of <20 eggshell fragments. Of 14 failed nests, 10 did not contain any egg remains within 5 m of the nest and 3 nests contained 5–10 egg fragments. One nest was discovered abandoned during the nesting survey; 2 whole eggs were next to the nest. The nest was not revisited during August nest fates.

Ten of the 24 nests examined hatched for an apparent nesting success of 42%. We began visiting inactive nests to determine nest fate in 2005 because some broods do not survive until the August brood-rearing survey; thus absence of a brood does not indicate always that a nest failed. In 2015, however, we did not conduct weekly nest and brood monitoring surveys as we had in previous years, which provide better estimates of the total number of nests and broods. Because of lower survey effort in 2015, nesting success based on the total number of nests detected is not directly comparable to previous years. Restricting the data to nests found only on the nesting survey allows a standardized comparison of apparent nesting success among years. Based on the nest survey and the associated nest fate data, apparent nesting success in 2015 was 33% (6 of 18 nests hatched [excludes 1 nest with unknown nest fate]), which was the second-lowest nesting success observed and well below the 11-year mean (52.7 ± 4.5%).

TIME-LAPSE CAMERAS

We typically deploy time-lapse cameras in late May prior to breakup to document nest initiation and seasonal phenology; however, because of the early breakup and extensive

Table 6. Habitat selection by nesting (1993–1998 and 2000–2015) and brood-rearing (1995–1998 and 2000–2015) 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	0.0	2.0	avoid	
Brackish Water	0	0.0	1.1	avoid	
Tapped Lake with Low-water Connection	0	0.0	5.4	avoid	
Tapped Lake with High-water Connection	34	7.1	5.3	ns	
Salt Marsh	1	0.2	2.6	avoid	
Tidal Flat Barrens	0	0.0	3.5	avoid	
Salt-killed Tundra	0	0.0	4.2	avoid	
Deep Open Water without Islands	46	9.6	4.8	prefer	
Deep Open Water with Islands or Polygonized Margins	129	26.8	2.5	prefer	
Shallow Open Water without Islands	0	0.0	0.3	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	0.4	0.1	ns	low
River or Stream	0	0.0	8.8	avoid	
Sedge Marsh	5	1.0	<0.1	prefer	low
Deep Polygon Complex	24	5.0	2.9	prefer	
Grass Marsh	9	1.9	0.3	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	55	11.4	8.8	prefer	
Patterned Wet Meadow	167	34.7	24.4	prefer	
Moist Sedge-Shrub Meadow	6	1.2	3.2	avoid	
Moist Tussock Tundra	0	0.0	0.9	avoid	low
Tall, Low, or Dwarf Shrub	3	0.6	6.5	avoid	
Barrens	0	0.0	12.1	avoid	
Human Modified	0	0.0	0.1	ns	low
Total	481	100	100		
BROOD-REARING					
Open Nearshore Water	0	0.0	2.0	avoid	low
Brackish Water	1	0.5	1.1	ns	low
Tapped Lake with Low-water Connection	0	0.0	5.4	avoid	
Tapped Lake with High-water Connection	46	21.0	5.3	prefer	
Salt Marsh	0	0.0	2.6	avoid	
Tidal Flat Barrens	0	0.0	3.5	avoid	
Salt-killed Tundra	0	0.0	4.2	avoid	
Deep Open Water without Islands	101	46.1	4.8	prefer	
Deep Open Water with Islands or Polygonized Margins	71	32.4	2.5	prefer	
Shallow Open Water without Islands	0	0.0	0.3	ns	low
Shallow Open Water with Islands or Polygonized Margins	0	0.0	0.1	ns	low
River or Stream	0	0.0	8.8	avoid	
Sedge Marsh	0	0.0	<0.1	ns	low
Deep Polygon Complex	0	0.0	2.9	avoid	
Grass Marsh	0	0.0	0.3	ns	low
Young Basin Wetland Complex	0	0.0	<0.1	ns	low
Old Basin Wetland Complex	0	0.0	<0.1	ns	low
Nonpatterned Wet Meadow	0	0.0	8.8	avoid	
Patterned Wet Meadow	0	0.0	24.4	avoid	
Moist Sedge-Shrub Meadow	0	0.0	3.2	avoid	
Moist Tussock Tundra	0	0.0	0.9	ns	low
Tall, Low, or Dwarf Shrub	0	0.0	6.5	avoid	
Barrens	0	0.0	12.1	avoid	
Human Modified	0	0.0	0.1	ns	low
Total	219	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] Low = expected number < 5.

flooding in 2015, we postponed the deployment until after breakup. We deployed 13 cameras, each at a traditional nest site, from 1 to 3 June. Eleven of the 13 territories were judged to have been flooded by the Colville River (Table 7). Water in those lakes was murky and portions of shorelines were littered with sediment and plant debris. Two territories appeared not to have flooded from the river because the water in those lakes was clear. During camera deployment, large lakes contained moats 3–6 m wide and were already occupied by Yellow-billed Loons, indicating that loons arrived on nesting lakes prior to 1 June. That date appears to be early for this species. In 2013 and 2014, loons were first seen on images on 3 June (median = 6 June 2013 and 7 June 2014; Johnson et al. 2014a, 2015). During 2 years of study in the same area, North (1986) documented 4 and 11 June as the arrival date on breeding lakes. The early influx of river water into many lakes and warmer than average May temperatures (see CONDITIONS IN STUDY AREA, above) likely hastened moat formation and allowed loons earlier access to territories than in previous years. Not only were loons already occupying territories during camera deployment, but nest sites at 10 of the 13 lakes appeared accessible at that time as well. Thus, although we did not document dates of occurrence with time-lapse cameras in 2015, ice breakup at individual territories, the arrival of Yellow-billed Loons on nesting lakes, and nest site accessibility all occurred before 1 June.

The start of incubation was documented by 6 cameras deployed in early June (Table 7). Two of those nests were built out of camera view and had 1 egg each during camera revisits. Second eggs were laid after cameras were re-aimed. The start date of incubation at those nests was determined by

Table 7. Nesting chronology and observations of Yellow-billed Loons at territories monitored by time-lapse cameras deployed in early June, Colville Delta study area, Alaska, 2015.

FLOOD SOURCE[a] Territory	Dates Monitored	Nesting Observed on Camera	Date Loons First Seen	Incubation Start Date
COLVILLE RIVER				
1	1–21 June	No[b]	1 June	21 June[c]
2	1–20 June	No[d]	1 June	–
4	1–21 June	No	1 June	–
6	1–8 July	No[e]	1 June	–
13	2–20 June	No[b]	2 June	19 June[c]
14	2–12 June[f]	No[d]	2 June	Unknown[g]
17	2–21 June	Yes	2 June	9 June
18	2–21 June	No	2 June	–
34	2–21 June	No[d]	2 June	–
39	2–20 June	Yes	2 June	9 June
46	3–21 June	No	3 June	–
LOCAL RUNOFF				
8	1–20 Jun	Yes	2 June	6 June
26	2–20 Jun	Yes	2 June	9 June

[a] Lakes were determined to have flooded by the river if shorelines and surrounding tundra were completely underwater and the lake was turbid, whereas lakes flooded by local runoff contained moats and were clear.
[b] Nest was found after the nesting survey during visit to retrieve camera.
[c] Incubation began prior to camera setup; incubation start date calculated by subtracting the laying interval (2.4 d) from the time that images showed the second egg was laid.
[d] Nest found at territory but not in camera view.
[e] Pacific Loon nested in site previously occupied by Yellow-billed Loons.
[f] Camera malfunctioned on 12 June.
[g] Incubation began after the nesting survey (19–21 June); nest found during brood-rearing survey 19 August due to presence of brood.

subtracting the laying interval (2.4 d) from the time the second egg was laid. The median start date of incubation in 2015 was 9 June (range 6–21 June, *n* = 6 nests). At 2 of the 6 nests, we also viewed both eggs being laid. During laying, females tipped forward for ~10 frames (~5 min) so that their tails appeared raised while feet and chests supported their bodies. The median laying interval between the 2 eggs at each nest was 2.3 and 2.5 d, which agrees closely with the 2.4 d interval observed in 2014 (*n* = 5 nests, range 2.4–2.5 d). Only 2 nests with known start dates hatched in 2015. Chicks were seen on day 27 and day 30 of incubation. That incubation period also is similar to observations in past years. In 2013, 1 nest had a pipped egg on day 29 of incubation. In 2014, the first chick at 2 different nests was seen on day 27 and day 28 of incubation. Thus, our data suggest a 26–29 d incubation period, which agrees closely with the 27–28 d incubation period reported by North (1994).

After the nesting survey in the Colville Delta study area in 2015, we replaced 5 of the previously deployed time-lapse cameras and set up an additional 6 cameras at Yellow-billed Loon nests. One of the 6 nests monitored by cameras setup in early June had already failed by the time cameras were redeployed in late June. In total, we monitored 12 of 25 nests in the Colville Delta study area with time-lapse cameras (Table 8). Cameras were placed 25–57 m from nests (mean = 40 ± 2.8 m, *n* = 11) that were active after the nesting survey. To deploy cameras, 2 researchers were transported to and from nesting lakes by helicopter. Researchers were at nests 23–44 min (mean = 33 ± 2.2 min, *n* = 11 nests). All 11 loons that were incubating left the nest during camera setup: 3 left as the helicopter landed, 3 left as researchers exited the helicopter, 4 swam away from their nests as researchers approached the camera setup location on foot, and 1 left as the helicopter took off after leaving researchers to set up the camera.

All 11 loons that left their nests during camera installation returned to incubate after installation. Two loons returned to nests before we departed in the helicopter. The remaining loons returned 4–85 min after we departed (mean = 28 ± 8 min, *n* = 9 nests). Loons were absent from nests 27–125 min during camera installation (mean = 54 ± 8 min, *n* = 11 nests).

Cameras successfully recorded daily nest survival at 11 of 12 nests. The camera at 1 nest malfunctioned after day 12; that nest eventually hatched. We were able to use camera images to identify the day of hatch or failure with all 11 of the cameras that functioned for the entire period (Table 8). Of the 12 camera-monitored nests, 6 hatched and 6 failed for an apparent nesting success of 50%, which was higher than the nesting success for nests without cameras (31%). The median start date for incubation at hatched nests was 8 June (range 4–10 June, *n* = 6) and the median hatch date was 6 July (range 2–9 July). Incubation at hatched nests started nearly a week earlier in 2015 than in previous years (median = 15 June, range 10–19 June, *n* = 7 years; Appendix I), likely an effect of the early breakup and access to nest sites. The median start date for failed nests in 2015 was 15 June (range 8–21 June, *n* = 6), which was similar to the long-term median. All camera-monitored nests that failed in 2015 did so by 29 June.

Incubation constancy of Yellow-billed Loons in the Colville Delta study area in 2015 (Table 8) was slightly lower than the mean observed since camera monitoring began in 2008 (Appendix I). During camera monitoring in 2015, loons at hatched nests spent 95.1% (SE = 1.0%, *n* = 6 nests) of their time incubating. The only other year with lower incubation constancy was 2013, which also was a year when the Colville River flooded loon territories. Loons at failed nests had the lowest incubation constancy observed since camera-monitoring began, spending 73.9% (SE = 8.1%, *n* = 6) of their time incubating. That figure, however, includes the constancy of 2 pairs that had extremely low nest attendance (52% and 54%) and eventually abandoned their nests.

Since 2008, predation of 1 or both eggs has been documented by time-lapse cameras at 62 of 132 nests, including 12 nests where predators were not captured on images (Figure 9). The majority (48%) of identified predators were Glaucous Gulls and Parasitic Jaegers, which take advantage of unattended nests rather than flushing the incubating loon. Of the 6 nests that failed to hatch in 2015, 1 failure was attributed to predation by Parasitic Jaegers and 1 to brown bears. The

Table 8. Nest history and incubation activity of Yellow-billed Loon nests monitored by time-lapse digital cameras, Colville Delta study area, Alaska, 2015.

Territory	Fate[a]	Incubation Start Date[b]	Predator	No. Eggs[c]	Date Camera Setup	Date of Hatch or Failure	No. Days Monitored[d]	Incubation Constancy[d] (%)	Exchange Frequency[d] (no/d)	Recess Frequency[d] (no/d)	Recess Length[d] (min/recess)
8	S	6 June[e]	Glaucous Gull[f]	2	6 June	2 July	25.1	97.0	2.1	3.6	11.2
10	S	9 June		2	20 June	7 July	16.3	91.7	0.8	4.2	29.3
11	S	10 June		2	20 June	9 July[g]	12.9	98.2	1.9	2.2	10.2
15	S	7 June		2	21 June	5 July	13.5	94.9	0.9	4.4	15.7
27	S	4 June		2	21 June	2 July	10.4	93.0	0.4	4.9	17.0
39	S	9 June[e]		2	9 June	8 July	27.6	95.9	1.6	3.6	16.4
Median/Mean		8 June			–	6 July		95.1	1.3	3.8	16.6
SE		–			–	–		1.0	0.3	0.4	2.8
1	F	21 June[h]	Parasitic Jaeger	1	21 June	25 June	4.1	63.5	1.5	12.0	47.6
13	F	20 June[h]	None, abandoned	1	20 June	26 June	5.8	54.3	1.2	11.1	50.4
17	F	8 June[e]	None, abandoned	2	8 June	16 June	8.2	51.8	1.7	10.7	62.1
26	F	9 June[e]	Brown Bear	2	9 June	24 June	15.1	93.1	1.5	6.3	16.4
31	F	11 June	Unknown	2	21 June	23 June	1.8	83.8	1.1	9.0	22.2
48	F	19 June	Unknown	2	20 June	29 June	9.1	96.6	1.8	3.3	14.0
Median/Mean		15 June			–	24 June		73.9	1.5	8.7	35.5
SE		–			–	–		8.1	0.1	1.4	8.3

[a] S = hatched, F = failed to hatch.
[b] Incubation start dates for successful nests estimated by subtracting 28 d from date chick first observed on camera images; for failed nests, nest age estimated using egg flotation schedule; if either method resulted in a nest age that was younger than the using the date found, the date found was used as the start of incubation.
[c] Recorded on aerial surveys, during camera setup, or maximum seen on camera images.
[d] Summarized from time loon returns to nest after camera installation to day before hatch, or to time of nest failure; excludes period of time when photo images could not be interpreted because of poor weather conditions.
[e] Start of incubation documented by camera images.
[f] Predation occurred on the second egg, and possibly the first-hatched chick, while adults were away from the nest.
[g] Hatch date estimated using egg flotation.
[h] Incubation began prior to camera setup; incubation start date calculated by subtracting the laying interval (2.4 d) from the time that images showed the second egg was laid.

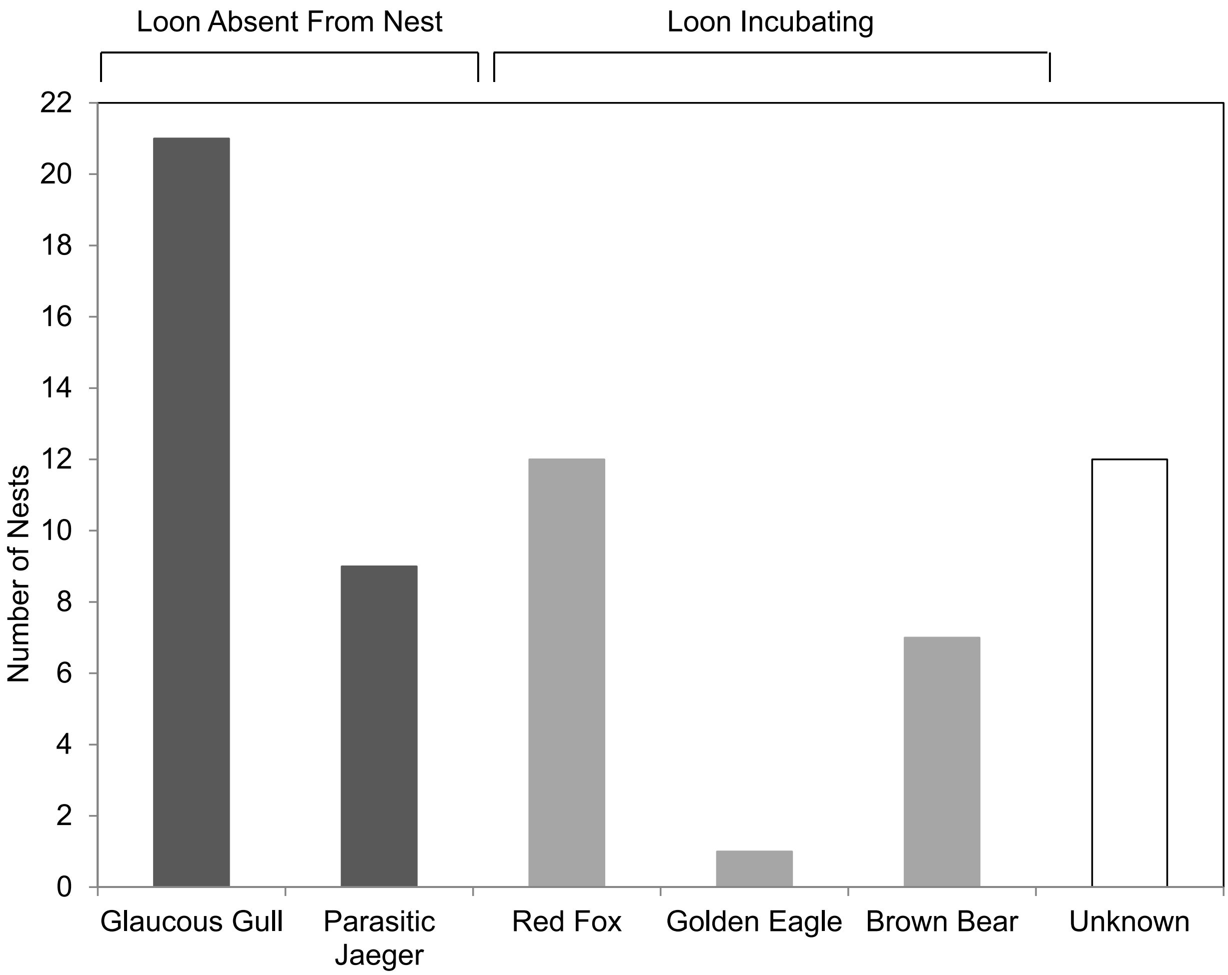

Figure 9. Predators seen taking eggs at camera-monitored Yellow-billed Loon nests (*n* = 132 nests), Colville Delta study area, Alaska, 2008–2015. Loons left nests 6–15 min prior to brown bear predation; we assume they were flushed into the water by the bears.

predator was not captured on images at 2 nests and the remaining 2 nests were abandoned (Table 8). The nest lost to Parasitic Jaegers was unattended at the time of predation. The pair at this nest had the third lowest incubation constancy of the birds monitored in 2015. A high frequency of intruding Yellow-billed Loons (Figure 10) and warm temperatures (>15 °C) likely contributed to their low nest attendance. An intruding loon was recorded at least 8 times on 3 different days, including the day of nest failure. The incubating loon left the nest on every occasion to interact with the intruder. In addition, the maximum daily temperature observed at Colville Village was >23 °C during 3 of the 4 days that the nest was monitored. During such warm temperatures, incubating loons have been seen gular fluttering (a primary means of evaporative cooling in birds) and rubbing their heads on their backs, presumably in response to mosquito harassment. Loons may be attempting to increase heat dissipation by leaving their nests and entering the water. On the day of nest failure, the incubating loon left its nest and 99 min later, a pair of jaegers landed at the nest for 19 min and took both eggs. The loon returned to its nest ~5 h later and briefly examined the nest before ending incubation.

Loons appear to flush from nests when bears are in the area, as opposed to bears preying on unattended nests. In one instance, a loon was incubating but quickly left the nest ~9 min before the appearance of a bear in the camera image. The

Figure 10. Digital time-lapse photos of a nesting Yellow-billed Loon fighting an intruding Yellow-billed Loon and a brown bear eating eggs from a Yellow-billed Loon nest, Colville Delta study area, Alaska, 2015.

bear was at the nest for ~1.5 min (Figure 10). The loon returned to examine the nest ~26 min after the bear left but did not resume incubation, suggesting that the bear took both eggs. On 6 other occasions (at 5 nests), bears were captured on images without depredating loon nests. Loons left nests on 5 of 6 occasions and did so when bears were an average of 332 m from nests (range 140–500 m). One loon did not leave its nest; the bear was on the opposite side of its nesting lake ~400 m from the nest.

Two of the 6 camera-monitored nests that failed were abandoned. One nest was abandoned on day 7 of incubation and the other on day 9. Intruding loons may have contributed to nest abandonment at both territories. Intruders were in camera view at 1 nest for ~9 min/d whereas at the other nest, they were on images an average of ~22 min/d, which is 4–10 times as long as intruders were present at other nests (mean = 2.0 ± 2.4 min/d, n = 8 nests). The eggs in 1 nest were scavenged by Glaucous Gulls 2 d after abandonment and the eggs in the other abandoned nest persisted for at least 6 d, after which we collected the time-lapse camera.

Camera images also documented brood loss at 1 nest. An intruding loon appeared at this nest 1 d after hatch. The intruder was recorded at least 10 times in less than 24 h. The brooding/incubating loon left the nest each time to interact with intruder. Images showed loons chasing one another and engaging in physical contact (see image from another nest in Figure 10). When the attending loon left the nest, the 1-day old chick was seen swimming alone. The pair was not observed feeding the chick after the intruder appeared. The attending loon swam away from the nest when the chick was 2 days old, and the chick was not seen again. The attending loon returned to the nest for several minutes after the chick was last seen but did not incubate or brood. Three Glaucous Gulls landed at the nest 6.5 h later and ate the remaining egg.

Intrusions into occupied territories were identified by the presence of >2 adults or by aggressive interactions between 2 Yellow-billed Loons. In most cases, the appearance of an intruding loon elicited defensive behaviors among the birds such as fencing, rushing, and physical contact (for descriptions, see Sjölander and Ågren [1976]). In 2015, intruders were seen at 83% of camera-monitored nests in the Colville Delta study area (10 of 12 nests). In all cases, the incubating loon left the nest to interact with the intruder. The proportion of monitored nests with intruders on camera images in 2015 was well above the mean percentage detected since 2010 (61 ± 6.1%, n = 6 years). Camera images, however, likely underestimate the frequency of occurrence of intruders because intruders may occur out of camera view. These interactions may reflect attempts at territorial takeover by the intruders. Territorial fights and subsequent takeovers have been observed in Common Loons (Piper et al. 2000), but it is unknown whether this behavior plays an important role in the establishment of Yellow-billed Loon territories (North 1994).

TUNDRA SWAN

DISTRIBUTION AND ABUNDANCE

Tundra Swan abundance was below normal, but measures of reproductive effort matched long-term values on the Colville Delta study area in 2015. During the swan nesting survey, 293 swans, including 103 pairs, were counted in the Colville Delta study area (Table 9). The total swan count in 2015 was much lower than the 22-year mean of 378 ± 31.6 swans found in the study area, but well within the range of counts previously recorded (range 208–749). The reduced number of swans in the study area can be attributed to the lowest number of swans ever observed in flocks (defined as 3 or more swans together); only 56 swans were in flocks in 2015, compared to the long-term mean of 204 ± 32.1 swans (range 56–604, n =22 years). In contrast, the number of pairs of swans was the third highest in 22 years, behind only 2011 (118 pairs) and 2012 (117 pairs), suggesting a high reproductive potential. Thirty-five swan nests were found in the Colville Delta study area in 2015 (Figure 11, Table 9), slightly above the 22-year mean of 34 ± 1.9 nests (range 14–55). Seventeen nests were located in the CD North subarea, 7 were in the CD South subarea, and 11 were in the Northeast Delta subarea. Fourteen additional swan nests were discovered during helicopter-based loon surveys of portions of the Colville Delta study area, but are not included in the nest count from the swan survey (Table 9) for consistency with data presentations from previous years.

Table 9. Number and density of Tundra Swans, pairs, and nests during nesting, Colville Delta study area, Alaska, 1992–2015.

				Density[a]		
Year	No. Adults	No. Pairs	No. Nests	Adults/km²	Pairs/km²	Nests/km²
1992	249	42	14	0.45	0.08	0.03
1993	223	56	17	0.40	0.10	0.04
1995	208	67	38	0.38	0.12	0.07
1996	579	60	45	1.05	0.11	0.08
1997	749	63	32	1.36	0.11	0.06
1998	714	84	31	1.30	0.15	0.06
2000	365	75	32	0.66	0.14	0.06
2001	312	75	27	0.57	0.14	0.05
2002	280	97	55	0.51	0.18	0.10
2003	354	87	43	0.64	0.16	0.08
2004	228	59	37	0.41	0.11	0.07
2005	259	61	35	0.47	0.11	0.06
2006	279	55	29	0.51	0.10	0.05
2007	463	84	42	0.84	0.15	0.08
2008	411	90	36	0.74	0.16	0.07
2009	389	97	40	0.70	0.18	0.07
2010	373	91	25	0.68	0.16	0.04
2011	362	118	35	0.66	0.21	0.06
2012	505	117	40	0.91	0.21	0.07
2013	306	88	39	0.55	0.16	0.07
2014	413	99	23	0.75	0.18	0.04
2015	293	103	35	0.53	0.19	0.06
Mean	378	80	34	0.69	0.15	0.06
SE	31.6	4.4	1.9	0.06	0.01	<0.01

[a] Area surveyed = 552.2 km².

The number of adult swans recorded during nesting is highly variable and not apparently changing over time (ln(adults) = 0.004 (year) – 1.84, R^2 = 0.006, P = 0.74). The lack of trend can be attributed to the large fluctuations in the number of swans occurring in flocks on the delta. In contrast, the number of pairs of swans has grown at 3% annually (ln(pairs) = 0.029 (year) – 54.54, R^2 = 0.572, P < 0.001), indicating a steady increase in the reproductive component of the population. The number of nests has not increased at the same rate (ln(nests) = 0.012 (year) – 21.29, R^2 = 0.083, P = 0.19). The number of Tundra Swans recorded on the Arctic Coastal Plain during spring surveys has been growing annually at 4.6% (Stehn et al. 2013), which is similar to the trend in swan pairs on the Colville Delta study area.

HABITAT USE

Habitat selection was evaluated for 752 Tundra Swan nests recorded on the Colville Delta study area since 1992 (Table 10). Although some nest sites were used in multiple years (and thus not annually independent locations), we cannot 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

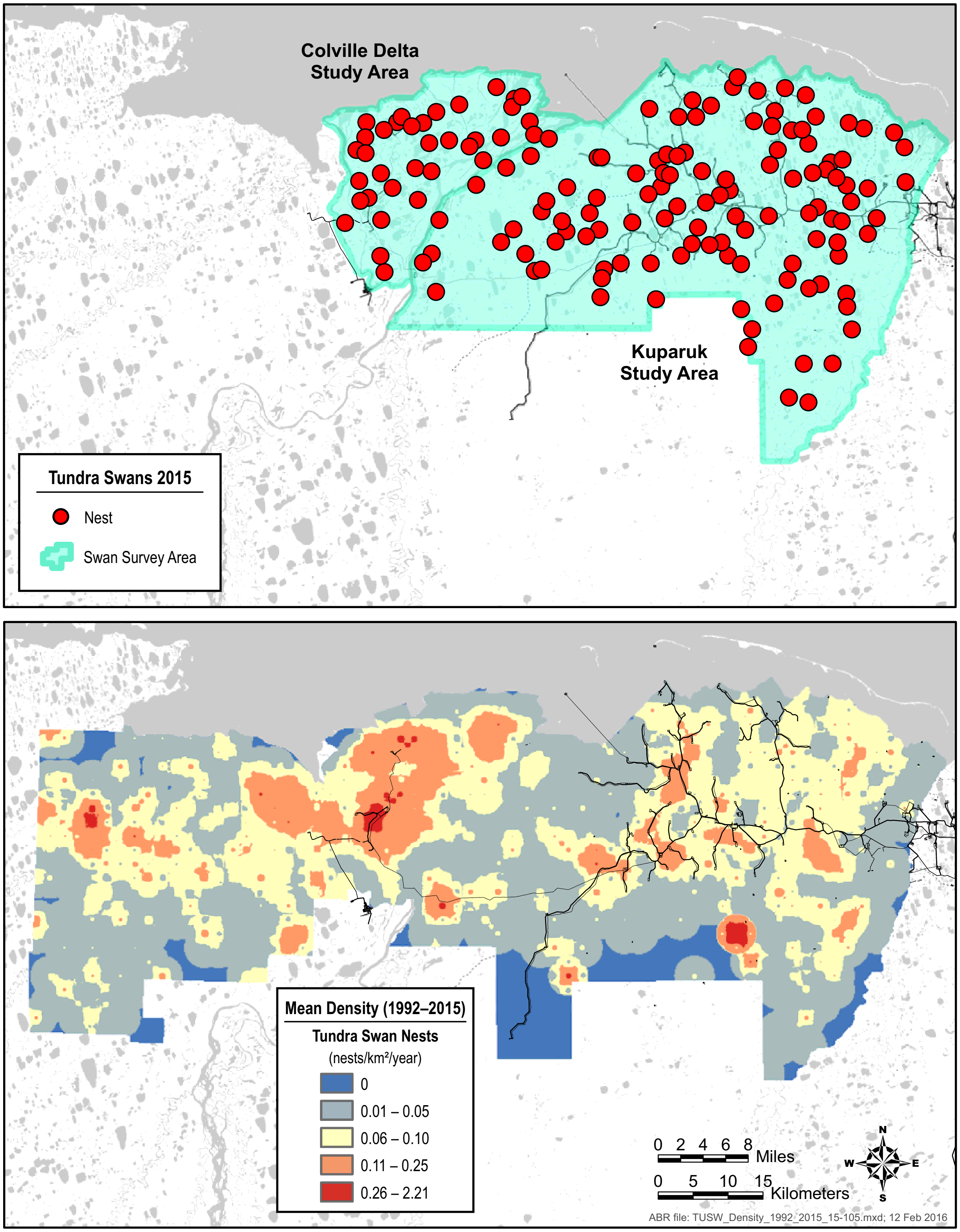

Figure 11. Tundra Swan nest locations in 2015 (top) and mean density distribution of nests in the Kuparuk, Colville Delta, and NE-NPR-A study areas, 1992–2015 (bottom). Kuparuk data from Morgan et al. (2016). NE NPR-A data only through 2014.

Table 10. Habitat selection by nesting Tundra Swans, Colville Delta study area, Alaska, 1992, 1993, 1995–1998, and 2000–2015.

Habitat	No. of Nests	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
Open Nearshore Water	0	0.0	1.8	avoid	
Brackish Water	11	1.5	1.2	ns	
Tapped Lake with Low-water Connection	2	0.3	4.0	avoid	
Tapped Lake with High-water Connection	8	1.1	3.7	avoid	
Salt Marsh	43	5.7	3.0	prefer	
Tidal Flat Barrens	8	1.1	10.6	avoid	
Salt-killed Tundra	81	10.8	4.6	prefer	
Deep Open Water without Islands	19	2.5	3.3	ns	
Deep Open Water with Islands or Polygonized Margins	47	6.3	1.9	prefer	
Shallow Open Water without Islands	5	0.7	0.4	ns	low
Shallow Open Water with Islands or Polygonized Margins	2	0.3	0.1	ns	low
River or Stream	1	0.1	15.0	avoid	
Sedge Marsh	3	0.4	<0.1	prefer	low
Deep Polygon Complex	103	13.7	2.4	prefer	
Grass Marsh	17	2.3	0.3	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	55	7.3	7.5	ns	
Patterned Wet Meadow	275	36.6	18.5	prefer	
Moist Sedge-Shrub Meadow	34	4.5	2.2	prefer	
Moist Tussock Tundra	9	1.2	0.6	ns	low
Tall, Low, or Dwarf Shrub	12	1.6	5.0	avoid	
Barrens	17	2.3	13.8	avoid	
Human Modified	0	0.0	0.1	ns	low
Total	752	100	100		

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

conducted. Previous investigations have reported that 21–49% of swan nests are located on mounds used during the previous year (Hawkins 1986, Monda et al. 1994) and that nest sites reused from previous years were slightly more successful than new nest sites (Monda et al. 1994). Therefore, deletion of multi-year nest sites from selection analysis could bias the results towards habitats used by less experienced or less successful pairs. Instead, we have chosen to include all nest sites, while recognizing that all locations may not be annually independent.

Tundra Swans on the Colville Delta study area used a wide range of habitats for nesting. Over 22 years of surveys, Tundra Swans nested in 20 of 24 available habitats, of which 8 habitats were preferred and 7 were avoided (Table 10). Eighty percent of the nests were found in the preferred habitats: Salt Marsh, Salt-killed Tundra, Deep Open Water with Islands or Polygonized Margins, Sedge Marsh, Grass Marsh, Deep Polygon Complex, Patterned Wet Meadow, and Moist Sedge-Shrub Meadow. Nests occurred most frequently in Patterned Wet Meadow (37% of all nests), Deep Polygon Complex (14%), and Salt-killed Tundra (11%).

GULLS

DISTRIBUTION AND ABUNDANCE

The count of Glaucous Gull nests on the Colville Delta study area in 2015 was the second highest in 14 years of surveys. We recorded 83 Glaucous Gull nests during the aerial survey for nesting loons; 49 of those nests were in the CD North subarea, 31 nests in the CD South subarea, and 3 nests in the Northeast Delta subarea (Figure 12). The number of Glaucous Gull colonies in 2015 increased to 6 with the addition of a 3-nest colony ~2 km north of the CD-2 drill pad. The largest of the 6 colonies contained 15 nests and was located ~6 km northeast of the CD-4 drill pad. The

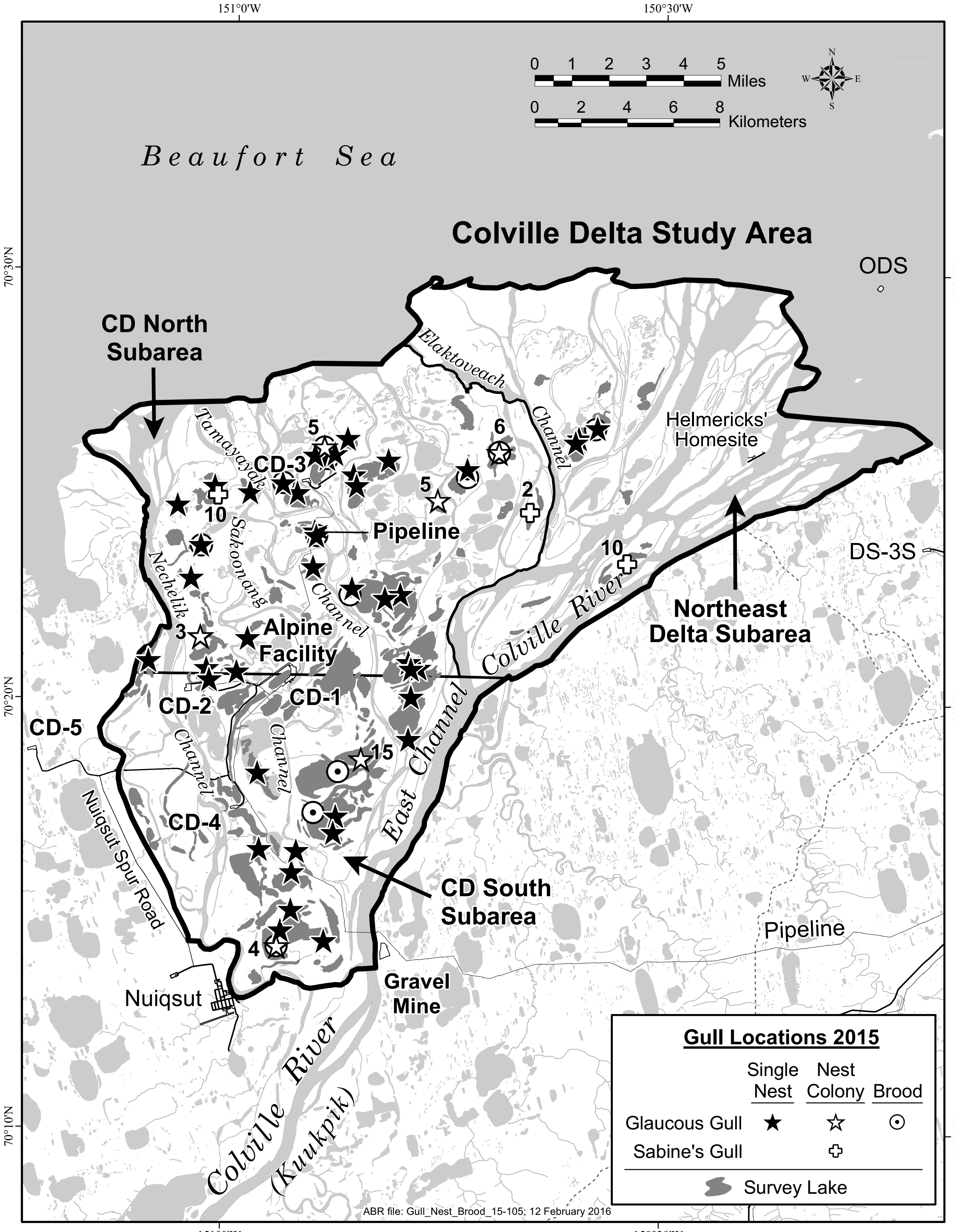

Figure 12. Glaucous and Sabine's gull nests and broods, Colville Delta study area, Alaska, 2015. Numbers of nests are listed for colony locations.

maximum number of nests we have seen at this colony over 14 years of monitoring was 23 nests in 2013 (Table 11). Other colonies in the Colville Delta study area include 2 with 5–6 nests in the northeastern part of the CD North subarea, 1 with 5 nests ~1.7 km north of the CD-3 drill pad, and 1 with 4 nests ~5 km south of the CD-4 drill pad (Figure 12). Glaucous Gull colonies are not common in the study area; only 14% of the 42 waterbodies occupied by nesting gulls held a colony in 2015.

For the past 14 years, numbers of Glaucous Gull nests have increased on the 50 index lakes that are monitored annually during the aerial survey for nesting loons in the Colville Delta study area (Figure 12, Table 11). Counts of Glaucous Gull nests at the index lakes have ranged from 28 to 63 nests. In 2015, 60 nests were found on 27 index lakes. The annual growth rate for nests on the index lakes is 5%, (ln(nests) = 0.054 (year) – 103.92, $R^2 = 0.745$, $P = <0.001$). The percentage of index lakes occupied by gull nests also has increased from 28 to 54% over the survey period. Three lakes were occupied in 2015 for the first time in the 14-year survey. New lakes were colonized by single nests in 2015, which is the typical pattern of expansion. Gull nests were not evenly distributed among lakes. The 4 colonies among the 50 index lakes contained 50% of nests (30 nests) but occupied only 8% of the lakes (4 lakes).

In 2015, 15 groups of Glaucous Gulls with young were recorded on 11 waterbodies in the Colville Delta study area during the survey for brood-rearing loons (Figure 12). Broods totaled 23 adults and 34 young. The majority of the young

Table 11. Number of Glaucous Gull nests recorded during aerial surveys for nesting loons on 50 index lakes, Colville Delta study area, Alaska, 2002–2015.

Year	Number of Nests: CD North Subarea[a]	CD South Subarea[b]	Northeast Delta Subarea	Total	No. of Lakes with Nests[c]
2002	11 (2, 1)	24 (18)	1	36	15
2003	11 (1, 1)	17 (14)	0	28	14
2004	19 (7, 1)	17 (13)	0	36	16
2005	18 (5, 1)	22 (15)	0	40	19
2006	15 (4, 1)	21 (16)	1	37	19
2007	16 (5, 1)	21 (13)	2	39	19
2008	19 (5, 1)	26 (18)	2	47	22
2009	17 (6, 1)	27 (19)	2	46	21
2010	17 (5, 2)	16 (6)	2	35	21
2011	17 (5, 2)	36 (17)	2	55	24
2012	26 (7, 5)	34 (17)	2	62	28
2013	19 (5, 4)	35 (23)	3	57	22
2014	27 (6, 5)	34 (18, 3)	2	63	27
2015	29 (6, 5)	29 (15, 4)	2	60	27
Mean	18.6	25.6	1.5	45.8	21
SE	1.4	1.9	0.3	3.1	1.2

[a] First number in parentheses is the number of nests at the colony site in the northeastern part of the CD North subarea and second number is the number of nests at the site north of the CD-3 drill pad (see Figure 12).
[b] First number in parentheses is the number of nests at the colony site northeast of CD-4 drill pad and second number is the number of nests at site south of CD-4 drill pad (see Figure 12).
[c] Of 50 lakes monitored annually for the presence of Glaucous Gull nests, 2 occur in the Northeast Delta subarea, 20 in the CD South subarea, and 28 in the CD North subarea.

were found in colonies. Ten young were observed at the colony site in the northeastern part of the CD North subarea, 4 young at the colony site north of the CD-3 drill pad, and 7 young at the most southern colony site south of the CD-4 drill pad. Young from some nests were flight capable at the time of the loon survey and may have moved away from nest sites. For a second year in a row, no broods were observed at the colony northeast of the CD-4 drill pad, even though adults were still present at this site in August. Brown bears are likely the cause of nest failure at this colony. Brown bears were observed on time-lapse camera images taken at loon nests on this lake in 2014 and on a neighboring lake in 2015.

HABITAT USE

Glaucous Gull nests and colonies were found in 9 different habitats in the Colville Delta study area (Table 12). The 4 most commonly used habitats also contained colonies: Deep Open Water with Islands or Polygonized Margins (37% of nests), Patterned Wet Meadow (19%), Tapped Lake with High-water Connection (16%), and Grass Marsh (11%). The largest Glaucous Gull colony (15 nests) was located on a large island classified as Patterned Wet Meadow. The remaining nests were found on islands or complex shorelines in 5 other habitats.

Table 12. Habitat use by nesting Glaucous Gulls, Colville Delta study area, Alaska, 2015.

Habitat	Nests	Use (%)
Brackish Water	1	1.2
Tapped Lake with High-water Connection	13	15.7
Deep Open Water without Islands	3	3.6
Deep Open Water with Islands or Polygonized Margins	31	37.3
Shallow Open Water with Islands or Polygonized Margins	2	2.4
Deep Polygon Complex	1	1.2
Grass Marsh	9	10.8
Nonpatterned Wet Meadow	7	8.4
Patterned Wet Meadow	16	19.3
Total	83	100

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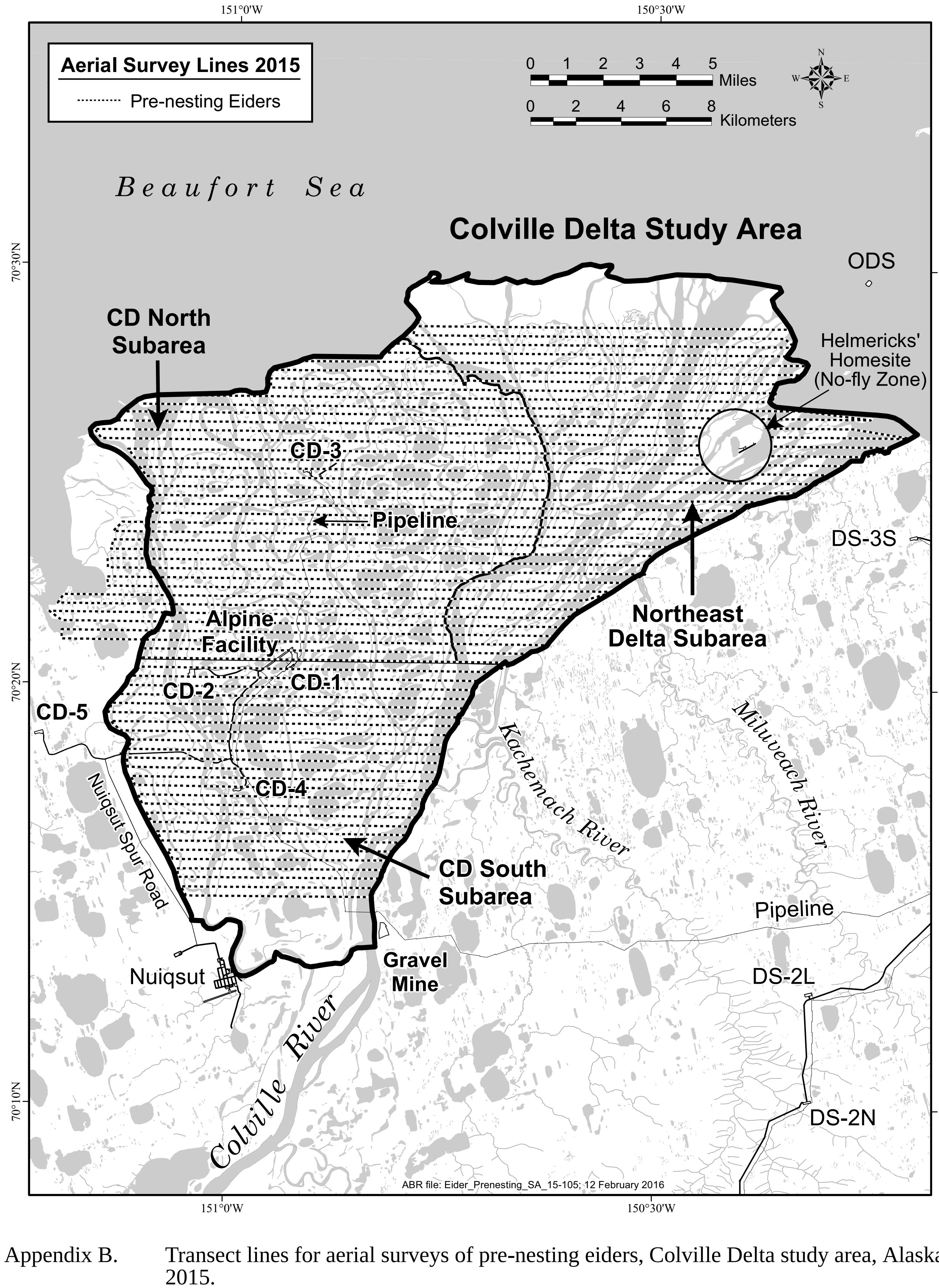
PERSONAL COMMUNICATIONS

Issac Helmericks (via A. Stickney), Kuparuk airport manager—Kuparuk Oilfield, AK.

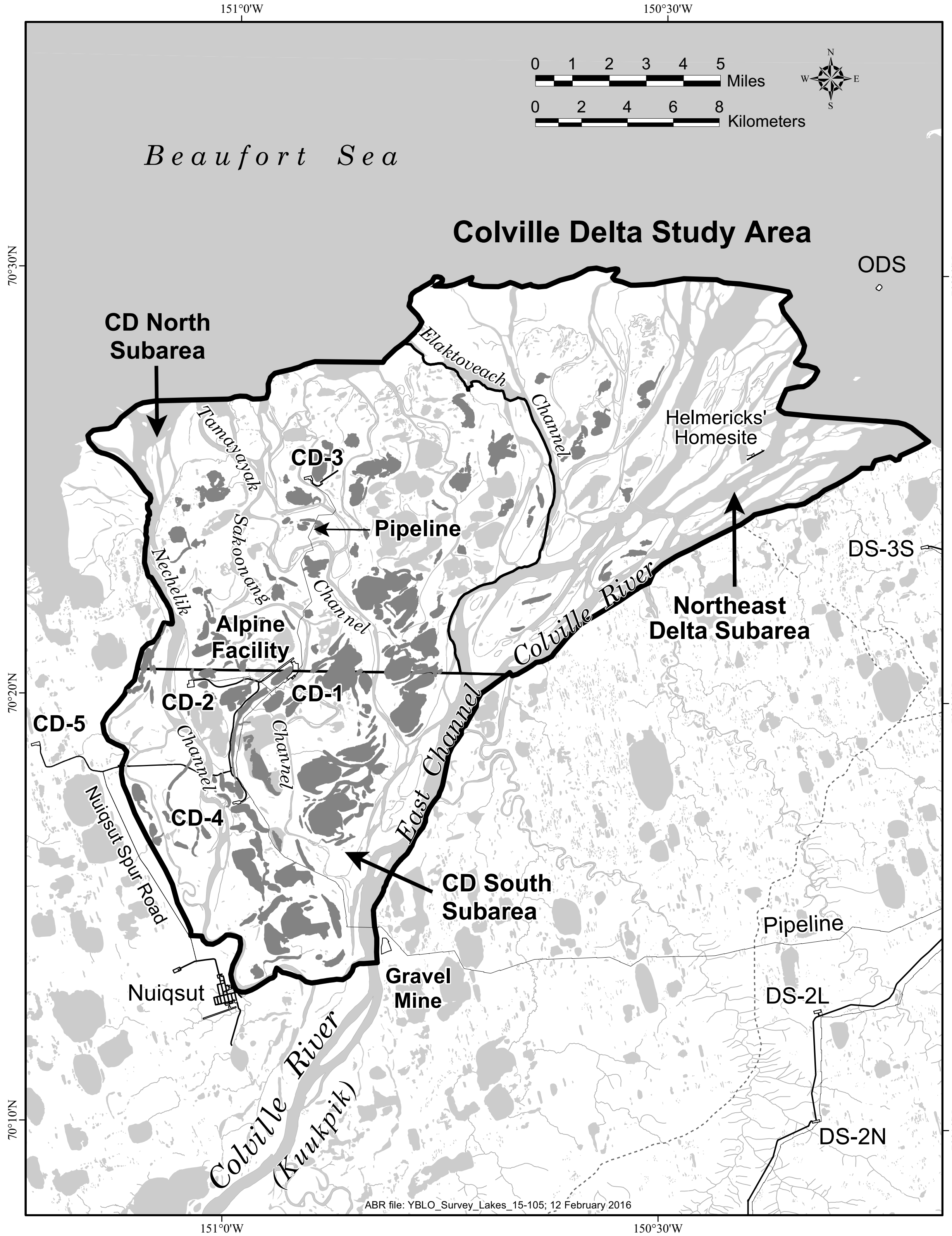
Jonathan Bart, U.S. Geological Survey Forest and Rangeland Ecosystem Science Center, Boise, ID.

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

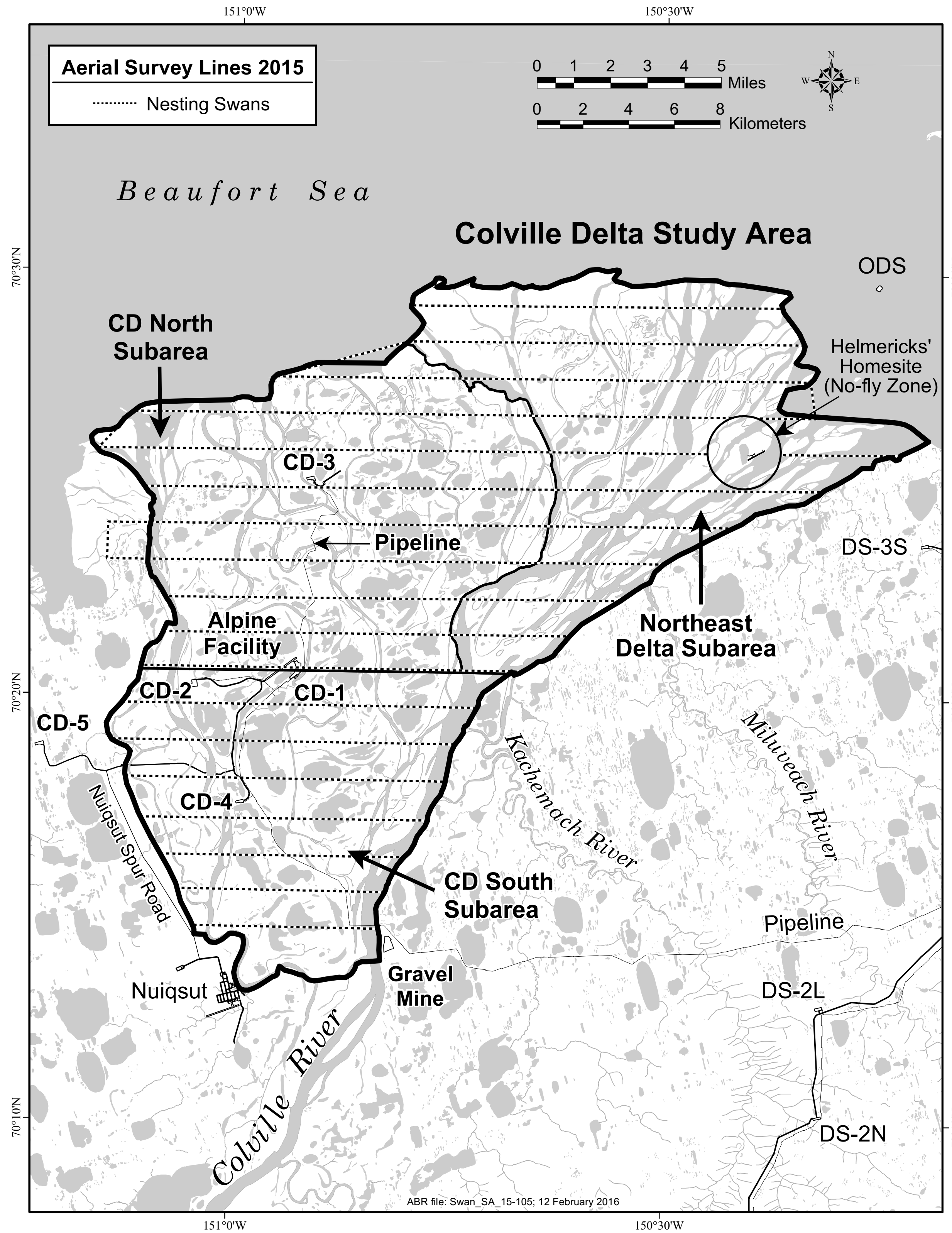
Common Name	Inupiaq Name	Scientific Name
Birds		
Snow Goose	Kaŋuq	*Chen caerulescens*
Brant	Niġlinġaq	*Branta bernicla*
Cackling Goose/Canada Goose	Iqsraġutilik	*Branta hutchinsii/B. canadensis*
Greater White-fronted Goose	Niġliviq	*Anser albifrons*
Tundra Swan	Qugruk	*Cygnus columbianus*
Northern Pintail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



Appendix B. Transect lines for aerial surveys of pre-nesting eiders, Colville Delta study area, Alaska, 2015.



Appendix C. Lakes included in aerial surveys for Yellow-billed Loons, Colville Delta study area, Alaska, 2015.



Appendix D. Transect lines for aerial surveys of nesting Tundra Swans, Colville Delta study area, Alaska, 2015.

Appendix E. Number and density (birds/km²) of eiders during pre-nesting aerial surveys, Colville Delta study area, Alaska, 2015.

SPECIES Subarea Location	Observed				Indicated Total[a]	Observed Density[b]	Indicated Density[a, b]
	Males	Females	Total	Pairs			
SPECTACLED EIDER							
CD North							
On ground	26	14	40	14	52	0.19	0.25
In flight	12	6	18	6	–	0.09	–
All birds	38	20	58	20	–	0.28	–
Northeast Delta							
On ground	1	0	1	0	2	0.01	0.01
In flight	0	0	0	0	–	0	–
All birds	1	0	1	0	–	0.01	–
CD South							
On ground	0	0	0	0	0	0	0
In flight	0	0	0	0	–	0	–
All birds	0	0	0	0	–	0	–
Total (subareas combined)							
On ground	27	14	41	14	54	0.08	0.11
In flight	12	6	18	6		0.04	–
All birds	39	20	59	20		0.12	–
KING EIDER							
CD North							
On ground	9	7	16	7	18	0.08	0.09
In flight	12	5	17	5	–	0.08	–
All birds	21	12	33	12	–	0.16	–
Northeast Delta							
On ground	9	7	16	7	18	0.10	0.11
In flight	1	1	2	1	–	0.01	–
All birds	10	8	18	8	–	0.11	–
CD South							
On ground	3	2	5	2	6	0.04	0.04
In flight	1	0	1	0	–	0.01	–
All birds	4	2	6	2	–	0.04	–
Total (subareas combined)							
On ground	21	16	37	16	42	0.07	0.08
In flight	14	6	20	6		0.04	–
All birds	35	22	57	22		0.11	–

[a] Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987a).
[b] Density based on 100% coverage of subareas: CD North = 206.7 km²; Northeast Delta = 157.6 km², CD South = 137.2 km², all subareas combined = 501.4 km²; numbers not corrected for sightability.

Appendix F. Number and density of loons and their nests, broods, and young during aerial surveys, Colville Delta study area, Alaska, 2015.

	Yellow-billed Loon					Pacific Loon[a]			Red-throated Loon[a]		
STUDY AREA	Number			Density (number/km²)		Number			Number		
Subarea[b] Survey Type	Adults	Nests/ Brood	Young	Adults	Nests/ Broods	Adults	Nests/ Broods	Young	Adults	Nests/ Broods	Young
COLVILLE DELTA											
CD North											
Nesting	32	13[c]	–	0.15	0.06	138	12	–	22	0	–
Brood-rearing	27	6[d]	6	0.13	0.03	128	33	39	21	5	7
CD South											
Nesting	26	10[e]	–	0.17	0.06	87	3	–	31	0	–
Brood-rearing	29	4	5	0.19	0.03	54	12	14	10	1	2
Northeast Delta[f]											
Nesting	5	2[c]	–	0.03	–	21	1	–	12	1	–
Brood-rearing	2	0	0	0.01	–	29	6	6	5	1	2
Total (subareas combined)[g]											
Nesting	63	25	–	0.16	0.06	246	16	–	65	1	–
Brood-rearing	58	10	11	0.15	0.03	211	51	59	36	7	11

[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; see Figure 7.
[c] Number includes 1 nest found after the nesting survey during retrieval and deployment of time-lapse cameras.
[d] Number includes 1 brood (assume 1 young) determined only by eggshell evidence and camera images.
[e] Number includes 2 nests found during the brood-rearing survey and 1 nest inferred from the presence of a brood.
[f] Densities were not calculated for the Northeast Delta subarea because only a portion of the subarea was surveyed.
[g] Total is the sum of all subareas but density calculations included only CD North and CD South for Colville Delta.

Appendix G. Annual density (number/km²) of Yellow-billed Loons, nests, and broods in the CD North and South subareas, Colville Delta study area, Alaska, 1993–2015.

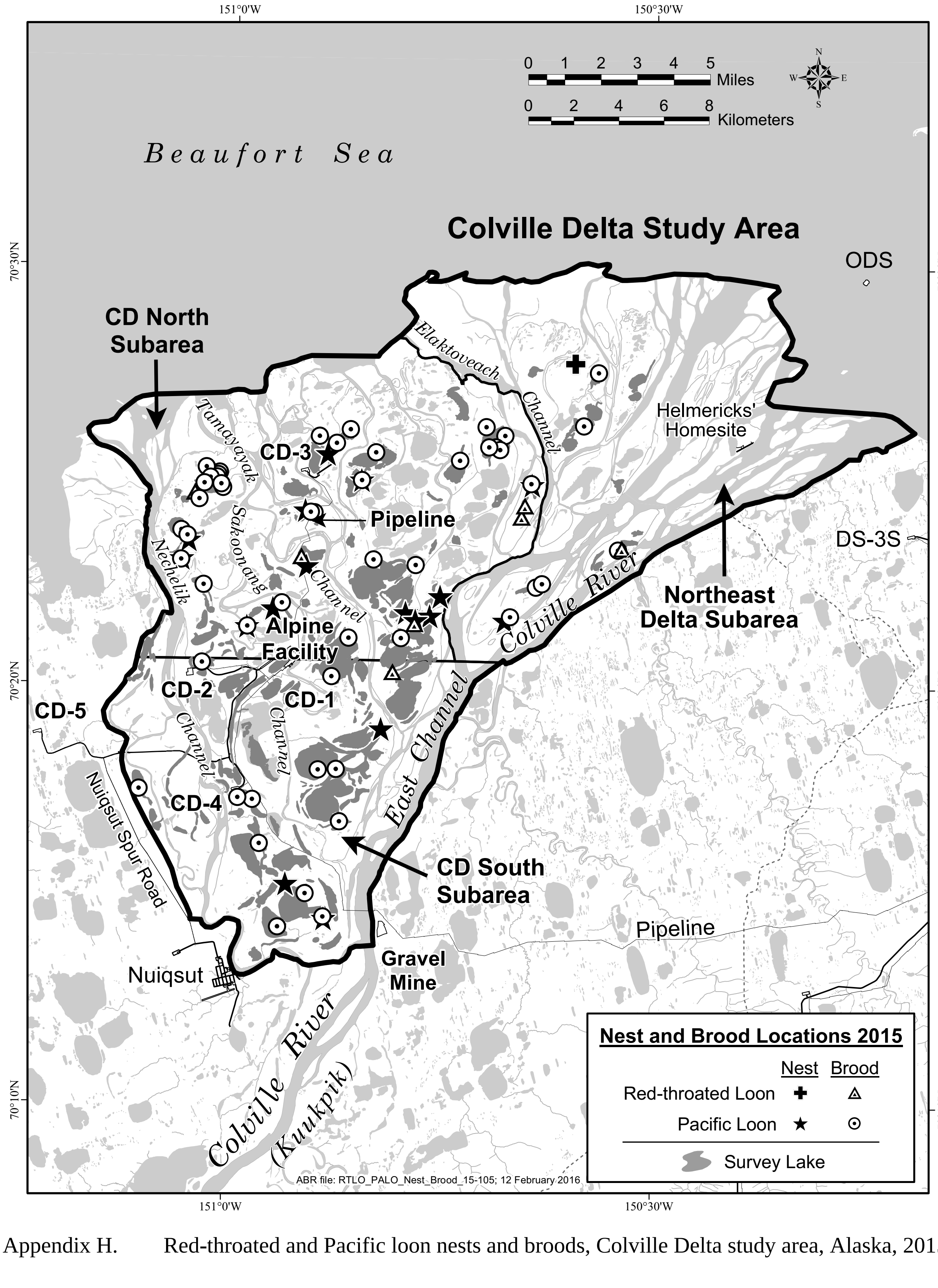
STUDY AREA Year	Nesting Survey Adults	Nests[a]	Brood-rearing Survey Adults	Broods[b]
COLVILLE DELTA[c]				
1993	0.14	0.02 (0.04)	0.08	0.02
1995	0.11	0.03 (0.05)	0.14	0.02
1996	0.12	0.03 (0.05)	0.17	0.02
1997	0.13	0.03 (0.04)	0.18	0.01
1998	0.09	0.04 (0.06)	0.14	0.03
2000	0.15	0.04 (0.04)	0.04	0.01
2001	0.15	0.05 (0.05)	0.07	0.01
2002	0.13	0.05 (0.06)	0.18	0.02
2003	0.14	0.07 (0.07)	0.13	0.04
2004	0.11	0.07 (0.07)	0.14	0.03
2005	0.15	0.08 (0.08)	0.10	0.04 (0.05)
2006	0.17	0.06 (0.07)	0.18	0.03 (0.04)
2007	0.17	0.07 (0.08)	0.14	0.05 (0.06)
2008	0.18	0.09 (0.10)	0.15	0.06 (0.07)
2009	0.17	0.07 (0.08)	0.15	0.02 (0.03)
2010	0.18	0.06 (0.09)	0.16	0.04 (0.04)
2011	0.19	0.06 (0.07)	0.12	0.03 (0.04)
2012	0.15	0.06 (0.08)	0.14	0.03 (0.04)
2013	0.18	0.03 (0.04)	0.11	0.02 (0.02)
2014	0.22	0.07 (0.09)	0.13	0.01 (0.02)
2015	0.16	0.05 (0.06)	0.15	0.02 (0.03)
Mean	0.15	0.05 (0.08)[d]	0.13	0.03 (0.04)
SE	<0.01	<0.01 (<0.01)[d]	<0.01	<0.01 (<0.01)

[a] Density of nests found on the nesting survey and, in parentheses, cumulative density including additional nests found during revisit (1996–2002), monitoring (2006–2014), and early nest surveys (2011, 2012, 2014), early camera monitoring (2013–2015), and nests inferred from the presence of broods where no nest was found during other surveys (1993–2015).

[b] Density of broods found on the brood-rearing survey and, in parentheses, cumulative density including additional broods found during monitoring surveys (2005–2014) or inferred from eggshell fragments at the nest (2008–2015).

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

[d] Mean density and SE with additional nests and broods includes only years when monitoring surveys were conducted: 2006–2014 for nests, 2005–2014 for broods.



Appendix H. Red-throated and Pacific loon nests and broods, Colville Delta study area, Alaska, 2015.

Appendix I. Nest history and incubation activity of Yellow-billed Loon nests monitored by time-lapse digital cameras, Colville Delta study area, Alaska, 2008–2015.

	Median				Mean				
STUDY AREA/ Year/ Fate	Start of Incubation	*n*	Hatch or Failure	*n*	Incubation Constancy[a] (%)	Exchange Frequency[a] (no/d)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)	*n*
COLVILLE DELTA									
2008									
Hatched	10 June	10	8 July	9	97.1 ± 0.7	1.1 ± 0.1	2.1 ± 0.3	17.1 ± 2.2	9
Failed	11 June	3	29 June	3	98.5 ± 1.0	2.1 ± 0.2	1.4 ± 0.4	13.0 ± 6.5	3
2009									
Hatched	11 June	9	9 July	9	98.2 ± 0.4	1.5 ± 0.2	1.7 ± 0.4	12.6 ± 1.6	9
Failed	10 June	6	29 June	7	95.7 ± 2.2	1.5 ± 0.5	2.5 ± 1.0	14.6 ± 5.9	4
2010									
Hatched	19 June	9	16 July	7	98.0 ± 0.2	1.8 ± 0.1	2.6 ± 0.2	10.0 ± 0.8	9
Failed	21 June	10	6 July	9	89.8 ± 3.9	1.6 ± 0.3	5.0 ± 0.7	34.9 ± 17.1	9
2011									
Hatched	15 June	13	13 July	13	98.0 ± 0.3	1.5 ± 0.1	2.6 ± 0.3	10.2 ± 1.0	13
Failed	19 June	7	4 July	7	93.1 ± 2.2	1.3 ± 0.2	5.0 ± 1.0	24.0 ± 8.1	6
2012									
Hatched	14 June	11	12 July	9	97.6 ± 0.5	1.6 ± 0.2	2.8 ± 0.3	10.6 ± 1.2	10
Failed	14 June	8	29 June	8	95.9 ± 1.8	1.7 ± 0.4	4.5 ± 1.6	12.0 ± 1.9	6
2013									
Hatched	17 June	4	16 July	3	92.8 ± 1.2	1.0 ± 0.2	4.5 ± 0.3	23.3 ± 5.0	4
Failed	17 June	8	27 June	8	87.2 ± 3.6	1.2 ± 0.3	4.4 ± 0.6	77.8 ± 18.7	9
2014									
Hatched	16 June	8	13 July	8	96.8 ± 0.7	1.6 ± 0.1	2.5 ± 0.3	12.8 ± 2.8	6
Failed	19 June	13	2 July	13	95.2 ± 0.6	1.8 ± 0.2	4.6 ± 0.5	14.7 ± 1.3	11
2015									
Hatched	8 June	6	6 July	6	95.1 ± 1.0	1.3 ± 0.3	3.8 ± 0.4	16.6 ± 2.8	6
Failed	15 June	6	24 June	6	73.9 ± 8.1	1.5 ± 0.1	8.7 ± 1.4	35.5 ± 8.3	6

Appendix I. Continued.

STUDY AREA/ Year/ Fate	Median				Mean				
	Start of Incubation	*n*	Hatch or Failure	*n*	Incubation Constancy[a] (%)	Exchange Frequency[a] (no/d)	Recess Frequency[a] (no/d)	Recess Length[a] (min/recess)	*n*
Total									
Hatched	14 June[b]	9	12 July[b]	9	97.2 ± 0.3	1.5 ± 0.1	2.6 ± 0.1	13.1 ± 0.8	66
Failed	16 June[b]	9	29 June[b]	9	90.7 ± 1.5	1.5 ± 0.1	4.8 ± 0.4	31.5 ± 5.2	54

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