KING EIDER STUDIES FOR THE GREATER MOOSES TOOTH PROJECT, NATIONAL PETROLEUM RESERVE-ALASKA, 2020

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Prepared for

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COVER
ABR biologist Kristen Rozell setting up camera on King Eider nest for the Greater Mooses Tooth project, 2020. Inset: King Eider pair. Photograph by ABR.

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EXECUTIVE SUMMARY

- In 2020, ABR initiated the first year of a 5-year study focused on King Eiders (*Somateria spectabilis*) in 2 new oil developments in support of GMT rezone stipulations. We conducted pre-nesting aerial surveys for King and Spectacled eiders (*Somateria fischeri*), and searched for King Eider nests on the ground, with the goal of evaluating the effects of the 3 phases of development on the abundance, distribution, habitat use, and nesting success of King Eiders in the GMT and Willow development areas.
- Pre-nesting eider surveys were flown in early June along pre-determined transect lines with a small, fixed-wing aircraft. Ground-based nest searches were conducted in mid-June and the fate of nests were determined in July.
- Spring conditions in 2020 had above average snow depth through most of May, with rapid melt in late May that occurred almost a week earlier than the long-term mean recorded at Alpine. The Colville River experienced a short duration, high magnitude flood event due to ice jams which breached banks and inundated surrounding lowlands.
- We recorded 157 observed and 120 indicated total King Eiders during pre-nesting aerial surveys; the indicated density was below the long-term average for the NPR-A, however the 2020 study area does not include the high-density areas to the north that were surveyed previously. King Eiders in the NPR-A study area have had an annual growth rate of 9% over a 15-year period (1999–2014).
- We observed no Spectacled Eiders during aerial surveys; the lowest density since surveys began in 1999. Spectacled Eiders are infrequently observed in the NE NPR-A, especially in the inland GMT and Willow areas. The population trend for Spectacled Eiders has been stable over the 27 years that ABR and others have monitored them on the Arctic Coastal Plain (ACP).
- Pre-nesting King Eiders used 17 of 26 available habitats during 19 years of aerial surveys in the NPR-A. There were 11 preferred habitats, 5 avoided habitats and 10 that were used in proportion to their availability.
- For the nesting study, we used temperature-sensing eggs and cameras to examine nest attendance patterns of King Eiders and identify causes of nest disturbance or failure. We monitored human disturbance (traffic) using time-lapse cameras on the GMT2 road. We also quantified potential nest predators and assessed the abundance of small mammals on plots, because of their relationship to productivity and success of nests on the North Slope of Alaska.
- We found 8 King Eider nests; 5 of these nests were in the GMT treatment site and 3 were in the Willow reference site. The nesting density of King Eiders was 3.1 nests/km² in the GMT treatment site and 2.9 nests/km² in the Willow reference site. No King Eider nests were found in GMT reference or Willow treatment sites. King Eiders nested in 2 of the 11 available wildlife habitats in our study areas.
- Incubation constancy was 98.4 ± 0.4% (n = 3 nests) for successful nests and 95.7 ± 3.0% (n = 2 nests) for nests that failed. Females took 1 ± 0.2 recesses/day at successful nests (n = 3 nests) and 1.7 ± 0.6 recesses/ day at nests that failed (n = 2 nests). Sample sizes were too small to compare incubation constancy between control and treatment sites.
- Four of 5 eider nests in the GMT treatment site failed, all from predation. Two nests failed following predation by Common Ravens that appeared to force females from their nests. Of the 3 nests in the Willow reference site, only 1 nest failed from abandonment. The probability of any nest surviving the entire nesting period of 27 days (23 days incubation and 4 days laying) was 0.22 ± 0.1.
- The proportion of avian predators observed in GMT and Willow study areas was similar. No mammal predators were recorded on predator scans at either site or recorded incidentally. The abundance of small mammals on plots was much lower in 2020 than the previous summer when peak numbers were recorded.

- In our first year observing possible effects of disturbance on nesting King Eiders, small sample sizes limited the power of statistical analyses and inferences from our results. In subsequent years of this study, and with more nests, we will evaluate disturbance and other factors affecting nesting King Eiders

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ACKNOWLEDGMENTS

Aerial surveys and nest searches in the GMT and Willow study areas of NE NPR-A could not have occurred without the assistance of many people, both in the field and in the office. Soloy helicopter pilots Zach Russell, Cody Prudden, and Jimmy Finney skillfully piloted us to and from nest plots that were not road accessible. On the ground, Zac Hobbs and Darren McGrevy coordinated the helicopter flights and kept us on schedule. Robert McNown and Brian Houseman of ABR spent long hours walking the tundra in search of eider nests, and Gustavo Fejervary (CPAI) assisted with checking nest fates and retrieving cameras. In our Fairbanks office, Dorte Dissing and Pam Odom provided expert support in figure and report preparation. Chris Swingley and Brian Houseman helped manage and analyze our data. Kelly Lawhead spent many hours viewing photos from our eider and traffic cameras. Logistics were handled by Pam Odom and Tony LaCortiglia, and Will Lentz supported our electronic equipment. We thank all the ConocoPhillips Alaska staff and contractors at the Alpine Oilfield for providing a safe and welcoming work environment, especially field coordinators Mike Hauser and Ari Haunschild. This study was funded by ConocoPhillips Alaska, Inc., and was administered by Christina Pohl, Robyn McGhee and Jasmine Woodland for ConocoPhillips Alaska, Inc. We thank everyone for making 2020 a successful year of field studies in the NE NPR-A despite the coronavirus-related challenges of this year.

INTRODUCTION

The 2 westernmost oil developments in the Northeast Planning Area of the National Petroleum Reserve in Alaska (NE NPR-A) are at different stages of construction by ConocoPhillips Alaska, Inc., (CPAI). The development called GMT2/MT7 is currently under construction and consists of a drill pad and all-season gravel road connected to the Alpine Facility on the Colville River, where oil will be processed. The Willow development, by contrast, is still in the planning stages, but will have as many as 5 drill pads and its own processing facility. The Willow development area will be located to the southwest of GMT2/MT7 and will be connected to the GMT2/MT7 drill pad by a gravel road. Wildlife surveys for selected birds and mammals in the Colville River delta and NE NPR-A have been conducted since 1992 in support of the Alpine Satellite Development Project (ASDP). For a review of previous studies conducted in the area see Johnson et al. (2015, 2016, 2018, 2019) and for 2019–2020 studies in the Willow project (Shook et al. 2020 and Parrett and Shook 2021) and Kuparuk areas (Attanas and Shook 2020).

Qiŋalik, the Iñupiaq name for King Eider (*Somateria spectabilis*), is a sea duck with a breeding range spanning the Arctic Coastal Plain, and a subsistence species for local Iñupiaq people (Appendix A). At the request of the North Slope Borough (NSB), CPAI is conducting a multi-year study focused on King Eider to address possible effects of development on their breeding biology and behavior. ABR was contracted in 2020 to conduct this study. The study design for this project was approved by the NSB and includes aerial surveys of pre-nesting eiders to investigate broad-scale distribution and abundance, and ground-based nest monitoring on plots to investigate habitat use, nest density, and nest survival. The occurrence of Qavaasuk–Spectacled Eider (*Somateria fischeri*) in the study area will also be recorded in pre-nesting and nesting surveys due to their importance as a federally listed “threatened” species. For the Willow development, the study design will include 1 year of pre-development data collection near proposed Willow infrastructure, 2 years of construction, and 2 years of operation, depending on construction scheduling. The goal of the study is to evaluate the effects of the 3 phases of development on the abundance, distribution, habitat use, and nesting success of King Eiders in the GMT and Willow development areas. The 4 primary objectives of the 5-year study are:

- describe annual patterns in distribution and abundance of pre-nesting eiders near and far from infrastructure
- determine the effects of construction period, distance to infrastructure, and habitat on incubation behavior and nest survival
- identify the primary causes of nest failure for eiders
- evaluate changes in the frequency of occurrence of nest predators among construction periods

In this report, we present the first year of results of the King and Spectacled Eider pre-nesting survey in the GMT and Willow study areas and the King Eider nesting study. Required state and federal permits were obtained for all survey activities, including a Scientific or Educational Permit (Permit No. 20-130) from the State of Alaska and a Federal Fish and Wildlife Permit—Native Threatened Species Recovery—Threatened Wildlife; Migratory Birds (Permit No. TE012155-7 issued under Section 10(a)(1)(A) of the Endangered Species Act [58 FR 27474-27480]).

STUDY AREA

The GMT2/MT7 drill pad (0.06 km²) is west of the GMT1/MT6 drill pad, connected by an all-season gravel road (12.9 km long) (Figure 1). Construction of the GMT2/MT7 pad and road began in the winter of 2019, and pipeline installation was initiated during the winter of 2020.

Landforms, vegetation, and wildlife habitats in the NE NPR-A study area were described in the Environmental Impact Statement (EIS) for the lease area (BLM 2019), and the ASDP EIS (BLM 2004), and in Jorgenson et al. (2003, 2004). Coastal plain and riverine landforms dominate the NE NPR-A study area. On the coastal plain, lacustrine processes, basin drainage, and ice

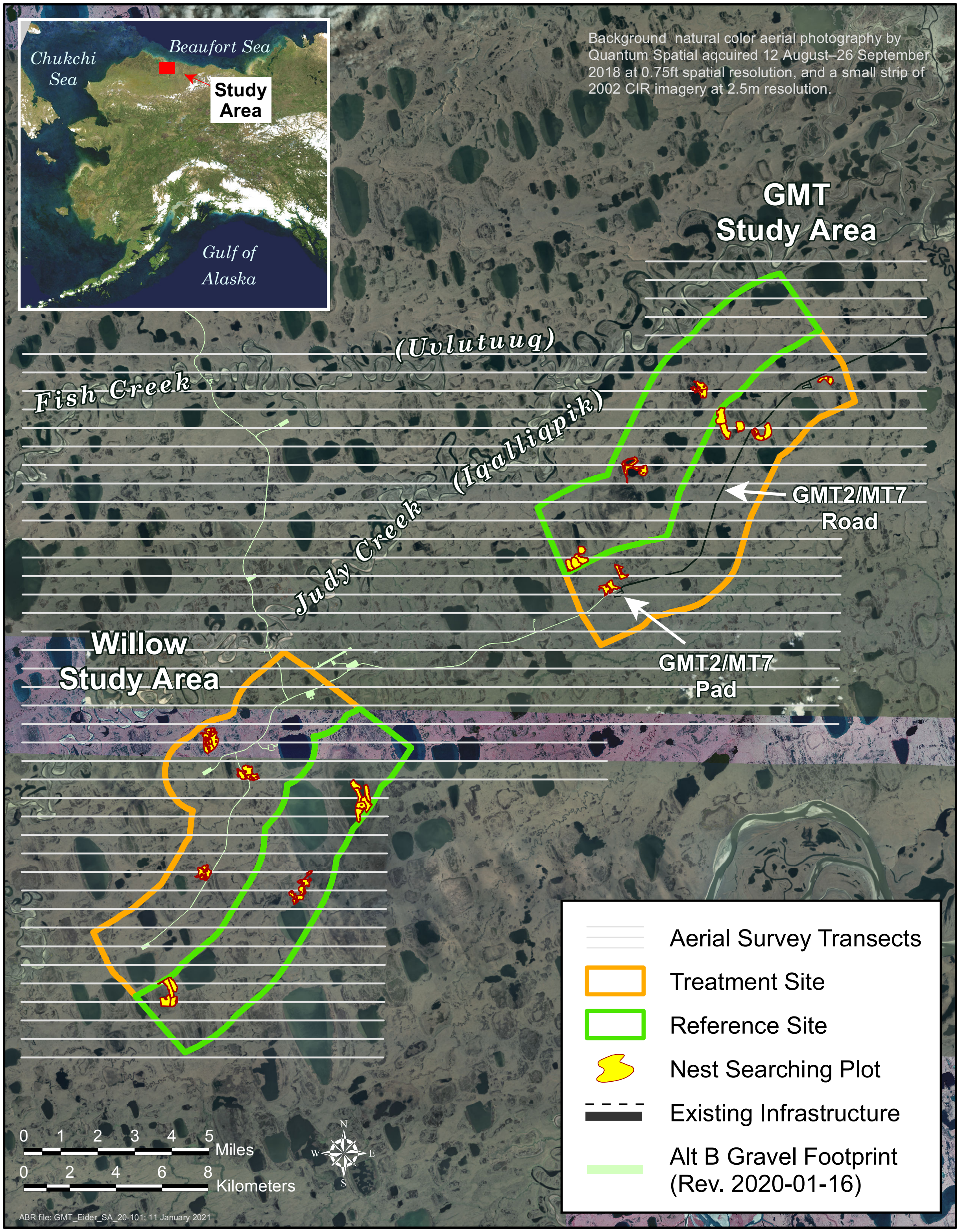

Figure 1. Study area for aerial surveys of pre-nesting eiders and King Eider nest plots in GMT and Willow study areas, NPR-A, Alaska, 2020.

aggradation are the primary geomorphic factors that modify the landscape. In riverine areas along Fish and Judy creeks, fluvial processes predominate, although eolian and ice-aggradation processes also contribute to ecological development (Jorgenson et al. 2003).

Eleven wildlife habitats occurred on the plots that were searched for nests. The most abundant wildlife habitats were Old Basin Wetland Complex (32%), Shallow Open Water with Islands or Polygonized Margins (19%) Patterned Wet Meadow (17%), Nonpatterned Wet Meadow (11%), and Sedge Marsh (9%). The remaining habitat types each contributed <5% of the total habitat. A variety of birds and mammals are commonly observed in the NE NPR-A (Appendix A).

METHODS

PRE-NESTING EIDERS

Aerial surveys were used to collect data on eiders in the GMT and Willow study areas because of the large size of the study area and the short periods of time that eiders are at the optimal stage for data collection. The survey was scheduled specifically for the period when eiders are most easily detected (males are in bright breeding plumage and accompanied by a female, if paired for breeding) and when the species is at an important stage of its breeding cycle (pre-nesting; Table 1). In 2020, we conducted 1 survey for eiders during pre-nesting from a fixed-wing aircraft and 2 surveys for Yellow-billed Loons, which are addressed in a separate report (Parrett and Shook 2021).

Concerns about disturbance to local residents and wildlife from survey flights have dictated that we conduct the fewest survey flights necessary and at the highest altitudes possible. Flight altitudes were set at the maximal level at which the target species could be adequately detected and counted (see survey protocols for each species group below). Survey flights specifically avoided the areas around the village of Nuiqsut and any active hunting parties. Daily phone calls with Nuiqsut subsistence representatives, coordinated by the ConocoPhillips Village Outreach group and the Helicopter Coordinator based at Alpine, were used to identify locations of active hunting parties. Additionally, aerial observers looked for people, boats, and off-road vehicles that might indicate the presence of subsistence hunters. If hunting parties were present, we diverted the airplane to reduce disturbance to hunters.

During the surveys, locations of eiders were recorded on digital orthophoto mosaics of 23–30 cm (8–12 in) resolution natural color imagery acquired in 2004–2015 by Quantum Spatial (Anchorage, AK). Observations were collected on tablet computers with a customized application employing a moving map based on the orthophoto mosaic imagery. Bird locations plotted on tablets were reviewed before they were exported into a geographical information system (GIS) database.

Table 1. Avian surveys conducted in GMT and Willow study areas, NE NPR-A, 2020.

	Pre-nesting Eider Survey[a]	Ground Nest Searches	
		Nesting	Nest Fate
Number of Surveys	1	1	1
Survey Dates	12–13 June	17–18, 21–30 June	25–26 July
Aircraft[b]	C185	Truck/A-Star	Truck/A-Star
Transect Width (km)	0.4	–	–
Transect Spacing (km)	0.8	–	–
Aircraft Altitude (m)	35–45	–	–
Notes	50% coverage	Drop-offs when not near road	Drop-offs when not near road

[a] Surveys were for Spectacled and King Eiders.
[b] C185 = Cessna 185 fixed-wing airplane; A-Star = Airbus AS 350 B2 helicopter.

In this report, we present data summaries with means (± SE), unless noted otherwise. Where appropriate, we report median values. Statistical significance is assigned at $p \leq 0.05$ unless otherwise stated.

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 during the pre-nesting period (Table 1), when male eiders were still present on the breeding grounds. Steller's and Common eiders were recorded if they were encountered. In 2020, we conducted the pre-nesting survey on 12–13 June using the same methods that were used on the Colville Delta study area since 1993. The survey was flown in a Cessna 185 airplane at 35–45 m above ground level (agl) and at approximately 145 km/h. Two observers sat on opposite sides of the airplane and each counted eiders in a 200 m wide transect on their respective side (400 m total transect width). A Global Positioning System (GPS) receiver was used to navigate east–west transect lines that were spaced 800 m apart achieving 50% coverage of the study area.

Results are presented as the total number of eiders observed and the indicated total. Indicated total is a standardized calculation in which the observed number of males is doubled to compensate for the lower detectability of females (USFWS 1987). Only males observed in singles, pairs, and small groups on the ground are included in the indicated total; flying birds are excluded. To calculate indicated total birds:

Indicated Total Birds = (lone males × 2) + (flocked males × 2) + (pairs × 2) + (group total ×1).

Lone males are single, isolated males without a visibly associated female; flocked males are 2–4 males in close association (no females in the flock); a pair is a male and female in close association; and a group is 5 or more of a mixed-sex grouping of the same species in close association, which cannot be separated into singles or pairs (e.g., 1 female with 3 males was considered to be 4 indicated total birds [a pair plus 2 males]).

POPULATION TRENDS

We calculated population trends using the log-transformed indicated total in a linear regression. Because the same area was not surveyed in all years, we adjusted indicated totals to a standardized survey area by multiplying indicated density by the maximal area surveyed 1999–2020 (755.1 km^2).

NESTING EIDERS

NEST PLOT SELECTION

We established 2 study areas—the GMT and Willow study areas—and spaced them 10 km apart at their closest boundaries to reduce potential spatial bias. We established 1 reference and 1 treatment area for each of the 2 larger study areas (Figure 1) to quantify potential disturbance effects of the existing GMT1/MT6 to GMT2/MT7 road and the planned Willow infrastructure. Each treatment area is within 1.6 km (1.0 mi) of existing (GMT) or proposed (Willow) infrastructure, and each reference area is 1.6–4.8 km (1.0–3.0 mi) from existing or proposed infrastructure and is adjacent to a treatment area. We then established 41 permanent plots, 19 in the GMT study area (9 reference and 10 treatment plots), and 22 in the Willow study area (13 reference and 9 treatment plots; Figure 1) to search for eider nests. All plots established in 2020 will be searched in subsequent years of this study.

Because nesting densities of King Eiders are low in the study areas, we located plots based on habitat preferences in order to maximize nest detection. We used the results of Monte Carlo simulations of wildlife habitat selection for pre-nesting King Eiders recorded on aerial surveys in NPR-A during 1999–2019 (n = 730 groups; Appendix B; Shook et al. 2020), as well as King Eider nesting records (n = 109 nests) from the same time period (Johnson et al. 2005, Johnson et al. 2015, Rozell et al. 2020) to inform plot selection. First, we selected habitats that were preferred by pre-nesting King Eiders. To this list, we added Nonpatterned Wet Meadow and Patterned Wet Meadow because King Eiders frequently nest in these habitats when they are located near (within ~100 m) permanent water (Attanas and Shook 2020; ABR unpublished data). We used a raster image in a GIS to identify permanent waterbodies that were ≥0.00625 ha (2002 raster at 2.5 m resolution, band 1, range 1–55 of 255). Next, we intersected these permanent waterbodies with Nonpatterned Wet Meadow and Patterned Wet Meadow habitats and clipped out the area that was >100 m from permanent water. We excluded coastal habitats not found in the study area (Brackish Water, Tapped Lake with Low-water Connection, Salt Marsh), as well as lake and riverine habitats with little to no nesting substrate and/or few King Eider nest records; (Deep Open Water without Islands, Deep Open Water with Islands or Polygonized Margins, Shallow Open Water without Islands, River or Stream). We also excluded Grass Marsh due to the low sample size, low use by pre-nesting eiders, and no use for nesting King Eiders. In all, we identified 6 priority habitat types for nesting King Eiders (Shallow Open Water with Islands or Polygonized Margins, Sedge Marsh, Old Basin Wetland Complex, Nonpatterned Wet Meadow, Patterned Wet Meadow, and Young Basin Wetland Complex). Ninety-one percent of previous nesting records of King Eiders in the NPR-A occurred within these 6 habitat types (ABR, unpublished data). These 6 habitats were then merged together into polygons that formed the basis of the plot boundaries.

The footprints of existing and proposed ice roads and infrastructure were excluded from survey areas because they would have disturbed or altered plot habitats in 2020 or future years. The remaining areas were divided into plots that averaged 12 ± 0.005 ha (6–23 ha). Plots were clustered together around waterbodies/wetlands and distributed throughout the study areas. To further reduce spatial bias, plots were located over a range of distances from infrastructure within the study areas. We established more plots than could be searched during the 10-day period in case some plots were inaccessible, or time allowed for additional searches. We refined plot selection in the field based on locations of pre-nesting King Eiders recorded on eider and loon aerial surveys conducted within 1 week of the start of ground nest searches.

During nest searches, we searched a cluster of 1–4 plots each day, all within walking distance of each other. Searches alternated daily between clusters of plots that were in the GMT or Willow study areas, and we alternated between reference and treatment areas. During subsequent survey years, plots will be searched in the same order and within a 10-day period to avoid introducing a timing effect that might influence annual comparisons among plots.

NEST SEARCHING

We conducted nest searches for King Eiders on plots in the GMT and Willow study areas during 17–30 June, commuting by truck or by helicopter from Alpine each day (Figure 1, Table 1). A crew of 4 people spaced 20 m apart searched for nests by walking a zigzag pattern, to achieve total coverage of the tundra within each plot's boundaries. Plot boundaries were displayed on a map on handheld CAT Android devices. Crew members focused on finding eiders, but also recorded nests of other large waterbirds including geese and waterfowl; seabirds (gulls, terns, and jaegers); and some large shorebirds including Whimbrels and Bar-tailed Godwits. Nests of Willow Ptarmigan and small shorebirds and passerines were sometimes found and recorded as incidental observations. Nest searchers communicated with hand-held radios when nests other than of King Eiders were spotted to avoid flushing incubating birds.

For each nest found, we recorded the species, location (GPS coordinates in WGS 84), nest status (active: nest attended or eggs were warm, or inactive: unattended and without eggs or cold eggs), distance to nearest water (ephemeral or permanent water), distance to nearest waterbody (permanent water ≥0.25 ha in area), waterbody class, whether or not the bird flushed, the distance at which it flushed, the number of eggs, and the float angle of eggs from a subset of nests. We floated eggs in a small clear container of water to estimate the age of eggs and incubation start dates (Westerkov 1950, Mabee et al. 2006). We floated 1–3 eggs from all eider nests (intentionally flushed) and White-fronted Goose nests (only those inadvertently flushed) and recorded the float angle and position of the egg in the water column. Nest data were recorded on a CAT Android device using an app developed by ABR. Data were downloaded to laptop computers and the ABR server at the end of each day.

Unattended nests were identified to species or species group based on the size and color pattern of contour feathers, down, or eggs in the nest

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

TEMPERATURE-SENSING EGGS

Artificial temperature-sensing eggs and data loggers were installed in all active King Eider nests to record incubation activity and data on daily nest survival. The eggs were constructed from plastic eggs that were painted pale green. The temperature sensor (TMC1-HD, TMC6-HD, and TMC6-HA cables; Onset Computer Corporation, Bourne, MA) consisted of a 2.5 cm metal sensor taped to the inside of each egg and attached to a 6 ft long cable. The cable exited the temperature-sensing egg close to where the egg was glued to the top of an 8 in metal spike. The temperature cable was connected to a small data logger (HOBO® models H8-002-02, U12-006, and U12-013, Onset Computer Corporation, Bourne, MA) external to the egg. Loggers were programmed to record nest temperature every 5 minutes. A separate temperature-sensing egg and data logger was attached to a nest stake at ground level to record ambient temperatures in the study area.

All eider eggs were removed from nests before installing temperature sensors. The cable from the temperature sensor was hidden in a shallow trench (2–3 cm deep) leading to the data logger, which was sealed in a waterproof bag and buried 3–5 cm under the vegetation mat. To prevent the removal of equipment by eiders or nest predators, the metal spike is pressed into a hole in the tundra in the center of the nest bowl, and the cable attached to the egg was staked to the ground outside the nest bowl using a tent stake. After installation, the eggs were returned to the nest and covered with down and vegetation. After the nesting season, artificial eggs and data loggers were retrieved and the temperature data were exported using HOBOware version 3.7.1.

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

TIME-LAPSE CAMERAS

In 2020, we deployed 6 time-lapse cameras to record nest attendance patterns of King Eiders, compare these patterns to nests that were simultaneously monitored by temperature-sensing eggs (6 nests), and identify causes of nest disturbance or failure. We set up cameras on 5 nests found active with > 1 egg on the same day the nest was found. One camera was set up on a nest several days following nest discovery. We used PC800 Silent Image® Professional cameras with 2× telephoto lenses, which take 3.1-megapixel images (Reconyx, Lacrosse, WI). The cameras were mounted on tripods that were tied down to stakes to stabilize them against the wind. Cameras were equipped with 32-GB memory cards and programmed to take 1 image/30 sec. All cameras were run on 12 AA lithium batteries. We chose settings, memory cards, and batteries so that cameras could take the maximum number of photos possible for 23–28 d without requiring maintenance (i.e., battery or memory card changes).

We reviewed digital images on personal computers with Irfanview software (version 4.33). Eider activity was classified into 3 categories: incubation, break, and recess. Incubation included sitting postures of normal incubation (head up and posture relaxed, or head resting on back), alert incubation (head up in a rigid, attentive posture), concealed incubation (head and body down and flattened in vegetation), and gathering nest material while on the nest. Break activities included brief standing activities at the nest, including changing positions, settling on the nest after changing position, standing over the nest, and egg moving. Recess activities were absences from the nest, including standing or sitting beside the nest, and those activities immediately preceding and following the recess, including egg moving, covering eggs with down, walking to and from the nest, flying, and out of camera view. We identified predators in the camera view to species, estimated their distance from the nest, and described their behavior. We also recorded the activity and distance from the nest of other waterfowl and caribou.

We calculated incubation constancy by summing the time spent on the nest (minutes of incubation plus breaks) and dividing by the minutes monitored. We calculated the frequency of incubation breaks, frequency of recesses, recess duration, and time off the nest relative to the total monitored by the cameras following definitions used for temperature monitoring data.

Nest images were reviewed from the day of camera set-up through nest failure or when the eider female and her young were observed leaving the nest. Because we could not see precisely when hatching began on images, we used the day the brood left the nest to estimate the start of hatching. We defined hatch as beginning at midnight the day before the brood departed the nest. A nest was judged as failed if the female did not resume incubation after a predator was seen at the nest. The time of failure was determined as the first image containing the predator.

For temperature-sensing eggs and cameras, days of partial monitoring, which included the day the egg monitoring and/or camera was installed, the day of hatching, and any days when data were not collected due to equipment malfunction, were excluded from calculations. On cameras, periods of time when images could not be interpreted due to poor weather conditions (e.g., fog) or direct sun, also were excluded.

NESTING SUCCESS

We revisited all eider nests in late July to determine nest fates. A nest was considered successful if evidence suggested that at least 1 egg hatched. Hatch was determined by the presence at the nest of detached egg membranes, eggshells with thickened membranes that peeled easily from the shell, eggshell pipping fragments (less than 5 mm), and eggshell tops or bottoms. The presence of yolk, blood, eggshells with holes, egg fragments with attached membranes, or the total absence of egg remains was recorded as nest failure. Any evidence of predation (fox scent, fox scat, or a disturbed nest site) was recorded.

Temperature data from nests with installed thermistors also were reviewed for indications of hatch or failure. In a study of Greater White-fronted Geese, temperature records during hatch showed a long period of nest attendance followed by an increasing frequency of breaks 24–36 h before the female and brood left the nest (Johnson et al. 2003). The increase in break frequency is apparent in the graph of nest temperature against time as a gradual cooling of the nest temperature. The female and brood were judged to have departed the nest when 5 consecutive records had an average nest temperature <9° C, or when nest temperature appeared to track ambient temperature. After brood departure, nest temperature cycles with ambient temperature. In contrast, temperatures from failed nests usually drop abruptly before tracking ambient temperatures. The hatch date of a nest was recorded as the day before the female and brood departed the nest.

Apparent nesting success of King Eiders was estimated by dividing the number of nests that hatched by the number of nests found, including nests that were inactive at discovery. Apparent nesting success is generally acknowledged to overestimate success because it does not take into account the length of time nests were exposed to predators and other risk factors (Mayfield 1961, 1975). We also calculated nesting success for eider nests containing temperature sensing eggs and/or cameras by estimating daily survival probability (DSR). The DSR is the probability that the nest will survive from 1 day to the next and can be used to calculate unbiased estimates of nesting success but requires periodic monitoring of nests to determine status. DSRs were estimated using the Mayfield equation:

$$DSR = (\text{exposure days} - \text{failed nests}) \div \text{exposure days}$$

Nest survival is the probability that a nest fledges at least 1 young and was calculated by raising the DSR to the exponent of the average number of days of the King eiders' nesting cycle (27 d), which includes the laying and incubation periods. The incubation period for King Eiders is reported to be 22–24 d and the egg laying interval is 1 egg per day (Powell and Suydam 2020). We assumed 23 d for the incubation period for King Eider, the number of days used in a study of incubating behavior of King Eiders in Alaska at Kuparuk and Teshekpuk lake (Bentzen et. al. 2008), and 24 d incubation period for Greater White-fronted Geese (Rozell et al. 2020). We estimated incubation start dates and nest initiation dates for King Eiders and White-fronted Geese using egg-flotation data (described above) or backdating in the case of nests with known hatch dates from temperature sensors and cameras. Each floated egg was assigned an age from a float schedule for King Eiders (Tim Bowman, USFWS, unpublished data); and White-fronted Geese (Jerry Hupp, USGS, unpublished data) based on the angle and position of the egg in the water column. The float schedules provide estimates of ages in 2–4 d increments; we used the midpoint of the age range or the earlier date in the case of 2 d ranges. We used the youngest (last-laid) egg sampled in each nest to arrive at the start date for incubation. The date of nest initiation was calculated for eiders by backdating 1 day for each egg laid from the incubation start date. For White-fronted Geese, we multiplied the clutch size by the estimated laying interval (1.33 d/egg; Ely and Dzubin 1994, Mowbray et al. 2002, Burgess et al. 2013) and backdated from the incubation start date.

PREDATOR SCANS

In each plot, we marked 1–2 predator survey points with pink survey whiskers on a metal spike and recorded a GPS point for future relocation. We conducted visual predator scans on all plots to determine the types and numbers of potential nest predators in the GMT and Willow study areas. Binoculars were used to search for avian predators (e.g., jaegers, gulls, raptors, ravens, and owls) and mammalian predators (e.g., foxes and bears) during each scan. On each plot ≥500 m in length, we conducted 2 scans of 10 min each for predators within plot boundaries and ≤300 m outside plot boundaries. On smaller plots, we conducted 1 scan. Predator scans were always conducted prior to searching a plot, a second scan was conducted at the end of nest-searching. Because the GMT and Willow study areas had different numbers of reference and treatment plots and plot size also varied (influencing the number of predator scans), we standardized our overall predator counts by dividing the number of predators by the number of scans conducted in each reference and treatment site. Predators seen incidentally during nest searches were also recorded.

Upon conclusion of the nest-search on each plot, we made a qualitative assessment of small mammal abundance (e.g., lemmings and voles). Small mammals are important prey for foxes and avian predators (Maher 1974, Wiklund et al. 1999, Ims and Fuglei 2005) and might influence the level of predation on nests. The level of small mammal activity (winter nests, trails, scat, or live animals) observed on each plot was scored: 0 = none, 1 = low, 2 = moderate, and 3 = high.

HABITAT MAPPING AND ANALYSIS

A wildlife habitat was assigned to each observation of pre-nesting eider groups (on the ground) or nests by plotting their coordinates on the wildlife habitat map (Appendix B). Habitat use (% of all observations in each identified habitat type) was determined separately for pre-nesting and nesting eiders. For each species, we calculated 1) the number of adults, flocks, or nests in each habitat, and 2) the percent of total observations in each habitat (habitat use). Habitat use was calculated from group locations for eiders (single birds, pairs, groups, or flocks and excluded flying birds) and individual locations of King Eider nests. We calculated habitat availability as the percent of each habitat within the GMT aerial survey area and in the total area occupied by the 41 GMT and Willow plots (ground survey area, Table 2).

Table 2. Wildlife habitats mapped in the GMT and Willow study areas and habitat availability during aerial and ground nest surveys for eiders, NE NPR-A, 2020.

Habitat	Aerial Survey Area		Ground Survey Area	
	Area (km^2)	Availability (%)[a]	Area (km^2)	Availability (%)[a]
Deep Open Water without Islands	32.59	8.0		
Deep Open Water with Islands or Polygonized Margins	16.86	4.2	0.24	4.9
Shallow Open Water without Islands	6.02	1.5	0.06	1.2
Shallow Open Water with Islands or Polygonized Margins	4.17	1.0	0.93	18.9
River or Stream	3.74	0.9		
Sedge Marsh	11.33	2.8	0.43	8.7
Grass Marsh	1.82	0.5	0.21	4.3
Young Basin Wetland Complex	1.36	0.3		
Old Basin Wetland Complex	25.7	6.3	1.56	31.8
Riverine Complex	1.53	0.4		
Dune Complex	3.77	0.9		
Nonpatterned Wet Meadow	19.82	4.9	0.54	10.9
Patterned Wet Meadow	53.02	13.1	0.85	17.2
Moist Sedge-Shrub Meadow	66.76	16.4	0.06	1.2
Moist Tussock Tundra	128.25	31.6	0.02	0.5
Tall, Low, or Dwarf Shrub	25.03	6.2	<0.01	0.1
Barrens	4.46	1.1		
Human Modified	0.05	0.0		
Total	406.28	100	4.91	100

[a] Percent availability calculated proportion of mapped area.
[b] Tall, Low, or Dwarf Shrub includes Moist Tall Shrub, Dry Tall Shrub, Moist Low Shrub, Moist Dwarf Shrub, and Dry Dwarf Shrub.
[c] Barrens includes Dry Halophytic Meadow and Moist Herb Meadow.

For pre-nesting eiders, we evaluated habitat selection, and whether habitats were used in proportion to their availability. Multiple years of comparable survey data were used in the analysis of pre-nesting habitat selection. Observations and habitats from the Alpine West, Development, and Exploration subareas (see Figure 1 in Johnson et al. 2015) were combined with those from the Willow and GMT eider survey areas. Fish Creek Delta and Fish Creek West subareas were excluded from the analysis because those areas contained large areas of coastal and deltaic habitat types not available in the GMT and Willow study areas. We calculated the number of observations and the area (km²) for each wildlife habitat in all survey years (1999–2006, 2008–2014, and 2017–2020) to represent the total habitat use and availability, respectively.

We inferred habitat selection by comparing observed habitat use to random habitat use. Monte Carlo simulations (10,000 iterations) were used to calculate a frequency distribution of random habitat use, with the sample sizes in each simulation equaling the number of observed nests or groups of birds in that year. The resulting distribution was used to compute 95% confidence intervals around the expected value of habitat use (Haefner 1996, Manly 1997). We defined habitat preference (i.e., use > availability) as observed habitat use greater than the 95% confidence interval of simulated random use, which represents an alpha level of 0.05 (2-tailed test). Conversely, we defined habitat avoidance (i.e., use < availability) as observed habitat use below the 95% confidence interval of simulated random use. The simulations and calculations of confidence intervals were conducted in the statistical program R (version 4.0.3; R Core Team 2020). For nesting eiders, we reported habitat use but did not have an adequate sample of nests after the first year of this 5-year study to statistically evaluate habitat selection.

HUMAN DISTURBANCE

Data on human activity in the GMT study area were collected using 1 digital time-lapse camera (described above) to monitor vehicle activity on the road between the GMT1/ MT6 pad and GMT2/ MT7 pad. The camera was located 975 m west of the GMT1/MT6 pad with views of a straight stretch of road to the southwest, and a ramp that provides all-terrain vehicles [ATV] access to the tundra. This camera recorded traffic from 18 June to 15 July, corresponding with most of the eider incubation period.

Except for machinery and non-oilfield vehicles, we assumed most vehicles heading west of GMT1/MT6 were travelling to the GMT2/MT7 drill pad. From camera images, we recorded the frequency and duration (total time in view) of all vehicles and people observed. The duration of a vehicle on the road was based only on vehicles seen in photos. Data were summarized by small truck (pickup trucks and small passenger vans), large trucks (trucks >1 ton capacity, buses, water truck), machinery (roller, loader, grader), non-oilfield vehicles (cars, trucks, ATVs), and people (on the road or walking on the tundra). We calculated the frequency of vehicle types, or number of times vehicles traveled between GMT1/MT6 and GMT2/MT7. Frequency was calculated as the number of photos with vehicles in view. Because of the slow speed of machinery and tendency to travel back and forth on a small stretch of road, a single vehicle may be counted multiple times. We quantified event duration minutes (amount of time that ≥1 vehicle type, or person was active), and cumulative vehicle-, or person-minutes (cumulative sum of vehicles, or persons active; thus, 2 vehicles operated concurrently would have twice the duration of 1 vehicle).

DATA MANAGEMENT

All data collected during nest searches were compiled into a centralized database following CPAI's data management protocols (version 11.3, CPAI 2019). Locations of nests were recorded on a CAT android device with decimal-degree coordinates in the WGS 84 map datum and later reprojected into the NAD 83 map datum. Uniform attribute data were recorded for all observations, proofed after data collection, and proofed again during data entry. Survey data were submitted to CPAI in GIS-ready format with corresponding metadata.

RESULTS

SEASONAL CONDITIONS IN THE STUDY AREAS

There are multiple weather stations located in the vicinity of the GMT development, including at CD-5, Alpine, Nuiqsut, and Colville Village (Helmerick's homestead). Colville Village has the longest dataset in the region, but the station stopped recording data in 2019. The CD-5 weather station is the closest, but its snow and precipitation instrument is extremely unreliable. Snow depth data are not available from the Nuiqsut weather station either. Therefore, we used temperature data from the nearest station at CD-5 and snow depth data from Alpine to describe general 2020 weather patterns. Additionally, we used spring breakup and hydrological data reported by Michael Baker International (Michael Baker 2020)

Compared to the previous 5 years of data at CD-5, temperatures were generally low for the first few weeks of May (with the exception of a 2-day warm-period during 9–10 May), average in late-May and early-June, and high in mid-June (Figure 2, bottom). The sum of thawing degree days (the sum of average daily temperatures >0 °C, TDD) was below average during the last 2 weeks of May when early migrating birds arrived, and was above average during the first 2 weeks of June when later migrating birds arrived (Figure 3). Snow was deeper than in any of the previous 5 years at Alpine for the first week of May, but steadily decreased throughout the month, melted by that brief warmup in mid-May and the subsequent near-average temperatures. By late-May/early-June, snow depth was unmeasurable at Alpine (Figure 2, top).

Breakup occurred over a very brief period and was dramatic (Micheal Baker 2020). Pooling snow and ice melt were observed on 18 May, but flowing ice and water was not apparent until 22 May. Floodwaters started rising on 22 May on the Colville Delta and gradually increased until an ice jam formed upstream of Nuiqsut at Horseshoe Bend on 26 May, causing water to recede downstream. On 27 May, the ice jam broke free, sending large volumes of ice and water downstream. New ice jams formed at the head of the Nigliq channel, diverting flow into the East Channel where additional ice jams also formed. This caused the eastern floodplain waters to increase and peak on 28 and 29 May, 2 days ahead of the average peak. The peak stage recorded at Monument 1 upstream of Nuiqsut was the second highest ever recorded. These floodwaters breached banks and inundated the surrounding lowlands. On 29 May, the ice jams broke, and the water quickly receded.

The nearest observation to the GMT project was at the Tinmiaqsiugvik River bridge. Surface meltwater was first observed on 24 May, with flowing water first observed on 28 May. The water stage peaked on 31 May with little ice jamming or overflow near the bridge. By 1 June, the river was mainly flowing ice-free. Observations during this time indicated that snow cover was near 85% on 24 May, while photos on 30 and 31 May show little snow cover remaining.

HUMAN DISTURBANCE

During the first year of this study, there was active construction at the GMT2/MT7 pad and road maintenance throughout the breeding season, although there may have been less activity than a "normal" construction year because of COVID precautions. A traffic camera operated 24-h/d and provided 1,440 min/d of monitoring from 18 June until the internal batteries died on 15 July (n = 28 d). Cameras documented small pickup trucks, vans, loaders, rollers, graders, pickups of 1-ton capacity, a bus, water truck, and non-oilfield vehicles (i.e. cars, sport utility vehicles [SUV], pickups, and ATVs), and people.

In 28 days of observation, we recorded 807 camera images of small trucks (mean = 29.7 ± 3.0 images/day); 367 camera images of large trucks (mean = 13.57 ± 6.9 images/day); 1,373 camera images of machinery (mean = 50.5 ± 34.0 images/day); and 74 camera images of non-oilfield vehicles (mean = 2.7 ± 0.4 images/day) (Appendix C).Counts of images with machinery were especially high on 20 June and 15 July, when improvements to a stretch of road occurred in camera view. A total of 2,621 images of vehicles of all types was recorded on the road (mean = 96.5 ± 10.4 images/day). The mean duration that ≥ 1 vehicle was on the road during the observation period was 44.1 ± 4.2 min/day (Appendix C).

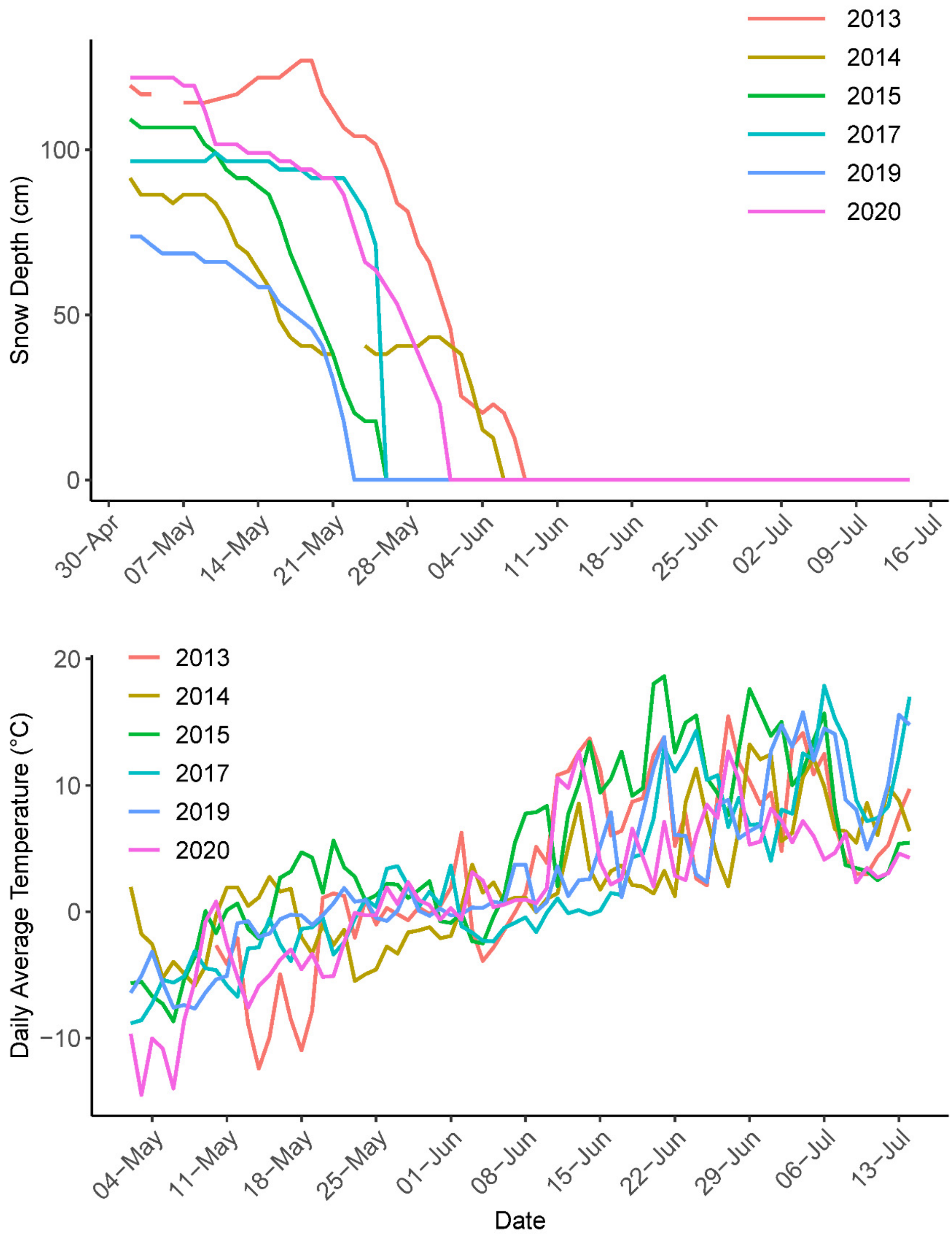

Figure 2. Snow depth (top) and daily average temperature (bottom) for spring and summer 2020 with means for 2013–2020, CD-5 and Alpine, NPR-A and Colville River delta, Alaska.

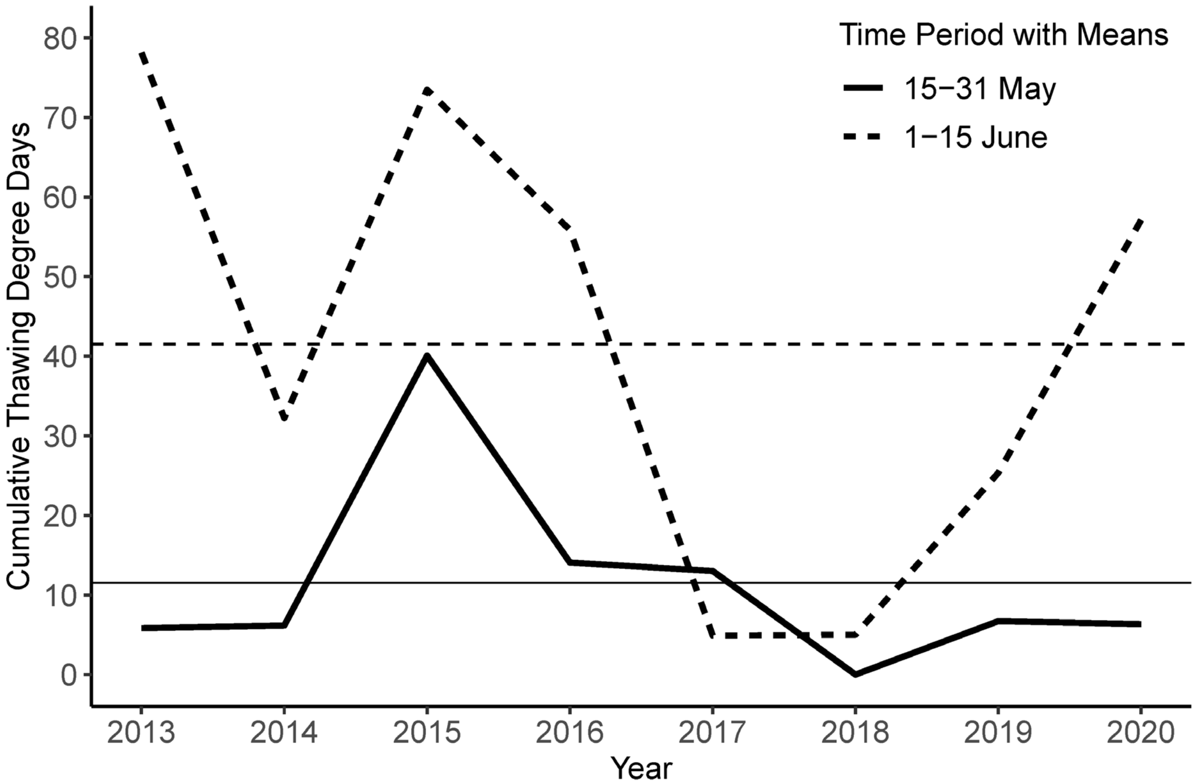

Figure 3. Cumulative number of thawing degree-days and means (horizontal lines) for 15–31 May and 1–15 June recorded at CD-5, NPR-A, Alaska, 2013–2020.

Images of people on the road, ramp, and tundra were also recorded from our traffic camera. On 24 June, we observed 1 group of 4 people on the road for 1.5 min. On 13 July, 2 people were working on the ramp for a total of 4.5 min and 1 person walked on the tundra for 1.5 min before walking back up the ramp. All persons observed were wearing safety vests and likely oilfield employees. All-terrain vehicles were recorded on the road on 3 different days but were not observed using the ramp to access the tundra.

PRE-NESTING EIDERS

DISTRIBUTION AND ABUNDANCE

In 2020, we recorded 157 observed (on the ground and flying) and 120 indicated total King Eiders during the pre-nesting aerial survey that sampled 50% of the GMT and Willow study areas (Figure 4, Table 3). Extrapolating to the entire survey area, we estimate 314 observed total and 240 indicated total King Eiders were present. The distribution of King Eiders in 2020 was generally uniform throughout the area surveyed. Since 1999, when ABR began pre-nesting surveys in NE NPR-A, the highest densities of pre-nesting King Eiders have been in the north (near Fish Creek and Kalikpik River) with some areas of high density in the southern and eastern portions of the GMT and Willow study areas (Figures 5 and 6). The indicated density of King Eiders in 2020 (0.25 indicated birds/km²) was below the long-term mean of 0.35 ± 0.04 indicated birds/km²; Figure 5, Table 3). Although we have a shorter period over which to measure trends in the NPR-A compared to the Colville River delta or Kuparuk, King Eiders recorded on ABR's surveys in NE NPR-A have significantly increased at a rate of 9% annually during 1999–2014 (95% CI, R^2 = 0.65, p < 0.001, n = 15 years). We excluded 2017–2020 due to potential bias because the study areas for these years were further from the areas of high density near the coast.

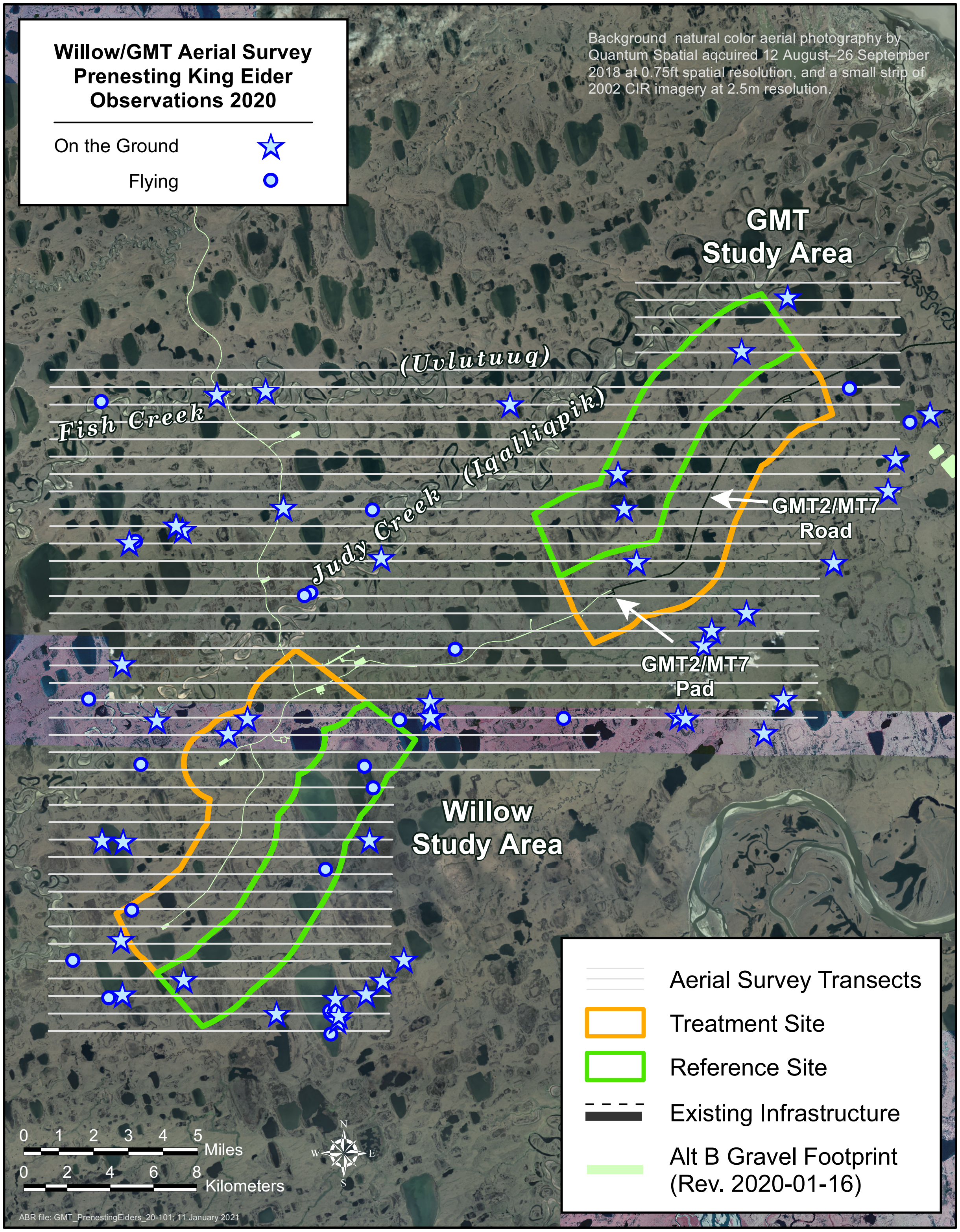

Figure 4. King and Spectacled eider locations during pre-nesting in the GMT and Willow study areas, Alaska, 2020.

Table 3. Annual number and density of eiders during pre-nesting aerial surveys in the GMT and Willow study areas and other NE NPR-A survey areas in 1999–2006, 2008–2014, and 2017–2020. The GMT/Willow area was surveyed in 2017–2020.

		King Eider				Spectacled Eider			
	Area Surveyed	Total[a]		Density[b]		Total[a]		Density[b]	
Year	(km^2)	Observed	Indicated	Observed	Indicated	Observed	Indicated	Observed	Indicated
1999	143.4	41	16	0.29	0.11	4	6	0.03	0.04
2000	278.3	55	38	0.20	0.14	6	6	0.02	0.02
2001	511.0	128	98	0.26	0.19	23	22	0.05	0.04
2002	550.1	182	188	0.39	0.39	12	14	0.02	0.03
2003	557.6	169	114	0.34	0.23	10	12	0.02	0.02
2004	430.3	154	119	0.39	0.30	14	10	0.03	0.02
2005	755.1	230	166	0.34	0.25	9	2	0.01	<0.01
2006	755.1	305	320	0.42	0.44	31	26	0.04	0.03
2008	755.1	468	480	0.65	0.67	41	46	0.05	0.06
2009	755.1	358	330	0.51	0.48	29	30	0.04	0.04
2010	755.1	582	433	0.82	0.61	23	24	0.03	0.03
2011	172.0	93	70	0.69	0.55	9	10	0.05	0.06
2012	172.0	68	76	0.47	0.52	4	2	0.02	0.01
2013	172.0	98	80	0.71	0.57	17	14	0.10	0.08
2014	332.7	102	88	0.43	0.36	8	10	0.02	0.03
2017	706.2	248	132	0.35	0.19	16	4	0.02	0.01
2018	733.2	247	168	0.34	0.23	14	10	0.02	0.01
2019	733.2	196	168	0.27	0.23	6	10	0.01	0.01
2020	477.1	157	120	0.33	0.25	0	0	0.0	0.0
Mean	514.9	–	–	0.43	0.35	–	–	0.03	0.03
SE	55.9	–	–	0.04	0.04	–	–	0.005	0.005

[a] Observed total includes flying and non-flying eiders. Indicated total birds was calculated according to standard USFWS protocol (USFWS 1987). Mean and SE calculated for n = 19 years.

[b] Numbers not corrected for sightability. Density (birds/km^2) based on 100% coverage of area in 1999 and 2000 and 50% coverage in all other years. Mean and SE calculated for n = 19 years.

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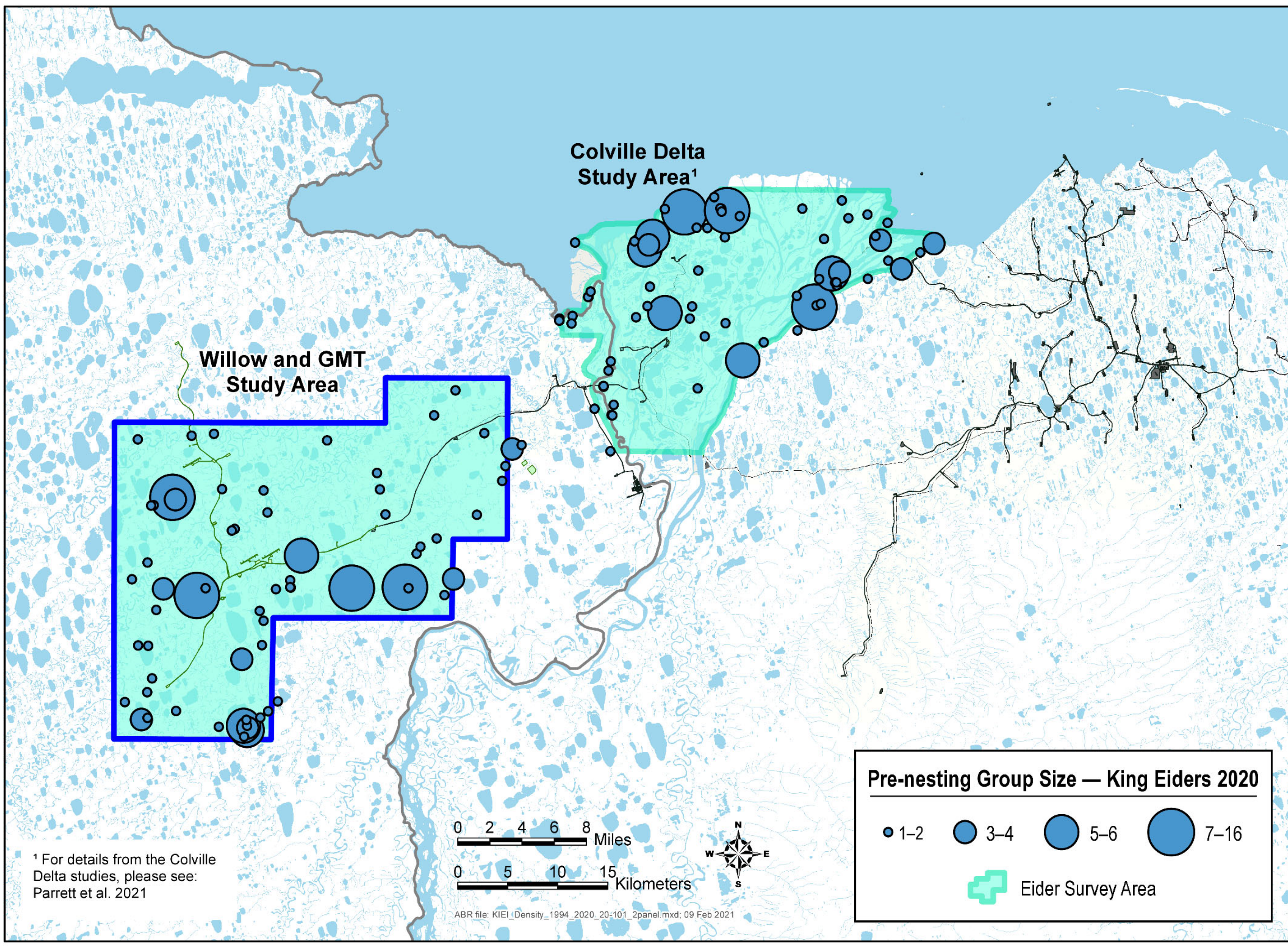

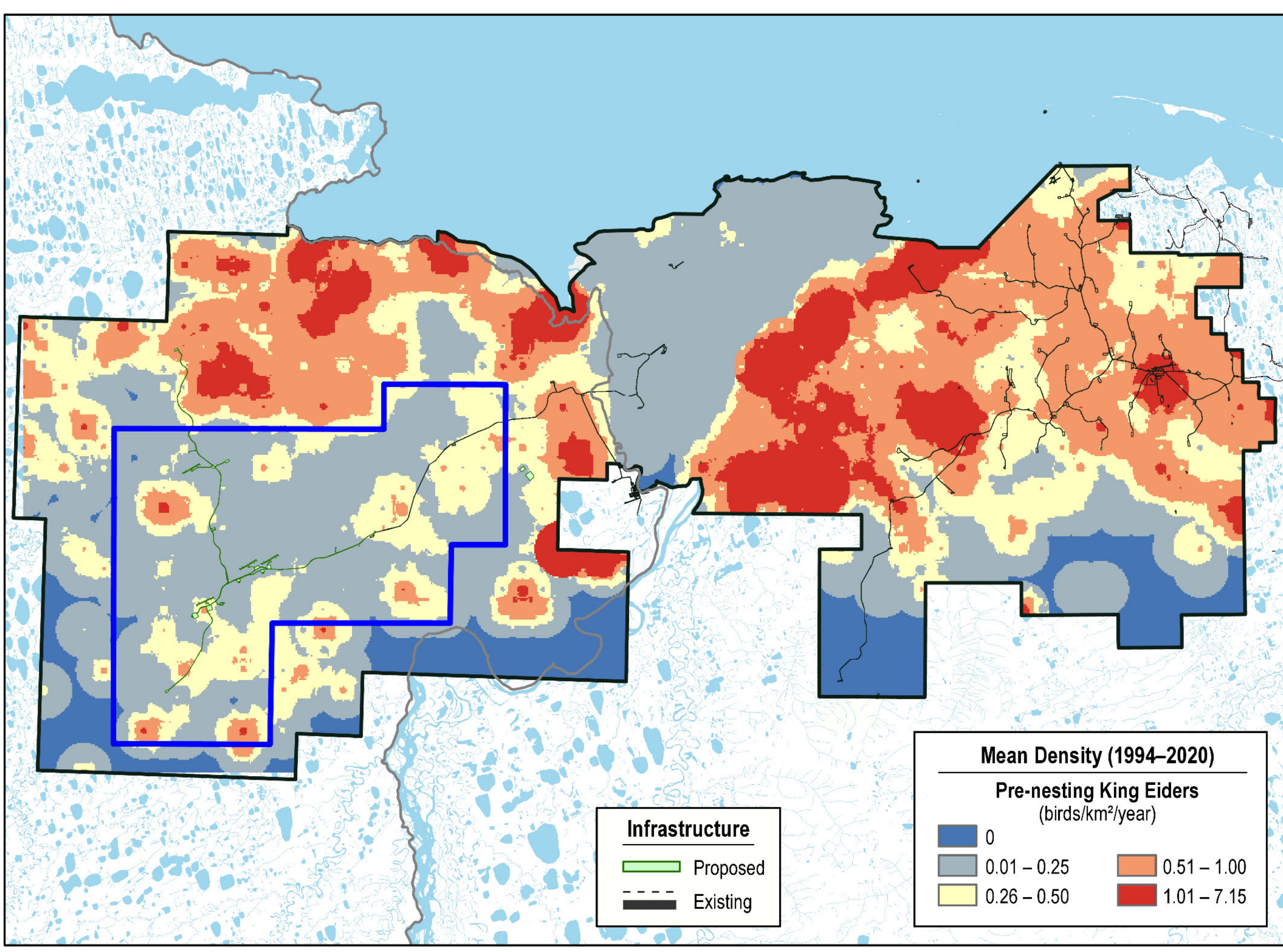

Figure 5. Observations in 2020, and long-term mean densities of King Eiders observed during pre-nesting aerial surveys, in the Colville Delta and Kuparuk study areas, NPR-A, Alaska, 1994–2020. The study area within the NPR-A is outlined in blue.

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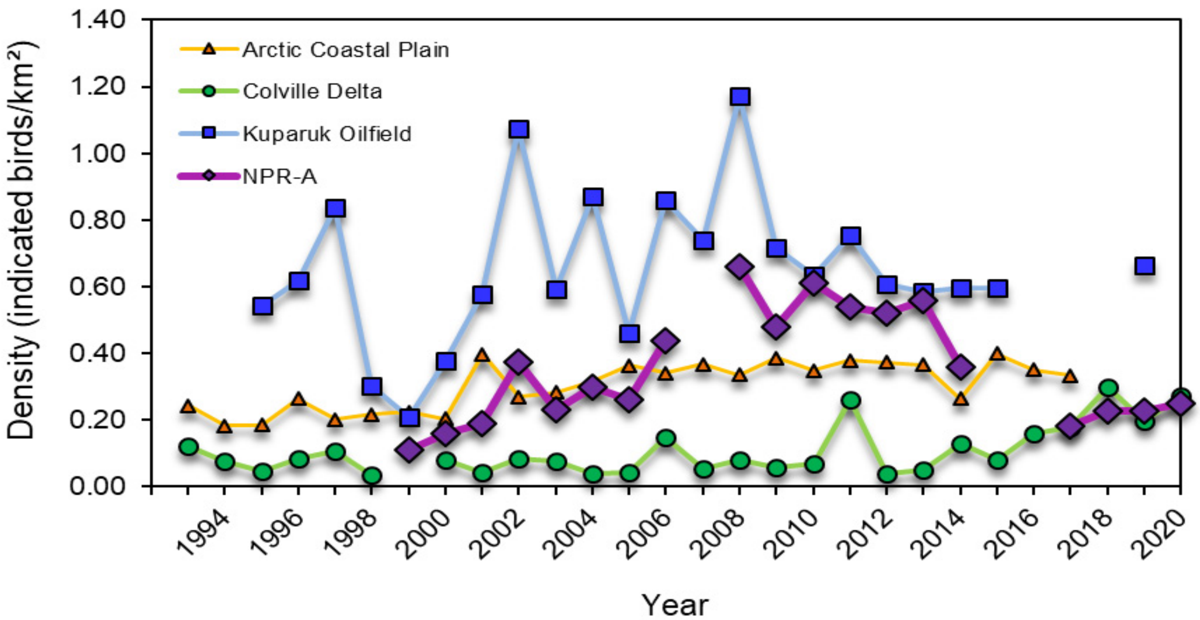

Figure 6. Annual densities of indicated total King Eiders during pre-nesting aerial surveys in 4 study areas on the North Slope, Alaska, 1993–2020. The Arctic Coastal Plain surveys were performed by U.S. Fish and Wildlife Service.

In 2020, we observed no Spectacled Eiders during aerial pre-nesting surveys, and this was the lowest density since surveys began in 1999 (Figure 4, Table 3). A low density of Spectacled Eiders is typical in the NE NPR-A and especially for the inland GMT and Willow areas (Johnson et al. 2015, 2019, Shook et al. 2020). Historically, Spectacled Eiders have been sparsely distributed throughout the GMT and Willow study areas (Figure 7).

Over the 27 years that ABR and others have monitored Spectacled Eiders along the central Beaufort Sea coast, their population trend has been relatively stable (Figure 8). The GMT and Willow eider study areas appear to support lower densities of Spectacled Eiders compared to other ABR survey areas in the NE NPR-A; therefore, we did not include data from 2017–2020 in the population growth rate to avoid a potentially negative bias. In the NE NPR-A, a non-significant, positive growth rate near 2.5% was observed through 2014 (95% CI, $R^2 = 0.02$, $p = 0.60$, $n = 15$ years).

HABITAT USE

The GMT and Willow eider study areas were 954 km^2 of which 821 km^2 have been mapped for wildlife habitats (Jorgenson et al. 2003, Wells et al. 2018a, 2018b). The aerial surveys flown in 2020 covered approximately 50% (477 km^2) of the area, with 406 km^2 in the mapped area.

Over 19 years of aerial surveys, King Eiders used 17 of 26 available habitats during pre-nesting (Table 4). King Eiders preferred 11 habitats (i.e., use was significantly greater than availability), 6 of which were also preferred by Spectacled Eiders in NE NPR-A. Old Basin Wetland Complex was the most used habitat (17.0%) followed by Shallow Open Water with Islands or Polygonized Margins, Deep Open Water with Islands or Polygonized Margins, and Deep Open Water without Islands, each with >10% use. Pre-nesting King Eiders avoided 5 habitats, including the 2 most abundant habitats: Moist Sedge-Shrub Meadow (18.6% available) and Moist Tussock Tundra (28.9% available). All other habitats were used in

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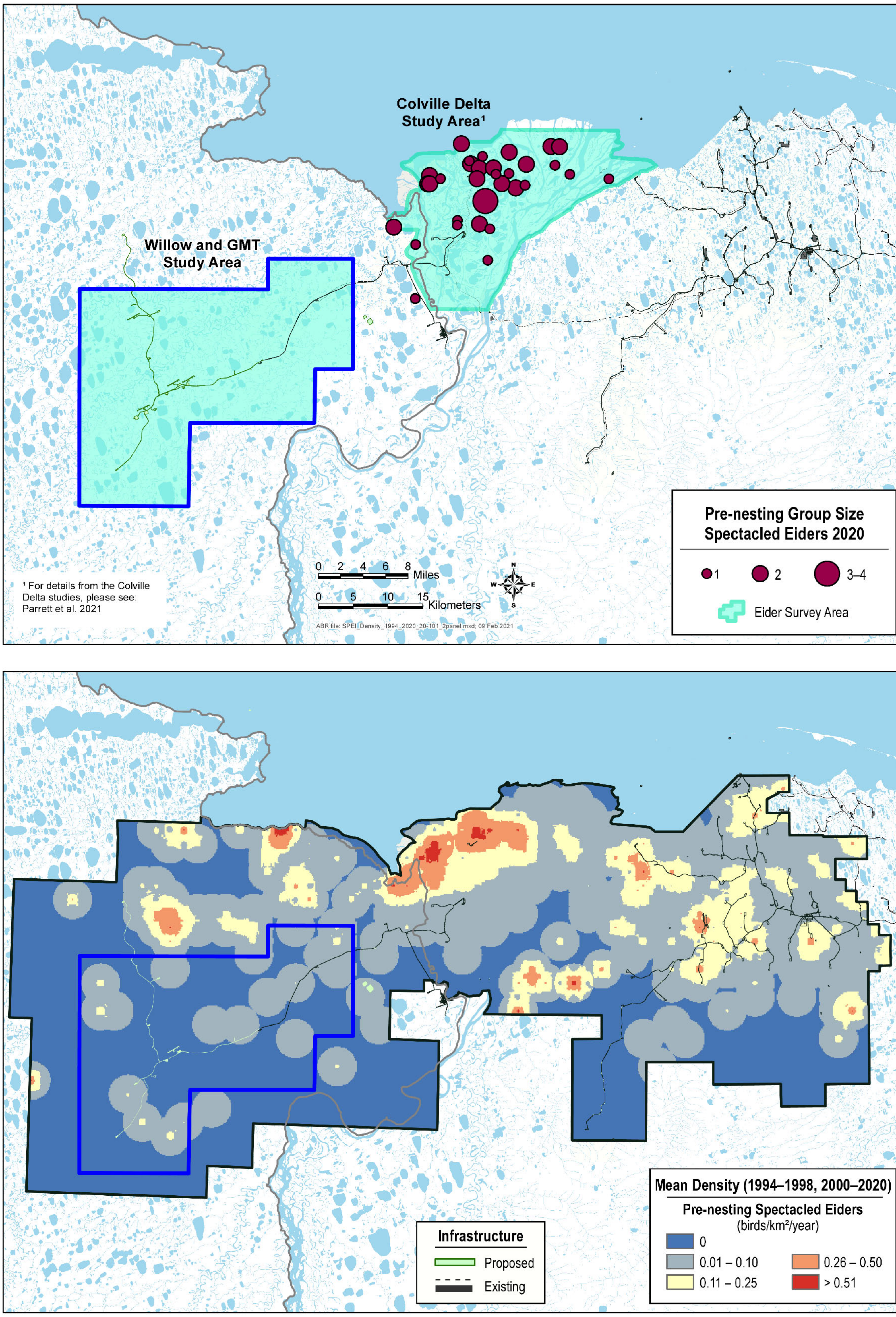

Figure 7. Observations in 2020 and long-term mean densities of Spectacled Eiders observed during pre-nesting aerial surveys in the Colville Delta and Kuparuk study areas, NPR-A, Alaska, 1994–2020. The study area within the NPR-A is outlined in blue.

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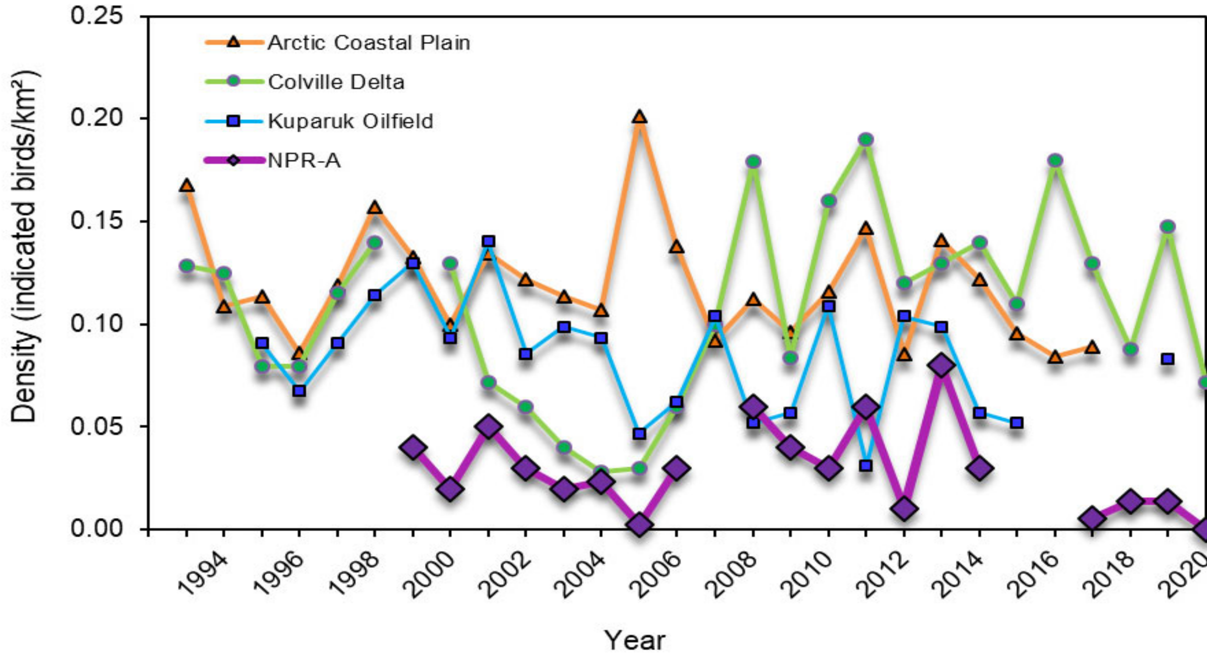

Figure 8. Annual densities of indicated total Spectacled Eiders during pre-nesting aerial surveys in 4 study areas on the North Slope, Alaska, 1993–2020. The Arctic Coastal Plain surveys were performed by U.S. Fish and Wildlife Service.

proportion to their availability or had availability was too low to determine preference or avoidance.

Pre-nesting Spectacled Eiders used 13 of 26 available habitats in the NE NPR-A study area over 19 years of aerial surveys (Table 4). Six habitats were preferred including 1 primarily coastal, salt-affected habitat (Brackish Water), 3 aquatic habitats (Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, and Shallow Open Water without Islands, Grass Marsh), and 1 complex of mixed terrestrial and aquatic habitats (Old Basin Wetland Complex). Old Basin Wetland Complex was the most-used habitat with 20% of the Spectacled Eiders located there. Deep Open Water with Islands or Polygonized Margins, Shallow Open Water with Islands or Polygonized Margins, Shallow Open Water without Islands, and Patterned Wet Meadow each were used by ≥10% of Spectacled Eider groups. Brackish Water was present in the portion of the NE NPR-A north of CD-5 that was included in 15 of the 19 years analyzed for habitat selection (Johnson et al. 2015) but does not occur in the GMT or Willow eider study areas. Two habitats were avoided (used significantly less than availability): Moist Sedge-Shrub Meadow and Moist Tussock Tundra, which also were the most abundant habitats (18.6% and 28.9% of the area, respectively). All other habitats were used in proportion to their availability or had low availability precluding a determination of preference or avoidance.

NESTING SURVEYS

DISTRIBUTION AND ABUNDANCE

In 2020, we searched for nests on plots totaling 4.91 km² in the GMT and Willow study areas. We recorded nests and calculated densities for 7 waterbird species (King Eider, Greater White-fronted Goose, Cackling/Canada Goose, Tundra Swan, Greater Scaup, Long-tailed Duck, and Pacific Loon), 2 large shorebirds (Bar-tailed Godwit and Whimbrel), and 4 seabirds (Parasitic Jaeger, Sabine's Gull, Glaucous Gull, and Arctic Tern). We also recorded incidental observations of

Table 4. Habitat selection by Spectacled and King eider groups during pre-nesting in the GMT and Willow study areas of NE NPR-A in 1999–2006, 2008–2014, and 2017–2020. The GMT/Willow area was surveyed in 2017–2020.

SPECIES Habitat	No. of Adults	No. of Groups	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
KING EIDER						
Open Nearshore Water	0	0	0	0.3	ns	low
Brackish Water	12	6	0.8	0.3	prefer	low
Tapped Lake with Low-water Connection	34	10	1.3	0.2	prefer	low
Tapped Lake with High-water Connection	0	0	0	<0.1	ns	low
Salt Marsh	26	12	1.6	0.7	prefer	
Tidal Flat Barrens	0	0	0	0.2	ns	low
Salt-killed Tundra	0	0	0	<0.1	ns	low
Deep Open Water without Islands	261	85	11.3	8	prefer	
Deep Open Water with Islands or Polygonized	234	91	12.1	5	prefer	
Shallow Open Water without Islands	134	72	9.6	1.3	prefer	
Shallow Open Water with Islands or Polygonized	284	119	15.8	1.3	prefer	
River or Stream	33	15	2.0	0.9	prefer	
Sedge Marsh	98	49	6.5	2.2	prefer	
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	36	13	1.7	0.4	prefer	low
Young Basin Wetland Complex	0	0	0	0.3	ns	low
Old Basin Wetland Complex	253	128	17.0	7.7	prefer	
Riverine Complex	9	4	0.5	0.4	ns	low
Dune Complex	0	0	0	0.9	avoid	
Nonpatterned Wet Meadow	52	31	4.1	4	ns	
Patterned Wet Meadow	160	80	10.6	12.4	ns	
Moist Sedge-Shrub Meadow	43	20	2.7	18.6	avoid	
Moist Tussock Tundra	23	12	1.6	28.9	avoid	
Tall, Low, or Dwarf Shrub	9	6	0.8	5	avoid	
Barrens	0	0	0	1.1	avoid	
Human Modified	0	0	0	<0.1	ns	low
Total	1,701	753	100	100		
SPECTACLED EIDER						
Open Nearshore Water	0	0	0	0.3	ns	low
Brackish Water	8	4	7.4	0.3	prefer	low
Tapped Lake with Low-water Connection	0	0	0	0.2	ns	low
Tapped Lake with High-water Connection	0	0	0	<0.1	ns	low
Salt Marsh	0	0	0	0.7	ns	low
Tidal Flat Barrens	0	0	0	0.2	ns	low
Salt-killed Tundra	0	0	0	<0.1	ns	low
Deep Open Water without Islands	4	2	3.7	8.0	ns	low
Deep Open Water with Islands or Polygonized	14	8	14.8	5.0	prefer	low

Table 4. Continued.

SPECIES Habitat	No. of Adults	No. of Groups	Use (%)[a]	Availability (%)	Monte Carlo Results[b]	Sample Size[c]
Shallow Open Water without Islands	8	6	11.1	1.3	prefer	low
Shallow Open Water with Islands or Polygonized	19	7	13.0	1.3	prefer	low
River or Stream	1	1	1.9	0.9	ns	low
Sedge Marsh	1	1	1.9	2.2	ns	low
Deep Polygon Complex	0	0	0	<0.1	ns	low
Grass Marsh	5	4	7.4	0.4	prefer	low
Young Basin Wetland Complex	0	0	0	0.3	ns	low
Old Basin Wetland Complex	19	11	20.4	7.7	prefer	low
Riverine Complex	0	0	0	0.4	ns	low
Dune Complex	2	1	1.9	0.9	ns	low
Nonpatterned Wet Meadow	4	2	3.7	4.0	ns	low
Patterned Wet Meadow	14	6	11.1	12.4	ns	
Moist Sedge-Shrub Meadow	1	1	1.9	18.6	avoid	
Moist Tussock Tundra	0	0	0	28.9	avoid	
Tall, Low, or Dwarf Shrub	0	0	0	5.0	ns	low
Barrens	0	0	0	1.1	ns	low
Human Modified	0	0	0	<0.1	ns	low
Total	100	54	100	100		

[a] Use = (groups / total groups) × 100.
[b] Significance calculated from 10,000 simulations at $\alpha = 05$; ns = not significant, prefer = significantly greater use than availability, avoid = significantly less use than availability.
[c] Low = expected value < 5.

nests of Willow Ptarmigan, small sandpipers (3 species), and phalaropes (Table 5). This year, we found many nests that failed prior to their discovery. Therefore, we reported nests as active and inactive.

We found 8 King Eider nests; 5 of these nests (including 1 inactive) were in the GMT treatment site and 3 were in the Willow reference site (Figures 9 and 10, Table 5). The nesting density of King Eiders was 3.1 nests/km² in the GMT treatment site and 2.9 nests/km² in the Willow reference site. No King Eider nests were found in GMT reference or Willow treatment sites, although both sites had eider habitat, and evidence of eiders nesting in years prior (i.e. nest bowls, eggshells) or adult King Eiders were observed in the area.

The most abundant nesting waterfowl in both study areas were Cackling/ Canada Geese, with 16 nests in GMT study area and 15 nests in Willow study area. Greater White-fronted Geese were the second most abundant species with 12 nests in GMT study area and 9 nests in Willow (Figures 9 and 10, Table 5).

The Willow reference site had the highest species abundance and diversity despite having the smallest search area (1.03 km²). We found 57 nests (37 active and 20 inactive) of 9 species (nesting density = 56.3 nests/km²). The GMT treatment site had the second highest number of nests with a total of 31 nests (22 active and 9 inactive) of 7 species, and a nesting density of 24.4 nests/ km². We found the fewest nests in the Willow treatment site (11 active and 4 inactive) despite it including the largest area searched (1.57 km²; Figure 10, Table 5).

NEST INITIATION AND INCUBATION

We floated eggs from 7 King Eider and 6 Greater White-fronted Goose nests to estimate nest age and the start of incubation. By the time nest

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Table 5. Number and density of bird nests found on GMT and Willow study plots, 2020. Numbers in parentheses represent nests that failed before they were found.

		GMT2/MT7					Willow					
		Reference		Treatment			Reference		Treatment			
Species Group	Species	Nests Active/ (Inactive)[a]	Density[b] nests/km^2	Nests Active/ (Inactive)[a]	Density[b] nests/km^2	Total	Nests Active/ (Inactive)[a]	Density[b] nests/km^2	Nests Active/ (Inactive)[a]	Density[b] nests/km^2	Total	All Nests
Waterbird	King Eider	0	0.0	4 (1)	3.1	4	3	2.9	0	0.0	3	7
	Greater White-fronted Goose	2 (1)	2.9	8 (1)	7.1	12	2 (3)	4.9	4	2.5	9	21
	Cackling /Canada Goose[c]	4 (4)	7.7	3 (5)	6.3	16	5 (7)	11.7	1 (2)	1.9	15	31
	Unidentified goose[d]	0	0.0	1 (1)	1.6	2	(4)	3.9	(1)	2.5	5	7
	Tundra Swan	1	1.0	0	0.0	1	0	0.0	0	0.0	0	1
	Greater Scaup	1	1.0	0	0.0	1	0	0.0	0	0.0	0	1
	Long-tailed Duck	2	1.9	'(1)	0.8	3	5 (3)	7.8	1	0.6	9	12
	Unidentified duck	(1[e])	0.0	0	0.0	1	(2)	1.9	(1)	0.6	3	4
	Pacific Loon	1	1.0	1	0.8	2	2 (1)	2.9	0	0.0	3	5
Shorebird	Whimbrel	0	0.0	0	0.0	0	1	1.0	0	0.0	1	1
	Bar-tailed Godwit	1	1.0	0	0.0	1	0	0.0	0	0.0	0	1
Seabird	Parasitic Jaeger	0	0.0	0	0.0	0	0	0.0	1	0.6	1	1
	Sabine's Gull	0	0.0	0	0.0	0	5 (1[e])	5.8	0	0.0	6	6
	Glaucous Gull	1	1.0	5	3.9	7	5	4.9	3	1.9	8	15
	Arctic Tern	1	1.0	0	0.0	1	9	8.7	1	0.6	10	11
	Total	**14 (6)**	**18.3**	**22 (9)**	**24.4**	**51**	**37 (20)**	**56.3**	**11 (4)**	**11.5**	**73**	**124**
Incidental Nests[e]												
Landbird	Willow Ptarmigan	–	–	–	–	–	–	–	1	–	1	1
Shorebird	Stilt Sandpiper	–	–	–	–	–	1	–	–	–	1	1
	Pectoral Sandpiper	–	–	–	–	–	–	–	1	–	1	1
	Semipalmated Sandpiper	1	–	–	–	1	2	–	–	–	2	3
	Unidentified sandpiper—small	–	–	–	–	–	1	–	1	–	2	2
	Red-necked Phalarope	1	–	–	–	1	–	–	1	–	1	2
	Unidentified phalarope	–	–	1	–	1	–	–	–	–	0	1
	Total	**2**		**1**		**3**	**4**		**4**		**8**	**11**

[a] Inactive nests, were nests of this season that had failed prior our nest visit
[b] Density calculations were based on 1.04 km² reference area and 1.27 km² treatment area for GMT2/MT7 study site, and 1.03 km² reference area and 1.57 km² treatment area for Willow study site.
[c] Nest belonging to either Cackling or Canada goose.
[d] Either Greater White-fronted or Cackling/ Canada goose nest
[e] Nests of landbirds and medium and smaller shorebirds were found incidentally and therefore not included in density calculations.

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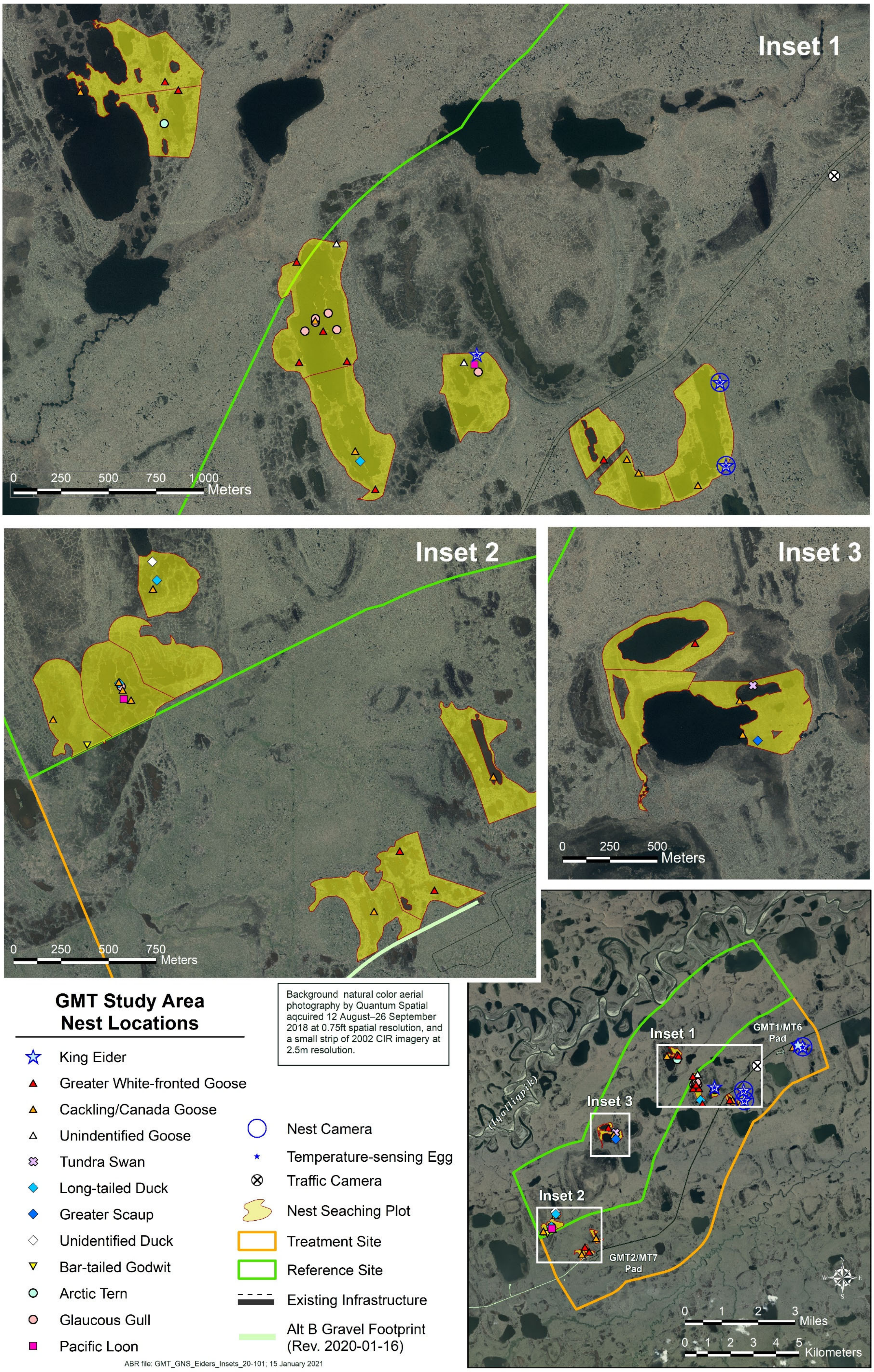

Figure 9. Nest locations of waterbirds, seabirds, and large shorebirds on nest plots in the GMT study area, Alaska, 2020.

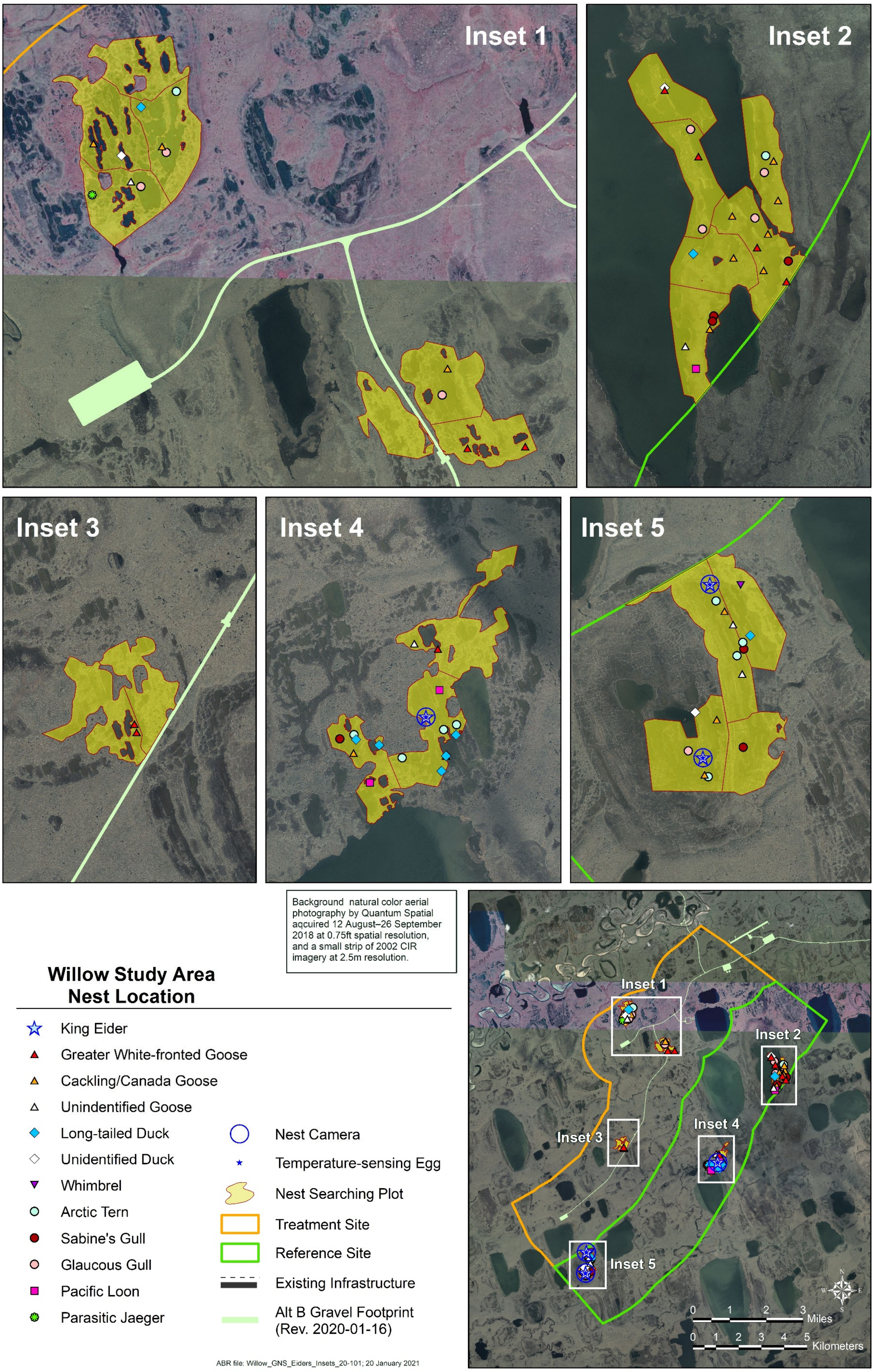

Figure 10. Nest locations of waterbirds, seabirds, and large shorebirds on nest plots in the Willow study area, Alaska, 2020.

searching began on 17 June, we estimated that 5 of 7 of the eiders had initiated incubation. The median start date of incubation for King Eiders was 19 June (range 14–27 June). The median date of nest initiation (first egg laid) for King Eiders was 16 June (range 1–26 June). Mean clutch size for nests with complete clutches (eggs >3 d old) was 4 ± 0.4 eggs.

The median incubation start date for Greater White-fronted Geese was 13 June (range 7–18 June). Mean clutch size for nests with complete clutches was 4.7 eggs (SE = 0.67). The dates of nest initiation for Greater White-fronted Geese ranged from 4 to 10 June, and the median initiation date was 8 June.

TEMPERATURE-SENSING EGGS

Temperature-sensing eggs, along with time-lapse cameras, and egg floatation data provided detailed histories used for survival analyses (see NESTING SUCCESS), and activity budgets for incubating females (Table 6). We installed 7 temperature-sensing eggs in King Eider nests and set up cameras on 6 of those nests. One nest failed before we were able to set up a camera. Three of the nests were monitored until day of hatch or brood departure and 4 nests were monitored until day of failure. Nest 410, with a temperature sensor and no camera, provided nest temperatures too variable to quantify incubation behaviors, although we were able to use the data to determine the date of nest failure. Nest 244 was monitored by a temperature sensor and camera, but the female abandoned this nest on the same day it was discovered. We observed this female return to the nest briefly after the temperature sensor was installed (and departure of researchers from the nest site). Within 30 seconds of returning to the nest, she was seen sitting in view of the camera but >10 m away. Subsequent images confirmed that the female never returned to the nest to incubate.

TIME-LAPSE CAMERAS

We monitored 6 of the 7 active King Eider nests with time-lapse cameras (Table 6). Cameras were placed 25–45 m from nests (mean ~30 m). At all nests, camera installation, egg flotation, and hobo placement occurred simultaneously, and setup took 25–40 min. Memory cards and batteries lasted the entire monitoring period and therefore no camera maintenance was required during the observation period.

Of the 6 nests monitored with time-lapse cameras, 3 hatched young and 3 failed (Table 6). Two nests failed following predation by Common Ravens that appeared to force females from their nests. Both depredated nests were in the GMT treatment area and were 370 m and 620 m from roads. The third nest, in the Willow reference site, failed because it was abandoned by the female. Of note, 15 days following abandonment, a Parasitic Jaeger with young found the nest, uncovered the eggs, and consumed the contents. Without photo evidence of this activity, we would have concluded that the nest failed from depredation based on nest contents on our nest fate check.

INCUBATION BEHAVIOR

In 2020, we compared incubation behaviors calculated from temperature sensors and cameras on 5 King Eider nests (Table 6), and pooled nests from both study areas to calculate means ± SE for successful versus failed nests. The sample size in this first year of the study was too small to compare nests in control and treatment sites.

Excluding the days of instrumentation and hatch, temperature-sensing eggs monitored nest temperature in 3 successful nests for 4.9–21 d (mean = 13.3 ± 4.6 d) and 2 failed nests for 2.9 and 10.8 d (mean = 6.9 ± 4 d). Nest cameras monitored 3 successful nests for 12.7–21 d nests (mean = 15.6 ± 2.7 d) and 2 failed nests for 2.6 and 6.4 d (mean = 4.5 ± 1.9 d) When temperature sensors were deployed in King Eider nests, the incubating birds were flushed from their nests. Females at successful nests took 85 ± 45 min (range 40–130 min) to return to incubate after installing a temperature-sensor. Females from nests that later failed took longer to return to nests after instrumentation (mean = 128.3 ± 66.5 min, range 10–240 min).

Incubation constancy from temperature sensors and cameras ranged between 91.9 ± 1.5% and 99.5 ± 0.2% for nests that hatched or failed, with estimates differing between temperature and camera data. Using temperature data, we found that females incubated nests that hatched young 98.9 ± 0.2% (*n* = 3 nests) of the total time observed and spent 99.1 ± 0.2% (*n* = 2 nests) incubating nests that failed. Incubation constancy calculated using

Table 6. Nest history and incubation activity of King Eider nests monitored by temperature-sensing eggs and time-lapse digital cameras in the GMT and Willow study areas, NE NPRA, Alaska, 2020.

					Dates Monitored		Days Monitored[a]		Incubation Constancy (%)[a]		Mean Daily No. Recesses[a]		Mean Recess Length (min)[a]	
Nest	Distance to GMT (km)	Min. clutch Size	Fate	Predator	Temp.-sensing Egg	Camera	Temp.-sensing Egg	Camera	Temp.-sensing Egg	Camera	Temp.-sensing Egg	Camera	Temp.-sensing Egg	Camera
GMT2/MT7														
113	0.27	5	S	–	25 June–15 July	25 June–15 July	21	21	99.1	97.9	1.6	1.3	8.2	23.7
403	0.37	4	F	Raven	22 June–24 June	22 June–24 June	2.9	2.6	99.4	99.5	1.0	0.8	8.3	9.5
114	0.62	5	F	Raven	24 June–5 July	29 June–5 July	10.8	6.4	98.8	91.9	2.5	2	7.2	57.2
410	0.56	5	F	avian[b]	24 June–28 June[c]	–	–	–	–	–	–	–	–	–
Willow														
211	18.7	3	S	–	24 June–28 July [d]	24 June–6 July	4.9 [d]	12.7 [e]	93.2 [d]	98.8 [e]	3.5 [d]	0.9 [e]	27.1 [d]	19.5 [e]
247	26.23	4	S	–	1 July–13 July	1 July–13 July	14	13	98.6	99.8	1.1	0.7	19	23.8
244	25.6	2	F[f]	–	1 July–26 July	1 July –26 July	–	–	–	–	–	–	–	–

[a] Excludes day of instrumentation, hatch, or fledging. Differences in the time a nest was monitored by a temperature sensor and camera was either because they were not set up at the same time or day, or equipment malfunctions or periods when photos were obscured by the sun or fog, reduced the amount of usable data.
[b] Egg remains in nest indicated avian predator
[c] We returned to nest on 28 June to set up a camera and found the nest had failed. Temperature data was too variable to calculate incubation constancy
[d] After 28 June, nest temperatures became too variable to calculate incubation constancy, but was possible to determine that the female was incubating until 8 July
[e] Includes 1 day when 311 min of data were lost due to sun glare
[f] Female abandoned the nest on the same day it was found

camera data found a greater difference in the amount of time females incubated successful versus failed nests compared to estimates using temperature data. And the average amount of time females incubated both successful and failed nests was lower from estimates using camera data than from temperature data. Incubation constancy for successful nests monitored by cameras was 98.4 ± 0.4% (*n* = 3 nests), and 95.7 ± 3.0% (*n* = 2 nests) for nests that failed (Table 6). Using temperature data, we calculated that females on average take 1.4 ± 0.2 recesses/day at successful nests (*n* = 3 nests) and 1.8 ± 0.6 recesses/day at nests that failed (*n* = 2 nests). With camera monitoring, we found that females on average take 1 ± 0.2 recesses/day at successful nests (*n* = 3 nests) and 1.7 ± 0.6 recesses/day at nests that failed (*n* = 2 nests). The average recess length from temperature data was 13.6 ± 4.4 min for successful females and 7.8 ± 0.4 min for nests that failed; compared to longer recesses (23.8 ± 0.04 min and 33.4 ± 19.5 min respectively) calculated from our camera data. Differences in calculations of incubation behavior between temperature sensors and cameras can be partially explained by differences in the number of days temperature sensors or cameras monitored nests. Also, cameras record nest breaks and recesses more accurately than temperature sensors because images clearly document when a female leaves a nest. When ambient temperatures are high (>10 C) temperature sensors fail to detect short breaks in incubation and underestimate recesses because nests retain heat for longer periods of time.

The day of nest hatch was not included in summaries because the exact time could not always be discerned from temperature records and partial days of incubation are not adequate for measuring recess frequency and time off the nest, but we did include the day the nest failed. Incubation behavior on the day of nest failure may be important because predation risk can be influenced by nest attendance behavior.

NESTING SUCCESS

In 2020, 7 of 8 King Eider nests were active when found. A failed nest was found with the down lining pulled outside the nest bowl. We later confirmed that the nest was a King eider based on contour feathers collected from this nest. Four of 5 eider nests in the GMT treatment site failed, all from predation. Of the 3 nests in the Willow reference site, only 1 nest failed from abandonment. Apparent nesting success (the proportion of nests hatching ≥1 egg) of King Eiders, was 38% (*n* = 8 nests).

Daily survival rate (DSR, probability of a nest surviving 1 d) was calculated for nests that were monitored by temperature sensors or cameras. The DSR for 7 monitored King Eider nests was 0.95 ± 0.2. The probability of a nest surviving the entire nesting period of 27 days (23 days incubation and 4 days laying) was 0.22 ± 0.1. Apparent nesting success was substantially higher than estimates of nest success from DSR, but as discussed in the methods, apparent nesting success tends to be biased high relative to DSR estimates that account for time of exposure. We did not calculate DSR for other species of waterbirds.

HABITAT USE

King Eiders nested in 2 of the 11 available wildlife habitats in our study areas. Habitats used for nesting were Shallow Open Water with Islands or Polygonized Margins (2 nests), and Old Basin Wetland Complex (6 nests; Table 7). These habitats composed 19% and 32% respectively of the total area searched. We did not have an adequate sample of nests to examine habitat selection.

NEST PREDATORS

In 2020, we observed 4 species of nest predators on predator counts (Glaucous Gulls, Parasitic and Long-tailed jaegers, and 1 Common Raven) and no mammals (i.e., foxes and bears). Glaucous Gulls and jaegers (primarily Parasitic Jaegers) were the most abundant and widespread nest predators observed during predator scans on and outside nest plots in the GMT and Willow study areas (Table 8). Glaucous Gulls seen on plots during predator scans composed 64% (27 of 42) predator sightings in the GMT study area, although 21 of 27 gulls observed were reported in the treatment site. The proportion of Glaucous Gull observations in the Willow study area was similar to the GMT study area (63%, or 33 of 52 predator sightings), and 25 of 33 of these observations were in the reference site. Only 1 Common Raven was observed on predator scans, and this was in the Willow reference site. Observations of jaegers accounted for 36% (15 of 42) predator sightings in

Table 7. Habitat use by nesting King Eiders on nest plots at GMT and Willow study areas, NE NPR-A, Alaska, 2020.

Habitat	Area (km^2)	No. of Nests	Use (%)[a]	Availability (%)
Deep Open Water with Islands or Polygonized Margins	0.24	0	0	4.9
Shallow Open Water without Islands	0.06	0	0	1.2
Shallow Open Water with Islands or Polygonized Margins	0.93	2	25	18.9
Sedge Marsh	0.43	0	0	8.7
Grass Marsh	0.21	0	0	4.3
Old Basin Wetland Complex	1.56	6	75	31.8
Nonpatterned Wet Meadow	0.54	0	0	10.9
Patterned Wet Meadow	0.85	0	0	17.2
Moist Sedge-Shrub Meadow	0.06	0	0	1.2
Moist Tussock Tundra	0.02	0	0	0.5
Tall, Low, Dwarf Shrub	<0.01	0	0	0.1
Total	4.91	8	100	100

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

the GMT, and 35% (18 of 52) predator sightings in Willow. The number of jaegers in reference and treatment sites in both study areas was similar (Table 8). Long-tailed Jaegers were observed only in the Willow study area and accounted for 50% of all jaeger observations there. Outside plot boundaries (within 300 m of plot boundaries), we recorded fewer gulls and jaegers than on plots, but the proportions of these avian predators was similar to observations on plot (Table 8).

The average number of predators in each study area was similar, but differences in the average number of predators observed per predator scan between sites (control and treatment) was greater (mostly from Glaucous Gulls) in both the GMT and Willow study areas (Table 8) The 2 sites with the most Glaucous Gulls were the same 2 sites where we found nests of King Eiders.

An ordinal measure of small mammals on plots (based on sightings of fresh winter trails, nests, scat, and lemmings or voles seen on each plot) indicated generally low abundance of small mammal prey available to avian predators and foxes that also prey on bird nests. The average rating of small mammal signs was 0.8 in the GMT reference site and 1.1 in the treatment site. In the Willow study area, the average small mammal rating was 0.6 at both the reference and treatment sites. In comparison, the average rating for small mammals on plots in CD5 was 2.2 in 2019 (Rozell et al. 2020).

DISCUSSION

PRE-NESTING EIDERS

In the GMT and Willow study areas, 4 species of eiders may occur, however only King and Spectacled eiders are recorded regularly. Of these 2 species, the Spectacled Eider has received the most attention because it is federally listed as “threatened” in 1993 (58 FR 27474–27480) under the Endangered Species Act of 1973, as amended. The nearby Colville River delta is a concentration area for breeding Spectacled Eiders relative to surrounding areas; nonetheless, Spectacled Eiders nest in the GMT and Willow study areas at low densities. Inland areas of the NE NPR-A such as the GMT and Willow eider survey area support even lower densities (Burgess et al. 2003, Shook et al. 2019 and 2020). The King Eider, which is not

Table 8. Number of nest predators observed in and near nest plots in the GMT and Willow study areas, NE NPR-A, Alaska, 2020. Predators included Long-tailed and Parasitic Jaegers (jaegers); Glaucous Gulls (gulls); and Common Ravens (ravens).

	GMT2/MT7						Willow					
	On plot			Outside plot[a]			On plot			Outside plot[a]		
Species	Reference	Treatment	Total	Reference	Treatment	Total	Reference	Treatment	Total	Reference	Treatment	Total
Jaegers	7	8	15	3	0	3	10	8	18	2	3	5
Gulls	6	21	27	1	13	14	25	8	33	8	5	13
Ravens	0	0	0	0	0	0	1	0	1	0	0	0
Total predators	13	29	42	4	13	17	36	16	52	10	8	18
No. predator scans[b]	16	21	37	16	21	37	25	16	41	25	16	41
Predators/scan	0.8	1.4	1.1	0.3	0.6	0.5	1.4	1.0	1.3	0.4	0.5	0.4
SE	0.2	0.5	0.3	0.1	0.4	0.3	0.2	0.3	0.2	0.2	0.2	0.1

[a] Predators observed outside plot but ≤300 m from plot boundary
[b] Two predator scans were conducted on each plot >500 m in length, and 1 scan if <500 m

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, in CPAI survey areas in NE NPR-A, and the immediate surroundings as these areas are east of their current Alaska breeding range centered near Utqiaġvik. The NE NPR-A is within the range of Common Eiders, which nest primarily on barrier islands and coastlines, but are seen rarely on surveys inland in the NE NPR-A.

The low indicated density of King and Spectacled eiders in 2020 compared to other years in the NPR-A may be related to the 2020 study area being smaller and further from the coast. Generally, densities of both species are higher near the coastal areas of the NPR-A. Although there was a relatively low indicated density of King Eiders in the GMT and Willow study areas, the adjacent Colville Delta study area had the third highest indicated density in 2020 (the highest density in the Colville Delta was 2018), and particularly on the East Channel where flocks often congregate but infrequently nest. Some of these eiders may have moved inland (e.g., to the NE NPR-A and Kuparuk Oilfield) after the pre-nesting survey to nest. King Eiders on the ACP have been increasing at a significant rate of 2.5% annually since 1986 (Wilson et al. 2018). King Eiders on the Colville Delta study area have had a similar annual growth rate (3.8%) since surveys began in 1993 (95% CI, $R^2 = 0.26$, $p = 0.01$). Both estimates were lower than the 9% annual growth estimated from surveys conducted by ABR in NE NPR-A during 1999–2014.

Densities of Spectacled Eiders recorded in the NE NPR-A have been consistently low since we began surveys in 1999, generally only 25% of the density recorded on the Colville River delta (Shook et al. 2020). Similar to the NE NPR-A, the annual growth rate for the adjacent Colville Delta study area also was not statistically significant (Shook et al. 2020 and Parrett et al. 2021). In contrast, Spectacled Eiders in the Kuparuk study area had a negative growth rate of –3% for 1993–2015 (Morgan and Attanas 2016). A slightly negative and non-significant growth rate (–2%) was also estimated from the North Slope waterfowl surveys conducted for Spectacled Eiders across the entire Arctic Coastal Plain (ACP; Wilson et al. 2018). Only the Kuparuk growth rate differs significantly from equilibrium, which suggests that, although there is substantial year-to-year variation, the population on the ACP is stable to slightly decreasing.

NESTING EIDERS

In 2020, the abundance of King Eider nests in our study area was slightly lower than targeted (≥ 10 nests) but expected based on pre-nesting aerial surveys which indicated low densities of eiders distributed over a large area. In the first year of nest-searches conducted in the GMT and Willow study areas, nesting densities of King Eider was nearly 3 times higher than any year of nest-searching in the CD5 NE-NPRA study area, where eider densities ranged from 0.8–1.0 nests/km² (2013–2019, Rozell et al. 2020). By selecting study plots in preferred King Eider nesting habitat, the probability of finding nests of this species was likely maximized.

There was some evidence that the timing of nest searches was early in the GMT and Willow study areas during 2020. King Eider males typically leave the vicinity of their nest before the last egg is laid (Lamothe (1973) in Powell and Suydam 2020). Therefore, observations of male King Eiders on the breeding grounds suggest that nest initiation is in the early stages or has not yet begun. In the GMT treatment site on 18 June, we observed a group of 2 males and 2 females (plot GT-11) where the males were acting aggressive towards each other. We observed another female on this plot that did not appear to be attending a nest. On 24 June, also in the GMT treatment site, we observed a pair of King Eiders (plot GT-30) that did not appear to be nesting. In the Willow reference site on 23 June, we found a pair of King Eiders, but did not find a nest. In subsequent years of this study, we may consider a later start date for nest-searching.

In our study areas, the median date of nest initiation was 16 June (n = 7 nests), which was 1–3 d earlier than the average nest initiation observed for King Eiders at study sites in Alaska to the east (Kuparuk) and west (Teshekpuk) of this study. A study of 289 King Eider nests found over 4 years (2002–2005) reported average nest initiation dates of 17 June in Kuparuk and 19 June in Teshekpuk (Bentzen et al. 2008). The median date of nest initiation for a small sample of Greater White-fronted Goose nests was 8 June (n = 6) in the GMT and Willow study areas. Nest initiation was ~1 week later than any year except 1 reported for geese at CD5. In 2013, snowmelt was later than average and nest initiation for Greater White-fronted Geese was 10 June (Rozell et al. 2020). Conditions in the study area in 2020 were probably not the cause of delayed nest initiation, as late-May and early-June temperatures, and timing of snowmelt was average for this year.

In the GMT study area, we found King Eider nests only in the treatment site and none in the reference site. Four of 5 eider nests in the GMT treatment site failed from depredation with camera images confirming that Common Ravens were the cause of 2 of these failures. Ravens were not regularly observed in either study area, but an active raven's nest (that fledged young) was found under the Tinmiaqsiugvik River bridge, ~10 km from GMT study plots. Camera images on both nests showed multiple ravens appearing while each of the females was incubating and caused the females to leave their nests without attempting defense. Ravens are a nest predator associated with development in the arctic (Day 1998, Powell et al. 2009), and would likely not occur on the North Slope without the use of infrastructure for nesting habitat. Red foxes have also been associated with oilfield development in the North (USFWS 2003, Savory et al. 2014). Unlike most other years, we saw no live red foxes and 2 dead red foxes during our field work on the Colville Delta and the NE-NPRA; and there were no confirmed red foxes on any of our camera images. Reports from Alpine security, and confirmed by CPAI environmental staff, stated that many red foxes died during the previous winter, apparently from exposure during a ~30-day cold snap with temperatures <-65 °F with wind chill (Sarah Byam, pers. comm).

In 2020, the Willow study area (control and treatment sites) was effectively a control site because there was no development in the area. Of the 3 active King Eider nests in Willow, only 1 nest failed—perhaps from disturbance by nest-searchers. This nest was found late in the season (30 June) and the female was incubating 2 eggs which is fewer than the average full clutch of 4 eggs; and based on egg-float estimates she had probably recently initiated incubation. These factors suggest the female had limited reserves for nesting and was potentially more vulnerable to effects of disturbance. We also suspect eiders are more sensitive to disturbance during laying and the first days of incubation because they have less time invested in the nest. Disturbance by observers has been shown to have a significant negative effect on the nesting success of King Eiders in Kuparuk and Teshekpuk, Alaska (Bentzen et al. 2008), and Greater White-fronted Geese nesting in the Arctic Coastal Plain (Meixell and Flint 2017), though in both of these studies nests were checked frequently throughout incubation. By only visiting nests once, we minimize the disturbance to the incubating bird and reduce exposing the nest to predators.

The overall apparent nesting success of King Eiders was comparable to the average nesting success over 5 years in the CD5 study area (38%, n = 17 nests, ABR unpublished data). In the summer of 2020, a large proportion of waterbird nests (e.g., Greater White-fronted Goose, Cackling/Canada Goose, and Long-tailed Duck) were depredated before they were found. This follows a year of peak small mammal populations at CD5, and Greater White-fronted and Cackling/Canada Geese had higher than average nesting success (Rozell et al. 2020), presumably due to the abundance of food in the area. The low abundance of small mammals in the GMT and Willow study areas in 2020 may have contributed to increased predation pressure on waterbird nests.

In our first year of 5, observing possible effects of disturbance on nesting King Eiders, small sample sizes (n = 8) limited the power of statistical analyses and inferences from our results. In subsequent years of this study, and with more nests, we will evaluate disturbance and other factors affecting nesting King Eiders.

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

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

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Appendix C. Number of images, duration, and type of vehicles[a] on the GMT2/MT7 road, as recorded by a time-lapse camera, NE NPR-A, Alaska, 2020.

	Small Truck			Large Truck			Machinery			Non-Oilfield Vehicle			All Vehicles			
Date	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Min Monitored
18	26	13.0	13.0	2	1.0	1.0	0	0	0	0	0	0	28	14.0	14.0	1,199
19	68	33.5	34.0	5	2.5	2.5	71	35.0	35.5	3	1.5	1.5	147	72.5	73.5	1,440
20	77	38.5	38.5	198	98.5	99.0	904	348.5	452	5	2.5	2.5	1,184	488.0	592.0	1,440
21	16	8.0	8.0	5	2.5	2.5	9	4.5	4.5	3	1.5	1.5	33	16.5	16.5	1,440
22	25	12.5	12.5	7	3.5	3.5	3	1.5	1.5	1	0.5	0.5	36	18.0	18.0	1,440
23	21	10.5	10.5	6	3.0	3.0	1	0.5	0.5	2	1.0	1.0	30	15.0	15.0	1,440
24	28	13.5	14.0	4	2.0	2.0	2	1.0	1.0	6	3.0	3.0	40	19.5	20.0	1,440
25	17	8.5	8.5	3	1.5	1.5	0	0	0	5	2.5	2.5	25	12.5	12.5	1,440
26	22	10.5	11.0	4	2.0	2.0	0	0	0	2	1.0	1.0	28	13.5	14.0	1,440
27	24	11.0	12.0	2	1.0	1.0	2	1.0	1.0	6	3.0	3.0	34	16.0	17.0	1,440
28	42	21.0	21.0	3	1.5	1.5	0	0	0	2	1.0	1.0	47	23.5	23.5	1,440
29	28	14.0	14.0	11	5.5	5.5	3	1.5	1.5	7	2.5	3.5	49	23.5	24.5	1,440
30	25	12.5	12.5	4	2.0	2.0	4	2.0	2.0	1	0.5	0.5	34	17.0	17.0	1,440
01	35	17.5	17.5	3	1.5	1.5	23	11.5	11.5	4	2.0	2.0	65	32.5	32.5	1,440
02	24	12.0	12.0	5	2.5	2.5	0	0	0	3	1.5	1.5	32	16.0	16.0	1,440
03	26	12.0	13.0	9	4.5	4.5	0	0	0	3	1.5	1.5	38	18.0	19.0	1,440
04	24	12.0	12.0	10	5.0	5.0	0	0	0	0	0	0	34	17.0	17.0	1,440
05	19	8.5	9.5	4	2.0	2.0	2	1.0	1.0	0	0	0	25	11.5	12.5	1,440
06	27	12.5	13.5	4	1.5	2.0	0	0	0	1	0.5	0.5	32	14.5	16.0	1,440
07	16	8.0	8.0	10	5.0	5.0	0	0	0	0	0	0	26	13.0	13.0	1,440
08	24	12.0	12.0	3	1.5	1.5	3	1.5	1.5	2	1.0	1.0	32	16.0	16.0	1,440
09	24	12.0	12.0	4	2.0	2.0	1	0.5	0.5	1	0.5	0.5	30	15.0	15.0	1,440
10	23	11.5	11.5	7	3.5	3.5	0	0	0	3	1.5	1.5	33	16.5	16.5	1,440
11	25	12.5	12.5	7	3.5	3.5	0	0	0	3	1.5	1.5	35	17.5	17.5	1,440
12	68	33.5	34.0	6	3.0	3.0	0	0	0	6	3.0	3.0	80	39.5	40.0	1,440

Appendix C. Continue.

	Small Truck			Large Truck			Machinery			Non-Oilfield Vehicle			All Vehicles			
Date	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Images	Duration (min)[b]	Veh. Min[c]	Total Min Monitored
13	15	7.5	7.5	2	1.0	1.0	2	1.0	1.0	3	1.5	1.5	22	11.0	11.0	1,440
14	21	10.5	10.5	23	11.5	11.5	0	0	0	2	1.0	1.0	46	23.0	23.0	1,311
15	17	8.5	8.5	16	8	8	343	171	171.5	0	0	0	376	187.5	188	486
Total	807	397.5	403.5	367	182.5	183.5	1,373	582.0	686.5	74	36.0	37.0	2,621	1,198.0	1,310.5	39,125.0
Mean[d]	29.7	14.2	14.9	13.5	6.7	6.8	50.5	21.4	25.3	2.7	1.3	1.4	96.5	44.1	48.2	1,297.3
SE	3.0	1.6	1.5	6.9	3.4	3.5	34.0	13.6	17.0	0.4	0.2	0.2	10.4	4.2	5.2	34.8

[a] Small Truck = pickups, vans; large trucks = bus and vehicles >1 ton capacity; machinery = roller, loader and grader; non-oilfield vehicles = pickups, sport utility vehicles, ATVs
[b] Duration = number of min ≥1 vehicle was in camera view on the road; may count single vehicle (especially machinery) multiple times
[c] Vehicle Minutes (Veh. Min) = cumulative sum of minutes each vehicle was in camera view on road, thereby accounting for multiple vehicles operating at one time
[d] Daily means for vehicles are calculated with number of days = total minutes monitored / 1440 min, whereas daily mean minutes monitored = total minutes monitored / number of days camera was in place