

GREATER WHITE-FRONTED GOOSE STUDY AT CD-5,
NATIONAL PETROLEUM RESERVE-ALASKA:
A SYNTHESIS REPORT, 2013–2019

Kristen B. Rozell
Charles B. Johnson
Alex K. Prichard
Adrian E. Gall



Prepared for
CONOCOPHILLIPS ALASKA, INC.
Anchorage, Alaska

Prepared by
ABR, INC.—ENVIRONMENTAL RESEARCH & SERVICES
Fairbanks, Alaska

**NESTING GREATER WHITE-FRONTED GOOSE STUDY AT CD-5,
NATIONAL PETROLEUM RESERVE-ALASKA:
A SYNTHESIS REPORT, 2013–2019**

Prepared for

ConocoPhillips Alaska, Inc.

P.O. Box 100360

Anchorage, AK 99510

Prepared by

Kristen B. Rozell

Charles B. Johnson

Alex K. Prichard

Adrian E. Gall

ABR, Inc.—Environmental Research & Services

P.O. Box 80410

Fairbanks, AK 99708

August 2020



Printed on recycled paper.

TABLE OF CONTENTS

List of Figures.....	iv
List of Tables.....	iv
List of Appendices.....	v
Acknowledgments.....	vi
Introduction.....	1
Study Area.....	2
Methods.....	4
Nest Plot Selection.....	4
Nest Searching.....	4
Nest Attendance.....	5
Temperature-sensing Eggs.....	5
Time-lapse Cameras.....	6
Nesting Success.....	7
Habitat Mapping and Analysis.....	8
Predator Scans.....	9
Resource Selection Modeling.....	9
Data Management.....	10
Results.....	10
Seasonal Conditions in the Study Area.....	10
Distribution and Abundance.....	11
Habitat Use.....	17
Nest Initiation and Clutch Size.....	17
Incubation Activity.....	17
Temperature-sensing Eggs.....	17
Time-lapse Cameras.....	20
Nesting Success.....	30
Apparent Nesting Success.....	30
Daily Nest Survival.....	32
Models of Nest Distribution and Success.....	33
Other Nesting Birds.....	34
Distribution and Abundance.....	34
Habitat Use.....	35
Nest Predators.....	35
Discussion.....	36
Literature Cited.....	43

LIST OF FIGURES

Figure 1.	Study area and plot locations for ground-based surveys of nesting Greater White-fronted Geese at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	1
Figure 2.	Mean daily temperatures during May–July recorded at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	11
Figure 3.	Cumulative number of thawing degree-days for 15–31 May and 1–15 June in 2013–2015, 2017, and 2019, and the 8-year means recorded at CD-5, NE NPR-A	13
Figure 4.	Daily snow depth recorded during spring at Colville Village, Colville River Delta, Alaska, 2013–2015, 2017, and 2019	13
Figure 5.	Nest locations and nest fate of Greater White-fronted Geese, and location of temperature-sensing eggs and time-lapse cameras on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	15
Figure 6.	Nest locations of all species but Greater White-fronted Geese on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.	16
Figure 7.	Wildlife habitats and nest plots for the CD-5 Greater White-fronted Goose nesting study in the NE NPR-A, Alaska.....	19
Figure 8.	Median incubation start dates for nests of Greater White-fronted and Cackling/Canada geese, CD-5, NE NPR-A, 2013–2015, 2017, and 2019	23
Figure 9.	Parasitic Jaeger depredating nest 420 while the female Greater White-fronted Goose is on a recess at CD-5, NE NPR-A, 2019	27
Figure 10.	Greater White-fronted Goose defending nest 420 from a red fox, CD-5, NE NPR-A, 2019	29
Figure 11.	Example of the effects of nest age and incubation constancy on daily nest survival of Greater White-fronted Geese.....	34
Figure 12.	Distribution of Greater White-fronted Goose nests each year relative to infrastructure and ice-roads built the previous winter at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	37
Figure 13.	Number of predators observed on 40-plots during predator scans each year, and assessment of small mammal activity/plot at CD-5, NE NPR-A	41
Figure 14.	Four-wheeler tracks across the tundra northwest of the CD-5 drilling pad, NE NPR-A, June 2019	42

LIST OF TABLES

Table 1.	Yearly summer construction phases, and timing of nest-searching at CD-5, NE NPR-A, 2013–2015, 2017 and 2019	3
Table 2.	Mean monthly temperatures (calculated from daily mean temperatures) and the long-term mean at CD-5, NE NPR-A.....	12
Table 3.	Numbers and densities of nests of all species recorded in the study area at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	14
Table 4.	Habitat selection by nesting Greater White-fronted Geese on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	18
Table 5.	Habitat use by all nesting bird species on study plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	21

Table 6.	Apparent nesting success of Greater White-fronted Geese and number of nests monitored with temperature-sensing eggs at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	24
Table 7.	Comparison of incubation activities between successful and failed Greater White-fronted Goose nests monitored with temperature-sensing eggs at CD-5, NE NPR-A, 2014–2015, 2017, and 2019.....	25
Table 8.	Incubation activities of Greater White-fronted Goose females at nests monitored by time-lapse cameras at CD-5, NE NPR-A, 2019	30
Table 9.	Comparison of incubation activities at 6 Greater White-fronted Goose nests monitored by camera at 30-sec intervals and by temperature-sensing eggs at 5-min intervals at CD-5, NE NPR-A, 2019	31
Table 10.	Mean distance from infrastructure by fate of Greater White-fronted and Cackling/Canada Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	32
Table 11.	Model selection results of factors influencing daily nest survival for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	33
Table 12.	Model selection results for the resource selection function analysis of nest distribution for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.....	35
Table 13.	Parameter estimates for the best model of nest distribution for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	40
Table 14.	Model selection results for the analysis of nesting success for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	40
Table 15.	Parameter estimates for the best model of nesting success for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019	41

LIST OF APPENDICES

Appendix A.	Comparison of nesting activities between nests monitored by time-lapse cameras and temperature-sensing eggs for 6 Greater White-fronted Goose females at CD-5, NE NPR-A, 2019	46
Appendix B.	Number of nest predators observed in and near 40 10-ha nest plots at CD-5, NE NPR-A, 2013–2015, 2017 and 2019	47

ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc., and was administered by Robyn McGhee, Environmental Studies Coordinator and her predecessor, Caryn Rea, Senior Staff Biologist and Environmental Studies Coordinator for ConocoPhillips Alaska, Inc. We especially thank Robyn McGhee for supporting the continuation of these long-term monitoring studies, the benefits of which are being realized in other biological studies, in past and future National Environmental Protection Act (NEPA) documents, in species status reviews, and in development of permit applications. Nest searches in the CD-5 area of NE NPR-A could not have occurred without the assistance of many people, both in the field and in the office. Helicopters pilots, Josh Toal and Sjaan Porhola (Bristow Alaska), Dave McKnight, Ben Neel, and Garth Murdock (Pathfinder Aviation), and Tom Brand, Cody Pruden, Zach Russell, and the late Charles Weimer (Soloy) skillfully piloted us to and from our nest plots when transects could not be accessed by road. Eric Burney, Zac Hobbs, Mary Hrynyk, Ray Rush, and Candy Fitzpatrick coordinated the helicopter flights and kept us on schedule. Jamie Blankenship, Ashley Hovis, Matt Macander, Liz Miner, Tawna Morgan, and James Smith spent long hours with the co-authors walking the tundra in search of goose nests. In our Fairbanks office, Dorte Dissing and Pam Odom provided expert support in figure and report preparation. Joe Welch produced weather figures. Chris Swingley helped manage and analyze data and Julie Parrett set up a database for our time-lapse camera images. Logistics were handled by Pam Odom and Tony LaCortiglia, and electronic equipment was supported by Will Lentz. We thank all the ConocoPhillips Alaska staff and contractors at the Alpine Oilfield for providing a safe and welcoming work environment, especially Alpine and CD-5 field coordinators, Sarah Byam, Shellie Colgrove, Lynn DeGeorge, Keegan Fleming, Jessika Gonzalez, Ari Haunschild, Jodi Smith, Tom Richardson, and Sam Widmer, Mike Hauser, and Jon Ribich helped to secure a rental truck for us to use 2019. We thank all the above for contributing to the success of the CD-5 goose study.

INTRODUCTION

The first oil development in the Northeast Planning Area of the National Petroleum Reserve in Alaska (NE NPR-A) was constructed during 2014 and 2015 by ConocoPhillips Alaska, Inc., (CPAI) as part of the Alpine Satellites Development Plan (BLM 2004). The new development, named CD-5, consists of a gravel road and pipeline connected to the Alpine Facility on the Colville River delta, where produced oil from CD-5 is processed.

Niglivik, the Iñupiaq name for Greater White-fronted Goose (*Anser albifrons*), is a major subsistence species for local Iñupiat people (Naves 2011). The village of Nuiqsut is located 6 miles

south of the CD-5 road, and since 2014, the Nuiqsut Spur Road has connected the community to the CD-5 development (Figure 1). At the request of the North Slope Borough per rezone ordinance 75-6-54 Stipulation 3.c.(1), CPAI agreed to conduct a multi-year study of Greater White-fronted Geese (henceforth, White-fronted Geese) out of concern for potential development effects. ABR, Inc., was contracted in 2013 to conduct this study. The original pre-post construction study design for CD-5, approved by the North Slope Borough, included collection of nesting data during 1 year of the pre-construction (2013), 2 years of the construction (2014 and 2015), and 2 years of the operation (2017 and 2020). However,

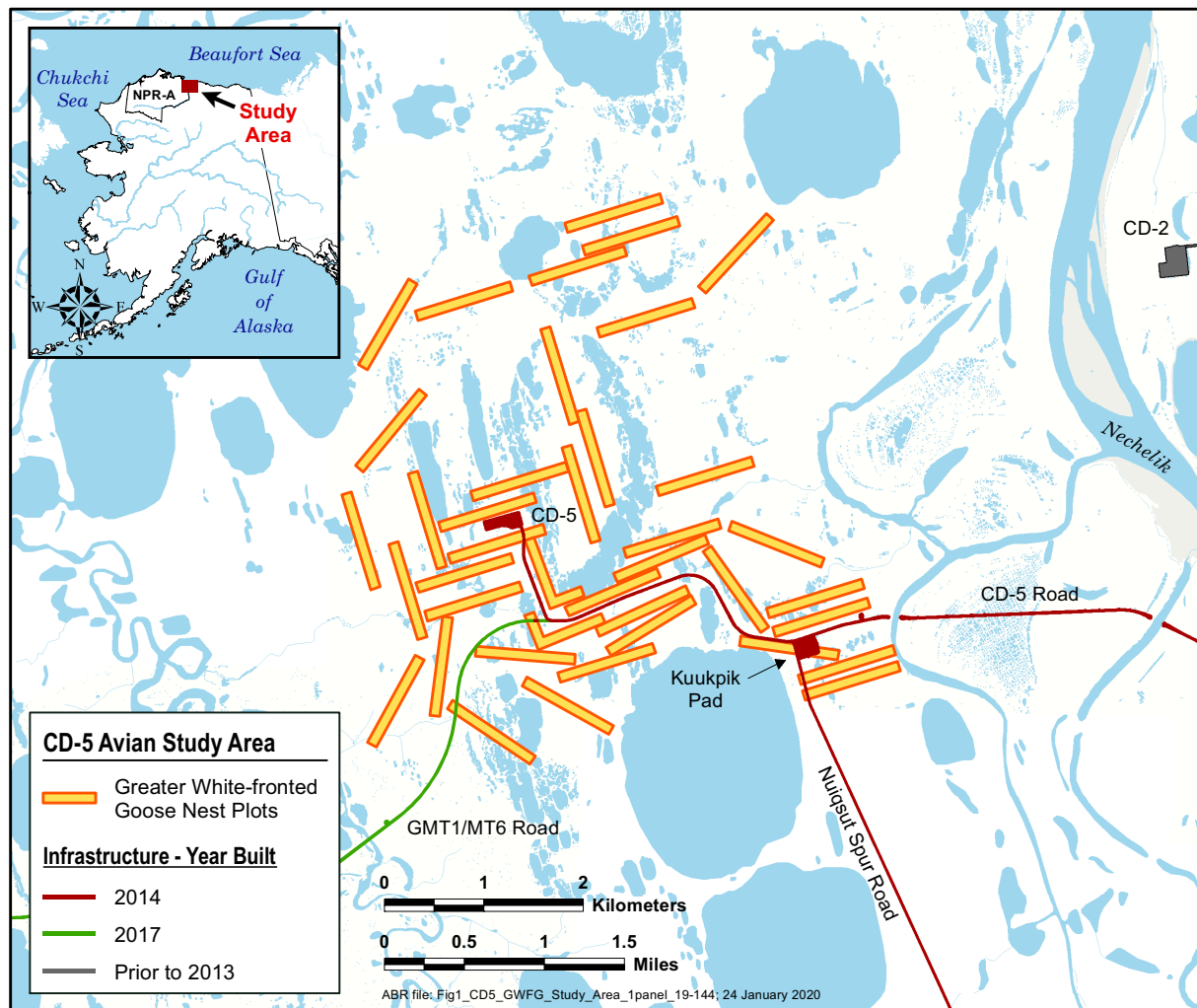


Figure 1. Study area and plot locations for ground-based surveys of nesting Greater White-fronted Geese at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

the development schedule changed over the course of the study. Gravel laid down during the winter of 2013–2014 could not support vehicle use in 2014 and needed to be “seasoned” until 2015, which resulted in 1 year of baseline data and 1 year of gravel infrastructure present with no activity. As expected, the summer of 2015 was a year of heavy construction activity and vehicle traffic on roads and pads in the study area. The summer of 2016 was a year of operation and drilling, but no nest searching was conducted by design. During the winter of 2016–2017, gravel was laid for the GMT1/MT6 road, which branches from the CD-5 road and intersects some of the study plots (Figure 1). The following summer of 2017 was an operation year with drilling activity, and although the GMT1/MT6 road was in place, it was impassable except by ATVs. The second year of operation for the study was revised to 2019 due to the increased activity on GMT1/MT6 expected in 2020 (Table 1). The goal of this study was to evaluate the effects of 3 phases of development: pre-construction (2013–2014), construction (2015), and operation (2017 and 2019) on White-fronted Geese nesting in the CD-5 area (Table 1). The specific objectives of this study were to:

1. record the abundance, distribution, and fate of nests of White-fronted Geese and other large waterbirds, and evaluate the relationships of these variables to distance to potential disturbance sources and the phases of development;
2. monitor a sample of nesting White-fronted Geese for changes in incubation behavior that may result from activities at the CD-5 development; and
3. identify changes in the occurrence and frequency of nest predators among all phases of development.

We report here the results of the White-fronted Goose nesting study conducted in 2013–2015, 2017, and 2019. Required state and federal permits were obtained for all survey activities, including a Scientific or Educational Permit (Permit No. 17-132) from the State of Alaska and a Federal Fish and Wildlife Permit—Native Threatened Species Recovery Threatened Wildlife; Migratory

Birds (Permit No. TE012155-6 issued under Section 10(a)(1)(A) of the Endangered Species Act [58 FR 27474-27480]).

STUDY AREA

The CD-5 drill site is located approximately 7 km west of the Nigliq Channel of the Colville River in the NE NPR-A (Figure 1). A gravel road (9.6 km long) and 4 bridges connect CD-5 to the CD-4 access road on the Colville River delta. Development of the CD-5 pad, gravel road, and bridges began in 2014, and was completed and open to vehicles and construction equipment during the summer of 2015. The pipeline was also completed in 2015. The Nuiqsut Spur Road (9.3 km) from Nuiqsut to the CD-5 road was constructed in 2014 and completed in 2015 by the Kuukpik Corporation. The Kuukpik Pad (initially a laydown pad for storage) also was built in 2014 at the intersection of the CD-5 and Nuiqsut Spur roads. During winter 2016–2017, the GMT1/MT6 drill pad and its 12.3-km long access road were constructed, tying into the CD-5 road from the west. Between 2014 and 2017, new construction (roads and pads) intersecting CD-5 study plots converted 0.04 km² of potential nesting habitat on study plots into the Human Modified habitat type (i.e., gravel). Every winter since 2014, ice roads were used in the CD-5 study area and intersected our study plots. Although ice roads were no longer present during nest-searching, their footprints on the tundra were visually apparent and altered the vegetation by compacting vegetation and reducing the height of graminoid cover used by nesting geese. Besides ice roads and pads, there were no additional developments in the CD-5 study area prior to the 2019 field season.

Landforms, vegetation, and wildlife habitats in the NE NPR-A were described in the Environmental Impact Statement for the Alpine Satellite Development Plan (BLM 2004) and in Jorgenson et al. (2003, 2004). Coastal plain and riverine landforms dominate the NE NPR-A. On the coastal plain, lacustrine processes, basin drainage, and ice aggradation are the primary geomorphic factors that modify the landscape. In riverine areas along Fish and Judy creeks, fluvial processes predominate, although eolian and ice-aggradation processes also contribute to

Table 1. Yearly summer construction phases, and timing of nest-searching at CD-5, NE NPR-A, 2013–2015, 2017 and 2019.

Year	Development Phase	Description	Relative Level of Human Activity ^a	Nest Searching Dates
2013	Pre-construction	No roads or pads in the study area	0	12 June–21 June
2014	Pre- construction	CD-5 roads and pads and Nuiqsut spur road and Kuukpik pad in place but not used by traffic or construction activity during incubation	1	9 June–18 June
2015	Construction	Heavy vehicle traffic on CD-5 road and construction activity on pad, drilling in progress. Nuiqsut Spur Road used by Nuiqsut residents and Kuukpik pad used for equipment storage.	5	8 June–17 June
2017	Operation	Operational use of CD-5 roads and pads and drilling in progress. GMT1/ MT6 road constructed in winter but not in use. Vehicle traffic on Nuiqsut Spur Road and Kuukpik pad with inactive work camp and equipment storage.	3	8 June–18 June
2019	Operation	Operational use of road and pads in CD-5, and drilling in progress. Vehicles using GMT1/ MT6 road. Vehicle traffic on Nuiqsut Spur Road and active work camp at Kuukpik Pad.	4	6 June–15 June

^a Relative ranking of yearly human activity (people, vehicle traffic, construction and drilling activity) during the breeding season.

ecological development of landforms and vegetation (Jorgenson et al. 2003).

Sixteen wildlife habitats occur on the 40 10-ha plots searched for nests. The most abundant wildlife habitats were Patterned Wet Meadow (28% of the plot area), Moist Sedge-Shrub Meadow (26%), Old Basin Wetland Complex (23%), and Moist Tussock Tundra (13%). Only 2 other habitats had >1% coverage: Shallow Open Water with Islands or Polygonized Margins (5%), and Sedge Marsh (2%).

METHODS

NEST PLOT SELECTION

In 2013, we established 40 fixed plots to search for White-fronted Goose nests in each of the year of the study (Figure 1). We selected plot locations from a 6 × 6 km grid centered on the CD-5 drill site. The grid contained 3,600 points spaced 100 m apart, of which 60 points were randomly selected. Each randomly selected point was used to locate the start of a 100 m × 1,000 m (10 ha or 0.1 km²) plot, oriented parallel to the nearest proposed road or pad. Plots were discarded if they overlapped a previously selected plot or had more than 25% of area in lakes. During nest searches, we completed a cluster of 1–5 plots each day, all within walking distance of each other (<2 km from the end of one to the start of another). Each successive day we alternated between clusters of plots that were near proposed facility locations and clusters that were far from facility locations. Plot clusters were searched in the same order each year and within a 10-d calendar period to avoid introducing a timing effect that might influence annual comparisons among plots. Unless stated otherwise, means are presented with standard errors (mean ± SE).

NEST SEARCHING

In all years of this study, we searched all 40 plots and used the methods described in prior annual reports (Johnson et al. 2014, 2015; Rozell and Johnson 2016, Rozell and Johnson 2018). Nests of White-fronted Geese and other large waterbirds were recorded as they were encountered. The combined plot area comprised 4.0 km². There were 0.03 km² eliminated from the nest searching area in 2014 and 2015 due to

incursions of the Nuiqsut Spur Road and Nuiqsut Laydown Pad into several study plots. In 2017, another 0.01 km² of study area was covered by the GMT1/MT6 road (Figure 1).

We completed the annual nest searches in ~10 days during the second and third weeks in June, commuting by truck or helicopter from Alpine each day. A crew of 4 people spaced 25 m apart searched for nests by walking zigzag patterns, to achieve total coverage of the tundra within each plot boundary. When lakes or ponds were encountered, we searched all shorelines, islands, islets, and emergent vegetation. Plot boundaries were displayed on a moving map on handheld GPS units. Both ends of each plot were marked with survey “whiskers” (spikes topped with fluorescent plastic) to indicate plot locations. Crew members searched for nests of large birds including waterfowl, loons, larids (gulls and terns), jaegers, Bar-tailed Godwits, and ptarmigan; any other shorebird and songbird nests were not recorded. Nest searchers communicated with hand-held radios when nests other than of White-fronted Geese were spotted to avoid flushing incubating birds. For each nest found, we recorded the species, location (GPS coordinates in WGS 84), status (active: nest attended or eggs were warm; or inactive: unattended and without 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 a sample of eggs from nests that were unoccupied or from nests where the incubating bird flushed. Eggs were floated 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 nests of White-fronted Geese (intentionally flushed) and from nests of Cackling/Canada Geese that were inadvertently flushed. Each floated egg was assigned an age from a float schedule based on the angle and position of the egg in the water column (Jerry Hupp, USGS, unpublished data). The float schedule provided estimates of ages in 2–4 d increments; we assigned to each egg the midpoint of the age range or the earlier date in the case of 2-d ranges. Nest data were recorded on a GPS and downloaded to a database at the end of each day.

A sample of nest contents was collected from all unattended waterfowl nests of unknown species and upon examination of size and color pattern of contour feathers, down, or eggs collected, nests were identified to species or species group (Anderson and Cooper 1994, Bowman 2004). Some nests remained unidentified because too few feathers were in the nest or feathers were not clearly definitive in determining species. Wooden survey stakes (45 cm high) were placed ≥ 15 m from active nest sites to assist in relocating the nest later in the season (see NESTING SUCCESS). 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. Following the 2019 field season, all survey stakes and plot markers (whiskers) were removed from the tundra.

NEST ATTENDANCE

TEMPERATURE-SENSING EGGS

Temperature-sensing eggs were used to monitor nest attendance for a sample of White-fronted Geese each year. Artificial temperature-sensing eggs and data loggers were installed in ~ 41 (range = 38–43) goose nests each year to record incubation activity and data on daily nest survival. Four to six sensors were installed each day in White-fronted Goose nests on the same day that nests were found, to ensure the sensors were distributed across all plots in the study area. Temperature sensors were deployed using the same methods each year except in 2013, when we conducted temperature-monitoring using bare sensors without enclosing them in artificial eggs, but otherwise followed the procedures described below.

Artificial eggs were constructed from plastic “Easter” eggs that were painted white. The thermistor (TMC1-HD, TMC6-HD, and TMC6-HA cables; Onset Computer Corporation, Bourne, MA) consisted of a 2.5 cm temperature sensor taped to the inside of each egg. The thermistor cable (connected to the temperature sensor) exited the temperature-sensing egg where the egg was attached to a 15 cm threaded toggle-bolt (sheetrock wall anchor). The thermistor 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. To establish baseline ambient temperatures for reference, one thermistor was attached to a nest stake at ground level and recorded temperatures every 15 minutes at a site centrally located in the study area.

Eggs were removed from nests before installing temperature sensors. The thermistor cable 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 geese or nest predators, the toggle-bolt on the temperature-sensing egg was pressed into a hole in the center of the nest bowl so that the wings of the bolt could act as barbs and hinder removal, and the thermistor cable was staked to the ground using 1–2 tent stakes. After installation, the original eggs were returned to the nest and covered with down and vegetation. After the nesting season, artificial eggs and data loggers were retrieved and the temperature data were exported using BoxCar Pro version 4.0.7.0 or HOBOWare version 3.7.1, depending on the model of the data logger used.

In 2013 only, the metal-tipped temperature sensor (not contained in an artificial egg) was staked down approximately 3–5 cm above the nest floor and the goose eggs were positioned around it. This method was proven successful in studies of loons and Emperor Geese (Daniel Rizzolo, U.S. Fish and Wildlife Service, Fairbanks, AK; pers comm), but in White-fronted Goose nests, the sensor was gradually buried by nesting material, and became less sensitive to temporal changes in temperature. Temperature data from 2013 provided us with end dates for female nest departure but did not provide the detail needed for calculations of nest attendance. Artificial eggs were used in subsequent years to keep the temperature sensors in place.

Classifications of incubation activity were made using temperature data collected from the data loggers, applying rules of interpretation developed for White-fronted Geese in a previous multi-year study that 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 temperature records. When the egg temperature 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 egg temperature decreased by ≥ 1 °C from the previous temperature record but egg temperature remained ≥ 28.3 °C; if ≥ 28.3 °C and the temperature change did not decrease 1.0 °C or more (i.e., decreased < 1 °C, no change, or increased), the female was assumed to be incubating. If the egg temperature was < 28.3 °C, the female was assumed to be off the nest on a recess. Recesses also were identified when the egg 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 egg temperature rose above 28.3 °C. At high ambient temperatures (> 12 °C), we used the same temperature threshold (28.3 °C) to determine whether or not the female was on a recess, but the difference in nest temperature required between 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., egg temperatures for the initial recess record usually started above 28.3 °C and dropped > 1 °C as the egg 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. Incubation constancy was calculated as the percentage of recording records each day during which the female was on the nest (incubation plus incubation breaks).

We used general linear models with random intercepts to compare differences in nesting behavior between successful and unsuccessful nests for 5 metrics of nesting behavior measured daily (incubation constancy, recess frequency, recess length, time off nest, and break frequency). We modeled each nesting behavior metric using success or failure of the nest as a fixed factor and including nest ID number as a random variable to

account for correlation among nests. Each of the 5 models of nest metrics was run separately each year and for all years combined. To better meet the assumptions of the models, incubation constancy was arcsine transformed [$\arcsine(\sqrt{\text{incubation percentage} / 100})$], and recess length and time off of the nest were log transformed [$\ln(\text{recess length} + 1)$, $\ln(\text{time off nest} + 1)$] prior to analysis. We used Poisson models to test for differences in recess frequency and break frequency because these metrics were daily counts.

TIME-LAPSE CAMERAS

In 2019, we deployed 10 time-lapse cameras to record nest attendance patterns, compare these patterns to nests that were simultaneously monitored by temperature-sensing eggs (6 nests), and identify causes of nest disturbance or failure. Five cameras were installed on the day of nest discovery, and 5 were installed several days following nest discovery in order to maximize the distribution of cameras. 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 external rechargeable 12V sealed lead acid batteries. We chose settings, memory cards, and batteries so that cameras could take the maximum number of photos possible for 23–28 d without requiring maintenance (i.e., battery or memory card changes).

We reviewed digital images on personal computers with Irfanview software (version 4.33). Goose activity was classified into 3 major types of activity: incubation, break, and recess. Incubation included sitting postures of normal incubation (head up and posture relaxed, or head resting on back), alert incubation (head up in a rigid, attentive posture), concealed incubation (head and body down and flattened in vegetation), and gathering nest material while on the nest. Break activities included brief standing activities at the nest, including changing positions, settling on the nest after changing position, standing over the nest, and egg moving. We calculated incubation constancy by summing the time spent on the nest (incubation

minutes plus break minutes) and dividing by the minutes monitored. Recess activities were absences from the nest, including 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 gone from view. We identified predators in camera view to species, estimated their distance from the nest, and described their behavior. We calculated incubation constancy, the frequency of incubation breaks, frequency of recesses, recess duration, and time off nest, following definitions used for temperature monitoring data. For summaries of incubation activity, the data were pooled by year for all nests active on each day before hatch or day before failure (sample unit = nest-d [1 nest monitored for 1 d]). Mean recess length for each year was calculated by pooling all recesses from all active nests each day. The length of incubation breaks could not be measured with temperature-sensing eggs because breaks were shorter than the 5-min interval between recordings.

Nest images were reviewed from the day of camera set-up through nest failure or when the geese and their young were observed leaving the nest. Because we could not see precisely when hatch began on images, we used the day the brood left the nest to estimate the start of hatch. We defined hatch as beginning at midnight the day before the brood departed the nest. A nest would be judged as failed (none this study) if the goose did not resume incubation after a predator was seen at the nest. The time of failure would be determined as the first image containing the predator.

For temperature-sensing eggs and cameras, any 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, operator error, or logistical constraints, were eliminated from the dataset. On cameras, periods of time when images could not be interpreted due to poor weather conditions were also excluded. We tested differences in nesting behavior metrics calculated simultaneously by cameras and hobos on White-fronted Goose nests. We first calculated the difference in each of the 5 metrics for each day and then tested to determine if that difference was significantly different from

zero. We ran general linear models with random intercepts for each metric using the daily difference as the response variable and including nest ID as a random variable to account for correlation within nests.

NESTING SUCCESS

Each year in early to mid-July, we revisited all nests of geese and waterfowl 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 predators at the nest (fox scent, fox scat, or a disturbed nest site) was recorded as supplemental information, but not used to judge nest fate.

Temperature data from nests with installed thermistors also were reviewed for indications of hatch or failure. Temperatures from failed nests typically drop abruptly and quickly begin tracking ambient temperatures. Temperature records of successful nests during hatching typically show a long period of nest attendance followed by increasingly frequent breaks 24–36 h before the female and brood leave the nest (Johnson et al. 2003) and the increase in break frequency is apparent in the graph of nest temperature by 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 $<9^{\circ}\text{C}$ or temperature appeared to track ambient temperatures. The hatch date of a nest was recorded as the day before the female and brood departed the nest.

Apparent nesting success was estimated by dividing the number of nests that hatched by the number of nests found, including nests that were inactive at discovery. Apparent nesting success is generally acknowledged to overestimate success because it does not take into account the length of time nests are exposed to predators and other risk factors (Mayfield 1961). We report apparent nesting success for all nests found because it is

easily calculated for large numbers of nests without the added disturbance or expense of periodic visits or monitoring devices.

For those nests containing temperature-sensing eggs and information on incubation behavior, we used the nest survival model from program MARK (White and Burnham 1999) to examine the nest-specific and temporal factors influencing variation in daily nest survival (the probability that a nest survives 24 hours, DNS). One hypothesis of the effects of oil development is that disturbance from human activity (e.g., vehicle traffic, workers, and construction activity) can affect the behavior of incubating adults, reducing their attendance at the nest and possibly increasing exposure of the nests to predation. We examined this hypothesis by including nest-specific measures of incubation activity in the model set: incubation constancy, average duration of incubation recesses, and average number of recesses per day. We also included the logarithm of distance to road or pad (distance) as a covariate to evaluate whether proximity to infrastructure influences DNS. We included nest density (density), the number of White-fronted Goose nests within each plot where a nest occurred, to examine the hypothesis that DNS is influenced by the number of neighboring nests (Bêty et al. 2001). DNS also may vary with nest age or day of season and among years with differences in weather or other year-specific factors. We constructed a set of 13 models and ranked them using Akaike's Information Criterion corrected for small sample size (AIC_c). The ΔAIC_c values and Akaike weights were used to infer support for the candidate models (Burnham and Anderson 2002); models within 2 AIC_c units of the top model were considered well-supported by the data. We evaluated the parameter estimates and their associated 95% confidence intervals from the best-supported model to identify which factors influenced DNS. We built all models and ran the analysis using package RMark (Laake 2013) in program R (R Core Team 2018).

We estimated incubation start dates and nest initiation dates for White-fronted Geese and Cackling/Canada Geese using egg-flotation data (described above) or by backdating in the case of nests with known hatch dates (nests with temperature sensors and/or cameras). We used the youngest (last-laid) egg floated in each nest to

determine the start date for incubation. The date of nest initiation was calculated by multiplying the clutch size by the estimated laying interval (1.33 d/egg; Ely and Dzubin 1994, Mowbray et al. 2002, Burgess et al. 2013) and backdating from the incubation start date.

HABITAT MAPPING AND ANALYSIS

A wildlife habitat was assigned to each nest by plotting its coordinates on the wildlife habitat map (Jorgenson et al. 2003, 2004). For each bird species, habitat use (% of all nests in each identified habitat type) was determined. Habitat availability also was calculated as the percent of each habitat in the total area on the 40 plots.

We conducted a statistical analysis of habitat selection of White-fronted Goose nests to evaluate whether habitats were used in proportion to their availability. We combined 5 years of nest search data in the analysis of habitat selection. We inferred selection (preference or avoidance) from comparisons of observed habitat use with random habitat use by means of Monte Carlo simulations (1,000 iterations). We defined habitat preference (i.e., use > availability) as observed habitat use greater than the 95% confidence interval of simulated random use. Conversely, we defined habitat avoidance (i.e., use < availability) as observed habitat use below the 95% confidence interval of simulated random use. The simulations and calculations of confidence intervals were conducted with Microsoft® Excel. Details are provided by Johnson et al. (2015).

In 2019, CPAI provided GIS vector layers of ice roads and pads used for transportation and construction during the winters of 2014, 2015, 2017, and 2019 in the CD-5 study area. Some of these layers specified a width that we used to buffer centerlines in order to reconstruct the ice road footprint. For the lines that did not specify a width, we assumed 10.7 m (35 ft), except for the Alpine re-supply ice roads which were assumed to be 16.8 m (55 ft) wide. Ice roads intersected several of our study plots and altered the habitat for the following breeding season. We examined the use or avoidance of this habitat for all years that ice roads were used during this study (see RESOURCE SELECTION MODELING below).

PREDATOR SCANS

We conducted predator scans visually on all plots to determine the types and numbers of potential nest predators in the CD-5 area. Binoculars were used to search for avian predators (i.e., jaegers, gulls, raptors, ravens, and owls) and mammalian predators (i.e., foxes and bears) during each scan. On each plot, we conducted 2 scans of 10 min each for predators inside or within 300 m outside of the plot boundary. Predator scans were conducted on the center line of each plot at the beginning and again at the end of the nest-search effort (1 km apart), 10 min before the start and 10 min after the end of the nest-searching effort for each plot. The level of predator activity in the area was represented by the number of predator observations during both 10-min scan. Observations of predators seen incidentally during nest searches also were recorded.

We also made a qualitative assessment of small mammals (e.g., lemmings and voles), which 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. Following the nest search on each plot, the level of small mammal activity (winter nests, trails, scat, or live animals) observed on the plot was scored: 0 = none, 1 = low, 2 = moderate, and 3 = high.

RESOURCE SELECTION MODELING

We used resource selection function (RSF) models (Boyce and McDonald 1999, Manly et al. 2002) to assess the distribution of White-fronted Goose nest locations with respect to multiple factors that could influence nest distribution in the study area. RSF models compare actual locations with random locations (use vs. availability) and can test for important factors influencing habitat selection and assess relative importance of different areas based on the spatial pattern of those factors. To conduct the RSF analysis, we ran logistic regressions (Manly et al. 2002) in Program R. We generated a number of random locations in non-water landcover classes within the study plots equal to 50 random locations per actual nest location. An equal number of random locations were assigned to each year.

Variables assessed included habitat type (5 types used by geese), year, predator counts on a plot, small mammal activity on the plot (ranked 0 to 3), ice road or pad (whether nest is within boundary of ice road or pad from previous winter), and distance to gravel roads or pads. Because we were primarily interested in the effect of distance to roads or pads, we ran a two-stage model selection process. We first found the best model from all combinations of variables other than distance to roads or pad (with no interaction terms) using the *glmulti* package in Program R (Calcagno and de Mazancourt 2010). The ΔAIC_c values and Akaike weights were used to infer support for the candidate models (Burnham and Anderson 2002); models within 2 AIC_c units of the top model were considered well-supported by the data. Once we found the best model from this first stage, we added the variables derived from Distance to road or pad (based on the location of roads and pads present in 2014) to the best model one-at-a-time and used AIC_c to determine which final model fit the best. The distance metrics we compared included: Distance, a linear function of distance to roads or pads (km), $\ln(\text{Distance} + 1)$, $\ln(\text{Distance} + 1/6)$, 0.5 km (within 0.5 km of roads or pads versus beyond 0.5 km), and Spline Distance, a natural spline of distance to roads or pads (with one knot at 1 km). The natural spline provides a flexible model that fits two cubic equations that meet at the knot. All distance metrics were modeled as an interaction with year, so that the model was allowed to vary for each year. We also modeled the same 5 distance metrics versus development phase instead of year. We used the 3 development phases: Pre-construction Phase in 2013 and 2014, before the CD-5 road and pad were built (2013) and when no vehicle traffic could use the CD-5 road (2014); Construction Phase in 2015, when the highest rates of traffic used the CD-5 road and pad; and Operation Phase in 2017 and 2019, when traffic rates were low to moderate and CD-5 was operational (Table 1). In 2017, GMT1/MT6 gravel was in place but unused by vehicles, while in 2019 the GMT1/MT6 road and pad were operational. The resulting ten models were compared using AIC_c values and Akaike weights to determine which model was the best model in the candidate set (Burnham and Anderson 2002).

The GMT1/MT6 road was present in 2017, but too soft to drive. In 2019, the GMT1/MT6 road had traffic on it. To account for nests that were closer to this new road than the roads that were present in 2014, we added an additional variable to all ten models. This additional distance variable (Diff. Distance) measured the difference in distance to roads present in 2014 and distance to the GMT1/MT6 road. It was calculated as the distance to the nearest road present in 2017 minus the distance to roads present in 2014. This new distance variable was calculated for 2019 White-fronted Goose nests only because no traffic occurred on the GMT1/MT6 road in 2017 and the road did not exist in earlier years. For all nests in years before 2019, the distance of this new variable was zero.

All locations were tested for collinearity between explanatory variables by calculating variance inflation factors (VIF) for the full model using the DescTools library in Program R (Signorell et al. 2019). We tested the fit of the best models for each period using k-fold cross-validation (Boyce et al. 2002). At each step, we withheld one-fifth of the White-fronted Goose nest locations and calculated relative probabilities of use for locations occupied by those nests (testing data) based on the remaining data (training data). We repeated this process 5 times, that is, one time for each one-fifth of the nest locations. We used the mean Spearman's rank correlation coefficient for the 5 testing data sets as a measure of model fit.

We used similar methods to test for factors influencing nesting success of all nests in the study area except rather than comparing actual nest locations to random points, we compared successful nests to failed nests using logistic regression models. Because few nests were in areas with ice roads the previous winter, this variable was dropped from the analysis. This analysis differed from the DNS analysis in that it included data from all 5 years of the study.

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 GPS receiver with decimal-degree coordinates in

the WGS 84 map datum and later transferred into the NAD 83 map datum. Uniform attribute data were recorded for all observations and proofed after data collection and proofed again prior to analysis. Survey data were submitted to CPAI in GIS-ready format with corresponding metadata.

RESULTS

SEASONAL CONDITIONS IN THE STUDY AREA

Multiple sources of evidence suggest that seasonal phenology was late in 2013, advanced in 2015, and mixed but within the 8-year average in 2014, 2017, and 2019. Temperature data were collected at CD-5, whereas snow depth was recorded at Colville Village near the mouth of the Colville River. Spring conditions at the 2 sites are correlated, with Colville Village recording colder temperatures and having later snowmelt than at CD-5 due to the village's proximity to the marine pack ice. The temperature pattern for all years and months was variable but increased from below freezing in May (mean -2.5 °C), to about $+5$ °C in June and about $+10$ °C in July (Figure 2). Mean temperature for May was lower in 2013 (-6.5 °C) than the 8-year mean and all other years of the study, whereas the mean temperature in June of that year ($+6.6$ °C) was slightly above the long-term mean ($+4.9$ °C, Table 2). Temperatures in May and June 2015 (-0.6 °C and $+8.8$ °C, respectively) were higher than the same months in all other years. Cumulative thawing degree-days (TDD, the number of days with mean temperatures above 0 °C) for late May (15–31 May; arrival and early nest initiation period) were highest in 2015 and lowest in 2013, 2014, and 2019 (Figure 3). Early June (1–15 June; late nest initiation and early incubation period) TDD were above average in 2013, 2015, and 2016, and below average in 2017 and 2019. Snow depth in early May was greatest in 2013 and 2019 (Figure 4). Snowmelt was essentially completed by 22 May in 2015 but was delayed until 1–6 June in the other study years, although June snowfalls prolonged snow cover a few additional days in 2014 and 2015. Breakup dates for the Colville River, the nearest large stream, appeared to be related to May temperatures. Peak water stage on the Colville

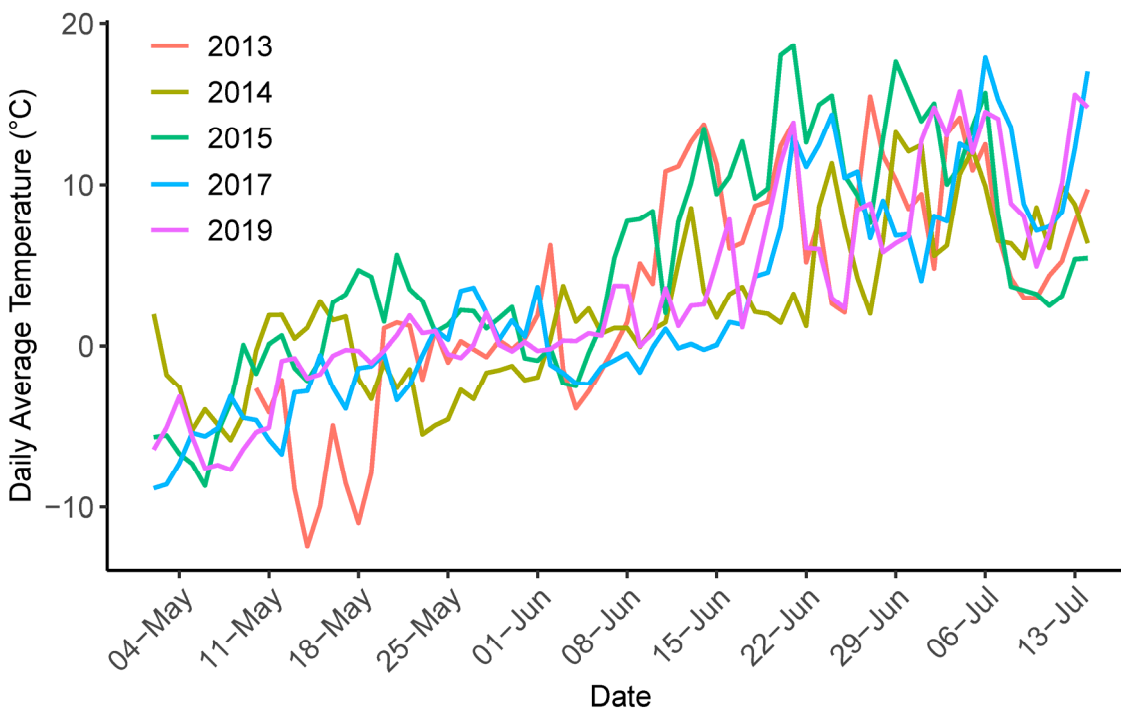


Figure 2. Mean daily temperatures during May–July recorded at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

River (measured at Monument 1) was the latest of all years in 2013 on 3 June and the earliest in 2015 on 21 May and in 2019 on 24 May; the other years were at or near the average date (30 May) for timing of high water during breakup (Michael Baker International 2019). The combination of snowmelt timing and May and June temperatures suggest that tundra-nesting birds arriving early may have had earlier access to nest sites in 2015 and later access in 2013 and possibly 2017 and 2019. The relationship of seasonal phenology to timing of nesting and other nesting parameters in White-fronted Geese will be evaluated in subsequent sections of this report.

DISTRIBUTION AND ABUNDANCE

Four species of geese nested on the 40 10-ha plots in the CD-5 area in all years of this study, and their combined nests accounted for 91% of all nests recorded. White-fronted Geese were the most abundant nesting waterfowl in the study area with the maximal nesting density in 2019 at 45.2 nests/km² (Table 3). Cackling/Canada Geese

were second in overall abundance with nesting densities of 10.1 nests/km² in 2019 (Table 3). Two Brant nests and 1 Snow Goose nest were found on plots over the 5 year-study. White-fronted and Cackling/Canada goose nests were widely distributed among the plots (Figures 5 and 6). White-fronted Goose nests were found on all 40 plots over the 5 years of the study, and Cackling/Canada Goose nests occurred on 35 plots. Combining all years, the mean number of White-fronted Goose nests found was 3.3 ± 0.2 nests/plot ($n = 5$ years). The plots with the highest nesting densities of White-fronted Geese averaged 6.6 ± 0.9 and 6.4 ± 1.4 nests/year ($n = 5$ years). Nesting densities of both White-fronted and Cackling/Canada geese have increased throughout this study. White-fronted Goose nests increased from 21.8 nests/km² in 2013 to 45.2 nests/km² in 2019; the average logarithmic growth rate was 11% ($\ln(\text{nests}) = 0.11(\text{year}) - 221$; $R^2 = 0.95$, $P < 0.01$). Cackling/Canada Goose nests increased from 1.5 nests/km² in 2013 to 10.1 nests in 2019.

Table 2. Mean monthly temperatures (calculated from daily mean temperatures) and the long-term mean at CD-5, NE NPR-A. Long-term mean calculated from 8 years (2012–2019).

	2013		2014		2015		2017		2019		Long-term Mean	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
May	-3.2	1.0	-1.6	0.5	-0.6	0.7	-2.8	0.7	-2.1	0.5	-2.5	0.4
June	6.6	1.0	3.8	0.7	8.8	1.1	3.8	1.0	4.2	0.7	4.9	0.6
July	9.9	0.7	7.2	0.5	6.8	0.7	10.9	0.7	10.9	0.5	9.3	0.3

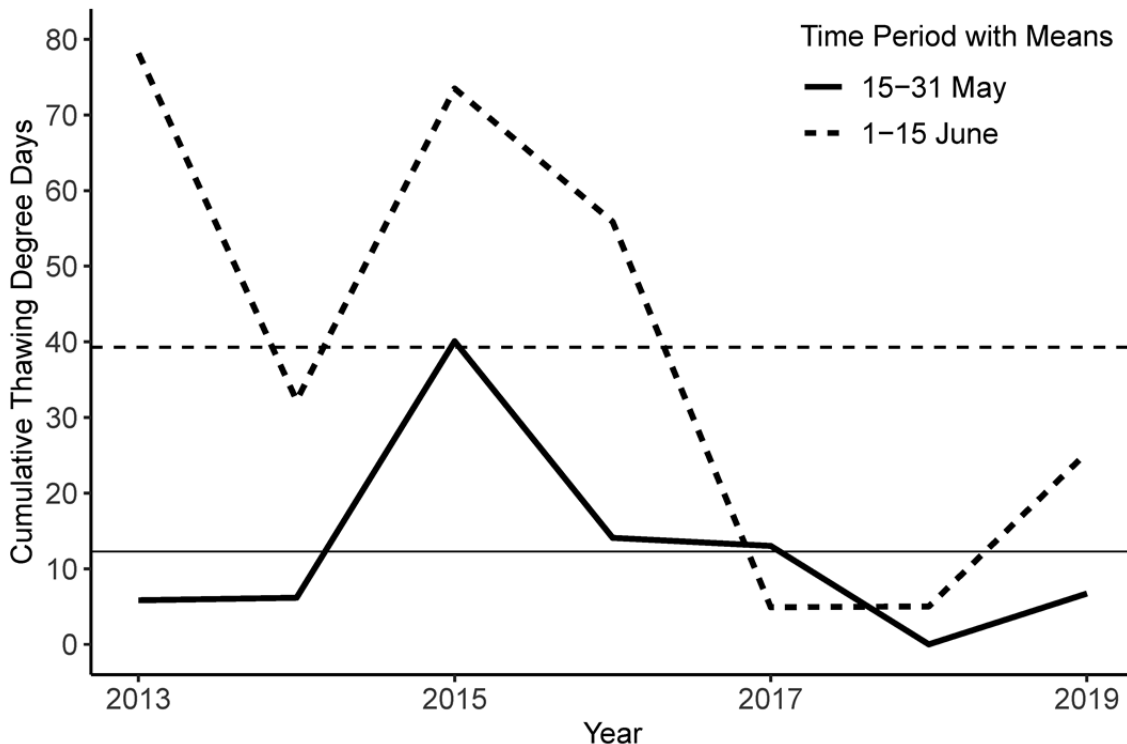


Figure 3. Cumulative number of thawing degree-days for 15–31 May and 1–15 June in 2013–2015, 2017, and 2019, and the 8-year means recorded at CD-5, NE NPR-A.

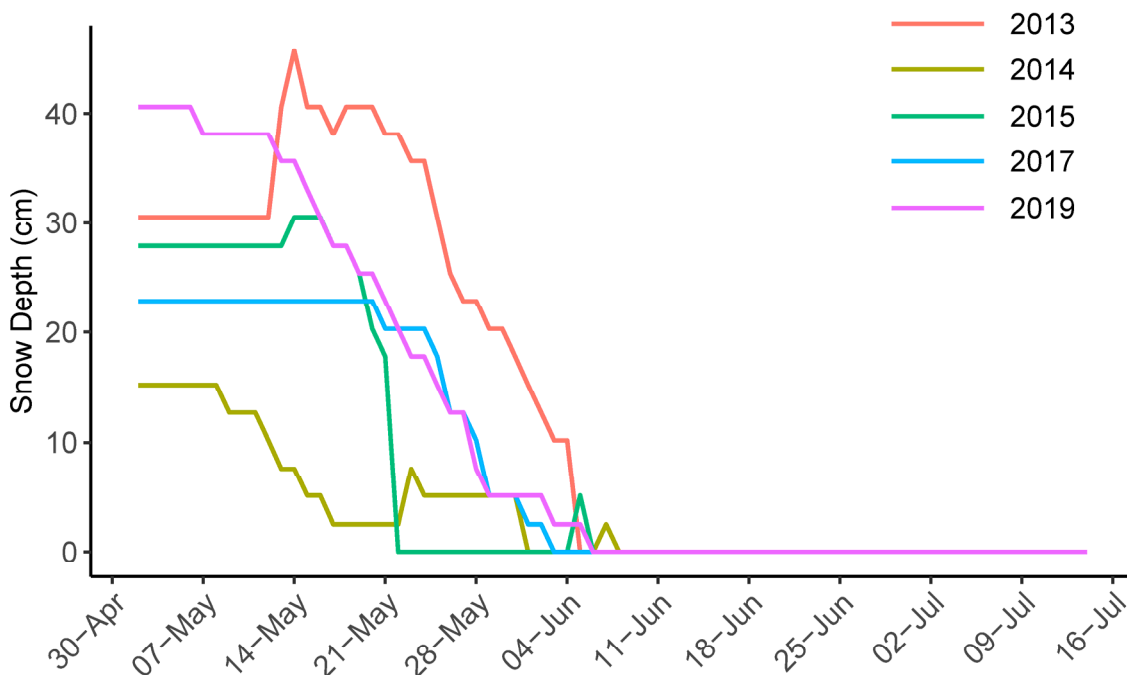


Figure 4. Daily snow depth recorded during spring at Colville Village, Colville River Delta, Alaska, 2013–2015, 2017, and 2019.

Table 3. Numbers and densities of nests of all species recorded in the study area at CD-5, NE NPR-A, 2013–2015, 2017, and 2019. Number of nests found outside plot boundaries are in parentheses. Nest densities are only calculated for nests within plots.

Species	Total Number of Nests					Nest Density (nests/km ²) ^a				
	2013	2014	2015	2017	2019	2013	2014	2015	2017	2019
Greater White-fronted Goose	87(23)	114(33)	120(42)	152(62)	179(36)	21.8	28.7	30.2	38.4	45.2
Snow Goose	0	1	0	(1)	0	0	0.3	0	0	0
Brant	1	0	(1)	1(1)	(1)	0.3	0	0	0.3	0
Cackling/Canada Goose ^b	6(4)	23(3)	21(8)	35(22)	40(9)	1.5	5.8	5.3	8.8	10.1
Unidentified goose ^c	1	0	0	1	0	0.3	0	0	0.3	0
Tundra Swan	0	1	0	0	0	0	0.3	0	0	0
Northern Pintail	2(1)	1(1)	2	2	1	0.5	0.3	0.5	0.5	0.3
Green-winged Teal	1	0	0	0	3	0.3	0	0	0	0.8
King Eider	4	3(2)	3	4(2)	3(2)	1.0	0.8	0.8	1.0	0.8
Unidentified eider	0	0	0	(1)	0	0	0	0	0	0
Long-tailed Duck	2	3(1)	2(1)	2(1)	(1)	0.5	0.8	0.5	0.5	0
Unidentified duck	0	1	0	0	0	0	0.3	0	0	0
Willow Ptarmigan	2	1	0	1(1)	2	0.5	0.3	0	0.3	0.5
Red-throated Loon	0	0	0	(1)	0	0	0	0	0	0
Pacific Loon	0	0	1	1	0	0	0	0.3	0.3	0
Black-bellied Plover	0	(1)	0	0	0	0	0.3	0	0	0
Bar-Tailed Godwit	3	1	3	0	1	0.8	0.3	0.8	0	0.3
Sabine's Gull	3	0	1	0	1	0.8	0	0.3	0	0.3
Glaucous Gull	1	(2)	(1)	2(2)	1(1)	0.3	0	0	0.5	0.3
Arctic Tern	2	2	0	2(2)	1(1)	0.5	0.5	0	0.5	0.3
Parasitic Jaeger	2	(1)	1	0	0	0.5	0	0.3	0	0
Rough-legged Hawk	0	0	0	0	(1)	0	0	0	0	0
Total	117(28)	152(44)	154(53)	203(96)	232(52)	29.3	38.3	38.8	51.3	58.6
Total number of species	14	11(3)	10(2)	11(3)	10(3)					

^a Density calculations were adjusted for minor reductions in study area from new infrastructure.

The original study area in 2013 was 4.0 km², in 2014 it was reduced to 3.97 km², and in 2017 and 2019 it was reduced to 3.96 km².

^b Nest belonging to either Cackling or Canada goose.

^c An inactive goose nest that failed before discovery and could not be determined whether it belonged to White-fronted Goose or Cackling/Canada Goose.

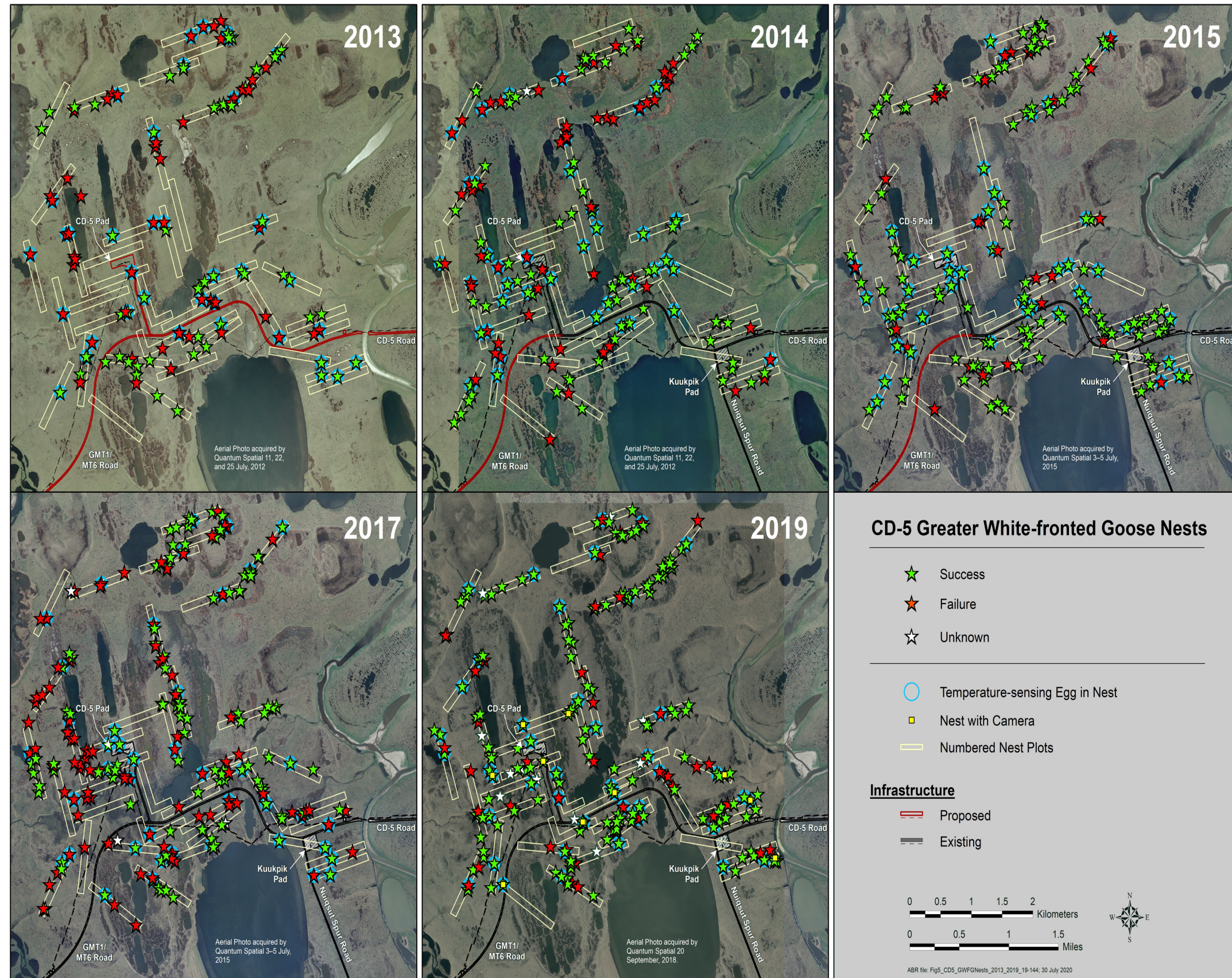


Figure 5. Nest locations and nest fate of Greater White-fronted Geese, and location of temperature-sensing eggs and time-lapse cameras on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019..

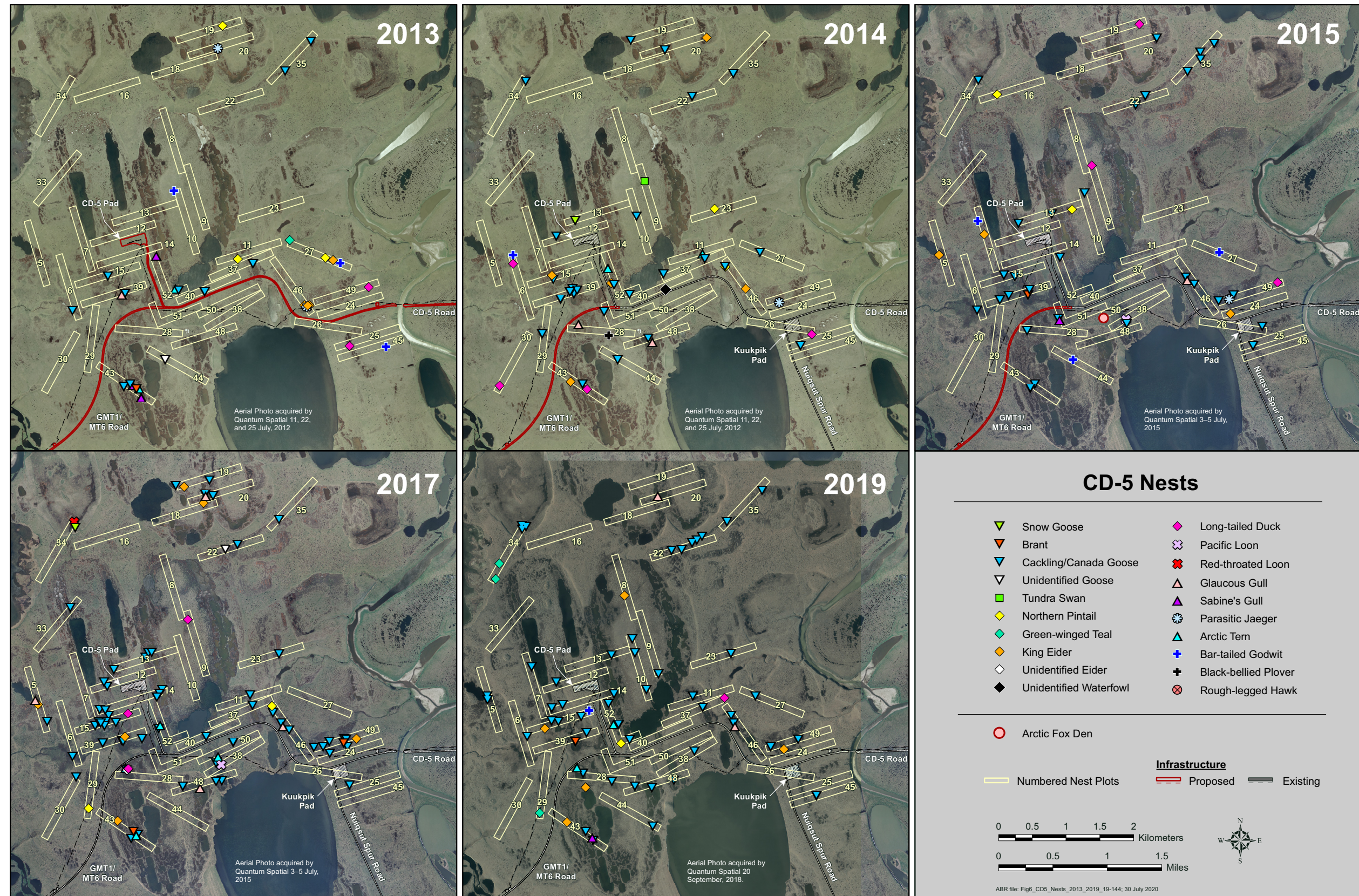


Figure 6. Nest locations of all species but Greater White-fronted Geese (see Figure 5) on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

HABITAT USE

The most prevalent habitat types in the CD-5 study plots included Patterned Wet Meadow (5.64 km², 28% of study area), followed by Moist Sedge-Shrub Meadow (5.09 km², 25% of study area), and Old Basin Wetland Complex (4.66 km², 23% of study area; Table 4, Figure 7). These habitat types also supported the majority of nests totaling 72% (704 of 857) of all nests found (Table 5). White-fronted Geese nested in 5 different habitats over the years, but 86% of all nests (562 of 652 nests) were in the 3 most abundant habitat types (Table 5). Eleven percent of White-fronted Goose nests were found in Moist Tussock Tundra and 2% were found in Sedge Marsh. A Monte Carlo analysis of habitat selection using 652 White-fronted Goose nests from 5 years of this study found nesting White-fronted Geese used all habitats in proportion to availability except for Patterned Wet Meadow, which was a preferred habitat (Table 4). White-fronted Geese avoided nesting in Shallow Open Water with Islands or Polygonized Margins, Shallow Open Water without Islands, and Human Modified Habitats. Cackling/Canada Geese nested in 8 different habitats over all years of this study, with the largest proportion of nests in Old Basin Wetland Complex (46%, 57 of 125 nests) and in Shallow Open Water with Islands or Polygonized Margins (27%, 34 of 125 nests) (Table 5), a habitat avoided by White-fronted Geese. Compared with nests of White-fronted Geese, Cackling/Canada Goose nests tended to be placed in the wetter habitats, on islands or shorelines of water bodies.

NEST INITIATION AND CLUTCH SIZE

We floated eggs from 777 White-fronted Goose nests and 65 Cackling/Canada Goose nests over the 5-year study to estimate nest age and the start of incubation. By the time nest searching began on 12 June 2013, only 27% of White-fronted Geese had started incubation. In contrast, in 2015, 94% of females were incubating eggs when we started nest-searching on 8 June. The median date of the start of nest incubation in 2013 (14 June, range = 6–18 June) was later than any other year of this study, whereas 2015 and 2019

had the earliest nest incubation start date (median date = 5 June, range = 26 May–11 June; Figure 8).

The spring/summer of 2013 was characterized by periods of below-average temperatures in May, late snowmelt and a late breakup (Table 2, Figures 2–4), resulting in relatively late nest initiation (i.e., median date of first egg laid = 10 June, range = 31 May–17 June). In contrast, 2015 was much warmer in the spring, breakup was early, and White-fronted Geese used the favorable conditions on the breeding grounds to initiate nests early (median date = 24 May, range = 20 May–9 June). Despite conditions in 2019 being more similar to the colder years with a later snowmelt (but relatively early Colville River breakup), nest initiation (median date = 26 May, range = 21 May–7 June) was more similar to that of 2015.

Mean clutch size for White-fronted Goose nests with complete clutches (eggs > 3 d old) was largest in 2019 at 4.3 ± 0.12 eggs ($n = 182$ nests), and smallest in 2017 with 3.7 ± 0.13 eggs ($n = 178$ nests).

The median incubation start dates for Cackling/Canada Geese in general were the same as or slightly earlier than the White-fronted Geese (Figure 8). Like White-fronted Geese, Cackling/Canada Geese had the latest median incubation start date in 2013 (13 June, range = 9 June–14 June, $n = 6$ nests), and the earliest in 2015 (1 June, range = 27 May–9 June, $n = 11$), 4 days earlier than the median incubation start date for White-fronted Geese. In 2019, nest initiation dates did not mirror their early timing of 2015 as they did for White-fronted Geese. Median nest initiation in 2019 for Cackling/Canada Geese (4 June, range = 31 May–4 June, $n = 20$) was 6 days later than in 2015 and only 1 day earlier than in 2017. Mean clutch size for nests with complete clutches ranged from 3.0 ± 0.9 eggs ($n = 4$ nests) in 2013 to 5 ± 0.3 eggs ($n = 11$ nests) in 2015.

INCUBATION ACTIVITY

TEMPERATURE-SENSING EGGS

Over 5 years of this study, we installed an average of 41 temperature-sensing eggs per year in White-fronted Goose nests. Each year, a varying proportion (63–95%) of those eggs provided temperature data that could be used to quantify incubation behaviors. In 2013, however, we were

Table 4. Habitat selection by nesting Greater White-fronted Geese on nest plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

Habitat	Area z (km ²)	No. of Nests	Use (%) ^a	Availability (%)	Monte Carlo Results ^b	Sample Size ^c
Deep Open Water without Islands	0.04	0	0	0.2	ns	low
Deep Open Water with Islands or Polygonized Margins	0.09	0	0	0.5	ns	low
Shallow Open Water without Islands	0.14	0	0	0.7	avoid	low
Shallow Open Water with Islands or Polygonized Margins	1.06	3	0.5	5.3	avoid	
River or Stream	<0.01	0	0	<0.1	ns	low
Sedge Marsh	0.40	13	2.0	2.0	ns	
Grass Marsh	0.01	0	0	<0.1	ns	low
Old Basin Wetland Complex	4.66	171	26.2	23.3	ns	
Riverine Complex	0.02	0	0	0.1	ns	low
Nonpatterned Wet Meadow	0.05	0	0	0.2	ns	low
Patterned Wet Meadow	5.64	220	33.7	28.2	prefer	
Moist Sedge-Shrub Meadow	5.09	171	26.2	25.4	ns	
Moist Tussock Tundra	2.63	74	11.3	13.1	ns	
Tall, Low, Dwarf Shrub	0.03	0	0	0.2	ns	low
Barrens	<0.01	0	0	<0.1	ns	low
Human Modified	0.12	0	0	0.6	avoid	low
Total ^d	19.99	652	100	100		

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

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

^c “Low” = expected number < 5.

^d Total area searched over 5 years of this study.

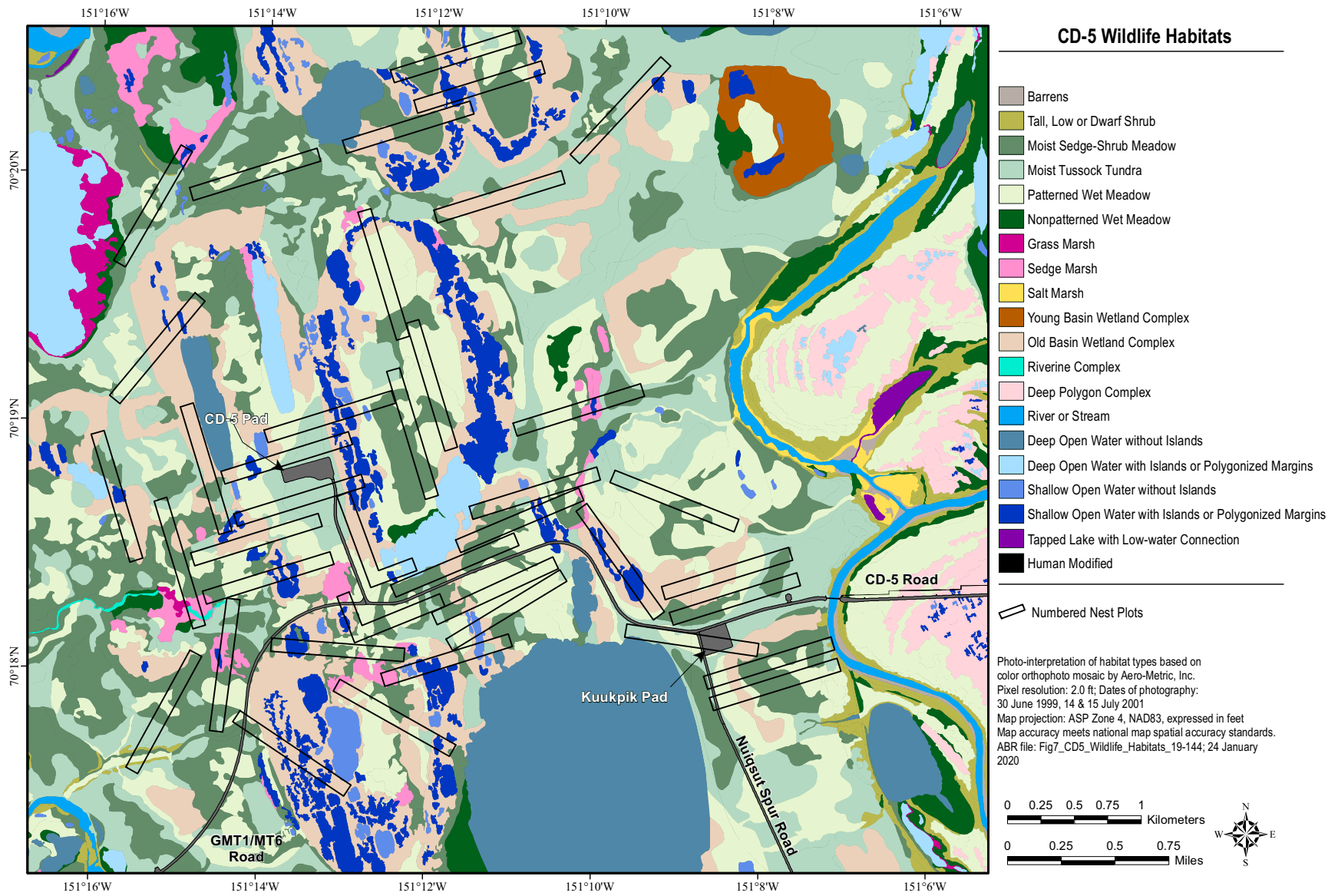


Figure 7. Wildlife habitats and nest plots for the CD-5 Greater White-fronted Goose nesting study in the NE NPR-A, Alaska.

unable to use data from any temperature sensor to estimate incubation activity of females (see METHODS: TEMPERATURE-SENSING EGGS), although we were able to use those temperature data to determine incubation end dates (the last day the female was on the nest) for 28 of 38 monitored nests. The primary causes of problems with individual temperature-sensing eggs and data loggers were:

1. temperature sensors were not properly attached or became unattached during set-up, or moisture seeped into data loggers
2. the temperature-sensor was compromised during monitoring (i.e., movement of the goose on the nest, or predators at the nest, had disconnected or damaged the temperature-sensors or data loggers)
3. temperature-sensing eggs or loggers were removed from nests by predators such as foxes or bears and never retrieved (especially in 2017)
4. data loggers recorded erroneous temperature data for no obvious reason.

Over 5 years, we installed temperature monitors in 207 nests. Of the instrumented nests, 143 were successful and 64 failed (Table 6). The apparent nesting success for nests with temperature sensors was 69% ($n = 207$ nests) and was similar to the apparent nesting success for all nests without temperature sensors (70%, $n = 641$ nests). This suggests that the disturbance caused by instrumenting nests and the addition of artificial eggs did not compromise hatching success.

Incubation activity calculated from data from the temperature-sensing eggs was compared for 2014, 2015, 2017, and 2019. The days when instrumentation, hatch, and failure occurred were not included in incubation summaries because partial days of incubation were not adequate for measuring recess frequency or time off nest and because the exact time of hatch or failure could not always be determined from temperature records. Females at failed nests tend to have lower nest attendance in the final day of incubation, but this is difficult to quantify without a definitive time for nest failure.

Temperature-sensing eggs monitored nest temperature in 129 White-fronted Goose nests, of which 103 hatched and 26 failed. When temperature-sensing eggs were deployed, the incubating birds were flushed from their nests. The length of time females at successful nests took to return to incubate after instrumentation averaged 87 ± 7 min (range 25–630 min, $n = 103$ nests). Females from nests that failed later took 24% longer on average to return to nests after instrumentation (mean = 108 ± 79 min, range 30–410 min, $n = 26$ nests). The relationship between nest fate and the amount of time to resume incubation, however, varied annually. In 2014, successful nesters took almost twice as long to return to nests (mean = 148 ± 34 min, $n = 17$ nests) as failed nesters (mean = 81 ± 21 min, $n = 4$ nests). In 2015, failed nesters returned to nests on average 10 min later (mean = 94 ± 3 min, $n = 5$) than successful nesters (mean = 84 ± 6 min, $n = 35$). In 2017 and 2019, failed nesters took on average 130 ± 34 min and 108 ± 15 min to return to nests, respectively, compared with successful nesters whom averaged 80 ± 9 min and 61 ± 6 min to return to nests.

The incubation constancy for successful and failed nesters varied annually, but on average was higher for successful nesters (mean = $98.5 \pm 0.1\%$ time on the nest) than failed nesters ($94.7 \pm 0.6\%$, $P = <0.01$) (Table 7). In 2017, incubation constancy was the lowest of all years for successful ($97.2 \pm 0.28\%$) and failed nesters ($93.3 \pm 1.0\%$). In 2014 and 2015, the mean incubation constancy was the highest of all years for successful ($\geq 99\%$) and for failed ($>98\%$) nesters. For all years combined, successful White-fronted Goose females took on average 1.23 ± 0.06 incubation recesses/d and females that failed took 2.53 ± 0.19 recesses/d, with an average recess duration of 14.8 ± 0.2 min for successful females compared with 23.5 ± 0.8 min for females from failed nests (Table 7). Females at failed nests were off their nests more than 3 times longer each day (76.1 ± 8.5 min) than females at successful nests (20.7 ± 1.3 min, $P < 0.01$).

TIME-LAPSE CAMERAS

In 2019, time-lapse cameras provided visual imagery on incubation behavior and visits by predators at 10 White-fronted Goose nests. All

Table 5. Habitat use by all nesting bird species on study plots at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

Habitat	Greater White-fronted Goose ^a	Snow Goose	Brant	Cackling/Canada Goose ^b	Unidentified Goose	Tundra Swan	Northern Pintail	Green-Winged Teal	King Eider ^a	Long-tailed Duck	Unidentified Duck	Willow Ptarmigan	Pacific Loon	Bar-tailed Godwit	Sabine's Gull	Glaucous Gull	Arctic Tern	Parasitic Jaeger	Total Nests	Habitat Use (%) All Species
Deep Open Water with Islands or Polygonized Margins	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	14	0	2	<1
Shallow Open Water without Islands	0	0	0	1	0	0	0	0	0	0	0	0	50	0	0	0	0	0	2	<1
Shallow Open Water with Islands or Polygonized Margins	0	0	50	27	0	0	0	0	12	0	0	0	0	0	100	75	0	0	48	6
Sedge Marsh	2	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	2
Old Basin Wetland Complex	26	0	50	46	50	0	0	0	59	22	0	17	50	13	0	25	86	100	255	30
Patterned Wet Meadow	34	100	0	16	50	100	38	0	24	44	0	33	0	50	0	0	0	0	260	30
Moist Sedge-Shrub Meadow	26	0	0	2	0	0	50	50	6	33	100	33	0	13	0	0	0	0	188	22
Moist Tussock Tundra	11	0	0	1	0	0	13	50	0	0	0	17	0	25	0	0	0	0	81	9
Total Nests	652	1	2	125	2	1	8	4	17	9	1	6	2	8	5	4	7	3	857	100

^a Includes nests identified to species from feather and down samples.

^b Nest belonging to either Cackling or Canada goose.

Page intentionally left blank.

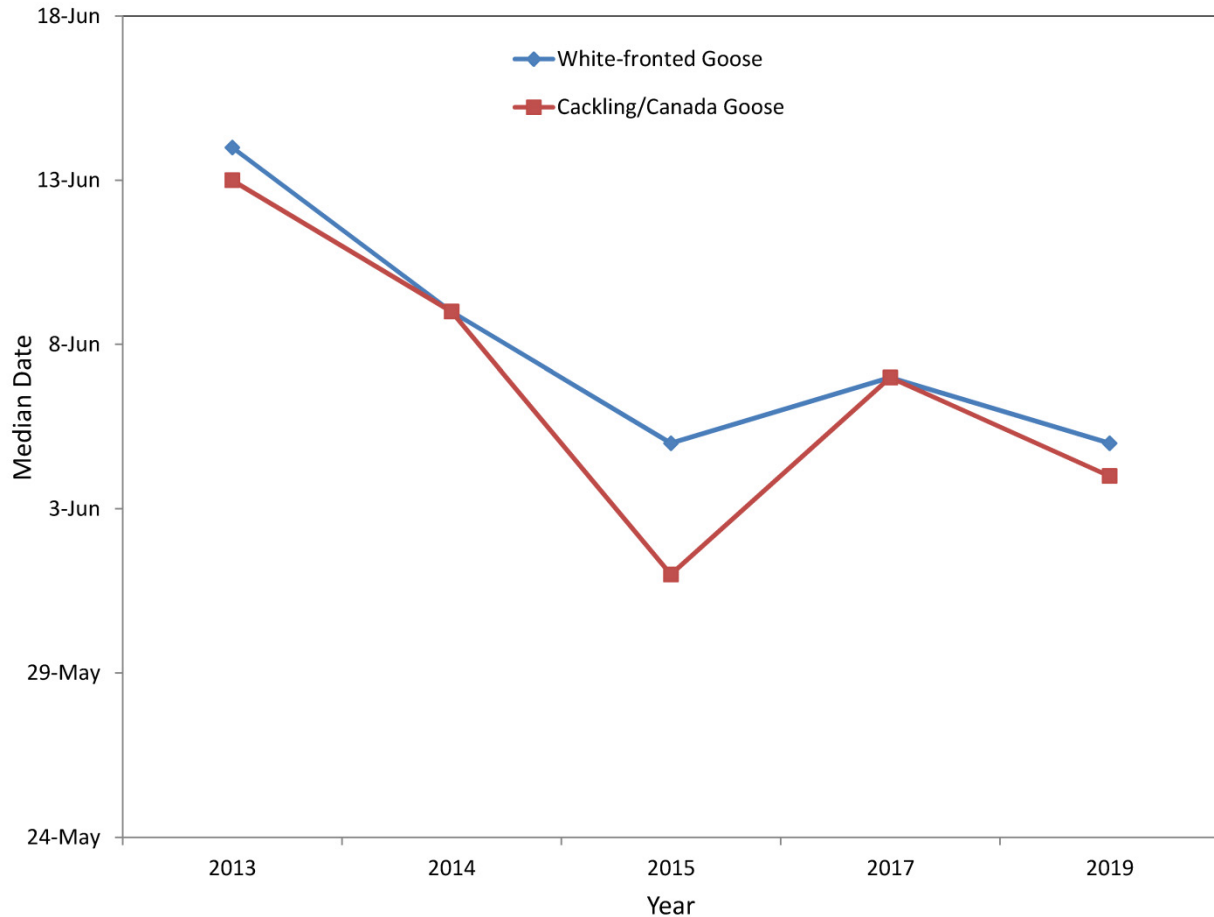


Figure 8. Median incubation start dates for nests of Greater White-fronted and Cackling/ Canada geese, CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

nests monitored by cameras ($n = 10$) were successful (≥ 1 young hatched). We observed predation events at 2 nests (nests 124 and 420, Figure 9) that probably resulted in the loss of at least 1 egg, but ultimately each nest was successful as confirmed in the camera images. In both cases, predators took advantage of normal recesses taken by the female. The female goose at nest 124 had left the nest for 10-min before a red fox appeared on an image with its head down in the nest. In the following frame, the female was back on the nest with no fox in view. At nest 420, the female goose covered the nest with down and was seen walking away from the nest. The female was gone for 30 sec before a Parasitic Jaeger was at the nest for about 3.5 min with its head down in the nest (Figure 9). The male and female geese returned to the nest, and in the following image, the jaeger is

no longer present. The jaeger likely caused significant damage to eggs, as the female goose stood by the nest for 5 min and then spent over 25 min removing remains from the nest (i.e., egg fragments and yolk). The male and female were seen leaving the nest again for 1 min, and when they returned, the female did not resume normal incubation for another 4 min. Prior to the egg predation by the Parasitic Jaeger at nest 420, the nest camera captured an image of the female goose with wings outstretched defending her nest from a red fox (Figure 10). In the following frame, the female goose is back on the nest and there is no fox in view.

Incubation constancy for nests monitored by cameras was $98.7 \pm 0.4\%$ ($n = 10$ nests). Females took an average of 1.4 ± 0.37 recesses each day that were on average 11.6 ± 1.06 min in duration,

Table 6. Apparent nesting success of Greater White-fronted Geese and number of nests monitored with temperature-sensing eggs at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

Year	Nests on Plot				All Nests ^a				Apparent Nesting Success (%) ^b	Total Nests with Temperature-Sensing Eggs ^c	Total Nests with Cameras
	Total	Successful	Failed	Unknown	Total	Successful	Failed	Unknown			
2013	87	43	44	0	110	58	52	0	53	0 (38)	–
2014	114	66	47	1	147	84	62	1	58	21 (41)	–
2015	120	98	22	0	162	134	28	0	83	40 (43)	–
2017	152	80	72	0	214	116	95	3	55	31 (42)	–
2019	179	137	33	9	215	162	42	11	79	37 (43)	10
Total	652	424	218	10	848	554	279	15	65	161 (207)	10

^a Includes nests located outside plot boundaries

^b Apparent nesting success = successful/(successful + failed) * 100; successful nests hatched ³¹ egg.

^c Number of temperature-sensing eggs used in analyses of incubation behavior. Monitors excluded if < 1 full day of data. In parentheses: total temperature-monitors deployed each year.

Table 7. Comparison of incubation activities between successful and failed Greater White-fronted Goose nests monitored with temperature-sensing eggs at CD-5, NE NPR-A, 2014–2015, 2017, and 2019. Sample size was 103 successful nests (hatching ≥ 1 egg) and 26 failed nests. Statistical tests were conducted using random intercepts general linear models.

Year	Incubation Variable	Successful			Failed			Model	
		mean	SE	n^a	mean	SE	n^a	Test statistic	P
2014	Incubation Constancy (%) ^b	99.28	0.07	304	98.30	0.35	40	1.04	0.31
	Recess Frequency (no./d) ^c	0.75	0.07	304	2.20	0.40	40	1.22	0.22
	Recess Length (min/recess) ^d	13.31	0.42	229	12.58	0.45	88	0.35	0.73
	Time off Nest (min/d) ^d	10.33	1.05	304	27.00	4.99	40	1.05	0.31
	Break Frequency (no./d) ^c	10.20	0.22	304	11.38	0.62	40	0.35	0.73
2015	Incubation Constancy	99.27	0.08	388	98.89	0.23	49	0.62	0.54
	Recess Frequency	0.73	0.08	388	1.18	0.24	49	0.86	0.39
	Recess Length	14.04	0.55	283	13.32	0.51	58	0.11	0.92
	Time off Nest	10.49	1.10	388	15.92	3.38	49	0.65	0.52
	Break Frequency	12.48	0.28	388	12.59	0.61	49	0.05	0.96
2017	Incubation Constancy	97.23	0.28	309	93.27	1.03	116	2.32	0.03
	Recess Frequency	2.04	0.11	309	3.12	0.36	116	1.64	0.10
	Recess Length	17.37	0.46	629	25.15	0.98	362	2.02	0.05
	Time off Nest	39.85	4.00	309	96.94	14.77	116	1.70	0.10
	Break Frequency	8.41	0.23	309	10.97	0.39	116	2.56	0.01
2019	Incubation Constancy	98.21	0.26	482	93.05	1.24	104	1.97	0.06
	Recess Frequency	1.42	0.09	482	2.64	0.35	104	1.24	0.22
	Recess Length	14.06	0.39	685	30.68	1.77	275	2.52	0.02
	Time off Nest	23.07	2.60	482	100.14	17.91	104	1.30	0.20
	Break Frequency	9.95	0.22	482	10.88	0.42	104	0.78	0.44
All Years	Incubation Constancy	98.50	0.11	1,488	94.71	0.59	309	4.07	<0.01
	Recess Frequency	1.23	0.06	1,483	2.53	0.19	309	3.06	<0.01
	Recess Length	14.76	0.21	1,826	23.53	0.77	783	3.30	<0.01
	Time off Nest	20.66	1.27	1,483	76.12	8.45	309	3.09	<0.01
	Break Frequency	10.34	0.13	1,483	11.25	0.24	309	1.20	0.23

^a n = number of days, except for recess length, where n = number of recesses.

^b Arcsine transformation of incubation constancy in all years.

^c Poisson models were used to test for difference in recess frequency and break frequency in all years.

^d Natural log transformation of recess length and time off nest in all years.

Page intentionally blank.



Figure 9. Parasitic Jaeger depredating nest 420 while the female Greater White-fronted Goose is on a recess at CD-5, NE NPR-A, 2019.

Page intentionally left blank.



Figure 10. Greater White-fronted Goose defending nest 420 from a red fox, CD-5, NE NPR-A, 2019.

for a total of 17.3 ± 5.2 min of time off the nest each day. Females took 21.3 ± 1.98 breaks/day (during breaks, females stayed at the nest, but were not incubating) (Table 8).

In a paired comparison of incubation activities recorded by time-lapse cameras and temperature-sensing eggs for 6 successful nests, we found estimates of mean incubation constancy, recess frequency, and recess duration were essentially identical (Table 9). The primary difference between the 2 methods of monitoring was the number of breaks recorded each day. Time-lapse cameras recorded significantly more breaks than did the temperature-sensing eggs. Breaks are usually less than 5 min long, which is the interval between recordings for temperature monitoring. Cameras recorded images every 30 sec, which provided a better estimate of relatively short-duration breaks. Appendix A provides a comparison of incubation behavior for each nest with a camera and thermistor egg.

NESTING SUCCESS

APPARENT NESTING SUCCESS

The average apparent nesting success (the proportion of nests hatching ≥ 1 egg) for White-fronted Geese over 5 years was 65% (Table 6). Nesting success was low in 2013, 2014, and 2017, ranging from 53 to 58%. In 2015 and 2019, nesting success of White-fronted Geese was higher by $\geq 20\%$ (83% and 79%, respectively; Table 6, Figure 5).

To evaluate whether human activity (traffic and construction) affected nesting success of

White-fronted Geese, we examined whether nests that failed were nearer or farther to oilfield facilities than those that hatched (Table 10). Our hypothesis was that geese nesting closer to facilities and at times with the higher levels of human activity (e.g., people, traffic, construction activity), would be more likely to fail because of increased disturbance causing geese to flush more often or leave their nests for longer (increased time off nest and reduced incubation constancy) making them more vulnerable to predation. In 2013, before any construction in the CD-5 area, there was essentially no difference between successful and failed nests and their distance to the future location of roads and pads. Roads and pads constructed the following winter (2014) were unable to support vehicles during the breeding season and were largely unused. Activity on CD-5 roads and pads was highest in 2015. Contrary to the expected disturbance response, in both 2014 and 2015, successful nests were nearer to the road and pad than were failed nests. In 2017, during operational use of roads and pads, failed nests were closer on average to roads and pads than were successful nests. In 2019, the final operational year in the study, the average distances of successful and failed nests to roads and pads was nearly the same (Table 10). Thus, there was no consistent relationship between nest success and proximity to facilities by development phase. Only 2017, despite being an operational year with relatively low traffic and human activity, fit the expected response of lower nest success of White-fronted Goose nests near oil infrastructure, with failed nests averaging 269 ± 21 m nearer to roads and

Table 8. Incubation activities of Greater White-fronted Goose females at nests ($n = 10$) monitored by time-lapse cameras at CD-5, NE NPR-A, 2019. All nests monitored by cameras were successful.

Incubation Variable	Time-Lapse Camera		
	mean	SE	n^a
Incubation Constancy (%)	98.7	0.4	123.4
Recess Frequency (no./d)	1.4	0.37	123.4
Recess Length (min/recess)	11.6	1.06	170
Time off Nest (min/d)	17.3	5.2	123.4
Break Frequency (no./d)	26.3	1.98	123.4

^a n = number of days, except for recess length, where n = number of recesses.

Table 9. Comparison of incubation activities at 6 Greater White-fronted Goose nests monitored by camera at 30-sec intervals and by temperature-sensing eggs at 5-min intervals at CD-5, NE NPR-A, 2019. All nests were successful. Statistical tests were conducted using random intercepts general linear models of daily differences between methods.

Incubation Variable	Time-Lapse Camera			Temperature-Sensing Egg			Model		
	mean	SE	<i>n</i> ^a	mean	SE	<i>n</i> ^a	t-value	<i>n</i> ^a	<i>P</i>
Incubation Constancy (%)	98.9	0.15	75	98.6	0.29	75	-0.74	69	0.46
Recess Frequency (no./d)	1.2	0.15	75	1.4	0.21	75	0.51	69	0.61
Recess Length (min/recess)	12.4	1.14	90	12.9	0.47	105	0.02	24	0.99
Time off Nest (min/d)	15.0	2.10	75	20.2	10.10	75	0.76	69	0.45
Break Frequency (no./d)	25.4	1.08	75	17.38	1.40	75	-6.23	69	<0.01

^a *n* = number of days, except for recess length, where *n* = recesses.

Table 10. Mean distance from infrastructure (roads and drill pads) by fate of Greater White-fronted and Cackling/Canada Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

Species/Year	Distance (m) of Successful Nests			Distance (m) of Failed Nests			Apparent Nesting Success (%) ^a
	mean	SE	<i>n</i>	mean	SE	<i>n</i>	
Greater White-fronted Goose							
2013	1,326	158	58	1,301	154	52	53
2014	1,087	127	84	1,487	125	62	58
2015	1,130	205	134	1,514	213	28	83
2017	1,228	112	116	959	91	95	55
2019	1,067	157	162	1,037	151	42	79
All Years	1,146	53	554	1,207	61	279	65
Cackling/Canada Goose							
2013	1,510	730	4	1,100	523	5	44
2014	1,239	404	10	718	196	13	43
2015	1,068	251	21	2,076	560	5	81
2017	304	50	10	769	136	46	18
2019	1,077	224	23	915	219	12	66
All Years	1,010	132	68	884	105	81	46

^a Apparent nesting success = [number successful / (number successful + number failed)]. Nests of unknown fate were excluded.

pads than successful nests. One possible cause of increased nest failure near roads and pads in 2017 was the activity of a pair of grizzly bears that were observed near the CD-5 drill pad over multiple days disturbing and flushing nesting geese in the area and likely preying on eggs. Predators other than grizzly bears (birds and foxes) also likely contributed to the nest failures we observed in 2017.

The apparent nesting success of Cackling/Canada Geese averaged 46% for all 5 years of this study. Nesting success was much lower in 2017 than any other year at 18% (46 of 57 nests failed; Table 7). In contrast, Cackling/Canada Geese had much higher nesting success in 2015 and 2019 (81% and 66%, respectively) than in other years. Successful nests were closer to roads and pads than failed nests in 2015 and 2017 and distances were nearly the same in 2019 (Table 10). In 2013, when there were no roads or pads, and in 2014, when little to no human activity occurred on the new roads or pads, failed nests were closer to roads and pads (or their future location in the case of 2013) than successful nests. Cackling/Canada Geese build large nests with more down than

White-fronted Geese. These nests are very conspicuous on the tundra and this likely contributed to the low nest success in 2017, when grizzlies were active in the study area.

DAILY NEST SURVIVAL

Daily nest survival analyses were based on data from 112 nests over 4 years (2014, 2015, 2017, and 2019), with an effective sample size of 1,653 exposure days (the total of all days that nests were active). The model best supported by the data had a 57% chance (Akaike weight) of being the best model in the candidate model set and included the effects of nest age and incubation constancy (Table 11). The second-best model contained a time trend for day of season (date) and incubation constancy, providing further support for a trend in the decline of DNS throughout the season and a positive effect of incubation constancy, but had little support for being a competing model ($\Delta AIC_c = 2.12$).

The overall best model indicated that DNS declined with nest age ($\beta = -0.12$, 95% CI: -0.20 to -0.03); nests were more likely to fail during the second half of the incubation period. The model

Table 11. Model selection results of factors influencing daily nest survival for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019. Model variables included nest age (determined by egg flotation, or backdating from hatch date), incubation constancy (% time on nest), date (day of season), year, distance (logarithm of nest distance [km] to road or pad), recess length (mean of all recesses in minutes), number of recesses (mean frequency of recesses/day), and nest density (number of nests/plot).

Model	AICc	Akaike weight	Δ AICc
Nest Age + Incubation Constancy	215.94	0.57	0
Date+ Incubation Constancy	218.06	0.20	2.12
Nest Age	219.17	0.11	3.23
Incubation Constancy	221.72	0.03	5.78
Date	221.86	0.03	5.91
Nest Age + Year	222.41	0.02	6.47
Distance	223.01	0.02	7.06
Year+ Incubation Constancy	224.63	0.01	8.69
Recess length	226.41	<0.01	10.46
No. Recesses	226.51	<0.01	10.57
Constant	227.10	<0.01	11.16
Nest density	228.10	<0.01	12.15
Year	230.79	<0.01	14.85

also indicated that DNS increased proportional to the amount of time that an incubating adult was attending the nest ($\beta = 0.10$, 95% CI: 0.02 to 0.18; Figure 11). Nests were more likely to fail the more time that the female spent away from the nest. There was no support for the effects of nest density, duration of recesses, average number of recesses/day, distance to roads or pads, or for differences among years (Table 11). The data set did not include nests from 2013 because there were no associated behavior data from the nests in that year.

MODELS OF NEST DISTRIBUTION AND SUCCESS

We evaluated 32 models of the distribution of White-fronted Goose nests. The stage 1 model best supported by the data included year, the presence or absence of the nest within an ice road or pad boundary, and habitat type, and had a 44% chance of being the best model in the candidate model set (Table 12). The best model during the second stage of model selection included the variables from the best model in the first stage of model selection plus the distance to roads or pads (linear term) by development phase interaction. This model had a 39% chance of being the best model in the candidate model set and including the distance to

road by development phase interaction improved the model significantly (e.g., AICc declined by 28.24). The model with distance to road by year interaction also had some support as the best model in the candidate set (Δ AICc = 0.99, Akaike weight = 0.23; Table 12).

The overall best model indicated that nests were significantly less likely to be located within the footprint of ice roads and pads from the previous winter ($\beta = -2.32$, $p = 0.021$; Figure 12, Table 13). Nests were more likely to be located in Patterned Wet Meadow than in the reference habitat type, Moist Sedge-Shrub Meadow ($\beta = 0.22$; $p = 0.035$; Table 13). The number of nests increased from pre-construction to operation phases ($\beta = 0.66$, $p < 0.001$), but the increase from pre-construction to construction phases was not significant ($\beta = 0.31$, $p = 0.093$). The interaction term for distance to gravel road or pad by development phase indicated that although there were more nests away from roads and pads in 2013–2014 (main effect of distance to 2014 roads or pads; $\beta = 0.31$, $p < 0.001$), the slope of this relationship did not change significantly during the construction ($\beta = -0.09$; $p = 0.429$) or operation ($\beta = -0.10$; $p = 0.258$) phases (Table 13). These results suggest that gravel roads and pads did not affect the distribution of nests after accounting for the

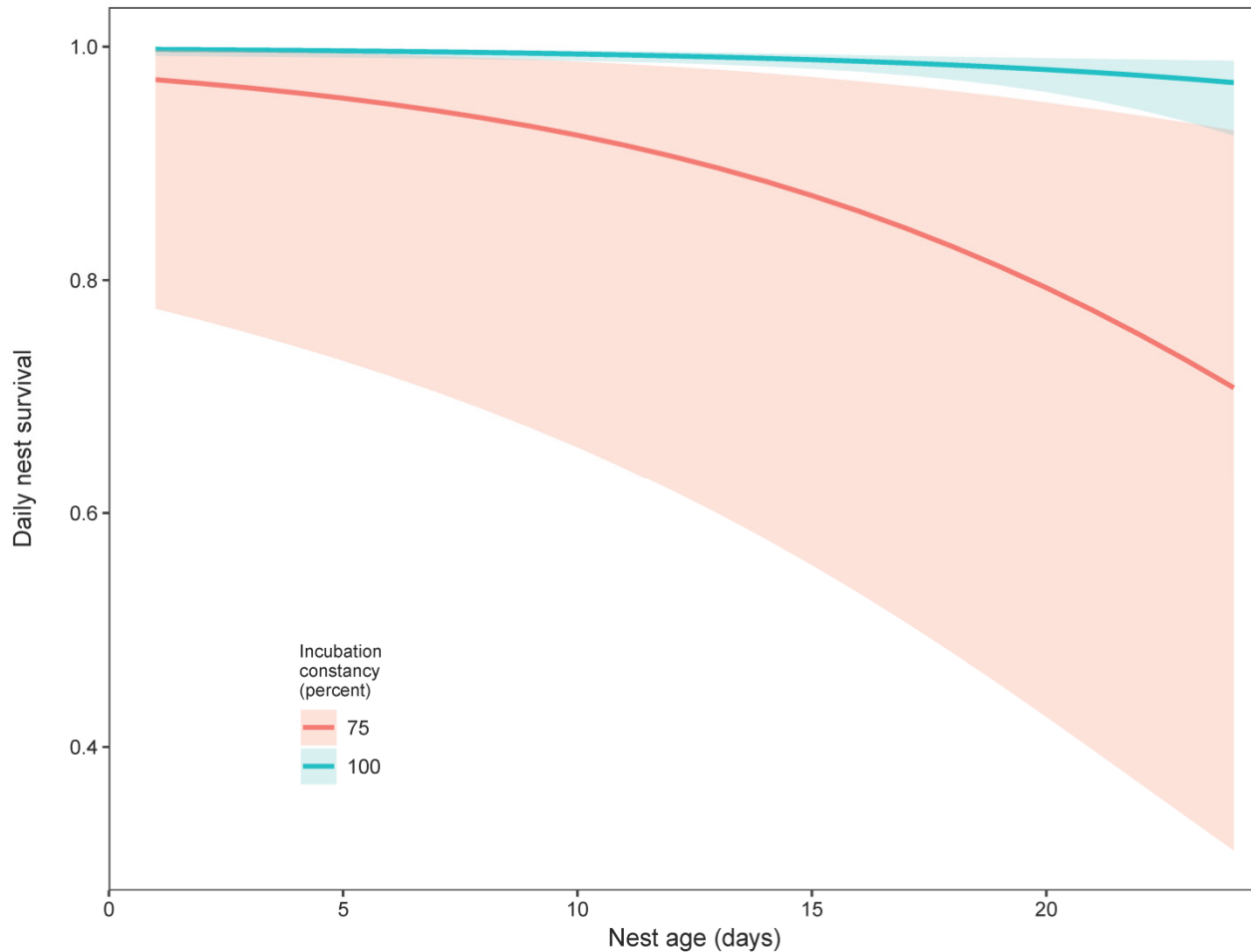


Figure 11. Example of the effects of nest age and incubation constancy on daily nest survival of Greater White-fronted Geese.

pre-construction baseline distribution. The overall best model had a k-fold cross-validation score of 0.78 indicating a moderate level of power to predict nest locations.

The best model for nesting success included only the year variable with a 41% chance of being the best in the stage 1 model set and 49% chance of being the best in the stage 2 model set (Table 14). Adding distance to road or pad variables did not improve the model (all $\Delta AICc \geq 2.29$). The model indicated that nest survival was significantly higher in 2015 and 2019 than in 2013 and was not significantly higher in 2014 or 2017 than in 2013 (Table 15). The best model had a k-fold cross-validation score of 0.65 indicating a low to moderate level of predictive power.

OTHER NESTING BIRDS

DISTRIBUTION AND ABUNDANCE

During the 5 years of this study, we found 1,131 nests belonging to 19 identified species of birds on and near nest plots (Figures 5 and 6, Table 3). Each year, the total number of nests increased but this was largely due to increases in White-fronted and Cackling/Canada Goose nests. Only 4% of all nests found belonged to species other than geese. Each year, we found 3–4 King Eider nests, 2–3 Long-tailed Duck nests, and 1–2 Northern Pintail nests. One Pacific Loon nest was found on plots in 2015 and 2017, and one Red-throated Loon nest was found off plot in 2017. Other species nesting on plots on all years combined included Willow Ptarmigan (6 nests),

Table 12. Model selection results (top 4 models in each of 2 stages) for the resource selection function analysis of nest distribution for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019. Model variables included year, ice road (whether nest is within the footprint of an ice roads or pads from the previous winter), habitat type (5 types), small mammal (abundance ranked from 0 to 3), and predators (counts of occurrence). Second stage of model selection includes top model from first stage in addition to development phase (pre-construction, 2013 and 2014, construction, 2015; and operation, 2017 and 2019), and distance (linear distance [km] to a road or pad present in 2014), $\ln(\text{distance} + 1)$, or interaction terms or interaction of year and distance variables.

Model Stage	Model	AICc	Akaike weight	ΔAICc
1	Year + Ice Road + Habitat Type	6144.87	0.44	0
	Year + Ice Road + Habitat Type+Small Mammal	6146.12	0.23	1.25
	Year + Ice Road + Habitat Type+Predators	6146.85	0.16	1.98
	Year + Ice Road + Predators+Small Mammal+Habitat Type	6148.07	0.09	3.20
2	Best + Development Phase*Distance	6116.63	0.39	0
	Best + Year*Distance	6117.62	0.23	0.99
	Best + Development Phase* $\ln(\text{Distance}+1)$	6118.56	0.14	1.93
	Best + Year* $\ln(\text{Distance}+1)$	6119.61	0.09	2.98

Tundra Swan (1 nest), Green-winged Teal (4 nests), Bar-Tailed Godwit (8 nests), Glaucous Gull (4 nests), Sabine's Gull (5 nests), Arctic Tern (7 nests), and Parasitic Jaeger (3 nests).

King Eiders (0.8–0.1 nests/km²) were often the third most common large waterbird nesting on plots (Figure 6, Table 3). The apparent nesting success of King Eider nests varied annually from 0% ($n = 4$ nests) in 2013, to 80% ($n = 5$ nests) in 2017. The apparent nesting success averaged for all years was 39%. A few Spectacled Eiders occurred annually in the study area, but no nests were found.

HABITAT USE

Like geese, most other species nested in the 3 most abundant habitat types: Patterned Wet Meadow (6 species), Moist Sedge-Shrub Meadow (7 species), and Old Basin Wetland Complex (8 species). Several species took advantage of some of the wetter and less abundant habitat types; Shallow Open Water with islands and Polygonized Margins was used by King Eider, Pacific Loon, Sabine's Gull, and Glaucous Gull for nesting, and Arctic Tern was one of the few species that nested in Deep Open Water with Islands and Polygonized Margins (Table 5). Moist Tussock Tundra. Sedge

Marsh, and Deep Open Water with Islands and Polygonized Margins were the habitat types least used by all species.

NEST PREDATORS

In all years of this study, gulls and jaegers were the most abundant and widespread nest predators observed during both predator scans and incidental observations on nest plots (Appendix B). Avian nest predators seen on plots during 5 summers of predator scans included Glaucous Gull (50%, or 408 of 825 predator sightings), jaegers (47%), Common Raven (2%), and raptors (1%). Parasitic Jaegers accounted for 83% (326 of 393 jaegers) of all jaeger observations on plots, followed by Long-tailed Jaegers (9%, or 35 of 393 jaegers). Observations of Glaucous Gulls during predator scans averaged 2.04 ± 0.16 birds per plot each year and observations of jaegers averaged 1.97 ± 0.4 birds per plot each year. The species composition and the proportions of the avian predators observed outside of plots (within 300 m of plot boundaries) were similar to those observed on plot during predator scans. Notably, arctic fox was the only mammal observed on plot during predator scans and it was observed only once in

2015. Grizzly bears and arctic and red foxes were observed more often off plot during predator scans or incidentally (during nest searching) each year, but ≤ 5 mammals were observed during predator scans and incidentally during nest searches in any year (Appendix B).

The total number of predators observed on 40 plots during predator scans has varied among years. Total counts of predators were the most similar in 2013 (pre-construction phase), and 2017 and 2019 (operation phase), ranging from 160–171 predators (Figure 13, Appendix B). The most predators were recorded during pre-construction in 2014 (226 predators) and the fewest (103 predators) during the construction phase in 2015. These results suggest that the number of avian predators has not increased with the development of CD-5, whereas mammal predators occur too infrequently to observe any trend. An ordinal measure of small mammals (i.e., lemmings and voles) on plots, an important prey item for many of the avian and mammal predators that also take eggs, indicates that small mammals were scarce in 2013 and abundant in 2019 (Figure 13). Interestingly, the two years with the highest small mammal abundance (2015 and 2019) and earliest nest initiation dates were years that White-fronted Geese had the highest apparent nesting success and daily survival rates. (Figure 13).

The summer of 2017 was the first in 4 years of the CD-5 project where gulls were more abundant than jaegers during predator scans and incidental observations, and this trend continued in 2019. Summer 2017 was also the first season red foxes were observed in the study area, and they were the only mammals recorded during predator scans and incidental observations that year (Appendix B). In 2013–2015, only arctic foxes were recorded in the study area. Although we did not record arctic foxes during predator scans or incidentally during nest searches in 2017, they were seen on several occasions from the CD-5 road as we were transiting the study area. No foxes were seen during predator scans or during nest-searching in the study area in 2019, but both species were observed in photos from nest cameras. Five grizzly bears (a sow with 2 first- year cubs, and 2 juvenile bears) were observed near our study area in 2014, and 1 bear was sighted in 2015 during

nest-searching, but none of these bears were observed in the area for more than a day. Bears were not seen in the study area during nest-searching in 2017, but during late-incubation and peak hatch of geese (late June–early July), grizzly bears were observed for a week near CD-5.

The use of the Nuiqsut spur road connecting to the CD-5 road may have increased the potential for disturbance by humans and nest predation in the CD-5 study area. Since 2014, (but probably more so in 2015, when the road could support vehicles) the residents of Nuiqsut were able to use the new roads from their village to facilitate their access to the study area. In 2017 and 2019, hunters on ATVs were observed using the roads to look for caribou, and on a few occasions, hunters were seen out on the tundra. Hunters could inadvertently disturb nesting geese and damage nests. During nest-searching in 2017 and 2019, we also noticed trails from ATVs on study plots (Figure 14). The collection of goose eggs by locals was observed by oilfield staff in the vicinity of the study area. Although we do not know whether or not eggs were harvested from any of the nests in our study plots, this activity could potentially affect nesting success and clutch size for any nests in harvest areas. Nonetheless, we have no clear evidence that harvesting activities affected geese nesting on study plots.

DISCUSSION

The presence of ice roads and pads and habitat type were the best predictors of the distribution of White-fronted Goose nests in the CD-5 study area. White-fronted Geese avoided nesting within areas used for ice roads in the previous winter. We suspect that the loss of vegetative cover may have reduced the suitability for nesting in these areas, but also some of the ice pads were not completely thawed by the time nest initiation had begun. Ice roads and pads have been shown to alter tundra vegetation, with the greatest impacts on higher and dryer areas, sometimes causing damage to shrubs, forbs, and tussocks (Pullman et al. 2005). The effects of ice roads and pads on tundra vegetation are evident for at least one growing season following removal of the ice road or pad (Guyer and Keating 2005, Pullman et al. 2005).



Figure 12. Distribution of Greater White-fronted Goose nests each year relative to infrastructure and ice-roads built the previous winter at CD-5, NE NPR-A, 2013–2015, 2017, and 2019..

Page intentionally left blank.

Habitat type was also an important predictor for where White-fronted Geese nested. White-fronted Geese exhibited a consistent preference for nesting in Patterned Wet Meadow, which was supported by previous surveys in NE NPR-A which found White-fronted Geese preferred Patterned Wet Meadow and Old Basin Wetland Complex (Johnson et al. 2005). Patterned Wet Meadow and a similar habitat type, Deep Polygon Complex, were preferred nearby on the Colville River Delta (Johnson et al. 2003). White-fronted Geese in this study avoided nesting on the coastlines of lakes and on lake islands (Shallow Open Water with Islands or Polygonized Margins and Shallow Open Water without Islands), and in Human Modified habitat. All other habitats on plots were used in proportion to availability, and although these habitats were not preferred, they accounted for 66% of the 652 nests found during the study. Currently, habitat does not appear to be limiting the number of nesting White-fronted Geese and Cackling/Canada Geese in the CD-5 study area, as the number of nests of both species has increased throughout this study. The NPR-A has supported some of the highest densities of both of these species and White-fronted Geese have increased the fastest in northern portions of the NPR-A compared to other areas of the Arctic Coastal Plain (ACP) (Amundson et al. 2019). The population of White-fronted Geese on the ACP has been growing at an annual average of 5–6% over the long term (1986–2017) and over the last 10 years evaluated (2008–2017) (Wilson et al. 2018). The annual increases in nesting White-fronted Geese in the CD-5 area through the development phases, and the positive effect of the operation period (2017 and 2019) over the pre-construction period (2013 and 2014) on occurrence in plots, is consistent with the growth in the White-fronted Goose population on the ACP.

We found no evidence that the placement of gravel roads and pads or the changes in amount of human activity (from pre-construction to construction to operation) associated with them has adversely influenced the abundance, distribution, incubation, daily nest survival, or apparent nesting success of White-fronted Goose nests in the CD-5 study area. Although there were more nests away from roads prior to construction and use of the road (2013–2014), that pattern of distribution remained

consistent during the construction and operation phases and suggests that the gravel roads and pads and associated traffic did not displace nesting White-fronted Geese. We also found no support for distance to roads and pads as a factor influencing daily nest survival. Failed nests tended to be farther from roads and pads than successful nests, contrary to a potential disturbance effect, with the exception of 1 operation year (2017), when traffic levels were relatively low. The construction year of 2015, when disturbance sources of traffic and activity on roads and pads peaked, had the highest apparent nesting success for both White-fronted and Cackling/Canada geese, and successful nesters of both species nested closer to roads and pads (384 m and 1,008 m, respectively) than failed nesters. The trends in nest abundance, distribution, and nesting success (and daily nest survival) therefore appeared unrelated to the development phase and human activity in the CD-5 area. The conclusions from this study support similar findings from research into the effects of disturbance on nesting White-fronted Geese at Point Lonely in NPR-A (Meixell and Flint 2017), on the Colville River delta (Johnson et al. 2003), and earlier work on nesting geese in Prudhoe Bay (Murphy and Anderson 1993).

White-fronted Geese attending their nests will tenaciously defend their nests against avian predators and foxes. The success of this behavior was supported by models of daily nest survival, observed in our camera footage, and noted in other studies of geese (Béty et al. 2002, Meixell and Flint 2017). Incubation constancy was significantly higher for geese that nested successfully than for those that failed. In a study of development and disturbance effects on breeding birds on the Colville River Delta, Johnson et. al. (2003) also found a significant difference in incubation constancy between White-fronted Geese at successful and failed nests. In 2017, incubation constancy was lower than in other years for both successful and failed nesting geese and may reflect the unique predator situation of that year. Two young grizzly bears and a sow with 2 cubs were observed (separately) near the CD-5 pad or road for 7 days between 23 June and 6 July and spent much of those days foraging in the area (CPAI security report submitted to Alaska Department of Fish and Game, 2017). Many nests near CD-5

Table 13. Parameter estimates for the best model of nest distribution for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019. Model variables are ice road (whether nest is within the footprint of ice roads or pads from the previous winter), habitat type (all types that geese used for nesting), diff. distance (difference in distance of nests from 2014 roads or pads and 2019 roads or pads), pre-construction phase (2013 and 2014), construction phase (2015), operation phase (2017 and 2019), and distance (linear distance [km] of nests from 2014 road or pad location) and distance by construction phase interaction.

Variable	Estimate	SE	P
Intercept	-4.58	0.13	<0.001
Ice Road	-2.32	1.00	0.021
Habitat Type-Moist Tussock Tundra ^a	-0.17	0.14	0.230
Habitat Type-Old Basin Wetland Complex ^a	0.08	0.11	0.454
Habitat Type-Other ^a	-12.77	189.52	0.946
Habitat Type-Patterned Wet Meadow ^a	0.22	0.10	0.035
Diff. Distance	0.28	0.35	0.424
Construction Phase ^c	0.31	0.18	0.093
Operational Phase ^c	0.66	0.14	<0.001
Distance	0.31	0.07	<0.001
Construction Phase *Distance ^c	-0.09	0.12	0.429
Operation Phase *Distance ^c	-0.10	0.09	0.258

^a Compared to reference category of moist sedge-shrub meadow. “Other” habitat type includes 3 additional habitats that comprise <1% of total habitat used for nesting.
^b Additional variable included to account for differences in nest distance to road for nests closer to GMT1/MT6 road in 2019, which was not present in 2014.
^c Compared to reference category of pre-construction phase.

Table 14. Model selection (top 4 models in each of 2 stages) results for the analysis of nesting success for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019. Model variables included year, small mammal (abundance ranked from 0 to 3), predators (counts of occurrence), habitat type (5 types). Second stage of model selection includes top model from first stage and interaction with distance variables: (ln(distance + 1/6), (natural logarithm of distance + 1), 0.5 km (nests were within or beyond 0.5 km of road or pad present in 2014).

Model Stage	Model	AICc	Akaike weight	ΔAICc
1	Year	806.83	0.41	0.00
	Year + Small Mammal	808.36	0.19	1.53
	Year +Predators	808.83	0.15	2.00
	Year + Habitat Type	810.09	0.08	3.26
2	Year	806.83	0.49	0.00
	Year*ln(Distance+1/6)	809.12	0.16	2.29
	Year*ln(Distance+1)	809.25	0.15	2.42
	Year*Less than 0.5km	809.94	0.10	3.11

Table 15. Parameter estimates for the best model of nesting success for Greater White-fronted Goose nests at CD-5, NE NPR-A, 2013–2015, 2017, and 2019.

Variable	Estimate	SE	P
Intercept	-0.02	0.21	0.915
2014 ^a	0.34	0.29	0.233
2015 ^a	1.52	0.32	<0.001
2017 ^a	0.14	0.27	0.600
2019 ^a	1.21	0.28	<0.001

^a Compared to the reference year of 2013.

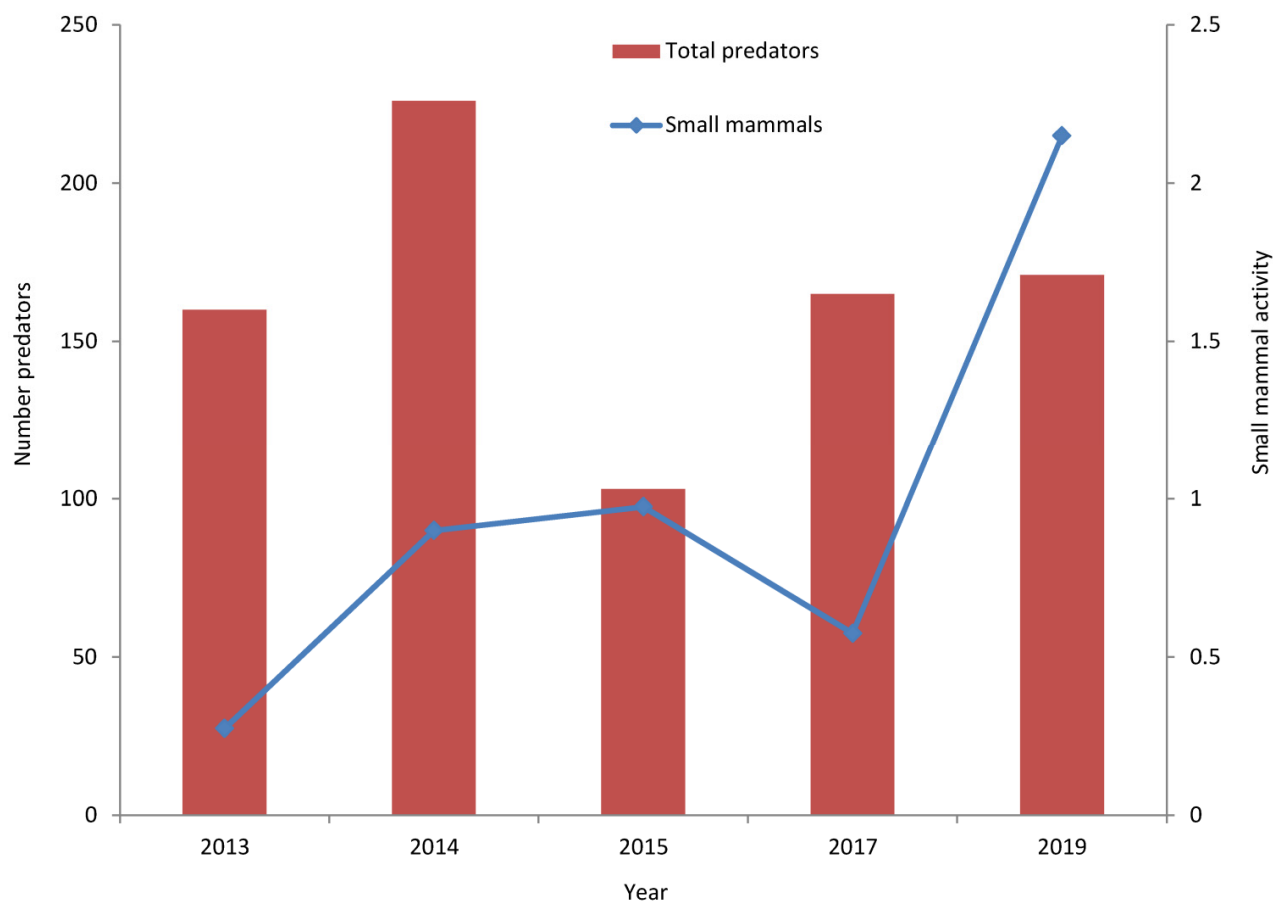


Figure 13. Number of predators observed on 40-plots during predator scans each year, and assessment of small mammal activity/plot at CD-5, NE NPR-A.



Figure 14. Four-wheeler tracks across the tundra northwest of the CD-5 drilling pad, NE NPR-A, June 2019.

showed evidence that they failed that year from direct predation by bears (e.g., eggs flattened in the nest, and nests with temperature-sensing eggs and data loggers that were missing or destroyed), and others may have failed indirectly from disturbance by the bears but ultimately depredated by foxes and avian predators taking advantage of unoccupied nests.

The presence of bears in the study area in 2017 likely caused unusual incubation activity at several temperature-monitored nests that made interpretation of the temperature data difficult. Only in 2017, we adjusted temperature cutoffs identifying recesses because recesses were unusually long and nest temperatures dropped below our cut point of 9 °C for longer than 25 min at a time. Normally, nest temperatures below 9 °C

for ≥ 25 min would indicate the end of incubation and that the temperature-sensing eggs were tracking ambient temperatures. In 2017, those decreases in temperatures occurred regularly in a number of nests at which females subsequently continued to incubate, and where we knew bear activity had occurred.

Nesting success of White-fronted geese varied each year, with nests in 2015 and 2019 having significantly higher apparent nest success than nests in 2013. These 2 years also shared the earliest nest initiation dates and one year (2019) had the highest index of small mammal activity. Lemmings are an important prey item for foxes and jaegers (Maher 1974, Garrot et al. 1983, Ims and Keating 2005), which are key predators of White-fronted Goose eggs. Egg predation by these predators has

been found to decrease in peak lemming years in other studies (Bêty et al. 2002, Meixell and Flint 2017). These combinations of environmental factors were more influential on nesting success than were measures of development (development phase and distance to infrastructure).

The distribution of nests was influenced by development phase, distance to roads or pads, and habitat type. Another factor that strongly influenced nest distribution was the footprint of ice roads or pads from the previous winter. With the exception of ice roads and pads, this study found little evidence that the construction and operation of CD-5 had adverse effects on nesting White-fronted Geese.

LITERATURE CITED

- Amundson, C. L., P. L. Flint, R. A. Stehn, R. M. Platte, H. M. Wilson, W. W. Larned, and J. B. Fischer. 2019. Spatio-temporal population change of arctic-breeding waterbirds on the Arctic Coastal Plain of Alaska. *Avian Conservation and Ecology* 14:18. <https://doi.org/10.5751/ACE-01383-140118>.
- Anderson, B. A., and B. A. Cooper. 1994. Distribution and abundance of Spectacled Eiders in the Kuparuk and Milne Point oilfields, Alaska, 1993. Report for ARCO Alaska, Inc., and the Kuparuk River Unit, Anchorage, AK, by Alaska Biological Research, Inc., Fairbanks, AK. 71 pp.
- Bêty, J., G. Gauthier, J.-F. Giroux, and E. Korpimäki. 2001. Are goose nesting success and lemming cycles linked? Interplay between nest density and predators. *Oikos* 93: 388–400.
- Bêty, J., G. Gauthier, E. Korpimäki, and J.-F. Giroux. 2002. Shared predators and indirect trophic interaction: lemming cycles and arctic-nesting geese. *Journal of Animal Ecology* 71: 88–98.
- Boyce, M. S., and L. L. McDonald. 1999. Relating populations to habitats using resource selection functions. *Trends in Ecology and Evolution* 14: 268–272.
- Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. *Ecological Modeling* 157: 281–300.
- Bowman, T. D. 2004. Field guide to bird nests and eggs of Alaska's coastal tundra. Alaska Sea Grant College Program, University of Alaska Fairbanks. 81 pp.
- BLM (Bureau of Land Management). 2004. Alpine Satellite Development Plan Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Land Management, with assistance from Minerals Management Service, Anchorage, AK.
- Burgess, R. M., C. B. Johnson, T. Obritschkewitsch, A. K. Prichard, J. P. Parrett, N. A. Schwab, and P. E. Seiser. 2013. Wildlife studies for the Nuna development project, 2012. Report for Pioneer Natural Resources Alaska, Inc., Anchorage, AK, by ABR, Inc., Fairbanks, AK. 55 pp.
- Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information–Theoretic Approach. 2nd edition. Springer–Verlag, New York. 488 pp.
- Calcagno, V., and C. de Mazancourt. 2010. *glmulti*: an R package for easy automated model selection with (Generalized) Linear Models. *Journal of Statistical Software* 34: 1–29.
- CPAI (ConocoPhillips Alaska, Inc.). 2019. Data Management Protocols North Slope Field Surveys, Version 11.3.
- Ely, C. R., and A. X. Dzubin. 1994. Greater White-fronted Goose (*Anser albifrons*). Account 131 in A. Poole, editor. The birds of North America online. Cornell Lab of Ornithology, Ithaca, NY. <http://bna.birds.cornell.edu/bna/species/131>. Accessed 28 October 2013.
- Garrot, R. A., L. E. Eberhardt, W. C. Hanson. 1983. Summer food habits of juvenile arctic foxes in northern Alaska. *Journal of Wildlife Management* 47: 540–545.

- Guyer, S., and B. Keating. 2005. The impact of ice roads and ice pads on tundra ecosystems, National Petroleum Reserve-Alaska. Bureau of Land Management 57 pp.
- Ims, R. A., and E. Fuglei. 2005. Trophic interaction cycles in tundra ecosystems and the impact of climate change. *BioScience* 55: 311-322.
- Johnson, C. B., R. M. Burgess, B. E. Lawhead, J. Neville, J. P. Parrett, A. K. Prichard, J. R. Rose, A. A. Stickney, and A. M. Wildman. 2003. Alpine Avian Monitoring Program, 2001. Fourth annual and synthesis report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 194 pp.
- Johnson, C. B., R. M. Burgess, A. M. Wildman, A. A. Stickney, P. E. Seiser, B. E. Lawhead, T. J. Mabee, A. K. Prichard, and J. R. Rose. 2005. Wildlife studies for the Alpine Satellite Development Project, 2004. Second annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 129 pp.
- Johnson, C. B., J. P. Parrett, T. Obritschkewitsch, J. R. Rose, K. B. Rozell, P. E. Seiser, and A. M. Wildman. 2014. Avian studies for the Alpine Satellite Development Project, 2013. Eleventh annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 115 pp.
- Johnson, C. B., J. P. Parrett, T. Obritschkewitsch, J. R. Rose, K. B. Rozell, and P. E. Seiser. 2015. Avian studies for the Alpine Satellite Development Project, 2014. Twelfth annual report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 124 pp.
- Jorgenson, M. T., J. E. Roth, M. Emers, S. Schlentner, D. K. Swanson, E. R. Pullman, J. Mitchell, and A. A. Stickney. 2003. An ecological land survey for the Northeast Planning Area of the National Petroleum Reserve-Alaska, 2002. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 84 pp.
- Jorgenson, M. T., J. E. Roth, M. Emers, W. Davis, E.R. Pullman, and G. J. Frost. 2004. An ecological land survey for the Northeast Planning Area of the National Petroleum Reserve-Alaska, 2003. Addendum to 2002 report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 40 pp.
- Laake, J. L. 2013. RMark: An R Interface for Analysis of Capture-Recapture Data with MARK. AFSC Processed Report 2013-01, Alaska Fisheries Science Center, National Marine Fisheries Service, Seattle, Washington. 25 pp.
- Mabee, T. J., A. M. Wildman, and C. B. Johnson. 2006. Using egg flotation and eggshell evidence to determine age and fate of arctic shorebird nests. *Journal of Field Ornithology* 77: 163-172.
- Maher, W. J. 1974. Ecology of pomarine, parasitic, and long-tailed jaegers in northern Alaska. *Pacific Coast Avifauna* 37.
- Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Second edition. Kluwer Academic Publishers, Dordrecht, The Netherlands. 209 pp.
- Mayfield, H. F. 1961. Nesting success calculated from exposure. *Wilson Bulletin* 72:255-261.
- Michael Baker International. 2019. 2019 Colville River delta spring breakup monitoring and hydrological assessment. Report for ConocoPhillips Alaska, Inc., Anchorage, AK, by Michael Baker International, Anchorage, AK.
- Meixell, B. W., and P. L. Flint. 2017. Effects of industrial and investigator disturbance on Arctic-nesting geese. *Journal of Wildlife Management* 81: 1372-1385. doi: 10.1002/jwmg.21312.
- Mowbray, T. B., C. R. Ely, J. S. Sedinger, and R. E. Trost. 2002. Canada Goose (*Branta canadensis*). Account 682 in A. Poole and F. Gill, editors. *The birds of North America*

- online. Cornell Lab of Ornithology, Ithaca, NY.
<http://bna.birds.cornell.edu/bna/species/682>.
 Accessed 15 November 2013.
- Murphy, S. M., and B. A. Anderson. 1993. Lisburne Terrestrial Monitoring Program: The effects of the Lisburne Development Project on geese and swans, 1985–1989. Report for ARCO Alaska, Inc., Anchorage, AK, by Alaska Biological Research, Inc., Fairbanks, AK. 202 pp.
- Naves, L. 2011. Alaska migratory bird subsistence harvest estimates, 2009, Alaska Migratory Bird Co-Management Council. Alaska Department of Fish and Game, Division of Subsistence, Anchorage, AK. Technical Paper No. 364.
- Pullman, E. R., M. T. Jorgenson, T. C. Cater, W. A. Davis, and J. E. Roth. 2005. Assessment of ecological effects of the 2002-2003 ice road demonstration project, 2004. Unpublished report for ConocoPhillips, by ABR Inc., Environmental Research & Services. 34 pp.
- R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>
- Rozell, K. B., and C. B. Johnson. 2016. Nesting Greater White-fronted Goose study at CD-5, 2015. Report for ConocoPhillips Alaska, Inc., and Anadarko Petroleum Corporation, Anchorage, AK, by ABR, Inc., Fairbanks, AK. 19 pp.
- Rozell, K.B., and C. B. Johnson. 2018. Nesting Greater White-fronted Goose study at CD-5, 2017. Report for ConocoPhillips Alaska, Inc, and Anadarko Petroleum Corporation, Anchorage, AK, by ABR Inc., Fairbanks, AK. 31 pp.
- Signorell, A., K. Aho, A. Alfons, N. Anderegg, T. Aragon, A. Arppe, A. Baddeley, et. al. 2019. DescTools: Tools for descriptive statistics. R package version 0.99.29. <https://cran.r-project.org/package=DescTools>.
- Westerkov, K. 1950. Methods for determining the age of game bird eggs. *Journal of Wildlife Management* 14: 56–67.
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46 (Supplement): 12–138 pp.
- Wiklund, C.G., A. Angerbjorn, E. Isakson, N. Kjellen and M, Tannerfeldt. 1999. Lemming Predators on the Siberian Tundra. *Ambio* 28: 281-286.
- Wilson, H. M., W. W. Larned, and M. A. Swaim. 2018. Waterfowl breeding population survey, Arctic Coastal Plain, Alaska. Unpubl. Rep., U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, Alaska.

PERSONAL COMMUNICATIONS

- Jerry Hupp, Research Wildlife Biologist, USGS—Alaska Science Center (retired), Anchorage, AK.
- Daniel Rizzolo, Wildlife Biologist, U.S. Fish and Wildlife Service, Fairbanks, AK.

Appendix A. Comparison of nesting activities between nests monitored by time-lapse cameras and temperature-sensing eggs for 6 Greater White-fronted Goose females at CD-5, NE NPR-A, 2019. All nests were successful.

Nest ID	Incubation Activities	Time-Lapse Camera			Temperature-sensing Egg		
		mean	SE	<i>n</i> ^a	mean	SE	<i>n</i> ^a
121	Incubation Constancy (%/d)	99.1	0.2	12.0	99.9	0.06	12.0
	Recess Frequency (no./d)	1.3	0.29	12.0	0.1	0.09	12.0
	Recess Length (min/recess)	9.7	1.22	15.0	10.0	–	1.0
	Time off Nest (min/d)	12.5	2.8	12.0	0.8	0.91	12.0
	Break Frequency (no./d)	21.1	1.95	12.0	13.1	0.84	12.0
155	Incubation Constancy	99.5	0.25	7.7	98.8	0.62	8.0
	Recess Frequency	0.9	0.52	7.7	1.5	0.74	8.0
	Recess Length	8.1	2.76	7	11.9	0.89	12.0
	Time off Nest	7.4	3.15	7.7	17.5	8.98	8.0
	Break Frequency	24.4	3.2	7.7	4.8	0.84	8.0
420	Incubation Constancy	99.4	0.22	17.8	97.9	1.10	18.0
	Recess Frequency	0.8	0.29	17.8	1.9	0.74	18.0
	Recess Length	9.3	1.71	15	13.3	0.92	34.0
	Time off Nest	8.0	2.95	17.8	30.6	15.94	18.0
	Break Frequency	32.1	1.94	17.8	10.8	1.23	18.0
425	Incubation Constancy	99.8	0.1	14.0	99.9	0.09	14.0
	Recess Frequency	0.2	0.12	14.0	0.1	0.08	14.0
	Recess Length	11.0	3.79	3	15.0	0.73	1.0
	Time off Nest	2.4	1.38	14.0	1.07	1.27	14.0
	Break Frequency	19.9	2.47	14.0	5.43	0.91	14.0
429	Incubation Constancy	96.8	0.36	10.0	95.4	0.79	10.0
	Recess Frequency	3.2	0.33	10.0	4.5	0.67	10.0
	Recess Length	14.3	0.52	32	14.7	0.32	45.0
	Time off Nest	46.7	4.87	10.0	66.5	11.38	10.0
	Break Frequency	36.3	4.12	10.0	12.5	1.39	10.0
444	Incubation Constancy	98.5	0.31	13.0	99.4	0.28	13.0
	Recess Frequency	1.4	0.34	13.0	0.8	0.29	13.0
	Recess Length	14.9	2.02	18	10.4	0.76	10.0
	Time off Nest	21.1	4.3	13.0	8.8	4.04	13.0
	Break Frequency	19.0	1.99	13.0	9.5	0.94	13.0
All Nests	Incubation Constancy	98.9	0.45	74.5	98.6	0.8	103
	Recess Frequency	1.3	0.34	74.5	1.4	0.67	103
	Recess Length	11.2	1.14	90.0	13.0	0.73	75
	Time off Nest	16.3	6.58	74.5	19.9	11.48	103
	Break Frequency	25.5	2.92	74.5	9.5	1.4	103

^a *n* = days, except for recess length, where *n* = recesses. Camera monitored days may be shorter than days monitored by temperature-sensing eggs because the female can sometimes be obscured on the nest (e.g., fog, precipitation, glare, or vegetation).

Appendix B. Number of nest predators observed in and near 40 10-ha nest plots at CD-5, NE NPR-A, 2013–2015, 2017 and 2019. Predators include Long-tailed, Parasitic, and Pomarine jaegers (jaeger); Glaucous Gull (gull); Common Raven (raven); Peregrine Falcon, Northern Harrier, Rough-legged Hawk, and Short-eared Owl (raptor); red fox, arctic fox, and grizzly bear (mammal).

Year	<i>n</i> ^c	Predator Scans ^a												Incidental Observations ^a											
		On Plot						Outside Plot ^b						On Plot						Outside Plot ^b					
		Jaeger	Gull	Raven	Raptor	Mammal	Total	Jaeger	Gull	Raven	Raptor	Mammal	Total	Jaeger	Gull	Raven	Raptor	Mammal	Total	Jaeger	Gull	Raven	Raptor	Mammal	Total
2013	40	99	57	3	1	0	160	30	32	1	2	0	65	43	20	4	2	0	69	14	15	3	0	0	32
2014	40	120	101	4	1	0	226	52	59	2	0	4	117	46	27	4	2	0	79	7	13	1	0	2	23
2015	40	59	42	1	0	1	103	49	48	5	0	1	103	45	39	9	0	0	93	14	15	6	0	0	35
2017	40	60	97	5	3	0	165	35	84	5	0	1	125	56	60	7	0	1	124	1	1	2	1	3	8
2019	40	55	111	2	3	0	171	17	62	1	0	0	80	67	100	1	3	0	171	7	21	1	2	0	31
Total	200	393	408	15	8	1	825	183	285	14	1	6	489	257	246	25	7	1	536	43	65	13	3	5	129
Mean		1.97	2.04	0.08	0.04	0.01	4.13	0.92	1.43	0.07	0.01	0.03	2.45	1.29	1.23	0.13	0.04	0.01	2.68	0.22	0.33	0.07	0.02	0.03	0.65
SE		0.14	0.16	0.03	0.02	0.01	0.22	0.13	0.15	0.02	0.01	0.02	0.22	0.10	0.12	0.03	0.01	0.01	0.19	0.06	0.09	0.02	0.01	0.01	0.12

^a Predator scans included, 2 × 10-min scans per plot; incidental observations were made during nest searching.

^b Predators observed outside plot but ≤300 m from plot boundary.

^c *n* = number of plots surveyed each year. Predator scans were summed into one value/plot.