TECHNICAL REPORT

BREEDING ECOLOGY OF STELLER'S AND SPECTACLED EIDERS NESTING NEAR BARROW, ALASKA, 2008-2010

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U.S. Department of the Interior

May 2011

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This report may be cited as follows:

Safine, D. E. 2011. Breeding ecology of Steller's and spectacled eiders nesting near Barrow, Alaska, 2008-2010. U. S. Fish and Wildlife Service, Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. Technical Report. 66 pp.

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ACKNOWLEDGMENTS

We would like to thanks the long list of individuals who assisted with field work on the eider project from 2008 through 2010. We received tremendous assistance from the following U.S. Fish and Wildlife Service (USFWS) staff: Jewel Bennett, Nora Rojek, Christopher Latty, Neesha Stellrecht, Kate Martin, Denise Walther, Kim Trust, Tamara Zeller, Kaithryn Ott, Nicholas Docken, Lyn Snoddy, Shawn Hawks, Michele Kuter, and Rebecca Howard. USFWS volunteers donate their time and energy to this project each year, and we would not be able to conduct a project of this scale without their valuable assistance. We would like to extend our sincerest gratitude to following volunteers: Jason Kopanke, Laura Jenkins, Kristin Bondo, Veronica Reed, Shiway Wang, Ben Hobson, Mark Breaks, Allison Miller, Barry and Eleanore Keefe, John Gustafson, Lillian Maupin, Pamela Rueda, Anitra Firmenich. Eider Journey students are a very important and enthusiastic part of the team, thanks to the following Barrow High School students: Mark Brower, Paige Bowen, Stephanie Nelson, Alaina Bankston, Josiah Patkotak, Ransom Rentenaar, Krystal Leavitt, Frederica Matumeak, Stacy Burke, Chad Nusunginya, Jordan Grimes, Alison Bankston, Donjoe Lampe, and Val Blackburn. We thank Nicholas Docken, Lyn Snoddy, and Nicole Legere for countless hours of nest camera data analysis. We appreciate the help of the USFWS Shorebird crew and Denver Holt of the Owl Research Institute for providing us with waterfowl and snowy owl nest locations. We value all the logistical assistance and support provided by staff at the North Slope Borough Department of Wildlife Management, particularly Taqulik Hepa, Robert Suydam, Todd Sformo, Joshua Bacon, and Brian Person. We thank Bryce Lake for help with analysis and study design. Thanks to the North Slope Borough School District, Barrow Arctic Science Consortium (BASC), and Neesha Stellrecht for facilitating the participation of Barrow High School students in our work. We appreciate the effort by Tuula Hollmen, Heidi Cline, and Ann Riddle of the Alaska SeaLife Center to help us assess and safely transport injured eiders. Thanks to Terry Smith and his trapping crew (Wildlife Services, USDA) for providing fox control in the study area each year. Thanks to Abby Powell (UAF) for lending the project trapping equipment. Philip Martin and Jennifer Jenkins's GIS and database support were greatly appreciated. We thank Paul Flint for his assistance with population model interpretation. We benefited greatly from the expertise of the aerial survey team of Jim King, Bob Ritchie, Tim Obritschkewich, and Julie Parrett. Thanks to Glenn Sheehan, Bryan Thomas, Lewis Brower, Nok Aker, and the rest of the BASC staff for providing logistical support and storage facilities which were greatly appreciated. We thank the people of Barrow for making us feel welcome in their community, and Ukpeagvik Inupiat Corporation, Inc. (UIC) for providing housing and allowing us to study eiders on their land. Thanks to the National Oceanic and Atmospheric Administration and the Climate Monitoring and Diagnostic Laboratory (NOAA/CMDL) for access to NOAA/CMDL and U.S. Geological Survey land. We appreciate the generous support of Ted Swem, Deborah Rocque, Sarah Conn, and Jimmy Fox of USFWS Fairbanks Fish and Wildlife Field Office. The U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, ConocoPhillips Alaska, Inc., and National Fish and Wildlife Foundation all provided critical project funding. Previous drafts of this report were greatly improved by reviews by Ted Swem, Kate Martin, Denise Walther, and Nicholas Docken.

INTRODUCTION

Background

Most of the world's Steller's eiders (*Polysticta stelleri*) nest in Arctic Russia and winter in waters adjacent to the Alaska Peninsula and Aleutian Islands. A much smaller group, the Alaska-breeding population, nests primarily on the Arctic Coastal Plain of Alaska (North Slope; Pitelka 1974) and a handful of pairs may continue to nest on the Yukon-Kuskokwim Delta (Kertell 1991, Flint and Herzog 1999). Since the mid 1970s approximately 10 nests have been documented on the Yukon-Kuskokwim Delta (Flint and Herzog 1999, B. Lake/USFWS pers. comm.). The Alaska-breeding population was listed as threatened under the Endangered Species Act in 1997 due to concerns over apparent declines in numbers inferred from a reduction of nesting range in Alaska.

Steller's eiders are sparsely distributed across the Arctic Coastal Plain of northern Alaska (USFWS, Migratory Bird Management, unpublished data from aerial waterfowl breeding pair surveys). Breeding pair density based on aerial surveys is greatest near Barrow. Steller's eiders can be among the most abundant of the waterfowl species in the Barrow area (Pitelka 1974), but abundance and breeding effort vary widely from year to year (Quakenbush and Suydam 1999). Periodic non-breeding of Steller's eiders near Barrow may be related to the response of predators to fluctuations in abundance of brown lemmings (*Lemmus trimucronatus*; Quakenbush and Suydam 1999).

The proximity of nesting Steller's eider to Barrow creates a unique opportunity to engage in research that might otherwise not be logistically and economically feasible on the Arctic Coastal Plain, but also gives rise to potential conflicts between a threatened species and an active, expanding community. Barrow is an important study site for Steller's eiders for two reasons: First, it is the most logistically feasible and only known location to consistently collect demographic data on the Alaska-breeding population, and second, site-specific information is necessary for conservation planning and to fulfill the Service's consultation responsibilities under section 7 of the U.S. Endangered Species Act.

In 1991, the U.S. Fish and Wildlife Service (USFWS) Ecological Services Fairbanks Field Office and the North Slope Borough Department of Wildlife Management initiated a study of the breeding biology of Steller's eiders near Barrow (Figure 1). The study focused on nest success, productivity, habitat use, nesting chronology, and annual variation in breeding effort of Steller's eiders and the avian predators (pomarine jaegers and snowy owls) related to their abundance and habitat use. Beginning in 1999, a breeding pair survey was added to the study to map distribution and relative abundance of Steller's and spectacled (*Somateria fischeri*) eiders and avian predators in the Barrow area. Demographic data (nest and brood survival) and nest locations have been collected on Steller's eiders since 1991, but only nest locations were recorded for other waterfowl species (primarily spectacled eiders). Understanding factors that limit reproductive output in Steller's eiders is critically important to species recovery, and comparing the nesting strategy of Steller's eiders to other arctic waterfowl species in the same area may help understand these factors. Broadening the scope of this project to examine demographics of other waterfowl species will improve the scope of inference of this study. Current limitations of the study include lack of demographic data for years when no Steller's eider nests are found and for other waterfowl species, and an inadequate sample size to directly examine sources of variation in nest survival. In 2009, we began collecting data on nest survival and incubation behavior of other common nesting waterfowl near Barrow. The focus of this study remains Steller's eiders, but increased effort is now placed on spectacled eiders, and to a lesser extent, on other nesting waterfowl.

Knowledge of Steller's eider density and breeding distribution on the North Slope is limited, mainly because this species is present in very low numbers and thus is difficult to survey. Aerial breeding pair surveys flown annually by USFWS Migratory Bird Management across the North Slope are conducted at a relatively low intensity (2-4% area coverage; Stehn and Platte 2009) given its vast area and limited resources. Because this species is present in low and highly variable numbers on the Arctic Coastal Plain, and survey coverage is limited, estimates of abundance and population trends are imprecise (Stehn and Platte 2009). Using the best available information from the Arctic Coastal Plain aerial surveys conducted from 1993-2008, Steller's eiders are estimated to number about 576 (292-859, 90% CI) in Northern Alaska (Stehn and Platte 2009). To estimate density and to examine annual breeding-season distribution of Steller's eiders in the Barrow area, more intensive aerial surveys were initiated in 1999 (within approximately 60 km of Barrow; Figure 2). This more intensive and localized aerial survey flown by ABR, Inc. is referred to as the Barrow Triangle Survey, and coverage varies from 25-50% of the survey area (~700-1400 km^2) depending on breeding conditions. The Barrow Triangle Survey typically observes more Steller's eider in a given year than the larger scale aerial surveys of the Arctic Coastal Plain (Stehn and Platte 2009, Obritschkewitsch and Ritchie 2010); however, inference from this survey is limited to the Barrow Triangle Region and cannot be extrapolated to the North Slope as a whole.

Figure 1. Location and features of the Steller's and spectacled eider study area near Barrow, Alaska.

Annual ground-based surveys covered in this report are the only effort that collects demographic data on the Alaska-breeding population, but are conducted on a smaller spatial scale than the two previously mentioned aerial surveys. Ground-based surveys are conducted in a ~170 km^2 area, within approximately 6 km of the road system near Barrow, Alaska (Figure 2) and are used to locate and monitor breeding pairs, nests, and broods.

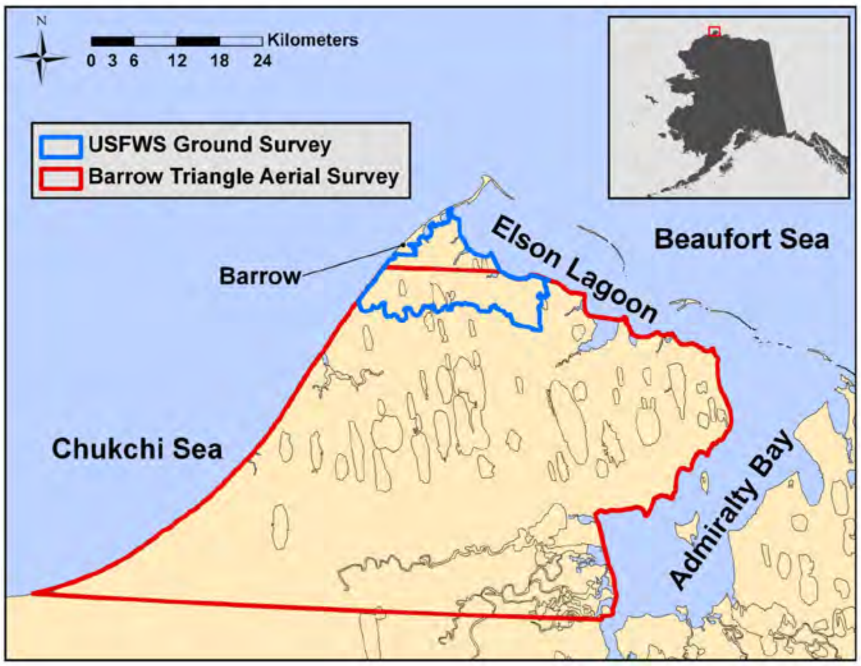

Figure 2. Location of the annual ground-based and aerial surveys conducted in the vicinity of Barrow, Alaska.

Objectives

Annual studies of Steller's and spectacled eiders near Barrow directly contribute to the development, implementation, and evaluation of management and conservation actions. Habitat protection, including section 7 consultations and the development of a Barrow Steller's Eider Conservation Plan to protect important nesting habitat, relies on up-to-date information on the distribution and abundance of eiders and their nests. Monitoring demographic parameters (mainly nest and brood survival) allows us to observe effects of management actions aimed at increasing reproductive success of birds nesting in the Barrow area. Without this monitoring, we would have no ability to assess the efficacy of actions or modify management actions in response.

A Recovery Plan for Steller's eiders was completed in 2002, and for spectacled eiders in 1996. Based on the plans, recovery priorities are periodically revised (annually or biannually), and recovery efforts at Barrow directly or indirectly address 21 high priority tasks identified on the most current recovery task lists (Steller's eider, February 2009; spectacled eider, December 2010). These tasks include:

Steller's eiders

- Continue standardized ground-based breeding pair surveys at Barrow
- Continue intensive aerial surveys in the Barrow Triangle
- Continue nest and brood monitoring at Barrow
- Determine brood survival (from hatch to fledging)
- Monitor changes in distribution and abundance of predators at Barrow
- Confirm identity of predator species causing egg/young loss
- Opportunistically collect eggs on the Yukon-Kuskokwim Delta and North Slope to establish a flock of known-geographic origin Steller's eiders at the Alaska SeaLife Center
- Determine the number and causes of infertile and inviable eggs in the Barrow breeding population
- Determine female breeding area fidelity by capturing, marking and re-sighting hens at Barrow
- Further analyze breeding female fidelity at Barrow
- Screen/monitor for lead exposure throughout the range of the listed population
- Acquire more genetic samples from birds breeding in known locations in Russia and Alaska
- Continue raven control near Barrow
- Continue fox control near Barrow
- Continue education and outreach (including Eider Journey) at Barrow to reduce disturbance of nests and ducklings
- Update and evaluate Population Viability Analysis with the most recent survey and demographic data

Spectacled eiders

- Improve education efforts across the range of the spectacled eider to eliminate take and the use of lead shot.
- Continue monitoring spectacled eider blood lead levels in areas where information is lacking, such as the North Slope and Russia, and monitor lead levels periodically throughout the range of the eider.
- Continue studies to increase understanding of the incidence and impact of diseases on eiders.
- Monitor for annual survival on the North Slope.
- Evaluate and predict effects of environmental change in breeding areas on spectacled eiders.

In order to implement these recovery tasks and to complement on-going conservation efforts, we continued our long-term monitoring efforts near Barrow, continued predator management projects that began in 2005, and implemented new research objectives all with the goal of increasing production of Alaska-breeding Steller's eiders. Specific objectives for research and monitoring of Steller's and spectacled eiders near Barrow from 2008-2010 were:

1. Continue the systematic study of the abundance and distribution of Steller's and spectacled eiders and their nests near Barrow using ground-based and aerial breeding pair surveys, and ground-based nest searches.
2. Estimate nest and brood survival of threatened eiders by monitoring nests during incubation and

following hens with broods using VHF radio telemetry.

3. Estimate nest survival of other species of nesting sea ducks and geese in the Barrow area to provide a comparison to threatened eiders, help investigate sources of variation in nest survival, and provide survival estimates for sea ducks in years when Steller's eider nests are not discovered.
4. Evaluate the relative importance of nest predator species and describe incubation behavior by monitoring a subset of sea duck nests with digital cameras.
5. Collect blood samples from nesting sea ducks for contaminants analysis, primarily focusing on exposure to lead.
6. Collect cloacal swabs from nesting sea ducks to examine health and disease exposure.
7. Involve local community members in Steller's eider conservation efforts by employing Barrow high school students for ground-based breeding pair and nest surveys and fox control.

Results of the aerial survey, fox control, and contaminants and disease projects will be reported separately. ABR, Inc. conducted the Barrow Triangle aerial surveys from 2008-2010 and provides detailed methods and results in their annual reports (Obritschkewitsch and Ritchie 2009, 2010, 2011). Fox control was conducted by USDA Animal Plant Health Inspection Service, Wildlife Services, and raven nest control by the North Slope Borough, Department of Wildlife Management and USDA Animal Plant Health Inspection Service, Wildlife Services. Specific objectives and methods for all other components of this project in the years 2008-2010 follow.

METHODS

Abundance and Distribution Surveys

Road-based survey

Starting when the field crew arrived in Barrow in early June, and extending until the start of breeding pair surveys, daily counts of Steller's eiders along the road system were conducted. The area covered each day fluctuates as the road conditions can be quite variable during break up. In the days just prior to starting the pair survey, road based counts may no longer be feasible due to the dispersal of birds away from the road. Road-based surveys are intended to provide an index of arrival and dispersal dates, and relative abundance of Steller's eiders near Barrow.

Ground-based breeding pair survey

We surveyed the study area using methods established in 1999 (Obritschkewitsch et al. 2001, and described below) within the survey area boundaries defined in 2002 (Obritschkewitsch and Martin 2002b; excluding the 1 km^2 gravel pit area southwest of the airport, the 0.4 km^2 new landfill located south of Gaswell Road, and the airport expansion area south of the runway). The survey area for each year was defined as the total area within the survey boundary minus lake areas >150 m from shoreline (thus water up to 150 m from the shoreline of larger lakes was included within the boundary) and varies among years (Appendix A). There was an approximately 134 km^2 area consistently surveyed in all years (1999-2010) and this is referred to as the "standard area." The amount of undeveloped land within the standard survey polygon has decreased over time due to development in the Barrow area. The standard survey area reported in past reports was approximately 134.5 km^2 (Rojek 2008), but with the airport runway expansion and the new landfill, the standard area reported here is approximately 134 km^2. Because the survey area has varied among years, numbers of eiders and avian predators within the minimally changed standard area are presented in the results to allow comparison among years.

Surveys commenced immediately after pairs of Steller's eiders dispersed from Footprint Lake and other wetlands where they congregated after arriving in Barrow. The survey area for each year was comprised of many sub-areas, each of which take a crew of 3-5 people approximately 4-6 hours to complete (Figure 3). Each crew searches one sub-area, and a total of ~3 sub-areas were completed each day. The entire survey takes about 10 days to complete, and surveys of sub-areas typically start near Barrow and continue eastward and southward following snow melt and road conditions. Search effort (person-hours per unit area) during 2008-2010 remained similar to previous years. Ground-based surveys were designed to provide near 100% coverage of the area.

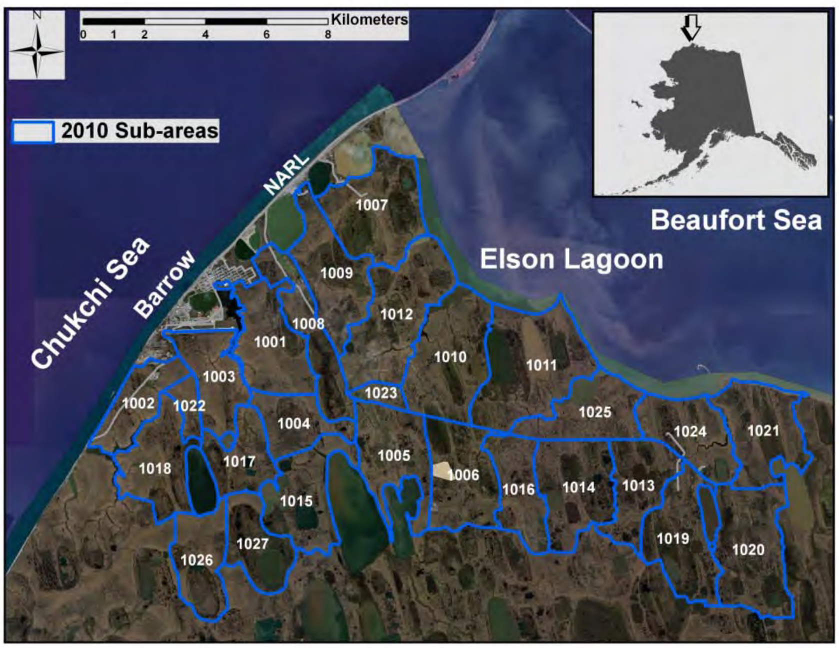

Figure 3. Size and location of sub-areas within the annual breeding pair survey conducted near Barrow, Alaska in 2010. Surveys were numbered by year and order completed, "1021" indicates survey year 2010 and 21st survey completed.

Searches were planned and conducted using GPS handheld units and high altitude infrared photography (high resolution satellite imagery was used in 2010) of the Barrow area enlarged to ~1:12,000 scale, which allowed identification of features as small as two meters across. Sub-areas were bounded by features that can be easily seen on photos and on the ground, such as streams, lakes, roads, and margins of drained lake basins. Searchers were instructed to spread out and walk in patterns that allowed them to view all water bodies in their units. In areas with little relief, distance between searchers was approximately 200-300 meters; in areas of greater relief, searchers spaced themselves closer together or walked in zigzag patterns to compensate for reduced visibility. Although it was impossible to see behind all of the mounds and ridges on the tundra using this protocol, the potential for sighting Steller's and spectacled eiders was high given the low vegetation and relatively flat topography of the coastal plain near Barrow. When target species were observed, the location was plotted on an aerial photograph and detailed information was recorded on datasheets. If the observation was a nest, a GPS was used to record latitude and longitude ± 6 m. Searchers kept track of birds previously recorded to reduce double-counting of birds, and team members used radios to communicate sightings.

Primary target species of the breeding pair-surveys were Steller's and spectacled eiders, but we also counted the following species of potential or confirmed predators of eiders: pomarine jaeger (*Stercorarius pomarinus*), parasitic jaeger (*S. parasiticus*), long-tailed jaeger (*S. longicaudus*), glaucous gull (*Larus hyperboreus*), snowy owl (*Nyctea scandiaca*), common raven (*Corvus corax*) and arctic fox (*Alopex lagopus*). Beginning in 2009, we also recorded nests of all waterfowl and loons incidentally found during pair surveys, but sightings of these species were not recorded. The data sheet for the pair survey includes the following fields: species, total observed, number male, number female, observation code, and habitat type. Observation code (5 categories) was a measure of the observer's confidence in the breeding status of the bird observed (Table 1). These categories varied from confirmed nesting to a bird flying through an area. For observations of multiple individuals, the lowest code appropriate for any individual was assigned to the group as a whole. Behavior codes were standardized among observers by reference to descriptions of behaviors that would indicate probable or possible nesting for each species. For example, the description for Steller's eiders behavior codes is as follows: "Probable nesting" was recorded if a female was observed to flush from the ground within 30 meters of an observer but no nest was found; "Possible nesting" was recorded if Steller's eiders were agitated by the observer's presence, yet were reluctant to leave (male or pair flushed, circled, and returned or if aggressive behavior by a male towards other birds was observed). If territorial or nesting behavior was observed, searchers briefly searched the area for possible nests.

Table 1. Behavior codes for avian species counted during the breeding pair survey area near Barrow, Alaska.

Code	Behavior	Description
1	Nest	Confirmed nest with eggs
2	Probable nest	Behavior strongly suggests nest presence, but no nest discovered
3	Possible nest	Behavior suggests possible presence of a nest
4	Present	No indication of nesting, but bird is doing something other than just flying through the area
5	Passing through	Bird moves through the area with no behavior other than flying

Wetland habitat type was recorded for Steller's or spectacled eider observations using nine wetland class categories developed by Bergman et al. (1977), with four additional categories added (Table 2).

Table 2. Wetland habitat types used to categorize Steller's and spectacled eider observations. Roman numerals correspond to wetland classifications described by Bergman et al. (1977).

Habitat Classification	**Description**
Ia	Flooded tundra (upland basins)
Ib	Flooded tundra (creek flats)
II	Shallow *Carex* ponds
III	Shallow *Arctophila* ponds
IV	Deep *Arctophila* ponds
V	Deep open lakes
VI	Basin complex
VIII	Coastal wetland
Ditch	Man-made channel with emergent vegetation
Stream	Any stream, excluding man-made channels
BM	Basin marsh
DT	Dry tundra

"Ditches" are man-made waterways with raised edges and emergent *Carex aquatilis* and pendant grass (*Arctophila fulva*) that formed when permafrost melted after the insulating vegetation mat was damaged by summer travel and/or removed by construction of winter roads. Streams are deep or shallow, typically meandering and containing emergent pendant grass and/or *Carex aquatilis.* Dry tundra applies to observations on tundra, not obviously associated with a water body. Bergman et al. (1977) defined a class VI basin-complex as a large, partially drained lake basin that becomes partially dry by late July, exposing relatively dry upland-like areas and a mosaic of pools with *Carex aquatilis* and/or *Arctophila fulva*. A new category of partially drained basin, the "basin marsh," was created to describe a heavily vegetated basin that remains entirely aquatic throughout the summer. The primary example of this wetland type in Barrow is Footprint Lake, a large (approximately 2 km^2) lake that was drained in 1950 (Britton 1957, Billings and Peterson 1980) and has since developed a dense stand of emergent *Arctophila fulva*. The class VI basin-complex, although present in the Barrow area, is rarely identified as a habitat used by eiders in this study because it generally occurs as a composite of other, smaller-scale wetlands. For example, a basin complex may contain a mix of class II, III and IV ponds, a stream, and both classes of flooded tundra. A Steller's eider seen in a class II pond in a basin-complex would typically be assigned to the class II habitat and not to a basin-complex.

For nests found during the pair survey, in addition to location, we recorded number of eggs and incubation stage from egg candling or floating when possible. Dens sites were noted for foxes.

Aerial survey

ABR, Inc. conducted aerial surveys for Steller's and spectacled eiders in the Barrow Triangle area during the same time period as the ground-based breeding pair surveys. The survey covered a 2725 km^2 area between Admiralty Bay and the Chukchi Sea coast from just south of Barrow to the southern end of Admiralty Bay (Figure 2). East-west oriented, 400 m-wide strip transects were flown 800 m or 1600 m apart, providing 50% or 25% coverage, respectively (see Obritschkewitsch and Ritchie 2010 for further details on methods). In years when Steller's eiders were relatively abundant and likely nesting according to conditions observed near Barrow in June, the survey was flown at 50% coverage. If Steller's eiders were less abundant or likely not nesting near Barrow, the survey was flown at 25% coverage to save resources. For each Steller's eider observation, number, sex, and a brief description of habitat were recorded.

Chronology

Data on weather conditions (temperatures, precipitation, and snow melt) were recorded at the National Oceanic and Atmospheric Administration (NOAA) weather station located at the Barrow airport (NOAA 2011). Nesting chronology was calculated as described in the "Statistical analysis" section of the methods.

Nest Searching and Monitoring

Nest searching

Limited nest searching was conducted during the breeding pair survey if territorial or nesting behavior was observed, and targeted nest searching began after the pair survey was completed. In 2008, efforts were focused on finding Steller's eiders nests, but other duck nests were encountered incidentally and recorded. In 2009 and 2010, we focused on Steller's and spectacled eiders, but all waterfowl nests found incidentally were recorded. In 2010, after we found 90 nests of greater white-fronted geese, we ceased collecting data on additional nests. Nest searching in 2008-2010 was conducted using several main strategies, none of which were randomized or intended to generate estimates of density, or nesting effort. Nest searching was not conducted randomly because this method would limit sample size for nest survival estimates (especially in 2009 and 2010 when Steller's eider abundance was low). Primary search areas were delineated based on three criteria: 1) areas within ~400 m of lone males or pairs seen during the breeding pair survey, 2) areas with higher nest densities in past years, and 3) areas perceived to be likely nesting habitat, especially for spectacled eiders. Nests were also found incidentally during other efforts (nest monitoring) and reported to us by other researchers (e.g., USFWS shorebird study crew).

Each day during nest searching a crew of 2-5 people would search an area. Some areas were searched in all years (2008-2010), and others may have been unique to one year (Figure 4). Some areas were searched more than once per year if we believed a nest was missed. We conducted searches from 0900-1800, Alaska Daylight Time. Searchers were spaced approximately 5-10 m abreast, and visually searched to either side and ahead as they walked. In addition to the method above, we added nest searching with a rope (i.e., rope dragging) in 2010. Rope dragging is a commonly used method to find waterfowl nests, and can increase the chances of detecting nests, especially with species that are hesitant to flush (e.g., eiders). Rope dragging also allows increased spacing among searchers, and thus fewer people can cover the same area as a crew without a rope. However, rope dragging is not as effective at locating failed or unattended nests (e.g., depredated or female on incubation break) given the increased spacing among observers. We conducted rope dragging with a team of 3, one observer towing each end of the rope (~25 m long and 3/8" diameter) and one observer walking behind the center of the rope (Figure 5).

A nest was defined as a scrape or depression that contained sufficient down, contour feathers, or eggs to positively identify species. Contour feather samples from known nests and a photographic field guide (Bowman 2004) were used to aid in identification of nests and eggs. When a nest was found or re-visited, we recorded the following information when possible: Date, time, species, observer, a unique nest number, latitude and longitude, nest status (active, abandoned, destroyed, hatched, unknown), number of eggs, shells, membranes, or ducklings, days of incubation (from egg candling or floating), amount of down (none, some, moderate, abundant), presence of male and female, and distance to flush. Effective clutch size was calculated as described in the "Statistical analysis" section of the methods.

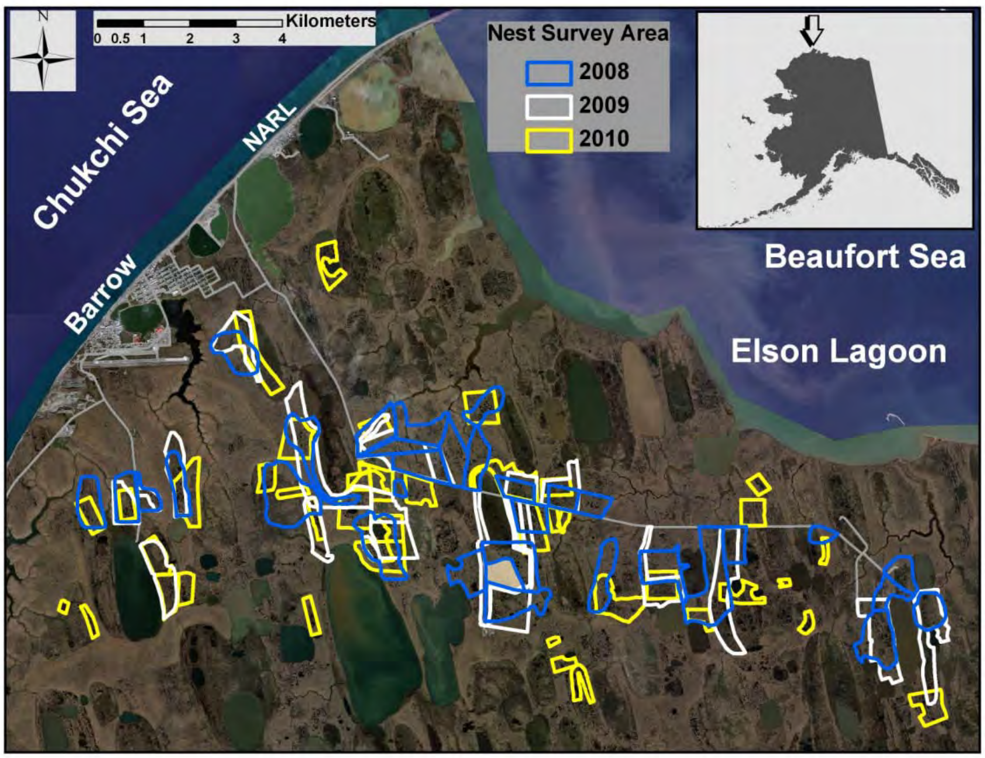

Figure 4. Nest survey area for Steller's and spectacled eiders near Barrow, Alaska 2008-2010.

Figure 5. Nest searching for eiders with a rope (rope dragging) near Barrow, Alaska in July, 2010. Photo: D. Safine/USFWS.

Nest monitoring

All Steller's eider nests found from 2008-2010, and all waterfowl nests found and recorded in 2009 and 2010 were monitored to determine fate. Nests were visited approximately every 7 days until nest fate was determined (hatched, destroyed, or abandoned). Goose and swan nests were usually visited less frequently, especially greater-white fronted geese (*Anser albifrons*; ~10 day intervals). All attempts were made to minimize effects of nest visits on nest survival. Nests were not physically marked, but were relocated using GPS coordinates and maps. Many hens were flushed when a nest was first encountered, however, during subsequent nest visits we avoided flushing females and confirmed their presence on a nest from 10-40 m away using binoculars. If the female was accidently flushed or not present, nests were visited to age eggs (if active) or determine the cause of failure (if inactive). Nests may have been visited more frequently and females intentionally flushed, late in incubation to determine an accurate hatch date for timing capture of females (for sea ducks only). For Steller's eiders, nests were visited when females were on nest breaks if eggs needed to be aged.

After hatching or nest failure, egg membranes and/or contour feathers were collected for genetic analysis. Destroyed nests were examined for clues as to cause of predation, such as presence/absence, appearance, and location of eggshells.

Nest cameras

Digital time lapse cameras (15-second time intervals; Silent Image^{TM} Camera, Reconyx, LLP) were placed at a subset of sea duck nests from 2008-2010. The primary purpose for nest cameras was to positively identify nest predators and examine incubation behavior and potential sources of nest disturbance. In 2008, cameras were placed at Steller's eider nests. In 2009 and 2010, due to few Steller's eider nests, cameras were placed mainly at nests of other sea duck species (spectacled and king eiders and long-tailed ducks). In general, we placed cameras at nests that were >500 m but < 3 km from roads to reduce likelihood of discovery by humans, but facilitate camera maintenance. Nest cameras were placed on a tripod (Figure 6), ranging from 10-35 meters from the nest (depending on camera zoom and topography). Nests monitored with digital cameras were visited every 5 days to change batteries and memory cards. As cameras were placed away from nests, servicing them did not cause incubating hens to flush from nests. Nest camera images were reviewed and the following was recorded: start and end time of all images, start and end time of any period a female was not present on nest, cause of nest recess if known (human, nest predator, or other), means of leaving nest (fly or walk), predator and human presence, predation events, any events that occurred after hatch, and any missing camera time (due to battery and memory card changes, etc.).

Figure 6. A time lapse digital camera is positioned to monitor a sea duck nest near Barrow, Alaska. Photo: D. Safine/USFWS.

Habitat Use

Observations of Steller's and spectacled eider flock size, sex composition and behavior was recorded during the breeding pair surveys to form an overview of wetland use during the pre-laying and early nesting period. Habitat use information during the pair surveys was coarse scale, and involved assigning a habitat type to each eider observation (see Ground-based Breeding Pair Survey Section). After nest failure or hatch, we also collected nest and brood-rearing habitat information to characterize basic breeding requirements. In the field we recorded nest or brood site habitat type, nest bowl dimensions, distances to, and characteristics of, nearest permanent and temporary water bodies, and distance to ATV tracks and trails. Distances to nearest neighboring con-specific eider nests were calculated using the Animal Movement Extension (Hooge and Eichenlaub 2000) in ArcGIS.

Hen Capture and Brood Monitoring

A sample of adult female sea ducks were captured on nests during late incubation to monitor health and disease exposure, band females, and in some cases attach VHF radio-transmitters. Radio-marking was used to relocate adult females and ducklings to examine habitat use and estimate brood survival. Nest captures were targeted for 1-2 days before hatch (i.e., day 22-23 of incubation). Hens were captured by lowering a horizontally-stretched mist net onto the incubating female. This was accomplished by two persons approaching the nest holding the mist net in a horizontal plane, with one panel of the net stretched fully between hands of outstretched arms (method similar to that described in Bacon and Evard

1990). After lowering the net, the two persons kneeled on either end of the net and slowly crawled towards the hen. In most cases, the hen remained on the nest until the trappers were within 1 m. Bow-nets, spring powered hoop shaped nets that are remotely triggered using a 50 -100 m string, were used at nests where females would not allow a close approach.

USFWS metal bands (stainless steel, size 6 or 7A short) and plastic color tarsal bands (yellow with black alpha-numeric code for Steller's eider only) were applied to hens. Blood was drawn from the jugular vein for lead exposure, DNA, and hormone analyses. The tip of a secondary covert feather was collected for stable isotope analysis. A cloacal swab was taken for avian influenza or general viral screening, and a fecal swab was collected to examine bacterial exposure. We recorded body weight (± 1 g, using a spring or digital scale), culmen, tarsus (diagonal and total), and wing length (wing chord and flattened wing; ± 0.1 mm).

Prong and glue VHF transmitters (ATS, model A4450, 14 g) were attached to hens. A stainless steel prong (anchor) on the anterior of the transmitter was inserted sub-cutaneously between the scapulars through a 2-3 mm incision made with the tip of a scalpel blade. A few drops of veterinarian grade cyanoacrylate glue (Vet Bond™) were applied to seal the incision, and high quality hobby grade cyanoacrylate glue was used to anchor the transmitter to feathers. Transmitters were expected to be shed within 2-6 months after attachment.

Attempts were made to locate radio-marked females about once every seven days until broods failed, fledged, or repeated absence of a signal was recorded (assumed to indicate fledging and subsequent movement). We used a VHF receiver (Wildlife Track, WTI-1000) and 3-element hand-held Yagi antenna. To minimize disturbance, we observed hens and broods from a distance, departed areas as quickly as possible after locating females, and tracking was not conducted on stormy or unusually cold days. Information was recorded on brood size, behavior, habitat use, location, interactions with predators, and time. Latitude and longitude were recorded for each brood sighting at the location of the observer (not the brood) to avoid disturbing broods. Distance and direction from observer to brood were also recorded, and coordinates were corrected later using ArcGIS. However, as distance and direction to brood were estimated by observer, the actual brood location could be up to 100 m from the corrected coordinates shown on figures in this report.

Statistical Analyses

Clutch size and nesting chronology

We estimated effective clutch size from nests where eggs were observed at least once during incubation. This estimate may not reflect true clutch size (i.e., the number of eggs laid) as predation may reduce clutch size prior to nest visits. Effective clutch size estimates were derived from a combination of 2009 and 2010 data as 2009 sample sizes were too small to stand alone. For Steller's eiders, clutch size and nesting chronology data come from 2008 only, as 2009 and 2010 data were not sufficient for calculations. Sample size for clutch calculations were lower than number of nests found active as we avoided flushing females if possible, and some nests were destroyed before egg counts were obtained. Estimates of nest initiation and hatch dates were calculated using effective clutch size, incubation stage data from nest visits, and published information on length of incubation by species. Nests found in laying that failed before a count of the completed clutch was conducted, could only be used to estimate nest initiation date. Therefore, sample sizes for nest initiation and hatch dates may differ. Images from nests monitored with digital cameras were used when available to improve estimates of hatch date.

Nest and brood survival

The fate of each nest or brood was classified as successful or unsuccessful. A nest was considered successful if at least one duckling hatched, and was confirmed by observing at least 1 duckling or eggshell membrane in the nest (Klett et al. 1986). A brood was considered successful if at least one duckling fledged or reached fledging age. Causes of nest failures were determined whenever possible.

We estimated daily survival rate (DSR) of nests and broods using the nest survival model in Program MARK (White and Burnham 1999). Program MARK uses generalized linear models to generate maximum likelihood estimates of DSR. The nest survival model is a type of known fate analysis (White and Burnham 1999) and assumes the following about the nests or broods in the sample: fate is known with certainty, fate is independent, lack of heterogeneity in DSR within a grouping, and survival is not affected by the observer or markers (Williams et al. 2002, Dinsmore et al. 2002). These assumptions were violated in some cases. In the case of nests, a nest may become inactive after a visit due to the observer attracting a predator or causing abandonment. If we have data to confirm this was likely the case, data for that nest was censored after the last active visit, so as not to bias DSR low. We censored data after the last active visit for 3 sea duck nests that likely failed due to observers from 2008-2010. Our nest data likely violates the lack of heterogeneity within a group assumption when we combine multiple sea duck species in one group or multiple nests of the same species in the same group without spatial variables (e.g., distance to fox den). However, our limited sample size for sea ducks precludes the use of more complex models to reduce heterogeneity within groups. For broods, our clearest violation of the assumptions was failure to locate marked birds or their ducklings with telemetry (i.e., fate was not known with certainty in some cases). During brood monitoring, occasionally a female could be located, but the presence of a brood could not be confirmed without possibly disturbing (i.e., flushing) the hen. In these cases, the observer usually returned within a few days and confirmed the presence of ducklings. Often, particularly as a brood approached fledging age, the telemetry signal for a female became undetectable within the study area before her brood could be confirmed to have fledged. When this occurred, fledging and subsequent movement of the adult female from the study area could not be discerned from late brood loss and subsequent movement. Given the lack of aerial telemetry and radio-marked ducklings to help resolve this issue, we used criteria from Rojek (2007) to ascribe fate in these cases. Rojek (2007) assumed broods had fledged when ducklings reached 32 days of age, if flight was not directly observed. If a female could no longer be relocated, but the brood had survived to ≥32 days of age, we assumed fledging.

We performed three nest survival analyses in this report. The first analysis was for Steller's eiders in 2008 and 2010 (years when nests were found near Barrow). Given the limited sample size, we did not investigate sources of variation in DSR. We estimated daily survival rates by year from the null model (assuming DSR was constant), consistent with Mayfield estimates in previous years.
The second analysis was for all waterfowl in 2009 and 2010. For these years, data from multiple species was available, sample sizes were larger, and we investigated sources of variation in DSR. We had a two stage approach to modeling variation in DSR; first we built *a priori* models to incorporate what we

believed to be biologically important covariates (i.e., stage 1), and then we added models with variables of management interest to the most plausible model from the first stage (i.e., stage 2; Figure 7). In the first stage of modeling we built a small model set with the following sources of variation in an additive manner: group, year, and season day. Group indicated a species or tribe of waterfowl, and was included in models in two ways. We built models that separated the data into two groups (ducks and greater white-fronted geese) and three groups (dabbling ducks [Tribe Anatini], sea ducks [Tribe Mergini], and greater-white-fronted geese). Dabbling ducks were northern pintail (*Anas acuta*) and American green-winged teal (*A. crecca*), and sea ducks were Steller's, spectacled, and king (*Somateria spectabilis*) eiders, and long-tailed duck (*Clangula hyemalis*). Given sample size constraints, further splitting of species within sea duck and dabbling ducks was not plausible. We excluded tundra swans and black brant from the analysis as sample sizes were inadequate for them to be unique groups, and combining these species with greater white-fronted geese seemed biologically inappropriate. Season day was the day of the nesting season, with the earliest calendar day a nest was found in all years designated as day 1 (10 June). We also included a null and global model in the set. In the second stage of modeling, we addressed two more potential sources of variation in nest survival. First, does distance from nests to the nearest road or the new landfill (straight line distance) affect DSR? Second, does observer visitation affect DSR in the interval following a nest visit? For the distance covariates question and estimation of nest survival, we employed the censored nest data set (described above; data collected after observer-caused failure at 2 nests were excluded). To test the effect of nest visitation on DSR, we used uncensored nest data (including any known observer effects) as this would be more likely to detect the effect of observer visitation on DSR if it were present.

The third nest survival analysis investigated the effect of nest cameras on DSR. For this analysis, we used all sea duck nests from 2008-2010 to increase the limited sample size for this analysis. Again we used the uncensored data as it would be more likely to detect a negative effect of cameras. We tested a small suite of *a priori* additive models given the sample size, and included the parameters year and camera presence along with a null model.

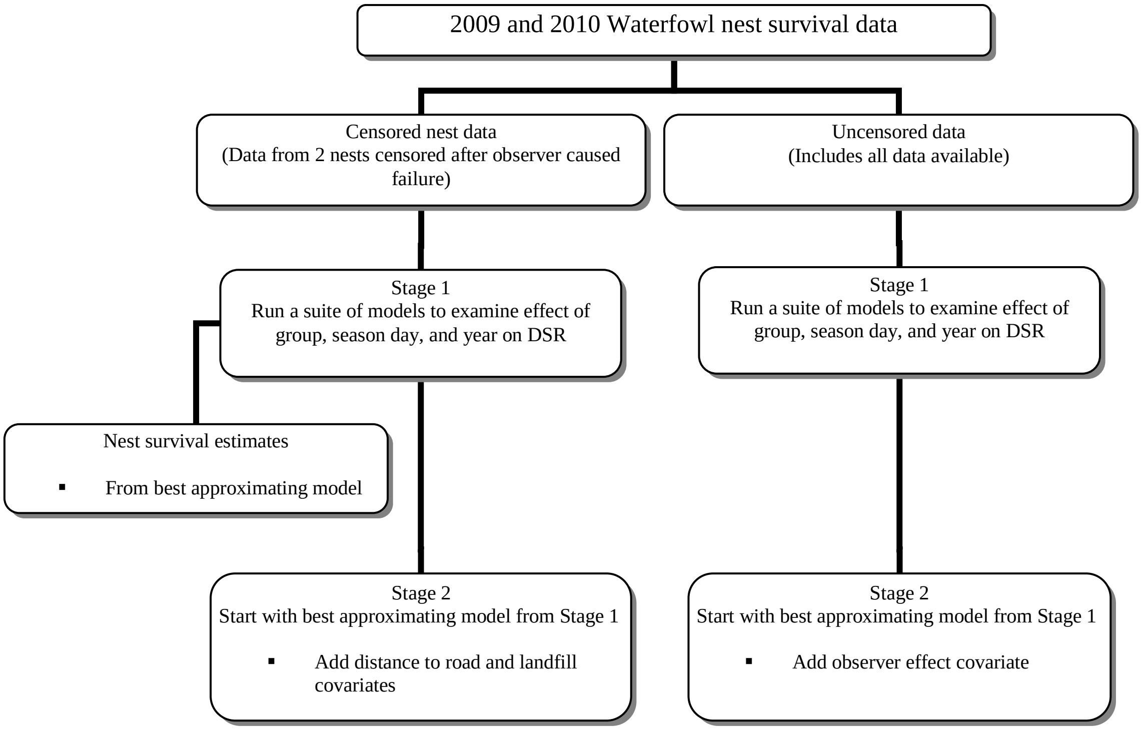

Figure 7. Flowchart to demonstrate the process of analyzing the 2009 and 2010 waterfowl nest survival data.

To generate estimates of nest survival for species or group of species (e.g., sea ducks), we extended DSR from the best approximating model from Stage 1 to the full exposure period (number of days a nest was exposed from onset of laying to hatch). The result is the probability a nest will survive the average exposure period required to hatch. For Steller's eiders, we used the exposure period consistently reported in the literature (30 days; Quakenbush et al. 2004, Rojek 2008). For other species, we calculated exposure period as clutch size + incubation period – 1day. We used published estimates for each species from similar latitude (if possible) for clutch size and incubation period, and assumed egg laying rates of 1 egg per 24 hours. For consistency we assumed incubation begins upon laying of the last egg, though some species likely begin incubation with the penultimate egg. We subtracted 1 day from the estimate as the exposure period does not begin until the first egg was laid. We only generated survival estimates for the most common waterfowl in our sample, and thus exposure periods in days are as follows: Steller's eiders (30), spectacled eiders (26; Flint and Grand 1999, Pearce et al. 1998), northern pintail (30; Austin and Miller 1995, Petrula 1994), long-tailed duck (32; Alison 1975), and greater white-fronted goose (28; Ely and Dzubin 1994). Nest survival estimates from models with a season day effect were based on egg laying beginning on the mean nest initiation date for that species at Barrow.

Brood survival data was only available for Steller's eiders in 2008. For brood survival, given a limited sample size, we estimated DSR based on the null model. To estimate brood survival, we also extended

DSR to the exposure period required to fledge a duckling near Barrow. Quakenbush et al. (2004) observed known-age ducklings flying at 36 days after hatch in Barrow, and Rojek (2006) observed two ducklings flying at 32 days of age. Given the uncertain fledging age, we present brood survival estimates based on 32 and 36 day exposure periods to bracket this range.

Nest survival comparisons between historical data (1991-2000) and more recent years (2005-2010) are compromised by the unknown effect of recent fox control. Fox control began in 2005, and was conducted in the study area each year from 2005-2010. Control efforts were initiated approximately late May or early June of each year, about two weeks prior to expected Steller's eider nest initiation dates, and continued through late July to include most of the nesting period. Changes in conditions on the study area in recent years that may have affected nest survival rates are confounded with fox control; however, we provide historical data on Steller's eiders as it is the only available comparison.

Incubation behavior

We compiled nest camera data from 2008-2010 to estimate average number per day and length of nest recesses and incubation constancy by species of sea duck. A nest recess was defined as any period of time a female was not on her nest. For the purposes of this analysis, we did not include recesses due to human disturbance (e.g., a nest visit or capture event) in calculations of incubation behavior. Average number of recesses per day was defined as the total number of nest recesses recorded for an individual divided by the number of days monitored (total hours nest monitored ÷ 24). The total time a nest was monitored was defined as the difference between the time nest fate was determined (hatch or fail) and the start time minus any missing camera time (e.g., maintenance). Nest recess length was defined as the difference between the time of the last image a hen was on the nest to that of the first image of the female on the nest after the break. Recess length was averaged across all breaks for an individual during monitoring. We defined incubation constancy for an individual as the proportion of time a hen spent on her nest out of the total time the nest was monitored ([total time monitored – sum of all recess lengths] / total time monitored). This estimate could be biased high if human caused nest breaks were compensatory and not additive to natural breaks. Incubation behavior metrics were averaged across all individuals of a species combining data from all years.

All error estimates presented in this report are standard errors unless otherwise noted.

RESULTS

Abundance and Distribution Surveys

Road-based survey

The USFWS crew arrived in Barrow on 5 June in 2008, 3 June 2009, and 1 June 2010. In 2008, road surveys were not conducted enough to see a pattern in arrival and dispersal of Steller's eiders along the road system, but Steller's eiders were already present along the road system during the first road survey on 7 June. Road surveys were conducted from 3-10 June 2009, and counts ranged from 0 to 23 Steller's eiders. Birds were first seen on 4 June, and numbers along the road peaked on 6 June, declining thereafter. Road surveys were conducted from 1-11 June 2010, and counts ranged from 10 to 89.

Steller's eiders were already present in the study area on 1 June when the crew arrived, numbers peaked along the road system on 8 June, and then sightings declined as birds either moved on to other areas or newly thawed habitat further away from the road.

Ground-based breeding pair survey

The annual survey area for each year was covered once during the survey period, and the total number of Steller's and spectacled eiders was variable (Table 3). The number of male Steller's eiders counted in both the ground-based standard survey area (consistent size in all years) and the Barrow Triangle aerial survey area (both surveyed since 1999) was relatively high in 2008 and low in 2009 and 2010 (Table 4). The second highest count of male Steller's eiders in the standard area (since surveys began in 1999) was in 2008 (105), whereas the second lowest count was in 2009 (6). The number of males counted in 2010 was the second lowest for a year when nests were found near Barrow. The highest count of spectacled eiders in recent years and since the survey began in 1999 was in 2010 (205; previous high count from ground-based survey area was 152 in 2003).

Table 3. Counts of Steller's and spectacled eiders from the annual ground-based breeding pair survey near Barrow, Alaska, 2008-2010.

Year	**Sub-areas**	**Total Steller's eiders Counted**				**Total spectacled eiders counted**			
		Male	Female	Unknown	Total	Male	Female	Unknown	Total
2008	26	114	78	3	195	60	35	3	98
2009	27	6	3	0	9	41	30	0	71
2010	27	18	15	0	33	135	70	0	205

Distribution maps of Steller's and spectacled eider observations and survey areas from the 2008-2010 ground-based breeding pair surveys are shown in Appendix A. Numbers of other avian species, arctic fox, nests, and dens counted in the ground-based pair survey are presented in Appendix B.

Aerial survey

The following paragraph is a summary of the detailed information found in the annual aerial survey reports by Obritschkewitsch and Ritchie (2009-2011).

ABR, Inc. conducted aerial surveys for Steller's eiders on the Arctic Coastal Plain from 16 to 21 June 2008, 15 to 19 June, 2009, and 19 to 22 June 2010. Aerial surveys during these years were conducted during the same period as the ground-based pair surveys. Total numbers of Steller's eiders estimated in the survey area were 96, 0, and 32 in 2008-2010, respectively. The highest estimated total from the aerial survey was in 1999 (224), and the lowest estimate, and only year no Steller's eiders were observed, was in 2009. Estimated total from 2008 was similar to that of the three previous years when nests were found (2005-2007). Numbers in 2010 were more similar to those in the years 2002-2004 (when nests were not found), but slightly higher. The estimated total in 2010 (32) was the lowest of any year since the survey began when nests were found near Barrow.

Table 4. Steller's eider males, nests, and pair densities recorded during ground-based and aerial surveys conducted near Barrow, Alaska 1999-2010.

Year	Overall Ground-based Survey Area for Each Year			Standard Ground-based Survey Area[a]		Aerial Survey of Barrow Triangle		Nests found near Barrow
	Area (km^2)	Males counted	Pair Density (males/km^2)	Males counted	Pair Density (males/km^2)	Males counted	Pair Density (males/km^2)[b]	
1999	172	135	0.78	132	0.98	56	0.04	36
2000	136	58	0.43	58	0.43	55	0.04	23
2001	178	22	0.12	22	0.16	22	0.02	0
2002	192	1	<0.01	0	0	2	<0.01	0
2003	192	10	0.05	9	0.07	4	<0.01	0
2004	192	10	0.05	9	0.07	6	<0.01	0
2005	192	91	0.47	84	0.62	31	0.02	21
2006	191	61	0.32	54	0.40	24	0.02	16
2007	136	12	0.09	12	0.09	12	0.02	12
2008	166	114	0.69	105	0.78	24	0.02	28
2009	170	6	0.04	6	0.04	0	0	0
2010	176	18	0.10	17	0.13	4	0.01	2

[a]Standard area (the area covered in all years) was ~134 km^2 (2008-2010) and ~135 km^2 in previous years.
[b]Actual area covered by aerial survey (50% coverage) was ~1408 km^2 in 1999 and ~1363 km^2 in 2000-2006 and 2008. Coverage was 25% in 2007 and 2010 (~682 km^2) and 27% in 2009 (~736 km^2). Pair density calculations are half the bird density calculations reported in ABR, Inc.'s annual reports (Obritschkewitsch and Ritchie 2011).

Chronology

Temperatures, precipitation, and snow melt

The first day the tundra was snow free (snow depth at Barrow weather station was 999.9 [i.e., no snow] not due to missing data) was 6 June 2008, 26 May 2009, and 15 June 2010. Mean first snow-free day at Barrow since the project began in 1991 was 31 May (± 2 SE), earliest was 10 May, and latest was 15 June (Figure 8). Later than average snow melt occurred in 2008, and the latest snow melt in the last 20 years occurred in 2010. Snow melt in 2009 was slightly earlier than average.

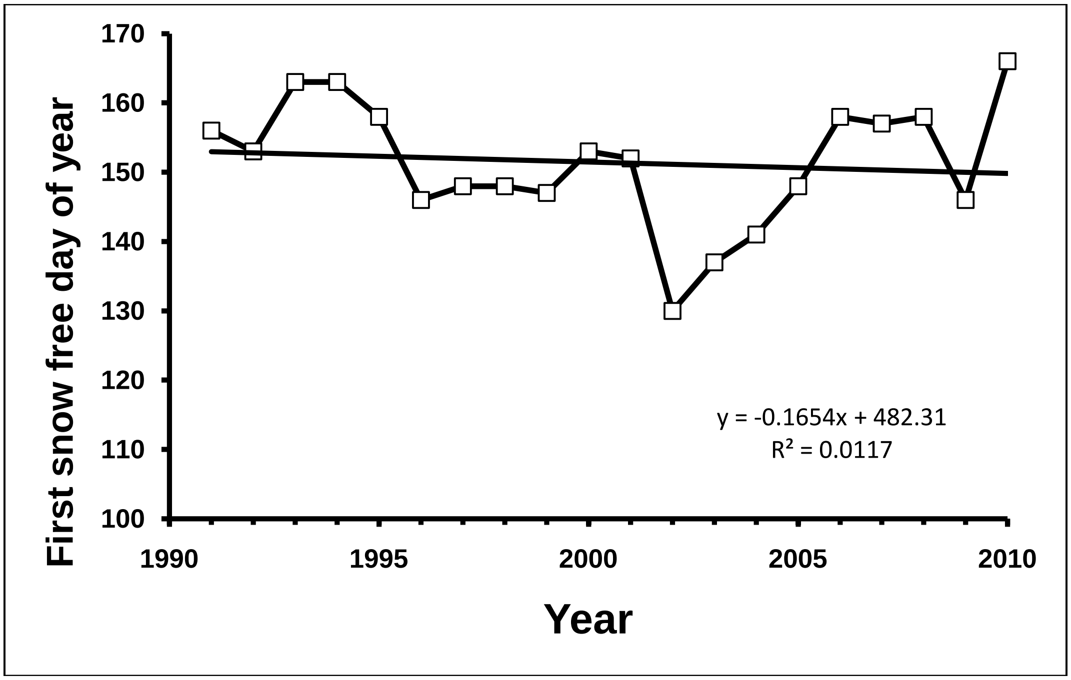

Figure 8. First snow free day of the calendar year at the NOAA Barrow, Alaska airport weather station from 1991-2010.

Average monthly temperatures in May and June 2008 were warmer than the long-term average (1945-2010), and July and August were similar or cooler than normal (Table 5). In 2009, temperatures were above average all summer, but especially May, July, and August. In 2010, early summer temperatures were below average (May and June), and late summer was above average, especially August. May, June and July 2008 had above average total precipitation, but August was fairly dry. In 2009, precipitation in May and August were above average, whereas June and July were drier. In 2010, May and July received above average precipitation, whereas June and August were drier.

Table 5. Mean monthly temperature and total precipitation at the NOAA weather station in Barrow, Alaska 2008-2010. Shaded columns are temperature and un-shaded are precipitation.

	May		June		July		August	
Long-term mean monthly temperature (°F) / total precipitation (inches)	20.1	0.12	35.0	0.32	40.4	0.87	38.7	1.04
2008 (change from mean)	+2.1	+0.13	+2.2	+0.18	-0.4	+0.46	-1.1	-0.74
2009 (change from mean)	+5.5	+0.33	+0.2	-0.14	+3.4	-0.12	+3.0	+1.09
2010 (change from mean)	-0.6	+0.41	-1.1	-0.15	+1.6	+0.77	+4.2	-0.70

Timing of the start of the ground-based breeding pair survey coincides with spring break up and the subsequent dispersal of Steller's eiders away from staging areas along the road system (e.g., Footprint Lake). Timing of the survey start was fairly consistent among years, the earliest start date was 11 June (2002) and latest 16 June (2005 and 2010; Table 6). Pair surveys began on the early to middle range in

2008 and 2009, and late in 2010 given the delayed snow melt. Average daily maximum temperatures during the pair survey were relatively low during 2009 and 2010, and high in 2008 (Table 6).

Table 6. Average daily high temperatures in Barrow for the month of June and during the ground-based breeding pair survey period, 1999-2010.

Year	June Survey dates	Average Maximum Daily Temperature, ^{o}F (std. dev. and N)	
		In June	**During ground-based survey**
1999	14-25	40 (5.3, 30)	41 (4.6, 12)
2000	14-29	45 (11.8, 30)	52 (10.1, 16)
2001	15-27	41 (7.9, 30)	44 (6.8, 13)
2002*	11-20	40 (6.6, 26)	41 (5.7, 7)
2003	12-20	40 (5.5, 30)	36 (3.8, 9)
2004*	14-23	44 (10.0, 29)	51 (8.4, 10)
2005	16-26	40 (6.9, 30)	42 (3.3, 11)
2006	12-21	44 (10.1, 30)	42 (5.4, 10)
2007	12-18	40 (5.6, 30)	43 (5.9, 7)
2008	13-24	42 (8.4, 30)	46 (7.8, 12)
2009	12-20	40 (4.3, 30)	38 (2.6, 9)
2010	16-25	38 (4.7, 30)	38 (3.0, 10)

*No data available 18-21 June 2002, and 24 June 2004.

<u>Nest initiation and hatch dates</u>

Nest initiation dates (defined as date first egg was laid) for Steller's eiders in 2008 ranged from 12 to 23 June 2008 (Figure 9; excludes nests with no or poor egg candling data), and hatch dates ranged from 12 to 24 July. Only one Steller's eider nest hatched in 2010 (22 July). We could not estimate a nest initiation date for this nest as low effective clutch size (3) indicated egg loss likely occurred before the count. Mean nest initiation and hatch dates for the most common nesting waterfowl in the study area (including spectacled eiders) are shown in Table 7. Only Steller's eiders are listed in 2008 as other species were not monitored that year. No data are listed for 2009 due to small sample sizes and inconsistent aging of eggs.

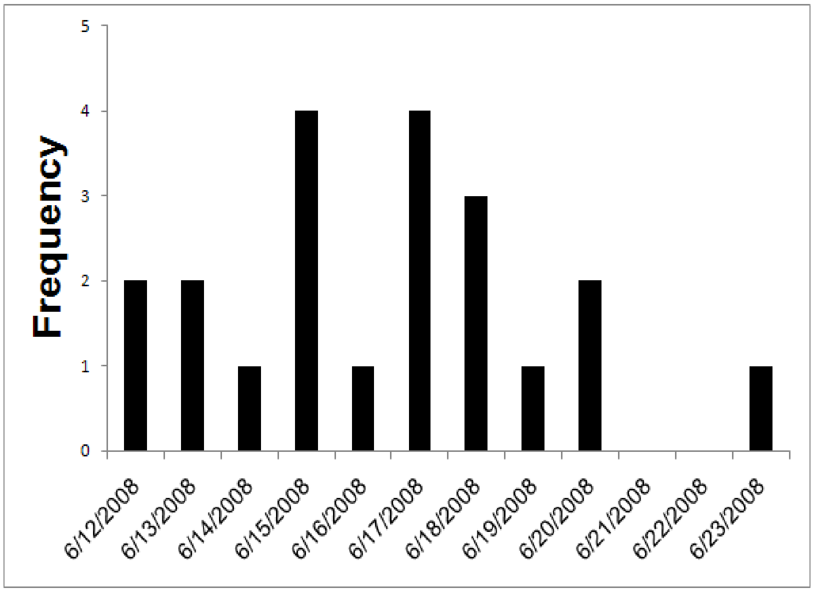

Figure 9. Frequency of known nest initiation dates for Steller's eiders near Barrow, Alaska in 2008.

Table 7. Mean nest initiation and hatch dates for most common waterfowl found near Barrow, Alaska 2008-2010. Numbers in parentheses are standard errors.

	2008				2010			
Species	Nest initiation	N	Hatch	N	Nest initiation	N	Hatch	N
Steller's eider	16 June (0.6)	22	16 July (0.6)	22			22 July (0)	1
Spectacled eider					20 June (0.8)	14	16 July (0.6)	12
King eider					22 June (1.7)	5	20 July (1.1)	4
Long-tailed duck					28 June (2.5)	10	28 July (5.2)	6
Northern pintail					14 June (1.7)	7	17 July (1.8)	6
Greater white-fronted goose							12 July (0.2)	72

Nest Searching and Monitoring

Nest searching

Both active and inactive (already destroyed or abandoned) nests were found during breeding pair surveys, nest searching, incidentally, and by other researchers (Table 8). Nest search areas varied annually (Figure 4). Total area searched in each year was 16.6, 12.5, 11.7 km^2 in 2008-2010, respectively (however, some areas were searched more than once). Maps with locations of Steller's and spectacled eider nests from 2008-2010 are in Appendix C. Average effective clutch size was calculated for Steller's eiders in 2008 and for all ducks 2009 and 2010 (Table 9).

Table 8. Waterfowl nests found near Barrow, Alaska 2008-2010.

							Total	Found
	2008		2009		2010		Found	Active
Species	All nests	Found active	All nests	Found active	All nests	Found active		
Dabblers (Tribe Anatini)								
Northern pintail	14	13	7	6	11	10	32	29
American green-winged teal	0	0	1	1	2	2	3	3
Sea ducks (Tribe Mergini)								
Steller's eider	28	27	0	0	2	2	30	29
Spectacled eider	5	5	5	3	21	17	31	25
King eider	4	4	6	3	15	6	25	13
Long-tailed duck	1	1	14	7	20	12	35	20
Unknown eider	2	2	3	1	0	0	5	3
Geese and swans (Tribe Anserini)								
Greater-white fronted goose			63	63	91	89	154	152
Black brant			7	7	13	13	20	20
Tundra swan			7	7	8	8	15	15

Table 9. Average effective clutch size of duck nests found near Barrow, Alaska 2008-2010. Numbers in parenthesis are standard errors.

	Year and sample size			
Species	2008	N	2009 and 2010	N
Steller's eider	5.9 (0.2)	24	3	1
Spectacled eider			4.1 (0.3)	14
King eider			5.0 (0.5)	5
Long-tailed duck			5.8 (0.5)	8
Northern pintail			7.4 (0.2)	10

Nest monitoring

Steller's eiders (2008 and 2010)

All Steller's eiders nests found in 2008 and 2010 were monitored until hatch or failure. For Steller's eiders in 2008, 19 of 27 active nests hatched. Daily nest survival rate (DSR) for Steller's eiders was 0.982 (95% CI 0.962-0.991) from the constant survival model (i.e., Mayfield survival). Nest survival probability for Steller's eiders in 2008 (30 day period; laying and incubation) was 0.58 (95% CI 0.32-0.77). An average of 5.2 (± 0.4) ducklings hatched per successful nests in 2008 (from counts of egg membranes; Appendix D). In 2010, one of two active Steller's eider nests hatched. Nest survival probability was estimated for Steller's eiders in 2010 (for consistency among years), but inference from this estimate should be limited given sample size. Nest survival probability (30 day period) for Steller's eiders in 2010 was 0.29 (95% CI 0.00-0.84). For comparisons in Steller's eider nest success among years see Appendix E. For details on egg fates for 2008 and 2010, including egg depredation, inviability, and number of ducklings per nest, see Appendix D. Egg candling was limited in 2008, and eggs listed as inviable in Appendix D were those found whole after hatch. Other nests may have had inviable eggs, but depredation of inviable eggs before final nests visits reduced detection. Therefore, egg inviability in this report is a minimum estimate.

All waterfowl (2009 and 2010)
All waterfowl nests found in 2009 and 2010 were monitored until hatching or failure. For this analysis we included dabbling and sea duck nests (N = 19 and 51, respectively), and greater-white fronted goose nests (N = 152) found active in 2009 and 2010. The dabbling duck group was primarily northern pintails, the sea duck group was mostly spectacled eiders and long-tailed ducks, and greater white-fronted goose was the only species in the third taxonomic group. The best approximating model from the first stage of nest survival analyses indicated that DSR was related to taxonomic group (3 groups) and season day (T). There were eight other models within 7 AIC_c units of the best approximating model, all of which include taxonomic group as an important source of variation in DSR (Table 10). Models with ducks separated into 2 groups (dabbling and sea) rank higher than those with all ducks combined despite the additional parameter. Similarly, a linear trend of season day also improves model fit. The year parameter had little effect on model fit. Parameter estimates from the best approximating model indicate DSR was highest in greater white-fronted geese, lower in sea ducks, and lowest for dabbling ducks (Table 11). Season day had a positive effect on DSR, therefore DSR increased during the nesting season each year (Figure 10). Nest survival was estimated for the most common species in the sample (using mean nest initiation date and nest period length for that species) from the best approximating model. Nest survival probability for greater white-fronted geese was 0.77 (95% CI 0.69-0.86), for long-tailed ducks was 0.24 (95% CI 0.13-0.44), for spectacled eiders was 0.19 (95% CI 0.11-0.34), and for Northern pintails was 0.02 (95% CI 0.00-0.12).

In the second stage of modeling, we tested for effects of distance to road and landfill and observers on DSR of nests by adding these parameters to the best approximating model from the first stage (3 Groups + T). AIC increases by 2 units for each parameter added to a model, and to counter that penalty, added parameters must improve model fit (or decrease deviance) more than they are penalized to be considered a more plausible model. Models with either one or both distance parameters added had little effect on deviance compared to the top model from stage 1. ΔAIC_c was +1.7 for each model that added a single distance variable to the "3 Groups + T" model, and +3.6 for the model that included both distance variables. Parameter estimates for distance to road (0.06, 95% CI -0.18-0.30) and landfill (0.03, 95% CI -0.06-0.12) were not estimated to be different from zero. These results suggest there was no linear relationship between distance to road or the new landfill and nest survival of waterfowl near Barrow in 2009 and 2010. When an observer effect parameter was added to the "3 Groups + T" model, Δ AIC_c was +2.0 (deviance changed -0.1 units). The observer effect parameter estimate was also not estimated to be different from zero (-0.16, 95% CI -1.63-1.31). This suggests that overall there were no observer effects on DSR of waterfowl nests the day following a nest visit in 2009 and 2010 near Barrow. However, we know of one sea duck nest in each year that was believed to fail due to observers.

Table 10. Model selection results for the first stage of nest survival analyses for waterfowl near Barrow, Alaska 2009 and 2010.

Model	Δ AIC_c[a]	AIC_c Weights[b]	K[c]	Deviance
S(3 Groups[d] + T[e])	0.0	0.34	4	325.9
S(2 Groups + T)	0.7	0.24	3	328.6
S(3 Groups + Year + T)	2.0	0.12	5	325.9
S(2 Groups + Year + T)	2.7	0.09	4	328.6
S(3 Groups)	2.7	0.09	3	330.6
S(3 Groups + Year)	4.1	0.04	4	330.0
S(2 Groups)	4.1	0.04	2	334.0
S(2 Groups + Year)	5.1	0.03	3	333.0
S(3 Groups * Year + T)	5.9	0.02	7	325.7
S(Constant)	72.7	0.00	1	404.6
S(Year)	74.7	0.00	2	404.6
S(T)	74.7	0	2	404.6

[a] Akaike's Information Criterion, adjusted for small sample size.
[b] Estimated probability that each model is best for the data (Burnham and Anderson 1998).
[c] Number of parameters.
[d] Taxonomic group (goose, sea duck, and dabbling duck).
[e] Logit scale linear trend of season day.

Table 11. Parameter estimates from the best approximating model of daily nest survival rate of waterfowl near Barrow, Alaska, 2009 and 2010.

Parameter	Estimate	SE	95% CI	
Intercept (dabbling duck)	1.39	0.45	0.52	2.26
Sea duck adjustment	0.57	0.34	-0.09	1.23
Greater white-fronted goose adjustment	2.68	0.36	1.98	3.38
Season day	0.03	0.02	0.00	0.07

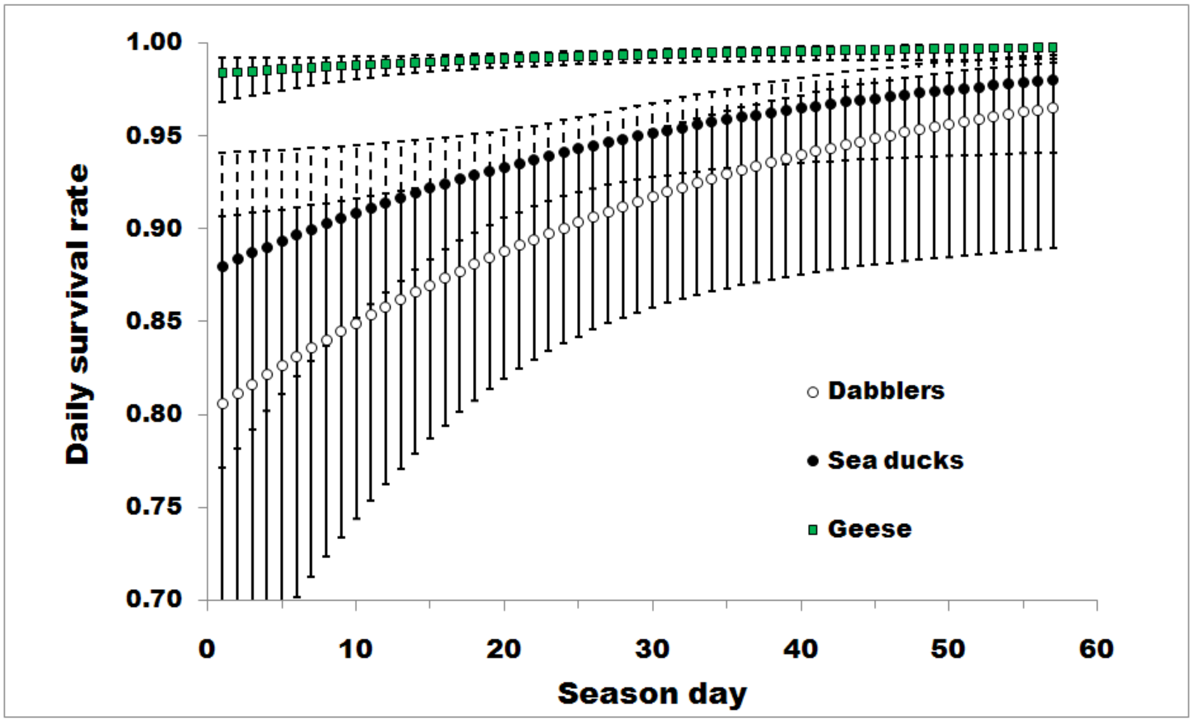

Figure 10. Effect of season day (day of nesting season) on daily nest survival rate for waterfowl by taxonomic group near Barrow, Alaska, 2009 and 2010. Error bars are 95% confidence intervals. Day 1 of nesting season was 10 June.

Sea duck nests monitored with cameras (2008-2010)

We investigated the effect of nest camera presence (N = 19) and camera absence (N = 59) on DSR of sea duck nests near Barrow from 2008-2010. All nests in 2008 were Steller's eiders, whereas in 2009 and 2010, nests were from multiple sea duck species. The best approximating model included year and camera presence, and no other competing models were within 7 AIC_c units. Adding either the camera or year effect to the constant survival model reduced AIC_c , and both parameters together greatly reduced AIC_c. Parameter estimates indicate DSR was lowest in 2009, higher in 2010, and highest in 2008. The effect of nest cameras on DSR was positive (i.e., nests with cameras had higher survival rates; Table 12). Nest survival estimates (30 day) from the best approximating model show considerable overlap in 95% confidence intervals among years and camera presence (Figure 11).

Table 12. Parameter estimates from the best approximating model of daily nest survival rate of sea ducks (with and without nest cameras) near Barrow, Alaska, 2008-2010.

Parameter	Estimate	SE	95% CI	
Intercept (2010)	2.4	0.2	2.0	2.9
2009 adjustment	-0.7	0.5	-1.7	0.2
2008 adjustment	1.3	0.4	0.4	2.1
Camera	1.5	0.5	0.6	2.4

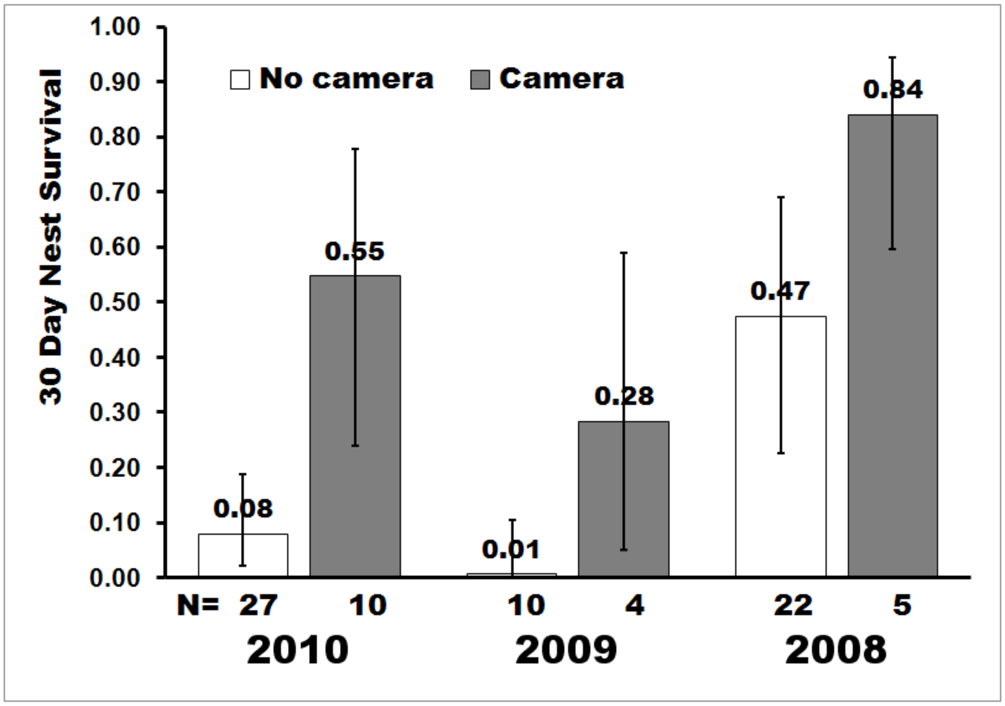

Figure 11. Effect of nest camera presence and year on 30 day nest survival for sea ducks near Barrow, Alaska, 2008-2010. Error bars are 95% confidence intervals.

Nest cameras

Nest predators

We placed nest cameras on Steller's eider (N = 6; 5 in 2008 and 1 in 2010), spectacled eider (N = 5; 1 in 2009 and 4 in 2010), king eider (N = 4; 1 in 2009 and 3 in 2010), and long-tailed duck nests (N = 4; 2 in 2009 and 2 in 2010). Nest predation events were identified and summarized by year (not species). During 2008, 5 of 5 Steller's eider nests hatched, but only 2 of 5 nests hatched the entire clutch. Jaegers (likely pomarine) were observed visiting and likely feeding at 3 of 5 nests. However, in 2 of 5 nests some feeding was observed after hatch, and jaegers may have been eating unhatched or inviable eggs after the brood left the nest. We can only confirm partial predation by jaegers of an active nest in 1 of 5 nests in 2008 (but likely in 2 nests). No arctic fox were observed by nest cameras in 2008. During 2009, 3 of 4 sea duck nests with cameras hatched, and 2 of 3 nests hatched a full clutch. The nest with partial predation was visited by an arctic fox and many glaucous gulls, but it appeared the arctic fox caused the partial predation. The nest that failed was due to parasitic jaeger predation, but that occurred only after the female abandoned the nest (likely due to researcher disturbance). During 2010, 4 of 10 camera monitored sea duck nests hatched, and 3 of 4 nests hatched with a full clutch. The nest with partial predation was likely depredated prior to camera monitoring as arctic fox and parasitic jaegers were observed near the nest on several occasions, but no depredation was documented. One nest was abandoned after a herd of caribou was present around the nest for many hours. One spectacled eider nest was destroyed by glaucous gulls and parasitic jaegers after the female was captured by researchers and delayed returning to incubate. The female did not abandon area, but she did not defend nest during predation event. The other four nests were destroyed by arctic fox (and in one case glaucous gulls after initial fox predation). In summary, for nests that researcher actions did not immediately precede predation, pomarine jaegers caused two partial nest predation events in 2008, arctic fox caused one partial nest predation in 2009, and arctic fox caused four full nest predation events in 2010 (Table 13). Arctic fox and pomarine jaegers appear to be the major nest predators in Barrow from 2008 to 2010.

Table 13. A summary of predation or abandonment events from a sample of 19 sea duck nests monitored with digital cameras near Barrow, Alaska 2008-2010. Abandonment or predation events (either partial or full) recorded in this table occurred prior to hatch and were not immediately preceded by researcher activities.

Year	Pomarine or parasitic jaeger		Arctic fox		
	Partial predation	Full predation	Partial predation	Full predation	Abandonment
2008	2	0	0	0	0
2009	0	0	1	0	0
2010	0	0	0	4	1
Total	2	0	1	4	1

Incubation behavior

Cameras were deployed at nests during incubation, with incubation stage at the start of recording ranging from ~1 to 16 days. One long-tailed duck nest was removed from this analysis as the female was not incubating consistently during the period monitored (female laying or delayed start of incubation). Attributes of incubation behavior were averaged across years for each species. We estimated mean number of recesses per day, recess length, and incubation constancy. Number of recesses per day was highest in Steller's eiders, followed by long-tailed ducks, and was lowest in king and spectacled eiders (Figure 12a). Recess length overlapped among species, but was generally longer for long-tailed ducks and shorter in eiders (Figure 12b), and incubation constancy was higher in the larger eiders (spectacled and king) and lower in the smaller sea ducks (Steller's eiders and long-tailed ducks; Figure 12c).

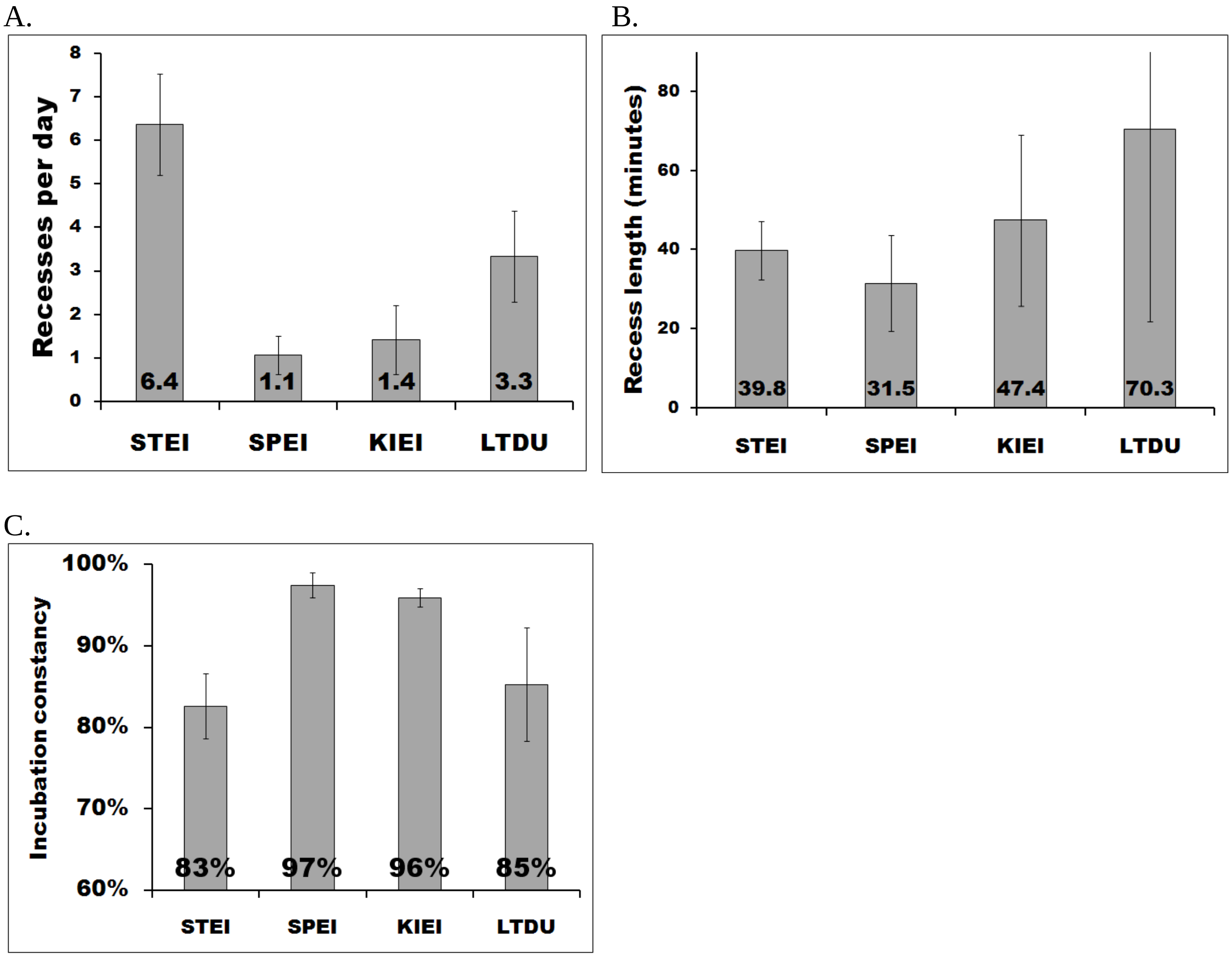

Figure 12. A) Average number of nest recesses per day, B) average nest recess length, and C) average incubation constancy for sea duck species monitored with nest cameras near Barrow, Alaska from 2008-2010. Error bars represent two standard errors. Abbreviations for species are Steller's (STEI), spectacled (SPEI), and king (KIEI) eiders and long-tailed ducks (LTDU).

Habitat Use

Ground-based breeding pair survey

There were 91 sightings of single, paired, or grouped Steller's eiders during the ground-based breeding pair survey where habitat information was recorded from 2008-2010 (Table 14). Shallow *Arctophila* pond was the most common habitat type used by Steller's eider during mid-June (the pre-laying, laying, and early incubation period), followed by shallow *Carex* pond, deep *Arctophila* pond, and flooded tundra.

Table 14. Habitat use by Steller's eiders during ground-based breeding pair surveys near Barrow, Alaska in June of 2008-2010.

Habitat	Number of Sightings (%)	Number of Steller's eiders (%)
I - Flooded tundra	8 (9)	14 (8)
II - Shallow-Carex	27 (30)	47 (26)
III - Shallow-Arctophila	34 (37)	72 (40)
IV - Deep-Arctophila	8 (9)	20 (11)
V - Deep-open	3 (3)	5 (3)
Stream	5 (5)	9 (5)
Dry tundra	6 (7)	11 (6)
TOTAL	91	178

Nests

Most Steller's eider nests in 2008 had permanent water bodies nearby; primarily *Carex* and *Arctophila* ponds (Table 15). Mean distance to permanent water was 19.1 ± 4.6 m (range 2-105 m, N = 28).

Table 15. Nearest permanent water bodies to Steller's eider nests in 2008.

Nearest Permanent Water Body (basin type)	# of Nests	%
Shallow *Carex* pond	12	43
Shallow *Arctophila* pond	9	32
Deep *Arctophila* pond	2	7
Flooded tundra	2	7
Ditch	1	4
Trough	1	4
Stream	1	4
TOTAL	28	

In 2008, Steller's eider nests were located primarily in the central and eastern study area (Appendix C-1). No nests were found in the west end of the study area near Freshwater Lake, and only one nest was found northwest of Footprint Lake (both areas were frequently used for nesting in past years).

Nearest distances between Steller's eider nests varied from 24 to 4854 m and averaged 750 ± 179 m. In 2008, 14% of nests were <100 m from a conspecific neighbor, 68% were 100-1000 m, and 18% were >1000 m. Pomarine jaeger and snowy owl nests were located throughout the study area in 2008 (See Appendix F for a comparison of number of Steller's eider and avian predator nests among years). We recorded 16 pomarine jaeger nests, and many other nests were present and not recorded. As the distance to the nearest pomarine jaeger and snowy owl nest (from a Steller's eider nest) was not recorded consistently, this distance and its relation to nest fate was not analyzed for 2008. Nest habitat was not analyzed for Steller's eiders in 2010 as sample size was too small. Brood habitat use is examined below.

Hen Capture and Brood Monitoring

Adult females 2008
Thirteen Steller's eider hens were captured on the nest during late incubation from 10 to 17 July, 2008. Average body weight was 708 (±15 SE) g, with a range of 640 to 815 g. We sampled all females for avian influenza exposure and collected a feather sample. Blood samples were collected from 11 females, and nine females were marked with VHF radio transmitters to track broods. Ten of the 13 females that were captured successfully hatched ducklings. Of the 13 females captured, two had been previously marked. One was banded in Barrow on a nest in 1996, and the other was banded during autumn at Nelson Lagoon, Alaska in 1996. Both recaptured females were adults when initially captured in 1996, and were at least 14 years old in 2008 (Table 16A). For the female banded near Barrow on a nest in 1996, the nest in 2008 was approximately 3-4 km from the previous nest (exact coordinates from 1996 were not available) and the 1996 nest failed.

Adult females 2010
No sea ducks were captured in 2009. In 2010, we captured Steller's (N = 1), spectacled (N = 8), and king (N = 2) eiders, and long-tailed ducks (N = 2) on the nest during late incubation from 11-31 July. The Steller's eider was 655 g (within the range of birds from 2008) and mean weight for spectacled eider females was 1104 (± 32 SE) g. Spectacled eiders ranged from 987 to 1236 g. We collected blood, feather, and cloacal swab samples from all females, but no females were marked with radio-transmitters. One of the 13 females was previously marked, a Steller's eider banded on a nest near Barrow in 2008 (Table 16B). The 2010 nest site for that female was ~135 m from the 2008 nest, see Brood Success and Movement Section for details.

Table 16. Capture history for previously marked Steller's eider hens caught on nests near Barrow, Alaska in 2008 (A) and 2010 (B).
A.

2008 Nest #	Year of 1st Banding	Original Banding Location	Barrow 2008			Age in 2008	Comments
			# of Inviable eggs	Nesting Success	Brood Success		
16 – 08	1996	Nelson Lagoon (September)	2 of 5	Hatch (3 of 5)	Failed	14+	Radio-marked. Female and brood survived to at least 11 days post-hatch. Female found dead and brood assumed dead at day 17.
20 – 08	1996	Barrow (nest)	1 of 6	Hatch (5 of 6)	Fledge (3 of 5)	14+	Radio-marked. Female and brood observed at fledging age (37 days old), not observed again. Assumed fledged.

B.

2010 Nest #	Year of 1st Banding	Original Banding Location	Barrow 2010 # of Inviable eggs	Barrow 2010 Nesting Success	Barrow 2010 Brood Success	Age in 2010	Comments
10-DES021	2008	Barrow (nest)	0 of 3 (partial clutch)	Hatch (3 of 3)	Unknown	4+	Full clutch size unknown. Not radio-marked. Female and brood of 3 seen 6 days after hatch, and not found again. Similar nest and brood rearing location to 2008.

<u>Broods 2008</u>

Success

Nine female Steller's eiders were marked with VHF radio-transmitters near hatch, seven of which hatched at least one duckling. Six of seven that hatched nests were observed at least once with a brood. Four of seven broods apparently fledged (i.e., ducklings were documented to survive ≥32 days of age). Each of the four apparently fledged broods was observed once between 34 and 39 days of age, and then not observed again. After the last observation of these four broods, ducklings were believed to have fledged and moved with females far enough from the road system that their signal could not be detected. In one case (nest 13-08), we believe the radio was shed after ducklings were 34 days of age (day 34). A brood was seen on day 40 in the same wetland as previously located on day 34, and there was a transmitter on mortality signal present in the area that could not be retrieved due to water depth. For fledged broods, number of ducklings at last observation was 1, 3, 3, and 4 (Table 17). Brood survival probability (probability a brood will fledge at least one duckling) was 0.58-0.62 (range is 32 to 36 day period). The more conservative estimate of brood survival probability is 0.58 (0.19-0.84, 95% CI; 36 day period). Due to small sample size, survival was imprecisely estimated.

Movements and Habitat Use

Steller's eider females moved their broods between 62 m and 588 m from the nest between hatch and first observation (4-9 days post-hatch; Table 17 and Figure 13). All broods stayed within one kilometer of their nest during brood rearing. The female from nest 05-08 apparently fledged three ducklings and was last observed when her brood was 37 days of age. On 6 September, 2008 the marked female was located near shore in the Chukchi Sea by NARL, about 10.5 km from the brood rearing area (Figure 14). The marked female was with three fledged juveniles (possibly her brood) and seven other Steller's eiders, her brood would have been 54 days of age on 6 September. Very few post-fledging observations of Steller's eider females and broods exist. The same female from nest 05-08 returned to Barrow to nest along Gaswell Road in 2010, and again hatched a nest (3 ducklings). We did not radio-mark the female in 2010, but were able to observe the brood on one occasion close to the 2010 nest site, six days post-hatch (Figure 15). Coordinates were recorded for two radio-marked Steller's eiders that failed to hatch, and one that hatched but lost her brood before the first resighting (Figure 16). The two females that failed to hatch were each observed once post-failure on 24 July, and the female that lost her brood early was observed three times to confirm brood failure from 4 to 12 August. Failed females appeared to stay in the vicinity of their nest for at least a short period after failure. A comparison of distances moved and habitats used by Steller's eider broods in 2008 compared to other years is presented in Table 18. Hens primarily used *Arctophila* (43% of resightings) and *Carex* (28% of resightings) ponds for brood rearing. Deep open ponds or lakes made up only 4% of the brood locations.

Table 17. Steller's eider brood movements in 2008. Error value is standard error.

Brood #	# Resightings with brood	Distance to first resight (4-9 days after hatch)	Maximum distance moved from nest	Average Distance Moved Between Resightings	# Hatch	# Fledge	Max age observed
04 – 08	5	62 m	143 m	72 ± 21 m	7	0	29
05 – 08[1]	9	237 m	365 m	167 ± 53 m	6	3	37
08 – 08	10	536 m	534 m	224 ± 61 m	3	1	39
13 – 08	11	305 m	541 m	215 ± 42 m	7	4	34
16 – 08	3	588 m	923 m	382 ± 106 m	3	0	11
20 – 08	9	347 m	420 m	266 ± 80 m	5	3	37
26 – 08[2]	0	–	–	–	5	0	–

[1] Does not include post-fledging observation.
[2] Brood was lost prior to first observation of adult female.

Table 18. Distances moved and habitats used by Steller's eider broods near Barrow, Alaska 1995-2008.

Year	# broods	# resightings	Maximum # days tracked post-hatch	Ave. maximum distance from nest	Dominant Habitat Type Used
1995	8	39	32	650 m	*Arctophila* (80%)
1996	5	20	35	700 m	*Arctophila* (85%)
2005	3	26	41	3.5 km*	*Carex* (58%)
2006	8	56	37	1.2 km	*Arctophila* (54%)
2008	7	47	39	488 m	*Arctophila* (43%)

*Not including last two movements of brood 06-05.

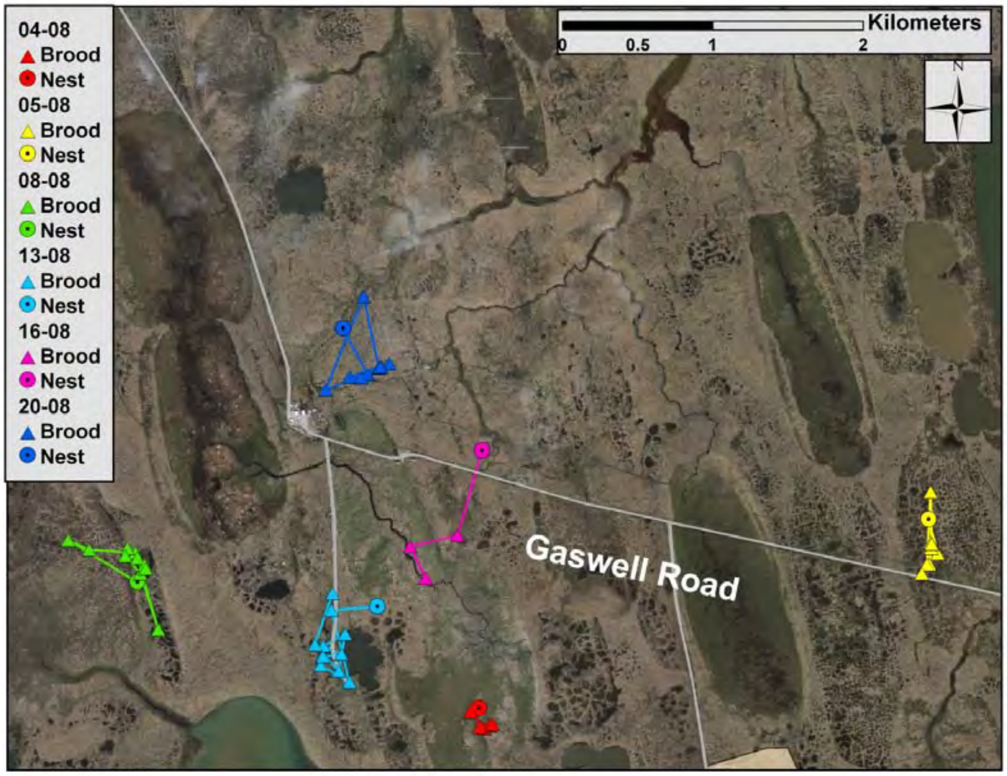

Figure 13. Radio-marked Steller's eider nest and brood locations and movements for females observed at least once with a brood near Barrow, Alaska in 2008.

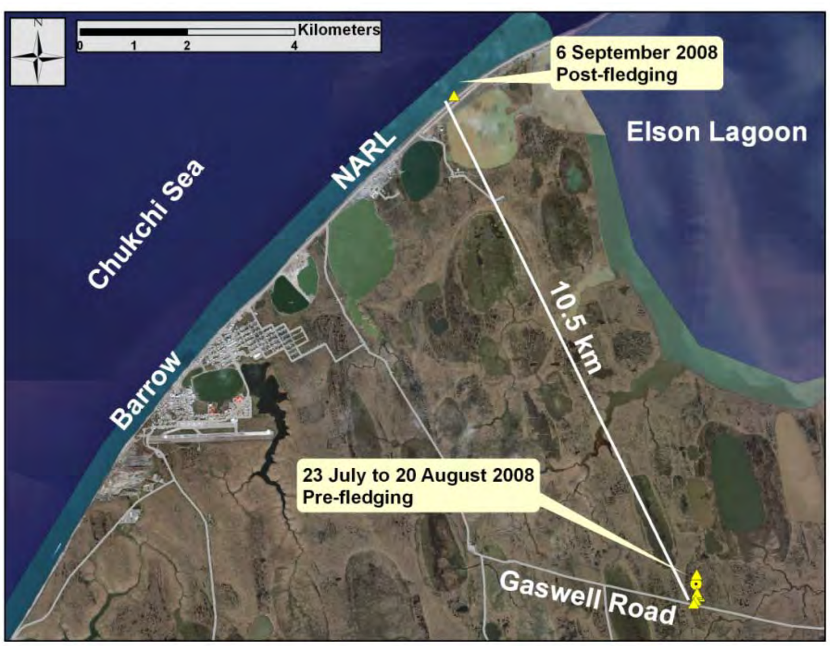

Figure 14. Location of adult female (and possibly three fledged ducklings at 54 days of age) from nest 05-08 on 6 September 2008 near Barrow, Alaska.

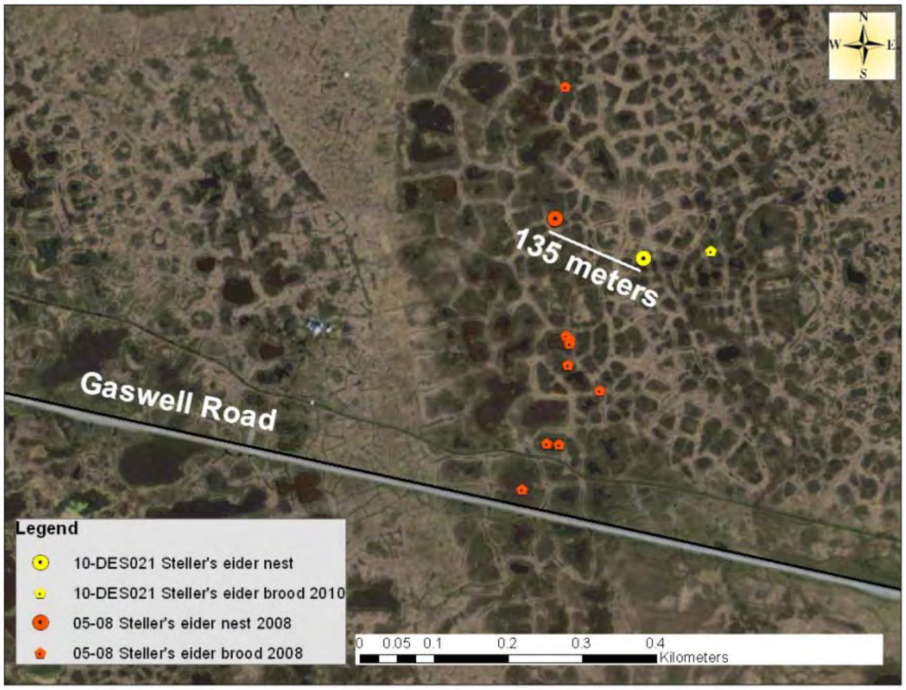

Figure 15. Nest and brood rearing locations for the same female Steller's eider (band number 2406-00622) in 2008 and 2010 near Barrow, Alaska.

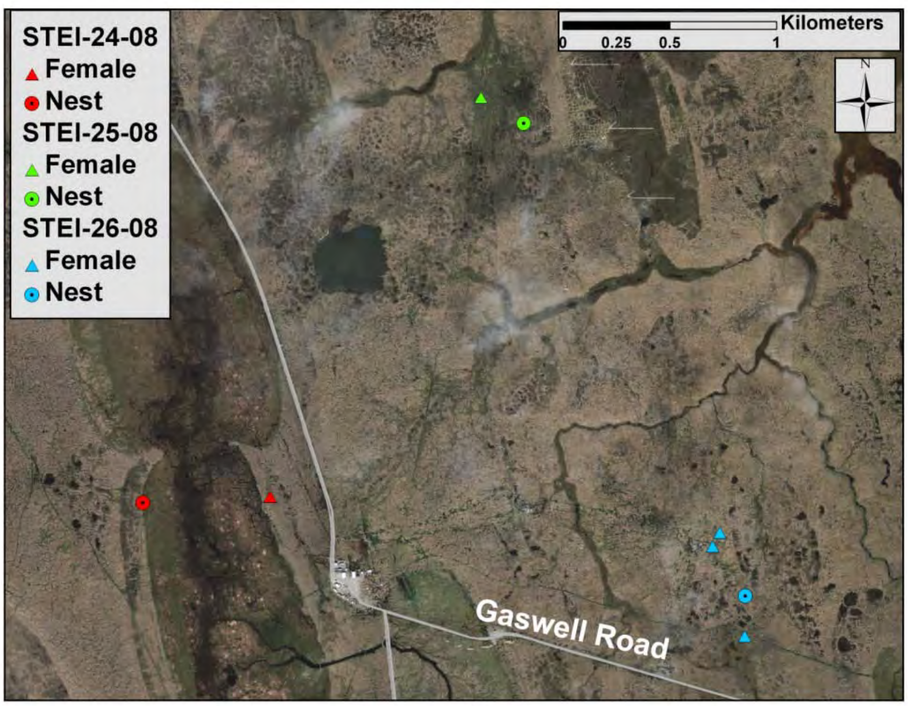

Figure 16. Locations of nests and female Steller's eiders that lost a brood or failed to hatch a nest near Barrow, Alaska in 2008. Locations are in late July or early August, soon after nest or brood loss.

During brood tracking (late July to mid-August), seven additional unmarked broods were located along the road system or near other marked females. Size of unmarked broods ranged from 1-8 ducklings, and locations were in the same vicinity as marked broods (from Footprint Lake to KBRW tower along Gaswell Road). Successful broods left brood rearing areas in late August or early September. Two of the four fledged broods were last observed on 20 and 21 August, and then not present in brood rearing areas by 26 August. The other two broods were still present on 26 August (the last radio-tracking day), but likely left brood areas soon thereafter. During additional tracking in early September, the only female that could be located from the road system was that from nest 05-08, Figure 14.

DISCUSSION

Survey data from 2008 and 2009 are consistent with the binomial concept of “nesting” and “non-nesting” years for Steller’s eiders near Barrow. However, years like 2010, with only two nests found, are inconsistent with this concept. The years 2010, 2007, and 1997 suggest nesting effort for Steller’s eiders near Barrow is not binomial, but likely a continuum from near zero (e.g., 2002 and 2009) to high effort (e.g., 1999 and 2008). The correlation between lemming abundance, avian predators (pomarine jaegers and snowy owls), and Steller’s eiders is quite evident in some years (e.g., 2008), and nearly absent in others (e.g., 2010). Data over the last 20 years near Barrow indicates years with high lemming and avian predator abundance are very likely to be higher effort years for Steller’s eiders. In those years, presence of jaegers and owls may be an important component of the nesting “habitat” that is selected. However, given that Steller’s eiders do nest in the absence of avian predators and at lower lemming densities, there are clearly other aspects to nesting habitat. Limited information is available on female nest site fidelity, but circumstances observed in 2006 and 2010 (female nesting <140 m from a nest site used in a prior year; Rojek 2007 and this report), provide evidence of some nest site fidelity. Even without nesting pomarine jaegers and snowy owls in 2010, the female selected a nest site 135 m from her previous location. Therefore, important elements of nest habitat may include previous use and success by a female. However, from other recapture information from Barrow (three other birds), the second nest was located farther away (3-6 km from the first). In these cases, females may have been selecting for physical habitat features and/or presence of avian predators. Additional years of marking and recapturing Steller’s eiders near Barrow will help assess the presence of any consistent patterns.

Mean nest survival rate for Steller’s eiders from 1991-2010 was 0.33 (± 0.08). The lowest nest survival occurred in 1997 (0.0) and highest in 2006 (0.88). In years prior to fox control (1991-2000), mean nest survival was 0.23 ± 0.09, after fox control began (2005-2010) nest survival was higher (0.48 ± 0.12; Figure 17). A comparison of mean nest survival rate in years with and without fox control is confounded by other factors, but it provides evidence of an apparently positive effect of fox control on nest survival.

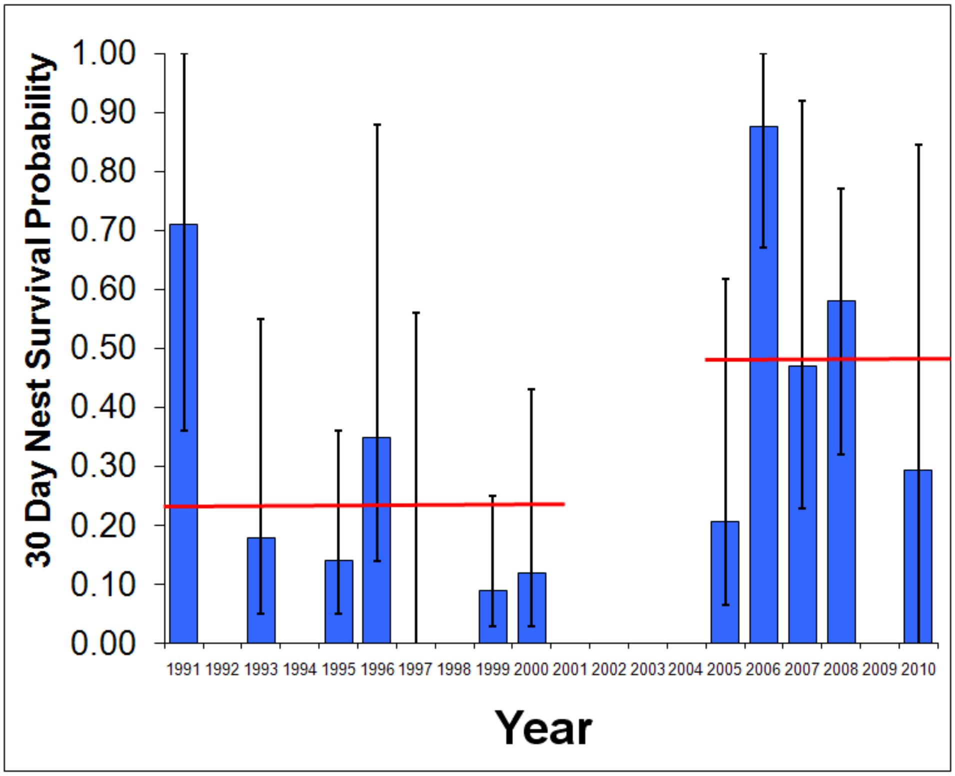

Figure 17. Nest survival probability for Steller's eiders near Barrow, Alaska from 1991-2010. Error bars are 95% confidence intervals. The red horizontal lines are mean nest survival before and after fox control was initiated in 2005.

Above average nest survival (0.58) and a higher number of nests found (N = 28) indicate that 2008 was a good production year for Steller's eiders near Barrow. With only two nests located, and nest survival rates for sea ducks near 0.2, 2010 was a poor production year. We did not detect any Steller's eider production (no nests found) in 2009 near Barrow. The brood survival probability estimate for Steller's eiders in 2008 (0.58; this report) is likely similar to brood survival rates from 2005 and 2006 (2 of 3 and 4 of 7 broods fledged; Rojek 2006 and 2007), but greater than survival rates observed during earlier studies in 1995 and 1996 (1 of 8 and 1 of 5 broods fledged; Quakenbush et al. 2004) near Barrow. We consider the 2008 brood survival estimate to be representative of survival rates in recent years with higher brood survival (i.e., 2005-2008). Number of ducklings fledged from a successful Steller's eider brood is about 3 (mean in 2005 was 3.0, 2006 was 3.4, and 2008 was 2.8).

We were interested in examining population growth rates for Steller's eiders using demographic parameters from this study (e.g., nest and brood survival, brood size, and breeding propensity), and in particular examining any differences between growth rates from earlier and later years of the study. We estimated population growth rate (λ) for Steller's eiders using a model built in PopTools (Hood 2010) by P. Flint (USGS). To estimate λ we also needed demographic parameters from other studies, first year survival (survival from fledging to 1 year old) and annual survival for adult females (>1 year old). First year survival is unknown for Steller's eiders, but it was estimated to be 0.67 for king eiders (Oppel and Powell 2010). We believed survival would be lower in the smaller Steller's eider, and we used 0.5 as a guess. We used annual survival rate estimates from birds on the Alaska Peninsula (primarily Russian nesting birds), 0.899 for females (Flint et al. 2000). Breeding propensity was estimated to be 0.6 (nests found in 60% of years near Barrow) for birds three and older, and zero for birds <3 years old. To estimate population growth rate from recent years, we used mean nest survival from the last 10 years (2001-2010; 0.48) and a brood survival range (to account for uncertainty) similar to 2008 (0.45-0.75). Under this scenario, $\lambda = 0.98\text{-}1.02$. To estimate population growth rate from the earlier years of the study (the 1990's), we used mean nest survival from 1991-2000 (0.23) and a brood survival range based on apparent survival from 1995 and 1996 (0.1-0.4), and estimated $\lambda = 0.91\text{-}0.94$.

These are estimates of population growth rate based on assumptions when parameters were unknown; therefore, the relative change in λ is more meaningful than its absolute value. Inference from above estimates of population growth rate can only be extended to the portion of the population that nests near Barrow, as these vital rates are not likely representative of birds nesting in other areas of the Barrow Triangle or elsewhere on the Arctic Coastal Plain. Management actions implemented to support recovery of Steller's eiders (e.g., fox control) do not likely affect more than one third of the Alaska-breeding population. Recent estimates of population growth rate (from 2001-2010) are about 9% higher than those estimated for the 1990s due to increased reproductive success. Fertility rates (the number of female offspring surviving to 1 year of age per adult female per year) for Steller's eiders nesting near Barrow in recent years have increased five-fold from the 1990s. Based on current reproductive rates, an adult female may replace herself in five nesting attempts, compared with over 20 needed in the 1990s. However, given breeding probability is ~0.6, currently an adult female may require 8 years after age three for replacement. Generation time from the most recent population model is ~12 years. This information emphasizes the importance of management actions that can maintain high annual survival and reproductive output. Actions must also be continued long enough to exceed replacement of females and allow recovery of the population. Reducing shooting mortality and fox control are currently the best management actions to maintain high annual survival and increase reproductive output.

Arctic fox control was conducted for the sixth consecutive year in the study area in 2010. Between late May and late July of 2008-2010, 88, 12, and 20 arctic fox were removed from the study area each year, respectively. The number of active dens located varied from zero in 2009 to 11 in 2008. In years with active dens (2008 and 2010), 35-50% of the total take was juveniles (Savory et al. 2009 and 2010). In 2008, many fox were present in the study area, there were many active dens, and we had a high take of fox; however, no arctic fox depredated camera-monitored nests. In 2009 and 2010, there were fewer fox present, little to no denning occurred, fewer fox were removed, but arctic fox did depredate camera-monitored nests. It appears as though our fox control efforts were less effective in 2009 and 2010 despite what appeared to be a smaller fox population, and there are several possible explanations. Beginning in 2009 we reduced the trap check interval for non-lethal traps to 48 hours, and eliminated the use of traps on top of tundra mounds due to increased incidental take of birds. These changes reduced the number of traps that could be checked by a trapper, and likely decreased trapping effectiveness in 2009 and 2010. To mitigate a possible loss in effectiveness, we added one additional full time trapper and two apprentice trappers in 2010. Other explanations involve changes in lemming abundance from 2008 to 2009 and 2010. In response to a high abundance of lemmings in 2008, arctic fox became more numerous and increased reproduction (more active dens found) in the study area; they also likely reduced their foraging radius from dens and switched their primary prey to lemmings. These responses by arctic fox made them easier to capture (denning fox with small home ranges versus transient fox) resulting in an increased take by trappers. Simultaneously, arctic fox were likely less inclined to prey on bird nests because lemmings provided abundant alternate prey. Additionally, denning fox are likely territorial and may exclude some transient fox from the area. The combination of reduced traps and low lemming abundance in 2009 and 2010, made it more challenging to take enough fox to significantly improve nest survival. However, given lemming abundance appears to be correlated with Steller's eider nesting effort, and may be correlated with effectiveness of fox control, our ability to improve nest success appears to be greatest in years when more Steller's eiders are present (when control has a greater potential to affect the population).

The increased scope of the eider project (including other species of waterfowl) has allowed us to generate nest survival estimates for sea ducks in years when we find no or few Steller's eider nests. This data is essential to understanding sources of variation in nesting effort and making comparisons among tribes of waterfowl nesting in the same area. Estimates of nest survival for sea ducks that did nest in 2009 and 2010 were relatively low (~0.2), compared to the long-term average for Steller's eiders near Barrow (0.33), and much lower than what has been observed in high success years (~0.5-0.9). If a larger number of Steller's eiders had nested in the study area in 2009 and 2010, we hypothesize they would have experienced low nest survival rates. Reducing nesting effort in poor nest survival years may be adaptive for a long-lived bird that can survive to nest in a subsequent year with higher nest survival. Nest survival rates for greater white-fronted geese were much greater than ducks (sea and dabbling) in 2009 and 2010 when survival rates were low for ducks. White-fronted geese likely have higher nest survival than ducks near Barrow for three reasons: bi-parental care, larger body size, and higher incubation constancy. These three traits likely allow geese to defend against most avian predation, and even some portion of fox predation. The ducks (Tribe Anatini and Mergini), with female-only care, smaller body size, and lower incubation constancy (for smaller sea ducks and dabbling ducks) are only able to defend against some of the avian predators and have no defense against fox predation. The difference in nest survival between geese and ducks was quite dramatic in low nest survival years (2009 and 2010), but could be reduced in years of higher lemming abundance when fox prey primarily on lemmings (and not nests). Despite small sample size within ducks, there was a suggestion that dabbling ducks had even lower nest survival than sea ducks, and again differences in body size and incubation constancy among species may be driving this difference. Additional years of data (both nest survival and incubation behavior) may allow us to refine these concepts further, possibly to the species level, and determine the most important sources of variation in nest success for eiders near Barrow.

We also investigated other factors that may affect nest survival near Barrow, including distance to a road or landfill, observer visitation, and presence of nest cameras. We did not detect an effect of distance to road or landfill on nest survival in 2009 and 2010. That means we either failed to detect an effect that was present or it does not exist. Our model was simple (using straight line distance) given the relatively small sample size, and the true relationship could have been more complex if present (e.g., non-linear). Our model assumed the effect of road and landfill to be equal across time, tribes of waterfowl, and years. In reality, the effect may only be present in some tribes (i.e., ducks) or one year. Personal observations of waterfowl nests near the road system indicate our results were likely valid as there does not appear to be a strong effect of roads on nest survival. In contrast, observations of failed nests near the landfill indicate that an effect of the landfill may exist, but was not detected in our analysis. We also did not detect an effect of observer visitation on nest survival the day following a visit, and similar to the above discussion, this could be due to a lack of an effect or because the model did not adequately represent reality (i.e., the true relationship). Overall, we believe the results are accurate and the effects of our visitation are minimal. However, in some cases we can clearly affect nest survival, and we strive to minimize those effects. When a nest is initially discovered, the female is often flushed by the observer, but on subsequent visits we avoid flushing females from nests. We minimize leaving scent near nests to reduce the risk of attracting fox to the area. We avoid nest searching early in the season when females are laying and capturing females more than four days prior to hatch (violating these protocols can cause nest abandonment). More complex models that account for visit type (flush or not), stage of incubation upon visit, number of days after visit, or waterfowl tribe may reveal a visitation effect, but would require a much larger dataset. Lastly, we found the presence of cameras at sea duck nests did not negatively affect nest survival. The effect of the cameras in this sample of nests was actually positive, either a spurious result due to small sample size or an actual positive effect. In either case, we have no evidence that nest cameras negatively affect nest survival, and their continued use to gather data on threatened eiders should not be a concern.

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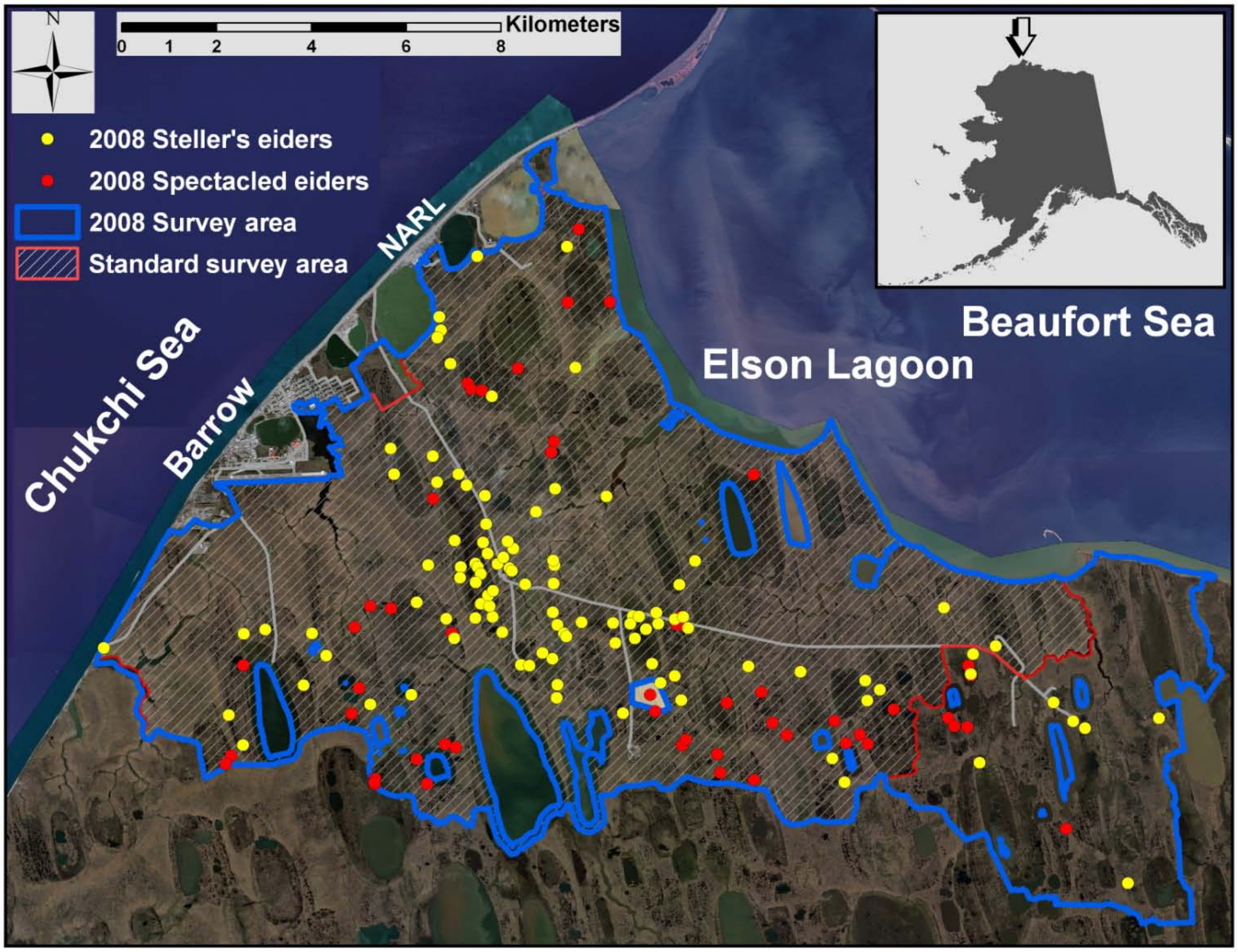
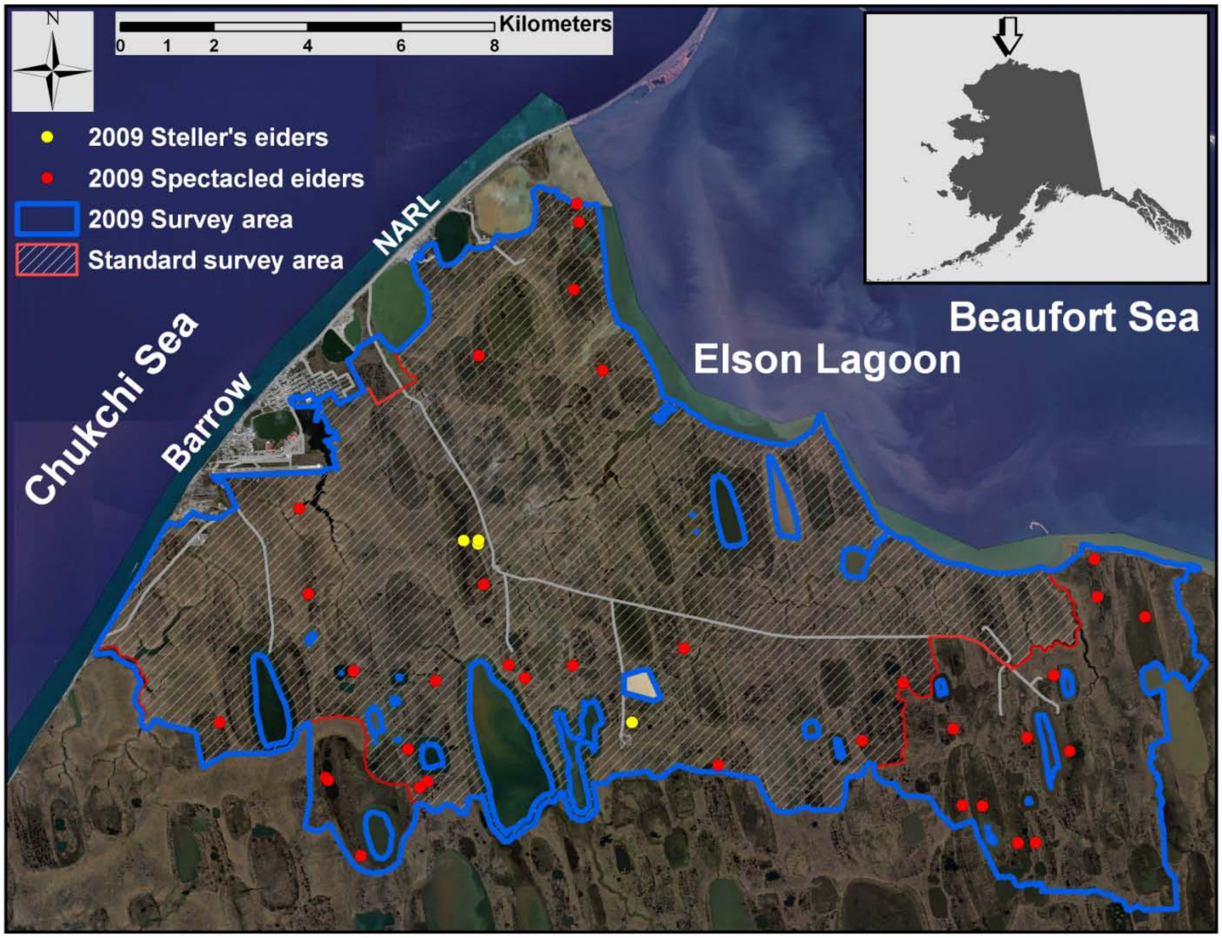
Appendix A. Observations of Steller's and spectacled eider adults and extent of annual survey area from the ground-based breeding pair surveys near Barrow, Alaska, 2008-2010. Yellow and red dots are Steller's and spectacled eiders, respectively. The blue outline is the total area surveyed each year and the cross hatched area outlined in red is the standard area that has been surveyed every year since 1999.

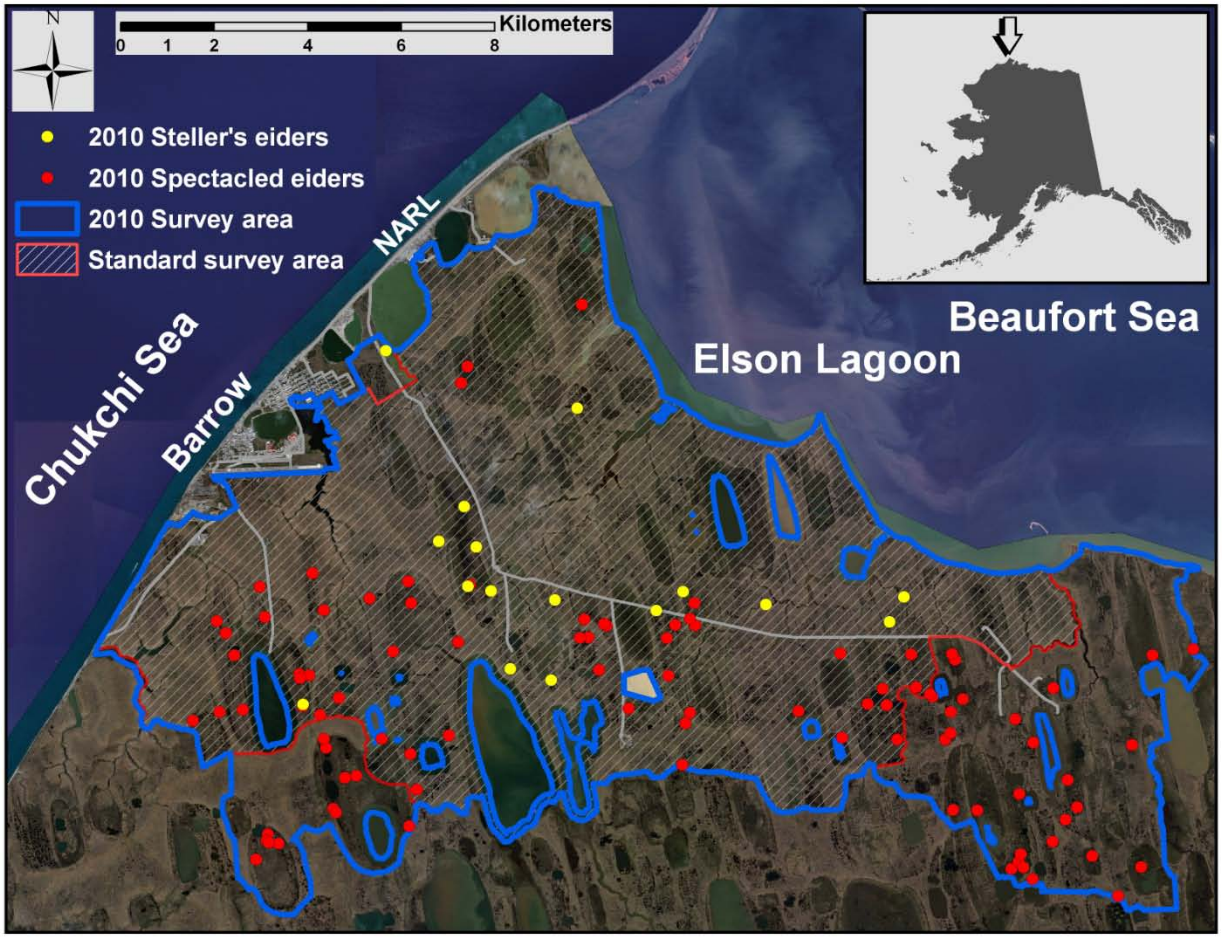
Appendix A-1: 2008



Appendix A-2: 2009



Appendix A-3: 2010



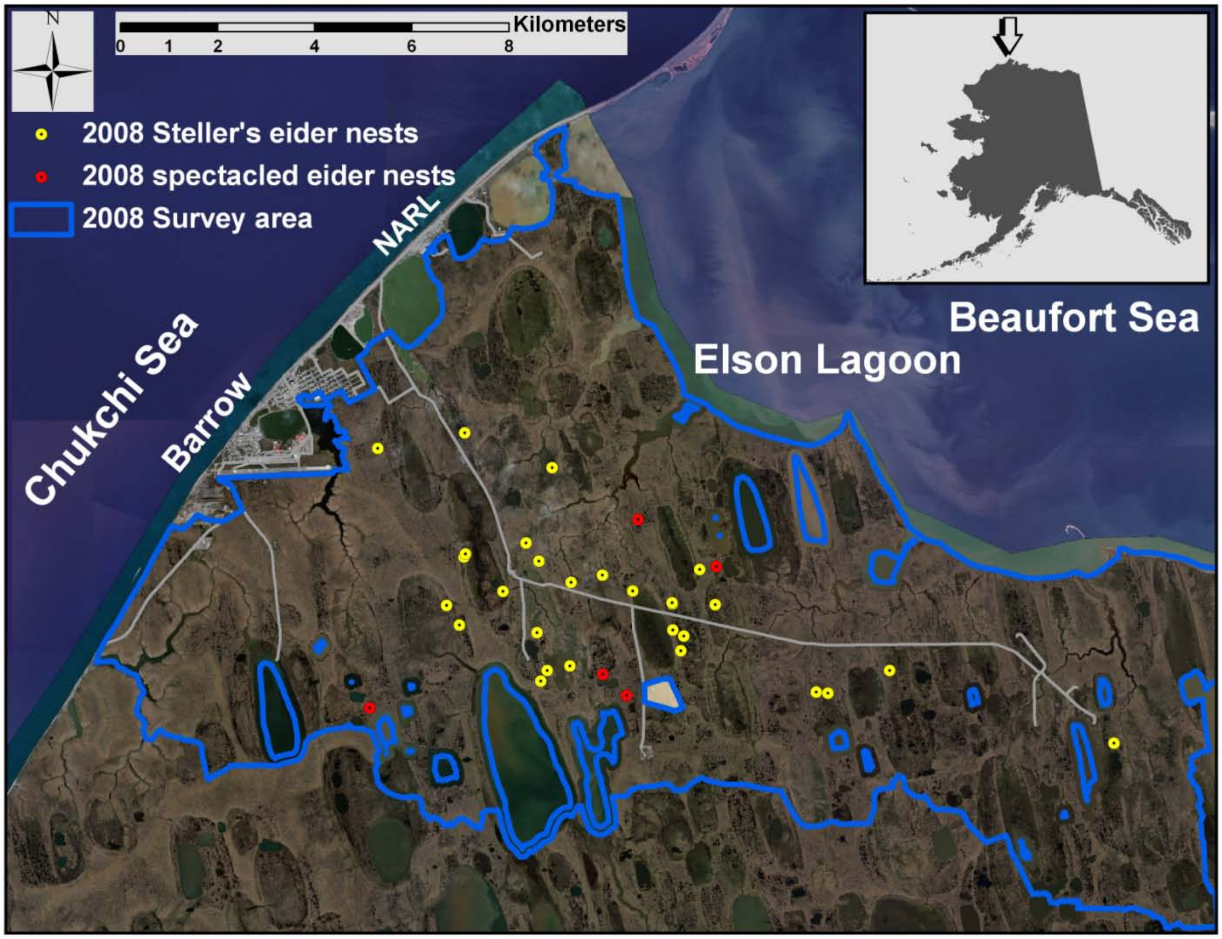
Appendix B. Ground-based pair survey results for all species counted near Barrow, Alaska 2008-2010. The number of confirmed nests is reported for survey results only; additional nests were found during nest searches or incidentally for Steller's eiders and other species. Density is birds/km^2.

	2008			2009			2010		
Species	Count	Density[a]	Nests/dens[b]	Count	Density	Nests/dens	Count	Density	Nests/dens
Arctic fox	1	0.01	0	6	0.04	0	5	0.03	0
Common raven[c]	3	0.02	0	0	0.00	0	4	0.02	0
Eider species	1	0.01	1	2	0.01	0	7	0.04	1
Glaucous gull	701	4.22	3	621	3.65	5	1227	6.97	10
Jaeger species	0	0	0	5	0.03	0	7	0.04	0
Long-tailed jaeger	9	0.05	0	14	0.08	0	24	0.14	0
Parasitic jaeger	60	0.36	2	130	0.76	0	212	1.20	0
Pomarine jaeger	1099	6.62	8	17	0.10	0	20	0.11	0
Short-eared owl	2	0.01	0	0	0.00	0	6	0.03	0
Snowy owl	162	0.98	8	5	0.03	0	57	0.32	0
Spectacled eider	98	0.59	1	71	0.42	1	205	1.16	7
Steller's eider	195	1.17	3	9	0.05	0	33	0.19	0

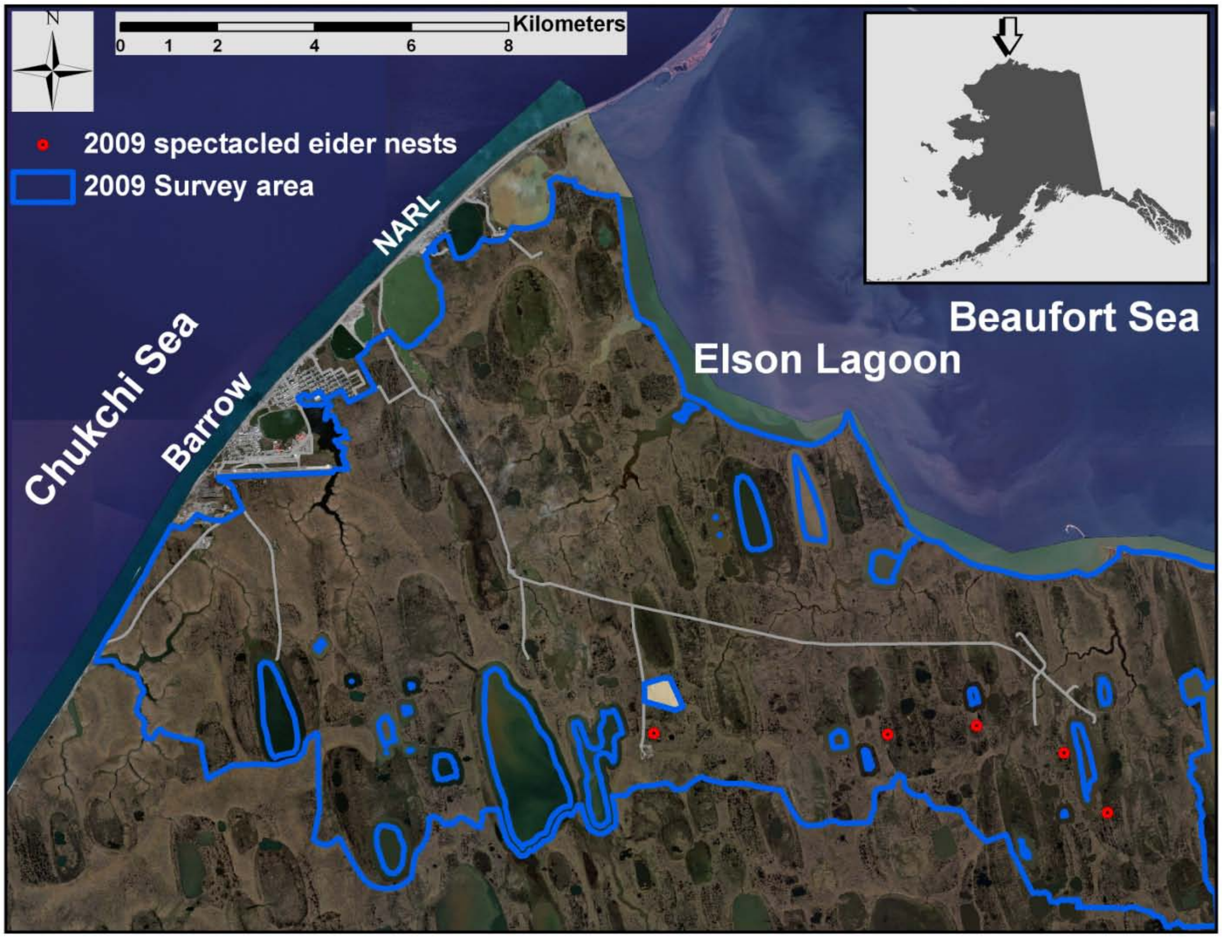
[a] Density is number of birds observed (male and female) in the entire survey area for that year (birds/km^2).
[b] Number of confirmed nests and dens found during the pair survey. Dens are generally not found during the survey but they do exist in the study area.
[c] A minimum of one pair resides in Barrow, with confirmed nesting on dewline towers north of NARL.

Appendix C. Steller's and spectacled eider nests found near Barrow, Alaska 2008-2010. Yellow and red symbols represent Steller's and spectacled eider nests, respectively.

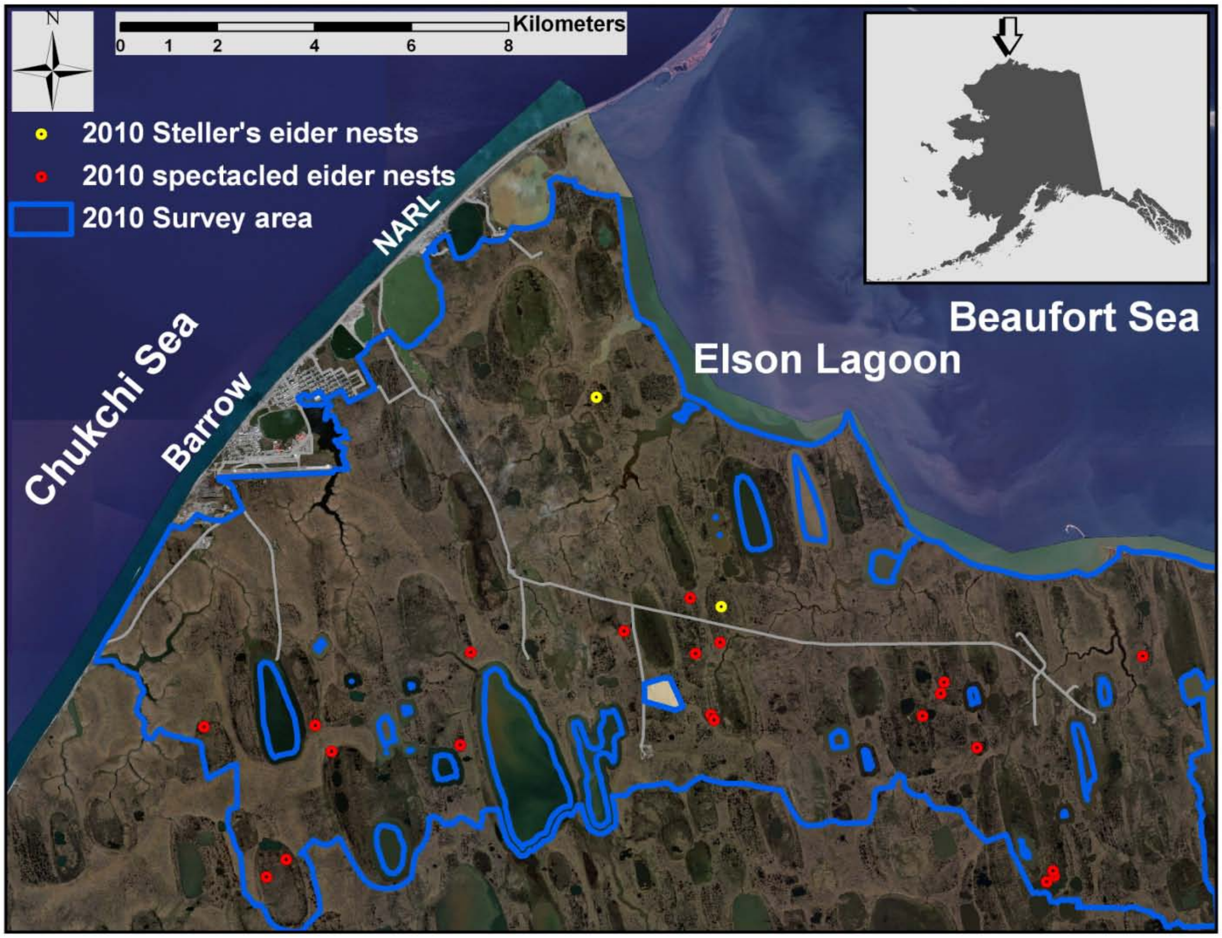
Appendix C-1: 2008



Appendix C-2: 2009



Appendix C-3: 2010



Appendix D. Egg fates for Steller's eider nests in 2008 and 2010 near Barrow, Alaska.

Nest	Year	Species	Known eggs laid	Found viable?	Egg Fates				
					Hatched	Inviable or found whole post- hatch[a]	Abandoned Whole	Vanished	Depredated, shells present
01-08	2008	STEI	3	Y	0	0	0	3	0
03-08	2008	STEI	4	Y	0	0	0	4	0
04-08	2008	STEI	7	Y	7	0	0	0	0
05-08	2008	STEI	7	Y	6	1	0	0	0
06-08	2008	STEI	7	Y	7	0	0	0	0
07-08	2008	STEI	7	Y	0	0	1	6	0
08-08	2008	STEI	5	Y	3	0	0	0	2
09-08	2008	STEI	4	Y	3	0	0	0	1
10-08	2008	STEI	4	Y	0	0	3	1	0
11-08	2008	STEI	5	Y	5	0	0	0	0
12-08	2008	STEI	6	Y	3	0	0	3	0
13-08	2008	STEI	7	Y	7	0	0	0	0
14-08	2008	STEI	7	Y	7	0	0	0	0
15-08	2008	STEI	6	Y	5	1	0	0	0
16-08	2008	STEI	5	Y	3	0	0	0	2
17-08	2008	STEI	7	Y	6	0	0	0	1
18-08	2008	STEI	4	Y	3	1	0	0	0
19-08[b]	2008	STEI	5	Y	≥1	0	0	0	0
20-08	2008	STEI	6	Y	5	1	0	0	0
21-08	2008	STEI	3	Y	0	0	0	0	3
22-08	2008	STEI	7	Y	7	0	0	0	0
23-08	2008	STEI	5	Y	5	0	0	0	0
24-08	2008	STEI	5	Y	0	0	0	2	3
25-08	2008	STEI	7	Y	0	0	7	0	0
26-08	2008	STEI	7	Y	5	0	0	2	0
27-08	2008	STEI	7	Y	7	0	0	0	0
28-08[c]	2008	STEI	5	Y	0	0	5	0	0
29-08	2008	STEI	2	N	0	0	1	0	1
10-DOH001	2010	STEI	5	Y	0	0	0	5	0
10-DES021[d]	2010	STEI	3	Y	3	0	0	0	0

[a]This is a minimum estimate only, and includes any eggs found whole after hatch. Due to limited egg candling, many inviable eggs may not have been detected, and subsequently destroyed by predators.
[b]Nest hatched, but number of membranes not recorded.
[c]Full clutch abandoned late in nesting season, possible entire clutch was inviable.
[d]Likely partial nest predation before eggs were counted.

Appendix E. Steller's eider nest survival near Barrow, 1991-2010.

Year	Nests found	Nests hatched	Apparent nest success (%)	Found viable	Number failed	Mayfield[a] nest survival	Lower 95% CI[b]	Upper 95% CI
1991	6	5	83	6	1	0.71	0.36	1.00
1992	0	0		0	0		0.00	0.00
1993	20	4	20	13	9	0.18	0.05	0.55
1994	0	0		0	0		0.00	0.00
1995	78	8	10	25	17	0.14	0.05	0.36
1996	22	6	27	11	5	0.35	0.14	0.88
1997	4	0	0	3	3	0.00	0.00	0.56
1998	0	0		0	0		0.00	0.00
1999	36	7	19	27	20	0.09	0.03	0.25
2000	21[c]	4	19	17	11[c]	0.12[d]	0.03	0.43
2001	0	0		0	0		0.00	0.00
2002	0	0		0	0		0.00	0.00
2003	0	0		0	0		0.00	0.00
2004	0	0		0	0		0.00	0.00
2005[e]	21	6	29	15	9	0.21[d]	0.07	0.62
2006[e]	16	15	94	16	1	0.88	0.67	1.00
2007[e]	12	7	58	12	5	0.47	0.23	0.92
2008[e]	28	19	68	27	8	0.58[d]	0.32	0.77
2009[e]	0	0						
2010[e]	2	1	50	2	1	0.29	0.00	0.84
Total	245	82	40	174	79	0.33 (SE 0.08)		

[a]Mayfield (1961, 1975)
[b]Johnson (1979)
[c]Excludes two nests that failed as a result of research activities.
[d]Includes pre-failure exposure intervals on any nest that was known to fail due to observer activities.
[e]Fox control occurred in study area.

Appendix F. Nesting by Steller's eiders and avian predators near Barrow, 1991-2010.

Year	Steller's eiders present past 15 June	Nesting by			Steller's eider nests[a]		
		Steller's eiders	Snowy owls (number of nests)[b]	Pomarine jaegers	Found viable	Found post-failure	Total found
1991	Yes	Yes	Yes (33)	Yes	6	0	6[c]
1992	No	No	No (0)	No	0	0	0
1993	Yes	Yes	Yes (20)	Yes	13	7	20
1994	Yes	No	No (0)	No	0	0	0
1995	Yes	Yes	Yes (54)	Yes	25	53	78
1996	Yes	Yes	Yes (19)	Yes	12	10	22
1997	Yes	Yes[d]	No (0)	No	3	1	4
1998	No	No	No (0)	No	0	0	0
1999	Yes	Yes	Yes (26)	Yes	27	9	36
2000	Yes	Yes	Yes (17)	Yes	17	6	23
2001	Yes	No	No (0)	No	0	0	0
2002	Yes[e]	No	Yes (4)	No	0	0	0
2003	Yes[f]	No	Yes (6)	Yes[g]	0	0	0
2004	Yes	No	No (0)	No	0	0	0
2005	Yes	Yes	Yes (4)	Yes	16	5	21
2006	Yes	Yes	Yes (35)	Yes	16	0	16
2007	Yes	Yes	No (0)	Yes	12	0	12
2008	Yes	Yes	Yes (31)	Yes	27	1	28
2009	Yes	No	No (0)	No	0	0	0
2010	Yes	Yes	No (0)	No	2	0	2

[a]Number of nests found are not comparable among years due to inconsistent search effort.

[b]Data on number of owl nests from Owl Research Institute surveys (213 km^2 that encompasses the Steller's eider ground-based survey area) in the Barrow area (Petersen and Holt 1999; Denver Holt, Owl Research Institute, personal communication).

[c]Much lower search effort than in other years.

[d]Very few Steller's eider nests were found despite considerable search effort.

[e]One pair was observed on 17 June at a site not visited in earlier years. Otherwise, none seen after 7 June.

[f]One pair observed on 19 June in a large stream. No other birds were observed after 14 June.

[g]Only one Pomarine Jaeger nest found during the survey, which was abandoned later in the season.

Appendix G. Steller's eider breeding biology study, 1991-2010: a brief review.

Steller's eider abundance and breeding effort vary widely near Barrow from year to year. We do not find Steller's eiders nests near Barrow in some years, and adults can be absent from the tundra by mid-June. During this study, nesting by Steller's eiders has been correlated with nesting by avian predators and lemming abundance. Following is a brief review of results from each year of this study. Details can be found in annual reports and other publications (Appendix H).

1991 Only six nests were found, but search effort was very low in the pilot year of this study. High success of nests monitored and presence of several broods from unknown nests (including four broods observed with mostly grown young in late August) suggest a relatively good breeding year.

1992 One pair was observed, on 15 June. No other Steller's eiders were seen in the study area in 1992. It was hypothesized that severe spring sea-ice conditions may have delayed spring migration and precluded nesting, however we cannot dismiss the possibility that Steller's eiders were present briefly and/or departed prior to initiation of ground surveys in the second week of June.

1993 Nests were initiated in mid- to late June. Most nests were found in a lake basin associated with Voth Creek, NW of Footprint Lake.

1994 Most Steller's eiders remained grouped on Footprint Lake until mid-July. Small groups and a few discrete pairs were observed away from Footprint Lake, but no nests were found or suspected.

1995 Steller's eiders arrived in early June. Nests were found in high numbers in various locations throughout the western half of the study area, including the Voth Creek basin, both sides of Freshwater Lake Road, and just east of Footprint Lake. Fledging success was low, but at least one brood was thought to have fledged.

1996 Warm May temperatures resulted in early snow melt. Steller's eiders dispersed to breeding areas almost immediately after arriving on 2 June. The main known nesting area was the Voth Creek basin, NW of Footprint Lake. Fledging success was low, but at least one brood was thought to have fledged.

1997 Steller's eiders arrived in early June and dispersed across the tundra in groups of 1-3 pairs after open water became available. Only four nests were found despite extensive search effort. None hatched. Groups began staging to depart in early July. No Steller's eiders were seen on the tundra after 10 July.

Appendix G continued

1998 Flocks occupied flooded wetlands in early June. A few discrete pairs were seen on tundra, but none remained for more than a few days. No nests were known or suspected. No Steller's eiders were observed on inland sites after 12 June.

1999 Steller's eiders arrived in early June. Nests were initiated throughout the latter half of June in various places in the western half of the study area, particularly in the Voth Creek basin.

2000 Steller's eiders arrived in early June. Nests were initiated primarily in the latter half of June. The greatest concentration of nests occurred near the SW corner of Footprint Lake.

2001 Mixed-sex flocks were observed in early June on flooded tundra and Footprint Lake. Pairs were observed briefly on the tundra during the latter half of June. No nests were initiated. No Steller's eiders were seen on the tundra past 25 June.

2002 A few flocks were seen in early June, but only a handful of discrete pairs were observed briefly on the tundra. Only one pair was seen at an inland site past 7 June (seen on 17 June) but was not present during a subsequent visit. For the first time during this study, snowy owls initiated nests in a year when Steller's eiders did not, however only 4 snowy owl nests were found (far fewer than in any other nesting year).

2003 Steller's eiders arrived in late May. Mixed-sex flocks were observed in Footprint Lake, Middle Salt Lagoon, and a few other flooded tundra areas and streams. Only 4 discrete pairs were observed on the tundra but they did not appear territorial. The last pair observed inland was on 19 June, which was the only pair observed after 14 June. Snowy owls initiated 6 nests.

2004 Phenology similar to 2003. Steller's eiders arrived in late May. Mixed-sex flocks were observed in Footprint Lake, Middle Salt Lagoon, and a few other flooded tundra areas and streams. Only 4 discrete pairs were observed on the tundra but they did not appear territorial. The last pair observations inland occurred on 21 June. On 7 July, one hen was observed on an inland pond and was reluctant to leave the area. Snowy owls did not nest and no pomarine jaeger nests were found during ground-based surveys.

2005 Steller's eiders present in early June. Nests were initiated throughout the latter half of June, mainly in the Voth Creek basin and west and east of Freshwater Lake Road. Two broods were known to have fledged. Four snowy owl and four pomarine jaeger nests were found in study area.

2006 Steller's eiders arrive in early June. Nests were initiated throughout the latter half of June in various locations throughout the study area. Four broods were known to have fledged. Snowy owls and pomarine jaegers nested in large numbers throughout the study area.

Appendix G continued

2007 Steller's eiders were present in small numbers in early June. Nests were initiated in the latter half of June in various locations but mainly found east of Freshwater Lake Road and at the end of Gaswell Road. Snowy owls did not nest but six pomarine jaegers nests were found in the study area.

2008 Steller's eiders were present in the study area in early June when the field crew arrived. Nests were initiated primarily during mid-June in the central and eastern portions of the study area along Cake Eater and Gaswell Roads. Four of the radio-marked broods fledged, and there were several other unmarked broods observed in the study area. fledged.

2009 Steller's eiders arrived in pairs and mixed sex flocks in small numbers in early June, then dispersed. Only one pair seen during survey in mid-June (total of nine Steller's counted), and very few Steller's present after mid-June. Three male and later three female Steller's eiders were seen feeding in Middle Salt Lagoon in early and mid-July. No Steller's eider, pomarine jaeger, or snowy owl nests found. Nest survival was low for sea ducks that did nest.

2010 Steller's eiders present in study area in early June when the field crew arrived. Breakup was quite late in 2010. Two Steller's eider nests were found in the study area, and a few other females likely initiated nests but failed before detection. One of the two nests hatched. This was only the second year since 1991 with Steller's eider nests found and no nesting by snowy owls and pomarine jaegers. Nest survival for sea ducks was slightly higher than 2009, but still low.

Appendix H. Reports of the Steller's eider breeding biology study for 1991-2010.

Publication	Years covered
Quakenbush et al. 1995	1991-1994
Quakenbush and Suydam 1999	1991-1995
Quakenbush et al. 2000	1991-1996
Quakenbush et al. 2004	1991-1999
Johnson and Korte 1997 (Appendix B in Obritschkewitsch et al. 2001)	1997
Obritschkewitsch et al. 2001	1998-2000
Obritschkewitsch and Martin 2002a	2001
Obritschkewitsch and Martin 2002b	2002
Rojek and Martin 2003	2003
Rojek 2005	2004
Rojek 2006	2005
Rojek 2007	2006
Rojek 2008	2007
This report	2008-2010