MARK-RECAPTURE SAMPLING OF ADULT FEMALE SPECTACLED EIDERS BREEDING ON KIGIGAK ISLAND, ALASKA: 2019 PROJECT ANNUAL REPORT

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BACKGROUND

In 2019, after a 4-year break, the U.S. Fish and Wildlife Service resumed long-term mark-recapture sampling of adult female Spectacled Eiders (*Somateria fischeri*; Fig. 1) breeding at Kigigak Island, on the Yukon-Kuskokwim Delta of Alaska. The Service restarted this project in response to recent years of low winter sea ice in the Bering Sea and new evidence suggesting low sea ice cover in the area used by wintering Spectacled Eiders was associated with low annual survival (Christie et al. 2018).

Figure 1. Female Spectacled Eider with plastic tarsal band coded 8XA flushing from its nest on Kigigak Island, AK.

In their analysis of 23 years of mark-recapture data from Kigigak Island, Christie et al. (2018) found both high and low winter sea ice concentrations in the Bering Sea were associated with decreased annual apparent survival of adult female Spectacled Eiders. However, because years with prolonged periods of low sea ice concentration were sparse in the data set (only 2 years with > 80 days of < 15% ice cover on the core wintering area; Christie et al. 2018), the estimated effect of low sea ice cover on survival had considerable uncertainty (Christie et al. 2018). Since 2014, winter conditions in the Bering Sea have been characterized by low sea ice cover (Stabeno et al. 2017). Further, the winters of 2017–2018 and 2018–2019 had the two lowest average daily sea ice extents on record going back nearly four decades (Spreen et al. 2019). Because mark-recapture sampling of Spectacled Eiders breeding at Kigigak Island stopped after 2015, the effect of recent extreme low-ice conditions in Bering Sea on Spectacled Eider annual survival is unknown.

Continuing mark-recapture sampling of adult female Spectacled Eiders at Kigigak Island will help clarify the effect of low sea ice by reducing the uncertainty around its estimated effect with additional years of band encounter data (Bradley 2018), assuming the trend of decreasing winter sea ice in the Bering Sea continues. This information will be critical for evaluating future conditions in species status assessments for Spectacled Eiders, which are used to inform 5-year reviews required under the Endangered Species Act (Smith et al. 2018).

In this report, I present summary statistics and results from analyses of data collected from Spectacled Eiders breeding on Kigigak Island in 2019. All results are preliminary and should not be cited without consent from the U.S. Fish and Wildlife Service.

OBJECTIVES

The two principal objectives of this on-going project are to read the unique codes on plastic tarsal bands and to deploy coded plastic tarsal bands on individuals without bands; these data permit estimating annual apparent survival probability.

Additional objectives include sampling blood to determine blood lead levels and monitoring nest fates to quantify nest survival probability.

METHODS

Field methods were modified from U.S. Fish and Wildlife Service, Yukon Delta NWR Standard Operating Procedures for monitoring Spectacled Eiders at Kigigak Island (USFWS 2015). Sampling effort in 2019 was shared among three projects based on Kigigak Island. A team of three biologists was focused solely on mark-recapture sampling of Spectacled Eiders. Mark-recapture data from Spectacled Eiders were also collected by biologists working on two projects that were conducted concurrently on Kigigak Island in 2019. Specifically, the Yukon Delta National Wildlife Refuge had a team of five biologists working on a mark-recapture project with breeding Emperor Geese on plots in the central area of the island (Fig. 2; Daniels and Friendly 2017). Of the 48 Spectacled Eider nest plots on Kigigak Island, 20 were contained either partially or wholly within the area searched for the Emperor Goose project. In addition, a biologist from the University of Alaska Fairbanks monitored Black Brant nesting colonies on Kigigak Island and recorded Spectacled Eider nests and bands he encountered. In this report, I refer to this team of biologists is collectively as *we*.

Nest Searching

To encounter Spectacled Eiders with coded plastic tarsus bands (Fig. 1) and to locate individuals without bands, we systematically searched established nest plots (plot dimensions: 412 × 412 m) on Kigigak Island for females incubating nests (sampling design described in Moran 2000; Fig. 2). To find incubating females, biologists searched slough banks, islands, the perimeter of all lakes, and walked transects through all meadows. Transects through meadows were spaced to maximize detection of incubating eiders and transect spacing varied with vegetation height. Each nest plot was typically searched by one biologist using a hand-held GPS unit and a satellite image of the plot to assist navigation. Biologists used GPS tracks to ensure complete coverage of each plot. Additional nests were found when biologists returned to plots to revisit known nests. Each biologists typically searched 1–2 plots each day.

Band Resighting

We resighted coded plastic tarsal bands on Spectacled Eiders primarily using digital cameras. Camera models used included Canon PowerShot SX60 HS point-and-shoot (65x zoom equivalent to 21–1365 mm) and Nikon digital SLR camera bodies (models D300, D700, and D7500) each with a 80–400 mm Nikkor AF-S lens.

We found breeding Spectacled Eiders while searching nest plots and while traveling between nest plots and the field camp. We often located breeding Spectacled Eiders as they flushed from their nests. If the flushed eider landed near the nest, the biologist marked the nest location on a GPS, covered the nest with nest lining, attempted to photograph the bird to confirm its band

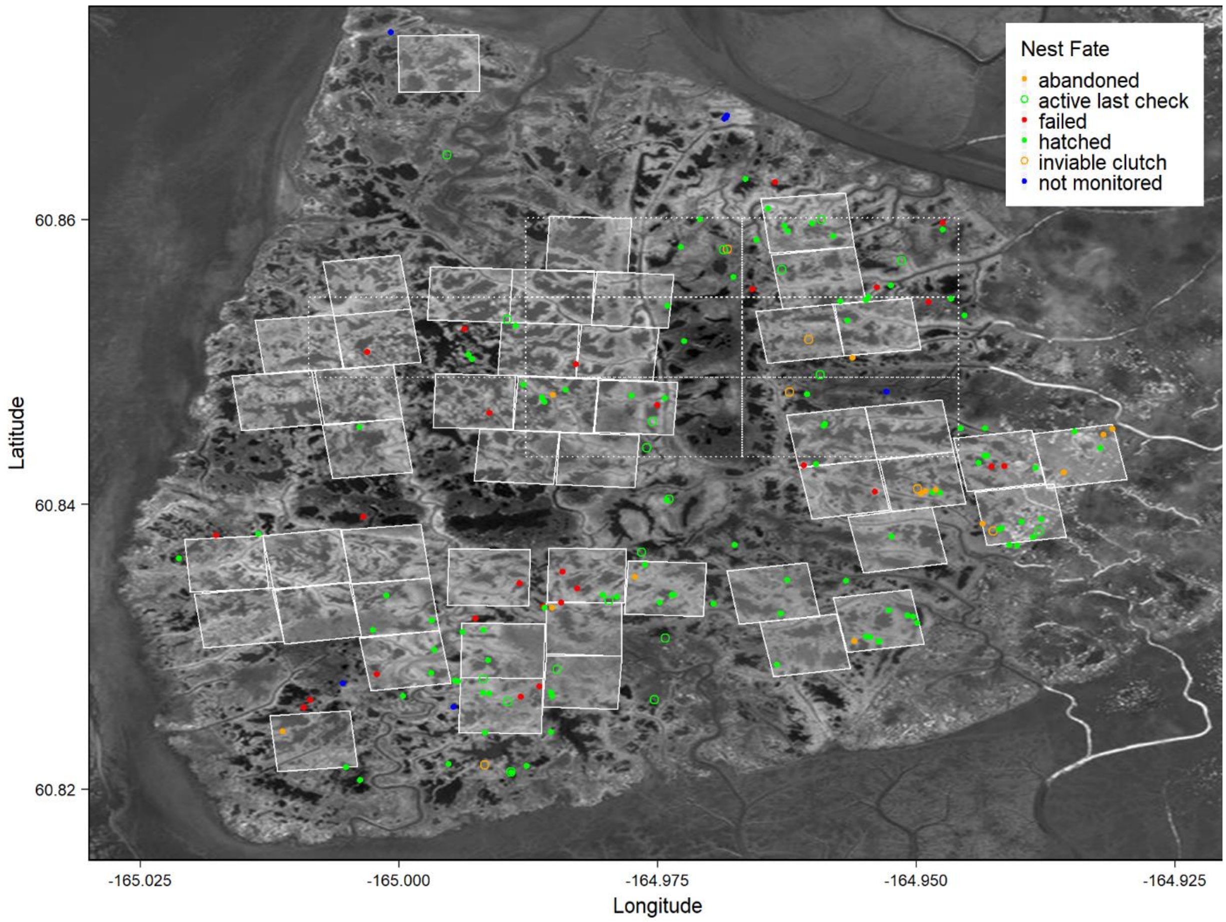

Figure 2. Satellite image of Kigigak Island showing the locations of Spectacled Eider nests (colored points) found in 2019. Spectacled Eider nests are colored by nest fate (see legend). White shaded squares indicate long-term nest searching plots for Spectacled Eiders (plot dimensions: 412 × 412 m). Rectangles outlined in white broken lines indicate Emperor Goose nest searching plots (1280 × 2980 m).

status, and, if banded, to read its band code. After photographing the bird, the biologist returned to record nest information.

If the biologist observed a Spectacled Eider incubating its nest, they photographed the eider as it flushed to determine its band status, and if banded, to read its band code. We also attempted to read the band code of any Spectacled Eider with a band that was not associated with a nest (e.g., in flocks or with broods).

When we were unable to determine band status or read a band code, we revisited the nest after 2–7 days; for individuals known to be banded but with an unread code, we returned after a shorter time interval to read the band code to reduce the risk of the nest being depredated before the band code was read.

If we were unable to determine band status or read the code of known banded birds, we returned 1–4 days before the estimated hatching date for the eggs in the nest to trap the incubating bird.

Banding Adult Females

We captured female Spectacled Eiders incubating nests 1–4 days before the estimate hatching date of their eggs. In order of priority, we captured: (1) banded birds with plastic band codes that we had failed to read, (2) birds banded with only metal tarsal bands (these individuals were either banded with only a metal band as ducklings, or had plastic bands that were lost), (3) birds with unknown banding status, and (4) birds known to be non-banded. We focused our banding effort on nests either within the long-term Spectacled Eider nest plots or near plot boundaries to increase the probability of encountering the bands in subsequent years. We captured birds using bow net traps (Salyer 1962) and temporarily replaced eggs with wooden eggs during the trap attempt to avoid damaging eggs.

Once captured, we banded each non-banded bird with a U.S. Geological Survey size 7A metal band and a yellow plastic band (manufactured by Spinner Plastics Inc.) with a unique alphanumeric code engraved in black, placing each band on a separate leg (we typically placed the plastic band on the right leg). For recaptured birds, we recorded the metal band number and plastic band code. If the bird had only a metal band, we banded it with a coded plastic band. For each bird we captured, we measured diagonal tarsus length, total tarsus length, culmen length, culmen width at nare, flattened wing length, and body mass (Dzubin and Cooch 1992).

From most captured birds, we also collected a 3 mL sample of blood via jugular venipuncture using a 5 cc syringe with a 1 inch × 23 gauge needle. We transferred each blood sample from the syringe to a heparinized 4 mL vial (BD Vacutainer) labeled with the metal band number after collection and placed vials in a liquid nitrogen dewer at the field camp. Because vacutainer labels no longer adhere to the plastic vial at low temperatures, we secured each label to its vial using transparent tape before we placed it into the liquid nitrogen.

Nest Monitoring

We recorded geographic coordinates of all Spectacled Eider nests we encountered, both on and off nest plots, using handheld GPS units (WGS84 datum, decimal degree units). We placed either a wooden tongue depressor (15.2 × 1.8 cm) on the north side of the nest bowl or a white vinyl survey flag (10.2 × 12.7 cm flag on a 53.3 cm wire) 3 m north of the nest, each with the unique nest code (observer initials and sequential nest number for that observer; e.g., ABC001). We classified the nest site into one of five categories (shore, peninsula, island, meadow, displaced island). We sequentially numbered each egg in the clutch using a felt-tip marker to monitor clutch size and determined the extent of embryo development using egg candling and/or egg flotation (Hanson 1953, Westerkov 1950).

In a subset of nests, we deployed a temperature logger (Thermochron iButton model DS19G-F5#) attached to a steel toggle-bolt wall anchor (7.6 cm length) to prevent the logger from being displaced from the nest. Temperature loggers were placed under the nest material and were programmed to sample temperature every 25 min, ensuring ≥ 30 d of data collection given the available memory.

We revisited nests prior to hatching only if the band status of the bird was unknown, the band code had not been read, or to capture the bird just prior to hatching for banding. We revisited nests after the predicted hatching date of the eggs to check for egg membranes indicating the eggs successfully hatched, or for evidence of egg predation or nest abandonment. Some nests were still active at the end of the project and thus had unknown nest fates.

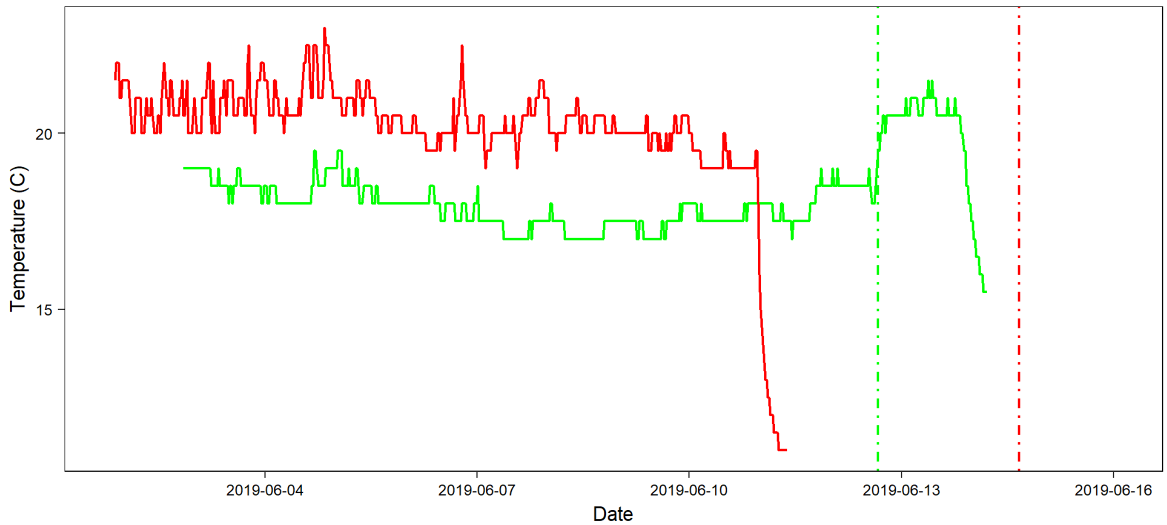

Figure 3. Data from two iButton temperature loggers deployed in Spectacled Eider nests: red line shows nest temperatures from a nest that was depredated (DJR001), as indicated by the decline in temperature before the estimated egg hatching date (vertical red dashed line); green line shows nest temperatures from a nest with hatched eggs (DJR008), as indicated by the increase in nest temperature coincident with the eggs hatching (vertical green dashed line), followed by temperature decline coincident with nest departure.

For nests with temperature loggers, I used nest temperature to determine the hatching date (indicated by an increase in nest temperature associated with the emergence of ducklings from eggs) or date of nest failure (indicated by a decrease in nest temperature associated with the departure of the incubating bird; Fig. 3). For nests without temperature loggers, I assumed a nest had been depredated if we did not find egg membranes or abandoned eggs when checked after the predicted hatching date.

Descriptive Statistics and Data Analyses

I estimated the nest initiation date for each nest based on either observed hatching date and maximum clutch size, or the maximum embryo age estimate and maximum clutch size assuming a 24-day incubation period and egg laying rate of 1 egg/day. Nests with pipped eggs were considered hatched and egg hatching dates were either directly observed during nest visits, determined from temperature logger data, or estimated based on embryo age estimates from egg flotation and candling.

We minimized the number of visits to monitor nests to reduce disturbance to incubating hens and thus do not know true clutch sizes. We estimated apparent clutch sizes based on the maximum clutch size observed for each nest. We did not include nests that were observed only during laying with either no subsequent visits or that were depredated after discovery. Average apparent clutch size is likely an under estimate of true average clutch because of unobserved partial predation of eggs within clutches.

Nest Survival Estimation

I estimated nest daily survival probability (DSP) using hierarchical models (Royle and Dorazio 2008, Schmidt et al. 2010) fit in JAGS 4.3.0 (Plummer 2013) and implemented in Program R (version 3.5.0; R Core Team 2016) using the jagsUI package (version 1.5.0; Kellner 2019).

I fitted models specifying a constant DSP and a DSP associated with the age of the nest (days since nest initiation, hereafter *nest age*) and day of season (days since the first nest in the sample was discovered). These temporal effects were included in nest DSP models both singly as main effects and together as additive effects, and as linear and quadratic trends. Nest age and day of season values were centered by subtracting the mean from each value and scaled by dividing each value the sample standard deviation.

I evaluated the importance of model parameters based on 95% credible intervals (CRI) coverage around logit-scale parameter estimates and considered any parameters with CRI broadly overlapping zero to be unsupported by the data. Parameters estimated as zero indicate no effect and broad confidence interval coverage, including both positive and negative values, indicates a high level of uncertainty in the direction and magnitude of the effect.

After determining important nest age and day of season effects, I further evaluated the association between nest DSP and the presence of a survey flag to the mark the nest site and observer visits to check nests. I evaluated the effect of nest flags using an index variable for nests where flags were deployed as markers (other nests were marked with only a tongue depressor). I evaluated the effect of observer visits to check nests using an index variable given the value of one for each day a nest was visited and zero otherwise. I added nest flag and nest visit variables separately to the model including important temporal explanatory variables.

I present estimates of DSP and cumulative nest survival probabilities (i.e. the probability a nest survives the 29-day period that includes nest initiation and incubation to hatch at least one egg) with their 95% CRIs. I assessed model convergence using trace plots and Gelman-Rubin statistics (i.e., r-hat) calculated for each parameter in each model; I accepted r-hat values near 1.0 for all parameters in a given model as indicating model convergence. I fit models using three chains run for 25,000 iterations and removed the first 1,000 iterations before estimating parameters to permit the chains to stabilize.

Permits

Banding was done under USGS Bird Banding Laboratory permit 21146 (valid 2 Feb 2018–21 Oct 2019) under permittee Ted Swem and sub-permittee Daniel Rizzolo (USFWS Fairbanks Field Office). All animal handling protocols were approved by the USFWS Region 7 Institutional Animal Care and Use Committee under assurance 2019-004 approved on 13 Feb. 2019. Work with threatened Spectacled Eiders was approved under ESA Section 10 permit TE778102-1 and research on state wildlife resources was approved under ADFG Scientific Permit 19-119.

RESULTS

Nest Searching and Monitoring

Nine biologists searched all 48 nest plots for Spectacled Eider nests over 35 days (17 May–21 June) and found 171 nests (Fig. 2; search effort summary Appendix 1); dedicated nest searching was completed on 9 June and additional nests were found while revisiting plots to read bands and trap adults. Of the 171 nests found, 92.4% were initially discovered by 10 June (Fig. 4). We found 119 nests on long-term Spectacled Eider nest plots and an additional 52 nests outside of those plots. Most nests (46%) were located along the shores of lakes (Fig. 5A).

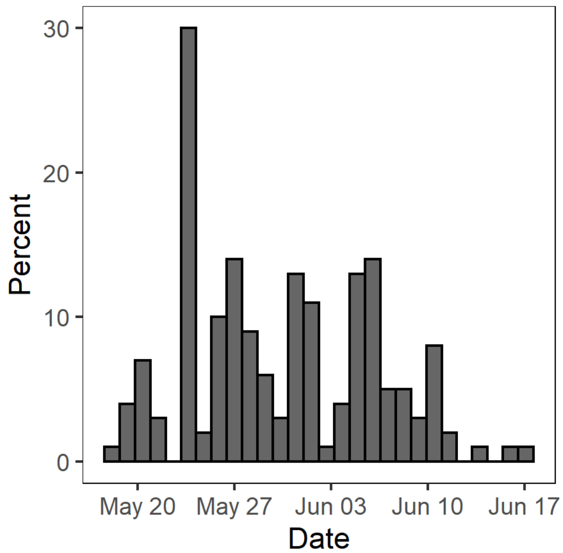

Figure 4. Frequency distribution of initial discovery dates for Spectacled Eider nests on Kigigak Island in 2019 (n = 171).

Nest Chronology

Nest initiation dates ranged from 8 May to 12 June, with average initiation on 19 May and median nest initiation on 18 May; the maximal number of nests were initiated on 14 and 18 May (n = 16 nests initiated each of these dates; Fig. 5B).

Egg hatching dates ranged from 6 June to 11 July, with average and median hatching on 17 June, and modal (i.e., peak) hatching on 16 June (n = 23 nests hatched; Fig. 5B).

Apparent clutch size ranged from one to six eggs, with an average size of 4.6 eggs and mode of five eggs.

We placed temperature loggers in 78 nests, of those 55 hatched, 19 were still active when last checked, three were abandoned, and 14 failed. For those failed nests, we used temperature logger data to identify the day of nest failure. For nests with eggs that hatched, we used temperature logger data to determine the exact hatching date.

We monitored all nests for hatching status except for seven off-plot nests and visited monitored nests an average of 2.5 times (range: 1–6 nest visits). Of the nests we monitored, 19 were still active when last checked but had not yet hatched and thus have an unknown final fate. Twelve nests were abandoned; abandoned nests were visited an average of 2.2 times (range 1–4 visits) and hens from five of the 12 abandoned nests were captured prior to abandonment. Eggs in six nests were inviable, as indicated by lack of development observed when candling or floating the eggs. Of the monitored nests, tongue depressors marked 85 nests and flags marked 60 nests. Excluding abandoned nests, nests with infertile eggs, and nests with unknown final fates, we monitored 126 nests. Of those 126 nests, 77.8% contained at least one egg that hatched.

Nest Survival

Nests last observed as active were included in the analysis of nest survival, for a sample size of 145 nests. From the constant survival rate model, nest DSP was 0.986 (CRI: 0.980, 0.991) and the probability of a nest surviving 29 days to hatch at least one egg was 0.669 (CRI: 0.635, 0.767).

Estimates from the DSP model that included nest age showed evidence of a small linear increase in DSP on the logit scale in association with nest age. DSP increased from 0.964 (CRI: 0.921, 0.989) on day 1 of nest period to 0.991 (CRI: 0.983, 0.996) on day 29. However, there was some uncertainty in the magnitude of the effect and the CRI around the estimate slightly overlapped zero (β_{age} = 0.328: -0.061, 0.695). Survival from laying to hatching estimated from the nest age model was 0.59 (CRI: 0.43, 0.73).

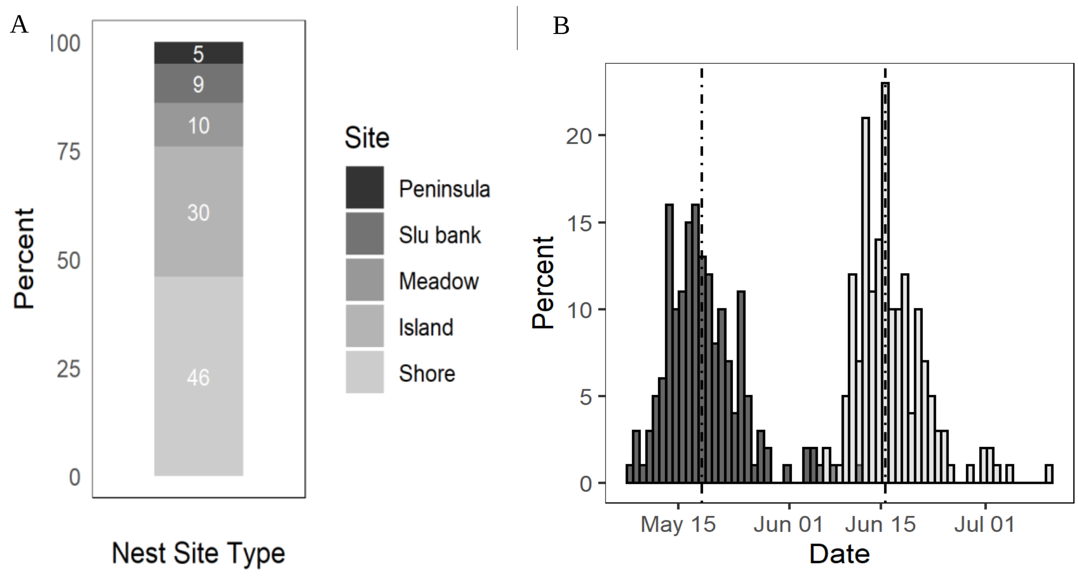

Figure 5. (A) Percent frequency of nest site categories used by Spectacled Eiders (n = 171) in 2019. (B) Frequency distributions of Spectacled Eider nest initiation dates (black bars) and egg hatching dates (gray) in 2019. Dashed lines indicate median nest initiation (19 May 2019) and median egg hatching (16 June 2019) dates.

Nonlinear effects of nest age, and linear and nonlinear effects of day of the season, were estimated either as near zero or had CRI that broadly overlapped zero (Appendix 2).

Neither flags used to mark nests (β_{flag} = 0.193, CRI: -0.571, 0.989), nor observer visits to check nests (β_{visit} = 1.94, CRI: -1.15, 4.84) were associated with nest DSP when these explanatory variables were added separately to the nest DSP model with a nest age effect.

Band Encounters

We read 39 coded plastic tarsal bands: 25 based on photographs and 14 upon capture. All but one encountered band was associated with a nest. Nine bands were encountered outside of long-term nest plots; the remainder were encountered on the nest plots. We were unable to read bands on six birds that we knew to be banded. Twenty-six nests were attended by hens whose band status we could not determine. Six birds were captured with only metal tarsus bands; all six had been banded previously with coded plastic tarsal bands that subsequently were lost. One individual had both a nasal disk and coded plastic tarsal band; no other nasal disks were seen.

Of the encountered banded birds, initial banding years included 2015 (n = 8), 2014 (n = 9), 2013 (n = 3), 2012 (n = 7), 2011 (n = 4), 2010 (n = 4), and one individual each from 2009, 2007, 2006, and 2004. The eider banded in 2004 was banded as a duckling. Band data and band resighting data were submitted to the USGS Bird Banding Laboratory via the Bandit program on 29 Aug 2019 by DJR.

Capture of Breeding Females

We captured 63 female Spectacled Eiders incubating nests using bow net traps and collected bloods samples from 53 of those captured birds. Blood samples will be analyzed for lead levels by the Trace Element Research Laboratory located at the Department Research Veterinary

Integrative Biosciences, Texas A&M University. We banded 49 previously non-banded hens and recaptured 14 hens. No captured birds were incidentally injured or killed.

Average embryo age at the time of capture was 21.6 days (range: 18–24 days). Most nests of captured hens hatched at least one egg (48 of 63 nests); of the remaining nests, five were abandoned, four were active when last checked, two had inviable eggs, and four were depredated.

Average (± 1 SD) morphometrics of captured birds were: total tarsus length 46.8 ± 1.9 mm (n = 54), diagonal tarsus length 55.5 ± 1.6 mm (n = 54), culmen length 25.5 ± 1.5 mm (n = 54), width of culmen at nare 20.6 ± 0.8 mm (n = 54), flattened wing length 25.7 ± 0.7 cm (n = 55), body mass 1149.2 ± 79.1 g (n = 62).

DISCUSSION

The successful restart of the mark-recapture sampling effort with breeding Spectacled Eiders at Kigigak Island in 2019 owed in large part to the large number of Spectacled Eiders that initiated nests and high nest survival, as well as high band encounter effort by the personnel on three collaborating projects. Given this combination of luck and effort, we encountered 39 banded Spectacled Eiders and deployed 49 new bands on previously non-banded eiders.

Search Effort

Search effort for banded Spectacled Eiders was high in 2019, with all 48 nest plots searched, in addition to an off-plot area corresponding the Yukon Delta NWR’s Emperor Goose nest plots. The number, location, and size of nest plots has varied over the course of this project from 29 plots with an area of 0.33 km^2 in 1993 (Moran and Harwood 1994) to 49 plots with an area of 0.17 km^2 in 1997 (Moran 2000). The current 48 plots and their locations apparently have been consistent since 2006 (Lake 2006). Since 1992, biologists have searched within plots with an average total area of 7.1 km^2 (range: 5.3–9.6 km^2; Appendix 2). Average distances between nests by the same female in consecutive years is ~300 m (Moran 2000), making off-plot movements of banded eiders likely. These off-plot movements likely contribute to the low encounter rates of banded Spectacled Eiders at Kigigak Island (average 0.504; Bradley 2018).

Resighting band codes using handheld digital cameras worked well, particularly for determining the band status (banded versus non-banded) at the discovery or first revisit to a nest. This information was valuable for allocating nest revisiting effort and capture effort as maximizing band encounter probability was a priority.

Spring Phenology and Nest Chronology

Spring conditions arrived early on the Yukon Kuskokwim Delta in 2019 and Spectacled Eiders responded accordingly. Winter 2018–2019 in western Alaska was characterized by warm ambient temperatures, frequent storms, and the second-lowest sea ice extent on record in the Bering Sea (NOAA 2019, Spreen et al. 2019). Satellite imagery indicated that shore-fast ice was absent from the coast of the Yukon Kuskokwim Delta in winter 2018–2019 and Kigigak Island was free of snow and ice as early as 5 May (NASA 2019). Spectacled Eider average nest initiation on Kigigak Island in 2019 (19 May) was earlier than the average for sample years at Kigigak Island for which data are available (27 May, n = 14 years; range: 19–27 May; Fig. 6) and the 30-year average (1985–2014) for the Yukon Kuskokwim Delta (28 May, range 18 May–

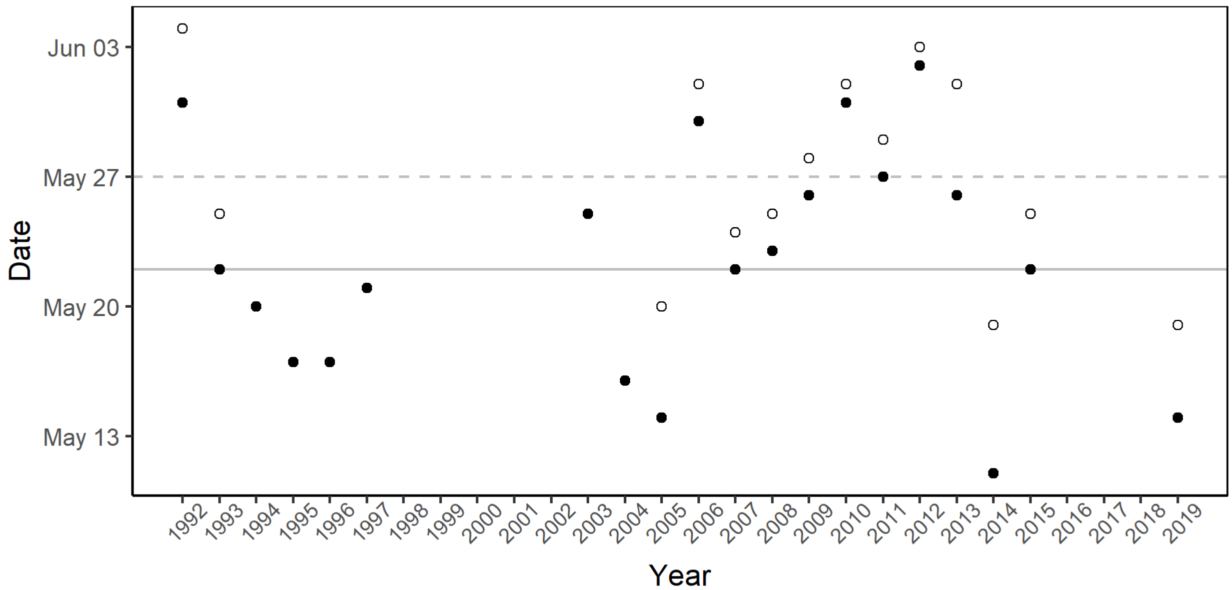

Figure 6. Peak nest initiation dates (filled circles) and average nest initiation dates (open circles) for Spectacled Eider nests on Kigigak Island, 1992–2019. Horizontal lines indicate values averaged over the time series (solid line = peak initiation, 22 May; dashed line = average initiation, 27 May).

7 June; Fischer et al. 2018). Neither average nor peak nest initiation dates of Spectacled Eiders on Kigigak Island (Fig. 6) or more broadly on the Yukon Kuskokwim Delta (Fischer et al. 2018) show any trend across sampling years.

Weather conditions during June continued to consist of above average ambient temperatures, few cloudy days, and even several days with afternoon thunderstorms (NOAA 2019). There were no significant storms during the nesting period and nest-related work was not affected by weather during the field season.

Nest Survival

The majority of nests initiated by Spectacled Eiders in 2019 hatched at least one egg. Nest survival probability in 2019 estimated from the constant survival model (similar to the Mayfield nest success estimator; Mayfield 1975) was near the long-term average for years sampled at Kigigak Island (average nest survival 1992–2015 = 0.622; Fig. 7) and higher than the last nest monitoring effort at Kigigak Island in 2015 (0.045: 0.015, 0.010; Moore and Sowl 2015).

Daily nest survival probability increased with age of the nest. Nest age effects in ground-nesting birds species have been associated with differences in nest vulnerability related to nest concealment (Klett and Johnson 1983, Garrettson and Rowher 2001), differences in predator communities (Wilson et al. 2007), and behavioral changes of incubating adults (Smith and Wilson 2010), all of which can vary by year. Estimators of daily nest survival that assume a constant survival rate can lead to biased estimates of nest survival when temporal effects, like nest age, influence nest survival. For Spectacled Eiders breeding at Kigigak Island in 2019, the positive association between nest survival and nest age led to a slight positive bias when nest age was not included in the model. To date, the annual nest survival estimates in the time series from

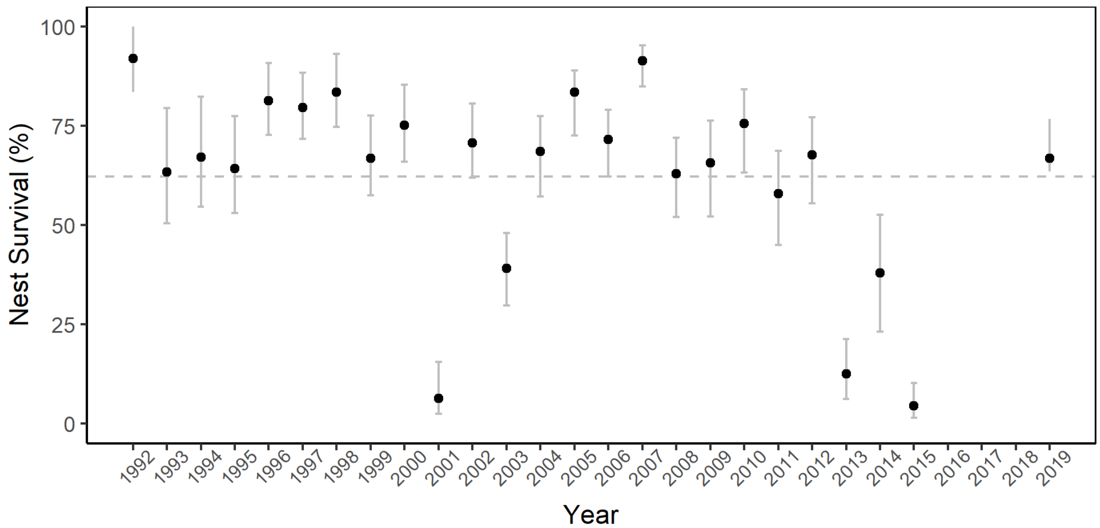

Figure 7. Time series of nest survival estimates for Spectacled Eiders breeding on Kigigak Island. Error bars indicate 95% confidence/credible intervals. Dashed horizontal line indicates the average nest survival over the time series (62.2%). No nest monitoring occurred in 2016–2018.

Kigigak Island has been estimated assuming a constant survival rate, thus I present the constant survival model estimate for 2019 in Fig. 7 for comparison.

Nest daily survival probability was not associated with either observer visits to monitor nest status or the presence of a survey flag to mark the nest location. These results are consistent with the results of Lake et al. (2007), who estimated the association between nest daily survival probability and observer visits to nests at Kigigak Island for the years 2002–2006. This analysis found the effect of observer visits to monitor nests varied by year and that its magnitude was typically negative, but small and not distinct from zero. Over the period examined, nest survival was high in all but one year and the effect of nest visits was highest in the year of lowest nest survival (2003), suggesting the potential effects of observer visits may be important in years of high nest depredation. Thus, the effects of observer visits should be considered to account for the potential negative bias in nest survival that may result in years of higher nest depredation. The effect of nest flags to mark nests, to my knowledge, had not been previously examined for Spectacled Eider nest survival. Similar to observer visits, although not important in 2019, the effect of marking nests may be greatest in years with higher nest depredation rates.

Use of iButton temperature loggers to indirectly monitor nest fate helped reduce disturbance to incubating hens with known band status and increased the precision of the nest DSP estimate by identifying the day of nest failure for depredated nests.

Egg Predators

Although fox removal has been conducted previously at Kigigak Island, there was no effort to remove foxes in 2019. The last fox removal effort at the study site was in 2016 (associated with the pilot effort to reintroduce Steller's Eiders). Spectacled Eider nest survival was high despite observations of both Arctic and red foxes on Kigigak Island in 2019. Only one active fox den, that of a red fox, was located in 2019. This den was under the camp weatherport floor. Upon arrival of the field team, the pups were placed in a tote and moved away from the field camp; the field crew observed an adult fox moving the pups from the tote to an unknown location.

Anecdotally, I observed little nest depredation by Glaucous Gulls or Parasitic Jaegers in 2019, which often capitalize on the disturbance caused by humans to feed on eggs in nests, although both species were seen most days during the nesting period. I also frequently encountered the remains of Pacific Herring at Glaucous Gull nesting colonies.

Annual Apparent Survival

Apparent survival of Spectacled Eiders varies in association with winter sea ice cover and blood lead levels (Christie et al. 2019, Flint et al. 2016, Flint and Grand 1997, Grand et al. 1998). Elevated blood lead levels result from consumption of spent lead shot as grit by eiders (Franson et al. 1998). On the Yukon Kuskokwim Delta, spent lead pellets persist in lake and pond sediments at a depth accessible to waterfowl for at least 10 years after deposition (Flint 1998, Flint and Schamber 2010). In the 1990s, lead exposure was associated with reduced survival rates of Spectacled Eiders at Kigigak Island (Grand et al. 1998) and mortality due to lead was directly observed (Franson et al. 1995).

Of 317 Spectacled Eiders sampled at Kigigak Island from 1993 to 1999, 14.2% had blood lead levels above the threshold indicating exposure (> 0.2 ppm wet mass; Flint et al. 2016). More recently, of a sample of 21 adult female Spectacled Eiders sampled during the pre-breeding period on Kigigak Island in 2018, only one had blood lead levels > 0.02 ppm wet mass (U.S. Fish and Wildlife Service, Fairbanks Field Office, unpublished data). Further, the eider with the high blood lead level died just prior to surgery to implant a satellite transmitter and during necropsy was found to have a lead pellet in its liver (U.S. Fish and Wildlife Service, Fairbanks Field Office, unpublished data).

Given that the probability of lead exposure increases with the duration of time spent on the breeding grounds (Flint et al. 1997), pre-breeding blood lead values may not accurately reflect current lead exposure rates at Kigigak Island. The larger sample of Spectacled Eider blood collected from breeding females just prior to eggs hatching in 2019 will be a more accurate measure of lead exposure. Further, given that blood lead levels in Spectacled Eiders on the Yukon Kuskokwim Delta have varied annual, multiple years of blood sampling are needed to determine accurately the prevalence of lead exposure.

Band encounter data from 2019 will be used to update band encounter histories for the long-term data set from Kigigak Island. The last band encounter effort on Kigigak Island occurred in 2015, thus the estimate obtained using 2019 band encounter data will represent survival over the 4-year interval 2015–2019. Additional years of band encounter data will improve estimates of band encounter probability and improve the precision of apparent annual survival estimates.

Bradley (2018) conducted an analysis of simulated data to gauge the potential increase in confidence in the nonlinear association between winter sea ice cover and Spectacled Eider annual apparent survival. These simulations examined a minimum of six years and a maximum of 10 years of additional capture-recapture sampling. This analysis found that six additional years of capture-recapture sampling under conditions of probable low winter sea ice cover (50–70% change of low ice cover), a 30 band per year marking effort, and 0.50 annual encounter probability resulted in moderate gains in confidence around the association between minimal sea ice days and apparent survival (Bradley 2018). Thus, the effort to understand the effects of low sea ice cover on Spectacled Eiders must be planned and executed over at least a 5-year timeframe. Given the recent, rapid, large decrease in winter sea ice extent in the Bering Sea and the effects of this change on the marine ecosystem (Duffy-Anderson et al. 2019), monitoring the association between Spectacled Eider survival and sea ice, as well as other aspects of Spectacled Eider winter ecology (e.g., winter distribution, habitat use, diet composition, body condition) is critical to making informed management decisions for this ESA threatened species.

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APPENDIX 1. Band encounter effort on long-term plots on Kigigak Island, Alaska[1].

Year	Plot size (km^2)	Plots searched	Area searched (km^2)
1992	0.33	22	7.26
1993	0.33	29	9.57
1994	0.17	33	5.61
1995	0.17	35	5.95
1996	0.17	34	5.78
1997	0.17	49	8.33
1998	--	--	--
1999	--	--	--
2000	--	--	--
2001	--	--	--
2002	0.17	45	7.65
2003	0.17	43	7.31
2004	0.17	46	7.82
2005	0.17	46	7.82
2006	0.17	48	8.16
2007	0.17	48	8.16
2008	0.17	45	7.65
2009	0.17	31	5.27
2010	0.17	34	5.78
2011	0.17	33	5.61
2012	0.17	48	8.16
2013	0.17	35	5.95
2014	0.17	42	7.14
2015	0.17	35	5.95
2019	0.17	48	8.16

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APPENDIX 2. Parameter estimates from models of the daily survival probability of Spectacled Eider nests at Kigigak Island in 2019.

			Credible Interval		
Model	**Parameter**	**Estimate**	**2.5%**	**97.5%**	**r-hat**
Null	Intercept	4.28	3.92	4.68	1.00
Age	Intercept	4.34	3.96	4.75	1.00
	Age	0.33	-0.06	0.69	1.00
Day	Intercept	4.28	3.92	4.68	1.00
	Day	0.02	3.92	4.68	1.00
Age + Age^2	Intercept	4.25	3.79	4.72	1.00
	Age	0.44	-0.04	1.01	1.00
	Age^2	0.13	-0.14	0.54	1.00
Day + Day^2	Intercept	3.95	2.76	4.92	1.00
	Day	0.02	-0.03	0.08	1.00
	Day^2	0.01	-4.76	4.76	1.00
Age + Day	Intercept	4.34	3.96	4.75	1.00
	Age	0.33	-0.05	0.69	1.00
	Day	-0.005	-4.747	4.744	1.00
Age + Age^2 + Day	Intercept	4.24	3.79	4.72	1.00
	Age	0.48	-0.04	1.01	1.00
	Age^2	0.14	-0.14	0.54	1.00
	Day	-0.004	-4.76	4.75	1.00
Day + Day^2 + Age	Intercept	3.79	2.63	4.86	1.00
	Day	0.03	-0.03	0.09	1.00
	Day^2	0.01	-4.74	4.75	1.00
	Age	0.36	-0.03	0.74	1.00
Age + Age^2 + Day + Day^2	Intercept	3.78	2.58	4.86	1.00
	Age	0.46	-0.02	1.01	1.00
	Age^2	0.12	-0.15	0.51	1.00
	Day	0.02	-0.03	0.09	1.00
	Day^2	-0.02	-4.75	4.75	1.00
Age + Flag	Intercept	4.26	3.75	4.81	1.00
	Age	0.31	-0.07	0.68	1.00
	Flag	0.19	-0.57	0.99	1.00
Age + Visit	Intercept	4.27	3.86	4.73	1.00
	Age	0.33	-0.05	0.69	1.00
	Visit	1.99	-1.04	4.84	1.00

APPENDIX 3. Summary of field logistics in 2019.

Figure A3.1. Kigigak Island Field Crew 2019: (From left to right) Abby Blake-Bradshaw, Jaden Anaver, Bryan Daniels, Megan Boldenow, Julie Morse, Jordan Thompson, Randall Friendly, Dan Rizzolo, Ty Donnelly.

The crew for Emperor Goose and Brant Goose projects (six people total) deployed to Kigigak Island on 15 May via Yukon Delta NWR fixed-wing aircraft on floats to setup the field camp and begin nest searching. Nest searching started on 18 May. Spectacled Eider nest plots 18, 19, 21, 20, 22, 61, and 1 (Fig. 2) were searched for Spectacled Eider nests before the arrival of Spectacled Eider project personnel.

Two members of the Spectacled Eider crew (D. Rizzolo, USFWS and M. Boldenow, UAF contract biologist) arrived in Bethel on 27 May and traveled to the field site on 31 May after a 4-day delay in Bethel waiting for perishable food to arrive from Fairbanks (food was shipped 22 May via Northern Air Cargo). Rizzolo and Boldenow traveled from Bethel to Newtok on a Grant Aviation commercial flight and then from Newtok to Kigigak Island via a 22' herring boat out of Newtok. Jonah Ayuluk in Newtok arranged the herring boat charter and assisted with transporting gear shipped from Bethel to Newtok and water jugs filled in Newtok using his ATV. Boat travel from Newtok to Kigigak Island often requires high tide as boats in Newtok are anchored in an intertidal area.

The remaining Spectacled Eider crewmember (UAF contract biologist Julie Morse) arrived at Kigigak Island from Bethel on 4 June via God's Country Aviation (Maule on tundra tires). This charter flight landed on the north coast of Kigigak Island to avoid disturbing the high density of nesting birds located on the island's interior.

The crew took down the field camp on 22–23 June and departed the field site on 24 June. Rizzolo, Boldenow, and Morse departed by a chartered herring boat out of Newtok, arranged by Jonah Ayuluk. This boat charter brought them to Newtok and they then traveled on a Grant Aviation commercial flight to Bethel with personal gear, electronics, data, and blood samples (blood samples were in a liquid nitrogen non-spillable dewer classified as non-hazardous for shipping). Jonah Ayuluk assisted with gear transport in Newtok. The Yukon Delta NWR crew departed by a refuge fixed-wing aircraft on floats. Additional gear was transported from the field site to Newtok via God's Country Aviation and then from Newtok to Bethel by a refuge fixed-wing on wheels.

Much of the gear for the Kigigak Island field camp is stored at the field site, including the weather ports (2), weather port floors, boardwalks, and shelving. Other gear (banding equipment, tents, sleeping bags) and non-perishable food was transported from Bethel to the field site via Yukon Delta NWR fixed-wing airplane on skis in late March. Potable water was also transported in March via fixed-wing aircraft and refilled as needed during the field season via refuge resupply flights.

Spectacled Eider project gear (tents, sleeping bags, banding gear.) is stored in a conex storage unit on the refuge's Wildlife Drive storage area in Bethel (gear inventory list is maintained at the Fairbanks Field Office). Project electronics (laptop computer, Rino GPS units, VHF radios) are stored in Fairbanks.