ARCTIC
VOL. 79, NO. 2 (JUNE 2026) P. 109–122
https://doi.org/10.14430/arctic84481

# Contemporary Evaluation of Spectacled Eider Breeding Success and Bird Community at Indigirka River Delta, Russia

Eugenia V. Bragina,[1,2] Martin D. Robards,[1] Daniel J. Rizzolo,[3] Randall J. Friendly,[4] Alexander I. Matsyna,[5] Ekaterina L. Matsyna,[5] Aleksandr A. Matsyna,[5] Polina S. Smagina[5] and Konstantin S. Maslovsky[6]

(*Received 12 February 2026; accepted in revised form 21 May 2026*)

ABSTRACT. The Indigirka River Delta (Republic of Sakha, Yakutia) has been recognized historically as an important breeding area for numerous Arctic bird species and has the largest breeding concentration for the threatened Spectacled Eider (*Somateria fischeri*). However, the most recent peer-reviewed studies from this region date to the 1990s, and contemporary information on breeding conditions is lacking. Given the continued decline of Spectacled Eider populations, updated data from this key breeding area are critically needed. To assess current breeding status of Spectacled Eiders and the overall bird community at this site, in 2022 to 2024 we repeated ground-based surveys conducted in 1994–95. Spectacled Eider arrival occurred several days earlier than in the 1990s, on 28 May to 1 June, instead of 6 June, though nest initiation timing was comparable. Reproductive performance over the three years of study (2022–24) was relatively low: cumulative nest survival over the 24-day incubation period was 0.44 (95% CI 0.36–0.52), below values reported from Alaskan populations. Consistent with earlier results, coastal islands provided habitat supporting higher nest survival. In the interior, but not at the coast of the Indigirka River Delta, daily nest survival increased with nest age. Minimum daily temperature had a negative effect on nest survival. Our results are consistent with prior surveys in the 1990s, confirming low reproductive success for Spectacled Eiders at this key breeding ground. With respect to the broader bird community, we recorded notable changes since the 1990s in species representation. Four species previously reported were not detected, 10 species were new to the area, and 10 species were newly confirmed breeding.

Keywords: nest success; breeding ecology; Indigirka; RMark; Spectacled Eiders

RÉSUMÉ. Le delta du fleuve Indiguirka (république de Sakha, Yakoutie) est historiquement reconnu comme un lieu de reproduction important pour de nombreuses espèces d'oiseaux de l'Arctique. C'est là que se trouve la plus forte concentration d'eiders à lunettes (*Somateria fischeri*), une espèce menacée. Cependant, les études les plus récentes ayant fait l'objet d'une évaluation par les pairs dans cette région remontent aux années 1990, si bien qu'il manque d'informations contemporaines sur les conditions de reproduction. Compte tenu du déclin continu des populations d'eiders à lunettes, il est indispensable de disposer de données actualisées provenant de cette zone de reproduction clé. Afin d'évaluer l'état actuel de la reproduction des eiders à lunettes et de la communauté aviaire dans son ensemble sur ce site, nous avons répété, de 2022 à 2024, les relevés au sol effectués en 1994-1995. L'arrivée des eiders à lunettes a eu lieu plusieurs jours plus tôt que dans les années 1990, soit du 28 mai au 1er juin, au lieu du 6 juin, bien que le moment du début de la nidification ait été comparable. La performance de reproduction au cours des trois années visées par l'étude (2022-2024) s'est révélée relativement faible : le taux de survie cumulatif des nids sur la période d'incubation de 24 jours s'est établi à 0,44 (IC à 95 % : 0,36-0,52), soit une valeur inférieure à celles observées chez les populations de l'Alaska. Conformément aux résultats antérieurs, les îles côtières offraient un habitat favorisant un taux de survie plus élevé des nids. À l'intérieur des terres, mais pas sur les rives du delta du fleuve Indiguirka, le taux de survie quotidien des nids augmentait avec l'âge de ceux-ci. La température quotidienne minimale a un effet négatif sur la survie des nids. Nos résultats concordent avec ceux de relevés antérieurs effectués dans les années 1990, confirmant le faible succès de reproduction des eiders à lunettes dans cette aire de reproduction clé. En ce qui concerne l'ensemble de la communauté aviaire, nous avons observé des changements notables dans la répartition des espèces depuis les années 1990. Quatre espèces déjà répertoriées n'ont pas été observées, dix espèces étaient nouvelles dans la région et la reproduction de dix espèces a été confirmée pour la première fois.

Mots-clés : succès de nidification; écologie de la reproduction; Indiguirka; RMark; eiders à lunettes

Traduit pour la revue *Arctic* par Nicole Giguère.

[1] Wildlife Conservation Society, Arctic Beringia Program, 302 Cushman Street, Suite 203, Fairbanks, Alaska 99701, USA
[2] Corresponding author: ebragina@wcs.org
[3] U.S. Fish and Wildlife Service, Northern Alaska Fish and Wildlife Field Office, 101 12th Avenue, Room 110, Fairbanks, Alaska 99701-4630, USA
[4] U.S. Fish and Wildlife Service, Yukon Delta National Wildlife Refuge, PO Box 346, Bethel, Alaska 99559, USA
[5] Working Group on Waders of Northern Eurasia, PO Box 631, Nizhny Novgorod 603000, Russia
[6] Federal Scientific Center of the East Asia Terrestrial Biodiversity, Far Eastern Branch of the Russian Academy of Sciences, Prospect 100let Vladivostoka, 159, Vladivostok, 690022, Russia

Резюме. Дельта реки Индигирки (Республика Саха – Якутия) – важный гнездовой биотоп для целого ряда арктических видов птиц. В частности, здесь расположено крупнейшее место гнездования очковой гаги (Somateria fischeri). Однако последние опубликованные данные по этому району относятся к 1990 – 1995 гг., а более современная информация о статусе гнездящихся птиц отсутствует. С учетом продолжающегося снижения численности очковой гаги крайне необходимо уточнить ситуацию с данным видом в его ключевом гнездовом биотопе. Мы оценили изменения гнездового статуса очковой гаги и других видов птиц в данном районе за 30 прошедшие лет. В 2022 – 2024 гг. очковые гаги прилетали на места размножения на несколько дней раньше, чем в 1994 – 1995 гг, тогда как сроки начала гнездования существенно не отличались. Успех гнездования в 2022 – 2024 был относительно низким: накопленная вероятность успешного гнездования за 24-дневный инкубационный период была 0,44 (95% доверительный интервал 0,36 – 0,52), то есть ниже, чем у гнездящихся на Аляски популяций. Как и в 1990 – 1995 гг, успех гнездования был выше на островах дельты по сравнению с её внутренней частью. Возраст гнезда оказывал значимое влияние на выживаемость гнезд во внутренней части дельты, но не играл существенной роли на островах. Минимальная суточная температура воздуха отрицательно влияла на гнездовой успех. Орнитофауна района в целом претерпела заметные изменения: четыре вида не были отмечены в 2022 – 2024 гг, тогда как зарегистрировано появление десяти новых видов. Для десяти видов гнездование в районе дельты подтверждено впервые. Восполняя 30-летний пробел в данных, наши результаты свидетельствуют о низком репродуктивном успехе очковых гаг в крупнейшем известном месте их гнездования.

## INTRODUCTION

The Indigirka River Delta (hereafter, the Delta), on the coast of the East Siberian Sea in Arctic Russia, is the core breeding range for the Spectacled Eider (*Somateria fischeri*) and provides habitat for multiple threatened and endangered species. Spectacled Eider populations in Russia, along with the two North American breeding populations in Alaska, are listed as threatened under the U.S. Endangered Species Act (USFWS, 1993). In addition, other species of concern (BirdLife International, 2018) that breed in the Delta include the critically endangered Siberian Crane (*Grus leucogeranus*), the threatened Lesser White-fronted Goose (*Anser erythropus*), and Steller's Eider (*Polysticta stelleri*). Several species reported in the Delta, such as the Dunlin (*Calidris alpina*) or Bar-tailed Godwit (*Limosa lapponica*), are also relevant to migratory shorebird flyway efforts; for example, the East Asian – Australasian Flyway, the Arctic Council's Arctic Migratory Bird Initiative, and the U.S. Fish and Wildlife Service's Birds of Conservation Concern (USFWS, 2021). The Delta is subject to the unprecedented rate of recent environmental change in the Arctic (Lee and Romero, 2023), where long-term increases in air and ground temperatures (Biskaborn et al., 2019; Fedorov et al., 2024) have driven vegetation and landscape changes, in particular advancing shrubs and trees northward (Myers-Smith and Hik, 2018). Warmer temperatures and newly developed vegetation complexes lead to borealization of Arctic ecosystems, including birds, sometimes advantaging boreal species at the expense of Arctic species (Descamps and Strøm, 2021; Ktitorov et al., 2021).

The Spectacled Eider was designated as threatened by the U.S. in response to a 96% decline of the Yukon – Kuskokwim Delta population between 1970 and the early 1990s (Stehn et al., 1993; Ely et al., 1994). Subsequently, some increase and stability in the population were reported (USFWS, 2021), but the most recent survey data suggest populations in Alaska have again declined substantially (USFWS, 2021; Wilson et al., 2025). Given that more than 90% of the global population of Spectacled Eiders is thought to breed in two Russian regions, Chukotka and Yakutia (Hodges and Eldridge, 2001; Petersen et al., 2005), we believe it is critical for conservation planning to establish whether the trends seen in Alaska also extend to those regions. However, despite the vast size and importance of the Russian populations, very little is known about Spectacled Eider breeding ecology outside of North America.

During the 1970s, the Spectacled Eider population in the Russian Arctic was estimated at approximately 50,000 breeding pairs (Dau and Kistchinski, 1977). An aerial survey of the eastern Arctic coast of Russia in 1993 – 95 resulted in a minimum population index of 146,245 individuals (Hodges and Eldridge, 2001). In 2019, an aerial survey in the range of Spectacled Eiders in Arctic Russia estimated substantially lower numbers (USFWS, 2021). However, widespread fires impacted survey timing, and remarkably early spring conditions limited the comparability of the 2020 survey with survey data from the 1990s. At the same time, a 2020 census of the Spectacled Eider population on the northern Bering Sea wintering area (Rizzolo et al., 2021) found 78% fewer Spectacled Eiders and no large flocks (i.e., tens of thousands of birds) compared to the most recent preceding count in 2010. While this survey could not resolve between birds missed by survey observers (within or outside the survey area) and population decline, significant concerns remain about the current population trend of Spectacled Eiders.

Knowledge of the Alaskan population of Spectacled Eiders indicates that multiple factors influence adult and nest survival. However, it remains unclear whether, and to what extent, these same factors affect populations breeding in Russia. The primary drivers include sea ice dynamics in the Bering Sea (the shared wintering area of both Russian and Alaskan populations), extreme spring temperatures and wind, exposure to lead, and predation by avian and mammalian species (Flint et al., 2016; Christie et al., 2018; Friendly et al., 2025). Sea ice extent in the Bering Sea accounts for a substantial portion of variation in adult female survival, but exhibits a nonlinear relationship, with maximum survival occurring at intermediate sea-ice levels. Thus, winter conditions play a critical role in shaping population trajectories of Alaskan eiders (Christie et al., 2018). Sea ice likely impacts Russian eiders similarly to those breeding in Alaska due to their shared Bering Sea wintering area, but Indigirka Delta breeders travel farther to breed than those in Alaska. This longer migratory distance may be important because marine-derived reserves accumulated during the non-breeding period support a substantial portion of the nutritional demand of spectacled eiders during incubation (Miller et al., 2022). Snow and ice melt timing further affects breeding phenology and may be profoundly different in the Russian versus the Alaskan Arctic, influencing nest initiation dates and the overall duration of the breeding season (Grand and Flint, 1997). With respect to lead, populations exposed to lead decline more rapidly than those without such exposure (Flint et al., 2016). However, the extent of this threat in Russia remains unclear. On the one hand, lead ammunition is widely used in Russia (and is not yet substantially abandoned for hunting in Alaska), but its population-level impacts may be mitigated by lower human density across the Russian breeding range and, hence, lower concentrations of lead within habitats of Russian eiders (USFWS, 2021). Both Alaskan and Russian populations experience nest predation from species such as Arctic foxes (*Vulpes lagopus*), gulls, and jaegers (Pearce et al., 1998a; Flint et al., 2016), but the magnitude of predator pressure on nest success of Russian populations is unclear. In summary, while the drivers of demographic change are well characterized for the Alaskan population, little is known about whether these same factors operate similarly in Russia, their direction of effect, or the strength and form of their relationships.

Given the large concentration of Spectacled Eiders breeding at the Delta, it was previously identified as a site for continued monitoring and conservation of the species (Pearce et al., 1998a). Since the 1990s though, no efforts were dedicated to monitoring Spectacled Eiders at this site. At the same time, in the neighboring Chukotka region to the east, mean nest densities for Spectacled Eiders on Ayopechan Island in the Chaun Delta declined by 8% per annum between the survey periods of 2003–09 and 2009–16 (Solovyeva et al., 2018). While mean clutch size and annual female survival did not change over this period, annual nest survival and hatching success declined significantly. Considering the low abundance of Spectacled Eiders in Alaska compared to their historical population sizes, as well as declines in nests in Chukotka, new data for the key breeding habitat of the Delta are critical for assessing overall conservation status. Further, given the profound environmental changes in the Arctic (Lee and Romero, 2023), a re-evaluation of the breeding bird community is warranted.

In this study, we did ground surveys in 2022–24 to assess the current breeding ecology of Spectacled Eiders at their largest known breeding grounds, the Indigirka Delta, and describe nesting phenology, clutch size, and nest survival in comparison to the most recent previous study, conducted three decades prior (Pearce et al., 1998a). Further, given the ongoing borealization of Arctic ecosystems and climate warming, we also surveyed bird species community composition and confirmed breeding species at the Delta to compare to the same historical period (Pearce et al., 1998b). Our results will shed light on how the breeding ecology of Spectacled Eiders has shifted in the context of long-term changes in avian community composition, seasonal phenology, and regional landscapes.

## METHODS

### *Study Area*

The Indigirka River stretches for 1726 km and drains a basin with an area of 360,000 km$^2$ into the East Siberian Sea, forming, at the confluence, a delta of 7600 km$^2$ located in the Allaikhovsky district of Republic Yakutia (Sakha). The Delta is ice-free from late May or early June until October. The regional sanctuary protected area, called the Kytalyk Reserve, is located in the study area (Russian: государственный природный заказник «Кыталык»). Kytalyk is an East Asian–Australasian Flyway Partnership Network site.

Most of the Delta is in the southern subzone of the Arctic tundra biome (Stishov et al., 1989), with characteristic landscape features, including polygonal tundra marshes, river meadows, and willow communities. Spectacled Eiders nest in the five most common vegetation communities: first, elevated and relatively dry tundra polygons covered with shrubs, sedges, mosses, and lichens (*Salix reptans* and *S. pulchra*, *Carex aquatilis*, *Arctagrostis latifolia*, *Saxifraga nelsoniana*, *Eriophorum vaginatum*, *Luzula tundricola, L. nivalis*, mosses *Bryum*, *Dicranum* and *Hylocomium splendens*, lichens *Cetraria islandica,* and others). Second, vegetation of low-area polygons includes willows, sedges, and green mosses, but no lichens. Third, in the hollows permanently filled with water (referred to as alases and thermokarst lakes), *Carex atherodes* dominates with *Hypnales* mosses like *Scorpidium spp.*, *Campylium stellatum, Calliergom richardsonii*, and herbaceous plants like *Comarum palustre*, *Dupontia fisheri*, and *Hierochloe pauciflora* are also common. Fourth, if the water level varies on slough sides, meadows with *Eriophorum polystachion*, *E. scheuchzeri*, *Dupontia fisheri,* and *Arctophila fulva* are typical. Fifth, another type of meadow occurs only on channel banks and includes horsetails and grasses (Troeva et al., 2010).

We focused on the two study areas used by Pearce et al. (1998a), the interior Delta 20–40 km inland from the coast of the East Siberian Sea, and the coastal Delta, with islands that


FIG. 1. Areas searched for Spectacled Eider nests on the Indigirka River Delta. In 2022, we concentrated efforts on the interior delta (rectangle). Nests found in 2023 (ellipses) and 2024 (triangles) reflect searches on both interior and coastal (Oleniy and Rechnikov Islands) areas of the delta.

are located close to the coast of the East Siberian Sea (Fig. 1). In 2022 we collected data from only the interior Delta, while in 2023 and 2024 we collected data from both areas.

The coastal Delta includes flat and low islands without polygonal structure, dominated by meadows and either low abundance or absence of mammalian predators. Coastal areas are prone to irregular and rare, but substantial water-level oscillations due to their low elevation. The interior Delta has various degrees of polygonal structures (e.g., high- and low-centered polygons) dissected by numerous sloughs and ponds. Arctic foxes are abundant, especially when the water level drops in late summer.

*Field Methods*

In all three years of our study (2022–24) we arrived at the Delta before the ice break-up on the Indigirka River, preceding the arrival and nest initiation of tundra-nesting birds. Each year, we recorded the date we first observed a Spectacled Eider at our camp (71.273 N, 150.31 E) and used this date as the first observation date for that year. We searched areas of favorable nesting habitat on foot for nesting Spectacled Eiders beginning when the tundra was free of snow. Consistent with Pearce et al. (1998a), we focused nest searching on areas with habitats likely to have the highest density of eider nests: (1) alases and thermokarst lakes in the interior Delta, and (2) meadows on islands in the coastal Delta, in particular Rechnikov Island (Fig. 1). We conducted nest searching along transects aiming to cover all promising habitats by walking transects in a sweep fashion. A 10 m width on each side of a transect allowed for reliable eider nest identification in the tundra habitats. Hence, our transects were ~20 m wide (10 m on each side).

Upon finding a Spectacled Eider nest, we assigned it a unique identification number, floated the eggs in water to determine the incubation stage (Westerkov, 1950), recorded the number of eggs present, and recorded the nest coordinates using a handheld global positioning system. Every active nest was revisited every 7–10 days throughout the ~24-day incubation period; nest status was determined for all nests as either laying (clutch not complete; eggs not incubated as determined by floating), incubating (eggs warm; clutch is complete and is being incubated as determined by floating), hatching/hatched (starred or pipped eggs, wet or dry ducklings, or egg membranes), abandoned (no hen present at or near nest; confirmed through repeat visits), or depredated (eggs missing before estimated hatch date; egg fragments or damaged eggs may or may not be present). Nest status was defined as laying if the nest contained eggs that flotation indicated had not yet been incubated, or incubating if flotation indicated embryo development had begun.

To quantify clutch size (i.e., maximum number of eggs laid by the female), we used both (1) the mean of the maximum observed clutch size for each nest, and (2) following Pearce et al. (1998a), we calculated mean clutch size, including only nests with at least three eggs, to exclude nests which might have suffered from partial egg predation prior to finding the nest.

*Nest Survival*

We used nest monitoring data to estimate daily nest survival rate (DSR, the probability that at least one egg in a clutch survives a given day of incubation) and evaluate a suite of factors potentially associated with variation in DSR. We included all nests found during laying, incubation, or hatching. In the nest survival analysis, each day represents one sample point, and the response variable is binary (whether a nest survived a given day of incubation or not). The generalized linear model applies a logit link to the data describing drivers of nest survival (Dinsmore et al., 2002; Rotella et al., 2004).

Previous studies identified several primary drivers affecting eider nest survival in Alaska, namely geographical location, nest age, and timing within and between seasons (Flint et al., 2016; Friendly et al., 2025). In our first step of model fitting to examine sources of variation in DSR, we considered these temporal and spatial explanatory variables with data from nests monitored in 2022–24:

**Year**: This categorical variable represents the calendar year in which the study occurred; we hypothesized that favorable years result in higher nest success.

**Site**: This is a categorical variable classifying nest location as either the interior or coastal delta. We hypothesized that the coastal Delta would have higher nest DSR because islands are more difficult for Arctic foxes to access.

**Nest Age**: This is a continuous variable for days since nest incubation started. We hypothesized that eider behavior changes throughout incubation and poorly concealed nests are lost early in the season.

**Day of the Season**: This continuous variable refers to calendar date. The first day of the season was the day when the first nest was found: 14 June in 2022, and 17 June in both 2023 and 2024. We hypothesized that as the abundance of ground nests of all species decreased through the season, clutch predation would increase, and nest DSR would decrease.

Hence, at the first stage of model fitting, our global model was:

DSR ~ Year + Site + Nest age + Day of the season + Site*Nest age + Site*Year + Nest age*Year + Year* Day of the season + Nest age* Day of the season. We then examined all possible combinations of main effects and two-way interactions of these explanatory variables (except for the interaction between Year and Site, as we only had two years of data collected at the coastal Delta).

**Environmental Variables**: After identifying the model with temporal and spatial variables most supported by the data, we then examined two environment-related variables in models fit to data from nests monitored in 2023–24:

**Minimum Daily Temperature**: Presumably, the warmer the air temperature is, the more likely a hen is to take an incubation break, leaving the nest vulnerable to increased predation risk. Thus, we predicted that as minimum temperature increases, nest DSR decreases. We also considered the relatively low heat tolerance of Arctic birds and, consequently, the potential negative impact of increasing temperature on DSR (Choy et al., 2021). A positive effect of higher temperatures has been demonstrated for ducks, but not in the Arctic (Hepp and Kennamer, 2012; Hope et al., 2020). We measured temperature with a temperature logging device (ThermoChron Revisor 5.2 from iButton; https://elin.ru/Thermochron). During each season, temperature was measured every three hours with an iButton deployed at our field camp. We used the lowest measurement every 24 hours.

**ProtectiveYN**: This binary variable indicates the presence of tundra nesting bird species whose nest defense behavior may benefit eiders nesting nearby (Quinn and Ueta, 2008; Solovyeva et al., 2018). ProtectiveYN was set to 1 when at least one nest of a protective species, including Vega Gull (*Larus vega*), Glaucous Gull (*Larus hyperboreus*), Pomarine Jaeger (*Stercorarius pomarinus*), or Long-tailed Jaeger (*Stercorarius longicaudus*) was present within 150 m from the eider nest (79 nests) and 0 otherwise (88 nests). The threshold of 150 m reflects the individually defended distance for jaegers (Maher, 1974); however, given that individual territory size varies multifold for both jaegers and gulls (Maher, 1974; Fiskum, 2024), we evaluated thresholds of 50, 100, 150, 200, 250, and 300 m. Threshold choice did not affect the modeling outcomes; therefore, we only reported results based on the 150 m threshold.

We used the RMark package (Laake, 2013) in R software (R Core Team, 2024) to estimate DSR. Cumulative nest survival (probability that at least one egg in a clutch survives to hatch) was calculated as the product of the 24 DSR estimates. We used Akaike's Information Criterion corrected for small sample sizes (AICc) to compare nest DSR models composed of combinations of nest habitat variables that represent our hypotheses in a set of candidate models (Burnham and Anderson, 2002). From our top model, we made inferences based on model parameter estimates and associated 95% confidence intervals (CI).

*Avian Community Composition*

We recorded all avian species observed at the site daily, including breeding status, as determined by the presence of nests or young. Following Pearce et al. (1998b), presence and activities of all species were observed from the first to the last day of each field season, on 23 May – 22 July in 2022, on 23 May – 19 July in 2023, and 16 May – 1 August in 2024. All our observations in 2022 and most in 2023 and 2024 were conducted in the interior Delta due to logistical constraints. We spent six days in 2023 and nine days in 2024 on the coastal Delta. However, unlike Pearce et al. (1998b), who recorded birds opportunistically, we conducted systematic point counts to estimate species richness (Ralph et al., 1995). Counts were performed every three hours throughout the field season, weather permitting. Passerines were counted within 150 – 200 m; shorebirds, within 300 – 400 m; and big birds, e.g., cranes, within 1 km. Similarly to Pearce et al. (1998b), we defined categories of bird abundance as: abundant (> 30 individuals per day), common (20 – 29), uncommon (4 – 19), occasional (2 – 3), and rare (1). Breeding status was defined as follows: breeder (nests or young birds observed); presumed breeder (breeding behavior, such as territorial displays, observed for a species within its expected breeding range); migrant (birds observed moving in a directional manner, often in flocks, during spring or late summer); and transient (irregular visitor outside its known or suspected breeding area).

## RESULTS

### *Nesting Phenology*

First observation dates for Spectacled Eiders at the Delta were 28 May in 2022, 30 May in 2023, and 1 June in 2024. Median arrival dates (25th, 75th quantiles of the distribution of first observation dates) were 1 June (30 May, 6 June) in 2022, 4 June (3 June, 6 June) in 2023, and 7 June (5 June, 11 June) in 2024. Most birds arrived in flocks ranging from 4 to 40 birds with an average flock size of 12.

Earliest nest initiation dates were 8 June, 11 June, and 16 June in 2022 – 24, respectively. Mean (± 1 SD) nest initiation dates were 18 June ± 5.8 days (n = 43) in 2022, 24 June ± 5.7 days (n = 65) in 2023, and 21 June ± 5.6 days (n = 105) in 2024. In 2024, additional coastal sites were searched, hence the nest number increased.

### *Clutch Size*

Mean clutch size was 4.3 eggs (95% CI 4.1 – 4.5, n = 192) across all years, with 4.0 (95% CI 3.7 – 4.4, n = 31) eggs in 2022, 4.2 (95% CI 3.9 – 4.5, n = 66) eggs in 2023, and 4.4 (95% CI 4.1 – 4.7, n = 95) eggs in 2024. Including only nests with at least three eggs to account for possible partial predation, mean clutch size was 4.6 (95% CI 4.4 – 4.7, n = 171) eggs across all nests in 2022 – 24, by year 4.3 (95%CI 4.0 – 4.6, n = 28) eggs in 2022, 4.5 (95% CI 4.2 – 4.8, n = 58) eggs in 2023, and 4.7 (95% CI 4.5 – 5.0, n = 85) eggs in 2024.

### *Nest Survival*

We monitored the fate of 212 nests between 2022 – 24 ($n_{2022}$ = 44, $n_{2023}$ = 74, $n_{2024}$ = 94), with 110 nests on the coastal Delta and 102 nests on the interior Delta. Average nest DSR for all nests together was 0.958 (95% CI 0.937 – 0.972) in 2022, 0.957 (95% CI 0.925 – 0.976) in 2023, and 0.975 (95% CI 0.957 – 0.985) in 2024. Over the 24-day incubation period, cumulative nest survival was 0.356 (95% CI 0.213 – 0.508) in 2022, 0.399 (95% CI 0.256 – 0.540) in 2023, and 0.544 (95% CI 0.416 – 0.655) in 2024. Across all years (2022 – 24), cumulative nest survival was 0.442 (95% CI 0.360 – 0.521).

At the first modeling step, the most supported model included site, nest age, and the interaction Site * Nest age ($w$ = 0.41, Table 1) while Year, Day of the season, or other interactions did not improve the model. While the coastal Delta nests on average had cumulative nest survival of 0.777 (95% CI 0.497 – 0.913), interior Delta nest survival was low, 0.084 (95% CI 0.000 – 0.481). The site-specific Nest age confidence interval on the coastal Delta overlapped zero, that is, age did not affect nest survival on the coastal Delta (logit-scale coefficient β = – 0.03, 95% CI – 0.06 to – 0.01, Table 2). However, the interaction between Site and Nest age indicated that Nest age impacted survival significantly for the interior Delta nests. Each day of incubation in the interior Delta improved logit-scale survival by 0.06 (95% CI 0.01 – 0.11, Table 2). Hence, at the start of incubation, when nests were one day old, cumulative 24-day survival was 0.096 (95% CI 0.086 – 0.106), for 12-day old nests, meaning, in the middle of incubation, 0.290 (95% CI 0.109 – 0.490), and for 23-day old nests, right before hatching, 0.523 (95% CI 0.137 – 0.800).

At the second model-fitting step, the most parsimonious model was the one that included the Site and Nest age interaction, as well as Temperature (Table 3). While some models with ΔAICc < 2 also included ProtectiveYN, as well as interactions between Temperature and Nest age, ProtectiveYN, and Site, those models had a larger number of parameters, and neither of these coefficients had 95% confidence intervals bound away from 0 (Table 4). Temperature had a negative association with DSR (logit-scale coefficient β = – 0.16, 95% CI – 0.278 to – 0.050). At the lowest temperature of 0.5˚C, daily nest survival was 0.991 (95% CI 0.977 – 0.997), which reduced to 0.849 (95% CI 0.673 – 0.939) at the highest temperature of 19˚C. Daily nest survival at the mean temperature of 5.6˚C was 0.981 (95% CI 0.949 – 0.993, Fig. 2).

### *Bird Species Richness*

We observed 70 bird species at the Indigirka River Delta in 2022 – 24 and documented breeding for 43 species. Four species were observed by Pearce et al. (1998b) but not in 2022 – 24: Velvet Scoter *Melanitta fusca*, Wood Sandpiper *Tringa glareola*, Red Knot *Calidris canutus*,

TABLE 1. Models examining previously known temporal and spatial variables associated with daily nest survival rate for Spectacled Eider at Indigirka River Delta in 2022–24. Models are ranked by AICc weights (w). ΔAICc is the difference between the model and the model with the lowest AICc value. AICc weights indicate the strength of support for the model given the data and relative to the other models considered; values closer to 1.0 indicate higher support. The number of parameters in the model is indicated by k.

| Model | k | AICc | ΔAICc | w |
|---|---|---|---|---|
| Site + Nest age + Site * Nest age | 4 | 323.0 | 0 | 0.41 |
| Site | 2 | 325.9 | 2.9 | 0.10 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Site * Nest age + Site * Day of the season + Nest age * Year + Day of the season * Year | 13 | 326.7 | 3.7 | 0.06 |
| Site * Day of the season | 4 | 327.1 | 4.0 | 0.06 |
| Nest age + Year + Day of the season + Site + Site * Nest age | 7 | 327.3 | 4.3 | 0.05 |
| Nest age + Site | 3 | 327.4 | 4.4 | 0.05 |
| Nest age + Year + Day of the season + Site + Nest age * Site + Nest age*Year | 9 | 327.5 | 4.4 | 0.04 |
| Day of the season + Site | 3 | 327.9 | 4.9 | 0.04 |
| Year + Site | 4 | 328.6 | 5.5 | 0.03 |
| Nest age + Day of the season + Site | 4 | 329.1 | 6.0 | 0.02 |
| Nest age + Year + Day of the season + Site + Site * Day of the season | 7 | 329.3 | 6.2 | 0.02 |
| Nest age + Year + Day of the season + Site + Site * Nest age + Site * Day of the season | 8 | 329.3 | 6.3 | 0.02 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Site * Nest age | 8 | 329.4 | 6.3 | 0.02 |
| Nest age + Year + Site | 5 | 329.6 | 6.5 | 0.02 |
| Nest age + Year + Nest age * Year | 6 | 330.1 | 7.1 | 0.01 |
| Day of the season + Year + Site | 5 | 330.4 | 7.4 | 0.01 |
| Nest age + Year + Day of the season + Site + Site * Day of the season + Nest age * Year | 9 | 330.7 | 7.7 | 0.01 |
| Nest age + Year + Day of the season + Site + Day of the season * Year + Nest age * Year | 10 | 330.7 | 7.7 | 0.01 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Site * Day of the season | 8 | 330.9 | 7.8 | 0.01 |
| Nest age + Year + Day of the season + Site + Nest age * Year | 8 | 331.2 | 8.2 | 0.01 |
| Nest age + Year + Day of the season + Site | 6 | 331.4 | 8.3 | 0.01 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Nest age * Year | 9 | 331.7 | 8.6 | 0.01 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season | 7 | 332.5 | 9.5 | 0.00 |
| Nest age + Year + Day of the season + Site + Site * Day of the season + Day of the season * Year | 9 | 333.2 | 10.2 | 0.00 |
| Nest age + Year + Day of the season + Site + Day of the season * Year | 8 | 333.8 | 10.8 | 0.00 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Day of the season * Year | 9 | 335.1 | 12.1 | 0.00 |
| Nest age + Year + Day of the season + Site + Nest age * Day of the season + Day of the season * Year | 9 | 335.1 | 12.1 | 0.00 |
| Year | 3 | 335.6 | 12.6 | 0.00 |
| Nest age + Year | 4 | 335.9 | 12.8 | 0.00 |
| Day of the season + Year + Day of the season * Year | 6 | 336.1 | 13.1 | 0.00 |
| Year + Day of the season | 4 | 337.2 | 14.2 | 0.00 |
| Intercept-only | 1 | 337.3 | 14.3 | 0.00 |
| Nest age + Year + Day of the season | 5 | 337.5 | 14.5 | 0.00 |
| Nest age | 2 | 338.9 | 15.9 | 0.00 |
| Day of the season | 2 | 339.3 | 16.3 | 0.00 |
| Nest age + Day of the season | 3 | 340.5 | 17.4 | 0.00 |
| Nest age + Day of the season + Nest age * Day of the season | 4 | 342.4 | 19.4 | 0.00 |

TABLE 2. Coefficient estimates and lower (LCI) and upper (UCI) 95% confidence limits from the most supported model DSR ~ Site + Nest age + Site*Nest age describing temporospatial variation in Spectacled Eider daily nest survival rate for monitored nests (n = 212), Indigirka River Delta. Model support was assessed based on AICc model selection statistics.

| Variable | Estimate | LCI | UCI |
|---|---|---|---|
| Intercept | 4.55 | 3.52 | 5.58 |
| Site (interior Delta) | – 2.33 | – 3.59 | – 1.07 |
| Nest age | – 0.03 | – 0.06 | 0.01 |
| Site (interior Delta)*Nest age | 0.06 | 0.01 | 0.11 |

and Naumann's Thrush *Turdus naumanni*. We observed 10 species not recorded in the 1990s (Table S1).

We recorded nine species breeding that were not reported by Pearce et al. (1998b): Pacific Diver *Gavia pacifica*, Common Teal *Anas crecca*, Baikal Teal *Anas formosa*, Sandhill Crane *Grus canadensis*, Pacific Golden Plover *Pluvialis fulva*, Spotted Redshank *Tringa erythropus*, Common Snipe *Gallinago gallinago*, Pin-tailed Snipe *G. stenura,* and Little Bunting *Ocyris pusillus*.

## DISCUSSION

This study provides the first assessment after a 30-year gap of breeding ecology and reproductive success of the threatened Spectacled Eider at its largest global breeding ground. Despite profound changes in Arctic environmental conditions, the Indigirka River Delta remains a key Arctic wetland habitat for threatened Spectacled Eiders and other Arctic bird species. Although this study was not designed to estimate abundance, Spectacled Eiders remained among the most prominent species at the Delta, and their nests were detected in all study years, similar to the 1990s. Compared to the 1990s, Spectacled Eiders now arrive at the Delta several days earlier, although mean nest initiation dates remain similar. Nest survival of Spectacled Eiders at the Delta was low (2022 – 24 mean nest survival was 0.44, 95% CI 0.36 – 0.52) compared to sites in Alaska, such as Utqiaġvik on the Arctic coastal plain, where mean nest survival was 0.67 (95% CI 0.58 – 0.76, 10-year mean), and at Kigigak Island, on the Yukon – Kuskokwim Delta, where nest survival was 0.78 (95% CI 0.71 – 0.86, 24-year mean) (Friendly et al., 2025). Among factors known to influence Spectacled Eider nest survival in Alaska, only Site and Nest age were important at the Delta; daily nest survival was significantly higher at the coastal than interior Delta and increased with nest age, but only at the interior Delta. Nest survival also declined with increasing minimum daily temperature.

Our results suggest that eiders arrive earlier now than 30 years ago. In the 1990s, Pearce et al. (1998a) reported eiders first observed on 6 June in 1994, and no later than 6 June in 1995. We, however, observed the first Spectacled Eiders arriving almost a week earlier in all three years of the present study. Despite earlier arrival, mean nest initiation dates were similar to the 1990s: 15 – 22 June in 1994 – 95 compared to 18 – 24 June in 2022 – 24. On Ayopechan Island in the Chaun Delta in Chukotka, Spectacled Eider nest initiation advanced with, but lagged behind, advancing spring phenology over an 18-year period (Solovyeva et al., 2022). The timing of Spectacled Eider nest initiation may be physiologically constrained because they rely on food resources from the breeding area for egg formation, rather than endogenous reserves created from marine prey ingested during the winter (Miller et al., 2022). Thus, nests can only be initiated when the energetic and nutritional demands of egg formation are met after arriving at the breeding area. In other words, hens need, first, snow- and ice-free habitats, and second, enough time to forage after snow and ice are gone. In Alaska, mean nest initiation date was also relatively stable in spite of changes in wintering habitats due to climate warming (Friendly et al., 2025).

TABLE 3. Models examining the association between environmental variables and nest survival added to the most supported temporospatial model of Spectacled Eider daily nest survival rate (DSR ~ Site * Nest age) for nests monitored in 2023 – 24 (167 nests). Environmental variables included minimum daily temperature (Temperature) and presence of a protective species in a nest vicinity (ProtectiveYN). All models with two-way interactions also include main effects. Models are ranked by AICc weights (w). The number of parameters in the model is indicated by k. While the model DSR ~ Site * Nest Age + Temperature + ProtectiveYN had the lowest AICc and the largest w, the most parsimonious model was DSR~ Site * Nest Age + Temperature, as it had the smallest k within the ΔAICc < 2 range, and all parameter estimates had 95% CIs bound away from zero.

| Model | k | AICc | ΔAICc | w |
|---|---|---|---|---|
| Site * Nest age + Temperature | 5 | 225.85 | 0.40 | 0.17 |
| Site * Nest age + Temperature + ProtectiveYN | 6 | 225.45 | 0.00 | 0.21 |
| Site * Nest age + Nest age * Temperature | 6 | 225.77 | 0.32 | 0.18 |
| Site * Nest age + Temperature * ProtectiveYN | 7 | 226.26 | 0.81 | 0.14 |
| Site * Nest age + Site * Temperature | 6 | 226.29 | 0.84 | 0.14 |
| Site * Nest age + Site * ProtectiveYN + Site * Temperature | 8 | 228.44 | 2.99 | 0.05 |
| Site * Nest age + Site * ProtectiveYN + Site * Temperature + Nest age * Temperature | 9 | 228.54 | 3.09 | 0.05 |
| Site * Nest age + ProtectiveYN | 5 | 229.47 | 4.02 | 0.03 |
| Site * Nest age | 4 | 230.01 | 4.56 | 0.02 |
| Site * Nest age + Site * ProtectiveYN | 6 | 231.48 | 6.03 | 0.01 |
| Intercept-only | 1 | 245.76 | 20.31 | 0.00 |

TABLE 4. Coefficient estimates and 95% confidence limits from models with ΔAICc < 2 describing the association between environmental variables and Spectacled Eider daily nest survival rate for monitored nests (n = 167), in 2023–24, Indigirka River Delta. ΔAICc is the difference between the model and the model with the lowest AICc value.

| | Variable | Estimate | LCI | UCI |
|---|---|---|---|---|
| DSR ~ Site * Nest age + Temperature ΔAICc = 0.40 | Intercept | 4.84 | 3.84 | 5.84 |
| | Site | – 2.55 | –3.97 | – 1.13 |
| | Nest age | 0.01 | – 0.03 | 0.05 |
| | Temperature | – 0.16 | – 0.28 | – 0.05 |
| | Site * Nest age | 0.06 | 0.01 | 0.12 |
| DSR ~ Site * Nest age + Temperature + ProtectiveYN ΔAICc = 0.00 | Intercept | 4.71 | 3.68 | 5.73 |
| | Site | – 2.75 | – 4.22 | – 1.27 |
| | Nest age | 0.01 | – 0.04 | 0.05 |
| | Temperature | – 0.16 | – 0.28 | – 0.05 |
| | Site * Nest age | 0.06 | 0.01 | 0.12 |
| | ProtectiveYN | 0.37 | –0.26 | 1.00 |
| DSR ~ Site * Nest age + Temperature * Nest age ΔAICc = 0.32 | Intercept | 7.12 | 3.65 | 10.60 |
| | Site | – 2.89 | – 4.42 | – 1.35 |
| | Nest age | – 0.08 | – 0.21 | 0.05 |
| | Temperature | – 0.47 | – 0.93 | – 0.01 |
| | Site * Nest age | 0.08 | 0.02 | 0.14 |
| | Temperature * Nest age | 0.01 | – 0.01 | 0.03 |
| DSR ~ Site * Nest age + Temperature * ProtectiveYN ΔAICc = 0.81 | Intercept | 4.59 | 3.45 | 5.73 |
| | Site | – 2.87 | – 4.44 | – 1.29 |
| | Nest age | 0.01 | – 0.04 | 0.05 |
| | Temperature | – 0.14 | –0.28 | – 0.01 |
| | ProtectiveYN | 0.69 | – 0.90 | 2.27 |
| | Site * Nest age | 0.07 | 0.01 | 0.13 |
| | Temperature * ProtectiveYN | – 0.04 | – 0.20 | 0.13 |
| DSR ~ Site * Nest age + Temperature * Site ΔAICc = 0.84 | Intercept | 4.90 | 3.88 | 5.91 |
| | Site | – 3.82 | – 5.97 | – 1.67 |
| | Nest age | 0.02 | – 0.03 | 0.07 |
| | Temperature | – 0.19 | – 0.32 | – 0.06 |
| | Site * Nest age | 0.03 | – 0.03 | 0.10 |
| | Site * Temperature | 0.32 | – 0.07 | 0.71 |

We observed the same mean clutch size as Pearce et al. (1998a) found in 1994–95: 4.3 eggs. For nests with at least three eggs, the mean clutch sizes also were similar: 4.6 in 2022–24 vs. 4.7 in 1994–95. Therefore, when considering complete clutches, mean clutch sizes were smaller than the reported range of 4.8–5.6 eggs at the Kashunuk River (Grand and Flint, 1997), and 4.8 (95% CI = 4.7–4.8) on Kigigak Island in the Yukon–Kuskokwim Delta, Alaska, but comparable with 4.3 (95% CI 4.0–4.5) at Utqiaġvik, Alaska (Friendly et al., 2025). The Kashunuk River and Kigigak Island are subarctic breeding sites further south than Utqiaġvik, and, not surprisingly, have larger clutch sizes (Friendly et al., 2025). Consequently, Indigirka's clutch size is within the typical range for higher-latitude habitats within this species' range.

Compared to Alaskan populations, nest survival in the Delta during 2022–24 (0.44, 95% CI 0.36–0.52) indicated low productivity, similar to nest survival documented in the 1990s (0.03 in 1994 and 0.34 in 1995; Pearce et al., 1998a). In contrast, across three sites in Alaska (Kashunuk River and Kigigak Island on the Yukon–Kuskokwim Delta, and Utqiaġvik on the Arctic Coastal Plain) over a combined 48 years of data, nest survival was < 0.50 in only eight years (Flint et al., 2016; Friendly et al., 2025). In contrast, at the Indigirka Delta, across five years of data, nest survival was < 0.50 in four years. On Ayopechan Island at the Chaun Delta in Chukotka, nest survival was similarly low from 2003 to 2016, with a declining trend over time (Solovyeva et al., 2018). Taken together, these findings support the conclusion that Spectacled Eiders have experienced persistently low reproductive success in the eastern Russian Arctic.

Nest survival of Spectacled Eiders was higher on the Indigirka's coastal Delta than the interior Delta, consistent with patterns documented in the 1990s (Pearce et al., 1998a), when nest survival on the coastal Delta was 1.8–2.6 times higher. Across all study years, the coastal Delta consistently exhibited higher nest survival, likely due to lower densities of Arctic foxes on coastal islands, according to anecdotal field observations. Indirect support for higher nest predation rates in the interior Delta comes from the higher survival of older nests in this region. If poorly concealed nests are more likely to be detected early in incubation in areas with high predator densities, then nest age should be a stronger predictor of survival in such habitats. This expectation was supported by our results: nest age was not an important predictor of survival when all nests were analyzed together; however, for interior Delta nests only, nest age was an important predictor.

Nest survival decreased with increasing daily minimum temperature. For Spectacled Eiders, which are relatively

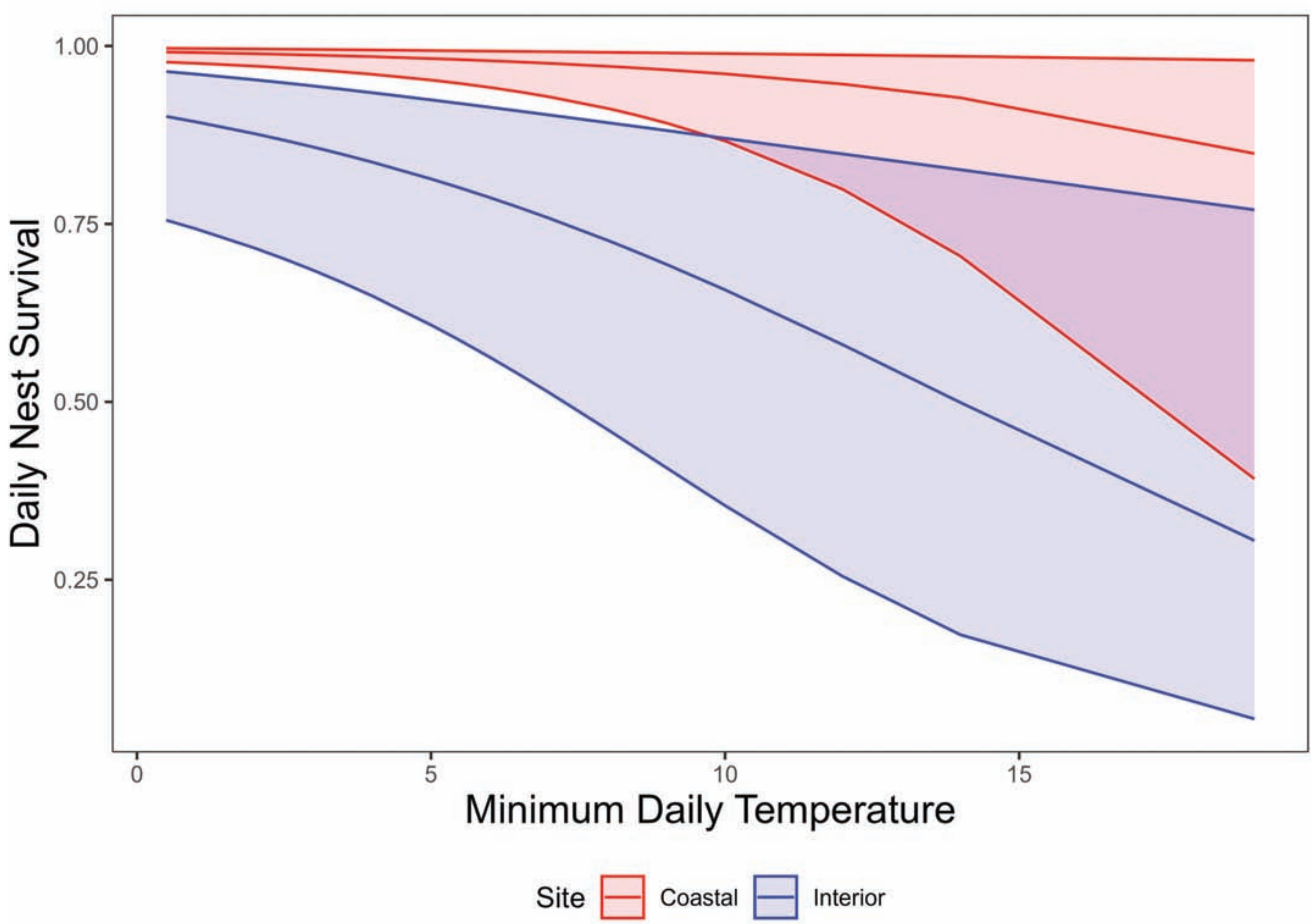


FIG. 2. Relationship between minimum daily temperature and daily survival rate in the coastal and interior areas of the Indigirka River Delta in 2023 and 2024. Nest daily survival rate declined with increasing minimum daily temperature, but only for nests at the interior delta.

large-bodied ducks, egg predation is likely facilitated by incubation breaks, by the female, that leave eggs vulnerable to egg predators. Temperature has been associated with incubation behavior in eiders. King Eiders had higher incubation constancy with increasing daily minimum temperature, indicating that females took more incubation breaks during cold temperatures; however, there was no clear association between nest survival and incubation behavior (Bentzen et al., 2008), even though this association has been established for other Arctic birds (Meyer et al., 2020). For Spectacled Eiders on the Yukon–Kuskokwim Delta, ambient temperature was not associated with the frequency or duration of incubation breaks, but females consistently took incubation breaks during the warmest hours of the day (Flint and Grand, 1999). This pattern may have reduced egg cooling but occurred at the risk of increased egg predation, as egg predators were more active during the time of day when eiders took incubation breaks (Flint and Grand, 1999). At the Delta, increased avian predator activity with temperature would lead to the observed pattern. However, this hypothesis requires additional data on predator abundance and behavior. Higher ambient temperatures may induce heat stress, prompting hens to increase the frequency of incubation recesses to dissipate excess heat. More broadly, quantifying variation in incubation constancy across temperature regimes could help clarify the relationship between weather conditions and nest survival.

An important question is whether the coastal Delta is a more favorable nesting habitat over a longer time frame compared to an inland site. The coastal Delta islands are low lying and vulnerable to wind-driven flooding, which, although infrequent, can cause large numbers of nests to fail. For instance, no flooding occurred during the 2023 nesting season, whereas, in 2024 water levels rose by approximately 0.7 m on 13 July and destroyed at least five Spectacled Eider nests. Although our three-year dataset is insufficient to evaluate flooding effects statistically, our observations suggest that flooding can be a major source of nest loss at the coastal Delta over a longer time frame. Thus, while the coastal Delta may provide higher-quality nesting habitat in most years, the interior Delta may have higher nest survival during years of extreme hydrological events due to the higher elevation of nests above sea level, especially if Indigirka runoff will increase as predicted (Gelfan et al., 2022).

Because the population ecology of Spectacled Eiders in the Delta appears broadly similar to conditions observed in the 1990s, the overall status of this species is concerning. Nest survival rates at the Delta, the largest breeding area for the species, are low and may continue to decline in a warming climate (Friendly et al., 2025). Although adult survival exerts the most influence on population trends of long-lived species like eiders (Mills, 2013), low productivity over a prolonged period can also cause population decline. Further, adult survival is likely to decline under plausible climate change scenarios (Christie et al., 2018). We highlight two priorities for Spectacled Eider conservation: (1) continued population monitoring, and (2) implementation of on-the-ground management interventions. Monitoring should encompass all critical life stages (i.e., nest and adult survival) and be conducted across the full geographic range of the species, including both Asian and North American breeding areas. Conservation actions may include collaboration with hunting management agencies to reduce harvest pressure in Asia, in addition to broader measures such as community outreach, enforcement and maintenance of legal protection, establishment of protected areas, and other targeted management practices.

Climate change has important implications for the broader community of bird species that rely on the Indigirka Delta for breeding habitat. We documented higher species diversity at the Delta compared to previous studies. The new species we documented represent both recovery from prior regional population declines and likely range expansions. Of the 10 additional species we observed, the Pacific Diver was likely present previously but not differentiated from the Arctic Diver, as Pearce et al. (1998b) classified it as an uncertain species identification. The Sandhill Crane is expanding its distribution westward in Arctic Russia (Gao et al., 2019; Rozenfeld et al., 2023). The Lesser White-fronted Goose and the Snow Goose were historically more abundant in Yakutia, but experienced substantial declines during the 20th century, most likely due to hunting and the impacts of reindeer husbandry. Since the mid-20th century, no permanent breeding grounds of the Snow Goose have been documented in the Russian Arctic outside Wrangel Island, although small numbers of breeding pairs were reported at various sites east of the Lena River Delta. Following the collapse of the Soviet Union in 1991 and the subsequent decline in reindeer husbandry, a weak trend toward recovery of Snow Goose populations has been observed (Krechmar and Kondratiev, 2006). Similarly, reduced hunting pressure since the 1990s (Klokov, 2025) may have contributed to the recovery of the Lesser White-fronted Goose. Nevertheless, both species remained rare migrants at the Delta during 2022–24, and our data are insufficient to draw robust conclusions about their current status. Pearce et al. (1998b) did not observe Pacific Golden Plover, but reported that the species was likely present and missed. We document the species as a breeder, consistent with this conclusion. Interestingly, we observed the previously unrecorded Willow Warbler and Brambling at the Delta for each of three years of our study. We suggest that the consistent presence of these two species may reflect shrub encroachment at the Delta, which is providing new breeding habitats for passerine birds (Henden et al., 2013; Boelman et al., 2015; Ktitorov et al., 2021). It is possible, however, that simply differences in weather conditions between Pearce et al. (1998b) and the present study, particularly interseasonal variation in temperature, wind, and precipitation, account for the additional species detected and absence of previously observed ones.

## CONCLUSION

Spectacled Eider nest survival rates in the Indigirka River Delta, the largest breeding area for the species, are relatively low and may continue to decline. Current population estimates offer little reason for optimism: while robust survey data are lacking, all available counts indicate reduced abundance (USFWS, 2021). This is not unexpected given the persistence of multiple threats, including climate change, predation, hunting, and lead poisoning (Flint et al., 2016; Klokov, 2025).

There is also little evidence to suggest that these threats will diminish in the foreseeable future. Climate warming poses increasing risks for Spectacled Eiders and other bird species that breed in the Arctic (Hof et al., 2017, Descamps and Strøm, 2021). Climate-related threats include increased predation risk (Ims et al., 2019), habitat alteration (Tape et al., 2012, Fedorov et al., 2024), decreased adult survival because of changes in sea ice extent (Christie et al., 2018), and more frequent extreme weather events (Overland and Wang, 2021). Hunting pressure remains a significant concern in the Russian Arctic. Although hunting intensity appears to be declining in Chukotka (Klokov, 2025), it remains widespread in Yakutia, including the Indigirka River Delta, despite the region's low human population density (Bragina et al., in prep.). Comprehensive monitoring and strengthened protection measures are needed across the Arctic for Spectacled Eiders and other Arctic-breeding birds of conservation concern.

## ACKNOWLEDGEMENTS

USFWS provided core funding for this project. Additional funds were provided by the Trust for Mutual Understanding, the U.S. Embassy in Moscow, and an anonymous private donor. R. Bentzen kindly helped to design the study. Data collection would not be possible without A.G. Dondua. We are grateful to E. Shemiakin and Y. Kazakov for logistical support. The research was carried out within the state assignment of Ministry of Science and Higher Education of the Russian Federation (theme No 124012400285-7). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the USFWS. We are grateful to the three reviewers for their constructive comments.

## REFERENCES

Bentzen, R.L., Powell, A.N., and Suydam, R.S. 2008. Factors influencing nesting success of King Eiders on northern Alaska's Coastal Plain. The Journal of Wildlife Management 72(8):1781–1789, https://doi.org/10.2193/2007-345

BirdLife International. 2018. Siberian Crane: *Leucogeranus leucogeranus*. The IUCN red list of threatened species 2018: e.T22692053A134180990. Accessed on 31 March 2026. https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22692053A134180990.en

Biskaborn, B.K., Smith, S.L., Noetzli, J., Matthes, H., Vieira, G., Streletskiy, D.A., Schoeneich, P., et al. 2019. Permafrost is warming at a global scale. Nature Communications 10:264. https://doi.org/10.1038/s41467-018-08240-4

Boelman, N.T., Gough, L., Wingfield, J., Goetz, S., Asmus, A., Chmura, H.E., Krause, J.S., et al. 2015. Greater shrub dominance alters breeding habitat and food resources for migratory songbirds in Alaskan Arctic tundra. Global Change Biology 21(4):1508–1520. https://doi.org/10.1111/gcb.12761

Burnham, K.P., and Anderson, D.R. 2002. Model selection and multimodel inference: A practical information-theoretic approach. New York: Springer-Verlag.

Choy, E.S., O'Connor, R.S., Gilchrist, H.G., Hargreaves, A.L., Love, O.P., Vézina, F., and Elliott, K.H. 2021. Limited heat tolerance in a cold-adapted seabird: Implications of a warming Arctic. Journal of Experimental Biology 224(13). https://doi.org/10.1242/jeb.242168

Christie, K.S., Hollmen, T.E., Flint, P., and Douglas, D. 2018. Non-linear effect of sea ice: Spectacled Eider survival declines at both extremes of the ice spectrum. Ecology and Evolution 8(23):11808–11818. https://doi.org/10.1002/ece3.4637

Dau, C.P., and Kistchinski, S.A. 1977. Seasonal movements and distribution of the Spectacled Eider. Wildfowl 28:65–75. https://tidsskrift.dk/Wildfowl/article/view/154357

Descamps, S., and Strøm, H. 2021. As the Arctic becomes boreal: Ongoing shifts in a high-Arctic seabird community. Ecology 102(11). https://doi.org/10.1002/ecy.3485

Dinsmore, S.J., White, G.C., and Knopf, F.L. 2002. Advanced techniques for modeling avian nest survival. Ecology 83(12):3476–3488. https://doi.org/10.1890/0012-9658(2002)083[3476:ATFMAN]2.0.CO;2

Ely, C.R., Dau, C.P., and Babcock, C.A. 1994. Decline in a population of Spectacled Eiders nesting on the Yukon-Kuskokwim Delta, Alaska. Northwestern Naturalist 75(3):81–87. https://doi.org/10.2307/3536829

Fedorov, A.N., Konstantinov, P.Y., Vasilyev, N.F., Varlamov, S.P., Skachkov, Y.B., Gorokhov, A.N., Kalinicheva, S.V., et al. 2024. Climate and permafrost shifts in Yakutia's Arctic and subarctic from 1965 to 2023. Land 13(12). https://doi.org/10.3390/land13122150

Fiskum, A.S. 2024. Food provisioning, diel activity, and home range size in the glaucous gull (*Larus hyperboreus*) on Bjørnøya. MS Thesis, Norwegian University of Life Sciences. https://static02.nmbu.no/mina/studier/moppgaver/2024-Fiskum.pdf

Flint, P.L., and Grand, J.B. 1999. Incubation behavior of Spectacled Eiders on the Yukon-Kuskokwim Delta, Alaska. Condor 101(2):413–416. https://doi.org/10.2307/1370007

Flint, P.L., Grand, J.B., and Petersen, M.R. 2016. Effects of lead exposure, environmental conditions, and metapopulation processes on population dynamics of Spectacled Eiders. North American Fauna (81):1–41. https://doi.org/10.3996/nafa.81.0001

Friendly, R.J., Lindberg, M.S., and Rizzolo, D.J. 2025. Carry-over effects of winter conditions on nesting *Somateria fischeri* (Spectacled Eider), a sea ice-associated sea duck. Ornithology (March):1–15. https://doi.org/10.1093/ornithology/ukaf008

Gao, L., Mi, C., and Guo, Y. 2019. Expansion of sandhill cranes (*Grus canadensis*) in east Asia during the non-breeding period. PeerJ 2019(8):1–15. https://doi.org/10.7717/peerj.7545

Gelfan, A.N., Gusev, E.M., Kalugin, A.S., Krylenko, I.N., Motovilov, Y.G., and Nasonova, O.N. 2022. Runoff of Russian rivers under current and projected climate change: A review 2. Climate Change Impact on the Water Regime of Russian Rivers in the XXI Century. 49(3):351–365.
https://doi.org/10.1134/S0097807822030058

Grand, J.B., and Flint, P.L. 1997. Productivity of nesting Spectacled Eiders on the lower Kashunuk River, Alaska. Condor 99(4):926–932.
https://doi.org/10.2307/1370143

Henden, J.A., Yoccoz, N.G., Ims, R.A., and Langeland, K. 2013. How spatial variation in areal extent and configuration of labile vegetation states affect the riparian bird community in Arctic tundra. PLoS ONE 8(5).
https://doi.org/10.1371/journal.pone.0063312

Hepp, G.R., and Kennamer, R.A. 2012. Warm is better: Incubation temperature influences apparent survival and recruitment of Wood Ducks (*Aix sponsa*). PLOS ONE 7(10): e47777.
https://doi.org/10.1371/JOURNAL.PONE.0047777

Hodges, J.I., and Eldridge, W.D. 2001. Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. Wildfowl 52:127–142.
https://tidsskrift.dk/Wildfowl/article/view/153962

Hof, A.R., Rodríguez-Castañeda, G., Allen, A.M., Jansson, R., and Nilsson, C. 2017. Vulnerability of subarctic and Arctic breeding birds. Ecological Applications 27(1):219–234.
https://doi.org/10.1002/eap.1434

Hope, S.F., Kennamer, R.A., Grimaudo, A.T., Hallagan, J.J., and Hopkins, W.A. 2020. Incubation temperature affects duckling body size and food consumption despite no effect on associated feeding behaviors. Integrative Organismal Biology 2(1): obaa003.
https://doi.org/10.1093/IOB/OBAA003

Ims, R.A., Henden, J.A., Strømeng, M.A., Thingnes, A.V., Garmo, M.J., and Jepsen, J.U. 2019. Arctic greening and bird nest predation risk across tundra ecotones. Nature Climate Change.
https://doi.org/10.1038/s41558-019-0514-9

Klokov, K. 2025. Modern bird hunting in the Arctic: An experience of socio-ecological assessment on the example of eastern Chukotka. Etnografia 2025(1):170–195.
https://doi.org/10.31250/2618-8600-2025-1(27)-170-195

Krechmar, A.V., and Kondratiev, A.V. 2006. Waterfowl birds of north-east Asia. Magadan: NESC FEB RAS.

Ktitorov, P., Ivanov, S., Kornilova, E., Kulikova, O., Ris, H., Sokolovskis, K., and Solovyeva, D. 2021. Shrub-dwelling species are joining the Arctic passerine bird community in the Chaun Delta (Western Chukotka, Russia). Polar Biology 44(9):1847–1857.
https://doi.org/10.1007/s00300-021-02915-3

Laake, J.L. 2013. RMark: An R interface for analysis of capture-recapture data with MARK. Alaska Fisheries Science Center. Processed Rep. 2013-01.
https://repository.library.noaa.gov/view/noaa/4372

Lee, H., and Romero, J. 2023. IPCC, 2023: Summary for policymakers. In: Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. 1–34.
https://www.ipcc.ch/report/ar6/syr/

Maher, W.J. 1974. Ecology of pomarine, parasitic, and Long-Tailed Jaegers in northern Alaska. Pacific Coast Avifauna 37.
https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1033&context=pca

Meyer, N., Bollache, L., Dechaume-Moncharmont, F.X., Moreau, J., Afonso, E., Angerbjörn, A., Bêty, J., et al. 2020. Nest attentiveness drives nest predation in Arctic sandpipers. Oikos 129(10):1481–1492.
https://doi.org/10.1111/oik.07311

Miller, M.W.C., Lovvorn, J.R., Graff, N.R., and Stellrecht, N.C. 2022. Use of marine vs. freshwater proteins for egg-laying and incubation by sea ducks breeding in Arctic tundra. Ecosphere 13(6):1–17.
https://doi.org/10.1002/ecs2.4138

Mills, L.S. 2013. Conservation of wildlife populations : Demography, genetics, and management. Chichester, West Sussex: Wiley-Blackwell.

Myers-Smith, I.H., and Hik, D.S. 2018. Climate warming as a driver of tundra shrubline advance. Journal of Ecology 106(2):547–560.
https://doi.org/10.1111/1365-2745.12817

Overland, J.E., and Wang, M. 2021. The 2020 Siberian heat wave. International Journal of Climatology 41(S1):E2341–E2346.
https://doi.org/10.1002/joc.6850

Pearce, J., Esler, D., and Degtyarev, A.G. 1998a. Nesting ecology of Spectacled Eiders *Somateria Fischeri* on the Indigirka River Delta, Russia. Wildfowl 49:110–123.
https://tidsskrift.dk/Wildfowl/article/view/154611

Pearce, J., Esler, D., and Degtyarev, A.G. 1998b. Birds of the Indigirka River Delta, Russia: Historical and biogeographic comparisons. Arctic 51(4):361–370.
https://doi.org/10.14430/arctic1079

Petersen, M.R., Grand, J.B., and Dau, C.P. 2005. Spectacled Eider (*Somateria fischeri*). The birds of North America Online. https://doi.org/10.2173/bna.547

Quinn, J.L., and Ueta, M. 2008. Protective nesting associations in birds. Ibis 150(SUPPL.1):146 – 167. https://doi.org/10.1111/j.1474-919X.2008.00823.x

R Core Team. 2024. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.scirp.org/reference/referencespapers?referenceid=3887298

Ralph, C.J., Sauer, J.R., and Droege, S. 1995. Monitoring bird populations by point counts. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. https://doi.org/10.2737/PSW-GTR-149

Rizzolo, D.J., Bishop, L.R., Safine, D.E., and Bowman, T.D. 2021. Late winter abundance and distribution of Spectacled Eiders in the Bering Sea: Aerial survey results, 03 – 04 March 2020. Fairbanks, AK.

Rotella, J.J., Dinsmore, S.J., and Shaffer, T.L. 2004. Modeling nest-survival data: A comparison of recently developed methods that can be implemented in MARK and SAS. Animal Biodiversity and Conservation 27(1):187 – 205. https://doi.org/10.32800/abc.2004.27.0187

Rozenfeld, S.B., Bysykatova-Harmey, I.P., Barykina, D.A., Kirtaev, G.K., and Solovyeva, D.V. 2023. Modern trends in populations of the Siberian Crane (*Grus leucogeranus*) and the Sandhill Crane (*Grus canadensis*) (Gruidae, Gruiformes) on the Tundra of Yakutia and Chukotka Based on Aerial Surveys. Biology Bulletin 50(8):1977 – 1989. https://doi.org/10.1134/S106235902308023X

Solovyeva, D.V., Vartanyan, S.L., Frederiksen, M., and Fox, A.D. 2018. Changes in nesting success and breeding abundance of Spectacled Eiders *Somateria fischeri* in the Chaun Delta, Chukotka, Russia, 2003 – 2016. Polar Biology 41(4):743 – 751. https://doi.org/10.1007/s00300-017-2235-8

Solovyeva, D., Barykina, D.A., Prokopenko, O.D., Balsby, T.J.S., and Fox, A.D. 2022. Annual variation in waterbird clutch initiation date in relation to spring thaw in Arctic Russia. International Journal of Biometeorology 66(5):1005 – 1012. https://doi.org/10.1007/s00484-022-02256-8

Stehn, R.A., Dau, C.P., Conant, B., and Butler, W.I. 1993. Decline of Spectacled Eiders nesting in western Alaska. Arctic 46(3):264 – 277. https://doi.org/10.14430/arctic1352

Stishov, M.S., Chernov, Y.I., and Vronskiy, N.V. 1989. Fauna and bird population of Arctic tundra subzone. Birds in Communities of Tundra Zone. Moscow: Nauka. 5 – 39.

Tape, K.D., Hallinger, M., Welker, J.M., and Ruess, R.W. 2012. Landscape heterogeneity of shrub expansion in Arctic Alaska. 15(5):711 – 724. https://link.springer.com/article/10.1007/s10021-012-9540-4

Troeva, E., Isaev, A.P., Cherosov, M.M., and Karpov, N.S. 2010. Plant biodiversity and ecology of Yakutia. Dordrecht: Springer.

Westerkov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14(1):56 – 67. https://doi.org/10.2307/3795978

Wilson, H.M., Safine, D.E., Frost, C.J., and Osnas, E.E. 2025. Population indices, trends, and distribution of breeding waterbirds on the Arctic Coastal Plain, Alaska, 2007 – 2024. US Fish and Wildlife Service Unpublished Report 1 – 110.

USFWS (U.S. Fish and Wildlife Service). 1993. Endangered and threatened wildlife and plants: Final rule; final rule to list Spectacled Eider as threatened. Federal Register 58(88):27474 – 27480. https://www.fws.gov/sites/default/files/federal_register_document/FR-1993-05-10.pdf

———. 2021. Species status assessment for the Spectacled Eider. Fairbanks Field Office, Fairbanks, Alaska. https://ecos.fws.gov/ServCat/DownloadFile/209520