

**Species Status Assessment for the
Alaska-breeding Population of Steller's Eiders
(*Polysticta stelleri*)**



Photo credit: Kevin McDonald (USFWS)

**U.S. Fish and Wildlife Service
Alaska Region
Northern Alaska Fish and Wildlife Field Office
Version 2.0
March 2025**

Suggested citation: U.S. Fish and Wildlife Service. 2025. Species Status Assessment for the Alaska-breeding Population of Steller’s Eiders (*Polysticta stelleri*), Version 2.0, March 2025. USFWS Northern Alaska Fish and Wildlife Field Office, Fairbanks, Alaska. 209 pp.

VERSION HISTORY

The Species Status Assessment (SSA) for the Alaska-breeding population of Steller’s eiders (USFWS 2019b, p. 1-149) was revised concurrent with the review of new information for conducting the 5-year Review (89 FR 1125 1126) in 2024. In version 2.0 of the SSA, we updated data where possible from monitoring and research projects conducted in recent years and re-analyzed population estimates of the Alaska-breeding population of Steller’s eiders (replacing and updating methods described in Appendix A from version 1.0, USFWS 2019b). In addition, we added Appendix E to incorporate additional information on the larger Pacific-wintering population (PWP) of Steller’s eiders because the revised recovery plan (USFWS 2021b, p. 1-23) includes criteria for understanding the trend of the larger PWP of Steller’s eiders, as the condition of the PWP is an important factor to consider in determining recovery of the listed population.

TABLE OF CONTENTS

TABLE OF CONTENTS..... 3

EXECUTIVE SUMMARY 6

1. BACKGROUND 10

2. INTRODUCTION 12

3. TAXONOMY AND PHYSICAL DESCRIPTION 14

4. LIFE CYCLE AND DISTRIBUTION 15

5. INFLUENTIAL FACTORS 20

 5.1. Factors influencing reproduction 21

 5.2. Factors influencing egg and nest survival 26

 5.3. Factors influencing duckling survival 28

 5.4. Factors affecting the western Alaska subpopulation during the breeding season 29

 5.5. Marine factors influencing survival and breeding propensity of adults and juveniles 29

 5.6. Defining the characteristics of a highly viable population of Steller’s eiders 35

6. CURRENT CONDITION OF THE POPULATION 37

 6.1. Abundance and population growth rate 37

 6.1.1. Western Alaska subpopulation 37

 6.1.2. Northern Alaska subpopulation 40

 6.1.3. Summary of population abundance data 48

 6.2. Demographic Rates 49

 6.2.1. Reproductive rates 49

 6.2.2. Survival 50

 6.2.3. Connectivity with the Russian-Pacific breeding population 51

 6.2.4. Resiliency of the Russian-Pacific breeding population 55

 6.2.5. Population dynamics modeling 57

 6.3. Population Viability Analyses 57

 6.4. Stressors 60

 6.4.1. Causes of decline 60

 6.4.2. Cause and effects analysis 60

6.5. Resiliency of the northern Alaska subpopulation	66
6.5.1. Current condition of Steller’s eider habitat requirements	66
6.5.2. Current condition - abundance and connectivity	69
6.5.3. Summary – Resiliency of northern sub-population	70
6.6. Resiliency of western Alaska subpopulation.....	72
6.7. Representation and redundancy of Alaska-breeding population.....	72
6.8. Summary: current viability of Alaska-breeding population	73
7. FUTURE CONDITION.....	74
7.1. Climate change.....	74
7.1.1. Climate change predictions	74
7.1.2. Possible impacts to Steller’s eider habitat and demographic rates.....	75
7.2. New stressors.....	79
7.3. Future scenarios.....	82
7.3.1. Methods.....	82
7.3.2. Results.....	86
8. CONCLUSION.....	88
9. LITERATURE CITED	90
Appendix A. Methods and results for estimating Alaska-breeding Steller’s eider numbers across the Arctic Coastal Plain, including the Utqiagvik Triangle area. From: USFWS 2024, entire.	109
Introduction	111
Methods.....	112
Survey areas and data source	112
Design-based estimates	113
Model-based estimates	114
Prediction and posterior simulation	116
Incorporating detection	117
Wavelet analysis	119
Results and Interpretation	120
Observations of Steller’s eider.....	120
Design-based estimates	122
Model-based Estimates: Triangle	124
Model-based Estimates: ACP	129

Model-based Estimates: Triangle and ACP combined	133
Wavelet analysis	136
Results summary.....	138
Discussion and Recommendations	138
References	142
Supplemental Material	144
Acknowledgements.....	145
Disclaimer.....	145
Version	145
Suggested Citation	145
Appendix B. Five competing model structures of population process and associated vital rates used in an attempt to describe the resiliency of the northern Alaska subpopulation of Steller’s eiders during this SSA analysis.....	146
Appendix C. Influence diagrams depicting pathways of how influential factors may affect the habitat and circumstances required for individual Steller’s eiders to survive and reproduce, and how those effects may influence demographic rates and, ultimately, resiliency of the population.	148
Appendix D. Cause and Effect Tables. This appendix describes how stressors may contribute to the current condition of the northern Alaska subpopulation of Steller’s eiders.....	150
Appendix E. Status of the Pacific-wintering population of Steller’s eiders	202

EXECUTIVE SUMMARY

This species status assessment (SSA) was developed to inform a 5-year status review (hereafter, 5-year review) of the Alaska-breeding population of Steller's eiders required under the Endangered Species Act (ESA). The Alaska-breeding population of Steller's eiders was listed as threatened under the ESA in 1997 due to the contraction of its breeding range in Alaska, resulting in the risk of becoming endangered due to natural and human-caused factors. The Alaska-breeding population was recognized as a distinct population segment (DPS) because it was considered both discrete and significant based on definitions of those terms in U.S. Fish and Wildlife Service (Service) policy.

This SSA synthesizes the available information on the listed population of Steller's eiders and provides an assessment of the population's current and future viability. Viability is defined as the likelihood that a species will persist over time and is a product of resiliency, representation, and redundancy. Viability is usually described at the species level. In this case, however, our primary interest is in the likelihood that a breeding population of Steller's eiders will persist in Alaska over time. We considered the Alaska-breeding population to be comprised of two geographic subunits, called "subpopulations": northern Alaska and western Alaska subpopulations. Here, we define **resiliency** as the ability of a subpopulation to withstand stochastic events, which is positively related to subpopulation size and growth rate. **Representation** is the ability of a population to adapt to environmental conditions over time and is characterized by genetic and ecological diversity within and among subpopulations. **Redundancy** is the ability of a population to withstand catastrophic events and is characterized by the number of resilient subpopulations distributed within the population's ecological settings and historical range. We also considered the impact of connectivity with the larger Russian-Pacific breeding population in evaluations of resiliency.

Alaska-breeding Steller's eiders spend the majority of their lives in the marine environment, occupying terrestrial habitats only during the breeding season, which occurs from approximately early June to early September. Nesting in northern Alaska is concentrated in polygonal tundra wetland habitat near Utqiagvik and occurs at lower densities elsewhere on the Arctic Coastal Plain (ACP). There is considerable uncertainty about specific habitat requirements of Alaska-breeding Steller's eiders, but based on the available information, factors that may influence demographic rates include: the quantity and quality of freshwater invertebrates, functional lemming-avian predator dynamics, the presence of polygonal tundra (both macro- and micro-level characteristics), lack of disturbance of incubating females, and duckling access to sources of freshwater.

After nesting, Alaska-breeding Steller's eiders migrate along the coast to southwest Alaska, where they undergo a flightless molt and mix with the larger Russian-Pacific breeding population. During molt they primarily occupy shallow marine areas with extensive eelgrass beds and/or intertidal mud and sand flats. After molt, Pacific-wintering Steller's eiders disperse throughout the Aleutian Islands, Alaska Peninsula, and western Gulf of Alaska including Kodiak Island and lower Cook Inlet until migrating back to the nesting areas in spring. In the marine environment, factors that may affect demographic rates include: quantity and quality of marine invertebrates; availability of shallow, nearshore mudflats and

sand flats and/or rocky intertidal areas, eelgrass beds, and deep ice-free waters; and other micro-habitat characteristics.

To evaluate the current resiliency of the subpopulations (western and northern Alaska), we considered information on abundance, vital rates, and the condition of habitat requirements, including stressors that may affect individuals and habitat. Very few observations of Steller's eiders have been made in western Alaska breeding areas since listing. The feasibility of reintroduction was evaluated by the Service and the Eider Recovery Team and ultimately determined to not be a viable recovery tool in the foreseeable future. Therefore, the western Alaska subpopulation is considered nearly extirpated, and the Alaska-breeding population is essentially reduced to one subpopulation in northern Alaska.

Regarding the northern Alaska subpopulation, the number of Steller's eiders present on the ACP annually is low and highly variable. Abundance and population trend of the subpopulation are not estimable because we cannot determine the proportion of the population available to be counted annually on the ACP. Measures of productivity such as breeding propensity and nest survival are also highly variable and difficult to estimate. Estimates of adult annual survival of Steller's eiders range from 0.75 to 0.86, but it is uncertain how these estimates relate to that of the entire northern Alaska subpopulation. Tundra and marine habitat conditions are influenced by highly variable environmental factors and ecological factors that are changing. This is demonstrated in the high annual variability in reproductive rates such as breeding propensity and nest survival near Utqiagvik.

Several potential stressors (i.e., threats) may affect the resiliency of the northern Alaska subpopulation of Steller's eiders in tundra habitat (breeding season) and marine habitat (molting, wintering, and migration). In tundra areas, we concluded that ingestion of lead shot and shooting may have a high effect on the resiliency of the northern subpopulation of Steller's eiders because they directly affect adult survival and likely occur more often in areas with the highest density of nesting eiders (i.e., near the town of Utqiagvik). Collisions with power lines and other structures are considered a moderate stressor, as there are likely fewer individuals impacted annually compared to those exposed to lead or shooting. Human disturbance, avian and fox predation, and changes to the lemming-avian predator system on the ACP moderately affect population resiliency as they likely reduce reproductive success and productivity of a significant portion of the northern subpopulation. Habitat loss due to oil and gas development in other parts of the ACP, such as eastern National Petroleum Reserve- Alaska (NPR-A) and Prudhoe Bay, has a low effect on subpopulation resiliency due to the very low density of Steller's eiders in those areas. We also identified that changes have already occurred to tundra habitat due to climate change, and the nesting goose populations on the ACP have increased in recent decades, but the effect of these changes to Steller's eiders and the subpopulation's resiliency is unknown.

In marine areas, harsh winter weather, predation by eagles or other predators, disposal of fish processing waste, changing marine conditions in the Bering Sea and North Pacific, contaminants, disease, and human disturbance pose possible effects to resiliency, but the magnitude of effect is unknown. Shooting in marine areas is thought to currently have a low effect on resiliency because it is unlikely given their remote distribution.

In summary, based on an evaluation of the potential stressors and available data on habitat condition, tundra nesting habitat (at a large scale) and duckling access to fresh water are in high condition in northern Alaska. The presence of incubating females (i.e., lack of disturbance) is in moderate condition given the human activities in the densest area of Steller's eider nesting. Changes in the lemming-avian predator system are occurring near Utqiagvik; thus, that factor is considered in low condition. The condition of micro-level components of polygonal tundra habitat and the availability of freshwater invertebrates are unknown. In marine habitats, at a large scale, there is abundant shallow, nearshore, and deep ice-free waters in southwest Alaska; thus, we consider those factors to be in high condition. However, the condition of marine invertebrates and other micro-habitat characteristics is unknown across most marine areas used by Steller's eiders. We used abundance as a demographic measure of condition and consider it low given that only a few hundred Steller's eiders are present in northern Alaska annually.

The viability of the Alaska-breeding population may be tied to the viability of the Russia-Pacific breeding population if the Russian population provides recruits to Alaska. Information on the degree of connectivity between the breeding populations is limited. However, Pearce et al. (2005) analyzed tissue samples collected from Steller's eiders across their range to explore levels of genetic population differentiation. Tests of nuclear and mitochondrial DNA did not detect significant patterns of differentiation between the two breeding areas but did provide evidence of male dispersal and some female philopatry. Mark-recapture analysis of nesting females and egg membranes suggests high philopatry and female breeding site fidelity of birds within the Utqiagvik study area (Safine et al. 2020, p. 355). This work also suggests that temporary emigration is high; in some years females do not return to nest, but it is unknown if their absence is because they forgo nesting that year or nest in areas outside of the search area (in Alaska or Russia) (Safine et al. 2020, p. 355-358). Estimates of immigration, or the number of recruits entering the Alaska-breeding population from the Pacific-Russian population, are not available. Population modeling using aerial survey data suggest that the rates of immigration must be high in some years to sustain the population (Dunham and Grand 2016).

Attempts at estimating population viability offer equivocal results (Runge 2004, Dunham and Grand 2017; C. Bradley, USFWS Biometrician, pers. comm.); given the inadequacy of estimates of demographic parameters and population abundance, population viability is inestimable at this time.

In addition to resiliency, we considered redundancy and representation of the Alaska-breeding population. One subpopulation (the northern Alaska subpopulation) currently exists in Alaska. The northern Alaska subpopulation has a relatively wide distribution on the ACP, but very low densities outside of the Utqiagvik Triangle. The wide distribution during molt, winter, and staging, assuming even distribution of Alaska-breeding birds with the Pacific-Russian breeding birds, may provide some protection from a catastrophic event should one occur in a part of the non-breeding range. Overall, however, the Alaska-breeding population has low redundancy.

The Alaska-breeding population historically occupied two ecological settings in the breeding season – Arctic and subarctic tundra. They are now restricted to the Arctic, and possibly prefer specific habitats near Utqiagvik. Variation in behavior or life history strategy may exist, but it has not been tested.

Steller's eiders demonstrate some behavioral plasticity in their ability to respond to ice cover in winter by moving to deeper water, and they consume a variety of marine invertebrate species. Population genetic analyses show no sign of lack of genetic diversity, which is likely maintained by male-mediated gene flow, but there are no data on genetic adaptive potential. Overall, the available data suggests that the population has moderate representation (i.e., the ability to adapt to environmental changes).

In the future, we predict that the current stressors will continue, and possibly increase. In addition, within the range of Alaska-breeding Steller's eiders, increased marine shipping activities will increase oil spill and collision risks, oil and gas development (both tundra and offshore) is likely to increase, and community infrastructure at Utqiagvik will increase, thus increasing habitat loss, disturbance, collisions, and other anthropogenic factors. In addition, climate change will likely impact both the tundra and marine environments significantly. Given hypothetical but plausible scenarios of a range of management actions and possible changes to habitat due to climate change, we predicted that the resiliency of the northern Alaska subpopulation is likely to, at best, increase slightly or remain low. At worst, resiliency will decrease due to the effects of climate change and continuing stressors. We expect no increases in redundancy (currently low) or representation (currently moderate) of the Alaska-breeding population under either scenario.

1. BACKGROUND

Three breeding populations of Steller's eiders (*Polysticta stelleri*) are recognized – two in Arctic Russia and one in Alaska. In Arctic Russia, nesting distribution may overlap on the Taymyr Peninsula (Petersen et al. 2006, pp. 61-62), but, in general, the Russian-Atlantic breeding population nests west of the Khatanga River in Siberia and winters in the Barents and Baltic Seas, and the Russian-Pacific breeding population nests east of the Khatanga River and winters in the southern Bering Sea and northern Pacific Ocean. The Alaska-breeding population consists of two breeding subpopulations, referred to as the northern and western Alaska subpopulations, and mixes with the Russian-Pacific breeding population in the winter, which, combined, we refer to as the Pacific-wintering population of Steller's eiders in this assessment (USFWS 2002a, p. 4; Figure 1).

The Alaska-breeding population of Steller's eiders was listed as threatened under the Endangered Species Act (ESA) in 1997 due to the contraction of its breeding range in Alaska, resulting in the risk of becoming endangered due to natural and human-caused factors (62 FR 31748). The Alaska-breeding population was recognized as a distinct population segment (DPS) because it was considered both discrete and significant based on definitions of those terms in U.S. Fish and Wildlife Service (Service) policy (96 FR 4722). The population is discrete given its physical separation from Russia nesting populations by hundreds of kilometers across the Bering and Chukchi Seas. In addition, the Alaska-breeding population is delimited by an international boundary, marking differences in conservation status as demonstrated by the significantly higher abundance of the Russian-Pacific breeding population, and differences in conservation laws and mechanisms for implementing conservation in the two countries at the time of ESA listing (see Appendix E: Conservation status of Steller's eiders in Russia). The Alaska-breeding population is significant because the loss of the population would represent a significant reduction in the species' breeding range worldwide (62 FR 31748). While the Alaska-breeding population meets the definitions of discrete and significant set in Service policy, information about the biological connectivity (fidelity, gene flow, etc.) between the two breeding populations was not available at the time of listing.

In western Alaska, the species historically occurred on the coastal fringe of the Yukon-Kuskokwim Delta (Y-K Delta). Steller's eiders nested and were considered a common breeding bird at Kokechik Bay in the 1924 expedition to the area (62 FR 31748). In addition, low numbers of nests were reported in southwestern Alaska, the Seward Peninsula, and St. Lawrence Island prior to 1960 (62 FR 31748). Beginning in the 1960s few nests were observed by biologists despite considerable research activity in the area (Kertell 1991, p. 180, 62 FR 31748). The apparent loss of breeding Steller's eiders on the Y-K Delta represented the loss of the only subarctic portion of the species' breeding range.

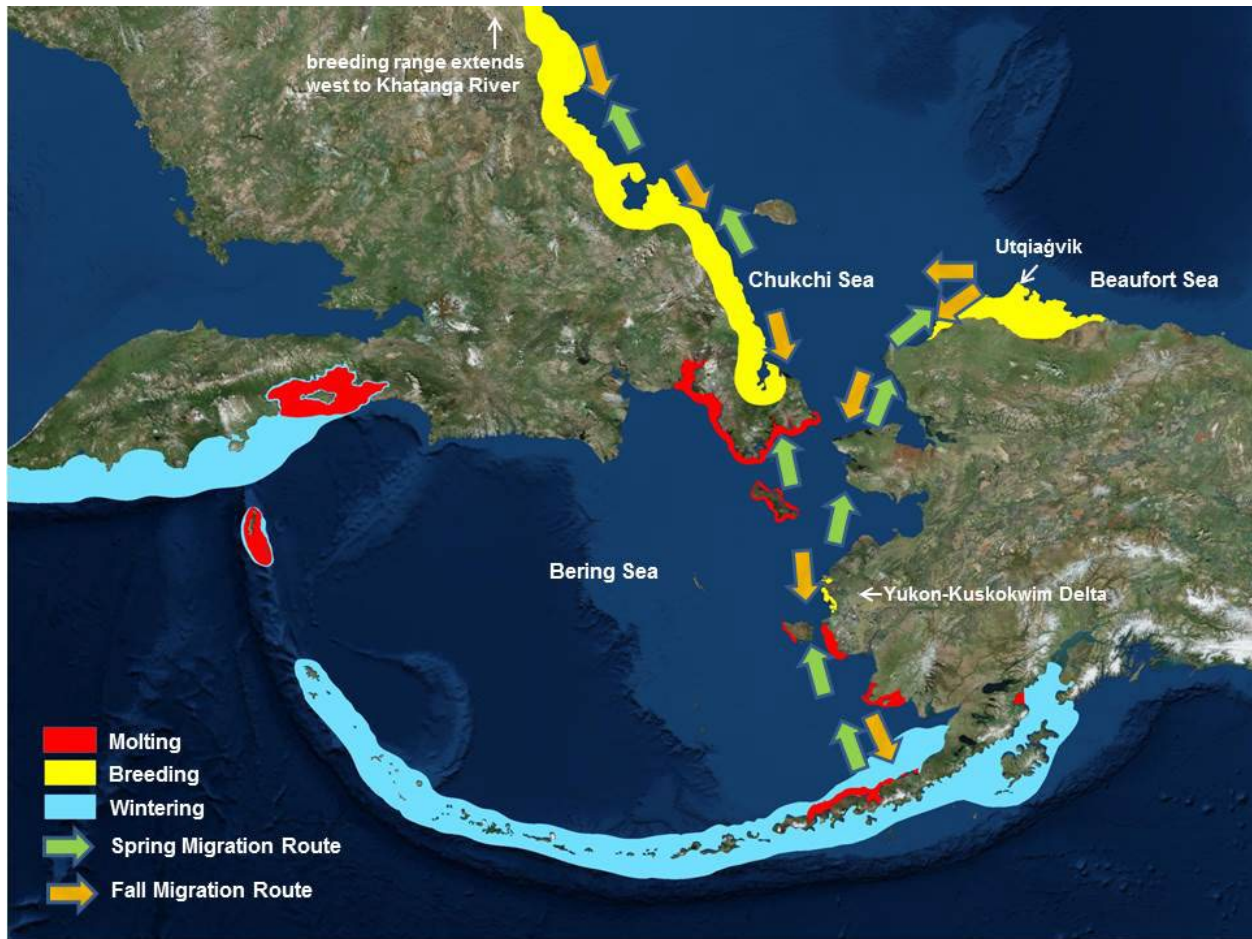


Figure 1. Distribution and general migration pathways of the Russian-Pacific breeding and Alaska-breeding populations (combined, referred to as the Pacific-wintering population).

The range of nesting Steller’s eiders also apparently contracted in northern Alaska. Naturalists observed Steller’s eiders in the eastern Arctic Coastal Plain (ACP) near Camden Bay, Barter Island, and Demarcation Bay in the 1910s and 1930s, and nests were recorded at sites in the central ACP near Cape Halkett and the Colville River Delta in the 1940s and 1950s (62 FR 31748). However, based on aerial and ground surveys in the 1980s and 1990s, Steller’s eider densities were considered extremely low throughout the ACP, and observations, particularly of nesting birds, were concentrated near Utqiagvik (formerly Barrow; 62 FR 31748). The cause(s) of the contraction in range of Steller’s eiders in Alaska are unknown.

In 2001, the Service designated 2,830 mi² (7,330 km²) of critical habitat for the Alaska-breeding population of Steller’s eiders, including historical breeding areas on the Y-K Delta; molting and staging areas in the Kuskokwim Shoals and Seal Islands; and molting, wintering, and staging areas at Nelson Lagoon and Izembek Lagoon (66 FR 8850). No critical habitat for Steller’s eiders has been designated on the ACP.

2. INTRODUCTION

The Species Status Assessment (SSA) version 1.0 was first developed to inform the 2019 5-year status review of the Alaska-breeding population of Steller’s eiders required under the ESA (hereafter, 5-year review). Concurrent with conducting the 2024 5-year review, we updated the SSA (version 2.0) to reflect new information since the previous 5-year review in 2019, including updates to the current condition section (Section 6) from ongoing aerial and ground surveys. We replaced Appendix A with the most up-to-date methods and results for estimating population size and trend of the northern Alaska subpopulation of Alaska-breeding eiders. Since the previous 5-year review, the Recovery Plan was revised (USFWS 2021, entire) and now incorporates demographic criteria of the larger Pacific wintering population of Steller’s eiders, so we added Appendix E to the SSA to describe the status of the larger Pacific population from various survey data in the wintering range of Alaska and Pacific-breeding range in Russia. The 2025, version 2.0 SSA synthesizes the current, best available information on the listed population of Steller’s eiders and provides an assessment of the population’s current and future viability.

Our analysis follows the SSA guidelines developed by the Service (USFWS 2016a), in which viability is defined as the likelihood that a species will persist over time and is a product of resiliency, representation, and redundancy, otherwise known as “the three Rs” (USFWS 2016a, p. 12-13). Viability is usually described at the species level. In this case, however, our primary interest is in the likelihood that a breeding population of Steller’s eiders will persist in Alaska over time. We consider the Alaska-breeding population to be comprised of two geographic subunits, called “subpopulations”: northern Alaska and western Alaska subpopulations (USFWS 2002a, p. 7). Here, we define **resiliency** as the ability of a subpopulation to withstand stochastic events, which is positively related to subpopulation size and growth rate. **Representation** is the ability of a population to adapt to environmental conditions over time and is characterized by genetic and ecological diversity within and among subpopulations. **Redundancy** is the ability of a population to withstand catastrophic events and is characterized by the number of resilient subpopulations distributed within the population’s ecological settings and historical range. In summary, we evaluated resiliency at the subpopulation level (northern and western Alaska subpopulations), and redundancy and representation at the population level (the Alaska-breeding population as a whole). We also considered the impact of connectivity with the larger Russian-Pacific breeding population in evaluations of resiliency.

To improve transparency, the SSA process was developed by the Service to separate evaluations of the best available science from the decision-making process that necessarily combines scientific evaluations with policy interpretation and risk assessment. While we limited this analysis to assessing the available scientific information and traditional ecological knowledge (TEK), we found it useful to identify the upcoming policy decisions and management needs to focus our analysis on the topics pertinent to those

decisions. This SSA is intended to be the basis for future recovery plan revisions, consultations with Federal agencies under ESA Section 7(a)(1) and 7(a)(2), prioritizing recovery actions, and other recovery program needs. However, the most pressing management task is the completion of a 5-year review of Alaska-breeding Steller's eiders. The primary purpose of a 5-year review is to determine, given new information since the last 5-year review (or, in this case, since listing), whether a proposal to re-classify the listed entity under the ESA should be developed. Additionally, distinct population segment designations are reviewed in light of new information on the population's biology and interpretation of policy.

In addition to using the available information in scientific literature and agency reports, we considered TEK gained through community visits, meetings of management councils such as the Alaska Migratory Bird Co-Management Council, and conversations with local communities over the past few decades. We are not aware of specific TEK reports or quantitative information resulting from TEK surveys on Steller's eiders. However, these conversations and meetings have informed our thought process in a general way; for example, we have learned through years of working on the ACP that Steller's eiders are not considered an important subsistence resource because of their rarity and small size. This lack of emphasis on harvesting Steller's eiders may also contribute to the apparent paucity of TEK on the species in Alaska.

We started the assessment by describing taxonomy and physical characteristics and the circumstances and resources that influence the ability of individuals in the Alaska-breeding population to successfully complete each life stage. We then evaluated the demographic and influential factors that may affect individual requirements and the current and future resiliency of the northern Alaska and western Alaska subpopulations and assessed the current and future representation and redundancy of the Alaska-breeding population.

3. TAXONOMY AND PHYSICAL DESCRIPTION

Steller's eiders are the sole member of the genus *Polysticta*. Based on a recent mitochondrial DNA genomic analysis, the Steller's eider is most closely related to the extinct Labrador duck (*Camptorhynchus labradorius*) within the sea duck tribe *Mergini* and is basal to the three other extant eider species in the genus *Somateria* (Buckner et al. 2018, p. 105). A recent analysis based on the nuclear genome and mitogenome (Lavretsky et al. 2021, p. 8) also corroborates results from Buckner et al. (2018) that Steller's eiders are distinct from true eiders. The Steller's eider may be a result of an ancestral gene flow event between long-tailed ducks and true eiders (*Somateria spp.*), and the resulting hybrids may have diverged into what we consider Steller's eiders today (Lavretsky et al. 2021, p. 8).

The Steller's eider is a small, compact sea duck, with an average body mass of 852 g (female) to 877 g (male) (Frederickson 2001, p. 2). It has a thick-based, slightly drooping bill and steep forehead and nape. While more closely related to large eiders, it resembles dabbling ducks in size, appearance, and the body-tipping foraging behaviors employed on the tundra breeding grounds. Compared to the large eiders, the body mass of Steller's eiders is 60% of spectacled eider (*Somateria fischeri*), 53% of king eider (*S. spectabilis*), and 34% of the common eider (*S. mollissima*) (Frederickson 2001, p. 2).

Steller's eider plumage is sexually dimorphic. Males are in breeding (alternate) plumage from early winter through mid-summer. They have a large white shoulder patch contrasting with chestnut breast and belly that darkens centrally, and a black spot on each side in front of their wings. Their head is white to silver with pale green on the lores, a distinctive black spot surrounding eye, and a dark olive patch flanked by black on the nape. Their neck is black, extending in arrow shape down the back. The non-breeding (basic) male plumage resembles female plumage but maintains white upper wing coverts. Females are dark mottled brown with a white-bordered blue wing speculum. Juveniles are dark mottled brown until fall of their second year, when they acquire breeding plumage. During flight, adult Steller's eiders are distinguished from other eiders by their faster wing beat, small size, black back, white belly, and white-bordered blue speculum.

4. LIFE CYCLE AND DISTRIBUTION

Steller's eiders spend most of their lives in the marine environment, occupying terrestrial habitats only during the nesting season. Pair formation commonly occurs prior to departure to breeding grounds (Fredrickson 2001, p. 10, McKinney 1965, p. 273), and first breeding occurs at 2-3 years of age (USFWS, unpublished data). Alaska-breeding Steller's eiders arrive at their nesting grounds in small flocks of breeding pairs in late May to early June. Nesting on the ACP is concentrated in tundra wetland habitat near Utqiagvik and occurs at lower densities elsewhere on the ACP from Wainwright east to the Sagavanirktok River (Quakenbush et al. 2002, p. 101; Obritschkewitsch and Ritchie 2017, p. 10; Figures 2 and 3). Alaska-breeding Steller's eiders typically initiate nesting in mid-June, but timing of nest initiation is affected by timing of snowmelt, which varies annually (USFWS 2018a, p. 18). Nests are commonly located on the rims of polygon-shaped tundra, formed by permafrost ice wedges, near permanent water bodies dominated by *Carex aquatilis* and *Arctophila fulva* (Quakenbush et al. 2004, p. 173, 175; USFWS 2011a, p. 30).

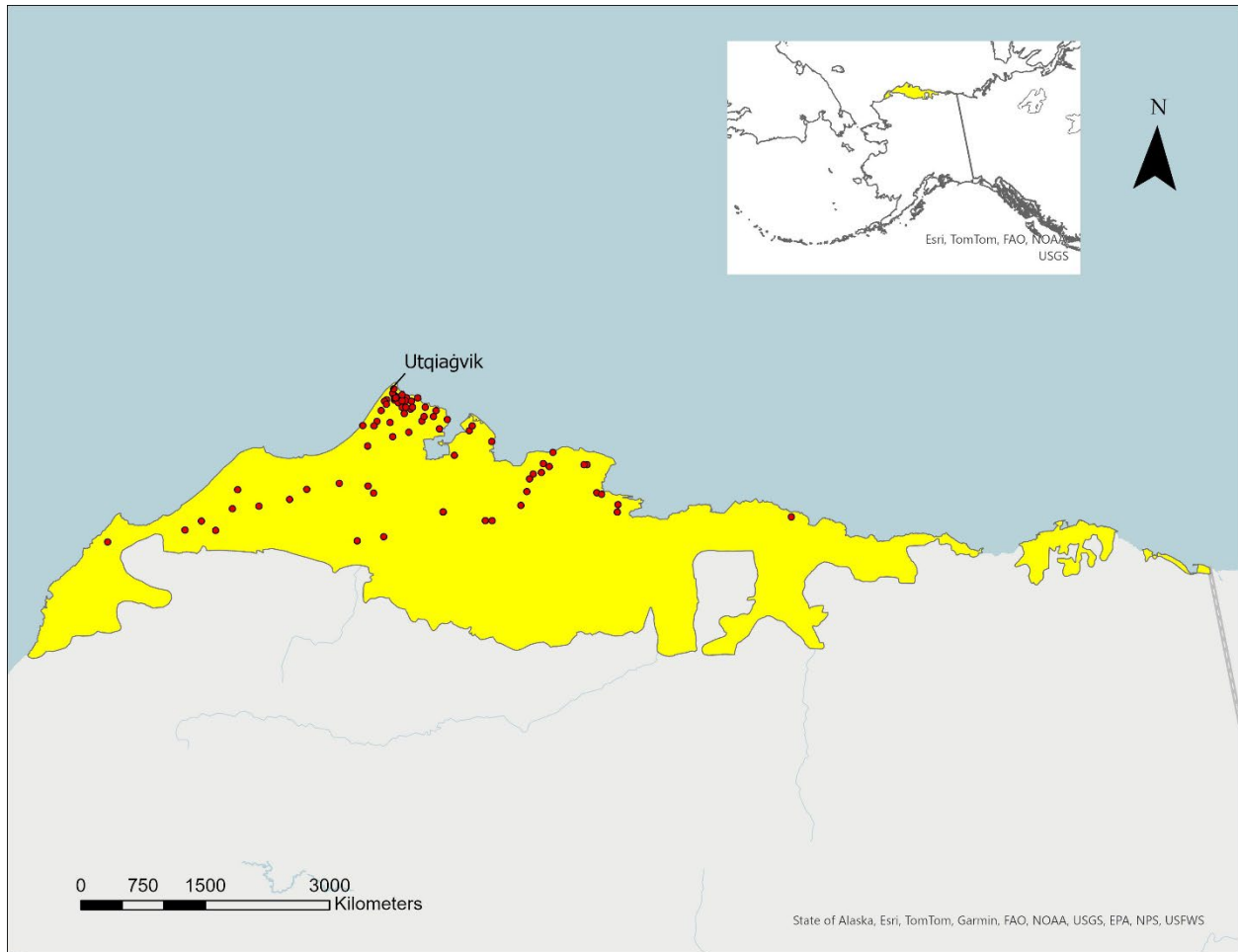


Figure 2. Observations of Steller’s eider males, pairs, and flocks from the Arctic Coastal Plain (ACP) aerial survey in June 1999 – 2024 (USFWS 2023b; USFWS unpublished data). Yellow area represents survey boundary on the ACP.

Hatching occurs approximately 30 days from nest initiation (start of egg laying), typically from mid-July through early August, after which females move their broods to adjacent ponds with emergent vegetation (Quakenbush et al. 2004, p. 173; USFWS 2011a, p. 32-33). Near Utqiagvik, the average maximum distance that radio-marked broods moved from their nests prior to fledging ranged from 488 m in 2008 (7 broods, 47 resightings) to 3.5 km in 2005 (3 broods, 26 resightings; USFWS 2011a, p. 32-33). Fledging occurs 32–36 days post-hatch (Quakenbush et al. 2004, p. 173; USFWS 2011a, p. 32).

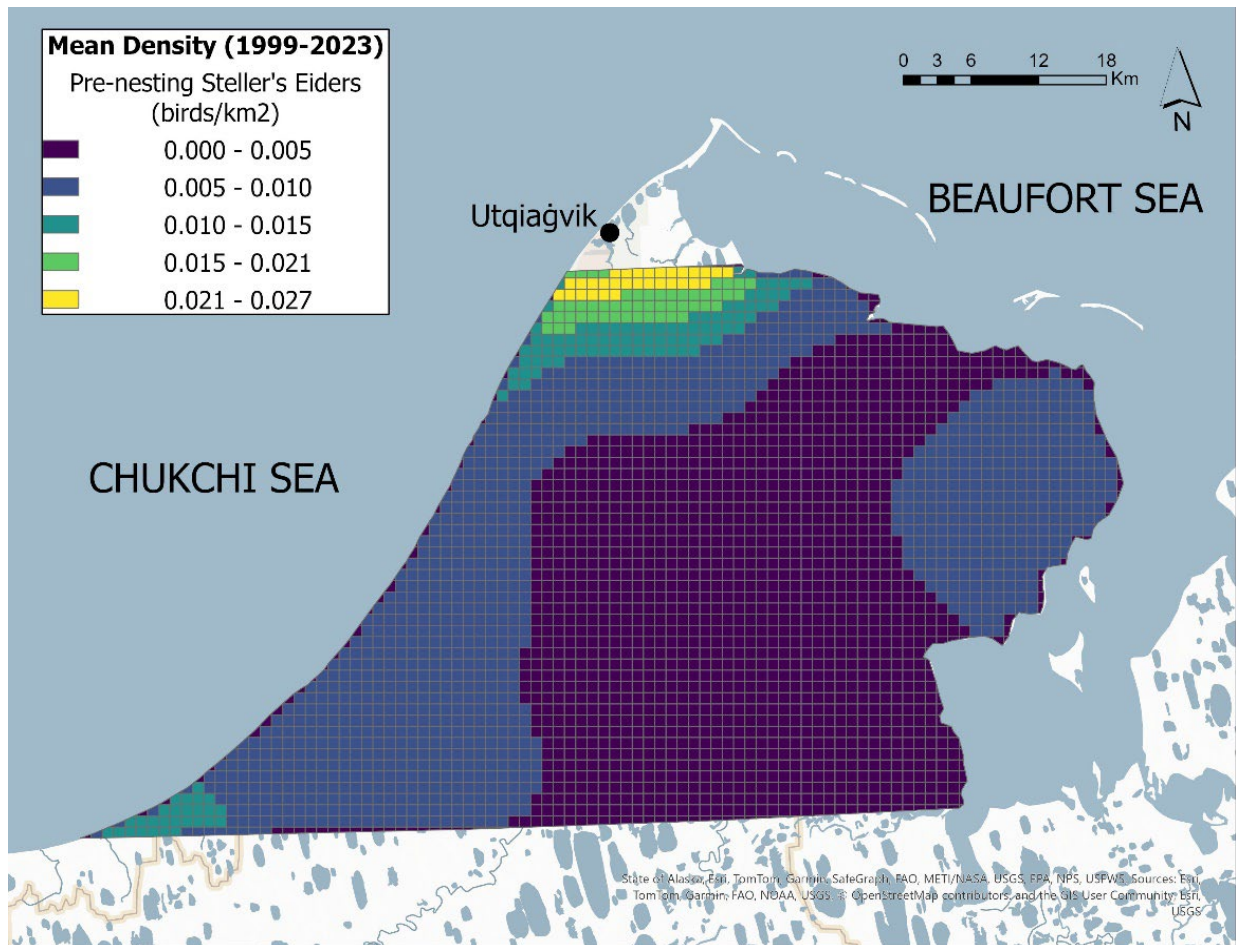


Figure 3. Average predicted densities of pre-nesting Steller’s eider pairs in the Utqiagvik Triangle, Alaska, June 1999–2023, not adjusted for incomplete detection (USFWS 2024g).

Timing of departure from the breeding grounds near Utqiagvik (and, we assume, the rest of the ACP) differs between sexes and varies depending on reproductive success. In years when Steller’s eiders nest, male Steller’s eiders form small flocks and leave the tundra after females begin incubating, typically from late June to mid-July (USFWS 2001b, p. 31-33; USFWS 2006a, p. 17-18; USFWS 2007a, p. 19-20). From mid-July to early August, flocks with a higher proportion of females (presumably failed breeders) are observed on the tundra and along the Chukchi and Beaufort Sea coasts near Utqiagvik (USFWS 2001, p. 31-33; USFWS 2006a, p. 17-18). In 2008 and 2011, nine Steller’s eider hens with broods were radio-marked and tracked after fledging near Utqiagvik (USFWS 2011a, p. 34, USFWS 2012a, p. 33). After juveniles could fly, they remained in freshwater wetlands from 2 to 12 days (n = 8), and then either left the study area or were located in salt water. Females and broods were then located on both the Chukchi and Beaufort Sea sides of the narrow spit of land north of Utqiagvik and observed south along the Chukchi coast near the town of Utqiagvik (USFWS 2011a, p. 34; USFWS 2012a, p. 33). Based on these observations, females with successfully reared broods begin to depart the Utqiagvik area

in early September (USFWS 2012a, p. 33-34). In years with low breeding effort, flocks composed of both sexes occupy coastal waters near Utqiagvik prior to fall migration and depart earlier than in years with higher productivity (Quakenbush et al. 2004, p. 174-175).

Following departure from the breeding grounds, Alaska-breeding Steller's eiders migrate to southwest Alaska, where they undergo a flightless molt for 3 weeks to > 1 month (Peterson 1980, p. 100-101; T. Hollmén, ASLC, pers. comm. 2018). Information on molt migration is limited to one study (Martin et al. 2015) that tracked 13 individuals (7 males, 6 females) from Alaska-breeding grounds to molting areas in 2000 and 2001. The duration of molt migration ranged from 1 to 53 days (30 ± 17 days) and did not differ significantly between sexes, although duration was more variable among females (Martin et al. 2015, p. 346). The primary molt migration stopover sites were along the north coast of Chukotka, Russia (56%), the Bering Strait region (including the east coast of Chukotka, Russia and the Seward Peninsula, Alaska; 20%), the Chukchi Sea coast of Alaska (19%), and the Y-K Delta (5%). Most (>95%) locations at stopover sites were in nearshore marine waters within 5 km of the coastline (Martin et al. 2015, p. 346).

At the molting sites, the Alaska-breeding population intermixes with the Russian-Pacific breeding population, and combined we refer to these two breeding populations as the Pacific-wintering population in this assessment. Sub-adult Steller's eiders are first to molt, with numbers peaking in early August based on observations at Nelson Lagoon (Petersen 1980, p. 100). Timing of molt for adults coincides with their arrival at molting areas: males arrive first in late August (Petersen 1980, p. 101), followed by unsuccessful breeding and non-breeding females, and finally successful females and broods (Rosenberg et al. 2014, p. 354; Martin et al. 2015, p. 346-347). The timing of female Steller's eiders varies annually based on breeding success that year; thus, the sex and age ratio of Steller's eiders at molting areas varies within the season and among years. Over the duration of 26 years (1993–2019), Hollmen et al. (2022) found that female and male Steller's eiders have delayed molting by 10 and 7 days, respectively, from eiders captured at Izembek Lagoon during their remigial molt (p. 45). The authors speculate that the delay in onset of molt could be explained by eiders taking advantage of the relatively longer Arctic summer seasons and remaining further north longer in favorable conditions (p. 49).

Pacific-wintering Steller's eiders prefer shallow molting areas with extensive eelgrass (*Zostera marina*) beds and intertidal mud and sand flats (Petersen 1981, p. 100-101; Laubhan and Metzner 1999, p. 695). Primary molting areas include the north side of the Alaska Peninsula (Izembek Lagoon, Nelson Lagoon, Port Heiden, and Seal Islands and other smaller lagoons; Petersen 1981, p. 258; USFWS 1986, p. 33; Rosenberg et al. 2014, p. 354) as well as Kuskokwim Shoals in northern Kuskokwim Bay (Dau 1987, p. 17; Martin et al. 2015, p. 346-347). USFWS (2006b) also reported > 2,000 Steller's eiders molting in lower Cook Inlet near the Douglas River Delta (p. 16; see also Rosenberg et al. 2014, p. 354), and some Steller's eiders marked with satellite transmitters were located near Nunivak and St. Lawrence Islands during molt (Rosenberg et al. 2014, p. 354; Martin et al. 2015, p. 347). Additionally, hundreds of molting and

post-molting Steller's eiders were observed during Service surveys of Nunivak Island in 1991-1992 and 1996 (USFWS 2001c, p. 1-3). Molting birds have been reported in smaller numbers near Cape Pierce in Bristol Bay (USFWS 1971, p. 46-47; Petersen and Sigman 1977, p. 666).

Banding studies of Pacific-wintering Steller's eiders¹ found that individuals molting at Izembek and Nelson Lagoons had a high degree of fidelity to specific lagoons (Flint et al. 2000, p. 265), and data from Steller's eiders marked with satellite transmitters near Kodiak Island in winter corroborate those findings (3 of 4 marked birds returned to same molting location in subsequent years; Rosenberg et al. 2014, p.356). From band recoveries, Dau et al. (2000) found that groups of Steller's eiders wintering in specific locations do not represent unique breeding subpopulations in eastern Russia (p. 545). Due to low recovery rates, banding data are inconclusive on whether Alaska-breeding birds segregate from the Russian-Pacific breeding population on the molting grounds (Dau et al. 2000, p. 547). The molt site of birds marked with satellite transmitters was independent of breeding location (Rosenberg et al. 2014, p. 354, 356). However, of 13 birds marked in Alaska during the breeding season near Utqiagvik, seven molted at Kuskokwim Shoals, suggesting that Alaska-breeding birds may disproportionately use this molting area over other molting areas (Martin et al. 2015, p. 348). The broad distribution of marked birds throughout the wintering range in southwest Alaska suggests that the Alaska-breeding population does not segregate from the Russian-Pacific breeding population in winter (Martin et al. 2015, p. 348).

After molt, Pacific-wintering Steller's eiders disperse throughout the Aleutian Islands, Alaska Peninsula, and western Gulf of Alaska including Kodiak Island and lower Cook Inlet (King and Dau 1981, p. 749; Rosenberg et al. 2014, p. 354; Martin et al. 2015, p. 347-348), although thousands may remain in molting lagoons unless freezing conditions force departure (Laubhan and Metzner 1999, p. 695). Pair bonding and courtship behavior begins in late winter and is completed prior to departure to breeding grounds (Fredrickson 2001, p. 10).

During spring migration in April and May, Steller's eiders first stage in estuaries along the north coast of the Alaska Peninsula or lower Cook Inlet (Rosenberg et al. 2014, p. 351). After leaving the Alaska Peninsula, marked birds staged for extended periods of time at Kuskokwim Shoals (21-38 days, Martin et al. 2015, p. 348; Rosenberg et al. 2014, p. 351). Eighty-three percent of Pacific-wintering Steller's eiders marked near Kodiak Island flew to Russian staging areas after staging near Kuskokwim Shoals, and the other birds remained in Alaska for the summer (Rosenberg et al., p. 351).

¹ Because we cannot distinguish between Alaska-breeding and Russian-Pacific breeding birds during the non-breeding season, and band recovery, telemetry, and genetic data suggest that Alaska-breeding and Russian-Pacific breeding populations intermix in southwest Alaska, we assume that data on distribution and habitat use and requirements of Pacific-wintering Steller's eiders during molt, winter, and spring staging applies to the Alaska-breeding population. Exceptions are noted.

5. INFLUENTIAL FACTORS

To assess the current and future condition of the population, we first identified factors that influence the ability of Steller’s eiders to complete each life stage (Table 1), and the demographic parameters that affect resiliency of subpopulations. We focused on the information pertaining to individuals in the Alaska-breeding population because that is the listed entity; however, where data were lacking for that population, we used data from the Russian-Pacific breeding population and noted it in the text. While we focus on the Alaska-breeding population, we acknowledge that the viability of the Alaska-breeding population may be tied to the viability of the Russia-Pacific breeding population. First, we describe factors that may affect reproduction, including ecological cues that we hypothesize Steller’s eiders might use in their “decision” to initiate breeding in a given year. Second, we describe factors affecting egg and duckling survival. Third, we describe what is known about these factors for the western Alaska subpopulation. Finally, we describe the factors in marine areas that affect juvenile and adult survival and reproductive capacity. See Figures 4 and 5 for conceptual models of the links between influential factors and demographic rates.

Table 1. Factors hypothesized to influence survival and reproduction of Steller’s eiders in the northern Alaska subpopulation.

Influential factor	
Terrestrial - Breeding Season	
Reproduction	quantity and quality of freshwater invertebrates
	lemming-avian predator dynamics
	availability of high-quality polygonal tundra habitat (macro-level)
	availability of high-quality polygonal tundra habitat (micro-level)
	social cues of other nesting sea ducks
Egg Survival	availability of high-quality polygonal tundra (micro-level – nest cover)
	adequately high nest attendance of incubating female
	lemming-avian predator dynamics
Duckling Survival	quantity and quality of freshwater invertebrates
	adequately high presence of adult female
	availability of high-quality polygonal tundra habitat (micro-level – cover)
	access to fresh water
Influential factor (continued)	
Marine - Molt, Winter, Staging, and Migration	
Adult and sub-adult survival and breeding propensity	quantity and quality of marine invertebrates
	shallow, nearshore mudflats and sand flats and/or rocky intertidal areas (macro-level)
	eelgrass beds and associated ecological community (macro-level)
	deep, ice-free waters (macro-level)
	micro-habitat needs

5.1. Factors influencing reproduction

While true breeding propensity is rarely measured (Bond et al. 2008, p. 1392), a portion of reproductively mature females in sea duck populations likely refrain from breeding in some years (Coulson 1984, p. 531; Mallory 2016, p. 342). This demographic characteristic may be even more pronounced in Steller’s eiders than in other sea duck species. Quakenbush et al. (2004) studied Steller’s eider breeding biology near Utqiagvik from 1991 – 1999. During some years of the study, Steller’s eider pairs were observed early in the breeding season, but no nests were found, leading to a hypothesis that Steller’s eiders experience population-level non-breeding events (Quakenbush et al. 2004, pp. 176-177).

Since 1999, the number of nests found annually near Utqiagvik continues to vary widely (0 - 78 nests found annually, USFWS 2024d, p. 36). However, we suspect that some of the observed variation was due to varying levels of search effort and detection rates. Especially given observations since 2005, annual nesting effort of Steller's eiders near Utqiagvik may be better characterized as falling on a continuum of low to high effort, rather than the binomial concept of breeding and non-breeding years (USFWS 2011, p. 36).

One factor that influences breeding propensity of waterfowl is body condition at arrival on the breeding grounds (Drent and Daan 1980, p. 226; Alisauskas and Ankney 1992, p. 54), which is affected by nutrient acquisition and energetic requirements during molt, wintering, migration, and staging periods in the marine environment (i.e., cross-seasonal and carry-over effects; Sedinger and Alisauskas 2014, p. 282-286; Alisauskas and DeVink 2015, p. 126-127). Factors influencing survival and maintenance of adequate body condition during the non-breeding season are described in more detail in Section 5.5 below.

Other factors that may influence breeding propensity and reproduction may be related to later snow melt and cold temperatures in the early breeding season. While these factors have not been measured for Steller's eiders in Utqiagvik, Pozdnyakov (2016, p. 94, 101) observed that in cold years eggs were laid later, clutches were smaller, and nest success was lower even with low predation pressure for Steller's eiders on the Lena River Delta in Russia.

Some waterfowl species rely on resources obtained on the breeding grounds to fuel egg production and nest attendance (Krapu and Reinecke 1992, p. 6; Sedinger and Alisauskas 2014, p. 280; Alisauskas and DeVink 2015, p. 143). Miller et al. (2022) analyzed the sources of proteins for Alaska-breeding Steller's eiders for egg-production and body maintenance during incubation using stable isotopes of collected egg membranes from nests and from red blood cells of incubating hens (p. 1). They found Steller's eiders to be especially dependent on local freshwater foods during egg-production and incubation relative to larger-bodied eiders, drawing no more than 5% of protein from marine-derived body tissues (Miller et al. 2022, p. 7-8). In addition, their small body size and behavior supports that females rely on resources at the breeding area to a significant degree. Compared to other eider species, Steller's eiders take several incubation breaks daily (USFWS, unpublished data); Steller's eider females nesting near Utqiagvik from 1991 – 1999 averaged about six recesses per day and had an average incubation constancy of 81%, suggesting that they left the nest to acquire local food to fuel incubation (Quakenbush et al. 2004, p. 170). For comparison, incubation constancy of larger-bodied common eiders and king eiders is nearly 1.0 (0.99 and 0.98, respectively; Alisauskas and DeVink 2016, p. 140-141, 143 and references therein).

Steller's eiders consume a variety of freshwater aquatic invertebrates, which are the most important source of nutrition for other female waterfowl during reproduction (Krapu and Reinecke 1992, p. 1). Quakenbush et al. (2004) reported *Chironomidae* and *Tipulidae* larvae and some vegetation found in the digestive tracts of two breeding female Steller's eiders found dead near Utqiagvik (p. 170). Stomach contents of five Steller's eiders shot in June in eastern Russia contained 53% plant material – moss and seeds of water plants – and 47% aquatic invertebrates from families *Diptera*, *Coleoptera*, and *Oligochaeta* (Solovieva 1999, p. 70). Other invertebrate taxa reported in Steller's eider diet include *Trichoptera*, *Plecoptera*, and *Corixa spp.* (Fredrickson 2001, p. 7). During egg production, oligochaetes contribute a substantial fraction (~52%) of protein to body tissues, as well as plant-derived foods (~32%) (Miller et al. 2022, p. 8). During incubation, Steller's eiders acquire more protein from insect larvae (30.8%), plant (25.6%), and crustacean (24.8%) derived foods (p. 8). These percentages are estimates from a stable isotope mixing model (Miller et al. 2022, p. 5–8), so these values are not known with certainty; however, the authors concluded that their mixing model approach yielded reasonable results based on comparisons with gut content analyses from other breeding areas, with the caveat that some bias is present in the insect larvae and crustacean model estimates (p. 10). As insect larvae are highly abundant within tundra wetlands, their low proportional input to egg production and incubation may mask a role as a lipid source, as only their total protein input was analyzed (Miller et al. 2022, p. 12).

Steller's eiders primarily use shallow flooded *Arctophila* and *Carex* ponds and deep *Arctophila* ponds for feeding during the pre-laying, laying, and early incubation periods (USFWS 2018a, p. 23; Miller et al. 2023, p. 8, 19) and during incubation (Solovieva 1999, p. 72). Occurrences of Steller's eiders were far lower in deep *Carex* ponds, deep lakes, and streams (Miller et al. 2023, p. 19). The authors suggest that *Arctophila*-dominated ponds may facilitate easier foraging by sea ducks because the pond bottoms beneath *Arctophila* stands include a layer of unconsolidated detritus from previous years, while *Carex* stands have dense root masses (Miller et al. 2023, p. 10–11). In addition, the submerged canopy of *Arctophila* may facilitate easier access to invertebrates (Miller et al. 2023, p. 10).

Shallow vegetated ponds dominated by *Arctophila* and *Carex* have the greatest diversity and evenness among invertebrate taxa and higher total biomass of detritivores compared to nearby streams or deep open lakes in the vicinity of Utqiagvik (Plesh et al. 2023, p. 17). The invertebrate community in ponds sampled near Utqiagvik in the 1970s consisted primarily of cladocerans, copepods, and anostracans in the water column and chironomid larvae dominating benthic habitats (Butler 1980 and Stross 1980 in Lougheed et al. 2011, p. 590). Sampling repeated in the same areas in 2009 - 2010 showed little change in invertebrate communities since the 1970s; 22 of the 27 genera sampled were in the family *Chironomidae* (Lougheed et al. 2011, p. 594-595). From invertebrate sampling in wetlands in the vicinity of Utqiagvik (summers 2013, 2017-2018), *Chironomidae* were the dominant taxon in all wetland types and had consistently high or the highest biomass of all invertebrate taxa (Miller et al. 2023, p. 7; Plesh et al. 2023, p. 10). In summary, while the availability of freshwater invertebrates and aquatic vegetation is

likely to affect the ability of Steller's eiders to reproduce, we lack data to identify the quantity or quality of invertebrates or vegetation required for clutch formation or incubation. However, we maintain that food availability influences breeding propensity.

Breeding propensity may also be influenced by specific ecological conditions. As mentioned above, annual nesting effort near Utqiagvik, measured by the number of Steller's eider nests found, varies considerably (USFWS 2024d, p. 36, Table 2). While this could be in part due to variation in detection rate, the number of Steller's eider nests found near Utqiagvik is higher in years with higher numbers of brown lemmings (*Lemmus trimucronatus*) and when pomarine jaegers (*Stercorarius pomarinus*) and snowy owls (*Bubo scandiacus*) nest (Quakenbush et al. 2004, p. 171, 176 - 178; Table 2). Two mechanisms have been hypothesized to explain this apparent ecological relationship. First, during years of peak lemming abundance, lemmings are a primary food source for nest predators including jaegers, owls, and Arctic foxes (*Vulpes lagopus*; Pitelka et al. 1955, p. 89, 114) to the degree that predators preferentially select for hyper-abundant lemmings, and bird nests are less likely to be depredated (Summers 1986, p. 107; Dhondt 1987, p. 153; Quakenbush et al. 2004, p. 177). Therefore, Steller's eiders would simply benefit from high lemming abundance through increased nest success due to prey switching (i.e., alternative prey hypothesis; Mallory 2015, p. 351). In addition, this association of higher nest success for Steller's eiders during high lemming years has also been observed on the Lena River Delta in Russia, where higher nesting densities are observed (Pozdnyakov 2016, p. 97). While this interaction has not been measured directly for Steller's eiders, studies on other species suggest that nest survival is positively influenced by higher lemming abundance (e.g., Bety et al. 2002, p. 94).

Second, although counterintuitive, the presence of nesting pomarine jaegers and snowy owls may positively affect Steller's eider nest survival. These avian predators nest near Utqiagvik in years of high lemming abundance (Haven Wiley and Lee 2000, Quakenbush et al. 2004, p. 168; Holt et al. 2015). Pomarine jaegers and snowy owls aggressively defend their nests against other predators, notably Arctic foxes, and this defense may indirectly impart protection to Steller's eiders nesting nearby. In 1996 and 1999 near Utqiagvik, Steller's eider nests were not found at distances greater than 200 m from pomarine jaeger nests and 1200 m from snowy owl nests despite the availability of suitable habitat, and nest survival was higher for nests closer to pomarine jaeger and snowy owl nests than those farther away (Quakenbush 2004, p. 171). Overall, observations at Utqiagvik suggest that Steller's eider breeding effort is higher in years with high lemming and avian predator abundance; therefore, we conclude that relatively normal population dynamics among these other species (i.e., intermittent high lemming abundance accompanied by substantial numbers of nesting pomarine jaegers and snowy owls) is an important factor influencing productivity of Steller's eiders.

Another important factor that could affect breeding propensity is the availability and quality of suitable habitat for nesting. Most Steller's eiders nest in a variety of habitats near Utqiagvik. While they

sometimes nest in grassy areas near wetlands surrounded by polygonal tundra or drier, more upland sites, they often choose nest sites near permanent water bodies on elevated rims of low- and high-centered polygons with emergent vegetation, primarily *Arctophila fulva* and secondarily *Carex aquatilis* (Solovieva 1999, p. 33; Quakenbush et al. 2004, p. 173, 175-176; USFWS 2011a, p. 30; USFWS 2018a, p. 22, D. Safine, USFWS Biologist, 2018). Thus, we consider the availability of high-quality polygonal tundra, and both the micro- and macro-habitat characteristics currently associated with that habitat type (e.g., specific plant species providing nest cover and the existence of polygonal wetlands, respectively), important habitat for Steller's eiders nesting in northern Alaska. It is important to note that we do not have data on specific micro-habitat characteristics preferred by Steller's eiders for nesting.

Social clustering of other sympatric-nesting sea ducks could also play an important role in reproductive effort for Steller's eiders. Miller (2023) compared various habitat characteristics around nests of Steller's eiders, spectacled eiders, king eiders, and long-tailed ducks to assess site selection among years from 1992-2022 at different spatial scales. For Steller's eider, 85.2% of the study area had low habitat suitability in a given year (p. 133-134), but there was high spatiotemporal variation in suitable habitat among years (p. 119). Among all categories analyzed, social clustering variables were the most important for delineating suitable nesting habitat. Habitat models indicated that for Steller's eiders, the presence of conspecifics was most important for nest site selection, as well as the presence of other sea duck species (p. 136, 141). Year of sampling was also highly important in defining suitable habitat for Steller's eiders as they exhibit high interannual variability in breeding effort unlike other species of sea ducks. Relative to social clustering and year factors, model results indicated that geophysical features and anthropogenic variables were less important in defining suitable habitat for Steller's eiders (Miller 2023, p. 136-139). Two explanations for the observed spatial clustering of sea ducks could be: 1) the first female to nest in a location may encourage a cascade of subsequent females to nest near her (i.e., a "decoy effect"), and/or 2) some of the observed social clustering could result from detection bias if most nests are detected due to the presence and activity of aggressive predatory birds (e.g., pomarine jaegers) and those predators were not detected during surveys (Miller 2023, p. 148). As models to investigate nest site suitability were primarily based on spatial locations between variables and nest sites, further investigation into the social cues by sympatric, nesting sea ducks is warranted, as well as what extent social cues may have on breeding propensity.

In summary, we have information to suggest that the following factors may influence breeding propensity of the northern Alaska subpopulation: 1) access to adequate marine invertebrates during migration, molt, winter, and spring staging (See Section 5.5); 2) access to adequate freshwater invertebrates in breeding habitat; 3) functional population dynamics of lemmings and avian predators; 4) availability of low-centered polygonal tundra (both macro- and micro-level characteristics); and 5) social cues of other nesting sea ducks.

5.2. Factors influencing egg and nest survival

Predation is a major factor affecting waterfowl egg and nest survival (Johnson et al. 1992, p. 464); thus, the factors influencing nest survival rates are generally related to protection from, and avoidance of, nest predators. As described above, high lemming abundance and the presence of nesting pomarine jaegers and snowy owls are also thought to positively influence egg and nest survival (Section 5.1). In addition, Steller's eider egg survival depends on the adequate presence of the incubating female. Incubating Steller's eiders have been observed actively defending their nests from avian predators (N. Graff, USFWS Biologist, pers. comm.; see USFWS 2018a). In Utqiagvik, depredation by Arctic foxes is likely the most common cause of nest failure among nesting sea ducks overall (USFWS unpubl. data). Furthermore, the majority of nest predation is thought to occur when female waterfowl are absent (Swennen et al. 1993, p. 51; Afton and Paulus 1992, p. 75-76); thus, waterfowl nest predation risk increases with the number of incubation recesses taken (Mallory 2015, p. 348), particularly in years with higher fox activity (Meixell and Flint 2017, p. 1380-1381). Incubating females not only provide predator protection but also maintain proper nest temperature and humidity for egg development (Johnson et al. 1992, p. 462) by providing protection from adverse weather, which may be particularly important in Arctic environments.

Also, nest site habitat characteristics/quality may affect egg survival. For many waterfowl, thick vegetative cover provides concealment from predators (Johnson et al. 1992, p. 460-461; Mallory 2015, p. 351). On the Arctic tundra of the ACP, however, vegetation is generally short, and females cannot necessarily rely on concealment for protection (Mallory 2015, p. 344). Yet, while not evaluated, it is possible that micro site characteristics of nest locations, such as elevation and vegetation type, provide protection from wind, flooding events, and low temperatures for Steller's eider nests.

Table 2. Nesting by Steller’s eiders and avian predators near Utqiagvik, 1991-2023 (From USFWS 2024d).

Year	Steller’s eiders present past 15 June	Nesting by Steller’s eiders	Nesting by snowy owls (number of nests) ^b	Nesting by pomarine jaegers	Steller’s eider nests ^a found viable	Steller’s eider nests ^a found post-failure	Total Steller’s eider nests ^a found
1991	Yes	Yes	Yes (33)	Yes	6	0	6 ^c
1992	No	No	No (0)	No	0	0	0
1993	Yes	Yes	Yes (20)	Yes	13	7	20
1994	Yes	No	No (0)	No	0	0	0
1995	Yes	Yes	Yes (54)	Yes	25	53	78
1996	Yes	Yes	Yes (19)	Yes	12	10	22
1997	Yes	Yes ^d	No (0)	No	3	1	4
1998	No	No	No (0)	No	0	0	0
1999	Yes	Yes	Yes (26)	Yes	27	9	36
2000	Yes	Yes	Yes (17)	Yes	17	6	23
2001	Yes	No	No (0)	No	0	0	0
2002	Yes ^e	No	Yes (4)	No	0	0	0
2003	Yes ^f	No	Yes (6)	Yes ^g	0	0	0
2004	Yes	No	No (0)	No	0	0	0
2005	Yes	Yes	Yes (4)	Yes	16	5	21
2006	Yes	Yes	Yes (35)	Yes	16	0	16
2007	Yes	Yes	No (0)	Yes	12	0	12
2008	Yes	Yes	Yes (31)	Yes	27	1	28
2009	Yes	No	No (0)	No	0	0	0
2010	Yes	Yes	No (0)	No	2	0	2
2011	Yes	Yes	Yes (3)	Yes	22	5	27
2012	Yes	Yes	Yes (7)	Yes	12	6	19
2013	Yes	Yes	No (0)	No	2	2	4
2014	Yes	Yes	Yes (22)	Yes	24	25	50
2015	Yes	Yes	Yes (3)	Yes	7	3	13
2016	Yes	Yes	Yes (4)	Yes	9	2	12
2017	Yes	Yes	No (0)	No	1	3	4
2018	Yes	Yes	Yes (5)	Yes	5	8	13
2019	Yes	Yes	Yes (4)	Yes	16	7	25
2020 ^h	NA	NA	NA	NA	NA	NA	NA
2021 ^h	NA	NA	NA	NA	NA	NA	NA
2022	Yes	Yes	Yes (2)	Yes	4	2	6
2023	Yes	No	No (0)	Yes	0	0	0

^aNumber of nests found are not comparable among years due to inconsistent search effort.

^bData on number of owl nests from Owl Research Institute surveys (213 km² that encompasses the Steller’s eider ground-based survey area) in the Utqiagvik area (Petersen and Holt 1999; Denver Holt, Owl Research Institute, personal communication).

^cMuch lower search effort than in other years.

^dVery few Steller’s eider nests were found despite considerable search effort.

^eOne pair was observed on 17 June at a site not visited in earlier years. Otherwise, none seen after 7 June.

^fOne pair observed on 19 June in a large stream. No other birds were observed after 14 June.

^gOnly one pomarine jaeger nest found during the survey, which was abandoned later in the season.

^hGround surveys were not conducted in 2020 or 2021 due to the global coronavirus pandemic.

5.3. Factors influencing duckling survival

Food availability and nutrient levels directly influence growth and survival of ducklings of other waterfowl species (Sedinger 1992, p. 116; Cox et al. 1998, p. 128; Flint et al. 2006, p. 908-909). Data on specific nutritional requirements and preferred foods in the wild is lacking, but limited information suggests that Steller's eider ducklings consume a diversity of aquatic vegetation and invertebrates. Young birds, shot in August at nesting areas in northern Alaska, had 40.3% plant material (*Potamogeton* sp. and *Empetrum* spp.) and 59.7% *Trichoptera* and *Chironomidae* larvae in their digestive tract (Cottam 1939 cited by Solovieva 1999, p. 74). Solovieva (1999, p. 73) sampled one area in Russia where a brood was observed feeding in shallow polygonal ponds in moss cover and found invertebrates in the *Oligochaeta* and *Gammarus* families the most abundant, with smaller amounts of *Diptera*, *Chironomidae*, and *Coleoptera*.

Consistent presence of the female is also essential for duckling survival. Hens provide temperature regulation via brooding until ducklings can thermoregulate, protect ducklings from predators, and lead broods to foraging and resting habitat (Afton and Paulus 1992, p. 83, 88-89 and references therein).

Quakenbush et al. (2004) suggested that predation is a major cause of Steller's eider duckling mortality based on observations in the 1990s near Utqiagvik (Quakenbush et al. 2004, p. 173, 176), and predation is commonly identified as a source of duckling mortality for other species (Sedinger 1992, p. 121). Many sea duck species form brood amalgamations as a predator defense (Mallory 2015 p. 353; Munro and Bedard 1977, p. 804) and congregate in large, deep water bodies where the ducklings dive in response to predators. However, Steller's eiders rely on a different brood rearing strategy. Steller's eider broods typically remain separated from one another, and females remain with their own brood until fledging (USFWS, unpublished data; Solovieva 1999, p. 57). Steller's eider broods in Utqiagvik primarily used shallow ponds filled with emergent *Arctophila* and *Carex* vegetation, with only 4% of observations in deep open ponds or lakes (n = 31; USFWS 2011a, p. 33). Therefore, Steller's eider ducklings likely require adequate vegetative cover and height in brood-rearing habitat to avoid predation, rather than relying on the brood amalgamation behavior of other sea duck species. *Arctophila* wetlands provide both dense and tall cover, which is important protection from predators and wind and likely provides good habitat for aquatic invertebrates (D. Safine, USFWS biologist, pers. comm. 2018). The availability of habitat with these characteristics near nest sites may reduce brood movements, decreasing risk of predation.

Finally, fresh water is an important habitat requirement for ducklings. Hollmen et al. (2023, p. 1891) found that Steller's eider ducklings (< 1 week of age) are impacted by acute exposure to salinity, suggesting that Steller's eider ducklings cannot survive when they only have access to water with salinity levels exceeding 3-6 ppt. Newly hatched ducklings lack functional salt glands to process saline water; therefore, salinization may negatively impact their growth and survival (Hollmen et al. 2023, p. 1884).

Nasal gland secretions were observed in all ducklings exposed to 6 ppt salinity at 8 days of age, indicating that Steller's eider ducklings possess functional salt glands by 1 week of age (Hollmen et al. 2023, p. 1892). However, when exposed to 6 ppt salinity levels at hatch, ducklings developed symptoms of salt toxicosis despite salt gland secretions, suggesting they were not able to fully process and compensate for salinity at the 6 ppt level at the early age (Hollmen et al. 2023, p. 1892-1893).

5.4. Factors affecting the western Alaska subpopulation during the breeding season

The habitat preferences and resource requirements of Steller's eiders that nested on the Y-K Delta prior to their near-disappearance are unknown. One habitat characteristic assumed to be important to Steller's eiders nesting in northern Alaska, the presence of nesting pomarine jaegers and snowy owls, which are dependent on extreme spikes in rodent populations, rarely occur on the Y-K Delta. In fact, the only evidence of nesting pomarine jaegers on the Y-K Delta was the anomalous rodent irruption in 1924 (Brandt 1943, p. 265-270; B. McCaffery, USFWS Biologist, pers. comm.), and nesting snowy owls have only been observed in relatively large numbers on a few occasions since 1924 (Harwood et al. 2000, p. 275). It is possible that Steller's eiders nesting in western Alaska used different cues and/or strategies to avoid nest predation than those in the Arctic; however, that is unknown. Overall, we can draw no conclusions about habitat or resource needs of the western Alaska subpopulation of Steller's eiders.

While Hollmen et al. (2023) did not analyze Steller's eider nesting distribution on the Y-K Delta in relation to wetland salinity conditions due to their rarity (p. 1886), Steller's eiders have nested at low elevation habitat on the coastal fringe of the Y-K Delta (p. 1893), and broadscale patterns across the Y-K Delta predicted having ≥ 6 ppt over several years (p. 1891). For spectacled eiders, they found that over 50% of eiders nested in areas with salinity at or above the tolerance threshold value for ducklings, which suggests spectacled eiders do not appear to actively avoid saline habitats (Hollmen et al. 2023, p. 1893). The authors did not explore fine-scale patterns of salinity; however, increases in storm surge frequency and magnitude may influence local scale heterogeneity in salinity (p. 1894).

5.5. Marine factors influencing survival and breeding propensity of adults and juveniles

Steller's eiders use two habitat types throughout the non-breeding season – shallow, nearshore intertidal sand flats and mudflats, and rocky or mud-bottomed deep water nearshore areas. During fall molt and staging period, and staging during spring migration, large numbers of Steller's eiders are associated with expansive beds of eelgrass on intertidal mudflats such as those found at Izembek Lagoon and other areas on the north side of the Alaska Peninsula and Kuskokwim Shoals (Fredrickson 2001, p. 6; Hogrefe 2014, p. 12461; Martin et al. 2015, p. 351). Steller's eiders may incidentally ingest eelgrass while feeding on the invertebrates associated with eelgrass (Metzner 1993, p. 89). The characteristics of eelgrass-associated invertebrate prey that are most important to Steller's eider

demographic rates has not been measured. However, their association with eelgrass communities during a large portion of their annual cycle suggests it is an important habitat factor.

During winter, particularly from January to April, a portion of the Pacific-wintering population moves to rocky intertidal areas or deeper nearshore waters such as areas on the south side of the Alaska Peninsula, the Aleutian Islands, Cook Inlet, and Kodiak Island (USFWS 2006b, p. 16-17; Rosenberg et al. 2014, p. 354; Martin et al. 2015, p. 349-350), while others stay in intertidal mudflats dominated by eelgrass. Observations at Izembek Lagoon indicate that when intertidal flats at Izembek Lagoon freeze in winter, Steller's eiders move to deeper (up to 30 m) gravel and mud-bottomed nearshore areas in Cold Bay (Laubhan and Metzner 1999, p. 695). Martin et al. (2015) also reported substantial use of habitats > 10 m deep during mid-winter (p. 350). Wintering Atlantic Steller's eiders in Norway were found to prefer feeding in shallow waters ranging between 1.7 and 5.9 m depth (Heggøy et al. 2019, p. 3).

The availability and quality of food resources on the non-breeding areas may impact an individual's ability to survive the winter and reproduce the following season. In waterfowl, the ability to store nutrient resources during the non-breeding season for use in reproduction is influenced by food availability and quality, the absence of disturbance affecting foraging, weather (Descamps et al. 2010, p. 1530), and other factors such as disease and parasite loads (Latorre-Margalef et al. 2009, p. 1031; Shutler et al. 2012, p. 757-758; Sedinger and Alisauskas 2014, p. 291).

Quality of available food resources can vary by prey type (i.e., crustaceans vs. bivalves), energy vs. protein content of prey, and size of prey. The digestibility of prey also varies between prey types, as bivalves and gastropods have dense shells that require mechanical crushing by the gizzard compared to softer-bodied crustaceans that can be readily digested (Ouellet et al. 2013, p. 8). In addition, the quality (i.e., size or nutrient content) of various prey types can differ between months (i.e., percent protein and fat content in July vs. August, Petersen 1981, p. 260), years (Maliguine 2024, p. 10), and locations. Previous work in Norway (Bustnes and Systad 2001) investigated the flexibility in feeding ecology of Atlantic Steller's eiders relative to co-occurring long-tailed ducks over two winters (p. 407-412). The prey species found in diets of Steller's eiders and long-tailed ducks were mostly the same, although long-tailed ducks were found to switch from a benthic invertebrate diet to exploit spawning capelin (*Mallotus villosus*) in early winter when they became available (p. 409-410). In addition, while diets of Steller's eiders and long-tailed ducks overlapped in species composition, they found that Steller's eiders consumed smaller mussels (mean size \pm SE = 6.0 \pm 0.09 mm) than available (mean size \pm SE = 9.98 \pm 0.07 mm) in the upper subtidal zone, where only 6% of the mussels were larger than 10 mm (p. 409). Steller's eiders also consumed smaller gastropods (where 75% gastropods were of size class between 0 - 2.5 mm) than long-tailed ducks (where 77% gastropods were of size class 2.6 - 5 mm) (p. 409). Overall, Bustnes and Systad (2001) suggested that Steller's eiders have low flexibility feeding ecology, which may

be constrained by their diving physiology (as they used the same shallow habitats throughout the winter) or bill morphology (p. 410); this may limit Steller's eiders from exploiting the same abundant resources consumed by co-occurring long-tailed ducks.

The wide selection of foods consumed by Steller's eiders suggests they exploit foods based on availability during the non-breeding season (Fredrickson 2001, p. 8), with the possible exception of the wing molt period (and Petersen 1981, p. 260-262). During the molt, Steller's eiders are flightless for about a month, requiring shallow molting sites with abundant, high-quality, and accessible prey to forage on for feather regrowth, and are limited to the available prey at the molting sites. Primary groups of invertebrates eaten by Steller's eiders from April through October at Nelson Lagoon, Alaska were bivalves and amphipods, including *Mytilus edulis* (*Pelecypoda*) and *Anisogammarus pugettensis* (*Amphipoda*) (Petersen 1980, p. 102), which may be indicative of their winter diet. Steller's eiders increased consumption of bivalves during molt at Nelson Lagoon, which have more energy per gram than the other common prey, amphipods, suggesting that they meet energetic demands of molt by consuming invertebrates with high energy content (Petersen 1981, p. 260-262). Similarly, crustacean prey formed a larger fraction of the total diet in May 1985 (30.3%) than September 1984 (2.4%) during the remigial molt period for Steller's eiders collected from nearshore waters of the North Aleutian Shelf, Alaska, and blue mussels (*Mytilus edulis*) made up the largest proportion of their diet during both months (67.4% and 90.7%, respectively) (Troy and Johnson 1987, p. 436-437). Although diets of Steller's eiders were not found to significantly differ between physiological stages (molt, pairing, staging, etc.), molting Steller's eiders consumed the highest amount of shelled prey (gastropods and bivalves) and lowest amount of crustacean prey relative to other physiological stages at Izembek Lagoon, Alaska (Metzner 1993, p. 85, 105-106). In addition, Steller's eiders had the highest amount of plant matter (eelgrass) in their diet during the molt period, and shelled prey are often found settling on or clinging to the eelgrass blades (Metzner 1993, p. 89). Petersen (1980) also found Steller's eiders to consume larger mussels (9 - 10 mm) during the remigial molt period, which were larger than the commonly available sizes (3 - 5 mm) from substrate samples at Nelson Lagoon (p. 104). In summary, Steller's eiders may have more of a specialized diet during the wing molt period relative to other physiological stages.

Esophageal contents of Steller's eiders throughout the year at Izembek Lagoon, Kinzarof Lagoon, and Cold Bay, Alaska, included diverse taxa from four classes of invertebrates (Crustacea, Bivalvia, Gastropoda, and Polychaeta), and suggests that Steller's eiders are opportunistic generalists in the marine environment (Metzner 1993, p. 68-70, 73, 85). The similarity of diets among sex and age classes and physiological stage (molt, pairing, etc.) at Izembek Lagoon also suggests that prey is consumed based on availability (Metzner 1993, p. 103-104). Other indications that Steller's eiders are relative generalists includes observations of herring egg and algae consumption in Lithuania in late winter/spring (Zydalis 2000, p.130), and at Dutch Harbor, Alaska, Steller's eiders were observed foraging near fish

processing sites where eutrophication increases local productivity of invertebrate scavengers such as amphipods (Reed and Flint 2007, p. 130).

Food availability at staging areas during spring migration also plays a key role in reproductive capability. Telemetry data suggests that Steller's eiders stage for extended periods of time in spring prior to arrival on the breeding grounds, presumably to forage. For example, marked Steller's eiders used Kuskokwim Shoals for an extended period of time in spring despite ice-free coastal waters further north that indicated migration was possible (Martin et al. 2015, p. 349). Steller's eider spring migration is characterized by frequent stopovers at coastal locations (Rosenberg et al. 2014, p. 354); therefore, a series of locations along their northward route for acquiring or maintaining adequate physiological condition prior to breeding may be required. Information on specific diet requirements of Steller's eiders during spring staging is lacking; however, Rosenberg et al. (2014) note that Steller's eiders arrive at Russian breeding grounds with greater mass than recorded at wintering areas, suggesting the importance of food resources at spring stopover sites (p. 355). PTT-marked birds exhibited rapid molt migration, flying directly to molt locations after departing summering areas (Rosenberg et al. 2014, p. 354); thus, stopover areas may be less important during fall migration.

In summary, the available information suggests that the following marine factors affect survival and reproductive capacity of Steller's eiders during the nonbreeding season: 1) adequate quality and quantity of marine invertebrates at molt, winter, and spring staging areas and migration stopover sites; 2) availability of shallow nearshore mudflats or sand flats rocky intertidal areas (macro-level); 3) availability of deeper, ice-free waters in late winter (macro-level); 4) availability of eelgrass bed communities; and 5) unidentified micro-habitat requirements in these ecotypes.

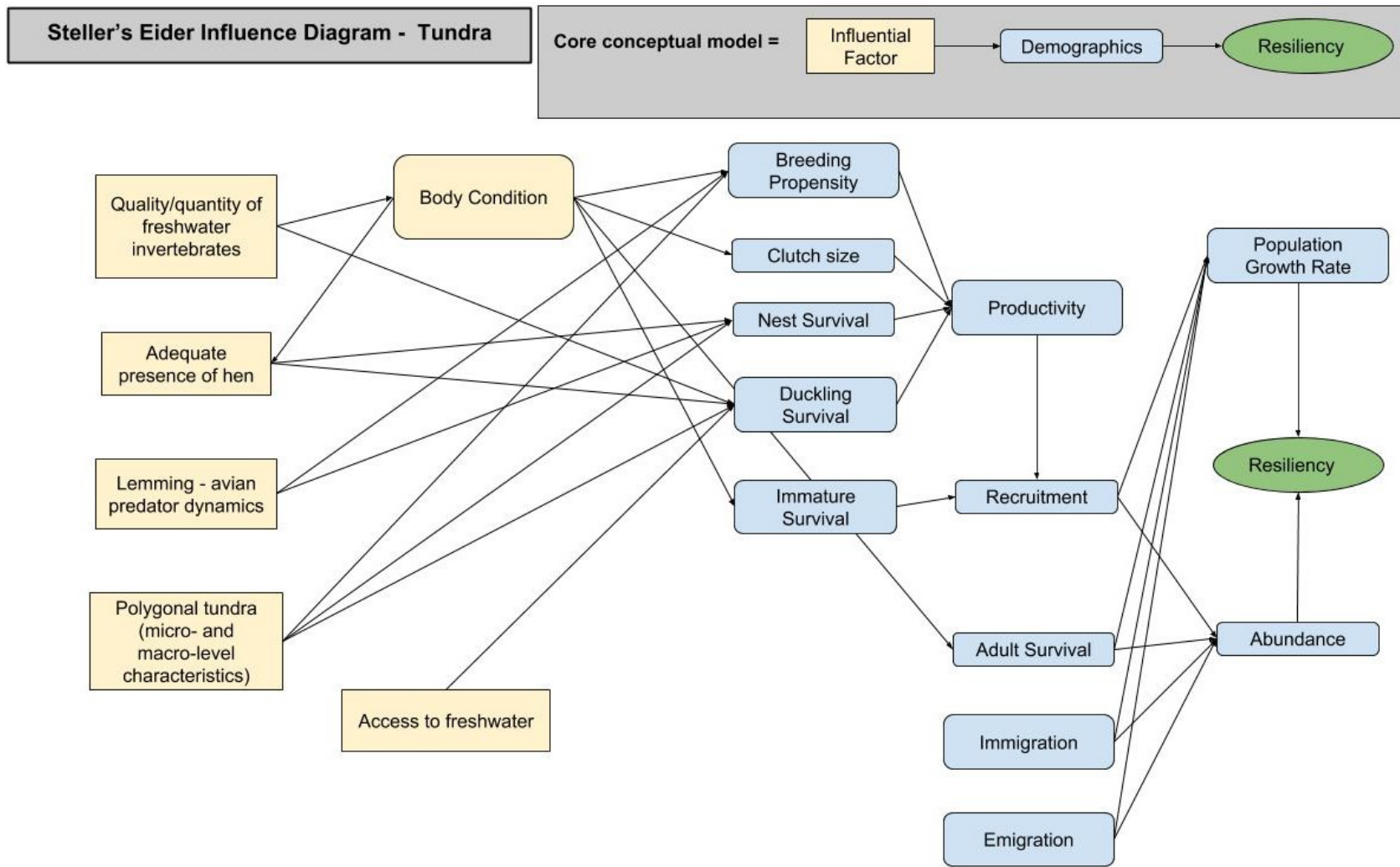


Figure 4. Influence diagram illustrating the links between required tundra habitat conditions, demographic rates, and resiliency of the northern Alaska subpopulation of Steller's eiders.

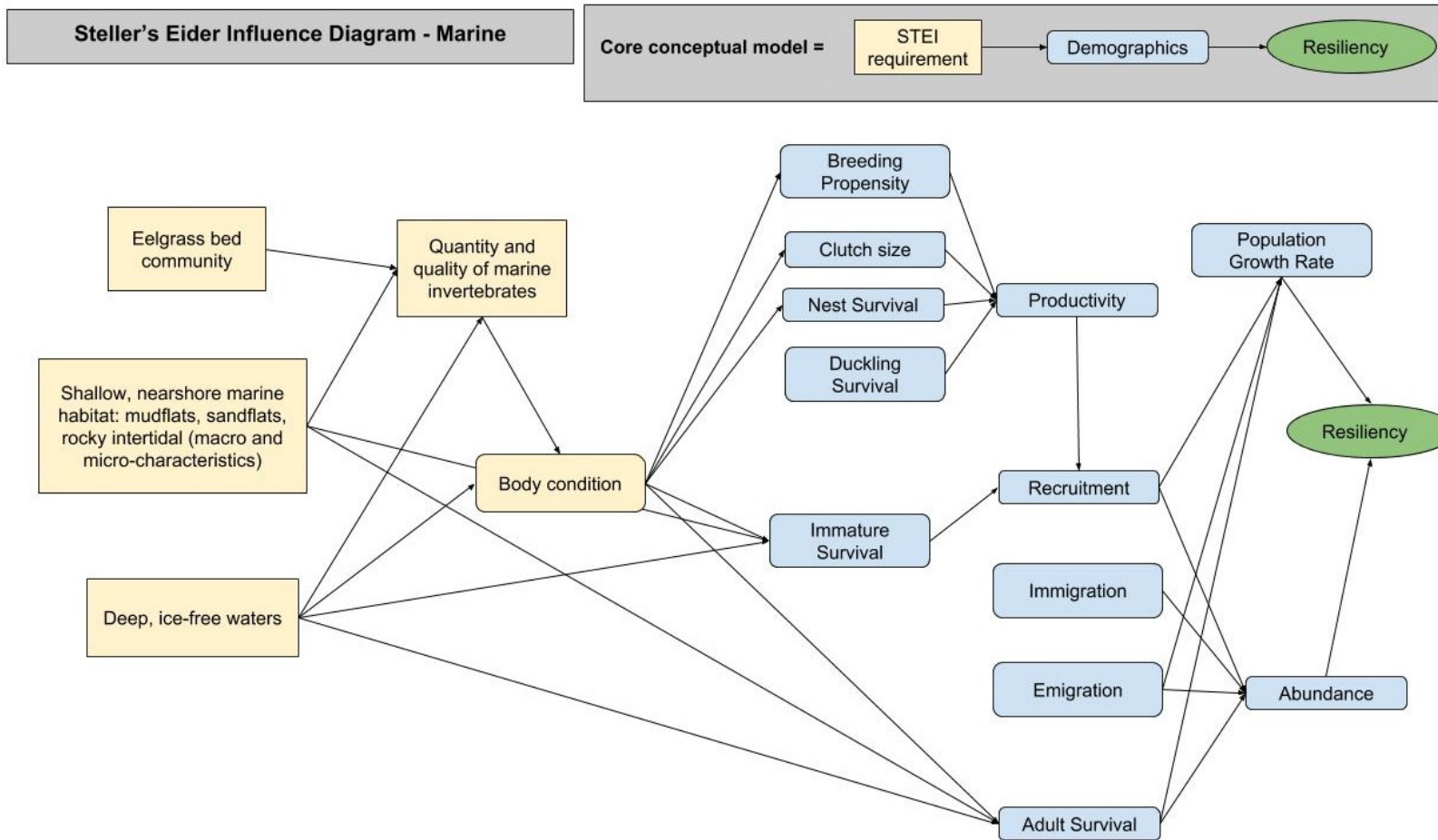


Figure 5. Influence diagram illustrating the links between required marine habitat conditions, demographic rates, and resiliency of Alaska-breeding Steller's eiders.

5.6. Defining the characteristics of a highly viable population of Steller's eiders

To assess the current and future condition of the population, we first identified characteristics of a viable population of Steller's eiders: in general, one that has subpopulations with high resiliency, defined as the ability of a subpopulation to withstand stochastic variation, and overall has adequate representation and redundancy such that the population is likely to persist in the future.

First, we considered both the habitat conditions and demographic characteristics that would contribute to resiliency. Above, we described habitat and ecological factors that influence survival and reproduction of Steller's eiders, which in turn ultimately affect subpopulation resiliency. We defined high, moderate, and low condition categories for these factors corresponding to their availability and quality, and the resulting impact on demographic rates at the subpopulation level. Habitat factors are considered in high condition when the availability or quality of the factor is not significantly affecting survival or reproductive rates of the subpopulation. Moderate condition was assigned when the availability or quality of this factor is not significantly affecting demographic rates of the subpopulation, but it may affect small numbers of individuals without rising to a subpopulation-level effect. Low condition was assigned when the availability or quality of this factor is significantly affecting demographic rates of the subpopulation.

We also defined high, moderate, and low condition categories for abundance. Conceptually, a subpopulation needs to have a large number of individuals (high abundance) to have a high level of resiliency. Alternatively, a moderate number of individuals and an increasing population trend over time may result in high resiliency, but we do not have trend data for Alaska-breeding Steller's eiders, so we relied strictly on measures of abundance. It is difficult to define high abundance for a population of Steller's eiders given that a minimum viable population size has not been estimated for this species. Due to the uncertainty in estimates of demographic rates for Alaska-breeding Steller's eiders, using stochastic population models to determine the level of abundance required for high resiliency is also not possible (C. Bradley, USFWS Biometrician, pers. comm.). For these situations, minimum viable population size "rules of thumb" have been suggested (Franklin 1980, p. 135-150; Traill et al. 2010, p. 30). Although there is considerable disagreement about their interpretation and applicability (Jamieson and Allendorf 2010, p. 578-579; Flather et al 2011, p. 314; Shoemaker et al. 2013, p. 548-549), a minimum population size in the thousands is a reasonable goal for maintaining long-term persistence and evolutionary potential (Brook et al. 2006, p. 378-379; Traill et al. 2007, p. 164; Traill et al. 2010, p. 315; Flather et al. 2011, p. 314; Reed and McCoy 2014, p. 869). Given this information and indications of high variation in demographic rates, a population size of 5000 seemed a reasonable threshold for high condition and a population of 500 individuals for the threshold for low condition. It is important to note that these thresholds do not correspond to population sizes required for reclassification of Alaska-

breeding Steller's eiders, as they are not derived from a species-specific population viability analysis (PVA).

We did not use estimates of demographic parameters as a measure of resiliency because of the uncertainty in the available data. Rather, we discuss what is known about demographic parameters such as survival, productivity, immigration, and emigration to provide the context of Alaska-breeding Steller's eider life history.

As mentioned in Section 2, the goal of an SSA is to characterize viability of a population, which is defined as the likelihood that a species will persist over time and is a product of not only the population's resiliency but also its representation and redundancy. To evaluate representation and redundancy, we describe the current information on Alaska-breeding Steller's eiders pertaining to each concept, but refrain from using numeric thresholds in determining high, moderate, or low representation or redundancy. Representation includes the geographic, genetic, morphological, and life history variation within the population that affects its ability to adapt to changing environmental conditions over time. For example, a population that occupies more than one ecological setting throughout its life cycle has a higher level of representation than one that requires a very specific habitat type or condition. Redundancy is the ability of the population to withstand catastrophic events and is measured by the number of subpopulations and their spatial extent across different ecological settings. In general, at least more than one highly resilient subpopulation in Alaska, over a large spatial extent, would be required for Alaska-breeding Steller's eiders to have high redundancy.

6. CURRENT CONDITION OF THE POPULATION

In this section, we describe the current condition of the Alaska-breeding Steller's eider population by describing the available information on: 1) population abundance, population growth rate, and demographic vital rates; 2) results of population viability analyses based on abundance and demographic data; 3) the influential factors acting on the resources required by Alaska-breeding Steller's eiders and/or directly on individuals; and 4) the resulting current condition of the habitat and demographic requirements considering the influential factors. We then use that information to make inferences about the current level of subpopulation resiliency, and redundancy and representation of the Alaska-breeding population. Current condition of the larger Pacific-wintering population, including the eastern Russian-breeding population, is presented in Appendix E.

6.1. Abundance and population growth rate

6.1.1. Western Alaska subpopulation

While historical observations of nesting Steller's eiders have been recorded in western and southwestern Alaska, including the Alaska Peninsula, the Seward Peninsula, St. Lawrence Island, and Agattu Island (62 FR 31748), more contemporary observations (1960s to present) of breeding Steller's eiders are limited to the central coastal zone of the Y-K Delta.

The Service has conducted three breeding waterfowl surveys annually on the Y-K Delta. These include two aerial surveys, the Waterfowl Breeding Population and Habitat Survey (1957 – 2024, USFWS 2023a, J.B. Fischer, USFWS Biologist, pers. comm.) and the Alaska Y-K Delta Aerial Breeding Pair Survey (1985 – 2024, USFWS 2024h), and one ground survey aimed at estimating the number of waterfowl nests on the central coast of the Y-K Delta (1985-2019, 2022; USFWS 2023c; USFWS 2024i). In addition, field research is conducted sporadically throughout the central coastal zone of the Y-K Delta by the U.S. Geological Survey (USGS), the Service, universities, and other research agencies. Serendipitous observations of Steller's eiders would likely be recorded during these activities given the species' rarity and the interest in the species and as mandated by refuge research permits.

Only 4 Steller's eiders have been recorded during aerial surveys from 1988 – 2023, in which 3 were observed in 1988, and 1 lone male was observed near the Manokinak River in 2018 (J. Fischer, USFWS Biologist, pers. comm.). Observations of 62 adult Steller's eiders, and 12 nests and 1 brood, were reported during nest plot surveys and other avian research from 1997 – 2023 (Flint and Herzog 1999; USFWS, unpublished data; Tables 3 and 4). Observations of adults consisted of pairs and lone males in wetland habitat and singles and pairs flying by researchers along a river or the coast (Table 3). Nests were found at Kigigak Island and near the Tutakoke and Kashunuk rivers (Table 4).

When the species was reviewed for listing prior to 1997, no Steller's eider nests had been found for approximately 20 years on the Y-K Delta (since 1975, Kertell 1991, p. 180). While some nests have been found since 1997 (Table 4), the small number of Steller's eider observations in nesting habitat, despite substantial research and survey activity, suggests that Steller's eiders breeding in western Alaska remain rare. Given the small number of observations, estimating a trend in population abundance since listing is impossible.

Because very few observations of breeding Steller's eiders have been made in western Alaska since listing, the use of translocation of captive Alaska-origin Steller's eiders to the Y-K Delta was evaluated by the Service and the Steller's Eider Recovery Team (Recovery Team) to determine its utility as a recovery tool. In 2005, at the request of the Recovery Team, the Alaska SeaLife Center established a captive flock of Steller's eiders from eggs collected near Utqiagvik. The Service and the Alaska SeaLife Center conducted field trials that involved using hens from surrogate species to incubate Steller's eider eggs in the wild on the Y-K Delta in 2016. While the program made significant progress developing methods for propagation, rearing, and field activities, field trials showed that methodological and technological challenges remain. The development of methods to enable reintroduced Steller's eiders to survive, return, and reproduce at rates high enough to ensure the establishment of a viable population would still take many years, and, without new technological advances, success would be difficult if not impossible to measure. After much deliberation, the Service determined that given the low likelihood of establishing a viable population of Steller's eiders within a reasonable conservation horizon and the high financial and opportunity costs of the reintroduction program, reintroduction was not a viable recovery tool at that time.

Table 3. Observations of adult Steller’s eiders on the Y-K Delta, 1997 – 2023. Total number of observations over the surveys was 62.

Year	Location	Lone Male	Lone Female	Pair	Total Birds
1997	Naskonat Peninsula			1	2
1997	Kigigak Island			2	4
1997	Hock Slough			1	2
1997	Tutakoke River			2	4
1997	Manokinak River			1	2
1998	Hock Slough	1		1	3
1998	Tutakoke River	1		2	5
1999	Kigigak Island			2	4
2000	Kigigak Island	1		2	5
2002	Kigigak Island		1		1
2003	Kigigak Island	1	1		2
2004	Kigigak Island		2		2
2005	Kigigak Island		2		2
2006	Kigigak Island	1			1
2010	Opagarak River and Aprothluk		1		1
2011	Kigigak Island		1	1	3
2013	Tutakoke River			1	2
2014	Big Slough			1	2
2015	Kigigak Island	1			1
2015	Manokinak River			1	2
2018	Manokinak River	1		1	3
2018	Kigigak Island				8
2023	Kigigak Island		1		1

Table 4. Observations of Steller’s eider nests and broods on the Y-K Delta, 1997 – 2024. Total number of reproductive attempts recorded (nests + broods) over the surveys was 12.

Year	Location	Clutch Size	Nest success	Broods	Brood Size
1997	Hock Slough	6	Yes		
1998	Hock Slough	7	Yes		
1998	Tutakoke River	4	No		
1998	Tutakoke River	unknown	No		
2002	Kigigak Island	6	Yes		
2004	Kigigak Island	7	Yes		
2004	Hock Slough	6	Unknown		
2005	Kigigak Island	6	No		
2005	Kigigak Island			1	2
2010	Opagyarak River	8	Unknown		
2013	Tutakoke River	7	Yes		
2016	Kigigak Island	5	Unknown		

6.1.2. Northern Alaska subpopulation

The number of Steller’s eiders in the northern Alaska subpopulation is difficult to estimate for several reasons. Alaska-breeding Steller’s eiders can only be distinguished from Russia-Pacific breeding Steller’s eiders when the populations are distributed on the breeding grounds, and thus methods to estimate abundance of the listed population are limited to surveys of breeding pairs in Alaska. However, the proportion of the northern Alaska subpopulation present on the breeding grounds may vary annually. Furthermore, the number of nests found annually during ground surveys near Utqiagvik is variable, ranging between 0 – 78 nests found per year since 1991 (USFWS 2024d, p. 36). If the number of nests is considered an index of breeding effort in any given year, then the proportion of the population breeding (i.e., breeding propensity) varies annually (assuming a constant population size). Non-breeding birds may remain in marine areas, stage in other terrestrial areas prior to molt, or visit northern Alaska briefly before moving back to marine habitat. It is also possible that some birds nest in Russia in years when they are not present in Alaska. As the surveys are designed to enumerate nesting pairs, in any of these scenarios some unknown portion of the population is not available to be detected in the surveys. Without an annual estimate of breeding propensity, the relationship between the number of pairs counted and the true number of Steller’s eiders in the population of interest is unknown.

While they do not provide data to estimate abundance of the northern Alaska subpopulation or Alaska-breeding population, three surveys, the ACP Waterfowl Breeding Population Aerial Survey, the Utqiagvik

Triangle (UT) Aerial Survey, and the Utqiagvik Ground-based (UG) Breeding Pair Survey, provide information on the number of Steller’s eiders present in northern Alaska annually.

ACP Survey. -- The ACP Survey has been conducted using consistent methods from 2007 – 2019 and 2022 – 2024 and covers 57,336 km² of Alaska’s ACP; the ACP survey was not conducted in 2020 or 2021 due to the global coronavirus pandemic. The aerial survey design follows standard operating procedures adopted for breeding pair surveys throughout North America (USFWS 2012b, p. 3). The survey area is divided into 4 geographic strata that vary in survey intensity from 1 – 8 % based on waterfowl densities and physiographic characteristics (E. Osnas, USFWS MBM Biometrician, pers. comm.). A total of 1 open flock (assumed a single male, E. Osnas, pers. comm.), 36 pairs, and 18 single male Steller’s eiders were recorded during the ACP survey from 2007 – 2019 and 2022 – 2024 (USFWS 2023b, Figure 6).

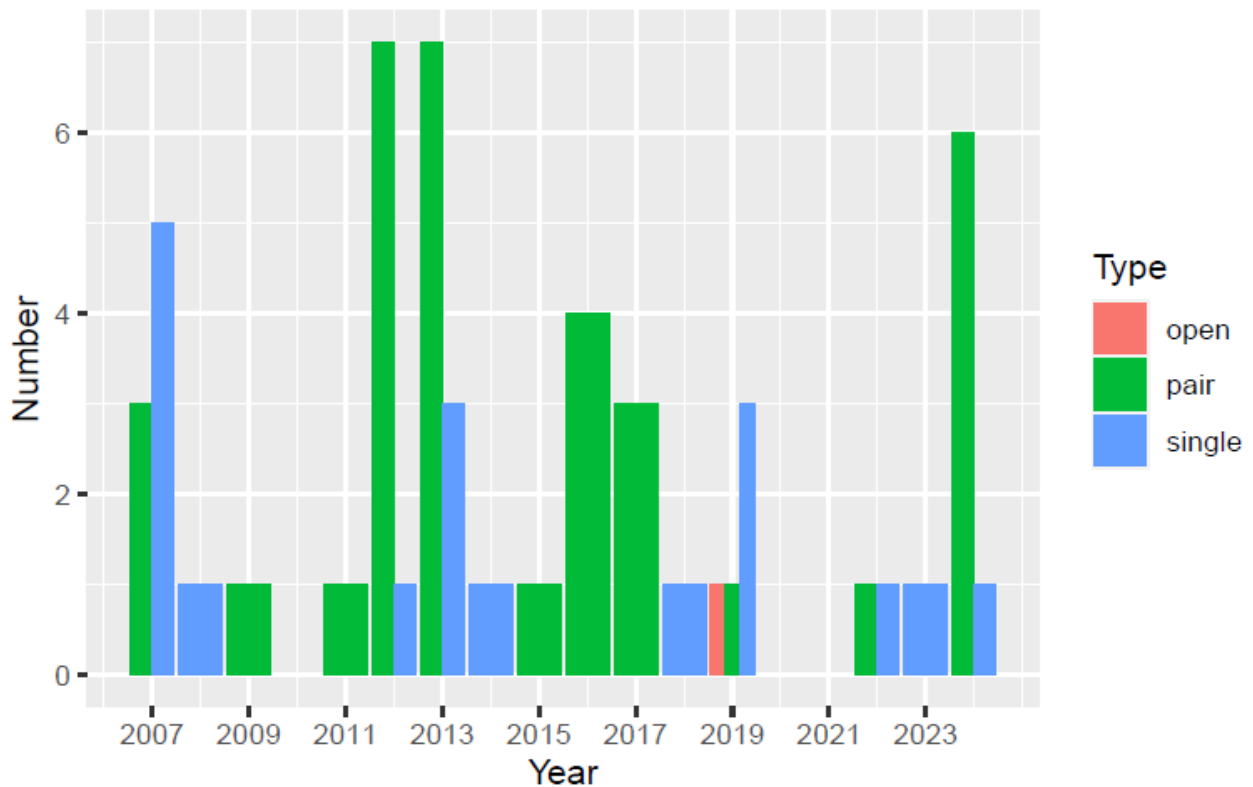


Figure 7. Number of observations of Steller’s eiders during the Arctic Coastal Plain aerial survey, 2007 – 2019, 2021 – 2024 (no surveys conducted in 2020 or 2021). In units, open, pair, and single refer to observations of flocks, pairs of birds, and single birds, respectively (USFWS 2023b, Appendix A).

UT Survey. -- Intensive aerial surveys focused on Steller’s eiders were conducted in a 2677 – 2757 km² area from Utqiagvik to the Meade River, Alaska from 1999 – 2019 and 2021 – 2023 following standard

protocols for breeding waterfowl surveys (Figure 7). Coverage of the survey area varied between 25 – 50% depending on predictions of breeding effort near Utqiagvik each year and fiscal constraints. Survey methods are described in further detail by ABR, Inc. (2017, 2024). The number of birds observed on the survey annually from 1999 – 2019, 2021 – 2023 ranged from 0 – 112 (Appendix B in ABR, Inc. 2024). The population of inference for this survey is the population of Steller’s eiders present in the UT survey area during the breeding season.

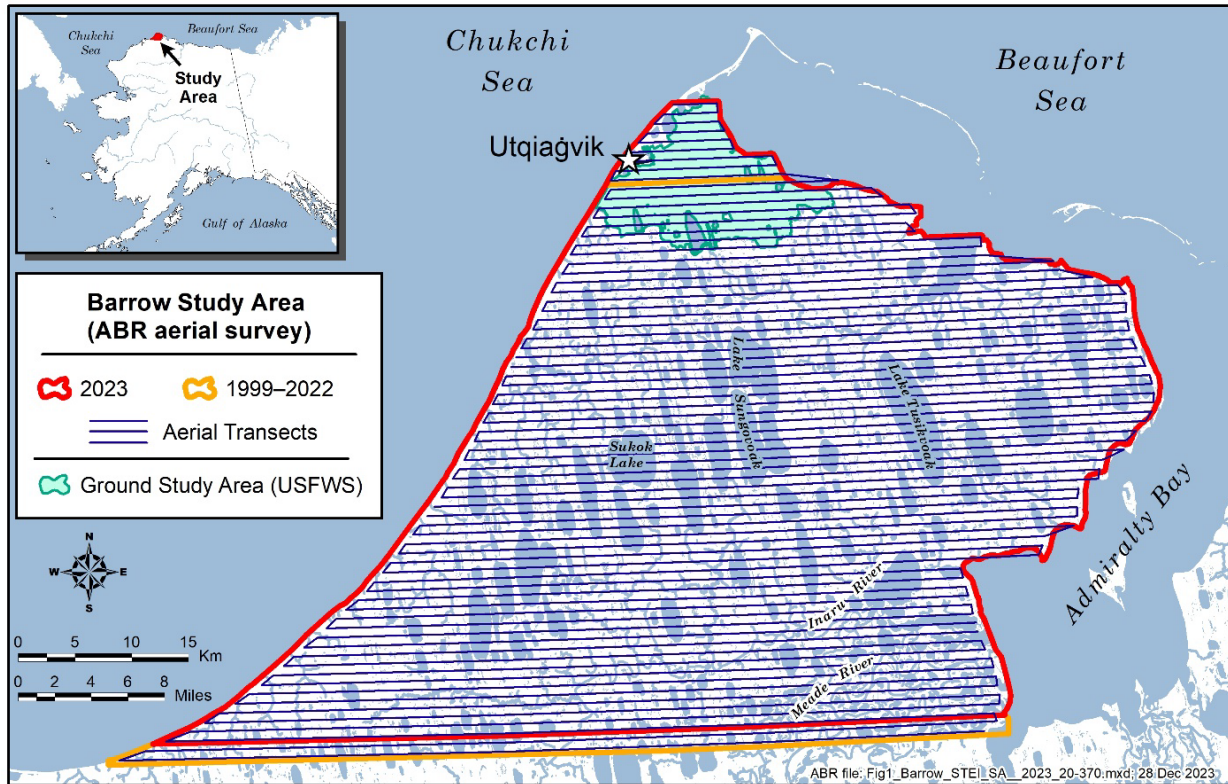


Figure 7. Steller’s eider ground survey area (shaded blue) and Utqiagvik Triangle survey area, June 1999-2019, and 2021-2023 (red and orange boundaries; referred to in the figure as ABR Aerial Survey; From: ABR, Inc. 2024, p. 2). Horizontal blue lines represent aerial transects over the survey area.

Breeding population size estimates and trend. -- To estimate population size of the Alaska-breeding population of Steller’s eiders, a negative binomial, spatiotemporal generalized additive model (GAM) was used, incorporating survey data from the ACP and UT aerial surveys (Amundson et al. 2019; Appendix A). This spatiotemporal GAM is an improvement from previous modeling efforts that used a binomial-Poisson state-space model that ignored spatial heterogeneity, likely introducing bias to previous population size estimates. The spatiotemporal GAMs account for spatial variation in density across transects while also accounting for temporal effects. Combining the ACP and UT datasets

provided improved population estimates for inference across the ACP survey area, as the ACP survey's sampling intensity is sparse in comparison to the UT survey area, and Steller's eiders occur in low density outside the UT area (see Appendix A for detailed analyses that were completed). The best model for inference of the smaller UT area excludes the ACP dataset (Appendix A).

As aerial surveys do not account for non-detection of eiders, we used a detection rate obtained from double observer sight-ability trials where Steller's eider decoys were placed on the tundra concurrent with the UT survey (USFWS 2018d). USFWS (2018d) found that detection rate primarily depended on distance from transect (p. 5). The detection rate we used (0.307, SE=0.092) was obtained by averaging the 2018 estimated detection probabilities from the sight-ability trials (USFWS 2018d, Table 3, p. 6). Population estimates could be further improved by continued analyses of the double observer sight-ability trial data from the UT survey, as the detection rate we used is based on 1 year of data (Appendix A).

The predicted mean estimate of Alaska-breeding Steller's eiders occurring across the ACP (but outside the UT area) from 2007 – 2024 is 152 eiders (median = 120.81, SD = 196.73, 95% CI: 59.19, 340.67; Figure 8), which is lower than previously reported possibly because of the differences in population models used for analysis (SSA v. 1.0, USFWS 2019b, p. 32-33). The estimated average annual number of Steller's eiders in the Utqiagvik Triangle from 1999 – 2023 is 213 eiders (95% CI: 123.7, 403.1); Appendix A; Figure 9). The highest density of Steller's eiders was in the northern section of the UT area, and the lowest density was in the southeast (Figure 3); through time, eider densities decreased in the southeastern portion of the UT area and increased in the north (Appendix A). Overall, the highest densities of Steller's eiders in the breeding season are within the UT (Figures 2 and 3); thus, this estimate represents a significant (but still annually variable) portion of the population. Together, the estimated average number of Steller's eiders present across the combined area from 2007 – 2024 is 406 eiders (median = 383.32, 95% CI: 207.67 – 750.02; Figure 10).

The combined model (integrating ACP and UT data) suggests that the Alaska-breeding Steller's eider population undergoes cyclical patterns of abundance with short periods of increases and decreases (Figure 9), with an approximate 6.5-year period; the population appears to undergo stable cycles of constant period but perhaps varying amplitude (Appendix A). The posterior 10- and 25-year (log geometric mean) growth rate was -0.03 (CI: -0.15, 0.06) and -0.02 (CI: -0.07, 0.02), respectively, with the shorter-term growth rate estimates with less precision. As the population appears to follow a cyclic pattern with a 6.5-year period, attention should be given to the start and end points for analyzing trends, and similar phases in the cycle should be used (Appendix A). For example, the 3-period trend from 2003 to 2024 is 0.06 (CI: -0.01, 0.10) but the estimate is sensitive to the start year of this trend (2002, 2003, or 2004) because the population changes quickly (Figure 2). If instead the interval 2002 to 2022 is analyzed (three periods centered on the trough), the trend estimate is 0.02 (CI: -0.02, 0.06) and

this is less sensitive to the exact choice of starting location, up to about plus or minus one year (Appendix A). Overall, the long-term population trend suggests an increasing or slightly decreasing population, depending on the time interval analyzed. Given the observed cyclical pattern in abundance of Alaska-breeding Steller’s eiders, conducting surveys frequently is important for estimating patterns and abundance over time.

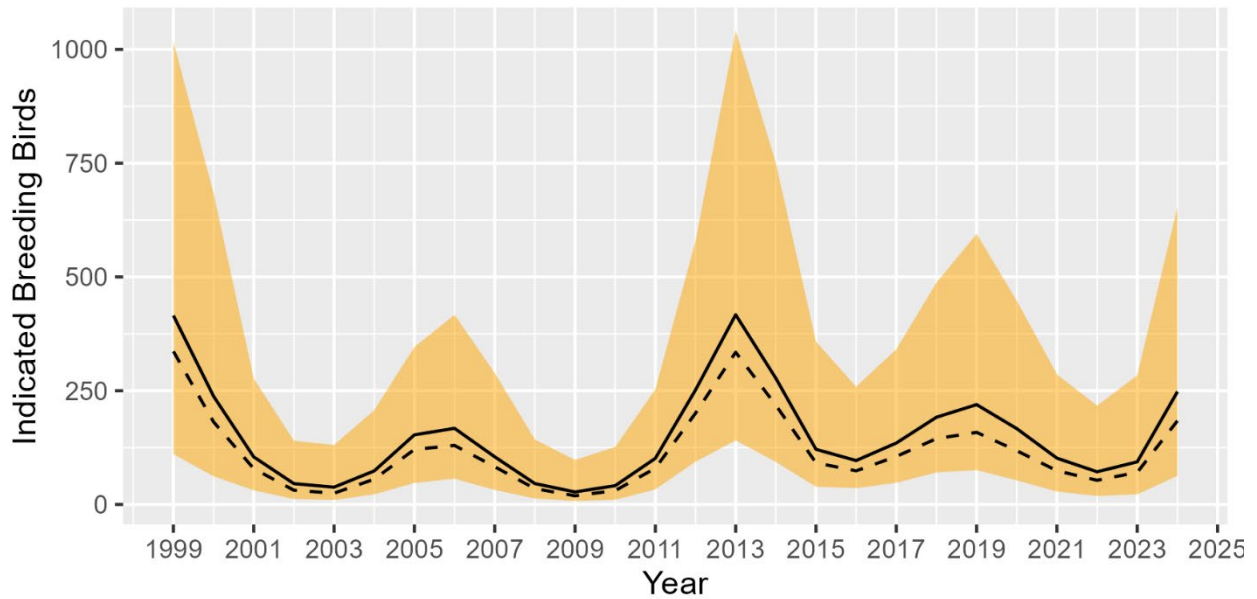


Figure 8. Posterior estimates of Steller’s eiders in the Arctic Coastal Plain survey area, but outside the Utqiagvik Triangle from the combined model (integrating ACP and UT data; Appendix A). Posteriors are shown after applying a detection correction. The black line is the posterior mean, dashed black line is the posterior median, and orange band is the 95% credible interval.

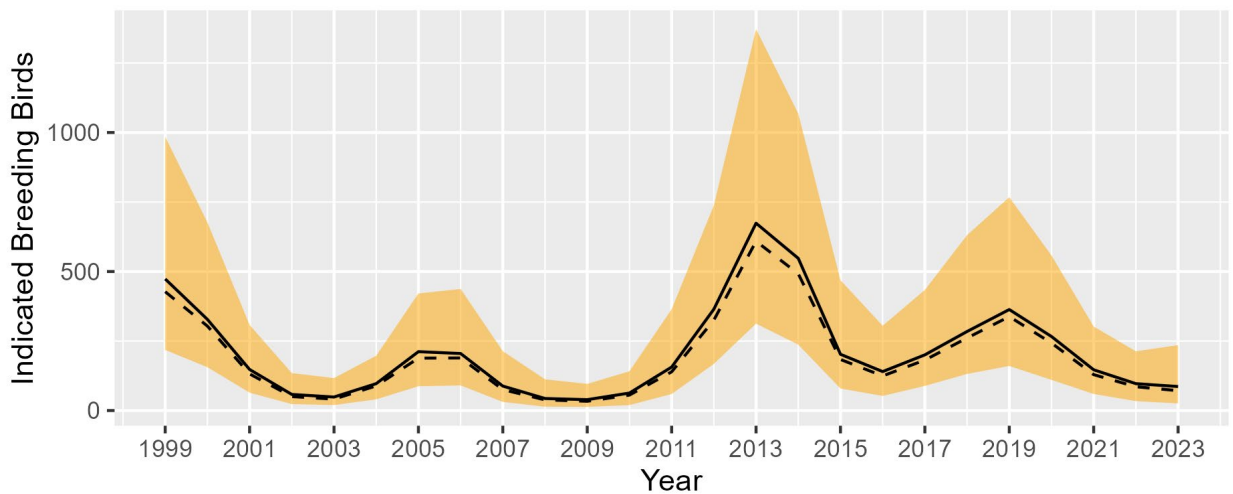


Figure 9. Posterior estimates of Steller’s eiders in the Utqiagvik Triangle survey area after applying a

detection correction from the Triangle-only model (Appendix A). The black line is the posterior mean, dashed black line is the posterior median, and orange band is the 95% credible interval.

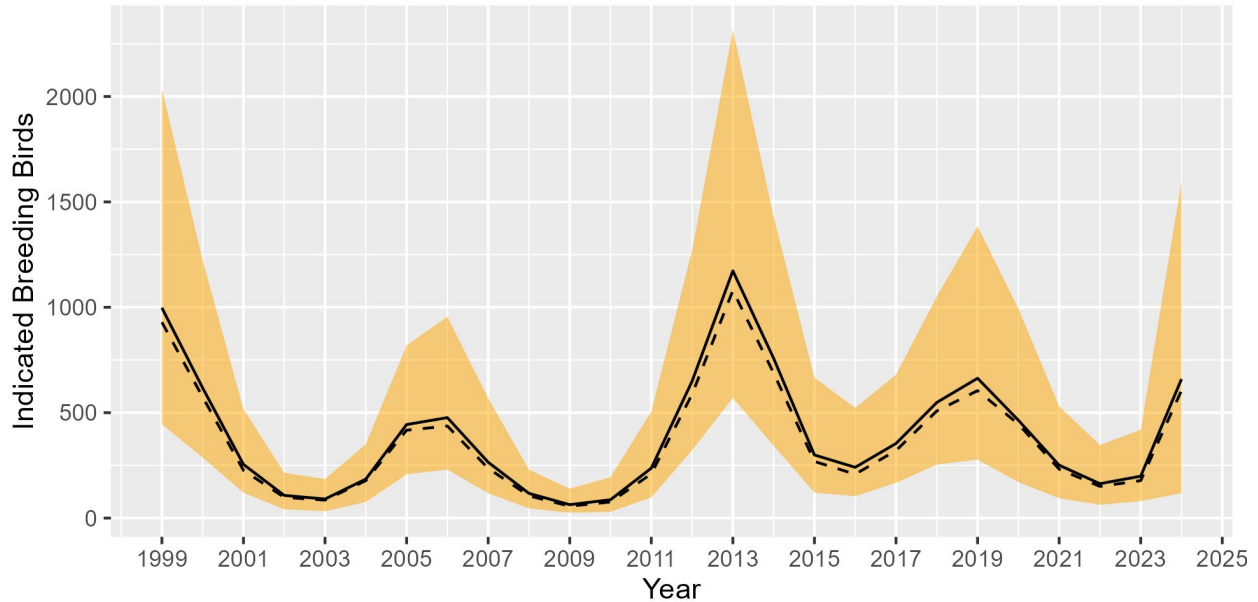


Figure 10. Posterior estimates of the northern Alaska subpopulation of Steller’s eiders from a combined model where both Arctic Coastal Plain and Utqiagvik Triangle survey data were integrated for model fitting (Appendix A). Posteriors are given after applying a detection correction. The black line is the posterior mean, dashed black line is the posterior median, and orange band is the 95% credible interval.

UG breeding pair survey. -- From 1999 – 2023, ground crews have surveyed a ~170 km² area near Utqiagvik and its associated road system to count the number of Steller’s eiders in the area (Figure 8), in which a standard survey area of 134 km² has been consistently monitored in all years (USFWS 2024d, p. 2, 5). Typically, males are counted (Table 5) and assumed to be associated with a more cryptic, and sometimes unobserved, female. The ground-based survey was designed to provide 100% spatial coverage of the study area and was conducted concurrently with the UT Survey, after Steller’s eider pairs were seen to disperse to tundra areas from initial terrestrial spring staging areas (USFWS 2018a, p. 6 - 9). The survey provides an index of Steller’s eider abundance in the study area (detection is not estimated) and identifies priority areas for nest searching. The number of Steller’s eider males observed in the standard area from 1999 – 2019 and 2022 – 2023 was highly variable among years (Figure 11) and ranged from 0 – 132 (mean = 51; SD = 39; Table 6). The mean number of Alaska-breeding Steller’s eiders in the standard area from 1999 – 2019, 2022 – 2023 is 101 eiders (SD = 78, range: 0 – 264); this estimate

was calculated by multiplying the mean number of males observed by 2 to account for paired, cryptic females.²

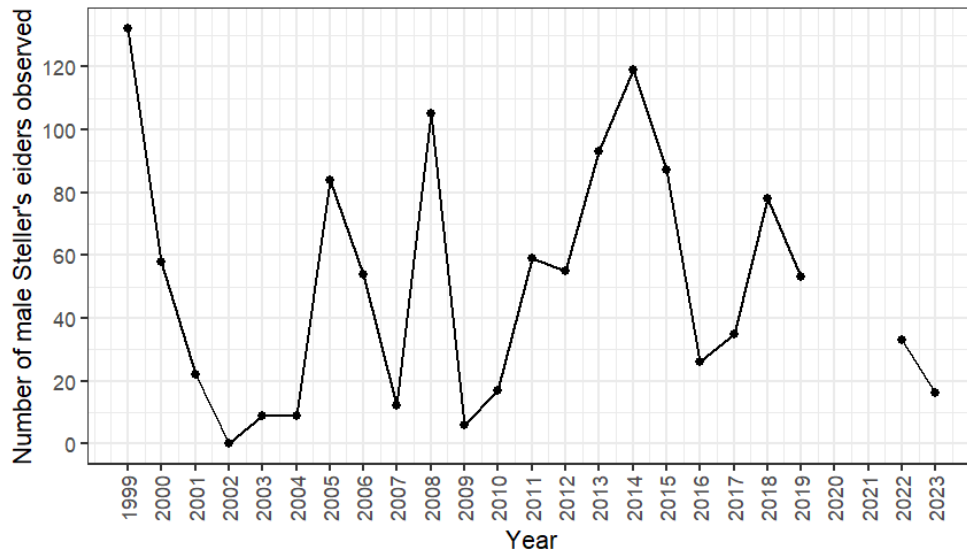


Figure 11. Number of male Steller’s eiders observed during ground-based survey (within standard survey area, 134 km²) near Utqiagvik, Alaska, 1999-2023.

Table 5. Number of Steller’s eider males observed during the Utqiagvik ground breeding pair survey and the pair density (males/km²), 1999-2023 within the standard 134 km² survey area (from: USFWS 2024d, p. 16).

Year	Number of males observed	Pair Density (males/km ²)
1999	132	0.98
2000	58	0.43
2001	22	0.16
2002	0	0
2003	9	0.07

² The revised demographic recovery criteria for the Alaska-breeding population of Steller’s eiders (USFWS 2021b, p. 17) specifies thresholds of 50 (alternative 1) and 75 (alternative 2) for the mean number of Steller’s eiders observed in the UG survey area, but excluding observations from the UT area, over the most recent 20 years. This estimate for the mean number of Steller’s eiders in the standard area does not account for exclusion of observations from the overlapping UT area.

2004	9	0.07
2005	84	0.62
2006	54	0.40
2007	12	0.09
2008	105	0.78
2009	6	0.04
2010	17	0.13
2011	59	0.44
2012	55	0.41
2013	93	0.69
2014	119	0.89
2015	87	0.65
2016	26	0.19
2017	35	0.26
2018	78	0.58
2019	53	0.40
2020 ^a	N/A	N/A
2021 ^a	N/A	N/A
2022	33	0.25
2023	16	0.12

^a Surveys were not conducted in 2020 or 2021 due to the global coronavirus pandemic

6.1.3. Summary of population abundance data

Survey data from the ACP, UT, and UG surveys suggest that the number of Steller’s eiders observed in northern Alaska is annually variable (Figures 10, 11). From data collected on the ACP and UT aerial surveys, the estimated average number of Steller’s eiders present across the ACP (including the UT area) from 2007 – 2024 is 405.6 eiders (median = 383.32; 95% CI: 207.67, 750.02; Figure 10), in which Steller’s eiders primarily occur within the UT survey area; the estimated average number of Steller’s eiders within the UT area (derived from the UT data only model) from 1999 – 2023 is 213.2 eiders (95% CI: 123.7, 403.1). As the breeding population appears to follow a cyclic pattern with a 6.5-year period, attention should be given to the start and end points for analyzing trends, and similar phases in the cycle should be used when interpreting estimates of trend for this population. The long-term breeding population trend suggests an increasing or slightly decreasing population, depending on the time interval analyzed.

Table 6. Summary of methods and results for surveys of the northern Alaska subpopulation of Steller’s eiders.

Survey	Population of inference (Steller’s eider)	Coverage and timing	Estimate of number of Steller’s eiders present in surveyed area	Other relevant information
ACP aerial breeding waterfowl survey	Northern Alaska subpopulation, minus birds within UT and UG surveys	1 – 8% 2007 – 2019, 2022 – 2024	Mean = 151.6 (95% CI: 59.2, 340.7)	- Number of observed eiders = 90 over 16 years - Analyzed using spatiotemporal generalized additive models, in which estimates were derived from a combined model (using ACP and UT survey data; see Appendix A) - Detection rate of 0.307 (SE = 0.092) applied (Appendix A)
UT aerial survey	Birds present from Utqiagvik to Meade River, excluding birds proximal to Utqiagvik	25 – 50%, 1999 – 2019, 2021 – 2023	Mean = 213.2 (95% CI: 123.7, 403.1)	- Annual counts of observed eiders ranged from 0 to 112 - Analyzed using spatiotemporal generalized additive models; estimates derived from UT-only data model (see Appendix A) - Detection rate of 0.307 (SE = 0.092) applied
UG breeding pair survey	Birds present within 6 km of road system near Utqiagvik	100%, 1999 – 2019, 2022 – 2023	Range = 0 – 264 Mean = 101.0 (95% CI: 69.28, 132.80)	- Conducted over 10 – 14 days, after birds have dispersed to nest areas - Survey provides index of population size (detection is not estimated) - Mean estimated by multiplying the number of males observed in the standard ground survey area (132 km ²) by 2 to account for paired, cryptic females

6.2. Demographic Rates

Several research and monitoring projects focused on Steller's eider demographic rates have been conducted since listing and development of the recovery plan; some are still on-going. Below we describe the most current information on demographics of the northern Alaska subpopulation of Alaska-breeding Steller's eiders; we have no data on these rates for the western Alaska subpopulation.

6.2.1. Reproductive rates

Data on reproductive parameters have been collected in the Utqiagvik study area from 1991 – 2019 and 2022 – 2023. It is unclear how estimates from the Utqiagvik study area relate to rates of the entire subpopulation. For example, nest survival likely varies geographically across the ACP due to habitat conditions and ecological community composition (i.e., fox, jaeger, gull, raven, and human populations). Nest survival near Utqiagvik may be negatively influenced by a higher amount of human disturbance from research and local activities on the road system than elsewhere on the ACP. Conversely, fox control was conducted annually from 2005 – 2016 near Utqiagvik, which may have artificially increased nest survival rate in the area, but it is not possible to estimate the effect of fox control on nest survival (G. Givens, Givens Statistical Solutions, pers. comm., 2016). Nest survival estimates in those years could be biased high, because of benefits from fox control or preferred habitat conditions near Utqiagvik, or low, because of increased disturbance or other factors. Unfortunately, effects of fox control and human disturbance are difficult to untangle from unquantified variation produced by other natural and anthropogenic factors acting on nest survival. These same caveats apply to varying degrees for breeding propensity, clutch size, and duckling survival.

Breeding propensity of Alaska-breeding Steller's eiders (the proportion of the population that breeds annually) has not been estimated, but surveys conducted annually from 1999 – 2019 and 2022 – 2023, indicate that both the number of breeding pairs and nests present in the Utqiagvik study area are highly variable from year to year. Breeding pair surveys are conducted by walking a standard 134 km² area once Steller's eiders have begun to disperse to tundra nesting areas in the spring. In most years, nest searching was conducted using methods that maximize the number of nests found rather than random or stratified sampling intended to estimate nest density in the area (USFWS 2018a, p. 10). The number of nests found in the study area annually from 1991 – 2023 ranged from 0 – 78 (Table 2; USFWS 2024d, p. 36).

Mean apparent clutch size of nests near Utqiagvik from 1991 – 2023 is 5.7 (range 4.8 – 6.6; SD = 1.17, n = 193; N. Graff, USFWS Biologist, pers. comm.). Apparent clutch size is likely lower than true clutch size because some eggs may have been removed by predators prior to the first nest visit in which eggs were counted.

Nest fate was monitored in the Utqiagvik study area from 1991 – 2023, and average annual nest survival probability, defined as the probability that at least one egg hatches in a nest, was estimated using the Mayfield model in program MARK (Mayfield 1961, p. 255-261; Mayfield 1975, p. 456-466). The mean nest survival probability in the Utqiagvik study area was 0.28 (SE of annual point estimates = 0.05) and ranged from 0.0 to 0.88 (USFWS 2024d, p. 36).

Steller's eider broods were monitored in five years between 2005 and 2012 near Utqiagvik by marking females with radio transmitters prior to hatch and locating broods with radio-tagged hens approximately every three days (USFWS 2006, p. 26-27; USFWS 2007a, p. 27-28; USFWS 2011a, p. 32-33; USFWS 2012, p. 29; USFWS 2013a, p. 29-30). The mean brood survival probability of all years of data collection was 0.65 (SE = 0.07, n = 35; D. Safine, USFWS Biologist, pers. comm. 2017; See USFWS 2013a p. 15-16 for description of similar data analysis methods). By using the ratio of the mean number of fledged juveniles per brood and the mean number of hatched ducklings per clutch, mean duckling survival probability was approximately 0.44 (D. Safine, USFWS Biologist, pers. comm.).

In summary, the available measures indicate high annual variability in demographic rates related to productivity. High variation results in lower mean demographic rates (Morris and Doak 2003, p. 25-27), which could have additional detrimental effects on the overall resiliency of the population.

6.2.2. Survival

Annual survival probability of Steller's eiders in the Pacific-wintering population has been estimated in two analyses using mark-recapture data from banded molting Steller's eiders at Izembek Lagoon on the Alaska Peninsula. Initial analyses were limited to using a small subset of the data, were hindered by low sample sizes in some years, and resulted in imprecise estimates (Frost et al. 2013, p. 174-175; see Flint et al. 2000). Frost et al. (2013), using a Pradel model framework and all data from years with consistent banding effort (1993 - 2006), estimated annual female apparent survival probability as 0.86 (SE = 0.03) and annual male survival probability as 0.87 (SE = 0.18). The direction of bias of this estimate relative to true survival is unknown. The sampled population consists of non-breeding and failed breeding females because successful females and their broods had not yet arrived at Izembek Lagoon during the capture period. Furthermore, the survival model in this case does not distinguish between permanent emigration and mortality; therefore, the estimate of apparent survival probability may be biased low compared to the true survival rate. However, the bias is likely small given that Pacific-wintering Steller's eiders have been shown to have high molt site fidelity (Flint et al. 2000, p. 265). In addition, it is unknown how applicable these estimates are to the Alaska-breeding population, as the population of inference is birds molting at Izembek Lagoon, which is dominated by birds from the Russia-Pacific breeding population, which presumably includes a small but unknown number of birds from the Alaska-breeding population.

Safine et al. (2020, p. 353-354) used genetic profiles of 217 nesting adult females from feathers deposited in nests and conducted a mark-recapture analysis to estimate apparent survival probability using Cormack-Jolly-Seber models (see Lebreton et al. 1992). Apparent survival probability of nesting females captured in the Utqiagvik study area from 1995 to 2016 was 0.78 (SE = 0.06; Safine et al. 2020, p. 355). Apparent survival probability is lower than true survival probability, because the model used in this analysis does not distinguish between permanent emigration and mortality. While this is the only direct estimate of annual apparent survival rate of birds in the Alaska-breeding population, it is unclear how it relates to the survival rate of the entire northern subpopulation, as the birds sampled were restricted to the Utqiagvik study area.

In another analysis, Dunham and Grand (2017) estimated demographic parameters that best described the count data from annual ACP aerial surveys using sequential importance sampling and a Bayesian state-space model framework (p. 7). From the population process model that best fit the data, which allowed for immigration from the Russian-Pacific breeding population and population-level non-breeding events, adult female survival probability was estimated as 0.754 (SD = 0.015; Dunham and Grand 2017, p. 6). This estimate is within the 95% confidence interval of the apparent survival probability estimate of 0.78 (SE = 0.06; Safine et al. 2020) derived directly from data on marked Steller's eiders nesting on the ACP. These results suggest that the northern subpopulation has lower survival than the Russian-Pacific breeding population (in comparison to Frost et al. [2013] survival estimate of 0.86 (SE = 0.03); Dunham and Grand 2017, p.12).

It is important to note the relative importance of adult female survival and productivity to population growth (and therefore resiliency) of Steller's eiders. Assuming that Steller's eiders fall within the continuum of typical sea duck life histories, changes in adult female survival have a larger effect on population growth rate than demographic parameters related to productivity, such as breeding propensity and nest survival (Flint 2015, p. 72-73).

Age-specific survival of Steller's eiders has not been estimated, although it is generally thought that waterfowl have lower survival rates in their first year than as adults (Johnson et al. 1992, p. 447-448; Opper and Powell 2010, p. 326).

6.2.3. Connectivity with the Russian-Pacific breeding population

As discussed in the Background section, delineation of Alaska-breeding and Russia-breeding populations was due to geography, political boundaries, and reasons related to conservation management; however, the distinction may not be biologically meaningful if there is a high rate of exchange between the breeding areas. At the time of listing, the degree and direction of movement between Alaska and Russia breeding populations was unknown. Since then, the level of movement between the Alaska-breeding and Russian-Pacific breeding populations from genetic analysis, movement data over multiple seasons

from birds marked with satellite transmitters, recaptures of banded birds, mark-recapture analysis of Alaska-breeding females, and population modeling, have provided some information about the level of movement between the Alaska-breeding and Russian-Pacific breeding populations and population structuring during the non-breeding season.

Genetic population differentiation. -- Pearce et al. (2005) analyzed seven nuclear microsatellite DNA loci and cytochrome b mitochondrial DNA (mtDNA) from tissue samples collected from Steller's eiders across their range to explore levels of genetic population differentiation. Low but significant differentiation was detected in nuclear DNA markers between Utqiagvik and Norway, and Utqiagvik and the Lena River, Russia breeding areas using traditional F-statistics; however, no significant difference was detected between Utqiagvik and the closest breeding area in Russia at the Indigirka River delta (Pearce et al. 2005, p. 751). Patterns of differentiation for breeding areas using nuclear DNA were not detected using a Bayesian clustering method (p. 749 - 750). Similarly, analysis of mtDNA data did not result in a significant difference in haplotype frequencies among breeding areas (p. 749-750). In addition, models describing molting and wintering birds as from a single population rather than from multiple breeding populations gained the most support in an information theoretic framework (p. 752). Comparisons of male and female mtDNA haplotype variation among sampled areas suggests female philopatry, but levels are not significant enough to result in genetic differentiation between Russia- and Alaska-breeding populations. These findings are generally consistent with other waterfowl species that show patterns of male dispersal and stronger female philopatry (Anderson et al. 1992, p. 370 - 371). Pearce et al. (2005) suggest that there may have been insufficient time since Pleistocene deglaciation and colonization of the current breeding range for differentiation to develop (p. 754).

Philopatry. – Using DNA genotypes of egg membranes and adult female feathers deposited in nests, Safine et al. (2020, p. 354-355) determined the number of females that nested near their natal site in the Utqiagvik study area. Egg membranes from successful nests were collected in 2005 – 2008 and 2012 – 2014 and compared to a genetic database of females nesting in the Utqiagvik study area from 2007 – 2008 and 2012 – 2016. Nine of 124 females hatched in 2005 – 2008 were recaptured as nesting adults in subsequent years. Low sample sizes precluded using a modeling framework to estimate philopatry. Instead, Safine et al. (2020, p. 354-356) compared the results observed to the number expected given available vital rate estimates and natal philopatry of 1.0. The difference between observed and expected values provided an inference into the level of philopatry in Steller's eiders. To calculate the total number of expected recaptured nesting hens, they applied the following vital rates to the number of female ducklings genetically identified in a given year: duckling survival (0.44; USFWS, unpublished data [brood survival adjusted for brood size at fledge]), first year survival (0.40 [Flint et al. 2015] to 0.67 [Oppel and Powell 2010]; king eider), second year survival (0.75; Dunham and Grand 2017), apparent annual survival (this study), and apparent capture probability (constant and year-specific model results from this study). Given first year survival estimates for Steller's eiders are based on surrogate species

and expert opinion, they used a range of values from 0.4-0.67 to calculate possible outcomes. They assumed all females would become capable of nesting at two years of age, as that was the earliest age that females in the study nested. Therefore, females hatched in the last and second to last study year (2015 and 2016) would have no chance of being detected. Calculations were made for the cumulative total expected recaptures for each cohort of ducklings across study years, and then summed for all cohorts. For example, for female ducklings in the 2008 cohort, they summed the expected number of recaptured nesting hens for each year between 2010 and 2016 and considered that the expected total for the cohort. The number of recaptures expected if philopatry was 1.0 ranged from 4 – 16. The number of observed returns falls in the middle of this range, indicating philopatry may range from 0.6 – 1.0, suggesting that female Steller’s eiders in the area sampled are moderately to highly philopatric to natal areas.

Breeding Site Fidelity and Emigration. – Using DNA genotypes from adult female feathers deposited in nests from 1995 – 2016, Safine et al. (2020) estimated the rate of permanent emigration (p. 353-355). They first estimated apparent survival rate and capture probability of adult females using a Cormack-Jolly-Seber model with constant survival and capture probability, in a maximum likelihood framework (Lebreton et al. 1992). Then, assuming that estimates of adult female survival from Flint et al. (2000; 0.90, SE = 0.03) and Frost et al. (2013; 0.86, SE = 0.03) equated to true survival, they calculated permanent emigration as $1 - (\text{apparent survival}/\text{true survival})$. Although the Frost et al. (2013) estimate includes some permanent emigration, it is probably minimal, at least at a local scale, because birds tend to show high rates of fidelity to lagoons (> 0.95 , Flint et al. 2000). Using these methods, the average estimate of permanent emigration of Steller’s eiders nesting in the Utqiagvik study area was 0.09 (SE = 0.07) (Safine et al. 2020, p. 355). Breeding site fidelity, or the probability that an individual associated with the population in year i remains associated with the population in year $i+1$ given survival between year i and year $i+1$, is the complement of permanent emigration. Thus, the average estimate of breeding site fidelity was 0.91 (SE = 0.07). While this estimate applies only to the birds in the population sampled (those females that nested in the area searched near Utqiagvik, see Safine et al. 2020, p. 356-359), it does suggest that female Steller’s eiders in the Utqiagvik study area have fidelity to previously used nesting areas.

Safine et al. (2020) also estimated the probability of temporary emigration, or the probability that a female is alive and associated with the population but is not present in the study area any given year (p. 353-355). To estimate temporary emigration, they derived closed capture probability, or the probability that an individual nest is detected annually given that it is present in the search area. To do this, they first estimated the number of nests initiated in the search area using the approach described by Miller and Johnson (1978) and Johnson and Shaeffer (1990). The number of nests initiated equals the number of nests observed to hatch that were initially found active divided by the probability that a nest survived to hatch at least one egg. Nest survival was estimated in Program MARK (White and Burnham 1999)

based on a 30-day exposure period (Quakenbush et al. 2004). Closed capture probability then equals the number of active nests found divided by the number of nests initiated in the search area. The average probability of temporary emigration, estimated as $1 - (\text{apparent capture probability} / \text{closed capture probability})$ from a time-varying model, was 0.77 (SE = 0.06; Safine et al. 2020, p. 355). Safine et al. (2020) suggest two potential explanations for this relatively high estimate of temporary emigration: in years they are not detected, temporary emigrants may forgo nesting; or they nest outside of the search area, either on the ACP or in Russia (p. 357). We do not have information to determine the relative likelihood of either explanation. However, average distance between successive nests of individual females was 2.6 km (SE = 0.5, range 0.1 – 10 km) (Safine et al. 2020, p. 354), suggesting that females nesting outside the study area explains a portion of temporary emigration.

In summary, genetic analysis provides some evidence of female natal philopatry, but not at levels significant enough to result in population-level differentiation between Alaska-breeding and Russian-Pacific breeding Steller's eiders. It is possible that the genetic markers used could not detect population differentiation because of recent population expansion. Given the high estimate for breeding site fidelity, the probability of permanent emigration of breeding females from the Utqiagvik study area is low. In addition, recaptures of breeding females that hatched in the study area also implies moderate to high levels of philopatry of birds to the Utqiagvik study area.

Migration patterns and fidelity to non-breeding habitats. -- Information is limited on migratory movements of Steller's eiders in relation to breeding origin. Martin et al. (2015) attached satellite transmitters to 14 Steller's eiders near Utqiagvik in 2000 and 2001 (p. 346). Although there was a small sample size, 7 of 13 satellite-tagged Steller's eiders used Kuskokwim Shoals during wing molt (Martin et al. 2015, p. 351). However, Martin et al. (2015) did not find marked Alaska-breeding Steller's eiders to preferentially use specific wintering areas (p. 348), and mortality and/or failure of satellite tags prevented data on locations in the subsequent breeding season.

A later study marked Steller's eiders wintering near Kodiak Island, Alaska and followed birds through the subsequent spring (n = 24) and fall molt (n = 16) migrations from 2004–2006 (Rosenberg et al. 2011, p. 350). In spring, most satellite-tagged birds traveled across the Bering Sea after leaving Kuskokwim Shoals (83%; Rosenberg et al. 2014, p. 361), suggesting that spring-migrating Alaska-breeding and Russia-breeding Steller's eiders diverge after leaving the Y-K Delta coast. Most birds marked near Kodiak Island migrated to eastern Arctic Russia prior to the nesting period and none were relocated in Alaska on land or in nearshore waters north of the Yukon River Delta (Rosenberg et al. 2011, p. 349, 353); thus, they likely represent the Pacific-Russian breeding population. While molt sites seemed to be independent of breeding area, three of four satellite-tagged birds returned to the same molting location in two consecutive years, suggesting high return rates (Rosenberg et al. 2014, p. 356). Similarly, 11 of 12

birds with functional satellite transmitters returned to the same wintering area (Rosenberg et al. 2014, p. 356).

Pacific-wintering Steller's eiders have been banded in a series of capture efforts at Izembek and Nelson Lagoons in southwest Alaska during molt (Jones 1965, p. 83; Flint et al. 2000, p. 262). Band recovery information suggests little or no subpopulation structuring during the molting period. Steller's eiders molting in these lagoons represent birds from multiple Russian breeding locations (Dau et al. 2000, p. 545). There are not enough band recoveries from Alaska-breeding birds to determine if the northern Alaska subpopulation is segregated from Russian-Pacific breeding birds on the molting or wintering areas (Dau et al. 2000, p. 547). However, Flint et al. (2000) estimated 95% or greater fidelity of Pacific-wintering Steller's eiders to molting areas in Izembek and Nelson Lagoons, Alaska (p. 265).

While molting site fidelity was previously found to be high for Steller's eiders (Flint et al. 2000, p. 265), recent surveys along historically important molting sites on the Alaska Peninsula have found reduced numbers of Steller's eiders using Izembek Lagoon in the fall (USFWS 2016c, p. 8). The reduction in number of eiders observed at Izembek Lagoon in the fall may represent changes in their fall molting distribution (i.e., resulting in lower site fidelity; USFWS 2019a, p. 6), or represent lower survival (Hollmen et al. 2022, p. 6; Maliguine 2024, p. 3).

6.2.4. Resiliency of the Russian-Pacific breeding population

Given the lack of observed genetic differentiation between Alaska- and Russian-Pacific breeding populations and the mixing of both populations during non-breeding seasons, some number of females originating from the Russian-Pacific breeding population may immigrate to the Alaska-breeding population annually and vice versa. Thus, immigration may be a source of recruits for the Alaska-breeding population. Although we have some evidence of female breeding site fidelity and natal philopatry in the Utqiagvik study area (Section 6.2.3), we have limited data from which to quantify the amount of immigration that occurs or its importance to the Alaska-breeding population's growth rate. If, however, dispersal to Alaska from Russia breeding areas is an important component to maintaining the Alaska-breeding population's size or growth rate, then factors affecting connectivity are important to consider when evaluating resiliency. Movement of individuals could be influenced by the size of the Russian-Pacific breeding population and that population's demographic rates such as productivity and recruitment. Therefore, we hypothesize that the abundance and productivity of the Russian-Pacific breeding population may ultimately affect the resilience of the Alaska-breeding population. Even if no female immigration from Russia occurs, the resiliency of the listed population is dependent to some degree on the Russia-Pacific population simply for a source of males with whom females can pair with during winter when they are co-located. Moreover, given the small size of the listed population, the genetic variation contributed by the Russia-Pacific breeding population will help the listed population avoid a genetic bottleneck.

However, information on demographic rates, abundance, or population growth rate of the Russian-Pacific breeding population from which to infer population resilience is limited (Appendix E), with the exceptions of estimates of adult survival (i.e., Frost et al. 2013) and measures of minimum population abundance of Pacific-wintering Steller's eiders during the non-breeding season in southwest Alaska.

The Service has conducted two surveys in southwest Alaska since 1992 to provide an index of abundance of the Pacific-wintering population of Steller's eiders. The first was flown annually from 1992 – 2012 in late spring when Steller's eiders stage during migration along the coast of southwest Alaska from the Y-K Delta to the western Alaska Peninsula (USFWS 2012c, p. 1). Annual Steller's eider counts from this survey ranged from 54,888 (2010) to 137,904 (1992), with a mean of 81,453 (USFWS 2012c, p. 12-13). There is no measure of precision for these annual counts because no replicates were conducted in most years due to weather and budget constraints (with the exception of 1992 – 1997 and 2008) and because they were not transect-based surveys where annual estimates of precision could be calculated. The resulting count was also highly variable due to weather, timing, and numerous other variables that are difficult or impossible to quantify (USFWS 2012c, p. 8). The many sources of potential error and bias, the high cost, and the difficult flying conditions during the spring led to a change in survey design (USFWS 2012c, p. 8; USFWS 2013c, p. 2).

The re-designed Steller's eider aerial survey was conducted during the fall molting and staging period in five primary molting lagoons along the northern Alaska Peninsula from 2012 – 2019, using photographic methods (USFWS 2016c, p. 2, USFWS unpublished data). Estimates of Steller's eider abundance in the surveyed area ranged from 30,407 (2013) to 70,320 birds (2014; USFWS 2016c, p. 7). The new fall survey design reduced some sources of error (e.g., flock size estimation), but challenges remained, which limited our inferences from the data for estimating abundance or trend of the Pacific-wintering population of Steller's eiders. For example, annual variation in weather, timing of migration, molt site use, and breeding success may lead to potentially large annual differences in fall distribution patterns and may affect the ability of the survey to consistently count the same proportion of the population. In addition, survey design has changed over time, and detection probabilities have not been estimated. These factors increase variability among years, decreasing the ability to detect trends, especially in a short time series (8 years). Results from the fall survey are considered minimum population counts and cannot be compared to counts from the spring survey conducted from 1992 – 2012 given the difference in study design, timing, and possibly portions of the population sampled. In summary, the available count data does not allow us to estimate abundance or trend of the entire Pacific-wintering population (C. Bradley, USFWS Biometrician, 2017, pers. comm.).

Additional aerial surveys over smaller geographic areas in Alaska count Pacific-wintering Steller's eiders in the fall and winter, but the surveys alone do not provide inference on the abundance or trend of the entire population (see Appendix E).

In addition to the lack of abundance and trend estimates, the condition of breeding habitat in Russia and the status of natural and anthropogenic factors acting on the resources required for successful breeding and survival of Steller's eiders in Russia are unknown. Therefore, we cannot evaluate the resiliency of the Russian-Pacific breeding population at this time.

6.2.5. Population dynamics modeling

In an effort to describe dynamics of the northern Alaska subpopulation of Steller's eiders, Dunham and Grand (2017) developed and tested open and closed population process models (p. 3). They fit four population models to indices of population size from ACP aerial breeding pair surveys (Dunham and Grand 2017, p. 3). The model allowing for population-level non-breeding events and immigration from Russia was the model most likely to explain observed variation in population size, while the closed model was the least likely (Dunham and Grand 2017, p. 8-9). The authors concluded that immigration is a key component of population dynamics of Alaska-breeding Steller's eiders; furthermore, they suggest that immigration occurs from the Russian-Pacific breeding population to the Alaska population (p. 10-12).

However, these results should be interpreted with caution given assumptions and caveats in the data set used for this analysis. The models were fit with indices developed from the ACP survey data, which, as described above in Section 6.1.2, are limited in their ability to describe abundance and trends of the northern Alaska subpopulation in part because observation error has not been estimated for Steller's eiders. Other limitations include: 1) the original count data from the ACP survey were adjusted using multipliers and an adjustment ratio to reconcile different time frames of annual surveys conducted prior to 2007 (described in USFWS 2013b, p. 1-4). In some years, zero Steller's eiders were counted in the ACP survey, and the differences between zero and nonzero counts in the original data are inflated by the expansions used to calculate the indices; 2) movement of Steller's eiders from near Utqiagvik to the broader ACP cannot be excluded as a possible mechanism for increased counts in some years as this portion of the Alaska-breeding population is not accounted for in the population index used in the model; and 3) observation error rather than ecological processes such as emigration could explain the observed zero events (observation error could result if individuals present in the survey area are not detected or members of the population are not present during the survey). In summary, considering the limitations of the analysis, Dunham and Grand (2016) did not provide compelling support for or against the hypothesis that high levels of immigration from the Russian-Pacific breeding population occurs, and the importance of immigration to the Alaska-breeding population remains unknown.

6.3. Population Viability Analyses

Population viability analysis (PVA), an analytical method that describes the probability that a population will persist over time, is a common conservation biology tool used to explore available demographic and abundance data and evaluate population resilience to stochastic variation (Himes Boor 2013, p. 38; Morris et al. 2002, p. 708-709). Version 1.0 of the Steller's eider recovery plan based the recovery criteria, the threshold to which we compare species' status, on probabilities of extinction determined by PVA; however, a PVA method is not specified in the plan (USFWS 2002a, p. 9). We considered whether

there is currently adequate information to use a PVA to describe resiliency of the Alaska-breeding population of Steller's eiders.

Since listing, two formal PVAs for the Alaska-breeding Steller's eider have been developed. First, Runge (2004) developed a population viability model for both Alaska-breeding and Pacific-wintering populations of Steller's eiders. Quasi-extinction probabilities (the probability that the population falls below 100 individuals) were estimated using a diffusion approximation model with abundance data from spring surveys of the Pacific-wintering population (i.e., Larned 2012) and a matrix projection model for the Alaska-breeding population using reproductive rates from the Utqiagvik study area and survival rates from Flint et al. (2000; Runge 2004, p. 2 and 4). The analysis assumed no permanent movement between Alaska- and Russia-breeding areas (Runge 2004, p. 13) and that the reproductive data collected at Utqiagvik was representative of the Alaska-breeding population (Runge 2014, p. 2). Some vital rates were estimated with high uncertainty or unknown (e.g., duckling survival, juvenile survival and breeding propensity; Runge 2004, p. 9-10). PVA results indicate that the Alaska-breeding population quasi-extinction probabilities are higher than those for the Pacific population. Under the assumptions of the closed model and with the vital rates used, elasticity analysis results suggest that to reach a population growth rate of 1.0, the Alaska-breeding population must have an adult survival rate of 1.0, which is impossible, or reproductive rates higher than any reported values for sea ducks (Runge 2004, p. 11-12; Savard et al. 2016, p. 341, 343). This led Runge (2004) to hypothesize that the Alaska-breeding population is sustained by supplementation from the Russia-breeding population (i.e., the population model does not represent the true process) and suggested increased effort to estimate breeding propensity and movement, as those demographic rates may be driving population dynamics of Alaska-breeding Steller's eiders (Runge 2004, p. 12-13).

The model developed by Runge (2004) was used during a structured decision-making workshop in 2008. Based on updated vital rate estimates and the assumption of a closed population, the probability of extinction of Alaska-breeding population was 1.0 in 10.2 years (USFWS, unpublished data). However, on average, hundreds of Steller's eiders continue to occupy the ACP annually (Section 6.1.2.) indicating either the closed population model structure or the vital rates used to parameterize the model do not represent reality.

Given the need for a more representative population model, Dunham and Grand (2016) used two matrix projection models to estimate the probability of extinction of the northern subpopulation: a model that included population-level nonbreeding events and time-varying immigration from the previous analysis (Dunham and Grand 2017, p. 6-7) and a closed population model. Posterior estimates from the most parsimonious model by Dunham and Grand (2017, p. 6; model including nonbreeding and immigration) were set as demographic parameters in the models, which were initialized at 1000 individuals and projected to 100 years (Dunham and Grand 2016, p. 3). The closed model resulted in a probability of

extinction of 1.0 in 42 years (Dunham and Grand 2016, p. 4). The open model resulted in 19% of iterations reaching extinction threshold of zero individuals, but, due to immigration, the population was recolonized; therefore, the model estimated the probability of “permanent” extinction in 100 years at 0.006 (Dunham and Grand, p. 4). However, the results of the PVA in the Dunham and Grand (2016) analysis must be interpreted with caution due to the limitations of the data available to fit the models, as described above in Section 6.2.5.

In an attempt to describe the resiliency of the northern Alaska subpopulation of Steller’s eiders during this SSA analysis, we also explored five competing model structures of population process and associated vital rates (See Appendix B). Our intention was to determine the average population growth rate, probability of population extinction in 40 years, average population size, and elasticities and sensitivities of the proposed vital rates for each model. Because the northern Alaska subpopulation has persisted at low and highly variable numbers since first observed in detail (1991-present), we hypothesized that the proposed model structures varied in their ability to replicate this characteristic of population dynamics. Models included varying levels of breeding propensity, including periodic population-wide non-breeding events and breeding propensity of 0.33, productivity rates similar to those observed near Utqiagvik or pulses of high productivity every 3-5 years, annual survival rates of high (0.86) or very high (0.9+), high or low philopatry, and varying rates of movement between Russia and Alaska breeding populations (See Appendix B for parameters used in the models). Our intent was then to use the best supported model or suite of weighted models to describe the current condition of the population and then use available information on environmental and anthropogenic drivers of vital rates to assess possible future trajectories of the population, similar to a PVA.

However, the high variation around the available vital rate estimates resulted in a large number of possible combinations that could explain the observations. Even when making assumptions about the true vital rates, the resulting probabilities of extinction projected in 30 years varied from 0 to 0.94 in the suite of biologically plausible models (USFWS, unpublished data; see Appendix B). We concluded that we lack the specificity in the current demographic and abundance data necessary to make clear inferences about current and future resiliency using a PVA approach.

In summary, given the uncertainty in Steller’s eider population dynamics, the probability of extinction of the northern Alaska subpopulation is largely inestimable at this time. Thus, we describe resiliency, representation, and redundancy of the Alaska-breeding population of Steller’s eiders qualitatively, given the paucity of available quantitative data.

6.4. Stressors

In this section, we describe the stressors that may currently influence resiliency of the population through impacts to habitat conditions or individuals.

6.4.1. Causes of decline

Steller's eiders were listed in 1997 due to a perceived range contraction and resulting small numbers in Alaska rather than an understanding that one or more threats had caused this contraction. At the time, the factors that resulted in a reduction in range or numbers were unknown. Additionally, information about historical abundance of the Alaska-breeding population is sparse, and we have no evidence to suggest Steller's eiders existed in numbers that would qualify the population as highly resilient to stochastic events based on abundance alone. Alaska-breeding Steller's eiders may have historically existed as a small population at the edge of the species' range that fluctuated in numbers, albeit with a broader nesting distribution across Alaska than the population currently occupies.

USFWS (1997) hypothesized that changes in the Bering Sea where Steller's eiders molt and winter and ingestion of lead shot on the Y-K Delta may have contributed to the range contraction, but habitat destruction, overutilization, inadequacy of regulatory mechanisms, disease, and predation were not suspected to be factors. However, USFWS (1997) concluded that, given their low numbers and restricted breeding range, the Alaska-breeding population was at risk of extirpation from natural and manmade factors such as disease, predation, disturbance, or major storms (p. 31755). In addition to changes in the marine environment and ingestion of lead shot, the 2002 recovery plan identified additional stressors that may have affected the population's current condition. These include: increased predation pressure, hunting, exposure to oil or other contaminants near fish processing facilities in southwest Alaska, risk of collisions with fishing vessels or other lighted structures, disturbance related to human activity near Utqiagvik, and loss or alteration of tundra nesting habitat from development (USFWS 2002a, p. 7-8).

In summary, we do not know what caused the apparent range contraction in Alaska. It was likely a combination of several factors that influenced the near-disappearance of Steller's eiders from the Y-K Delta and range contraction on the ACP.

6.4.2. Cause and effects analysis

We conducted a structured cause and effects analysis to evaluate stressors thought to be currently affecting the northern Alaska subpopulation's resiliency (see Appendices C and D for detailed analysis). We first identified the potential anthropogenic and natural stressors that may influence habitat requirements and demographics of Alaska-breeding Steller's eiders by reviewing the listing documents,

recovery plans, and more recent recovery-related documents such as notes from recovery team meetings and ESA Section 7 consultations. Stressors were organized into those that affect Steller's eiders and their habitat requirements in tundra habitat, marine habitat, and throughout their range.

For each stressor, we determined whether and how it affected the resources or habitat conditions required by Steller's eiders and whether it directly or indirectly affected individuals of the species. We described the exposure of individuals to the stressor, the timing and frequency of the stressor, the potential response of individuals, and whether conservation measures minimize effects of the stressor (see Appendix D). At the population level, we determined the geographic extent of the stressor and estimated the portion of the Alaska-breeding population that is currently affected by it. Using the description of effects and responses to individuals and the proportion of the population affected, we then described how the stressor may affect population characteristics such as productivity and survival rates. For all portions of the analysis, we assigned a rating describing our level of confidence in whether the relationships and assumptions used to make conclusions accurately reflect reality, based on the available scientific information (Appendix D, summarized in Table 7).

To determine the effect on population demographic rates, we determined the proportion of the population affected by the stressor. Several stressors, such as increased human disturbance from research and local activities, primarily affect the portion of the northern Alaska subpopulation that uses tundra habitat near Utqiagvik. Human disturbance also may occur in areas impacted by oil and gas development east of the Colville River and near Prudhoe Bay and areas immediately around other villages such as Atkasuk, Nuiqsut, and Wainwright. However, the density of Steller's eiders is very low outside of the Utqiagvik Triangle (Figure 2), and thus we assume that the number affected by these disturbances is very low.

We developed an explicit process to approximate the proportion of the northern Alaska subpopulation of Steller's eiders present near Utqiagvik and its associated road system. While we have observations and abundance estimates of Steller's eiders from three annual surveys on the ACP, the survey areas partially overlap, and the coverage and methods differ, making it difficult to combine aerial and ground survey data sets. The ACP and UT Survey data were combined (see Appendix A) to produce annual population estimates, and we can compare the relative proportion of eiders observed on the ground survey (although effort varies among years) to the combined model estimates (USFWS 2024g). We can approximate the proportion using the available data while making the following assumptions: 1) Steller's eiders using the area within the UG survey area will be affected by anthropogenic factors because the survey area is within 6 km of the road system; 2) the UT aerial survey is the best available estimate for the largest proportion of Steller's eiders on the ACP annually because density of Steller's eiders on the ACP is highest in the UT and the survey has high coverage; and 3) observations from the UT survey and the UG survey are independent, and individuals were not double-counted. Considering these

assumptions, the average proportion of the northern Alaska subpopulation present on the ACP annually that inhabits the UG survey area is 0.3 and ranges from 0.02 to 1.66 annually³. Therefore, this analysis assumes that approximately one third of the northern Alaska subpopulation is potentially affected by anthropogenic effects near Utqiagvik, and that proportion varies annually. It is important to note that this is not the proportion of the entire northern Alaska subpopulation, because we have not accounted for availability or temporary emigration of individuals, but rather represents the proportion of the birds present on the ACP in any given year that are potentially affected. While we recognize the imperfections in this calculation and associated assumptions, it is a reasonable first step in developing a framework to estimate the proportion of population affected by anthropogenic effects near Utqiagvik, which can be improved upon as knowledge and additional analyses become available.

Characterization of stressors in tundra habitat. -- We identified stressors affecting Steller's eiders during pre-breeding staging, nesting, and brood-rearing activities in tundra habitat (Table 7). Of these stressors, we concluded that shooting and exposure to lead shot may have a high effect on population resiliency. Shooting has been documented, and it is possible that tens of adults are shot annually, although this number varies and is difficult to estimate (USFWS 2018b, p. 38). Given the small number of Steller's eiders in the listed population (Section 6.1.2.), and assuming that population growth rate is highly influenced by adult survival rate (Section 6.5.2), loss of even a small number of individuals annually could result in a reduction in population resiliency. Similarly, ingestion of lead shot causes mortality, particularly of breeding females, and Steller's eiders are exposed to lead on the tundra breeding grounds (Appendix D). These factors combined result in a high level of concern and potential effect on resiliency (Appendix D). For this analysis, we assume roughly 1/3 of the Alaska-breeding population may be exposed to both of these stressors, but a smaller, annually variable number are actually affected (see above and Appendix D). Human disturbance, avian and fox predation, changes to lemming population cycles, and harsh weather during the breeding season moderately affect population resiliency as they likely reduce reproductive effort and success of a portion of the northern subpopulation (See Appendix D, summarized in Table 7).

The highest density of nesting Steller's eiders in northern Alaska is near Utqiagvik; thus, habitat loss due to infrastructure development in that area is a concern. We have no evidence to make inference as to whether and how this stressor affects subpopulation resiliency; therefore, we describe the current effect as unknown. We surmise that habitat loss due to oil and gas development in other parts of the ACP, such as eastern NPR-A and Prudhoe Bay, has less of an effect on subpopulation resiliency due to

³ We calculated this number as follows: For each year 1999 - 2023, we calculated the ratio of the observed Steller's eider males during the ground survey multiplied by 2 (Table 5) to the total estimated eiders across the ACP (including the UT area) using the model combined estimates (USFWS 2024g) for each year (excluding years 2020 and 2021 because ground surveys were not conducted). The number of eiders observed in the ground survey and during aerial surveys is annually variable; in 2008, there were more eiders observed on the ground survey than the total estimated across the ACP from aerial survey data.

the very low density of Steller's eiders in those areas. However, this is also undocumented; therefore, the effect of habitat loss in these areas is also unknown at this time (See Appendix D, summarized in Table 7).

Changes to tundra habitat due to climate change have been observed, but the links between observed changes in habitat, the responses of individual Steller's eiders, and the resulting impact to demographic rates of the subpopulation have not been documented. Therefore, we consider the current effect of habitat change on resiliency of the subpopulation to be unknown (See Appendix D, summarized in Table 7).

A final stressor we considered was the observed increase in populations of white-fronted geese (*Anser albifrons*) and cackling geese (*Branta hutchensii*) on the ACP. At high densities, goose populations have been shown to both negatively and positively affect elements of nest and brood-rearing habitat, freshwater invertebrate communities, and nest predation rates of waterfowl species in other areas of the Arctic (See Appendix D). While goose populations have increased in recent decades on the ACP (USFWS 2012b, p. 43), within the core breeding range of Steller's eiders in Alaska they have not reached densities similar to those shown to affect Arctic habitat. In addition, the direction of the potential effect on Steller's eiders is uncertain. Therefore, we characterized the effect of increasing goose populations as unknown at this time.

Characterization of stressors in marine habitats. -- We identified stressors potentially influencing Steller's eiders in marine habitat during migration, molting, wintering, and pre-migration staging activities (Appendices C and D). Factors that may moderately influence resiliency include predation (e.g., eagles) and exposure to fish processing waste that increases disease exposure and predation risk (but also may increase food availability; Reed and Flint 2007, p.130; Hollmén et al. 2010, p. 4 and 7; Appendix D). While possible, shooting during the non-breeding season is unlikely given the remote distribution of the birds and the small proportion of Alaska-breeding Steller's eiders compared to Russia-breeding Steller's eiders in the wintering area; therefore, shooting in marine areas has a low effect on resiliency. We consider human disturbance from fishing, shipping, and hunting activities as potential stressors, but have no evidence to make inference regarding the magnitude of effect on population resiliency.

Regime shifts and conditions in the North Pacific have been correlated with population trends of sea duck guilds (Flint 2013, p. 61), and Frost et al. (2013) found that the lowest estimate of Steller's eider adult survival, in 1999, occurred immediately after a brief warming event in the Pacific Decadal Oscillation in 1997-8 before it reversed to a cold trend (p. 175). However, the degree to which marine conditions influence the current resiliency of the Alaska-breeding Steller's eider population is unknown. For all stressors affecting Steller's eiders in the marine environment, there have been few studies

documenting the relationships between stressors, effects to habitat and individuals, and population-level effects; thus, in many cases we determined the effect is unknown (See Appendix D).

Characterization of stressors occurring throughout distribution. – Steller’s eiders can be exposed to naturally occurring disease, parasites, and toxins during any part of their life cycle, although individuals are more likely to be exposed to diseases requiring direct bird-to-bird transmission during molt and in winter when they may concentrate in large flocks. This is particularly true when they flock in harbors where fish waste is disposed and higher rates of potentially pathogenic *E.coli* and hydrocarbons are found (See Appendix D). However, studies on population-level effects of disease and parasites on sea ducks are lacking; therefore, the effect of this stressor on population resilience is unknown at this time.

Contaminants such as heavy metals (e.g., Se, Hg, Cd, Cu), hydrocarbons, and persistent organic pollutants (POPs) could contaminate Steller’s eider habitat or food (See Appendix D). While Steller’s eiders could be exposed to local sources of trace elements during the breeding season, most exposure to trace elements probably occurs in marine areas used during the non-breeding season (Miller et al. 2016, p. 304; Lovvorn et al. 2013, p.250). Documentation on the effects of exposure to reproduction or survival of Steller’s eiders is lacking; therefore, the effect of contaminants on population resiliency is unknown at this time.

Collisions can also cause mortality in both tundra and marine environments. Based on limited data, collisions with large marine vessels do occasionally occur; however, given the tendency of Steller’s eiders to frequent shallower near-shore habitats, the risk is low. Alaska-breeding Steller’s eiders are at risk from power line strikes near Utqiagvik, where multiple wire strike mortalities have been documented since 1991 (See Appendix D). Similar to shooting, mortality of a few breeding adults in the population could be detrimental to the resiliency of a small population such as Alaska-breeding Steller’s eiders; therefore, collisions pose a moderate effect on population resiliency.

Table 7. Summary of cause and effects analysis of how stressors may have contributed to the current condition of the northern Alaska subpopulation of Steller’s eiders. See Appendix D for detailed analysis of each stressor.

Stressor	Individual response (score) ⁴	Extent of subpopulation affected annually (score) ⁵	Effect to resiliency (score) ⁶	Confidence Level ⁷
Tundra				
Ingestion of Lead Shot	reduces female survival and mortality (4.5)	1-25% (2)	high (6.5)	moderate
Shooting	immediate mortality (5)	1-25% (2)	high (7)	moderate
Human disturbance	reduces reproductive success (3)	1-25% (2)	moderate (5)	moderate
Avian predation	reduces reproductive success (3)	1-25% (2)	moderate (5)	moderate
Fox predation	reduces reproductive success (3)	1-25% (2)	moderate (5)	moderate
Changes to lemming population cycles	reduces reproductive success (3)	25-50% (3)	moderate (6)	moderate
Harsh spring weather	may reduce reproductive success (2)	< 1% (1)	low (3)	low
Habitat loss near Utqiagvik	unknown	unknown	unknown	n/a
Habitat change	may reduce reproductive success (2)	unknown	unknown	n/a
Oil and gas development	may reduce reproductive success (2)	< 1% (1)	unknown	n/a
Nesting goose population	unknown	unknown	unknown	n/a

⁴ 1 = negative behavioral response (e.g., disruption of feeding), 2 = may reduce reproductive success or survival, 3 = reduces productivity (propensity, nest, or duckling survival), 4 = reduces survival probability of adult females, 5 = immediate mortality

⁵ % of northern Alaska subpopulation affected: 0 = no evidence that it currently affects individuals; 1 = 1% or less; 2 = 1 - 25%; 3 = 25 - 50%, 4 = 50 - 75%; 5 = 75 - 100%

⁶ Sum of scores for individual response and geographic scope: Low = 1-3, Moderate = 4-6, High > 6

⁷ **High Confidence:** We are more than 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.

Moderate Confidence: We are 50% to 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.

Low Confidence: We are less than 50% sure that this relationship or assumption accurately reflects the reality in the wild, as there is little or no supporting information available. Indicates areas of high uncertainty.

Marine				
Shooting	immediate mortality, but likelihood is low so may reduce survival (2)	< 1% (1)	low	low
Fish processing waste	may reduce reproductive success (2)	unknown	unknown	n/a
Harsh weather	may reduce reproductive success (2)	unknown	unknown	n/a
Marine conditions	may reduce reproductive success (2)	unknown	unknown	n/a
Human disturbance	may reduce reproductive success (2)	unknown	unknown	n/a
Predation	immediate mortality (5)	unknown	unknown	n/a
Entire distribution				
Collisions	immediate mortality (5)	< 1% (1)	moderate (6)	low
Disease, parasites, biotoxins	may reduce reproductive success (2)	< 1% (1)	unknown	n/a
Contaminants	may reduce reproductive success (2)	< 1% (1)	unknown	n/a

In summary, in many cases we have low confidence in the relationships and assumptions used for the analysis of cause and effects due to a lack of scientific information on the link between stressors, the extent of occurrence of those stressors, and the resulting effects on individuals and populations. In situations where we had no evidence to make inferences regarding population resiliency, we concluded the effect to be unknown. Exceptions include some stressors that directly affect individuals, such as ingestion of lead shot, collisions, and shooting, although there are few data on the number of individuals affected annually. These stressors rise to a moderate or high level of effect on resiliency because the loss of even tens of individuals could have a significant effect to resiliency of a small population that numbers in the hundreds. Several stressors were assigned low or moderate categories because they cause sub-lethal effects and/or affect a small portion of the population, but, taken as a whole, the cumulative or synergistic effects of these stressors on population resiliency may be significant.

6.5. Resiliency of the northern Alaska subpopulation

6.5.1. Current condition of Steller's eider habitat requirements

In this section we use the results of the cause and effects analysis and other information to summarize the current condition of the habitat characteristics that influence resiliency of subpopulations of Alaska-breeding Steller's eiders. Habitat requirements and other influential factors were described in Section 5 and are represented in the influence diagrams (Appendix C) by yellow boxes. A detailed description of

the analysis used to determine the effects of stressors can be found in Appendix D and are summarized in Table 8.

Polygonal tundra wetland habitat is extensive on the ACP and relatively undisturbed by human development. Therefore, at a macro-level, polygonal tundra habitat is in high condition. However, the condition of micro-habitat requirements within the large-scale polygonal tundra ecotype relative to the needs of Steller's eiders is difficult to assess. The density of Steller's eiders is positively related to latitude, with the highest densities in the UT. This could indicate either strong site fidelity, a preference for a particular habitat characteristic found in that area, or both. Additionally, there are some indications that habitat in the UT area is unique relative to the rest of the ACP. Maher (1970) reports that high lemming populations only occurred in the triangular portion of the ACP 130 km east and west of Utqiagvik and 40 to 50 km inland at its widest point south of Utqiagvik (i.e., the UT; p. 131). Maher (1970) also suggests that the tundra vegetation is composed of fewer species than tundra further inland as a result of climactic modification by the Arctic Ocean (p. 133). Furthermore, Walker et al. (2002) produced a circumpolar vegetation map (CAVM 2003) using remote sensing that shows a unique vegetation type in the UT and a few other limited northern coastal areas to the east of Utqiagvik on the ACP (sedge/grass, moss wetland). Winds are responsible for elliptically shaped thaw lakes that are uniformly oriented at 10-20 degrees west of north, which are most numerous in the northern portion of the ACP (Huryn and Hobbie, p. 40). Similarly, changes in climate, topography and ecological community to the south of the UT is mentioned by Pitelka (1974, p. 163). Unfortunately, additional evaluations or quantification of these potentially unique habitat characteristics are unavailable, and we also do not fully understand the micro-habitat requirements of Steller's eiders for nesting, brood rearing or feeding. Therefore, at this time we cannot determine if influential factors such as freshwater invertebrate abundance and availability, nest habitat availability, or brood-rearing habitat availability are currently limiting Steller's eiders' ability to successfully reproduce and survive.

The consistent presence of an incubating and brood-rearing female is important for survival of eggs and ducklings. Human disturbance causing females to flush from the nest or be separated from a brood can lead to decreased nest survival rates (see Appendices B and C). Considering the overlap of the highest density of nesting Steller's eiders and a relatively high density of humans using the tundra for research, recreation, and subsistence harvest near Utqiagvik, we consider the current condition of this requirement to be moderate. A significant portion of the northern Alaska subpopulation may be affected by human disturbance during the breeding season, and disturbance events may occur relatively frequently near Utqiagvik, where relatively high densities of Steller's eiders nest in some years. Effects on reproductive rates vary by individual tolerance and the number and frequency of disturbance events. One disturbance event may increase nest mortality risk by 4-14%; the effect on duckling survival is unknown (Appendix D). Conservation measures through ESA Section 7 consultation may reduce

probability of disturbance, but the amount of reduction is unknown. Persistent disturbance could affect reproductive rates of the population (See Appendix D).

Salinity was measured at ponds used by Steller's eider broods near Utqiagvik in 2012, and all wetlands were pure freshwater (USFWS 2013a; p. 30). Currently, at least in the UT area where the highest densities of nesting Steller's eiders are found, the availability of freshwater does not seem to be a limitation, and we consider its condition high.

Steller's eider breeding propensity and nest survival has been hypothesized to be influenced by lemming abundance and the presence of pomarine jaegers and snowy owls. The amplitude and/or frequency of lemming population fluctuations may have changed in the past few decades (See Appendix D for detailed analysis). Brown lemming populations underwent dramatic fluctuations in abundance every 3-4 years near Utqiagvik (Pitelka et al. 1955, p. 86, Pitelka and Batzli 2007, p. 329), and, although difficult to quantify, a year with very high lemming abundance has not been observed since 2008 (K. Ott, USFWS, pers comm.). There is strong evidence that other rodent species have undergone a shift from cyclic to noncyclic dynamics in the northern hemisphere in recent decades (Ims et al. 2008, p. 81). The cessation of high peaks in lemming abundance may have decreased the number of pomarine jaegers and snowy owls nesting on the northern ACP. While snowy owl and pomarine jaeger nests are recorded near Utqiagvik during the ground survey (USFWS 2024d) and on aerial surveys on the ACP (USFWS 2012b), we have no measure of detection and therefore no estimate of trend in nesting effort or presence/abundance over time. Assuming that abundance of both lemmings and avian predators that depend on lemmings have decreased, we consider the condition of these resources to be low. But, we caution that we have low confidence in this conclusion given limited information on lemming and jaeger abundance and the uncertainty in its effect on Steller's eider demographic rates (Table 8).

Marine habitats used by Steller's eiders, such as shallow, nearshore mudflats and eelgrass beds, and deep, ice-free waters, are extensive throughout southwestern Alaska. The eelgrass bed community has been identified as an important marine habitat factor for Steller's eiders, and several of the critical habitats (e.g., Izembek Lagoon, Nelson Lagoon) have eelgrass beds. The USGS has a long-term monitoring program of the eelgrass beds at Izembek Lagoon, which represent the largest continuous beds on the Pacific coast. Between 2006 and 2020, a net loss of 25 km² of eelgrass habitat was estimated from satellite imagery, and about 125 km² of eelgrass habitat was unchanged (Douglas et al. 2024, p. 13-14). Overall, the cumulative total biomass of eelgrass at Izembek Lagoon has been relatively stable through time (Douglas et al. 2024, p. 13-14; Ward and Amundson 2019, p. 7; Ward et al. 1997, p. 237-238). Thus, when viewed at a macro/landscape-level, the availability of such habitats does not appear to limit Steller's eider demographic rates, and we assigned them a high current condition (Table 8).

However, there is concern that changing marine conditions in the North Pacific and Bering Sea is affecting Steller's eiders through changes to the micro-habitat characteristics such as food availability. There is abundant published evidence that the Bering Sea and northern Gulf of Alaska have undergone massive regime shifts (Overland et al. 2008, p. 99), including a shift around 1989 that coincided with a low estimate of Steller's eider survival (Frost et al. 2013, p. 175). The shallow coastal habitats used by Steller's eiders, especially in eelgrass beds, are already subject to warmer temperatures (McRoy 1966, p. 30), and elevated temperatures could have major impacts on the benthic invertebrate community (Maliguine 2024, p. 2-3). Variable or lower quality foraging conditions at primary molting sites could influence the presence of Steller's eiders during this critical stage, as Maliguine (2024) found significant changes in prey availability at Izembek Lagoon, and the number of molting eiders at Izembek Lagoon has declined over time (p. 22-23; see Appendix E). Through replicating a benthic sampling effort conducted in Izembek Lagoon during the fall remigial molt period in 1998 (Petersen 2021), Maliguine (2024) found significantly less crustacean and bivalve biomass available in 2019 compared to 1998, and the size distribution of bivalves and gastropods in 2019 was significantly smaller than 1998. Maliguine (2024) suggests that the shift to decreased bivalve prey could have occurred over a longer duration of time, as there were also significantly fewer shell fragments (i.e., non-living shelled invertebrates) found in substrate samples compared to 1998 (p. 11-12). The change in prey availability in recent years may be less favorable for molting eiders (Maliguine 2024), as previous work found that Steller's eiders consume a larger proportion of shelled prey (bivalves and gastropods) during the molting period (Petersen 1980, Troy and Johnson 1987, Metzner 1993).

In addition, a correlation was found between sea duck population trends and North Pacific regime shifts (Flint 2012, p.3), and for populations of pelagic-foraging seabirds such as common murre (*Uria aalge*) and thick-billed murre (*U. lomvia*; Irons et al. 2008, p. 1460). More recently, seabird die-offs in the Bering Sea and Gulf of Alaska have been attributed to the impact of changing oceanic conditions on food availability (USGS 2016). While there is reason to believe changes in marine conditions may be currently affecting Steller's eiders, the micro-habitat characteristics required by Steller's eiders in these ecotypes are poorly described; therefore, the current condition of such influential factors is unknown (See Appendix D: marine conditions for more detailed analysis).

6.5.2. Current condition - abundance and connectivity

Although we have more information on demographic rates of the northern Alaska subpopulation than we have on Steller's eider habitat requirements, the only numeric measure of condition adequate for evaluating the current condition of the northern Alaska subpopulation was the number of Steller's eiders present in northern Alaska annually. The number of Steller's eiders observed in northern Alaska each year is highly variable, and, because availability bias and detection probability have not been estimated for Steller's eiders, abundance cannot be estimated (See Section 6.1.2). From data collected on the ACP aerial survey, the estimated average number of Steller's eiders present on the ACP per year

is 151.6 eiders (95% CI: 59.2, 340.7; Appendix A). In the UT, approximately 213.2 Steller's eiders (95% CI: 123.7, 403.1) are estimated to be present per year (95% CI; Appendix A). Compared to the condition categories described in Section 5.6, the results from any one of these surveys suggests that the current condition of this factor is low.

6.5.3. Summary – Resiliency of northern subpopulation

Overall, the available information, much of which comes from the Utqiagvik study area, suggests that the northern subpopulation of Steller's eiders has low resiliency for the following reasons. The subpopulation has low and variable numbers of Steller's eiders present on the ACP annually, suggesting a small population size. Stressors affecting adult survival (shooting, ingestion of lead shot, collisions) continue to occur in the area with the highest nesting densities of Steller's eiders in Alaska. Stressors affecting breeding propensity and/or nest and brood survival (habitat loss, changes in the lemming – avian predator system, disturbance) may also affect demographic rates of the northern Alaska subpopulation. This is of particular concern if females have high breeding site fidelity, as suggested by genetic mark-recapture data (Safine et al. 2020, p. 355-358), and if productivity is already low on average. Our impression of the resiliency of the northern Alaska subpopulation is primarily based on measures of abundance and the existence of stressors, rather than the condition of habitat, because of the considerable uncertainty about the specific resource requirements of Steller's eiders, how stressors affect these requirements, and the resulting population-level effects on resiliency. However, given that habitat conditions, both in the tundra and marine environments, are influenced by highly variable environmental factors and ecological processes that have changed in recent decades, our assessment of habitat conditions does not improve our impression of subpopulation resiliency.

Table 8. Summary of analysis of current condition of habitat resources and demographic rates that may affect resiliency of the northern Alaska subpopulation of Steller’s eiders. We lack information to conduct a similar analysis for the western subpopulation of Steller’s eiders.

INFLUENTIAL FACTOR	CURRENT CONDITION	LEVEL OF CONFIDENCE ⁸
Resources: Tundra		
Polygonal tundra (macro-level)	high	high
Polygonal tundra (micro-level)	unknown	n/a
Quality and quantity of freshwater invertebrates	unknown	n/a
Lemming – avian predator system	low	moderate
Adequately high presence of incubating female	moderate	moderate
Access to fresh water	high	high
Resources: Marine		
Shallow, nearshore marine habitat (macro-level)	high	high
Deep, ice-free waters (macro-level)	high	high
Micro-level habitat needs in shallow and deep waters	unknown	n/a
Eelgrass bed community	unknown	n/a
Quality and quantity of marine invertebrates	unknown	low
Demographics		
Abundance	low	moderate

⁸ **High Confidence:** We are more than 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.

Moderate Confidence: We are 50% to 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.

Low Confidence: We are less than 50% sure that this relationship or assumption accurately reflects the reality in the wild, as there is little or no supporting information available. Indicates areas of high uncertainty.

6.6. Resiliency of western Alaska subpopulation

We have very little information on the habitat requirements of Steller's eiders on the Y-K Delta. Changes to habitat caused by global climate change (see Section 7.1) and increases in goose populations (USFWS 2017a, p. 3-4) have occurred since Steller's eiders were listed, but the effect of these changes to habitat suitability for Steller's eiders is unknown. Given the small number of observations of Steller's eiders in this area, the lack of significant re-colonization since listing, and no plans for reintroduction in the foreseeable future, the population is considered functionally extirpated from that region of Alaska. Therefore, the current resiliency of the western Alaska subpopulation is very low.

6.7. Representation and redundancy of Alaska-breeding population

Representation describes the ability of a species (or in this case, a population) to adapt to changing environmental conditions over time. It is characterized by the number of niches or ecological settings the population occupies; the population's genetic diversity; and the variation in behavioral, morphological, or life history characteristics. The more represented or diverse a species is, the more capable it is of adapting to natural or human-caused changes in its environment. Redundancy refers to the ability of a population to withstand catastrophic events and is characterized by the number of resilient subpopulations distributed throughout the population's ecological settings and range (USFWS 2016a, p. 12).

Historically, the Alaska-breeding population consisted of two subpopulations: western and northern Alaska. The western Alaska subpopulation provided a level of redundancy that no longer exists within Alaska. The existence of the Russian-Pacific breeding population provides redundancy at the species-level but does not necessarily ensure that the Alaska-breeding population will continue to persist over time, unless immigration is occurring at a level that allows persistence. The northern Alaska subpopulation has a wide distribution, but the density increases near the UT. The very low densities of nesting Steller's eiders outside of the UT are so low as to provide little protection from catastrophic events occurring in the higher density area. Assuming that Alaska-breeding Steller's eiders are evenly distributed among the Pacific-wintering population (which has not been tested), the population has a wide distribution throughout southwest Alaska during molt, winter, and staging activities. This may provide some protection from a catastrophic event in part of the non-breeding range. Overall, the Alaska-breeding population has low redundancy.

Alaska-breeding Steller's eiders have moderate representation for the following reasons. Alaska-breeding Steller's eiders historically occupied two ecological settings during the breeding season: Arctic tundra of the ACP and the sub-arctic, tidally influenced coastal zone of the Y-K Delta. Currently, the breeding distribution of Steller's eiders in Alaska is restricted to the ACP. It is possible that the western Alaska subpopulation exhibited different genetic, behavioral, and life history adaptations given their use

of a sub-arctic nesting area that encompasses a different ecological community than northern Alaska, but differences were not documented prior to their disappearance. Within the northern subpopulation, the uneven distribution of Steller's eiders on the ACP may indicate a preference for unidentified habitat characteristics that are specific to the UT, suggesting some specialization, but again, we have no data on such variation. The movement of Steller's eiders to deeper water in response to high sea ice in shallow lagoons during the winter and their ability to consume a variety of invertebrate prey (Section 5.1 and 5.5) allows Steller's eiders to adapt to changing environmental conditions in marine areas. Steller's eiders have no known morphological diversity throughout their range in Alaska. We have little data from which to infer the genetic adaptive potential in Steller's eiders; however, analyses of nuclear microsatellite loci in DNA of Steller's eiders captured near Utqiagvik did not indicate signs of inbreeding or a lack of genetic diversity and contained a similar number of alleles as other breeding populations (Pearce et al. 2005, p. 748). Also, the highly migratory nature of Steller's eiders and the likelihood of male-mediated gene flow between the larger Russian-Pacific breeding population and the Alaska-breeding population (Pearce et al. 2005, p. 749-750) may introduce genetic diversity that allows the population to adapt to environmental changes over time.

In summary, the Alaska-breeding population has low redundancy and moderate representation. The functional loss of the western Alaska subpopulation indicates a decrease in both representation and redundancy from historical conditions.

6.8. Summary: current viability of Alaska-breeding population

In summary, the northern subpopulation of Alaska-breeding Steller's eiders currently exhibits characteristics that suggest low resiliency. The western subpopulation is considered functionally extirpated, and the northern subpopulation, while widely distributed on the ACP, is concentrated in the UT; thus, the Alaska-breeding population has very low redundancy. Alaska-breeding Steller's eiders show no signs of limited genetic variation, consume a variety of prey, and move to different wintering areas depending on conditions, suggesting a moderate level of representation.

7. FUTURE CONDITION

In this section, we describe how we projected the future condition of the Alaska-breeding population of Steller's eiders. First, we describe the potential effects of climate change on Steller's eider habitat in Alaska and hypothesize how these changes may impact the habitat requirements and demographic rates of the two subpopulations. We also evaluate whether stressors currently acting on the population will continue and describe additional stressors that may affect Steller's eiders in the future. We describe two scenarios reflecting the range of plausible population responses to climate change and alternative management actions and their associated assumptions. We then hypothesize how the condition of Steller's eider habitat requirements/circumstances may change under those scenarios, how these changes may affect demographic rates and resiliency of the northern Alaska subpopulation, and our level of confidence in these predictions. In all cases, we could not quantify the future impacts to the subpopulation given the available information and were limited to simply inferring whether the current conditions are expected to remain the same, improve, or deteriorate.

7.1. Climate change

Global climate change is widely accepted as one of the most significant risks to global biodiversity. While there is high certainty in predictions of how climate change will affect some physical characteristics of the northern environment, such as ocean and air temperatures, there is limited resolution and inherent uncertainty in the links between physical factors, biological factors, and their impact to Steller's eider subpopulations. Because of that uncertainty and the inadequacy of available demographic data for projecting Steller's eider population sizes and trends over time, we did not perform a formal climate change vulnerability assessment or project future population growth rates for this analysis. Instead, we summarized the physical changes that are predicted to occur in Steller's eider habitat as a result of climate change and used the available information to hypothesize how this might affect the habitat resources and circumstances required by Steller's eiders that were identified in Section 5.

7.1.1. Climate change predictions

IPCC (2023) synthesized the current state of knowledge concerning climate change science in the IPCC Sixth Assessment Report. The report identified several likely outcomes that are relevant to a discussion of the future condition of the listed population of Steller's eiders. IPCC (2023) used different CO² emission scenarios to project the effects of climate change on environmental factors through 2100 (p. 68). Under all assessed emissions scenarios, the global mean surface temperature change is projected to increase, although the magnitude of projected climate change is substantially affected by choice of emissions scenario (IPCC 2023, p. 68). The Arctic region will continue to warm more rapidly than the global mean, and there will be more hot and fewer cold temperature extremes on daily and seasonal

timescales (IPCC 2023, p. 69-70). Near-surface permafrost extent and spring snow cover at northern latitudes are likely to decrease (IPCC 2023, p. 69). Global ocean temperatures will continue to warm, and year-round reductions in Arctic sea ice and global sea level rise are projected in all scenarios assessed (IPCC 2023, p. 69). Models also project a global increase in ocean acidification for all emissions scenarios, particularly for polar marine ecosystems (IPCC 2023, p. 69).

7.1.2. Possible impacts to Steller's eider habitat and demographic rates

Tundra environment. -- Increases in air temperature and decreases in sea ice are predicted to influence snow conditions such as the duration of snow cover, snow depth, and snow quality. For example, total precipitation is predicted to increase in the high latitudes (IPCC 2023, p.70), with a concurrent increase in precipitation coming as rain in winter rather than snow, and rain-on-snow events are expected to become more frequent (ACIA 2004, p. 22). Snow conditions influence the ecology of northern voles and lemmings, as snow creates subnivean space that provides thermal insulation, access to food, and protection from predators (Kausrud 2008, p. 93). Factors that affect subnivean space, such as snow hardness and humidity, markedly affect populations of rodents in the Arctic (Kausrud et al. 2008, p. 93-95). For example, tundra vole survival rate is inversely related to number of days above freezing in winter, which results in alternating melting and freezing events (Aars and Ims 2002, p. 3451 - 3452). Also, increases in the length of the snow-free period are predicted to increase cycle length and reduce the amplitude and peak density of lemmings (Gilg et al. 2009, p. 2642). In turn, this is predicted to reduce the breeding success of specialized predators (Gilg et al. 2009, p. 2646) such as snowy owls and pomarine jaegers, which could ultimately lead to a decline in abundance or local extinctions of these species (Gilg et al. 2009, p. 2647). If the hypothesis that Steller's eider breeding effort and nest success is positively related to lemming and avian predator abundance is true, then we could expect reduced productivity as a result of these environmental changes.

Assuming that documented climate-related changes to tundra continue or increase in rate, we expect increased pond temperature (Lougheed et al. 2011, p. 313-314), higher nutrients and primary productivity in ponds (Loughheed et al. 2011, p. 313-314), and an increase in *Carex sp.* (Lougheed et al. 2011, p. 597) and other water-tolerant sedges in the UT area (Liljedahl et al. 2016, p. 313). We do not know how these changes, separately and/or combined, will alter the species composition of the aquatic invertebrate community. However, changes in pond temperature could change the availability of aquatic invertebrates, such as chironomids, which tend to emerge according to pond temperature (Hansson et al. 2014, p. 4). If Steller's eiders do not also alter their nest initiation dates in response to earlier snowmelt (as in lesser scaup; Gurney et al. 2011, p. 632), hatch of invertebrates may not occur when it is most advantageous to Steller's eider females or their ducklings (i.e., phenological mismatch; Hansson et al. 2014, p. 5-6; Visser et al. 1998, p. 1868-1869). This could lead to decreases in productivity, but we are unaware of data on Steller's eiders that could be used to support or refute this hypothesis. In summary, we cannot predict the direction of change in availability of freshwater

invertebrates for Steller's eiders given predicted changes to habitat; therefore, we assume that it is equally likely that availability of freshwater invertebrates will increase or decrease for Steller's eiders in tundra habitat in the future.

Permafrost degradation could lead to continued decrease in freshwater pond area and abundance, as was observed near Utqiagvik (Andresen and Loughheed 2015, p. 5), or lead to oil contamination via natural oil seeps (USGS 2024, p. 6-7), and increased coastal erosion may degrade shorelines and drain large lakes (Mars and Houseknecht 2007, p. 586). Environmental changes (including coastal erosion) near the community of Utqiagvik could displace current residents and businesses (Garland et al. 2022, entire), and this may lead to a scenario for future development in suitable nesting habitat for Steller's eiders. The higher relief areas closer to Utqiagvik may be preferred by Steller's eiders, and these areas may also be considered ideal for constructing new buildings (Miller 2023, p. 152). There is also strong evidence that permafrost loss caused by climate change is decreasing large lake area and abundance in areas with discontinuous permafrost in Siberia (Smith et al. 2005, p. 1429) and parts of subarctic Alaska (Riordan et al. 2006, p. 5). However, the impacts of warming permafrost and erosion on surface water dynamics in areas with continuous permafrost (such as the ACP and the UT) are dependent on many spatial and temporal variables, and thus are difficult to predict (Smith et al. 2005, p. 1429). This could reduce the availability of polygonal tundra pond habitat for nesting and brood-rearing Steller's eiders, but the specific changes to habitat, how that affects nest habitat availability, and the timescale at which this may happen is unknown.

As explained in Section 5.3, Steller's eider broods use emergent aquatic vegetation for cover and protection from predators. If the observed increase in *Carex sp.* near Utqiagvik (Loughheed et al. 2011, p. 597) continues, it may result in increased duckling survival rates and thus productivity; however, we have no data to support or refute this hypothesis. Alternatively, increases in aquatic vegetation may eventually convert ponds to terrestrial habitat, contributing to overall decreases in pond abundance resulting in decreased foraging habitat for nesting eiders.

Although in the short-term weather patterns may be more erratic and unpredictable than the past, it is predicted that there will be fewer cold temperature extremes on seasonal time scales (IPCC 2023, p. 69); thus, years with harsh springs and late snowmelt would be predicted to decrease over time. This could lead to a longer breeding season and increase Steller's eider productivity by reducing the energy required for thermoregulation of adults, eggs, and ducklings.

Climate change may impact the habitat on the central coast of the Y-K Delta, the suspected heart of the western population of Steller's eider historical range, differently than the habitat on the ACP. The Y-K Delta is characterized by low relief that makes it particularly susceptible to storm-driven flood tides (Jorgensen and Ely 2001, p. 132). A rising sea level, along with more frequent and larger storms in the Bering Sea, are expected to result in larger storm surge flooding events (IPCC 2023, p. 69). These storm

surges impact vegetation (Terenzi et al. 2014, p. 371) and may result in increased salinity in freshwater tundra ponds, accelerated permafrost melt, and/or increased rate of coastal erosion, although the complex processes of the coastal ecosystem make exact changes difficult to predict (Jorgensen and Ely 2001, p. 135). Furthermore, given the uncertainty in habitat requirements of the western population of Steller's eiders, the potential impacts of these climate change effects on habitat suitability are unknown.

Marine environment. -- While still lack information about how climate change may affect Steller's eider demographic rates, we have more information about predicted changes to components of Steller's eiders' marine habitat than changes in tundra habitat.

For example, Smith et al. (2019) assessed the vulnerability of seabird species and previously identified important bird areas in the Bering Sea and North Pacific Ocean using spatial projections of physical climate and forage variables. Included in the assessment were 12 areas used by Steller's eiders for molt, winter, and staging along the eastern Bering Sea and Gulf of Alaska. All three climate models used in the assessment projected that shallow sea water temperature will increase and sea ice concentration will decrease in the study area within the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska between 2003-2012 and 2030-2039. Projections of benthic infauna biomass (e.g., bivalves, amphipods, and polychaetes; marine invertebrate species used by Steller's eiders) from the three climate models were inconsistent (Smith et al. 2019, p. 15-20). However, the magnitude of change using the three-model average for benthic infauna shows a projected decrease in some areas, in particular Izembek Lagoon and Bechevin Bay in the eastern Bering Sea and areas in Cook Inlet, but a slight increase in other areas used by Steller's eiders along the northern Alaska Peninsula (Smith et al. 2019, p. 17, 26) over the next 30 years. Combining data for species core areas, one model predicted that all 12 Steller's eider core areas are climate vulnerable, another model found two to be vulnerable, but none were found vulnerable by all three models (p. 21). These results highlight the high uncertainty of forage availability for Steller's eiders in molt, winter, and staging areas over the next few decades.

Coastal erosion may influence the lagoon systems that Steller's eiders use during the remigial molt. Harsh storm surges can erode the barrier islands that protect the coastline and lagoon systems and potentially affect the invertebrate prey communities in nearshore environments. Coastal erosion is primarily due to ocean current, wave action, and storm surges; when high-frequency storm surges are combined with sea ice decline, sea level rise, and high tides, larger waves pose greater risk of coastal erosion.

Coastal habitats are increasingly under threat of erosion by the effects of climate change. The Army Corps of Engineers (Corps) conducted a statewide threat assessment in remote Alaskan communities, in which Port Heiden and the Village of Nelson Lagoon were identified to be at-risk from coastal erosion (Corps 2019, p. 5-12, A-1). The lagoons adjacent to these communities are used by Pacific Steller's eiders during the remigial molt, and Nelson Lagoon is currently the most important molting habitat used

by the Pacific population of Steller's eiders (USFWS 2016c, p. 8). In Nelson Lagoon, most of the eiders have been observed molting near the barrier islands (Kritskoi, Wreck, and Walrus Islands) and to a lesser degree in the lagoon south of the Village of Nelson Lagoon (T. Bowman, retired USFWS-Sea Duck Joint Venture Coordinator, pers. comm.). Recent observations at Nelson Lagoon suggest drastic changes in barrier island morphology are occurring—Walrus Island, one of the barrier islands separating Nelson Lagoon from the Bering Sea, is only a fragment of what it used to be (T. Bowman, pers. comm.). Barrier islands can move, erode, grow, or even disappear; therefore, the effects of coastal erosion can be long-term, everchanging, or unknown.

Coastal lagoons are low energy environments with flow driven by outlet of rivers, streams, and tidal currents, and they are protected by barrier islands (or other natural barriers) that absorb wave energy. The loss of coastal barriers to wave energy leads to sedimentation into the nearshore environment, which both impacts and modifies the nearshore benthic habitats and may result in unsuitable conditions for invertebrates that require stable attachment surfaces. Nelson Lagoon contains extensive mudflats and beds of blue mussels (*Mytilus edulis*), which are an important food source for Steller's eiders, particularly during the remigial molt period (Petersen 1980, p. 105). Mussels protect themselves from erosion by attaching to the underlying substrate or to conspecifics; while rocky shores provide solid substrate surfaces for mussels to attach to, Nelson Lagoon has soft intertidal substrates (e.g., mud to sand-gravel; Petersen 1980, p. 99). The extent to which coastal erosion may impact other critical habitats (e.g., the Seal Islands, Kuskokwim Shoals) along the Alaska Peninsula is unknown. Nearshore, shallow coastal lagoons in the southern Bering Sea are limited in number and perhaps sensitive to marine changes—recent benthic surveys conducted in Izembek Lagoon found significant changes in availability of marine invertebrates for molting Steller's eiders (Maliguine 2024, p. 10). Changes in marine habitat conditions (e.g., prey availability, refugia habitat) may influence the distribution of the Pacific population and which areas the population uses at different times of their annual cycle (i.e., molting, wintering, staging). An additional factor that may affect Steller's eider food availability is ocean acidification, which has been observed in the North Pacific (Byrne et al. 2010, p. 3) and is predicted to continue to increase in the future (Feely et al. 2009, p. 45; IPCC 2023, p. 69). Ocean acidification is predicted to reduce calcification, which has deleterious effects on growth rates and development in prey items such as bivalves (Gazeau et al. 2007, p. 3; Fabry et al. 2008, p. 419-420, IPCC 2014, p. 67). Although the degree to which ocean acidification affects marine invertebrates varies by species and other habitat factors (Goethel et al. 2017, p. 113, 118; Kroeker et al. 2013, p. 1888), abundance of bivalves in molt, winter, and staging areas may decrease in the future as a result of decreasing pH levels.

In addition, eelgrass beds and the ecological community that eelgrass supports may be impacted by warming ocean temperatures. A decrease in sea ice in the Bering Sea and/or advection from the North Pacific into the Bering Sea (Stebano et al. 2018, p. 3, 10 - 11) is projected to result in increased sea temperatures. Eelgrass is negatively affected by high water temperatures (Lefcheck et al. 2017, p. 3479 – 3480; Moore and Jarvis 2008, p. 141). The availability of the associated marine invertebrate prey used

by Steller's eiders in eelgrass beds may subsequently decrease; however, it is unknown if Steller's eiders are behaviorally flexible enough to shift to other food sources if this occurs or at what point the temperature of the Bering Sea will be high enough to realize effects to eelgrass.

In all, several lines of evidence suggest that marine invertebrates important in molting and wintering areas are at risk from increased sea temperatures and ocean acidification. While Steller's eiders seem to be diet generalists, their degree of behavioral flexibility is unknown and could vary by physiological stages (i.e., molting, wintering).

Survival probability could also be affected by warmer ocean and air temperatures. In the shorter term, fewer instances of sea ice formation in shallow lagoons used by Steller's eiders would increase the availability of such habitat and reduce the need for Steller's eiders to move to deeper waters. In addition to an increase in habitat availability in the winter, milder temperatures would reduce the thermoregulatory cost, which may increase survival probability. However, at the same time, warming temperatures may also increase exposure to novel diseases, parasites, or biotoxins through range shifts in disease organisms or their vectors (VanHemert et al. 2014, p. 550). Avian influenza and other viral diseases may spread through climate change-induced alterations in migratory routes, stopovers, or ecological communities. Some shifts may already be underway; avian malaria and avian cholera were recently documented for the first time in Alaska (Loiseau et al. 2012, p. 1-6; Bodenstein et al. 2015, p. 936), and harmful algal blooms have been detected in the Bering Sea and other Alaskan waters (Lefebvre et al. 2016, p. 16-17, Natsuike et al. 2017, p. 8), which is linked to increasing water temperatures (Natsuike et al. 2017, p. 7).

7.2. New stressors

Some stressors currently affecting Steller's eiders will continue or increase in magnitude, and new factors will emerge as a result of climate change and human population growth. For example, in response to decreases in sea ice, shipping activities have increased in the Chukchi and Beaufort Seas and through the Bering Strait (ICCT 2015, p. 11-12, 21-24) and are predicted to continue to increase up to 500% of 2013 levels by 2025 (ICCT 2015, p. 60-61). Increases in shipping traffic through Aleutian passes between the North Pacific and Bering Sea is also likely in response to changing oceanic conditions. Increased vessel traffic increases both the risk of hydrocarbon spills in marine environments and the risk of collisions between Steller's eiders and marine vessels. In March 2020, the National Marine Fisheries Service (NMFS) reported a mortality of a Steller's eider by a vessel in the trawl groundfish fishery of the Bering Sea/Aleutian Islands Management Area (BSAI) (NOAA Fisheries 2020). The vessel strike occurred at night while the vessel was in transit (i.e., not during fishing activities) near Cape Krenitzin, just north of False Pass in the NMFS reporting area 509. While previous collisions with Steller's eiders have occurred and been reported via the North Pacific Observer Program (Labunski et al. 2022; Figure 12), this instance was the first recorded take of an Alaska-breeding Steller's eider by any fisheries operating

in the BSAI or Gulf of Alaska Management Area (NOAA Fisheries 2020). Federally managed commercial groundfish fisheries off Alaska, including vessels 40 feet length overall and larger, and the commercial halibut fishery are subject to the North Pacific Observer Program requirements, except for catcher vessels delivering unsorted codends to a mothership. Vessel traffic density is high along the coast of the Alaska Peninsula and Aleutian Islands (Silber et al. 2021, p. 182-183) in the known non-breeding range of Steller’s eiders. It is possible that more vessel strike collisions occur from other fishing and non-fishing vessels (e.g., military, cargo, or tanker vessels) and may not be reported; therefore, the extent of this threat is largely unknown.

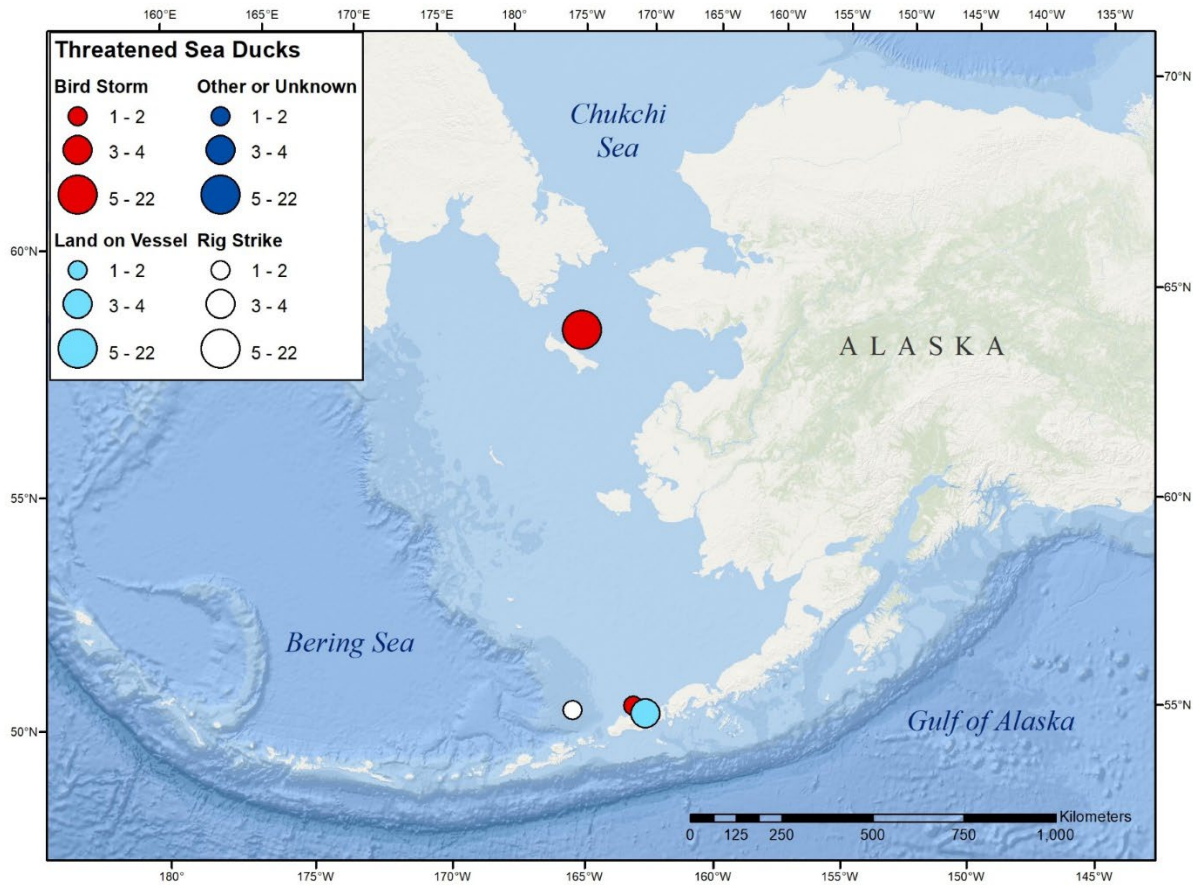


Figure 12. Location of opportunistic observations of vessel interactions with threatened sea ducks (Steller’s and spectacled eiders) from 2010-2021 in Alaska Groundfish Fisheries, in which there were up to 7 Steller’s eider collision events (From: Labunski et al. 2022).

In summer of 2024, an unknown release of oil was identified in a tundra lake that drains into Avak Creek, near Utqiagvik, where the highest concentrations of Alaska-breeding Steller’s eiders nest. The location of the oil occurrence was a few miles south of the UG survey area. The USGS investigated the

source of oil exposure and proposed that the oil originated from natural seeps that leaked from underground reservoirs (USGS 2024, p. 1, 7). The USGS suggests that the crude oil and gas were generated in Lower Cretaceous source rocks, migrated northward into the Avak Creek area, and were trapped there at a shallow depth. Shallowly trapped oil released as the upper permafrost layers deteriorated from warming over the recent 20 years, resulting in remobilization of the shallow oil and gas (USGS 2024, p. 7). Although there was no evidence of Steller's eiders affected by this incidence in 2024, this oil occurrence event presents concerns for future oil contamination originating from natural seeps in the core breeding area for Alaska-breeding Steller's eiders as permafrost thawing continues. Oil and gas development is expected to continue in Arctic Alaska. Onshore development is continuing around the existing oil field infrastructure and is spreading west into the NPR-A (e.g., GMT2 development, BLM 2018, p. 32). Future lease sales are also likely in the 1002 Area of the Arctic National Wildlife Refuge to the east as well as the Beaufort and Chukchi seas. With increased development comes new infrastructure along the coastline and increased shipping, leading to higher risk of oil spills in both marine and tundra areas. However, terrestrial areas projected to be impacted by oil and gas development have low densities of nesting Steller's eiders; therefore, the potential effect of terrestrial activities to the northern subpopulation is likely minimal.

Expansion of existing community infrastructure is expected to continue. The predicted expansion of Utqiagvik is of particular importance to Steller's eiders given that the highest densities are found in the UT. The growing community will likely require new roads, homes, and other infrastructure very near or in important Steller's eider breeding habitat, increasing the risk of disturbance, habitat loss, collisions with structures and power lines, and other anthropogenic factors. This is of concern given the proximity of Steller's eider nesting habitat to the community.

Two other proposed development projects have been noted for their potential impacts to Steller's eiders: development of a road between King Cove and Cold Bay, Alaska, through Izembek National Wildlife Refuge (USFWS 2013d), and Donlin Mine on the upper Kuskokwim River in southwest Alaska (USFWS 2024). The exchange of land between the Department of Interior and the King Cove Native Corporation is proposed to build a road across the Izembek-Kinzarof Lagoon isthmus to provide access to an airport (USFWS 2024e). The road itself will not be in habitat used by Steller's eiders (they remain in marine areas during molt and wintering), but Steller's eiders use both Izembek and Kinzarof Lagoons on either side of the isthmus. They also fly across the isthmus to find favorable foraging and resting areas depending on tides and weather. Effects from road construction to Steller's eiders is considered negligible to minor, because activities are of low to moderate intensity, of temporary duration, and of local extent. The long-term operation and maintenance of the road will result in increased noise and human activity (such as hunting), which may affect movements of Steller's eiders across the isthmus between Kinzarof and Izembek Lagoons or displace birds that may use areas in the lagoons near the isthmus (USFWS 2013d, p. 4-313). However, assuming an even distribution of Alaska-breeding birds

throughout the molt and winter areas, the potentially affected population consists primarily of Russian-Pacific breeding Steller's eiders.

The Donlin Mine development is proposed near the upper Kuskokwim River. The primary project component within the range of Steller's eiders involves marine barging during the ice-free season from the west coast of the continental U.S. to harbors in the Aleutians and through Bristol Bay and the Kuskokwim River Delta. Impacts could include disturbance, increased oil spill risk, and collisions with vessels. However, shipping is proposed to be conducted in existing shipping corridors and at existing harbors. Proposed barging is predicted to account for less than 1% of existing vessel traffic in the region, and noise from engines would be relatively less than noise from other louder commercial vessels (USFWS 2017b, p. 4). The Corps conducted spill risk and spill fate analyses and determined the probability of a spill was so low that effects on listed species would be discountable because a spill would be extremely unlikely to occur (USFWS 2017b, p. 4). To reduce spill risk, the project proponent has committed to using double-hulled barges; shipping during the ice-free season, May to September; maintaining vessel speeds of 10 knots or less; and implementing Oil Discharge Prevention and Contingency Plans for docks and vessel operations, which identify environmentally sensitive areas. The Service reviewed the proposed action and concurred with the Corps that the project may affect, but is not likely to adversely affect, Steller's eiders or their critical habitat, given the included minimization measures (USFWS 2017b, p. 4).

In summary, human activity such as shipping and infrastructure is expected to increase in Steller's eider habitat in the future. Some impacts may be minor and cause minimal disturbance. Others such as community expansion and oil spills, particularly when considered in concert with other influential factors, may have a greater impact on population resiliency; however, we lack data to quantify these potential effects.

7.3. Future scenarios

7.3.1. Methods

We developed two scenarios to assist in predicting future resiliency. We restricted this analysis to the northern Alaska subpopulation of Steller's eiders. These scenarios represent the range of plausible outcomes given the possible effects of climate change on Steller's eiders and potential effects of management actions on the subpopulation. Ideally, we would consider several climate change scenarios under different rates of carbon emissions, as uncertainty exists in the future rate of carbon emissions. However, we lack the detailed information to discern between the effects of one emission rate to another on Steller's eiders. Furthermore, there is considerable uncertainty in both the future effect of climate change on Steller's eider habitat and the individual and population-level responses of Steller's eiders. So, our future scenarios focus on the range of possible habitat changes and Steller's eider

responses to those predicted habitat changes. There is also uncertainty in future allocation of resources supporting measures aimed at conserving Steller's eiders and how effective these measures are at increasing demographic rates. Therefore, the scenarios reflect high and low levels of management effort by the Service and partners. In Scenario B we assume that the present level of effort/funding focused on Steller's eider conservation near Utqiagvik continues and is moderately effective. In Scenario A we assume the level of effort focused on Steller's eider conservation increases and is highly effective at reducing adult mortality and increasing productivity of Steller's eiders near Utqiagvik. See Table 9 for a detailed description of the two future scenarios.

After developing the scenarios, we considered the effect of each on the influential factors, the resulting changes to the condition of Steller's eider habitat requirements and demographic rates (same, improve, deteriorate), and our level of confidence in these predictions.

Table 9. Description of future scenarios used to illustrate the range of potential future condition of the northern subpopulation of Alaska-breeding Steller’s eiders. For some climate change predictions, assumptions for both scenarios are the same because there is less uncertainty in the resulting effects.

	SCENARIO A	SCENARIO B
Predictions: Climate change	Assumptions: Resulting effects to Steller's eider habitat requirements and/or Steller's eider response	
Degraded snow conditions	Lemming density and nests of associated avian predators on breeding grounds continue to decrease, but Steller's eiders find alternative breeding strategy.	Lemming density and nests of associated avian predators continue to decrease, and Steller's eider breeding propensity and nest survival rate decreases in response.
Increase in tundra pond temperature, productivity, and/or nutrients	Freshwater invertebrate availability is not affected OR Steller's eiders alter their diet or distribution to compensate for changes to prey availability.	Invertebrate availability decreases through mismatch in timing of emergence, changes in abundance, or species assemblage. Steller's eiders do not change timing of nest initiation or diet composition, resulting in decreased duckling survival and, therefore, productivity.
Reduction in pond number and/or size due to melting permafrost, and/or increase in coastal erosion and resulting lake drainage.	Reduction in number of polygonal tundra ponds, resulting in a reduction in nest habitat, but not at a scale that limits Steller's eiders' ability to find adequate nest sites.	Reduction in number of polygonal tundra ponds, resulting in a reduction in nest habitat availability, so optimal nest sites are limited.
Increase in density of emergent sedges in ponds	Increases the amount of optimal brood rearing habitat.	Increased emergent vegetation eventually converts ponds to terrestrial habitat and decreases available brood rearing habitat.
Increased salinization of ponds	Saltwater intrusion does not occur in ponds on the ACP in the foreseeable future and ponds remain fresh; no effect to Steller's eiders.	Saltwater intrusion from erosion and sea level rise increases salinity in ponds used by Steller's eiders on the ACP, reducing brood survival.
Increasing goose population on the ACP	Increasing breeding population of white-fronted geese (and possibly snow geese and brant) result in decreased predation pressure on Steller's eiders due to predator swamping, thereby increasing Steller's eider productivity.	Competition with geese for nesting habitat, and possibly habitat degradation (snow geese), could negatively affect productivity of Steller's eiders.
Fewer extreme cold days, longer breeding season	Fewer thermoregulatory costs and extended time for late nests/ducklings to survive to fledge before freeze up. Increases in nest success and duckling survival.	Same as Scenario A: Fewer thermoregulatory costs and extended time for late nests/ducklings to survive to fledge before freeze up. Increases in nest success and duckling survival.
Increased sea surface temperature and decrease in sea ice	No significant changes in benthic invertebrate species biomass or availability, or changes occur but Steller's eiders adapt by prey switching.	Decrease in benthic marine invertebrate biomass or availability, and Steller's eiders are not able to change their diet.
Increased sea surface temperature and decrease in sea ice	Lower thermoregulatory cost, and sea ice cover does not determine wintering distribution.	Same as Scenario A: Lower thermoregulatory cost, and sea ice cover does not determine wintering distribution.
Increased sea surface temperature and decrease in sea ice	No significant changes to the eelgrass community, or, if changes occur, Steller's eiders change their diet or move to more productive areas.	The eelgrass community changes or eelgrass beds decrease in size, resulting in reduced food availability/quality, and Steller's eiders do not alter diet to adapt.
Increased sea surface temperature and decrease in sea ice	Less sea ice in Arctic and North Pacific oceans results in increased shipping, resource development, and infrastructure development	Same as Scenario A: Less sea ice in Arctic and North Pacific oceans results in increased shipping, resource development, and

	in Steller's eider marine distribution. This increases the risk of collisions and exposure to hydrocarbons through oil spills.	infrastructure development in Steller's eider marine distribution. This increases the risk of collisions and exposure to hydrocarbons through oil spills.
Increased ocean acidification	No change in benthic invertebrate biomass or availability, or Steller's eiders switch diet.	Decrease in benthic invertebrate biomass and/or availability, and Steller's eiders are not able to change their diet.
Increase in temperature and resulting changes in ecological communities and/or species' distribution	Same as Scenario B: Increases disease exposure.	Increases disease exposure.
Increased harsh weather storms	No change in available nearshore lagoon habitats or the associated ecological communities.	Increased coastal erosion to barrier islands, reducing available shallow, nearshore refugia habitat for molting eiders. Loss of barriers reduces availability of important prey for eiders during critical life stages.
Management Actions (ACP)	Assumptions: changes given differing levels of effort for conservation actions	
Outreach and education	Shooting is significantly reduced/nearly eliminated.	Rate of shooting remains the same as current rate.
Outreach and education	The use of lead shot in Steller's eider breeding habitat is significantly reduced/nearly eliminated.	The use of lead shot continues at current rate.
Outreach and education	Disturbance during breeding season is significantly reduced through development of alternative monitoring methods and community outreach.	The current level of disturbance to nesting females from research and local activities continues.
Conservation planning and partnerships	Develop alternative power line structures/configurations to significantly reduce collisions near Utqiagvik.	No changes.
Conservation planning and partnerships	Develop a conservation plan that protects the most important Steller's eider nesting and brood rearing habitat near Utqiagvik.	No changes.
Conservation planning and partnerships	Develop a plan for the landfill to consistently use incinerator, which reduces nest predator (fox, gulls) abundance near Utqiagvik.	No changes.

7.3.2. Results

In Scenario A, we predict that while some habitat changes will occur, the majority of the factors influencing tundra habitat remain in the same condition as they are currently (See Table 10). The exception is that decreased disturbance (via increased outreach) would decrease the number of incubation breaks taken by nesting females (see Appendix D for details on disturbance effects), increasing that condition from moderate to high. For factors influencing the marine environment, conditions remain the same, as predicted changes to eelgrass and invertebrate communities do not change food availability for Steller's eiders. The number of Steller's eiders in the northern Alaska subpopulation may increase slightly due to implementation of effective management actions that reduce mortality and increase productivity near Utqiagvik. In summary, in Scenario A, the resiliency of Steller's eiders may increase slightly in the future if the assumptions associated with this scenario reflect reality and the predictions are realized. In Scenario B we predict that the condition of factors influencing Steller's eider habitat will decrease in the future or remain in the low category (See Table 10). Abundance will remain low or decrease. Therefore, if the associated assumptions and predictions are true, then the resiliency of the northern Alaska subpopulation will decrease in the future.

In summary, given these hypothetical but plausible scenarios, the resiliency of the northern Alaska subpopulation of Steller's eiders is likely to, at best, increase slightly or remain the same as it is currently. At worst, resiliency will decrease due to the effects of climate change. However, eliminating factors that negatively impact productivity and adult female survival, particularly near Utqiagvik, may buffer the potential impact of future habitat change. We expect no increases in redundancy (currently characterized as low) or representation (currently characterized as moderate) under either scenario.

Table 10. Projected future condition of resources and demographic conditions of the northern subpopulation of Steller’s eiders under two management and climate change scenarios and the current condition. Confidence level associated with these conclusions is very low.

INFLUENTIAL FACTORS	CURRENT CONDITION	SCENARIO A	SCENARIO B
Tundra			
Polygonal tundra (macro)	high	same as current condition	same as current condition
Polygonal tundra (micro)	unknown	same as current condition	lower than current condition
Quality and quantity of freshwater invertebrates	unknown	same as current condition	lower than current condition
Adequately high presence of female	moderate	higher than current condition	lower than current condition
Lemming – avian predator system	low	same as current condition	lower than current condition
Access to fresh water	high	same as current condition	lower than current condition
Marine			
Shallow, nearshore marine habitat (macro)	high	same as current condition	same as current condition
Deep, ice-free waters (macro)	high	same as current condition	same as current condition
Micro habitat needs in deep and shallow waters	unknown	same as current condition	lower than current condition
Eelgrass bed community	unknown	same as current condition	lower than current condition
Quality and quantity of marine invertebrates	unknown	same as current condition	lower than current condition
Demographics			
Abundance	low	same as current condition	lower than current condition

8. CONCLUSION

We used the best available information to describe the current and potential future condition of the Alaska-breeding population of Steller's eiders. Currently, the number of Steller's eiders present on the ACP annually (representing the northern Alaska subpopulation) is low and highly variable. Measures of productivity, such as breeding propensity and nest survival, are also highly variable, and in some cases, not available. While there is considerable uncertainty about habitat requirements and the condition of these requirements in both tundra and marine environments, a suite of stressors may be negatively affecting habitat and demographic rates at low to moderate levels. Collectively, these points indicate that the northern Alaska subpopulation currently has a low level of resiliency. The degree of connectivity with the Russian-Pacific breeding population and its level of impact on resiliency of the Alaska-breeding population are uncertain. However, the resiliency of the Pacific-wintering population (PWP) is an important factor for recovery of Alaska-breeding Steller's eiders as it includes individuals from the listed DPS, although the population trend of the PWP is unknown (see Section 6.2.4 and Appendix E). Many of the stressors identified to impact the Alaska-breeding population likely impact the Pacific- Russian- breeding population of Steller's eiders as well, and a declining PWP would contribute to declines in the listed population (Appendix E).

The western Alaska subpopulation is considered nearly extirpated, and therefore contributes minimally to the Alaska-breeding population's resiliency, redundancy, or representation. The Alaska-breeding population, therefore, is essentially reduced to one subpopulation in northern Alaska. Steller's eiders are widely distributed on the ACP during the breeding season but occur at very low densities outside of the UT, which provides little protection from catastrophic events should they occur in the summer. Based on the available information, Steller's eiders have a relatively wide distribution during molt, winter, and migration. Assuming even distribution of Alaska-breeding Steller's eiders throughout that distribution, they may have some protection from catastrophic events in the non-breeding season. Based on these considerations, we consider Alaska-breeding Steller's eiders to have low redundancy.

Alaska-breeding Steller's eiders historically occupied two ecological settings in the breeding season – Arctic and subarctic tundra. They are now restricted to the Arctic and concentrated near Utqiagvik, a human population center subject to significant anthropogenic effects and rapid climate change. Variation in behavior or life history strategy may exist, including a different breeding strategy in the subarctic, but there is little data to support or refute hypotheses related to behavioral variation. Alaska-breeding Steller's eiders likely consume a variety of foods, particularly in marine habitats, and have the ability to respond to ice cover in winter by moving to deeper water. The population has no known morphological diversity, but no sign of a lack of genetic diversity, although we have no data on genetic adaptive potential. Overall, we consider the Alaska-breeding population to have moderate representation.

Global climate change is predicted to significantly impact the Arctic tundra and marine habitats of Steller's eiders. There is considerable uncertainty surrounding how these habitat changes will translate to changes in demographic and population growth rates of Steller's eiders and the resulting resiliency of the extant subpopulation. Given hypothetical but plausible scenarios, resiliency is, at best, predicted to remain low or increase slightly. At worst, resiliency will decrease further due to effects of climate change and continuing, or increasing, stressors. We predict no increases in redundancy or representation. Management efforts to eliminate factors that directly impact both adult female survival, such as shooting, collisions, and the ingestion of lead shot, and productivity, such as disturbance and predation, may reduce the cumulative impacts of climate change and other stressors.

9. LITERATURE CITED

ABR, Inc. – Environmental Research and Services. 1988. Lisburne terrestrial monitoring program (1986-1987): The effects of the Lisburne power line on birds. Unpublished Report. Prepared by B.A. Anderson and S.M. Murphy for ARCO Alaska, Inc. Fairbanks, Alaska. 74pp.

ABR, Inc. – Environmental Research and Services. 1998. Predator populations and predation intensity on tundra-nesting birds in relation to human development. Unpublished report. Prepared by R.H. Day for Northern Alaska Ecological Services, U.S. Fish and Wildlife Service. Fairbanks, Alaska. 112pp.

ABR, Inc. – Environmental Research and Services. 2003. Collision potential of eiders and other birds near a proposed windfarm at St. Lawrence Island, October-November 2002. Unpublished Report. Prepared by R.H. Day, J.R. Rose, R.J. Ritchie, J.E. Shook, and B.A. Cooper for U.S. Fish and Wildlife Service and Alaska Industrial and Development Authority – Alaska Energy Authority. Fairbanks, Alaska. 37pp.

ABR, Inc. – Environmental Research and Services. 2005. Migration and collision avoidance of eiders and other birds at Northstar Island, Alaska, 2001-2004. Unpublished Report. Prepared by R.H. Day, A.K. Pritchard, and J.R. Rose for BP Exploration (Alaska) Inc. Fairbanks, AK. 154pp.

ABR, Inc. – Environmental Research and Services. 2017. Steller's eider surveys near Utqiagvik, Alaska, 2016. Unpublished report. Prepared by T. Obritschkewitsch and R. J. Ritchie for U.S. Bureau of Land Management and U.S. Fish and Wildlife Service. Fairbanks, Alaska. 22pp.

ABR, Inc. – Environmental Research and Services. 2024. Steller's eider surveys near Utqiagvik, Alaska, 2023. Unpublished report. Prepared by T. Obritschkewitsch and A. R. Bankert. 27 pp.

ACIA (Arctic Climate Impact Assessment). 2004. Impacts of a Warming Arctic: Arctic Climate Impacts Assessment. Cambridge University Press. Cambridge, United Kingdom. [Http://www.acia.uaf.edu](http://www.acia.uaf.edu). 146pp.

Aars, J. and R.A. Ims. 2002. Intrinsic and climatic determinants of population demography: The winter dynamics of tundra voles. *Ecology* 83:3449-3456.

Abraham, K.F., R.L. Jefferies, and R.F. Rockwell. 2005. Goose-induced changes in vegetation and land cover between 1976 and 1997 in an arctic coastal marsh. *Arctic, Antarctic, and Alpine Research* 37:269-275.

Afton, A.D. and S.L. Paulus. 1992. Incubation and brood care. Pages 62-108 *in Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis, MN. 635 p.

Alisauskas, R.T., and C.D. Ankney. 1992. The cost of egg laying and its relationship to nutrient reserves in waterfowl. Pages 30-61 *in Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis, MN. 635 p.

Alisauskas, R.T., J.W. Charlwood, and D.K. Kellett. 2006. Vegetation correlates of the history and density of nesting by Ross's geese and lesser snow geese at Karrak Lake, Nunavut. *Arctic* 59: 201-210.

Alisauskas, R.T. and D.K. Kellett. 2014. Age-specific in situ recruitment of female king eiders estimated with mark-recapture. *The Auk* 131:129-140.

- Alisauskas, R.T. and DeVink, J-M. 2015. Breeding costs, nutrient reserves and cross-seasonal effects: Dealing with deficits in sea ducks. Pages 125-168 *in Ecology and Conservation of North American Sea Ducks* (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, Eds.). *Studies in Avian Biology* 46. 610 p.
- Anderson, M.G., J.M. Rhymer, and F.C. Rohwer. 1992. Philopatry, dispersal, and the genetic structure of waterfowl populations. Pages 365-395 *in Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis, MN. 635 p.
- Anderson, M.G., M.S. Lindberg, and R.B. Emery. 2001. Probability of survival and breeding for juvenile female canvasbacks. *The Journal of Wildlife Management* 65:385-397.
- Andressen, C.G. and V. Loughheed. 2015. Disappearing Arctic tundra ponds: Fine-scale analysis of surface hydrology in drained thaw lake basins over a 65 year period (1948-2013). *Journal of Geophysical Research: Biogeosciences* 120:1-14.
- [BLM] Bureau of Land Management. 2018. Final supplemental environmental impact statement: Alpine satellite development plan for the proposed Greater Mooses Tooth 2 Development Project. Prepared by U.S. Department of Interior, Bureau of Land Management, Anchorage, Alaska. 641pp.
- Baldassarre and Bolen. 2006. *Waterfowl ecology and management*. Second Edition. Kreiger Publishing Company. Malabar, Florida.
- Baldwin, F.B., R.T. Alisauskas, and J.O. Leafloor. 2011. Nest survival and density of cackling geese inside and outside a Ross's goose colony. *The Auk* 128:404-414.
- Benson, A.J. and A.W. Trites. 2002. Ecological effects of regime shifts in the Bering Sea and eastern North Pacific Ocean. *Fish and Fisheries* 3: 95-113.
- Barron, D.G., J.D. Brawn, and P.J. Weatherhead. 2010. Meta-analysis of transmitter effects on avian behavior and ecology. *Methods in Ecology and Evolution* 1:180-187.
- Bety, J. G. Gauthier. E. Korpimaki and J-F. Giroux. 2002. Shared predators and indirect trophic interactions: lemming cycles and arctic-nesting geese. *Journal of Animal Ecology* 71:88-98.
- Blamber, S.J.M., D.P. Cyrus, J.J. Albaret, Chong Ving Ching, J.W. Day, M. Elliot, M.S. Fonseca, D. E. Hoss, J. Orensanz, I.C. Potter, and W. Silvert. 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems 57: 590-602.
- Black, A. 2005. Light induced seabird mortality on vessels operating in the Southern Ocean: Incidents and mitigation measures. *Antarctic Science* 17:67-68.
- Blums, P. R.G. Clark, and A. Mednis. 2002. Patterns of reproductive effort and success in birds: path analyses of long-term data from European ducks. *Journal of Animal Ecology* 71:280-295.
- Bodenstein, B., K. Beckmen, G. Sheffield, K. Kuletz, C. VanHemert, B. Berlowski, and V. Shearn-Bochsler. 2015. Avian cholera causes marine bird mortality in the Bering Sea of Alaska. *Journal of Wildlife Diseases* 51:934-937.

- Bogardus, R., C. Maio, M. McNeley, A. Johnson, S. McNeley, H. Baldwin, S. Hart, J. Christian, R. Glenn. 2021. Nelson Lagoon coastal hazard assessment. Report, Arctic Coastal Geoscience Laboratory. Fairbanks, Alaska. 97 pp.
- Bond, J.C., D. Esler, and T.D. Williams. 2008. Breeding propensity of female harlequin ducks. *Journal of Wildlife Management* 72:1388-1393.
- Brandt, H. 1943. Alaska bird trails. Bird Research Foundation, Cleveland, OH. 464 pp.
- Buckner, J.C., R. Ellingson, D.A. Gold, T.L. Jones, D.K. Jacobs. 2018. Mitogenomics supports an unexpected taxonomic relationship for the extinct diving duck *Chendytes lawi* and definitively places the extinct Labrador Duck. *Molecular Phylogenetics and Evolution* 122:102-109.
- Bustnes, J.O., M. Asheim, T.H. Bjorn, H. Gabrielson, and G. H. Systad. 2000. The diet of Steller's eiders wintering in Varangerfjord, northern Norway. *Wilson Bulletin* 112:8-13.
- Bustnes, J.O. and K.V. Galaktionov. 2004. Evidence of state-dependent trade-off between energy intake and parasite avoidance in Steller's eiders. *Canadian Journal of Zoology* 82:1566-1571.
- Bustnes, J. O., G. H. Systad. 2001. Comparative Feeding Ecology of Steller's Eider and Long-Tailed Ducks in Winter, 24(3):407-412.
- Burgess, R. M., R.J. Ritchie, B.T. Person, R.S. Suydam, J.E. Shook, A.K. Pritchard, and T. Obritschkewitsch. Rapid growth of a nesting colony of lesser snow geese on the Ikpikuk River delta, North Slope, Alaska, USA. *Waterbirds* 40:11-23.
- Byrne, R.H., S. Mecking, R.A Feely, and Z. Liu. 2010. Direct observations of basin-wide acidification of the North Pacific Ocean. *Geophysical Research Letters* 37: L02601.
- CAVM Team. 2003. Circumpolar Arctic Vegetation Map. Scale 1:7,500,000. Conservation of Arctic Flora and Fauna (CAFF) Map No. 1. U.S. Fish and Wildlife Service, Anchorage, Alaska
- [Corps] U.S. Army Corps of Engineers. 2017. Biological assessment Donlin Gold, LCC project. Revision v 1.7. September 2017. Anchorage, Alaska.
- [Corps] U.S. Army Corps of Engineers. 2019. Statewide threat assessment: identification of threats from erosion, flooding, and thawing permafrost in remote Alaska communities. Report #INE 19.03 for the Denali Commission. University of Alaska Fairbanks Institute of Northern Engineering, U.S. Army Corps of Engineers Alaska District. 99 pp.
- Coulson, J.C. 1984. The population dynamics of the Eider Duck *Somateria mollissima* and evidence of extensive non-breeding by adult ducks. *Ibis* 126:525-543
- Cox, R.R., M.A. Hanson, C.C. Roy, N.H. Euliss, D.H. Johnson, and M.G. Butler. 1998. Mallard duckling growth and survival in relation to aquatic invertebrates. *The Journal of Wildlife Management* 62: 124-133.
- Dau, C.P. 1987. Birds in nearshore waters of the Yukon-Kuskokwim Delta, Alaska. *Murrelet* 68:12-23.
- Dau, C.P., P.L. Flint, M.R. Petersen. 2000. Distribution and recoveries of Steller's eiders banded on the lower Alaska Peninsula, Alaska. *Journal of Field Ornithology* 71:541-548.

- Desholm, M. and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. *Biology Letters* 1:296-298.
- Descamps, S., N.G. Yoccoz, J-M. Gaillard, H.G. Gilchrist, K. E. Erikstad, S.A. Hanssen, B. Cazelles, M.R. Forbes, and J. Bety. 2010. Detecting population heterogeneity in effects of North Atlantic Oscillations on seabird body condition: get into the rhythm. *Oikos* 119:1526-1536.
- DeVink, J-M. A., H.G. Gilchrist, and A.W. Diamond. 2005. Effects of water salinity on growth and survival of common eider (*Somateria molissima*) ducklings. *The Auk* 122:523-529.
- Dick, M.H. and W. Donaldson. 1978. Fishing vessel endangered by crested auklet landings. *The Condor* 80:235-236.
- Drent, R. and S. Daan. 1980. The prudent parent: energetic adjustments in breeding biology. *Ardea* 68:225-252.
- Dhondt, A. A. 1987. Cycle of lemmings and geese: A comment on the hypothesis of Roselaar and Summers. *Bird Study* 34:151-154.
- Dunham, K. and J.B. Grand. 2016. Viability of the Alaskan breeding population of Steller's eiders. U.S. Geological Survey Open File Report 2016-1084. 8 pp.
- Dunham, K. and J.B. Grand. 2017. Evaluating models of population process in a threatened population of Steller's eiders: a retrospective approach. *Ecosphere* 8:1-15.
- Eadie, J.M. and J-P. L. Savard. 2015. Breeding systems, spacing behavior and reproductive behavior of sea ducks. Pages 365-416 *in* Ecology and Conservation of North American Sea Ducks (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, Eds.). *Studies in Avian Biology* 46, 610 p.
- Eisler, R. 1988. Lead hazards to fish, wildlife and invertebrates: A synoptic review. U.S. Fish and Wildlife Service Biological Report 85:1-14.
- Elder, W.H. 1954. The effect of lead poisoning on the fertility and fecundity of domestic mallard ducks. *The Journal of Wildlife Management* 18:315-323.
- Fabry, V.J., B.A. Seibel, R.A. Feely, and J.C. Orr. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science* 65: 414-432.
- Feely, R. A., S.C. Doney, and S.R. Cooley. 2009. Ocean acidification: Present conditions and future changes. *Oceanography* 22: 36-47.
- Flather, C.H., G.D. Hayward, S.R. Beissinger, and P.A. Stephens. 2011. Minimum viable populations: is there a magic number for conservation practitioners? *Trends in Ecology and Evolution* 26:307-316.
- Flemming, S.A., A. Calvert, E. Nol, and P.A. Smith. 2016. Do hyperabundant Arctic-nesting geese pose a problem for sympatric species? *Environmental Review* 24:393-402.
- Flint, P.L. and M.P. Herzog. 1999. Breeding of Steller's eiders, *Polysticta stelleri*, on the Yukon-Kuskokwim Delta, Alaska. *Canadian Field-Naturalist* 113:306-308.
- Flint, P.L., M.R. Petersen, C.P. Dau, J.E. Hines, J.D. Nichols. 2000. Annual survival and site fidelity of Steller's eiders molting along the Alaska Peninsula. *The Journal of Wildlife Management* 64:261-268.

- Flint, P.L., J.A. Morse, J.B. Grand, C.L. Moran. 2006. Correlated growth and survival of juvenile spectacled eiders: Evidence of habitat limitation? *The Condor* 108:901-911.
- Flint, P.L., E.J. Mallek, R.J. King, J.A. Schmutz, K.S. Bollinger, and D.V. Derksen. 2008. Changes in abundance and spatial distribution of geese molting near Teshekpuk Lake, Alaska: interspecific competition or ecological change? *Polar Biology* 31:549-556.
- Flint, P.L. and J.L. Schamber. 2010. Long-term persistence of spent lead shot in tundra wetlands. *Journal of Wildlife Management* 74:148-151.
- Flint, P.L. 2013. Changes in size and trends of North American sea duck populations associated with North Pacific oceanic regime shifts. *Marine Biology* 160: 59-65.
- Flint, P.L. 2015. Population dynamics of sea ducks: Using models to understand the causes, consequences, evolution, and management of variation in life history characteristics. Pages 63-96 *in Ecology and Conservation of North American Sea Ducks* (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, Eds.). *Studies in Avian Biology* 46, 610 p.
- Flint, P.L., J.B. Grand, and M.R. Petersen. 2016. Effects of lead exposure, environmental conditions, and metapopulation processes on population dynamics of spectacled eiders. *North American Fauna* 81:1-41.
- Fox, A.D. and C. Mitchell. 1997a. Rafting behavior and predator disturbance to Steller's eiders in northern Norway. *Journal fur Ornithologie* 138:103-109.
- Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-150 *In Conservation Biology: an Evolutionary-Ecological Perspective*. Sinauer Associates.
- Franson, J. 1986. Immunosuppressive effect of lead. P. 106-109 *In Lead Poisoning in Wild Waterfowl*. (J. S. Feierabend and A.B. Russell, Eds.) National Wildlife Federation, Washington, DC.
- Franson, J.C. 2015. Contaminants in sea ducks: Metals, trace elements, petroleum, organic pollutants, and radiation. Pages 169-240 *in Ecology and Conservation of North American Sea Ducks* (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, eds.). *Studies in Avian Biology* 46, 610 p.
- Franson, J. C., T. E. Hollmén, P. L. Flint, A. C. Matz. 2023. Trace elements in blood of sea ducks from Dutch Harbor and Izembek Lagoon, Alaska. *Journal of Fish and Wildlife Management*, 14(1):41–50.
- Fredrickson, L.H. 2001. Steller's Eider (*Polysticta stelleri*), version 2.0. *in The Birds of North America* (A. F. Poole and F. B. Gill, Eds). Cornell Lab of Ornithology, Ithaca, NY, USA.
- Frost, C.J., T.E. Hollmén, and J. H. Reynolds. 2013. Trends in annual survival of Steller's eiders molting at Izembek Lagoon on the Alaska Peninsula, 1993-2006. *Arctic* 66:173-176.
- Ganter, B., F. Cooke, and P. Mineau. 1996. Long-term vegetation changes in a snow goose nesting habitat. *Canadian Journal of Zoology* 74:965-969.
- Garland, A., A. Bukvic, A. Maton-Mosurska. 2022. Capturing complexity: Environmental change and relocation in the North Slope Borough, Alaska. *Climate Risk Management* 38, 100460: 1-12.
- Gazeau, F., C. Quiblier, J.M. Jansen, J-P. Gattuso, J.J. Middleburg, and C.H.R. Heip. 2007. Impact of elevated CO₂ on shellfish calcification. *Geophysical Research Letters* 34: L07603.

- Gilg, O., B. Sittler, and I. Hanski. 2009. Climate change and cyclic predator-prey population dynamics in the high Arctic. *Global Change Biology* 15:2634-2652.
- Goethel, C.L., J.M. Grebmeier, L.W. Cooper, and T.J. Miller. 2017. Implications of ocean acidification in the Pacific Arctic: Experimental responses of three Arctic bivalves to decreased pH and food availability. *Deep-Sea Research Part II* 144:112-124.
- Grand, J.B. and P.L. Flint. 1997. Productivity of nesting spectacled eiders on the Lower Kashunuk River, Alaska. *The Condor* 99:926-932.
- Grand, J.B., P.L. Flint, M.R. Petersen, and C.L. Moran. 1998. Effect of lead poisoning on spectacled eider survival rates. *The Journal of Wildlife Management* 62:1103-1109.
- Gurney, K.E.B., R.G. Clark, S.M. Slattery, N.V. Smith-Downey, J. Walker, L.M. Armstrong, S.E. Stephens, M. Petrula, R.M. Corcoran, K.H. Martin, K.A. DeGroot, R.W. Brook, A.D. Afton, K. Cutting, J.M. Warren, M. Fournier, and D.N. Koons. 2011. Time constraints in temperate-breeding species: influence of growing season length on reproductive strategies. *Ecography* 34:628-636.
- Hansson, L-A., M.K. Ekvall, M.T. Ekvall, J. Ahlgren, W. S. Holm, L. Dessborn, C. Bronmark. 2014. Experimental evidence for a mismatch between insect emergence and waterfowl hatching under increased spring temperatures. *Ecosphere* 5:120.
- Harwood, C.M., B.J. McCaffery, F.J. Broerman, and P.A. Liedberg. 2000. A local concentration of snowy owls on the Yukon-Kuskokwim Delta in summer 2000. *Journal of Raptor Research* 38:275-277.
- Haven Wiley, R. and D. S. Lee. 2000. Pomarine Jaeger (*Stercorarius pomarinus*), version 2.0. In *The Birds of North America* (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bna.483>
- Himes Boor, G.K. 2013. A framework for developing objective and measurable recovery criteria for threatened and endangered species. *Conservation Biology* 28:33-43.
- Hodges, J. I., W. D. Eldridge. 2001. Aerial surveys of eiders and other waterbirds on the eastern Arctic coast of Russia. *Wildfowl*, 52:127–142.
- Hogrefe, K., D. Ward, T.F. Donnelly, and N. Dau. 2014. Establishing a baseline for regional scale monitoring of eelgrass (*Zostera marina*) habitat on the lower Alaska Peninsula. *Remote Sensing* 6:12447-12477.
- Hollmén, T.E., C. DebRoy, P.L. Flint, D.E. Safine, J.L. Schamber, A.E. Riddle, and K.A. Trust. 2010. Molecular typing of *Escherichia coli* strains associated with threatened sea ducks and near-shore marine habitats of southwest Alaska. *Environmental Microbiology Reports* 3:1-8.
- Hollmen, T. E., P. L. Flint, S. E. G. Ulman, A. Maliguine. 2022. Are changes in suitability of essential lagoon habitats driving declines of Steller's eiders in the eastern Aleutians? Final Report NPRB Project 1814. Prepared for the North Pacific Research Board. 62 pp.
- Hollmen, T. E., P. L. Flint, S. E. G. Ulman, H. M. Wilson, C. L. Amundson, E. E. Osnas. 2023. Climate change and coastal wetland salinization: Physiological and ecological consequences for Arctic waterfowl. *Functional Ecology*, 37:1884-1896.

- Hollmén, T.E. and J.C. Franson. Infectious diseases, parasites, and biological toxins in sea ducks. Pages 97-124 in *Ecology and Conservation of North American Sea Ducks* (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, Eds.). *Studies in Avian Biology* 46, 610 p.
- Holt, D. W., M. D. Larson, N. Smith, D. L. Evans, and D. F. Parmelee. 2015. *Snowy Owl (Bubo scandiacus)*, version 2.0. In *The Birds of North America* (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bna.10>
- Hopkins, J.S., P.A. Sandifer, M.R. DeVoe, A.F. Holland, C.L. Browdy, and A.D. Stokes. 1995. Environmental impacts of shrimp farming with special reference to the situation in the continental United States. *Estuaries* 18: 25-42.
- Ims, R.A., J-A. Henden, and W.T. Killengreen. 2007. Collapsing population cycles. *Trends in ecology and evolution* 23:79-86.
- [IPCC] Intergovernmental Panel on Climate Change. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- [IPCC] Intergovernmental Panel on Climate Change. 2023. *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* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115.
- [ICCT] International Council on Clean Transportation. 2015. *A 10-year projection of maritime activity in the U.S. Arctic Region. Unpublished Report. Prepared by A. J. Azzara, H. Wang, and D. Rutherford for the United States Coast Guard.* 73pp.
- Irons, D.B., T. Ancker-Nilssen, A.J. Gaston, G.V. Byrd, K. Falk, G. Gilchrist, M. Hario, M. Hjernquist, Y.V. Krasnov, A. Mosbech, B. Olsen, A. Petersen, J.B. Reid, G.J. Robertson, H. Strom, K.D. Wohl. 2008. Fluctuations in circumpolar seabird populations linked to climate oscillations. *Global Change Biology* 14: 1455-1463.
- Jamieson, I.G. and F.W. Allendorf. 2012. How does the 50/500 rule apply to MVPs? *Trends in Ecology and Evolution* 27:578-584.
- Johnson. D.H., J.D. Nichols, and M.D. Schwartz. 1992. Population dynamics of breeding waterfowl. Pages 446-485 in *Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, eds). University of Minnesota Press, Minneapolis, MN. 635 p.
- Jones, R.D. 1965. Returns from Steller's eiders banded in Izembek Bay, Alaska. *Wildfowl Trust Annual Report* 16:83-85.
- Jordan, J.S. and F.C. Bellrose. 1951. Lead poisoning in wild waterfowl. *Biological Notes* No. 26. State of Illinois, Natural History Survey Division. 27pp.
- Jorgenson, T. and C. Ely. 2001. Topography and flooding of coastal ecosystems on the Yukon-Kuskokwim Delta, Alaska: Implications for sea-level rise. *Journal of Coastal Research* 17: 124-136.

- Kausrud, K.L., A. Mysterud, H. Steen, J.O. Vik, E.Ostbye, B. Caselles, E. Framstad, A.M. Eikeset, I. Mysterud, T. Solhoy, and N.C. Stenseth. 2008. Linking climate change to lemming cycles. *Nature* 456:93-97.
- Kelly, A. and S. Kelly. 2005. Are mute swans with elevated blood lead levels more likely to collide with overhead power lines? *Waterbirds* 28:331-334.
- Kertell, K. 1991. Disappearance of the Steller's eider from the Yukon-Kuskokwim Delta, Alaska. *Arctic* 44:177-187.
- King, J.G. and C.P. Dau. 1981. Waterfowl and their habitats in the Eastern Bering Sea. Pages 739-753 *in* The Eastern Bering Sea Shelf: Oceanography and Resources. (D. W. Hood and J.A. Calder,Eds.). Volume 2. University of Washington Press, Seattle, WA.
- Klokov, K., V. Davydov, M. Robards, E. Bragina. 2024. Assessing Hunting Pressure on Common Eiders in Chukotka, Russia. Final report Project #164, Sea Duck Joint Venture. 82 pp.
- Krapu, G.L. and K.J. Reinecke. 1992. Foraging ecology and nutrition. Pages 1-29 *in* Ecology and Management of Breeding Waterfowl (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, eds). University of Minnesota Press, Minneapolis, MN. 635 p.
- Kroeker, K.J., R.L. Kordas, R. Crim, I.E. Hendriks, L. Ramajo, G.S. Singh, C.M. Duarte, and J-P. Gattuso. 2013. Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. *Global Change Biology* 19: 1884-1896.
- Labunski, E., S. Fitzgerald, A. Kingham. 2022. A Review of Seabird Vessel Strikes in Alaska Groundfish Fisheries 2010-2021. Poster, 49th Annual Pacific Seabird Group Meeting, Virtual.
- Lance, E.W., A.C. Matz, M.K. Reeves, and L.A. Verbrugge. 2012. Petroleum hydrocarbon contamination in Nelson Lagoon, Alaska, sampling with three different matrices. *Marine Pollution Bulletin* 64:2129-2134.
- Latorre-Margalef, N., G. Gunnarsson, V.J. Munster, R.A.M. Fouchier, AID.M.E. Osterhaus, J. Elmberg, B. Olsen, A. Wallensten, P. D. Haemig, T. Fransson, L. Brudin, and J. Waldenstrom. 2009. Effects of influenza A virus infection on migrating mallard ducks. *Proceedings of the Royal Society B* 276:1029-1036.
- Laubhan, M.K. and K.A. Metzner. 1999. Distribution and diurnal behavior of Steller's eiders wintering on the Alaska Peninsula. *The Condor* 101:694-698.
- Lavretsky, P., R. E. Wilson, S. L. Talbot, S. A. Sonsthagen. 2021. Phylogenomics reveals ancient and contemporary gene flow contributing to the evolutionary history of sea ducks (Tribe Mergini). *Molecular Phylogenetics and Evolution*, 161(107164):1-11.
- Lebreton, J-D., K.P. Burnham, J. Clobert, and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. *Ecological Monographs* 62: 67-118.
- Lefcheck, J.S., D.J. Wilcox, R.R. Murphy, S.R. Marion, and R.J. Orth. 2017. Multiple stressors threaten the imperiled coastal foundation species eelgrass in Chesapeake Bay, USA. *Global Change Biology* 23:3474-3483.

- Lefebvre, K.A., L. Quakenbush, E. Frame, K.B. Huntington, G. Sheffield, R. Stimmelmayer, A. Bryan, P. Kendrick, H. Ziel, T. Goldstein, J.A. Snyder, T. Gelatt, F. Gulland, B. Dickerson, V. Gill. 2016. Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. *Harmful Algae* 55:13-24.
- Liljedahl, A.K., J. Boike, R.P. Daanen, A.N. Fedorov, G.V. Frost, G. Grosse, L.D. Hinzman, Y. Iijima, J.C. Jorgensen, N. Matveyeva, M. Necsoiu, M.K. Reynolds, V.E. Romanovsky, J. Schulla, K.D. Tape, D.A. Walker, C.J. Wilson, H. Yabuki, and D. Zona. 2016. Pan-Arctic ice-wedge degradation in warming permafrost and its influence on tundra hydrology. *Nature Geoscience* 9:312-319.
- Loiseau, C., R.J. Harrigan, A. J. Cornel, S.L. Guers, M. Dodge, T. Marzec, J.S. Carlson, B. Seppi, R.N.M. Sehgal. 2012. First evidence and predictions of *Plasmodium* transmission in Alaskan bird populations. *PLoS ONE* 7:e44729.
- Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. 2008. Height, guy wires, and steady-burning lights increase hazard of communication towers to nocturnal migrants: A review and meta-analysis. *The Auk* 125:485-492.
- Lougheed, V.L., M.G. Butler, D.C. McEwen, J.E. Hobbie. 2011. Changes in tundra pond limnology: re-sampling Alaskan ponds after 40 years. *Ambio* 40: 589-599.
- Lowvorn, J.R., M.F. Raisbeck, L.W. Cooper, G.A. Cutter, M.W. Miller, M.L. Brooks, J.M. Grebmeier, A.C. Matz, and C.M. Schaefer. 2013. Wintering eiders acquire exceptional Se and Cd burdens in the Bering Sea: Physiological and oceanographic factors. *Marine Ecology Progress Series* 489:245-261.
- Maliguine, A. M. 2024. Changes in benthic prey availability and quality suggest less favorable foraging conditions for threatened Steller's eiders (*Polysticta stelleri*) molting at Izembek Lagoon, Alaska. M.S. Thesis. University of Alaska Fairbanks. Fairbanks, Alaska. 66 pp.
- Mallory, M. L. 2015. Site fidelity, breeding habitats, and the reproductive strategies of sea ducks. Pages 337-364 *in Ecology and Conservation of North American Sea Ducks* (J-P.L. Savard, D.V. Derksen, D. Esler, and J.M. Eadie, Eds.). *Studies in Avian Biology* 46, 610 p.
- Mars, J.C. and D.W. Houseknecht. 2007. Quantitative remote sensing study indicates doubling of coastal erosion rate in past 50 yr along a segment of the Arctic coast of Alaska. *Geology* 35: 583-586.
- Martin, P. D., D. C. Douglas, T. Obritschkewitsch, and S. Torrance. 2015. Distribution and movements of Alaska-breeding Steller's eiders in the non-breeding period. *The Condor* 117:341-353.
- Mayfield, H. F. 1961. Nesting success calculated from exposure. *Wilson Bulletin* 73:255-261.
- Mayfield, H. F. 1975. Suggestions for calculating nest success. *Wilson Bulletin* 87:456-466.
- McKinney, F. 1965. The spring behavior of wild Steller's eiders. *The Condor* 67:273-290.
- McRoy, C.P. 1966. The standing stock and ecology of eelgrass (*Zostera marina* L.) in Izembek Lagoon, Alaska. M.S. Thesis. University of Washington. Seattle, Washington. 137 pp.
- Meixell, B. and P.L. Flint. 2017. Effects of industrial and investigator disturbance on arctic-nesting geese. *The Journal of Wildlife Management* 81:1372-1385.

Metzner, K.A. 1993. Ecological strategies of wintering Steller's eiders on Izembek Lagoon and Cold Bay, Alaska. M.S. Thesis. University of Missouri. Columbia, Missouri. 213pp. Miles, A.K., P.L. Flint, K.A. Trust, M.A. Ricca, S.E. Spring, D.E. Arrieta, T.E. Hollmen, and B.W. Wilson. 2007. Polycyclic aromatic hydrocarbon exposure in Steller's eiders and harlequin ducks in the eastern Aleutian Islands, Alaska, USA. *Environmental Toxicology and Chemistry* 26:2694 – 2703.

Miller, M. W. C. 2023. Wetland habitat use, protein sources for reproduction, and nest habitat selection by sea ducks facing rapid change in the Alaskan Arctic. PhD Dissertation. Southern Illinois University. Carbondale, Illinois. 268 pp.

Miller, M. W. C., J. R. Lovvorn, N. R. Graff, N. C. Stellrecht. 2022. Use of marine vs. freshwater proteins for egg-laying and incubation by sea ducks breeding in Arctic tundra. *Ecosphere*, 13(e4138):1-17.

Miller, M. W. C., J. R. Lovvorn, N. R. Graff, N. C. Stellrecht, S. P. Plesh. 2023. Prey availability and foraging activity by tundra-nesting sea ducks: Strong preference for specific wetland types. *Ecology and Evolution*, 13(e10375):1-23.

Miller, M. W., J. R. Lovvorn, A. C. Matz, R. J. Taylor, M. L. Brooks, T. E. Hollmén. 2019. Interspecific patterns of trace elements in sea ducks: Can surrogate species be used in contaminants monitoring? *Ecological Indicators*, 98:830–839.

Miller, M.W.C., J.R. Lovvorn, A.C. Matz, R.J. Taylor, C.J. Latty and D.E. Safine. 2016. Trace elements in sea ducks of the Alaskan Arctic Coast: Patterns of variation among species, sexes, and ages. *Archives of Environmental Contaminants and Toxicology* 71:297-312.

Ministry of Natural Resources and Environment of the Russian Federation. 2021. On approval of the list of fauna objects listed in the Red Book of the Russian Federation, dated April 2, 2020. Pages 42-43 in *The Red Book of the Russian Federation: Animals*, 2nd ed., (The Ministry of Natural Resources and Environment of the Russian Federation Ed.). 1127 pp. In Russian.

Moore, K.A., and J.C. Jarvis. 2008. Environmental factors affecting recent summertime eelgrass diebacks in the lower Chesapeake Bay: Implications for long-term persistence. *Journal of Coastal Research* 55:135-147.

Morris, W.F., P.L. Bloch, B.R. Hudgens, L.C. Moyle, and J.R. Stinchcombe. 2002. Population viability analysis in endangered species recovery plans: Past use and future improvements. 12:708-712.

Munro, J. and J. Bedard. 1977. Gull predation and creching behavior in the common eider. *Journal of Animal Ecology* 46:799-810.

Murphy, R.K., E.K. Mojica, J.F. Dwyer, M.M. McPherron, G.D. Wright, R.E. Harness, A.K. Pandley and K.L. Serbousek. 2016. Crippling and nocturnal biases in a study of sandhill crane collisions with a transmission line. *Waterbirds* 39:312-317.

Natsuike, M. R. Saito, A. Fujiwara, K. Matusno, A. Yamaguchi, N. Shiga, T. Hirawake, T. Kikuchi, S. Nichino, I. Imai. 2017. Evidence of increased toxic dinoflagellate blooms in the eastern Bering Sea in summers 2004 and 2005. *PLoS ONE* 12: 1-14.

[NOAA Fisheries] National Oceanic and Atmospheric Administration Fisheries. 2020, April 13. IB 20-32: NMFS Reports a Vessel-Strike Mortality of an Alaska-Breeding Population Steller's Eider in the BSAI.

<https://www.fisheries.noaa.gov/bulletin/ib-20-32-nmfs-reports-vessel-strike-mortality-alaska-breeding-population-stellers>

Oppel, S. and A.N. Powell. 2010. Age-specific survival estimates of king eiders derived from satellite telemetry. *The Condor* 112:323-330.

Oppel, S., A.N. Powell, and M.G. Butler. 2011. King eider foraging effort during the pre-breeding period in Alaska. *The Condor* 113:52-60.

Ouellet, J.-F., C. Vanpé, M. Guillemette. 2013. The body size-dependent diet composition of North American sea ducks in winter. *PLoS ONE*, 8(6):1–10.

Overland, J. S. Rodionov, S. Minobe, and N. Bond. 2008. North Pacific regime shift: Definitions, issues, and recent transitions. *Progress in Oceanography* 77:92-102.

Pearce, J. M., D. Esler, A. G. Degtyarev. 1998. Birds of the Indigirka River delta, Russia: historical and biogeographic comparisons. *Arctic*, 51(4): 361-370. Pearce, J.M., S. L. Talbot, M.R. Petersen, J.R. Rearick. 2005. Limited genetic differentiation among breeding, molting, and wintering groups of the threatened Steller's eider: the role of historic and contemporary factors. *Conservation Genetics* 6:743-757.

Petersen, M.R., M.J. Sigman. 1977. Field studies at Cape Pierce, Alaska 1976. Pages 633–693 *in* Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators, Vol. 4. NOAA, Boulder, Colorado.

Petersen, M.R. 1980. Observations of wing-feather moult and summer feeding ecology of Steller's eiders at Nelson Lagoon, Alaska. *Wildfowl* 31:99-106.

Petersen, M.R. 1981. Populations, feeding ecology and molt of Steller's eiders. *Condor* 83:256–262.

Petersen, M.R., J.O. Bustnes, and G.H. Systad. 2006. Breeding and moulting locations and migration patterns of the Atlantic population of Steller's eiders *Polysticta stelleri* as determined from satellite telemetry. *Journal of Avian Biology* 37:58-68.

Pitelka, F.A., P.Q. Tomich, G.W. Treichel. 1955. Ecological relations of jaegers and owls as lemming predators near Barrow, Alaska. *Ecological Monographs* 25:85-117.

Pitelka, F.A. and G.O. Batzli. 2007. Population cycles of lemmings near Barrow, Alaska: A historical review. *Acta Theriologica* 52: 323-336.

Plesh, S. P., J. R. Lovvorn, M. W. C. Miller. 2023. Organic matter sources and flows in tundra wetland food webs. *PLoS ONE*, 18(5):1-26.

Ponce, C., J.C. Alonso, G. Argandona, A. Garcia Fernandez, and M. Carrasco. 2010. Carcass removal by scavengers and search accuracy affect bird mortality estimates at power lines. *Animal Conservation* 13:603-612.

Powell, A.N. and S. Backensto. 2009. Common ravens (*Corvus corax*) nesting on Alaska's North Slope oil fields. Unpublished report for U.S. Department of Interior, Minerals Management Service. OCS Study MMS 2009-007. 42pp.

Pozdnyakov V. I. 2016. More about the Steller's eider. *Kazarka*, 19(2): 81-101. In Russian.

- Pozdnyakov, V. I. 2022. Chronicle of nature: monitoring the status of populations of protected waterfowl species in the Lena River delta (2015-2018). Pages 263-264 in Scientific Research in Nature Reserves and National Parks of the Russian Federation for 2015–2021, Vol. 5, (Ministry of Natural Resources and Ecology of the Russian Federation, All-Russian Research Institute for Environmental Protection (VNIIEcology) Ed.). 506 pp. In Russian.
- Quakenbush, L. T., R. H. Day, B. A. Anderson, F. A. Pitelka, and B. J. McCaffery. 2002. Historical and present breeding season distribution of Steller's Eiders in Alaska. *Western Birds* 33:99–120.
- Quakenbush, L.T., R.H. Suydam, T. Obritschkewitsch, and M. Deering. 2004. Breeding biology of Steller's eiders (*Polysticta stelleri*) near Barrow, Alaska, 1991–1999. *Arctic* 57:166–182.
- Ramey, A.M., J.M. Pearce, A.B. Reeves, J.C. Franson, M.R. Petersen, and H.S. Ip. 2011. Evidence for limited exchange of avian influenza viruses between sea ducks and dabbling ducks at Alaska Peninsula coastal lagoons. *Archives of Virology* 156:1813 -1821.
- Reed, D.H., J.J. O'Grady, B.W. Brook, J.D. Ballou, and R. Frankham. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. *Biological Conservation* 113:23-34.
- Reed, E.T., G. Gauthier, and J-F. Giroux. 2004. Effects of spring conditions on breeding propensity of greater snow goose females. *Animal Biodiversity and Conservation* 27: 35-46.
- Reed, J.A. and P.L. Flint. 2007. Movements and foraging effort of Steller's eiders and harlequin ducks wintering near Dutch Harbor, Alaska. *Journal of Field Ornithology* 78:124-132.
- Reed, J.M. and E.D. McCoy. 2014. Relation of minimum viable population size to biology, time frame, and objective. *Conservation Biology* 28: 867-870.
- Riordan, B., D. Verbyla, and A.D. MCGuire. 2006. Shrinking ponds in subarctic Alaska based on 1950-2002 remotely sensed images. *Journal of Geophysical Research* 111: 1-11.
- Rogacheva, E. V., V. I. Pozdnyakov, Y. V. Krasnov. 2021. Steller's eider. Pages 595-596 in *The Red Book of the Russian Federation: Animals*, 2nd ed., (The Ministry of Natural Resources and Environment of the Russian Federation Ed.). 1127 pp. In Russian.
- Rogacheva, E. V., E. E. Syroechkovsky. 2015. Eiders of Taymyr Part 2: common eider, Steller's eider. *Kazarka*, 18:57–87. In Russian.
- Ronconi, R.A., K.A. Allard, and P.D. Taylor. 2015. Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. *Journal of Environmental Management* 147: 34-45.
- Rosenberg, D.H., M.J. Petrula, J.L. Schamber, D. Zwiefelhofer, T.E. Hollmen, and D. D. Hill. 2014. Seasonal movements and distribution of Steller's Eiders wintering at Kodiak Island, Alaska. *Arctic* 67:347-359.
- Roth, J.D. Variability in marine resources affects arctic fox population dynamics. *Journal of Animal Ecology* 72: 668-676.
- Runge, J. 2004. Population viability analysis for Alaska breeding and Pacific populations of Steller's eider. Unpublished Report to the U.S. Fish and Wildlife Service. University of Montana, Missoula, Montana. 27pp.

- Safine, D. E., M. S. Lindberg, K. H. Martin, S. L. Talbot, T. R. Swem, J. M. Pearce, N. C. Stellrecht, G. K. Sage, A. E. Riddle, K. Fales, T. E. Hollmén. 2020. Use of genetic mark-recapture to estimate breeding site fidelity and philopatry in a threatened sea duck population, Alaska-breeding Steller's eiders. *Endangered Species Research*, 41:349–360.
- Samelius, G. and R.T. Alisauskas. 2009. Habitat alteration by geese at a large arctic goose colony: consequences for lemmings and voles. *Canadian Journal of Zoology* 87: 95-101.
- Sargeant, A.B. and D.G. Raveling. 1992. Mortality during the breeding season. Pages 396-422 *in Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis, MN. 635 p.
- Sedinger, J.S. 1992. Ecology of pre fledging waterfowl. Pages 109-127 *in Ecology and Management of Breeding Waterfowl* (B.D.J. Batt, A.D. Afton, M.G. Anderson, D.D. Ankney, D.H. Johnson, J.A. Kadlec, and G.L. Krapu, Eds.). University of Minnesota Press, Minneapolis, MN. 635 p.
- Sedinger, J.S., and R. T. Alisauskas. 2014. Cross-seasonal effects and the dynamics of waterfowl populations. *Wildfowl* 4: 277-304.
- Silber, G., D. Weller, R. Reeves, J. Adams, T. Moore. 2021. Co-occurrence of gray whales and vessel traffic in the North Pacific Ocean. *Endangered Species Research*, 44:177–201.
- Sittler, B., O. Gilg, and T.B. Berg. 2000. Low abundance of king eider nests during low lemming years in northeast Greenland. *Arctic* 53:53-60.
- Shoemaker, K.T., A.R. Breisch, J.W. Jaycox, and J.P. Gibbs. 2013. Reexamining the minimum viable population concept for long-lived species. *Conservation Biology* 27:542-551.
- Shutler, D., R.T. Alisauskas, and J.D. McLaughlin. 2012. Associations between body composition and helminths of lesser snow geese during winter and spring migration. *International Journal for Parasitology* 42:755-760.
- Smith, L.C., Y. Sheng, G.M. MacDonald, and L.D. Hinzman. 2005. Disappearing Arctic lakes. *Science* 308: 1429.
- Smith, M.A., B.K. Sullender, W.C. Koeppen, K.J. Kuletz, H.M. Renner and A.J. Poe. In review. An assessment of climate change vulnerability for Important Bird Areas in the Bering Sea and Aleutian Arc. *PLoSOne*.
- Solovieva, D.V. 1999. Biology and bioenergetics of the Steller's eider (*Polysticta stelleri*). Ph.D. Dissertation: Russian Academy of Sciences Zoological Institute and Lena-Delta State Nature Reserve. St Petersburg, Russia. 176pp.
- Stabeno, P.J., J.T. Duffy-Anderson, L.B. Eisner, E.V. Farley, R.A. Heintz, and C.W. Mordy. 2018. Return of warm conditions in the southeastern Bering Sea: Physics to fluorescence. *PloS ONE* 12:1-16.
- Stout, J.H., K.A. Trust, J.F. Cochrane, R.S. Suydam, and L.T. Quakenbush. 2002. Environmental contaminants in four eider species from Alaska and arctic Russia. *Environmental Pollution* 119:215-226.
- Summers, R. W. 1986. Breeding production of dark-bellied brant geese *Branta bernicla bernicla* in relation to lemming cycles. *Bird Study* 33:105-108.
- Swennen, C., J.C.H. Ursem, and P. Duiven. 1993.

Determinate laying and egg attendance in common eiders. *Scandinavian Journal of Ornithology* 24:48-52.

Taylor, P.C., W. Maslowski, J. Perlwitz, and D.J. Wuebbles. 2017. Arctic changes and their effects on Alaska and the rest of the United States. Pages 303-332 *In* Climate Science Special Report: Fourth National Climate Assessment, Volume I (Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, Eds.). U.S. Global Change Research Program, Washington, DC, USA.

Terenzi, J., M.T. Jorgenson, C.R. Ely. 2014. Storm-surge flooding on the Yukon-Kuskokwim Delta, Alaska. *Arctic* 67: 360-374.

Truill, L.W., C.J.A. Bradshaw, and B.W. Brook. 2007. Minimum viable population size: A meta-analysis of 30 years of published estimates. *Biological Conservation* 139:159-166.

Truill, L.W., B.W. Brook, R.R. Frankham, and C.J.A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. *Biological Conservation* 143:28-34.

Troy, D. M., S. R. Johnson. 1989. Marine birds. Pages 355-454 in Outer continental shelf environmental assessment program: final reports of principal investigators, Vol. 60 (J. C. Truett Ed.). U.S. Department of Commerce, U.S. Department of the Interior. 563 pp.

Trust, K.A., K.T. Rummel, A.M. Scheuhammer, I.L. Brisbin, and M.J. Hooper. 2000. Contaminant exposure and biomarker responses in spectacled eiders from St. Lawrence Island, Alaska. *Archives of Environmental Contamination and Toxicology* 38:107-113.

[USFWS] U.S. Fish and Wildlife Service. 1971. The natural history of Cape Pierce and Nanvak Bay, Cape Newenham National Wildlife Refuge, Alaska. Unpublished report. Prepared by M.H. Dick and L.S. Dick. Bethel, Alaska. 77 pp.

[USFWS] U.S. Fish and Wildlife Service. 1986. Abundance, age composition and observations of emperor geese in Cinder lagoon, Alaska Peninsula, 17 September–10 October 1986. Unpublished report. Prepared by R.J. Wilk, K.I. Wilk and R.C. Kuntz, II. King Salmon, Alaska. 41 pp.

[USFWS] U.S. Fish and Wildlife Service. 1997. Environmental contaminants in three eider species from Alaska and arctic Russia. Unpublished Technical Report. Prepared by K.A. Trust, J.F. Cochrane, and J.H. Stout. Ecological Services Office, Anchorage, Alaska. 49pp.

[USFWS] U.S. Fish and Wildlife Service. 2001. Breeding biology of Steller's eiders nesting near Barrow, Alaska, 1999-2000. Unpublished Report. Prepared by T. Obritschkewitsch, P. Martin, and R. Suydam. Northern Ecological Services, U.S. Fish and Wildlife Service, Fairbanks, Alaska, 113 pp.

[USFWS] U.S. Fish and Wildlife Service. 2001b. Steller's eider surveys at Kuskokwim Shoals and Nunivak Island. Memo from B. McCaffery to P. Martin. October 1, 2001. Yukon Delta National Wildlife Refuge. Bethel, Alaska. 3pp.

[USFWS] U.S. Fish and Wildlife Service. 2001c. Observations of molting Steller's eiders. Unpublished Report. Prepared by C. Dau. Office of Migratory Bird Management, Anchorage, Alaska. 8pp.

[USFWS] U.S. Fish and Wildlife Service. 2002a. Steller's Eider Recovery Plan. Fairbanks Fish and Wildlife Field Office. Fairbanks, Alaska. 27p.

[USFWS] U.S. Fish and Wildlife Service. 2002b. Breeding biology of Steller's eiders nesting near Barrow, Alaska, 2001. Unpublished Report. Prepared by T. Obritschkewitsch and P. Martin. Fairbanks Fish and Wildlife Field Office, U.S. Fish and Wildlife Service, Fairbanks, Alaska, 43 pp.

[USFWS] U.S. Fish and Wildlife Service. 2002c. Breeding biology of Steller's eiders nesting near Barrow, Alaska, 2002. Unpublished Report. Prepared by T. Obritschkewitsch and P. Martin. Fairbanks Fish and Wildlife Field Office, U.S. Fish and Wildlife Service, Fairbanks, Alaska, 23 pp.

[USFWS] U.S. Fish and Wildlife Service. 2006a. Breeding biology of Steller's eiders nesting near Barrow, Alaska, 2005. Unpublished Report. Prepared by N. Rojek. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 61 pp.

[USFWS] U.S. Fish and Wildlife Service. 2006b. Winter distribution and abundance of Steller's eiders (*Polysticta stelleri*) in Cook Inlet, Alaska, 2004-2005. Unpublished Report. Prepared by W.W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. OCS Study, MMS 2006-066. 37 pp.

[USFWS] U.S. Fish and Wildlife Service. 2007a. Breeding biology of Steller's eiders nesting near Barrow, Alaska, 2006. Unpublished Report. Prepared by N. Rojek. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 53 pp.

[USFWS] U.S. Fish and Wildlife Service. 2007b. Biological opinion on the effects of the construction of a harbor at Little South America – South, Unalaska, Alaska on the threatened Steller's eider. Consultation with the U.S. Army Corps of Engineers. Anchorage, Alaska. 94 pp.

[USFWS] U.S. Fish and Wildlife Service. 2009. Steller's eider distribution, abundance, and trend on the Arctic Coastal Plain, Alaska, 1989–2008. Unpublished report. Prepared by R. Stehn and R. Platte. Office of Migratory Bird Management, Anchorage, Alaska. 35pp.

[USFWS] U.S. Fish and Wildlife Service. 2011a. Breeding ecology of Steller's and spectacled eiders nesting near Barrow, Alaska, 2008–2010. Unpublished Report. Prepared by D. Safine. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 66 pp.

[USFWS] U.S. Fish and Wildlife Service. 2011b. Biological opinion for approval of the State of Alaska's mixing zones regulation section of the Alaska water quality standards. Consultation with the U.S. Environmental Protection Agency. Prepared by Anchorage Fish and Wildlife Field Office. Anchorage, Alaska. 228pp.

[USFWS] U.S. Fish and Wildlife Service. 2012a. Breeding ecology of Steller's and spectacled eiders nesting near Barrow, Alaska, 2011. Unpublished Report. Prepared by D. Safine. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 65 pp.

[USFWS] U.S. Fish and Wildlife Service. 2012b. Waterfowl breeding population survey, Arctic Coastal Plain, Alaska, 2011. Unpublished report. Prepared by W. Larned, R. Stehn, and R. Platte. Division of Migratory Bird Management, Anchorage, Alaska. 51 pp.

[USFWS] U.S. Fish and Wildlife Service. 2012c. Steller's eider spring migration surveys southwest Alaska 2012. Unpublished report. Prepared by W.W. Larned. Division of Migratory Bird Management, Anchorage, Alaska. 25 pp.

[USFWS] U.S. Fish and Wildlife Service. 2013a. Breeding ecology of Steller's and spectacled eiders nesting near Barrow, Alaska, 2012. Unpublished Report. Prepared by D. Safine. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 56 pp.

[USFWS] U.S. Fish and Wildlife Service 2013b. Analysis of aerial survey indices monitoring waterbird populations of the Arctic Coastal Plain, Alaska, 1986-2012. Unpublished Report. Prepared by R.A. Stehn, W.W. Larned, and R.M. Platte. Office of Migratory Bird Management, Anchorage, Alaska. 56 pp.

[USFWS] U.S. Fish and Wildlife Service. 2013c. Testing the feasibility and effectiveness of a fall Steller's eider molt survey in southwest Alaska. Unpublished Report. Prepared by H.M. Wilson, W.W. Larned, T.D. Bowman, and J.B. Fischer. Office of Migratory Bird Management, Anchorage, Alaska. 14 pp.

[USFWS] U.S. Fish and Wildlife Service. 2013d. Final Environmental Impact Statement: Izembek National Wildlife Refuge land exchange/road corridor. National Wildlife Refuge System, Anchorage, Alaska.

[USFWS] U.S. Fish and Wildlife Service. 2015. Biological Opinion for East Barrow shareholder lot roads. Consultation with U.S. Army Corps of Engineers, Anchorage, Alaska. Prepared by Fairbanks Fish and Wildlife Field Office, April 30, 2015. 58pp.

[USFWS] U.S. Fish and Wildlife Service. 2016a. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3.4. Dated August 2016.

[USFWS] U.S. Fish and Wildlife Service. 2016b. Breeding biology of Steller's and spectacled eiders nesting near Barrow, Alaska, 2015. Unpublished Report. Prepared by N. Graff. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 52 pp.

[USFWS] U.S. Fish and Wildlife Service. 2016c. Molting Pacific Steller's Eider surveys in southwest Alaska 2016. Unpublished Report. Prepared by A.R. Williams, T.D. Bowman, and B.S. Shults. Office of Migratory Bird Management, Anchorage, Alaska. 14pp.

[USFWS] U.S. Fish and Wildlife Service. 2017a. 2017 Yukon-Kuskokwim Delta coastal zone survey of geese, swans, and sandhill cranes. Memorandum to Pacific Flyway Council. Prepared by M.A. Swaim and H.M. Wilson, Office of Migratory Bird Management, Anchorage Alaska.

[USFWS] U.S. Fish and Wildlife Service. 2017b. Informal Consultation with U.S. Army Corps of Engineers 2017-I-0343. Prepared by the Anchorage Fish and Wildlife Conservation Office. Nov. 2, 2017. 6pp.

[USFWS] U.S. Fish and Wildlife Service. 2018a. Breeding ecology of Steller's and spectacled eiders nesting near Utqiagvik, Alaska, 2016-2017. Unpublished Report. Prepared by N. Graff. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 53 pp.

[USFWS] U.S. Fish and Wildlife Service. 2018b. Intra-service biological opinion for hunting regulations for the 2018 Spring/Summer Harvest. Consultation with the U.S. Fish and Wildlife Service – Office of Migratory Bird Management, Anchorage, Alaska. Prepared by Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 63 pp.

[USFWS] U.S. Fish and Wildlife Service. 2018c. Intra-service biological opinion for migratory game bird hunting regulations, 2016 - 2019. Consultation with the Division of Migratory Bird Management, Washington, D.C. 124 pp.

[USFWS] U.S. Fish and Wildlife Service. 2018d. Estimating detection probability in the Steller's eider Barrow Triangle aerial survey using a double-observer sightability model. Unpublished report. Prepared by C. Bradley. Fairbanks Ecological Services Office, Fairbanks, Alaska. 32 pp.

[USFWS] U.S. Fish and Wildlife Service. 2019a. Fall Izembek brant aerial survey, Alaska, 2018. Unpublished report. Prepared by H. M. Wilson. Office of Migratory Bird Management, Anchorage, Alaska. 17 pp.

[USFWS] U.S. Fish and Wildlife Service. 2019b. Status assessment of the Alaska-breeding population of Steller's eiders. Fairbanks Fish and Wildlife Service, Fairbanks, Alaska. 149 pp.

[USFWS] U.S. Fish and Wildlife Service. 2020a. Alaska winter brant survey 2020. Unpublished report. Prepared by H. M. Wilson and W. W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. 22 pp.

[USFWS] U.S. Fish and Wildlife Service. 2020b. Kuskokwim Shoals Steller's eider molt survey 2020. Unpublished report. Prepared by B. Daniels. Yukon Delta National Wildlife Refuge, Bethel, Alaska. 5 pp.

[USFWS] U.S. Fish and Wildlife Service. 2021a. Alaska winter brant survey 2021. Unpublished report. Prepared by H. M. Wilson and W. W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. 19 pp.

[USFWS] U.S. Fish and Wildlife Service. 2021b. Revised Recovery Plan for the Alaska-breeding Population of Steller's Eider (*Polysticta stelleri*). Northern Alaska Fish and Wildlife Field Office, Fairbanks, Alaska. Revised December 2021. 23 pp.

[USFWS] U.S. Fish and Wildlife Service. 2021c. Breeding ecology of Steller's and spectacled eiders nesting near Utqiagvik, Alaska, 2018-2019. Unpublished Report. Prepared by N. Graff. Fairbanks Fish and Wildlife Field Office, Fairbanks, Alaska. 52 pp.

[USFWS] U.S. Fish and Wildlife Service. 2022. Kuskokwim Shoals Steller's eider molt survey 2021. Unpublished report. Prepared by B. Daniels and P. J. Larson. Yukon Delta National Wildlife Refuge, Bethel, Alaska. 6 pp.

[USFWS] U.S. Fish and Wildlife Service. 2023a. Waterfowl Breeding Population Habitat Survey Alaska Abundance Estimate data. Data Release, by M. Swaim, D. Groves, J.B. Fischer. Alaska Region, Migratory Bird Management. <https://www.sciencebase.gov/catalog/item/editForm/65f49490d34ebfb8e1678dc2>.

[USFWS] U.S. Fish and Wildlife Service. 2023b. Alaska Arctic Coastal Plain Breeding Waterbird Aerial Survey, 2007-Present. Data Release, by M. Swaim, H. Wilson, J.B. Fischer. Alaska Region, Migratory Birds Management. <https://doi.org/10.7944/f6jd-2985>

[USFWS] U.S. Fish and Wildlife Service. 2023c. Alaska Yukon-Kuskokwim Delta Nest Plot Survey, 1985-2019. Project. Contacts: J.B. Fischer, E.E. Osnas, R.A. Stehn, T.B. Bowman. Migratory Bird Management, Alaska Region. <https://doi.org/10.7944/P9FFYJXD>

[USFWS] U.S. Fish and Wildlife Service. 2024a. Alaska winter brant survey 2022. Unpublished report. Prepared by H. M. Wilson and W. W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. 20 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024b. Alaska winter brant survey 2023. Unpublished report. Prepared by H. M. Wilson and W. W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. 21 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024c. Alaska winter brant survey 2024. Unpublished report. Prepared by H. M. Wilson and W. W. Larned. Office of Migratory Bird Management, Anchorage, Alaska. 21 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024d. Breeding ecology of Steller's and spectacled eiders nesting near Utqiagvik, Alaska, 2022-2023. Unpublished report. Prepared by N. Graff. Fairbanks Fish and Wildlife Service, Fairbanks, Alaska. 43 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024e. Izembek National Wildlife Refuge Land Exchange/Road Corridor, Draft Supplemental Environmental Impact Statement: Executive Summary. November 2024. 48 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024f. Kuskokwim Shoals Steller's eider molt survey 2024. Unpublished report. Prepared by N.W. Ramsey, R.J. Friendly, B.L. Daniels. Yukon Delta National Wildlife Refuge, Bethel, Alaska. 8 pp.

[USFWS] U.S. Fish and Wildlife Service. 2024g. Steller's eider (*Polysticta stelleri*) population and density estimates from the Arctic Coastal Plain and Utqiagvik Triangle surveys using generalized additive models. Unpublished report. Prepared by E.E. Osnas. Division of Migratory Bird Management, Anchorage, Alaska. Version 0.1.0, <https://doi.org/10.7944/3vzp-0r93>.

[USFWS] U.S. Fish and Wildlife Service. 2024h. Alaska Yukon-Kuskokwim Delta Aerial Breeding Pair Survey, 1985-Present. Project. Contacts: M. Swaim, C.J. Frost. Alaska Region, Migratory Bird Management. <https://doi.org/10.7944/jknp-jh20>.

[USFWS] U.S. Fish and Wildlife Service. 2024i. Alaska Yukon-Kuskokwim Delta Nesting Waterfowl Distance Sampling Survey 2022. Project. Contacts: E.E. Osnas, J.B. Fischer. Alaska Region, Migratory Bird Management. <https://doi.org/10.7944/avtd-j831>.

[USFWS] U.S. Department of Agriculture. 2016. Fox control on the Barrow Steller's eider conservation planning area. Unpublished Report for USFWS Fairbanks Fish and Wildlife Field Office. Prepared by L. Barto, M.W. Pratt, and D. Sinnett. Animal and Plant Health Inspection Service, Wildlife Services. Palmer, Alaska. 18pp.

[USGS] U.S. Geological Survey. 2016. A marine mystery: What's causing seabird die-offs in Alaska? Press release, released online December 8, 2016. Accessed February 8, 2019. <https://www.usgs.gov/news/a-marine-mystery-what-s-causing-seabird-die-offs-alaska>

[USGS] U.S. Geological Survey. 2024. Avak Creek oil occurrence, Alaska. Unpublished Report. Prepared by P. Botterell, D. Houseknecht, and M. Moldowan. Alaska Petroleum Systems Project. 22 pp.

VanHemert, C. J.M. Pearce, and C.M. Handel. 2014. Wildlife health in a rapidly changing North: focus on avian disease. *Frontiers in Ecology and Environment* 12: 548-556.

- Villareal, S., R.D. Hollister, D.R. Johnson, M.J. Lara, P.J. Webber and C.E. Tweedie. 2012. Tundra vegetation change near Barrow, Alaska (1972-2010). *Environmental Research Letters* 7:1-10.
- Visser, M.E., A.J. vanNoordwijk, J.M. Tinbergen, and C.M. Lessells. 1998. Warmer springs lead to mistimed reproduction in great tits (*Parus major*). *Proceedings of the Royal Society of London B* 265:1867-1870.
- Wilson, H. M., M.R. Petersen, D. Troy. 2004. Concentrations of metals and trace elements in blood of spectacled and king eiders in northern Alaska, USA. *Environmental Toxicology and Chemistry* 23:408-414.
- Wilson, H. M., P.L. Flint, C.L. Moran, and A.N. Powell. 2007. Survival of breeding Pacific common eiders on the Yukon-Kuskokwim Delta, Alaska. *The Journal of Wildlife Management* 71:403-410.
- Wilson, H.M., J.S. Hall, P.L. Flint, J.C. Franson, C.R. Ely, J.A. Schmutz, M.D. Samuel. 2013. High seroprevalence of antibodies to avian influenza viruses among wild waterfowl in Alaska: Implications for surveillance. *PLoS ONE* 8:e58308.
- Wolf, S., B. Hartl, C. Carroll, M.C. Neel, and D.N. Greenwald. 2015. Beyond PVA: Why recovery under the Endangered Species Act is more than population viability. *Bioscience* 65:200-207.
- Zydelis, R. 2000. Habitat choice of Steller's eider *Polysticta stelleri* wintering at Lithuanian coast of the Baltic Sea. *Acta Ornithologica* 35:129-131.

Appendix A. Methods and results for estimating Alaska-breeding Steller's eider numbers across the Arctic Coastal Plain, including the Utqiagvik Triangle area. From: USFWS 2024, entire.

The report (enclosed) for the SSA version 2.0 can be found at:

USFWS. 2024. Steller's eider (*Polysticta stelleri*) population and density estimates from the Arctic Coastal Plain and Utqiagvik Triangle surveys using generalized additive models. Unpublished report. Prepared by E.E. Osnas. Division of Migratory Bird Management, Anchorage, Alaska. Version 0.1.0, <https://doi.org/10.7944/3vzp-0r93>.

Steller's eider (*Polysticta stelleri*) population and density estimates from the Arctic Coastal Plain and Utqiagvik Triangle surveys using generalized additive models

Erik E. Osnas
Division of Migratory Bird Management
US Fish and Wildlife Service
Anchorage, AK
erik_osnas@fws.gov

December 17, 2024

Abstract

Annual populations and spatial density estimates are needed for the threatened Alaska-breeding population of Steller's eiders (*Polysticta stelleri*) to assess recovery status and guide recovery actions but these quantities are poorly estimated in this rare species using traditional methods. Therefore, population size and spatial variation in density were estimated across the Arctic Coastal Plain (ACP) and Utqiagvik Triangle (Triangle) survey areas using spatio-temporal generalized additive models and compared to traditional design-based estimates. Compared to design-based estimates, model-based estimates were more precise and less variable between years. Moreover, data sets can be combined to produce common estimates, detection probability can be incorporated to estimate population size, and spatial density maps can be produced at a small scale. Across both data sets and when combined, Steller's eider populations fluctuated with an approximate 6.52-year period (95% CI: 6.23, 6.76) with populations cycling from modelled posterior lows of 25 to 500 individuals and highs from 230 to >2000 individuals across the ACP. Over the long term, the posterior 25-year geometric mean growth rate was -0.02 (CI: -0.07, 0.02), and shorter term growth rates were less well estimated and fluctuating between positive and near zero. Mean population size over the last 20 years was 405 (CI: 208, 750) across the whole ACP and 214 (CI: 111, 402) in the Triangle area. Density maps showed a high density concentration in the northern part of the Triangle area and lower densities southward and across the ACP. Models fit to just the Triangle area, indicated that eider density has been shifting northward though time, but this pattern was not supported in the much sparser ACP data set, nor was it well estimated when the ACP and Triangle data sets were combined. Given the strong cycle in this population, population size estimates at similar cycle phases should be used for trend estimates.

Keywords: Steller's eider, *Polysticta stelleri*, Species Status Assessment, Arctic Coastal Plain, population trend, density map, threatened species

Introduction

The Pacific population of Steller's eider (*Polysticta stelleri*) is a rare sea duck that nests in northeastern Russia and Alaska, with the Alaska breeding population currently listed as Threatened under the Endangered Species Act. As such, frequent status assessments are needed to determine correct listing status and to guide recovery actions. Unfortunately, the rarity and low density of this eider make inferences of population size, trend, and distribution especially difficult. The effort described here is an attempt to make the most of the available data using modern model-based methods to distinguish sampling variation from the underlying signal of population differences between years and locations.

The approach here is inspired by Miller et al. (2013) and Amundson et al. (2019), where generalized additive models (Wood 2017) are used to estimate temporal and spatial variation in eider density. This approach to estimating population trend also borrows from the work of Sauer and Link (2002), Rosenberg et al. (2019), and Smith and Edwards (2021) among others, although the focus here is only one species. In general, the advantage of model-based estimates are that they help to separate noise (i.e., sampling variation) from the true underlying signal (i.e., temporal or spatial patterns in density, Gelman et al. (2014), Hooten and Hobbs (2015), many others) and is closely related to the concept of shrinkage or smoothing of random effects (Efron and Morris 1977; Gelman et al. 2014). This contrasts with pure design-based estimates, which make minimal assumptions, but suffer from high variability in this rare species. Specifically, sampling variation alone might lead to observations of zero eiders even when eiders did exist in the surveyed area. While correcting for the detection process is possible for design-based estimates, in the case of zero observations, no correction can be made, and these years will tend to underrepresent the true animal density. Sampling variation also inflates the year-to-year variance in estimates and will tend to make population trend estimates less precise and potentially more extreme, especially when multiple species are compared or statistical significance tests are used to detect trends (Sauer and Link 2002). In contrast, model-based estimates require the specification of a probability model for observations and help distinguish sampling from non-sampling variation. In the spatial and temporal context, where correlation is generally high and positive between nearby measurements, models that exploit this feature are especially helpful, and nearly all modern methods to detect trends in time and space use such models (see citations above, and Kéry and Royle 2015, 2020).

Below, I apply spatio-temporal models to provide the best available estimates of Steller's eider density and annual population size on the ACP. I first describe the data (Survey areas and data source). I then describe the calculations of design-based estimates (Design-based estimates). This is the first report of design-based estimates for the Triangle data that includes an estimate of uncertainty. These provide a reference point against model-based estimates. Importantly, the usual ratio estimator (Thompson 2012) is found to give very poor estimates with the Triangle data. I use an estimator modified from line transect surveys instead (Fewster et al. 2009; Buckland et al. 2001). I then describe the data formatting and a variety of spatio-temporal generalized additive models fit to the data (Model-based estimates). I then describe posterior simulations using fitted model estimates to calculate total population size and trend (Prediction and posterior simulation) and the detection estimate used during posterior simulations (Incorporating

detection). Finally, I conduct a wavelet analysis of the posterior mean population size across years to estimate and statistically test for a recurring periodic cycle in the eider population. This is of practical significance because it has been hypothesized that these eiders follow lemming cycles, and if there is a strong cycle, trend estimates will depend on the relative positions in the cycle that are used for endpoints. Thus, if the population is cycling, consistent relative positions in the cycle should be used. Throughout the results I try to provide some interpretation and provide comparisons to past work (Results and Interpretation). I end with a general discussion and provide some recommendations (Discussion and Recommendations).

Methods

Survey areas and data source

Data used in this report came from the Arctic Coastal Plain Survey (hereafter, ACP) and a survey conducted by ABR, Inc. (ABR) near Utqiagvik, Alaska (hereafter, the Triangle survey, Figure 1). The ACP survey has been described in Amundson et al. (2019), but here data from 2007 to 2019 and 2022 to 2024 are used. The timing of the survey differed before 2007, which causes a difference in observed response (the subject of the effort in Amundson et al. 2019). In addition, data collected before 2007 have not undergone the same level of quality control and have not been made available on a server with public access. The ACP data from 2007 to 2024 used in this report, a description of quality control processes, and a description of data manipulations are available at Osnas (2024a, 2024b).

The Triangle survey is described in unpublished reports from ABR (Obritschkewitsch and Bankert 2024). Data for the Triangle survey are not publicly available at this time, but were obtained from ABR. A lengthy quality control process was applied to make data available for use in this report (documented in the file wrangle_ABR.R, available at <https://github.com/USFWS/STEI-estimates>). Source data for this analysis is maintained by and available from the author.

Important differences between the surveys include the much higher sampling coverage of the Triangle survey (25- 50%) compared to the ACP survey (approximately 1 - 8%), the much larger area of the ACP survey, and the sampling effort is stratified in the ACP survey (Figure 1). Flying status of birds, females, and off-transect birds are also recorded on the Triangle survey, but these are not generally recorded during the ACP survey (lone females and off-transect observations were removed for all analyses). In addition, the ACP survey records all waterbird species, but the Triangle survey records a smaller subset (king and spectacled eiders in addition to Steller's, other species in some years). Standard protocol records single males, male-female pairs, and "flocked drakes" in groups less than five. Females not in association to males are not typically recorded. On the Triangle survey, however, lone females are recorded. Otherwise, the two surveys follow standard aerial waterfowl survey protocols (USFWS and CWS 1987). No flocked Steller's eiders were observed on either survey, and females outside of male-female pairs were dropped from the Triangle data for all analyses. There was one case of an 'open 1' Steller's eider in the ACP data set (a general category for

a group of unknown sex or pair status that is not appropriate for an observation of a single), and it was assumed to be a single male.

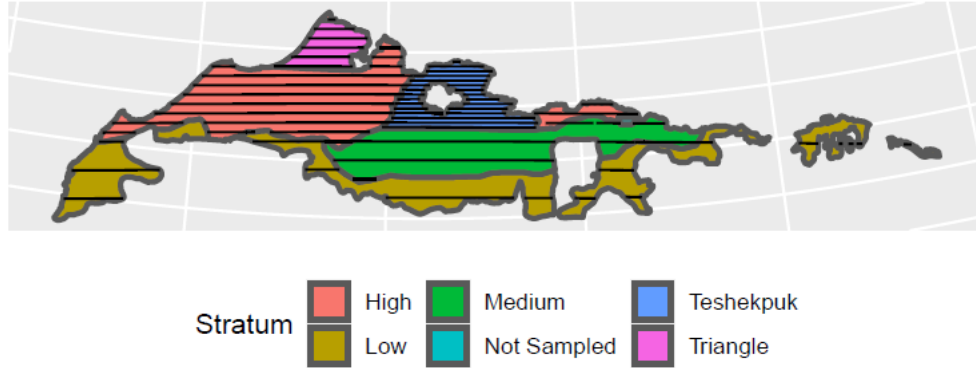


Figure 1: Arctic Coastal Plain (ACP) and Triangle survey areas. East-West transect lines are shown in black for one year on the ACP. Strata with different sampling intensity for the ACP are shown in thicker black lines and different fill colors. The Triangle area is shown as a stratum, but it is completely contained within the ACP stratum ‘High’. Transects in the Triangle area are very close (800m in most years) so would appear as a solid color at this scale. On the ACP, transects are rotated north-south over a four year period to increase spatial coverage (not shown).

Design-based estimates

I calculated a design-based estimate using formula “R3” of Fewster et al. (2009) and Buckland et al. (2001), modified for strip transects. A ratio estimator, which is more common for strip-transect surveys (Frost 2020), was investigated but found to be poor due to the distribution of observations and the triangle shape of the survey area, where most observations are on short transects in the north and longer transects in the south rarely have observed animals. This nullifies any advantage of a ratio estimator, which can produce a better estimate when the transect length and number of encounters are positively related (Cochran 1977; Thompson 2012). The point estimate was calculated as

$$\hat{N} = A \frac{\sum_i n_i}{\sum_i a_i}$$

and the variance of \hat{N} was calculated as

$$var(\hat{N}) = \left(\frac{A}{a}\right)^2 \frac{a}{k-1} \sum_i a_i \left(\frac{n_i}{a_i} - \frac{n}{a}\right)^2$$

where A is the total area of the study area, a_i is the area of strip transect i , n_i is the number of encountered single males or pairs on strip transect i , and n is the total encounters on the k surveyed strips, and a is the total area of the k surveyed strips. It is arguable if a finite population correction, $(1 - a/A)$, is appropriate, so I left it out as it is not used by Fewster et al. (2009) or Buckland et al. (2001) because observations on transects are not repeatable due to movement of birds and the detection

process. Fewster et al. (2009) showed that the above overestimates the variance of systematic surveys when there is a strong gradient in density, as there is in this area. Instead, they suggested a different estimator for systematic surveys (“O2” of Fewster et al. 2009), which I have not implemented at this time. In any case, the estimator above is much better than a standard ratio estimator in this specific case.

Model-based estimates

I used generalized additive models (GAMs, Wood 2017) to estimate eider density as a function of location and time. A GAM can be thought of as a generalized linear mixed model that fits smooth functions (splines) of covariates to predict the response, in addition to standard linear mixed model terms if specified. The optimal degree of smoothing is determined during model fitting through a model selection-like process. GAMs are widely used in animal density surface modeling (e.g., Miller et al. (2013), Amundson et al. (2019), and many others).

To set up the data for model fitting, I divided sampled transects into 1 or 6 km segments and assigned observations of eiders (including observation of zero eiders) to segment centroids. Segments on the boundary of the study area were often smaller due to boundary issues. I then assumed a half-strip width of 200 m and calculated an area for each segment. Total number of eider observations (pairs and males) were summed for each segment and the coordinates (in isomorphic UTM's) of the centroid were used for spatial location. Year was used as the covariate for temporal effects. The same procedure was used for both the entire ACP and for the Triangle survey, but for the ACP-only model (see below) the segment size for model fitting was 6 km. This was done for computational reasons (time) related to fitting many different models. When Triangle and ACP data were combined into one model, a common 1 km segment size was used. All spatial data manipulation was done using the R package *sf* (Pebesma 2018).

I fit a variety of models to explore spatial and temporal effects. The linear predictor for each model was:

$$\begin{aligned}
 M0 &: \text{Count} \sim s(X, Y) \\
 M1 &: \text{Count} \sim s(X, Y) + s(\text{Year}) \\
 M2 &: \text{Count} \sim s(X, Y) + s(\text{Year}) + ti(X, Y, \text{Year}) \\
 M3 &: \text{Count} \sim s(X, Y) + s(\text{Year}) + s_{re}(f\text{Year}) \\
 M4 &: \text{Count} \sim s(X, Y) + s_{re}(f\text{Year})
 \end{aligned}$$

In the above, *Count* is the total number of pairs or males observed in a transect segment, *s()* indicates a smooth function, *ti()* indicates a “tensor product smooth” (a multidimensional smooth that allows the units for dimensions to differ), and *s_{re}*() is a random effect in the usual mixed model sense (in *mgcv*: *s*(..., *bs* = 're')). *Year* is calendar year as a continuous numeric variable, and *fYear* is calendar year as a factor variable. Model *M0* is just a smooth of location that does not change through time. Model *M1* is a smooth of location and a separate smooth of year. This model means that on the log scale the spatial smooth does not change its relative shape through time but the overall height changes as a smooth function of year.

Model *M2* is a smooth of location, year, and a spatiotemporal interaction between location and year. Model *M2* allows the shape of the spatial pattern to change through time and allows the time trend to depend on location. Model *M3* estimates a smooth of location, a smooth of year, and a separate random effect of year, which allows abrupt non-smooth deviations from an underlying smooth trend (see Smith and Edwards 2021). Model *M4* estimates a smooth of location and treats year as a simple random effect. The model with year as a random effect still imposes smoothing on the year effect, just as in the usual mixed model, where year effects are pulled or “shrunk” toward an overall grand mean. In the models above, each effect is written as an “average” or “partial” effect relative to the others and all contain an intercept (not shown). Thus, $s(X, Y) + s(Year)$ is an average effect of location and an average effect of Year as a deviation from an overall intercept. All models used a negative binomial response, a log link function, and the log segment area as an offset, which controlled for varying areas of segments near study area boundaries. Thus, the model is estimating the expected response in 1 km^2 of area. The scale parameter of the negative binomial was estimated during model fitting. Other response models were fit (Poisson, Tweedie) and all were found to be substantially worse fitting than the negative binomial. All model fitting and prediction was done using the R package *mgcv* (Wood 2021). Model diagnostics were inspected using the residual simulation methods in R package *DHARMA* (Hartig 2022) and visualizations using the R package *gratia* (Simpson 2023). Special attention was given to quantile-quantile plots and over-dispersion and zero-inflation metrics. Residual simulations suggested that the negative binomial distribution appropriately modeled the large number of response zeros in these data. To select the best model, the *mgcv::AIC* function was used.

During posterior simulation (see below), it was found that the model gave widely unrealistic total population posterior predictions when applied to the ACP survey area. Further investigation revealed that this was due to infrequent posterior samples that gave clusters of relatively high eider density far inland. The original spline basis used to model eider density was based on a 2D Duchon spline (Wood 2017) across space with a first derivative penalty ($s(X, Y, bs = "ds", m=c(1, 0.5))$ in the syntax of *mgcv* Wood (2021)). This spline has worked well for other species but does not work well when few or no non-zero observations are made far inland. Therefore, I used a 2D spatial spline based on a second derivative penalty, which is more common and the default in *mgcv* (a ‘thin plate regression spline’ or $s(..., bs = "tp")$ in *mgcv*, Wood 2021). Upon simulation, the density surface was more smooth and lacked extreme high-density clusters far inland. However, when converted to total population estimates, some posterior samples still gave unrealistically high values ($\gg 10000$ indicated pairs) when simulations were drawn directly from the parameter estimates and covariance matrix using a multivariate normal distribution. This is due to the multivariate normal simulations being a poor approximation to the posterior when there are large sections of space that only contain zero observations (see the help files for the *mgcv* function *gam.mh* (Wood 2021) or (Simpson 2024)). Therefore, the Metropolis-Hastings algorithm was used for posterior simulation. The total population posterior distribution was still skewed high as would be expected due to the log-normal response and detection correction, but did not give as extreme predictions. For all results presented here, I used thin plate regression splines for spatial smooths and Metropolis-Hastings sampling for posterior simulations on ACP models.

For modelling the ACP data alone, additional models were fit that contained a random effect for observer.

The response for these models was observer-specific; therefore, each segment was only 200 m wide (i.e., each side of the plane was a separate observation 200 m wide). An additional five models were fit where each model above also contained an observer effect, $s_{re}(Observer)$. Observer effects were not estimated for the Triangle data because they were not available at the time of this writing. When I combined the Triangle data with the ACP data, I used a fixed factor effect for survey (Triangle or ACP) to model any average difference between surveys and used a model with spatial and temporal smooths as in $M1$. A model with a spatio-temporal interaction ($M2$) was also explored for the combined Triangle and ACP data, but because the two data series do not overlap during the period of 1999-2006, the interaction term was not well estimated and produced widely variable population estimates during posterior simulations for the years 1999 to 2007 when these data sets did not overlap. Therefore, this model was not used. During posterior simulation (see below), the survey covariate was set to predict the Triangle survey because this is the area where detection was estimated.

The flying status of birds is not recorded during the ACP survey but is during the Triangle survey. Approximately 25% of the observations on the Triangle survey are flying birds. Both surveys follow the same protocol with respect to recording flying birds, however, there is some subjectivity to the protocol. When Triangle and ACP data sets were combined, I used both flying and non-flying birds from the Triangle data. For design-based methods, I calculated estimates for the Triangle using both flying and non-flying birds and only non-flying birds.

Prediction and posterior simulation

I used the `predict.gam` function from `mgcv` package (Wood 2021, 2017) to predict the expected density of eiders across the study area (Triangle or ACP) in each year, from 1999 to 2023 for the Triangle and from 2007 to 2024 for the ACP. Note that years with no data collection are included in these predictions. To do this, the study area was gridded into 1 km^2 or smaller cells—smaller when the cells intersect the boundary of the study area—and centroids and areas of each cell were calculated. A data set was then created by replicating these point locations and areas for each year. This large data set was then used in the `predict` function along with the model object from the best fitting GAM model. For spatial maps to represent relative differences in eider density, predictions were made on the response scale (`predict` option `type = "response"`) and the year effect was excluded (`exclude = "s(Year)"` or `exclude = c("s(Year)", "ti(X,Y,Year)")`). Predictions at cell centroids were used for the entire cell, that is, the continuous smooth density surface was rasterized into 1 km^2 or smaller cells for display in maps. Posterior simulation was used to calculate population totals over the study area for each year (see examples in help files for `mgcv::predict` or Wood 2017, 342–43). Predictions were made once on the same grid and years as described above but `type = lpmatrix` was specified so that a design matrix, X , was returned with one row for each prediction location-year and one column for each term in the model. Multivariate normal samples of the model parameters, b_i were then simulated using the fitted model parameter vector and variance-covariance matrix. For the Triangle study area, direct simulation from a multivariate normal distribution was used. For all simulations on the ACP study area, a Metropolis-Hastings algorithm was used to obtain samples because large areas of zero observations caused poor performance based on direct multivariate normal simulation using the

parameter estimates and covariance matrix (see `?mgcv::gam.mh` in Wood (2021) or Simpson (2024)). A posterior sample on the response scale was then calculated as

$$y_i = \mathbf{a} \exp(\mathbf{X} \mathbf{b}_i)$$

where \mathbf{a} is a vector of the area of each grid cell and y_i is a vector of the expected responses. Note that y_i is the expectation of the negative binomial distribution and not an actual realization; thus, it is > 0 for all predictions. The above simulation was repeated a large number of times (500), and results were stored.

Various derived quantities of the posterior samples can also be calculated. To find the expected population total in a given year, the sampled vector can be summed over all cells for a given year. Let i index the posterior sample, j index year, and k index the cell, then a posterior sample for the expected population total in year j is

$$\hat{Y}_{ij} = \sum_k y_{ijk}$$

Because the model was fit to pairs and single males, the above gives the total “indicated pairs”. To transform this to birds and “indicated birds”, the above posterior sample would be multiplied by 2. A detection corrected population total for “indicated birds” can be found as

$$\hat{N}_{ij} = 2\hat{Y}_{ij}/d_{ij}$$

if detection varies only by year, where d_{ij} is a posterior sample of detection in year j . If detection varies with location or other covariates, then the adjustment needs to take place at a lower level of y_{ijk} .

The posterior trend on the log scale from year j to $j + t$ can be found as

$$T_{it} = \log \left[(\hat{N}_{ij+t}/\hat{N}_{ij})^{1/t} \right] = \frac{\log(\hat{N}_{ij+t}) - \log(\hat{N}_{ij})}{t}$$

Note that this measure of trend is identical to the slope parameter in a “log-linear” regression when the smooth of year in the GAM model, $s(\text{Year})$, gives a straight line. The advantage of the GAM is that the notion of trend can be generalized to non-linear cases where the trend may be increasing, decreasing, or changing cyclically through time. The posterior distribution for any quantity can then be displayed using a histogram or summarized with various metrics. I summarized the posterior with the mean and the 0.025, 0.5 (median), and 0.975 quantiles. For trend, I only used detection corrected posterior estimates (see below). All general data manipulation was done with program R (R Core Team 2023) and tidyverse packages (Wickham et al. 2019).

Incorporating detection

At the time of this writing, the decoy detection data from 2023 were not available for analysis, and staff time did not allow analysis of data from years 2017 to 2022. Therefore, I used a detection rate based on

available estimates from 2018 when the protocol was improved over the first year of the study (2017). The detection analysis was completed by Catherine Bradley (USFWS, retired) and showed that detection rate in 2018 depended only on distance from transect (Bradley 2018). Because distance was not available for observations outside the decoy detection study area (a sub-set of the Triangle area), I calculated the average ‘unconditional’ detection rate over the transect half-strip width (Table 3 from Bradley 2018). In the context of Bradley (2018), ‘unconditional’ is the detection rate estimated from double- observer sightability trials that include decoys not observed by either observer (a ‘00’ capture history). I also used this same detection rate for the ACP because no better estimate for Steller’s eider is available. The detection rate used here should be viewed as provisional until a more complete analysis can be conducted incorporating data from 2019 to 2023. As such, it is meant to be the average detection rate over all observations, including the covariates of distance, year, observer, sun angle, etc.

To calculate an average detection rate, I assumed that eiders (detected and undetected) were expected to be uniformly distributed with distance from the transect, which is true given the design of the Triangle and ACP surveys. I then averaged detection and the variance of the detection estimate over each of the four distance bins in Table 3 of Bradley (2018). Because distance bins were of equal width, detection was estimated as a factor of bin (i.e., a continuous distance function was not estimated), and no other covariates were found important, the mean and variance are a simple equally weighted average over the distance bins. In Table 3 of Bradley (2018) only the mean and ninety-five percent credible interval was given, so I approximated the standard error of the estimate in each bin by the range divided by $2*1.96$, which is the typical number of standard deviations in the range of a symmetric credible interval.

This worked out to a detection rate of 0.307 with a standard deviation of 0.092 (Figure 2). Note that this detection prior will result in a large amount of uncertainty in the estimated number of eiders. At detection rates of 0.16 and 0.47 (the fifth and ninety-fifth percentile of the distribution, respectively), the eider population estimate will be increased about 6- and 2-fold, respectively. Thus, increased information on detection would be valuable for improving our knowledge of the eider population size. Unfortunately, at the time of this writing, staff time was not available to produce improved estimates from the 2019-2023 data.

The posterior population estimate for “indicated breeding birds” (single males and pairs), accounting for constant detection, was then calculated as

$$\hat{N}_{ij} = 2\hat{Y}_{ij}/d_i$$

with d_i sampled from a Beta distribution with the mean and standard deviation above. If detection varies with year, location or other covariates, then the adjustment needs to take place at a lower level of Y and d , which would vary by year or other covariates.

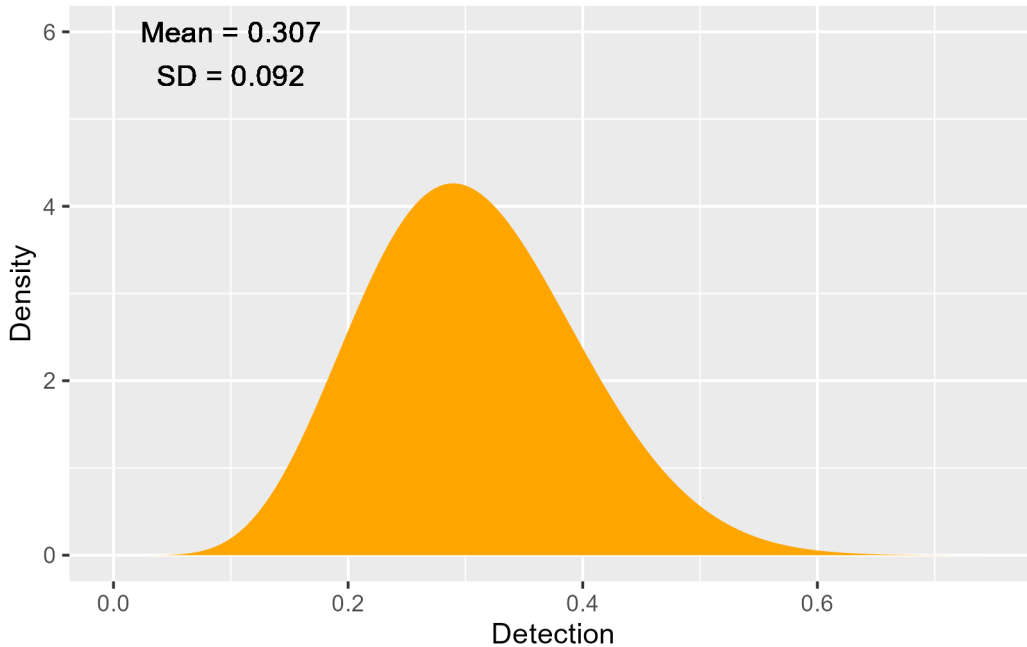


Figure 2: Steller’s eider detection probability prior used in simulations for population size calculations. This is the average ‘unconditional’ detection rate over distance estimated in 2018 from Table 3 of Bradley (2018).

In general, quantities \hat{Y} are designated as “indicated pairs” because single males are assumed to “indicate” an observed female on the nest (the male-female sex ratio is assumed equal). (Technically, within the tradition of waterfowl biology, “indicated pairs” include flocked drakes in groups of less than 5. However, none of these were observed in either data set; thus, “indicated breeding pairs” and “indicated pairs” are the same.) When “indicated pairs” are multiplied by 2, $2\hat{Y}$, then the quantity becomes “indicated birds” because each pair is 2 individuals. Hereafter, I use “indicated breeding birds”, and I use the word “index” to distinguish quantities that are not corrected for detection. Thus, $2\hat{Y}$ is the “indicated breeding bird index,” and $2\hat{Y}/d$ is simply “indicated breeding birds,” to reflect that it is a population estimate, at least conditional on the assumptions inherent with “indicated.”

Wavelet analysis

In order to formally estimate the period of a repeating cycle in the Steller’s eider population, I used wavelet analysis to detect and statistically test for the presence of a cycle. Wavelet analysis is too complex to fully explain here, but an accessible introduction can be found in the documentation to the R package WaveletComp (Roesch and Schmidbauer 2018). Briefly, a wavelet analysis is similar to a Fourier transform of a time series where the time domain is expressed in the frequency domain. Unlike a basic Fourier transform, however, a wavelet transform localizes the frequency information in time so that changes in the frequency of a signal can be examined. Thus, the main product of a wavelet analysis is a “power spectrum” (also known as a spectrogram) that is a three-dimensional surface showing the “power” (z-axis or a measure of the strength of a particular frequency or period) in a time series as a function of the wave period (y-axis)

and time (x-axis). High “power” ridges across time correspond to a large signal at that frequency (or period) in the time series. If the period is changing through time, the position of the ridge will change relative to the period axis as time increases. I used the function `analyze.wavelet` from the WaveletComp package (Roesch and Schmidbauer 2018) to calculate the wavelet properties of the posterior mean population estimate from the model that combined both Triangle and ACP data. I used the null hypothesis of white noise and 200 bootstrap simulations to test for statistical significant departure from white noise (a flat or uniform frequency spectrum). I then used the functions `wt.image` to visualize the power spectrum and `wt.avg` to visualize the average power spectrum across years. To find the full posterior of the dominant wave frequency, I calculated the wavelet properties of 500 posterior samples of the population time series and saved the wave period at the maximum average power across time for each sample. I then used the mean and 95% credible interval to summarize this posterior.

Results and Interpretation

Observations of Steller’s eider

Observed locations of Steller’s eiders across the study area are shown in Figure 3. Most observations are in the northern coastal area of the Triangle and Teshekpuk Lake area. No observations of Steller’s eiders have been made in the two southernmost ACP strata. Observations from the Triangle survey abruptly stop at the southern edge of the Triangle survey area, suggesting that eiders sometimes exist south of that area more often than observations from either survey suggest. Figure 5 shows the count of Steller’s eiders by year for both the Triangle and ACP surveys. For the Triangle survey, the count is separated for flying and non-flying birds. Note that about 25% of the total observations in the Triangle are of flying birds. The flight status is not recorded on the ACP survey, but all birds originate from or land on the transect strip. Figure 4 gives the count of Steller’s eiders by year and observation type for the ACP survey. The single observation of “open” was treated as a single male in all analyses. Note that there are no flocked drakes.

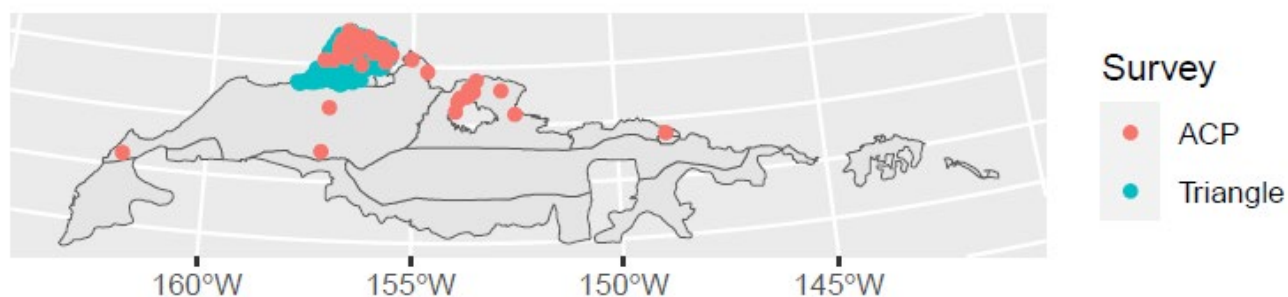


Figure 3: Observed Steller’s eiders during the ACP (2007-2024) and Triangle (1999-2023) surveys.

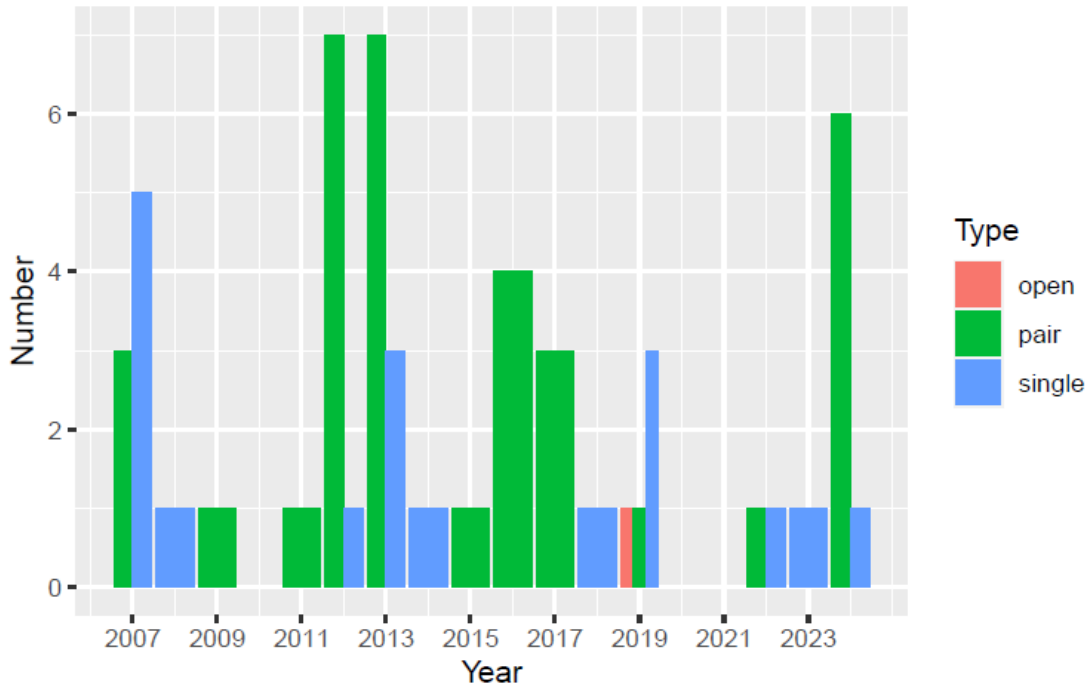


Figure 4: Observations of singles and pairs on the Arctic Coastal Plain (ACP) survey by year. The one 'open' observed in 2019 was treated as a single male.

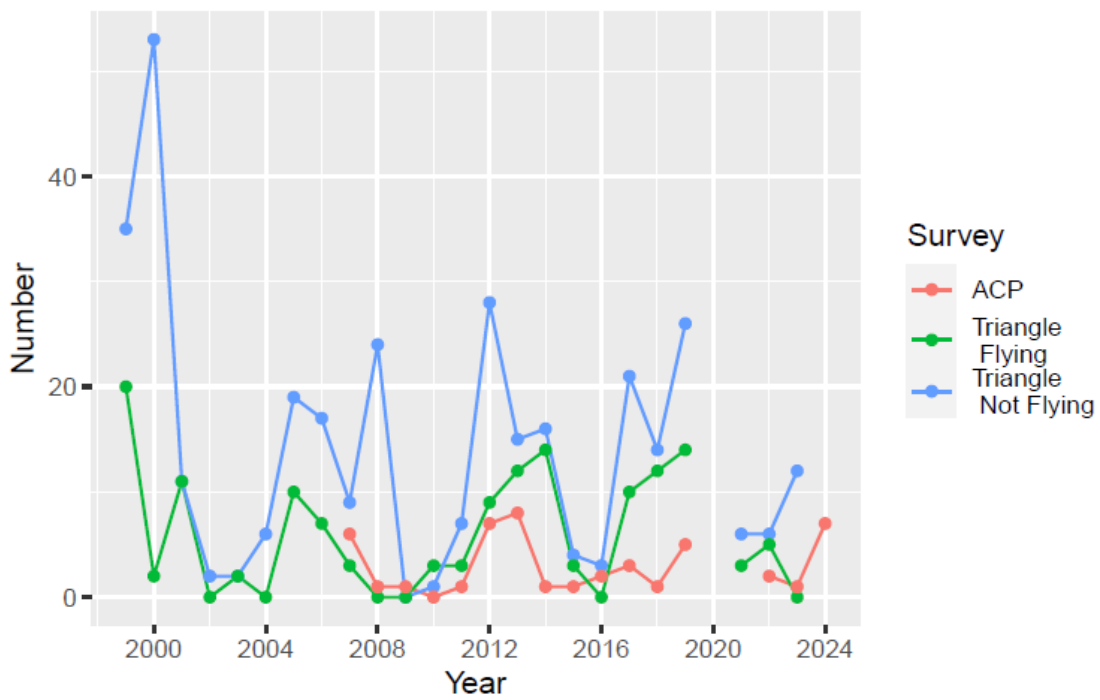
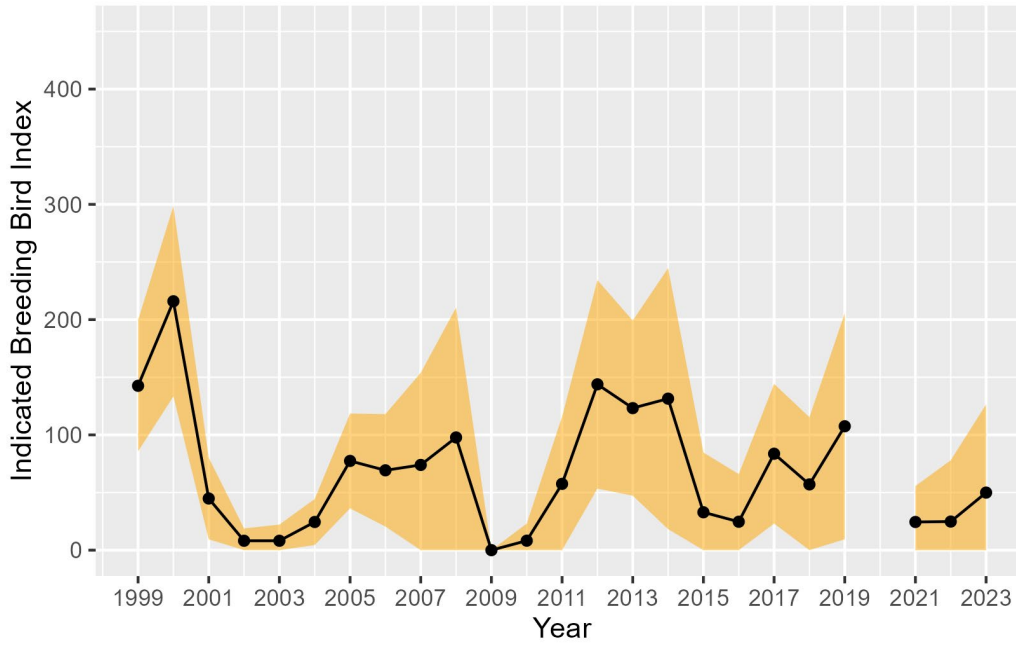


Figure 5: Number of Steller's eider observations by year for the ACP and Triangle surveys.

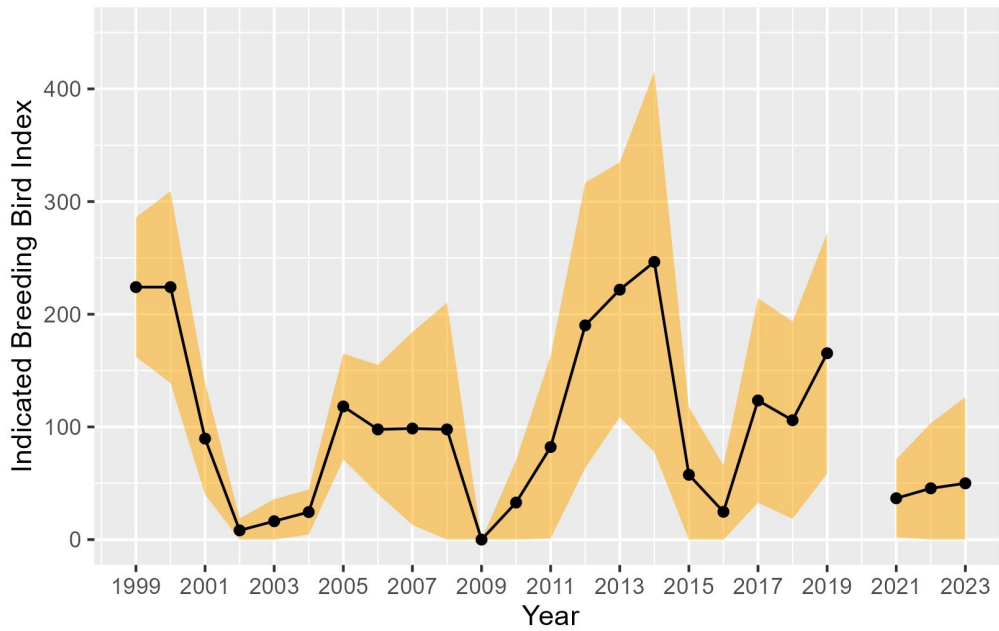
Design-based estimates

Design-based estimates for the Triangle survey area are shown in Figure 6 and for the ACP in Figure 7. No survey was conducted in 2020 for the Triangle survey or in 2020 and 2021 for the ACP. Estimates are presented for non-flying (a) and non-flying and flying combined (b) birds (Figure 6). Estimates for flying birds are higher because approximately 25% of the observed birds are flying. On the ACP (Figure 7) flying status is not recorded and only birds that originate from, are suspected to originate from, or land in the transect strip are recorded (USFWS and CWS 1987). As such, aerial density estimates can also be biased high due to flux, as much as a fast moving plane might allow (i.e., the faster the platform relative to the moving objects, the lower the bias). Variance of estimates is much larger for the ACP than for the Triangle survey.

Design-based estimates make minimal assumptions and provide an important check on model-based estimates. Two important assumptions behind design-based estimates are that (1) the survey design is unbiased (random or systematic selection of sampling units, here transects) and (2) the survey was implemented as designed. These assumptions are met in these surveys. An additional often unstated assumption is that the response is measured without error. In this case, measurement errors include a large detection bias and, presumably less often, species misidentification. Detection bias causes a lower mean response and increased variance in response. Finally, design-based estimates are based on estimating a mean response across all sampled transects, and then use statistical sampling theory to derive estimator variance. This works well for common species and large sample size (many transects), but for rare species that might not be encountered on any transects during a sample, the estimate and its variance are necessarily zero when there are no detection events, even when the species might have existed in the survey area. This might have been the case in 2009 on the Triangle area (Figure 6) and in 2010 for all strata of the ACP (Figure 7), and was the case in 2, 10, 16, and 16 years out of 16 for the High, Teshekpuk, Medium, and Low strata of the ACP, respectively.



(a) without flying birds



(b) with flying birds

Figure 6: Design-based estimates in the Triangle survey area without (a) and with (b) flying birds included. Confidence intervals (95%, orange band) have been truncated at zero. No detection correction was applied.

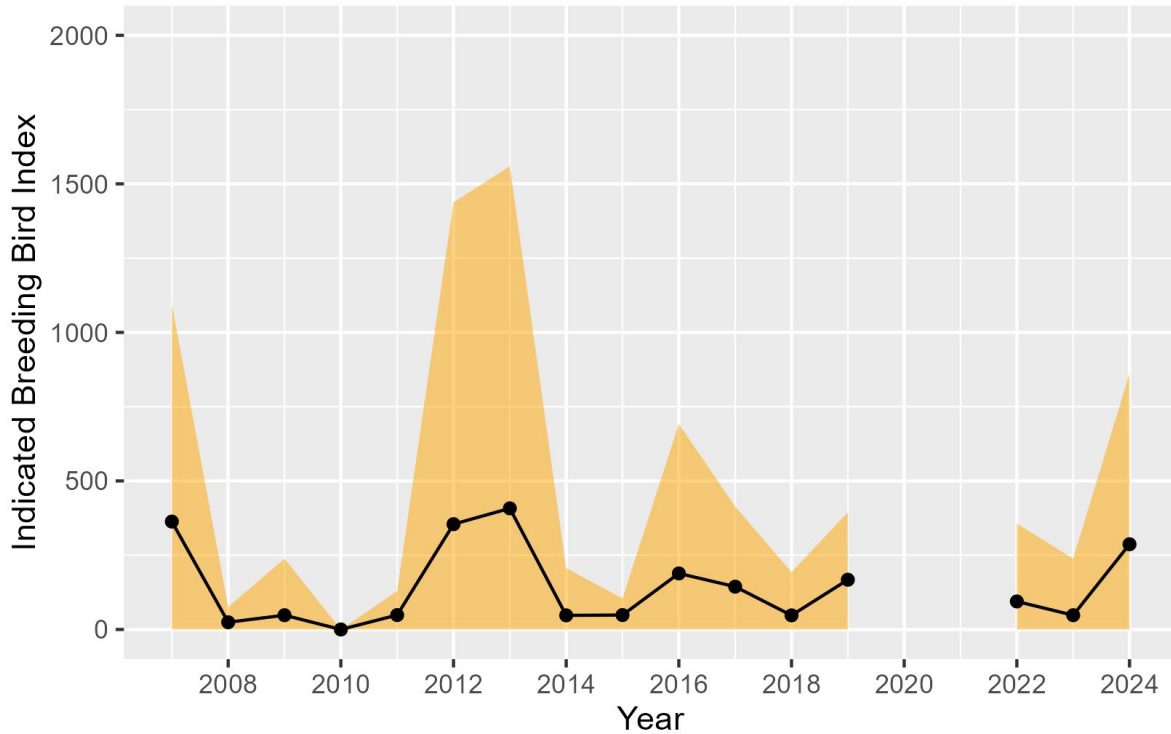


Figure 7: Design-based estimates in the Arctic Coastal Plain survey area. Confidence intervals (95%, orange band) have been truncated at zero. Flying status of birds is not recorded in this survey but all birds originate from or land on the strip transect. No detection correction was applied.

Table 1: AIC table for models fit to Triangle data. Model structures are described in the main text.

Model	Linear Predictor	df	AIC	DeltaAIC
M2	$s(X,Y) + s(\text{Year}) + \text{ti}(X,Y,\text{Year})$	35.48	2876.13	0.00
M1	$s(X,Y) + s(\text{Year})$	33.63	2881.94	5.81
M3	$s(X,Y) + s(\text{Year}) + s(\text{fYear})$	39.89	2884.29	8.15
M4	$s(X,Y) + s(\text{fYear})$	38.18	2888.06	11.92
M0	$s(X,Y)$	19.78	2979.11	102.98

Model-based Estimates: Triangle

Models fit to data from the Triangle showed that the best model contains a spatial smooth, a year smooth, and a spatio-temporal smooth (model M2, Table 1). The model with a separate space and time smooth (M1) and all other models were worse ($\Delta AIC > 5$). In exploratory model runs using a different spline smoother (see above, Methods: Model-based estimates), however, model M1 was slightly better but nearly identical to M2 in terms of AIC. For all results below, I used model M2.

The spatial, temporal, and spatio-temporal partial effects of model M2 are shown in Figure 8. Highest densities of Steller's eiders were in the northern section of the Triangle and the lowest densities were in the southeast, but as shown by the spatio-temporal smooth, density decreased through time in the southeast and increased in the northwest of the Triangle. Note that the spatio-temporal smooth has been shrunk to a simple 2D plane that is changing through time so that it is increasing in the northwest and decreasing in the southeast. The temporal pattern appears cyclic with a period of 5-7 years and no strong directional trend (Figure 8b).

Spatial density of Steller's eider across the Triangle after removing the effects of year and the space-by-year interaction (i.e., the average or partial effect of location) is shown in Figure 9. Relatively high densities have occurred in the north and moderate densities in the east and far southwest. With the spatio-temporal effect, however, these areas of higher densities in the south have decreased.

Population estimates across the Triangle survey area by year for indicated breeding birds without (a) and with (b) a detection correction is shown in Figure 10. The population appears to cycle on a period of 5-7 years. With the application of the detection estimate shown in Figure 2, there is a substantial increase in the population estimates, the uncertainty, and in the skew of the posterior toward higher population estimates. This is due to the low mean detection rate and high uncertainty in the detection prior. Note that the model predicts the population in 2020 when no survey was conducted.

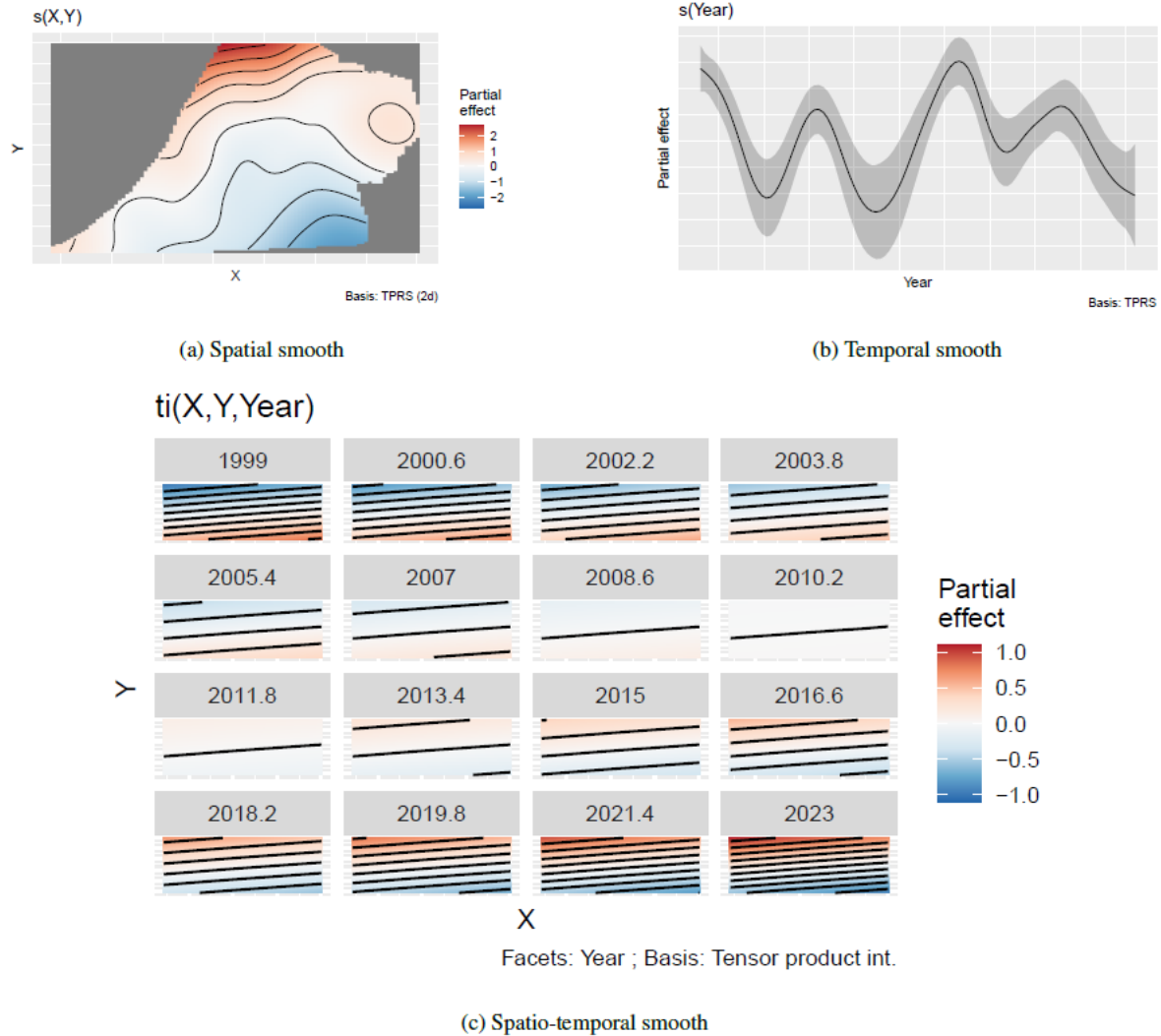


Figure 8: Plots of spatial (a), temporal (b), and spatio-temporal interaction (c) partial effects from the best fitting model. In (b) the shaded region is 2 standard errors. In (a) and (c) black lines show contour lines of equal partial effect, and color shows increased (red) or decreased (blue) density relative to the intercept. In (c) the interaction is shown by 16 density surfaces at different time points from 1999 to 2023. Each panel is as in (a) but has been simplified to the bounding rectangle of the survey area. Note that as time progresses, the upper left of each panel increases in density as indicated by the shift from blue to red.

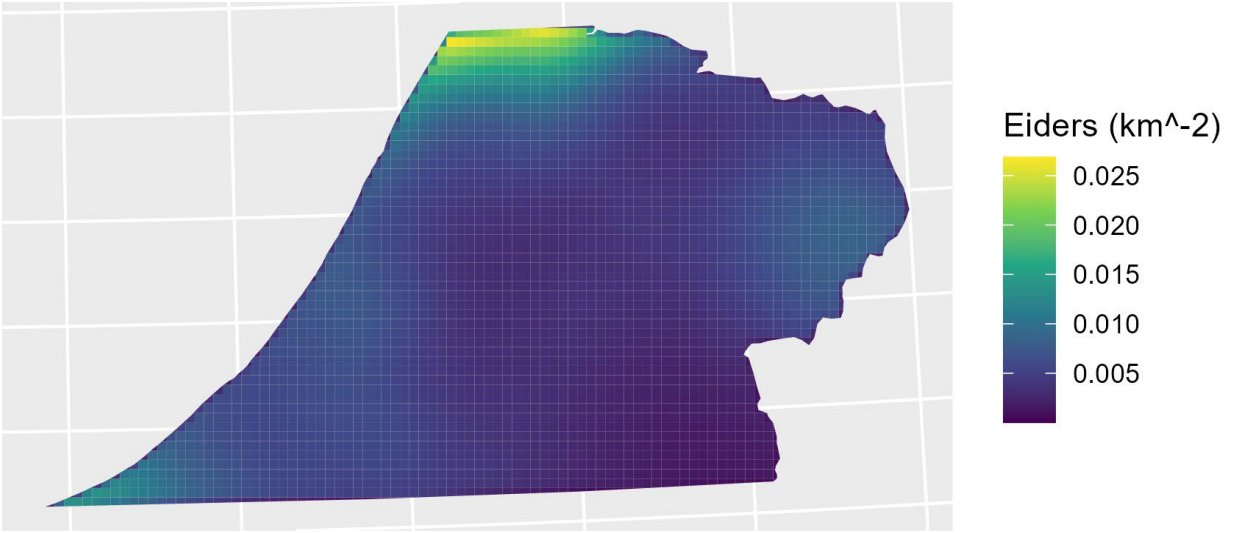
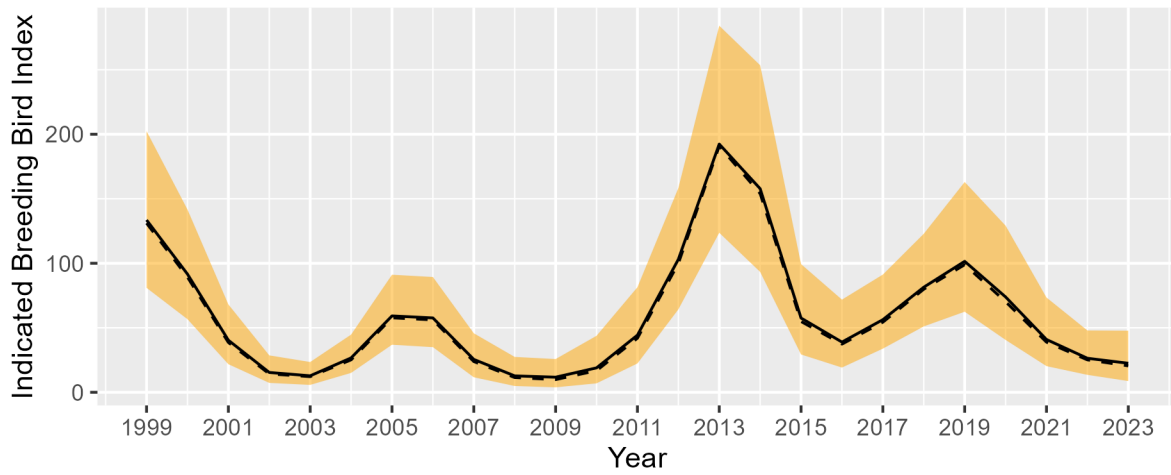
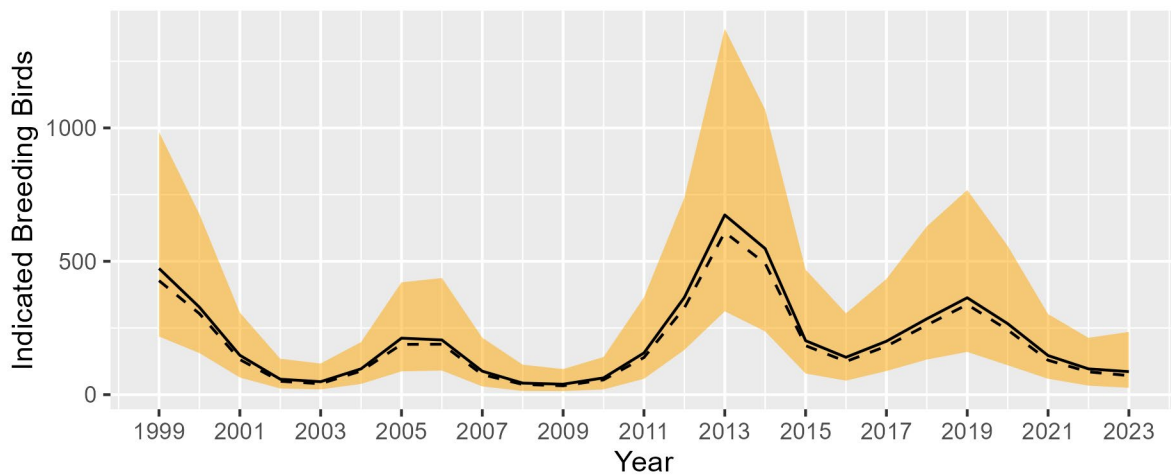


Figure 9: Predicted average density of Steller's eider after removing the effect of year and space-by-year interaction in the Triangle survey area.



(a)



(b)

Figure 10: Posterior estimates of Steller’s eider in the Triangle survey area without accounting for detection (a) and after applying a detection correction (b). These estimates include flying and non-flying birds. The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval.

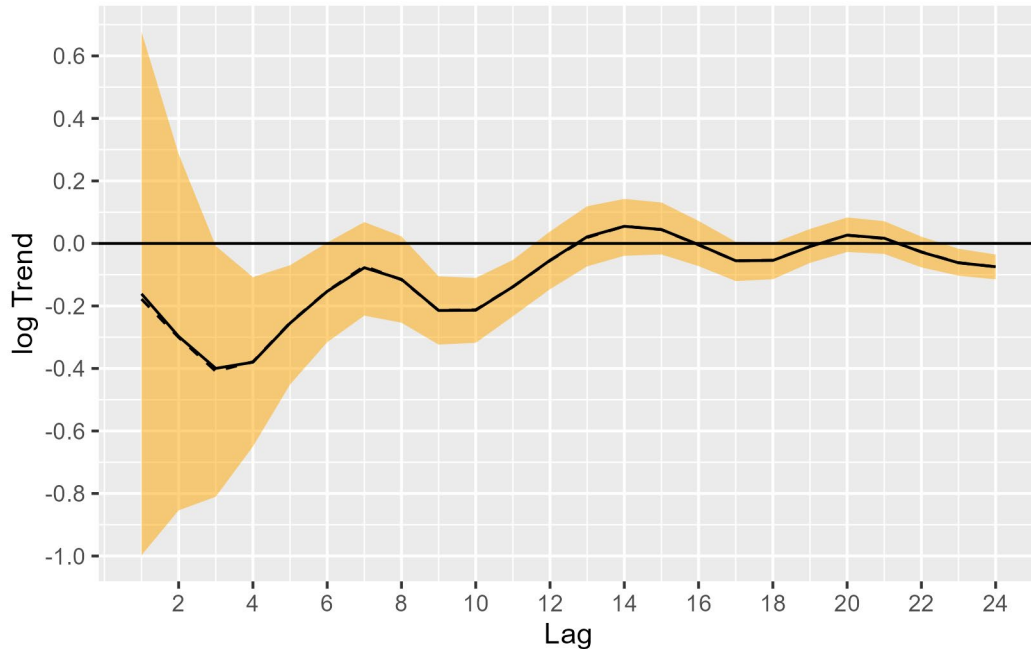


Figure 11: Posterior trend estimates for Steller’s eider in the Triangle survey area, 1999-2023. The y axis is the log of the geometric mean growth rate, and the x axis is the lag-year trend, i.e., for lag 10 gives the 10-year trend from 2013 to 2023. The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval. The horizontal thick black line is the y-axis origin.

Model-based Estimates: ACP

Models fit to the ACP data showed that a model with a random effect of year, rather than a smooth of year, fit best (Table 2). In addition, models with a random observer effect contributed nothing to improvement in AIC (Table 2). Upon examining model summary statistics, models with a smooth of year shrunk to a straight line and observer effect variance was essentially zero (results not shown). These results are likely due to the very few observations of Steller’s eider on the ACP survey. Spatial effects showed a simple decline in eider density as distance from the coast increase (Figure 12a), and temporal effects that varied greatly on the log scale (Figure 12b).

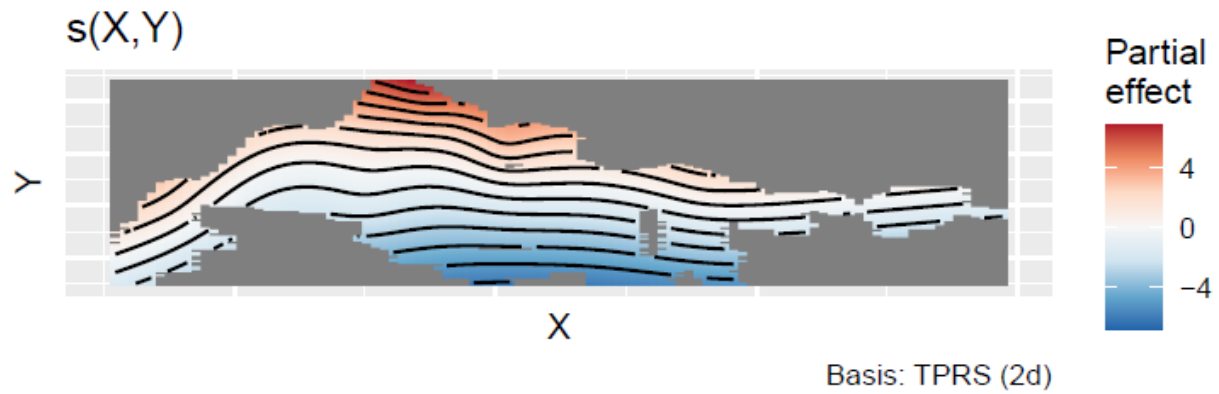
Posterior simulations of the year-specific total across the whole ACP are shown in Figure 13 without a detection correction (a) and with a detection correction (b). The population appears to fluctuate in a similar manner as in the model fit to Triangle survey data, but the year-specific estimates for the ACP are much less precise. Because the best model contained only a simple random effect and the survey was not completed in 2020 and 2021, predictions were not made for these years using this model. Such predictions could be made by simulating random effects for these years, but this would simply give an estimate that spans the range of historical estimates.

Note that year-specific estimates of the total number of eiders across the ACP based on the model (Figure 13a) are less extreme than those based on design-based estimates (Figure 7). That is, the model-based estimates are lower in high abundance years and higher in low abundance years compared to the design-based estimates. This is due to the ‘shrinkage’ or regularization of the year random effect. In general, design-based estimates might over-estimate the eider population when one or more eiders happen to be observed on a transect in one year and under-estimate when one or more eiders are not observed on a transect, even though they are in the study area.

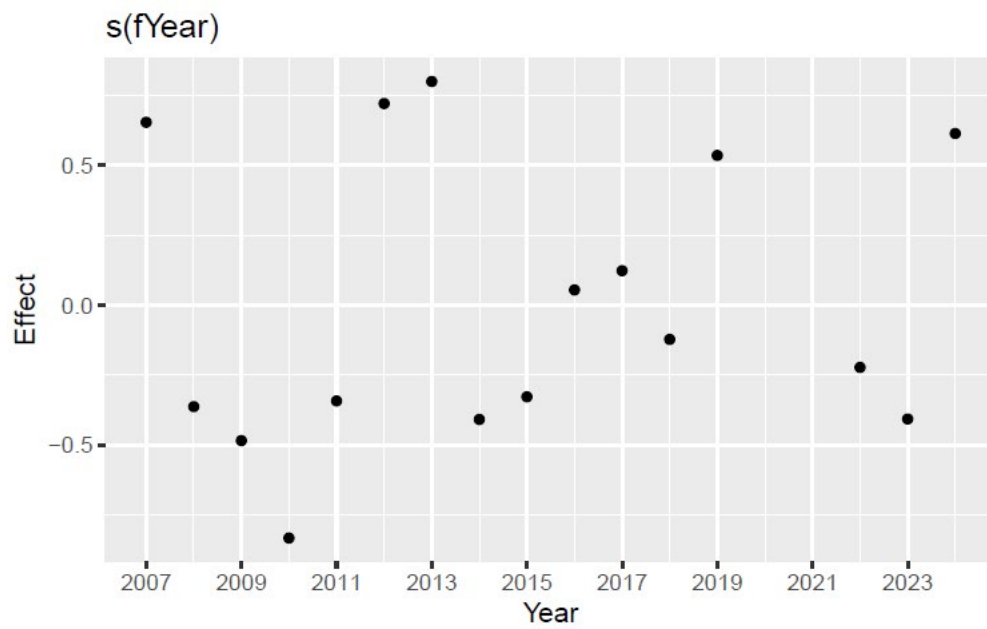
Trends for the Steller’s eider population across the ACP are shown in Figure 14. For all time ranges (lags), the trend was not well estimated. For example, the 10-year trend posterior mean was 0.11 (CI: -0.03, 0.23), which could be a modest decrease to a very fast increase (cf., Figure 13b). For all time periods, the 95% credible interval overlaps 0 and the upper bound was often > 0.15 (Figure 14).

Table 2: AIC table for model fit to ACP data. Model structures are described in the main text. The suffix ‘.obs’ indicates a model that contained a random effect of observer.

Model	Linear Predictor	df	AIC	DeltaAIC
M4	$s(X,Y) + s(fYear)$	23.65	531.58	0.00
M4.obs	$s(X,Y) + s(fYear) + s(Observer)$	23.65	531.58	0.00
M3	$s(X,Y) + s(Year) + s(fYear)$	24.51	531.83	0.25
M3.obs	$s(X,Y) + s(Year) + s(fYear) + s(Observer)$	24.53	531.86	0.28
M0	$s(X,Y)$	14.54	537.44	5.86
M0.obs	$s(X,Y) + s(Observer)$	14.54	537.44	5.86
M1	$s(X,Y) + s(Year)$	15.60	539.22	7.64
M1.obs	$s(X,Y) + s(Year) + s(Observer)$	15.60	539.22	7.64
M2	$s(X,Y) + s(Year) + ti(X,Y,Year)$	14.07	540.47	8.89
M2.obs	$s(X,Y) + s(Year) + ti(X,Y,Year) + s(Observer)$	14.07	540.47	8.89

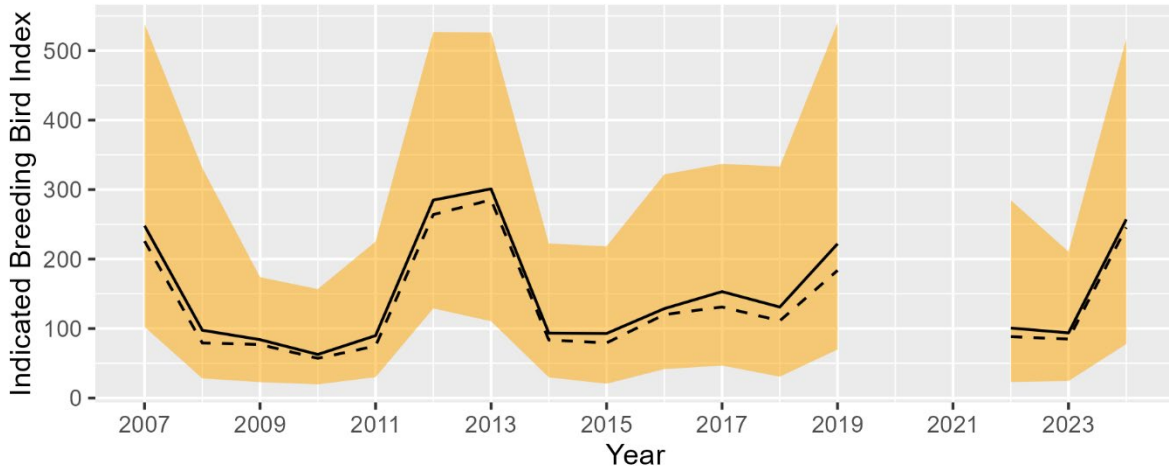


(a) Spatial smooth

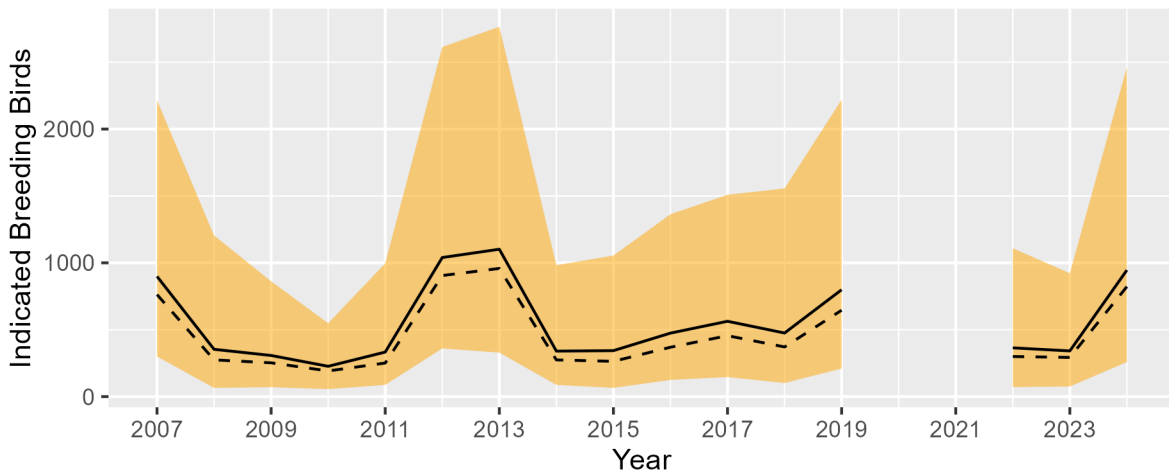


(b) Temporal effects

Figure 12: Partial effect of (a) spatial smooth and (b) year random effects for the ACP model M3. The map of density (a) shows decreasing density further to the south or away from the coast.



(a)



(b)

Figure 13: Posterior estimates of Steller's eider across the ACP survey area without accounting for detection (a) and after applying a detection correction (b). The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval.

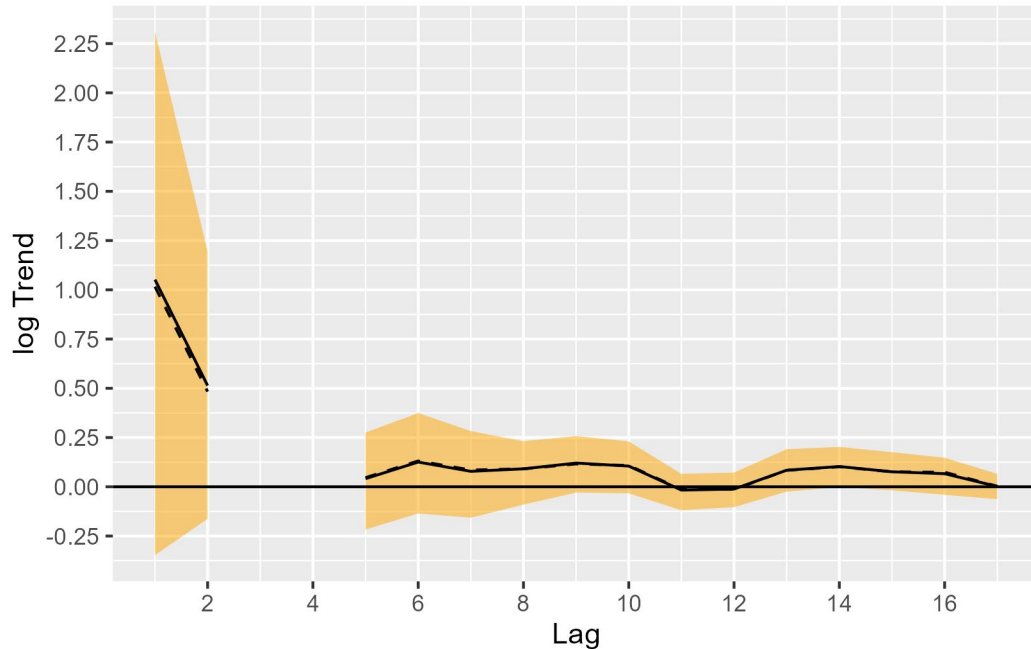


Figure 14: Posterior trend estimates for Steller’s eider in the ACP survey area, 2007-2024. The y axis is the log of the geometric mean growth rate, and the x axis is the lag-year trend, i.e., for lag 10 gives the 10-year trend from 2014 to 2024. The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval. The horizontal thick black line is the y-axis origin.

Model-based Estimates: Triangle and ACP combined

As described above (Methods: ACP and Triangle Combined), the model that included a spatio-temporal smooth produced widely high population predictions in 1999. Upon exploration, this was believed to be due to the interaction term, and that the two data sets do not overlap during this time period. Therefore, this model was not used. Instead, the model with separate spatial and temporal smooths was used. Partial effects of this model are shown in Figure 15. Similar to the ACP only model, eider density decreased from north to south and with distance from the coast (Figure 15a). Similar to other models, the temporal trend fluctuated with a 5-7 year period (Figure 15b). The survey effect was estimated at 0.46 (SE = 0.23) on the log scale. Because the Triangle survey was defined as the baseline (intercept), this means that the ACP crew observed almost sixty percent higher density on average as compared to the Triangle crew after controlling for year and spatial location. Spatial predictions on the response scale are shown for the Triangle area in Figure 15c.

Posterior distributions for the year-specific population predictions over the entire ACP area are shown in Figure 16a without a detection correction and in Figure 16b after the detection correction is applied. Note that the predictions are made through 1999-2006 and 2021 when ACP survey data do not exist and

for 2020 when no data exist. This is possible because of the space-time structure of the model. For 2020, predictions are due to the temporal correlation (smooth) and interpolating from nearby years when data exist. In 1999-2006 and 2021, the existing Triangle data is used to inform the temporal response, and then the temporally constant spatial effect informs the prediction across space.

Population trend posterior estimates show a strong increase over the most recent years and fluctuating trends as the time period increases (Figure 17). The posterior estimate for the 10-year trend is -0.03 (-0.15, 0.06), and for the entire series the 25-year trend is -0.02 (-0.07, 0.02).

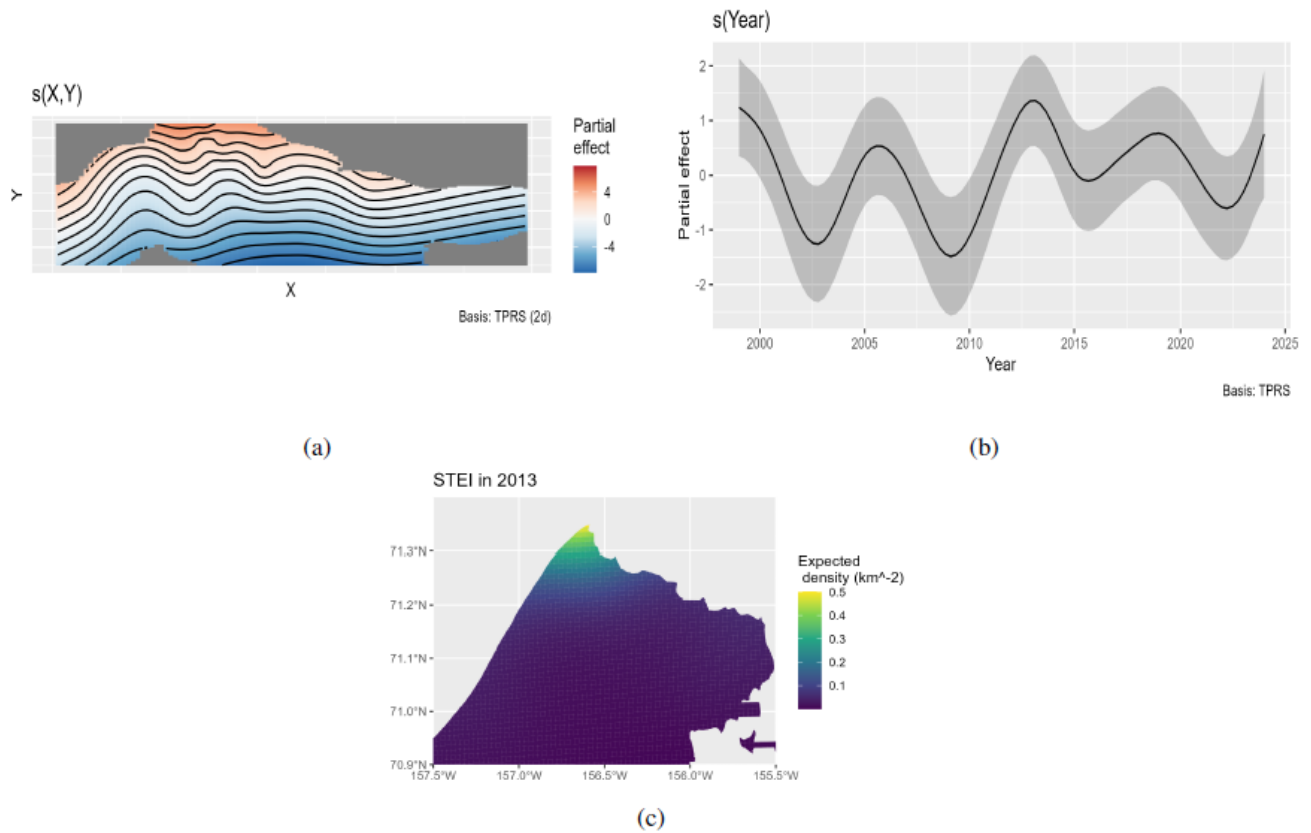
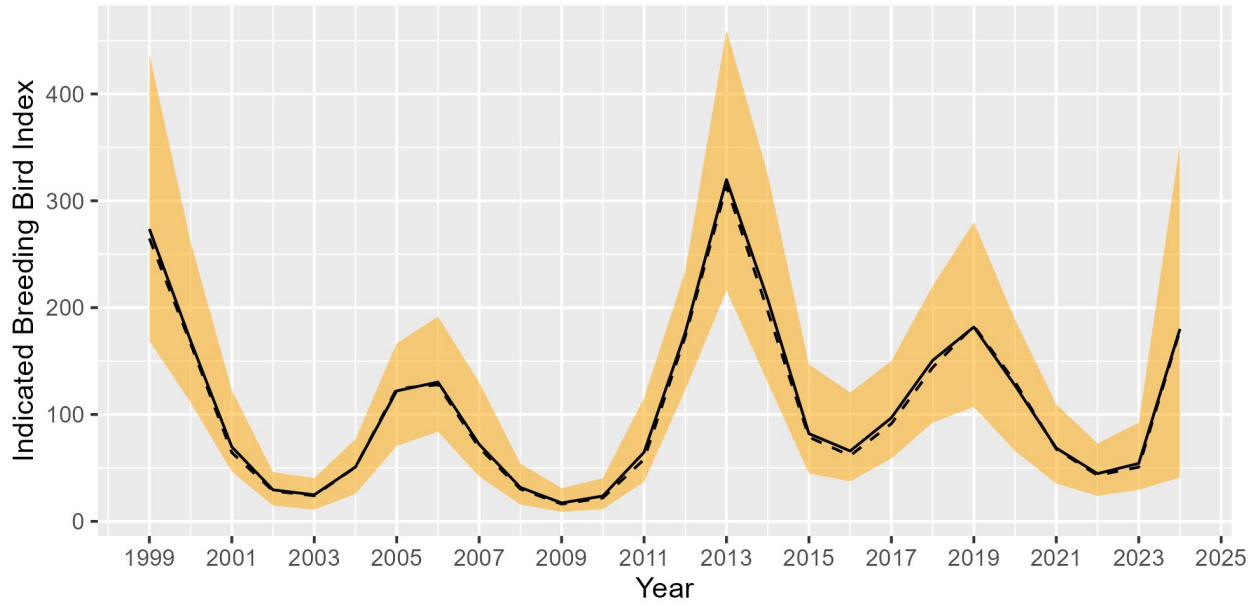
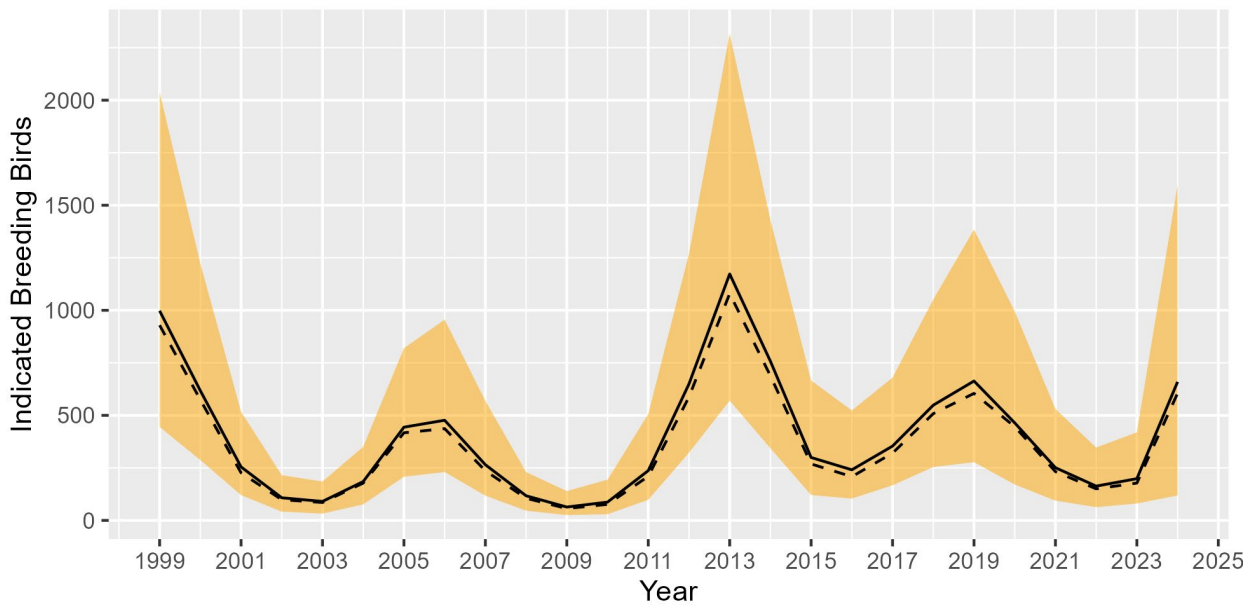


Figure 15: Partial effect plots for the spatial (a) and temporal (b) smooth from a GAM model fit to the Triangle and ACP data combined. There is no interaction in this model. Spatial prediction of eider density in 2013 zoomed in to the Triangle area (c). Shown in (c) is the indicated breeding bird index (no detection correction). Because there is no space-time interaction, relative densities are the same across years. Similarly, the detection correction does not vary across years or other covariates, and the relative surface does not change with or without a detection correction.



(a)



(b)

Figure 16: Posterior estimates of Steller’s eider in the ACP survey area with both ACP and Triangle data combined for model fitting. Posteriors are given without accounting for detection (a) and after applying a detection correction (b). The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval.

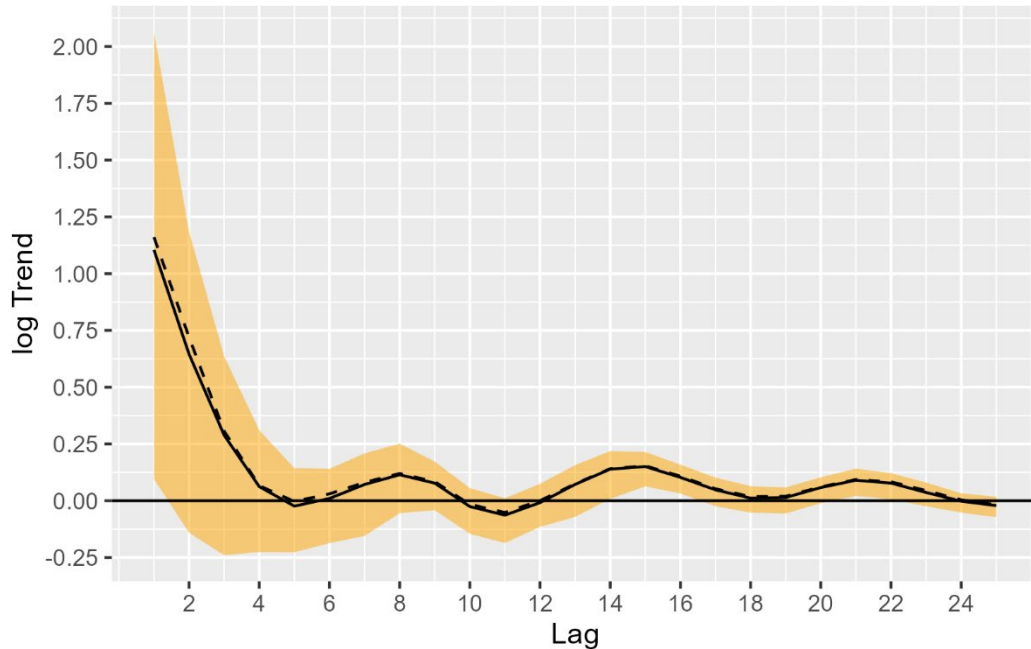


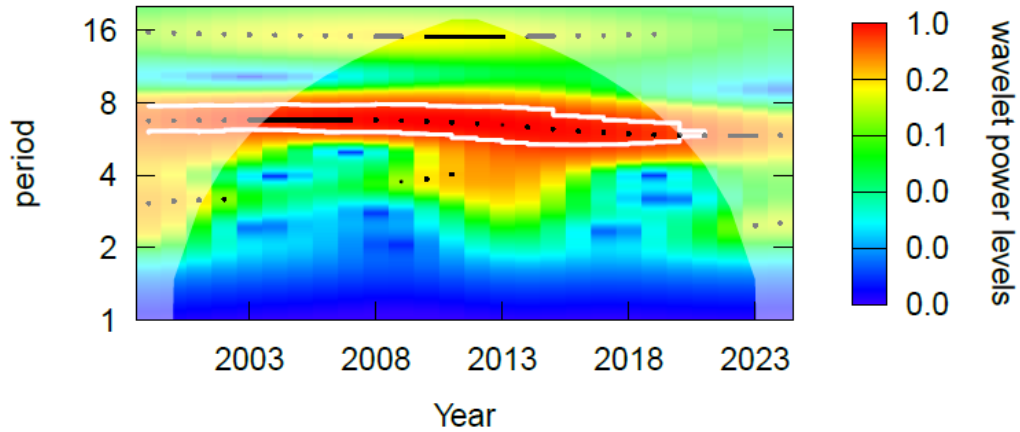
Figure 17: Posterior trend estimates for Steller’s eider in the ACP survey area using data from both the Triangle and ACP surveys, 1999-2024. The y axis is the log of the geometric mean growth rate, and the x axis is the lag-year trend, i.e., for lag 10 gives the 10-year trend from 2014 to 2024. The black line is the posterior mean, the dashed black line is the posterior median, and the orange band is the 95% credible interval. The horizontal thick black line is the y-axis origin.

Wavelet analysis

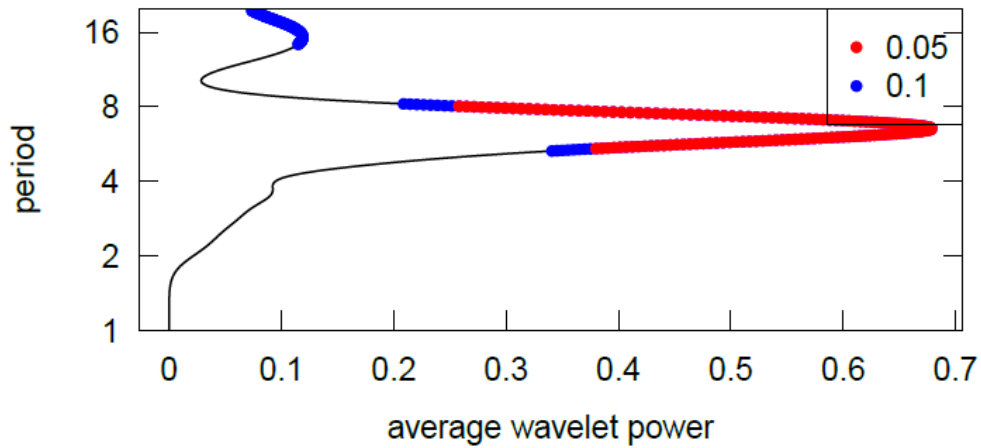
The Steller’s eider population is clearly fluctuating between short periods of increase and decrease with a period of approximately 5-7 years (Figure 16). In order to quantify and test for a period in the eider time series, I used a wavelet analysis to extract the wave period power spectrum and test for statistical significance using R package WaveletComp (Roesch and Schmidbauer 2018). A wavelet power spectrum (Figure 18a) is a 3-dimensional surface that shows the probability distribution or “power” (z-axis or surface color) of wave period (y-axis) by time (x-axis).

High “power” ridges across time correspond to the red area in Figure 18a. If the period is changing through time, the ridge will change position relative to the period axis as time increases. The power spectrum calculated at the posterior mean of the time series revealed a clear band across years that appears stationary with a period around 6 years (Figure 18a). When the power is averaged across all years, the average power gave a maximum power at period 6.53 (95% CI: 5.49, 7.72, Figure 18b). When the maximum power was found for 500 samples of the posterior, a similar mean was found (6.52) but the credible interval was narrower (CI: 6.23, 6.76). Because this second credible interval is based on a large sample of the full posterior distribution rather than just the posterior mean, it is a better representation of the true average period across the time series. Such periodic cycles will cause any estimate of trend to depend on the phase of the time points used for the calculation. Thus, when

calculating trend, it might be useful to control for period so that start and end points reference the same relative position of the cycle. That is, when using the results presented here for trend, use only integer multiples of the period (e.g., 6.5, 13.0, 19.6, and so on) so that similar phases of the cycle are compared. For example, a 19-year trend calculated from 2003 to 2022 gives a posterior mean of 0.03 (CI: -0.01, 0.09).



(a) Power spectrum



(b) Average wavelength

Figure 18: Wavelet power spectrum (a) for Steller's eider across the ACP based on the posterior mean of the total population. White lines give a 95% confidence interval for the period. Larger power levels (red) correspond to greater probability density of the wave period. The 'cone of influence' is shown by the slightly blurred area where boundary effects on estimating wave period are large. Average power spectrum across years (b) with statistical significance level shown in colors.

Results summary

Posterior mean population size over the last 20 and 25 years for Triangle survey only, (excluding 2020), 18 years for ACP survey only (excluding 2020 and 2021), and 20 years for the combined Triangle and ACP survey data are shown in Table 3. Note that 19 years is almost 3 whole phases of the cycle.

Table 3: Posterior distributions for the 25 year (Triangle), 20 year (Triangle and Combined surveys), or 18 year (ACP) mean population size of Steller’s eider. Outside refers to a population estimate from the combined survey but excluding the Triangle survey area. Statistics are the mean, standard deviation (SD), median, lower 2.5 percentile (Lower), and upper 97.5 percentile (Upper) of the posterior 20- or 18-year mean population size. All results incorporate the detection prior.

Survey	Time	Mean	Median	SD	Lower	Upper
Triangle	1999 - 2023 ^a	213.2	-	-	110.2	403.1
	2004 - 2023	213.77	199.24	75.94	111.15	402.34
ACP	2007 - 2024	556.71	496.00	239.19	267.50	1,217.36
Combined	2005 - 2024	405.61	383.32	154.78	207.67	750.02
Combined-Outside	2005 - 2024	151.65	120.81	196.73	59.19	340.67

^aThe long-term 25-yr mean for the Triangle Survey was not included in USFWS (2024g) report; long-term mean estimates and 95% CIs were shared by E. Osnas after requesting for this information

Discussion and Recommendations

Steller’s eider numbers were estimated using generalized additive models and traditional design-based methods for two survey areas, and then using models after combining the two data sets. The Triangle data survey is a small subset of the ACP that contains most of the eiders and is sampled intensively; whereas the ACP is a much larger area that covers additional areas where Steller’s eiders have been observed, such as the area around Teshekpuk Lake, but is sampled at a lower intensity. Because of the rarity of Steller’s eiders in all areas but the most northern area of the Triangle, design-based estimates are imprecise, and the sampling process can cause increased variance and zero observations in some years. This is especially the case for the ACP survey where few or no Steller’s eiders exist in most sample strata.

Model-based estimates can ameliorate some of these issues by using an explicit probability model for the sampling process and sharing information across years and space to smooth or “regularize” estimates. With these advantages, however, come additional assumptions and complexities.

Which results should one use? This depends on the purpose. If one is simply interested in comparing survey results across years, then the design-based estimate can help interpret the role of random

sampling chance in estimates and make rough assessments of changes in the underlying populations by comparing estimates and confidence intervals across years. These calculations can also be useful for assessing design properties of the surveys, such as sampling effort and power. They are also very simple and should represent the minimum level of analysis for reporting of survey results. While detection corrections can be applied to design-based estimates, interpreting years of zero observations is problematic, as no detection correction can be made in these years without specifying a probability model. If one is interested in population size, populations trends, or variation in density across space, then some form of probability model that includes “regularization” of estimates should be used. While other models can be used, the GAMs presented here are easily applied, seem to describe the data well, and have all of the advantages discussed above. They are also commonly applied for trend estimation (e.g. Amundson et al. 2019; Rosenberg et al. 2019; Smith and Edwards 2021). Another advantage of the linear models used here (GAMs) is that interpretation and understanding is straightforward, where effects can be partitioned out into time, space, and space-by-time interaction effects (e.g., Figure 8, Figure 12, Figure 15a).

For inference in the Triangle area, results from the models fit to the Triangle-only data are best. This is for several reasons. First, sampling intensity is high and consistent across space. This affects the amount of smoothing that the GAM will select. Under sparse sampling, a smoother surface will result, all else being equal (i.e., the true wiggleness of the density surface). Compared to results in the Triangle area from the combined model, the smooth of the density surface will reflect the average properties across the whole ACP and this will result in over-smoothing the Triangle area. This can be seen by comparing Figure 9 to Figure 15c. In addition, the high sampling intensity across a relatively long time period has allowed the estimation of a simple space-time interaction effect in the Triangle area where density is increasing in the north and decreasing in the south through time (Figure 8c). The model also estimates the temporal effect well with much better precision than the design-based estimates (compare Figure 10a to Figure 6b).

For inference outside the Triangle or the ACP as a whole, then the model using the combined data sets is best. This is because design-based estimates using only the ACP data are extremely imprecise for the Steller's eider (Figure 7), and even model-based estimates, while better, are not precise (Figure 13) compared to results from the combined data. Thus, combining data sets allow the Triangle data to inform the temporal estimate, while the ACP data allows estimation of density outside the Triangle area. Comparing Figure 10 to Figure 13 or inspecting Table 3 shows that relatively few eiders are outside the Triangle area in most years, even though there are observations outside the Triangle in some years (Figure 3). Because the space-time interaction of the Triangle-only model shows a decreasing trend in the south (Figure 8c), there may be fewer eiders outside the Triangle in recent years than there were in earlier years. In any case, including the ACP survey data allows estimation of eider density in the Teshekpuk and other areas of the ACP. If the ACP data is not available, however, then survey effort in the Triangle area only is likely sufficient to monitor abundance and trends of the population, given the current distribution.

The model and approach used here is similar to that of Amundson et al. (2019), with two important simplifications. First, the time series for the ACP data was restricted to 2007 through 2024. This allows a

much simpler model because adjusting for survey timing differences pre-2007 is not necessary. Thus, the phenology covariates used in Amundson et al. (2019) are not included or necessary in the models used here. Second, restricted maximum likelihood (Wood 2011) as implemented in mgcv was used instead of direct Bayesian simulations (Markov chain Monte Carlo). This is much easier from a development and computational time perspective, making the current approach easy to apply without custom coding in Bayesian software. Instead, these models can be applied in R using more familiar linear model syntax, the model fitting algorithm is much faster than direct Bayesian simulations, and results are easier to assess. Another difference is that the current effort estimated observer effects, which were not in Amundson et al. (2019). While the observer effects contributed nothing for the Steller's eider (Table 2), they have for many abundant species of waterbirds in separate analyses. Therefore, observer effects are probably also important for the Steller's eider but simply cannot be justified based on parsimony inherent in AIC model selection criteria. The effect of "Survey" in the combined analysis is curious. This suggests a strong effect of observer if there are not large differences in protocol between the surveys. This effect deserves more investigation. In any case, for population estimates, predictions were made setting the survey parameter to the Triangle (the intercept) because this is the survey area for which detection was estimated. Because there are so few observations of Steller's eiders on the ACP survey, however, this effect may not be estimated well and deserves more investigation. One solution might be to sample the Triangle area with higher intensity during the ACP survey.

One interesting comparison to Amundson et al. (2019) is that they found very linear time trends for Steller's eider. This was also the case here when models included a spatio-temporal interaction and were fit to ACP-only data (model M2, Table 2, results not shown). This model, however, was not well-supported compared to simpler models (Table 2). When fit to data that combined ACP and Triangle data, the model with a spatio-temporal interaction was well-supported but was not used here because it gave widely unbelievable predictions from 1999 to 2006. I attributed this to the spatio-temporal mismatch in data sets during this period and a spatio-temporal mismatch in sampling intensity. This was not a problem in the data of Amundson et al. (2019), but they did not fit simpler models without a space-time interaction. Because the simpler model without a space-time interaction reported here produced reasonable predictions and all other data sets produced similar cyclic temporal patterns, I believe the simpler model with temporal and spatial effects is a more appropriate model when data sets are combined, and the results of Amundson et al. (2019) are simply due to a lack of power to detect anything other than linear smooths of year in their more complex model. In any case, a perfectly straight temporal trend is hard to believe and most likely represents a power issue or other modelling artifact of this more complex model when confronted with sparse or mis-matched data in time and space.

Previous modelling efforts for population and trend estimation reported in the Species Status Assessment of 2019 (U.S. Fish and Wildlife Service 2019) used a binomial-Poisson hierarchical or state-space ("N-mixture") model (Kéry and Royle 2020). In this model, the true unobserved population (the state) was modeled as a Poisson random variable with an AR1-type temporal autocorrelation structure for the Poisson rate parameter, and the observed data (response) was modeled as a binomial random variable with parameters p , the detection probability, and N , the size of the population in the sampled area (the state). These models were originally developed to estimate population size in the presence of

non-detection using only repeated counts of a sampled area. In the case of the Triangle area, a model was fit to the summed total number of eiders observed across all transects for each year because transect-specific counts were not available. Therefore, the sample size for each year was one with no measure of precision and no information in the data to separate true population processes from sampling processes. Thus, all the information to estimate growth rate and population size came from the Poisson assumption, the prior used in the binomial detection, and the linear trend of annual observations. Because there was only one observation each year, there was no way to assess this model for the Triangle area. In effect, there was no information in the data to separate the observation process from the state process, and the model served only to incorporate detection to estimate population size and (linear) trend, given these assumptions. The model used in 2019 for the ACP was similar but used transect specific observations and ignored spatial variation in density across transects. If it was evaluated in 2019, the model would have been found to under-represent the heterogeneity among transects in the Poisson rate. While both models seem to capture basic temporal patterns, the approach used here is an improvement because spatial and temporal effects were accounted for by the linear predictor and the negative binomial likelihood adequately described the variation in response. While the state-space models used in 2019 are appealing because there is a mechanistic separation of observation and biological process to estimate population size and linear trend, ignoring spatial heterogeneity has been shown to bias population size estimates but (shockingly) not the linear trend (Kéry and Royle 2020). In the negative binomial GAM model used here, spatial-temporal heterogeneity is directly estimated from the data, including non-linear trend, and residual variation in response is also directly estimated by the scale parameter of the negative binomial. Detection is then accounted for during posterior simulation outside of the estimation process. In this sense, the current approach is better than that used in 2019 to estimate population size and trend.

Steller's eider populations on the ACP, including the Triangle area, are clearly undergoing cyclical patterns of abundance with a period of about 6.5 years (Figure 10, Figure 16, Figure 18). While it has been hypothesized that this is due to lemming cycles (Quakenbush et al. 2004), this effort cannot determine the cause of the cycles. It is clear that cycles exist and that the population has been fluctuating around (apparently) stable cycles for at least 25 years. Thus, any measure of trend will show an increasing, decreasing, or stable estimate depending on the beginning and ending points for the trend calculation (Figure 11, Figure 17). Recovery criteria and species status assessment should incorporate this understanding into status determination. Future work might attempt to partition cyclical from directional trends in the time series to understand overall population dynamics, but the long-term geometric means reported here do average over almost four periods of these cycles (Figure 17). Attention should be given to the start and end points for trends so that similar points in the cycle are used (multiples of approximately 6.5). While each cycle is a stochastic realization that will not follow exactly the same period, care should be taken when interpreting estimates of trend. For example, a 10-year trend from 2013 to 2023 would show a large and significant decrease just due to different points in the cycle phase, whereas 2009 to 2019 would show a large increase. Instead, the population seems to be undergoing fairly stable cycles of constant period but perhaps varying amplitude. Note that the long-term growth rate from 2003 to 2022 (similar points in the cycle) would show a long-term stable or perhaps increasing population (0.03 [CI: -0.01, 0.09], Figure 16b).

The detection estimate used here (0.307, SD = 0.092) is substantially lower and more variable than used in the 2019 SSA (0.43, SD = 0.028, U.S. Fish and Wildlife Service 2019), which was based on estimates for long-tailed duck that did not account for detection by both observers ('sightability'). Analyses previous to the 2019 SSA (Bob Stehn, unpublished) used a point estimate of 0.3 (SD = 0) based on expert judgement, which is remarkably close to the mean estimate used here, but did not include any uncertainty. Therefore, the population estimates reported here will be higher and skewed toward larger values than past reports. To the extent that the detection distribution used here reflects true uncertainty of the detection rate, then these new estimates are more 'correct' than previous attempts. It is unfortunate that estimates from 2019 to 2023 are not available at the time of this writing, as increased precision of the detection estimate could greatly change the population estimate. Including these additional data might, however, reveal that other covariates are important for determining detection. If this is the case, precision of detection estimates might not be improved, especially if estimates are back-applied to years where covariate data was not collected. Until such estimates are available and population estimates are updated, the current estimates should be treated as the best available.

References

- Amundson, Courtney L, Paul L Flint, Robert A Stehn, Robert M Platte, Heather M Wilson, William W Larned, and Julian B Fischer. 2019. "Spatio-Temporal Population Change of Arctic-Breeding Waterbirds on the Arctic Coastal Plain of Alaska." *Avian Conservation & Ecology* 14 (1).
- Bradley, Catherine. 2018. "Estimating detection probability in the Steller's eider Barrow Triangle aerial survey using a double-observer sightability model."
- Buckland, Stephen T, David R Anderson, Kenneth Paul Burnham, Jeffrey Lee Laake, David Louis Borchers, Leonard Thomas, et al. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford (United Kingdom) Oxford Univ. Press.
- Cochran, W. G. 1977. *Sampling Techniques*. New York, New York: John Wiley; Sons.
- Efron, Bradley, and Carl Morris. 1977. "Stein's Paradox in Statistics." *Scientific American* 236 (5): 119–27.
- Fewster, Rachel M, Stephen T Buckland, Kenneth P Burnham, David L Borchers, Peter E Jupp, Jeffrey L Laake, and Len Thomas. 2009. "Estimating the Encounter Rate Variance in Distance Sampling." *Biometrics* 65 (1): 225–36.
- Frost, Charles. 2020. "AKaerial: Analysis of Alaska Region Aerial Survey Data." <https://github.com/USFWS/AKaerial>.
- Gelman, Andrew, John B Carlin, Hal S Stern, David B Dunson, Aki Vehtari, and Donald B Rubin. 2014. *Bayesian Data Analysis*. CRC press.

Hartig, Florian. 2022. DHARMA: Residual Diagnostics for Hierarchical (Multi-Level / Mixed) Regression Models. <https://CRAN.R-project.org/package=DHARMA>.

Hooten, Mevin B, and N Thompson Hobbs. 2015. "A Guide to Bayesian Model Selection for Ecologists." *Ecological Monographs* 85 (1): 3–28.

Kéry, Marc, and J Andrew Royle. 2015. *Applied Hierarchical Modeling in Ecology: Analysis of Distribution, Abundance and Species Richness in r and BUGS: Volume 1: Prelude and Static Models*. Academic Press.

Kéry, Marc, and J Andrew Royle. 2020. *Applied Hierarchical Modeling in Ecology: Analysis of Distribution, Abundance and Species Richness in r and BUGS: Volume 2: Dynamic and Advanced Models*. Academic Press.

Miller, David L, M Louise Burt, Eric A Rexstad, and Len Thomas. 2013. "Spatial Models for Distance Sampling Data: Recent Developments and Future Directions." *Methods in Ecology and Evolution* 4 (11): 1001–10.

Obritschkewitsch, Tim, and Andy R. Bankert. 2024. "Steller's Eider Surveys Near Utqiagvik, Alaska, 2023."

Osnas, Erik E. 2024a. "ACP-Mapping." GitHub Repository. <https://github.com/USFWS/ACP-Mapping>; GitHub.

Osnas, Erik E. 2024b. "Arctic Coastal Plain Waterfowl and Waterbird Spatial and Temporal Trends." ScienceBase. <https://doi.org/10.7944/qtgn-y170>; U.S. Fish; Wildlife Service, Alaska Region, Migratory Bird Management Alaska.

Pebesma, Edzer. 2018. "Simple Features for R: Standardized Support for Spatial Vector Data." *The R Journal* 10 (1): 439–46. <https://doi.org/10.32614/RJ-2018-009>.

Quakenbush, Lori, Robert Suydam, Tim Obritschkewitsch, and Michele Deering. 2004. "Breeding Biology of Steller's Eiders (*Polysticta stelleri*) Near Barrow, Alaska, 1991-99." *Arctic*, 166–82.

R Core Team. 2023. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. <https://www.R-project.org/>.

Roesch, Angi, and Harald Schmidbauer. 2018. *WaveletComp: Computational Wavelet Analysis*. <https://CRAN.R-project.org/package=WaveletComp>.

Rosenberg, Kenneth V, Adriaan M Dokter, Peter J Blancher, John R Sauer, Adam C Smith, Paul A Smith, Jessica C Stanton, et al. 2019. "Decline of the North American Avifauna." *Science* 366 (6461): 120–24.

Sauer, John R, and William A Link. 2002. "Hierarchical Modeling of Population Stability and Species Group Attributes from Survey Data." *Ecology* 83 (6): 1743–51.

Simpson, Gavin L. 2023. *gratia: Graceful ggplot-Based Graphics and Other Functions for GAMs Fitted Using mgcv*. <https://gavinsimpson.github.io/gratia/>.

Simpson, Gavin L. 2024. gratia: Posterior Simulation.

<https://gavinsimpson.github.io/gratia/articles/posterior-simulation.html>.

Smith, Adam C, and Brandon PM Edwards. 2021. "North American Breeding Bird Survey Status and Trend Estimates to Inform a Wide Range of Conservation Needs, Using a Flexible Bayesian Hierarchical Generalized Additive Model." *The Condor* 123 (1): duaa065.

Thompson, Steven K. 2012. *Sampling*. Hoboken, New Jersey: John Wiley; Sons.

U.S. Fish and Wildlife Service. 2019. "Status Assessment of the Alaska-breeding Population of Steller's Eiders." Version 1. Fairbanks, AK: Fairbanks Fish; Wildlife Field Office.

<https://ecos.fws.gov/ServCat/DownloadFile/163633>.

USFWS, and CWS. 1987. "Standard Operating Procedures for Aerial Waterfowl Breeding and Ground Population and Habitat Surveys in North America." United States Fish; Wildlife Service; Canadian Wildlife Service.

Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Golemund, et al. 2019. "Welcome to the tidyverse." *Journal of Open Source Software* 4 (43): 1686. <https://doi.org/10.21105/joss.01686>.

Wood, Simon N. 2011. "Fast Stable Restricted Maximum Likelihood and Marginal Likelihood Estimation of Semi-parametric Generalized Linear Models." *Journal of the Royal Statistical Society Series B: Statistical Methodology* 73 (1): 3–36.

Wood, Simon N. 2017. *Generalized Additive Models: An Introduction with r*, Second Edition. Boca Raton, Florida: Chapman; Hall/CRC.

Wood, Simon N. 2021. *Mgcv: Mixed GAM Computation Vehicle with Automatic Smoothness Estimation*. <https://CRAN.R-project.org/package=mgcv>.

Supplemental Material

All R code to reproduce these analyses, results, and this report can be found at the GitHub repository, <https://github.com/USFWS/STEI-estimates>.

All R model objects, posteriors samples, figures, and csv files summarizing various posteriors can be found at <https://www.sciencebase.gov/catalog/item/6761f393d34e9734dd458942>.

ACP data used in these analyses can be found at <https://doi.org/10.7944/qtgn-y170> (Osnas 2024b).

Triangle data are not publicly available at this time. The version of the Triangle data used for this report is maintained by the author and is available at

<https://www.sciencebase.gov/catalog/item/6761f392d34e9734dd458940>. Otherwise, an authoritative

copy of the Triangle data is not maintained by the US Fish and Wildlife Service. The Triangle data used in this report were obtained from ABR, Inc.

Acknowledgements

Comments from Annie Maliguine, John Nash, Dave Safine, Julian Fischer, and Chuck Frost improved the manuscript. Tim Obritschkewitsch (ABR, Inc.) provided data, including improvements in data over that available in 2019, and helped to interpret data so that they could be used in this analysis.

Disclaimer

Results presented in this manuscript have not been reviewed by experts outside the USFWS. All methods and results are due to the professional judgment of the author. Errors may be present. It was attempted to make this document and results fully reproducible from the code and data available at the links above. Inspection or review of that code is meant to provide all details of analysis choices made during development of this product. Data sources differ from those used in 2019. Improvement in quality control and data management practices have changed some data since 2019. Triangle data are maintained by ABR, Inc. and the author takes no responsibility for those data.

Version

This document was produced from commit 440ee11 found at <https://github.com/USFWS/STEI-estimates>.

Suggested Citation

Osnas, E.E. 2024. Steller's eider (*Polysticta stelleri*) population and density estimates from the Arctic Coastal Plain and Utqiagvik Triangle surveys using generalized additive models. US Fish and Wildlife Service, Division of Migratory Bird Management, Anchorage, AK. Version 0.1.0 <https://doi.org/10.7944/3vzp-0r93>.

Appendix B. Five competing model structures of population process and associated vital rates used in an attempt to describe the resiliency of the northern Alaska subpopulation of Steller’s eiders during this SSA analysis

	live.long		rescue*		periodic. norm**		periodic. pulse**		panmixia		closed	
Parameters	mu	sd	mu	sd	mu	sd	mu	sd	mu	sd	mu	sd
m.0A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.1A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.2A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.3A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.0R	0.00001	0.00002	0.0075	0.002	0.00001	0.00002	0.00001	0.00002	0.0009	0.0005	0	0
m.1R	0.00001	0.00002	0.005	0.002	0.00001	0.00002	0.00001	0.00002	0.0009	0.0005	0	0
m.2R	0.00001	0.00002	0.005	0.002	0.00001	0.00002	0.00001	0.00002	0.0009	0.0005	0	0
m.3R	0.00001	0.00002	0.005	0.002	0.00001	0.00002	0.00001	0.00002	0.0009	0.0005	0	0
s.0	0.5	0.1	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1
s.1	0.9	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05
s.2	0.9	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05
s.3	0.9	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05	0.86	0.05
B.2	0.75	0.05	0.75	0.05	0.6	0.05	0.8	0.05	0.75	0.05	0.75	0.05
B.3	0.9	0.05	0.9	0.05	0.75	0.05	0.95	0.05	0.9	0.05	0.9	0.05
fem.clutch	2.8	0.01	2.8	0.01	2.8	0.01	2.8	0.01	2.8	0.01	2.8	0.01
s.nest	0.3	0.2	0.3	0.2	0.2	0.2	0.7	0.2	0.3	0.2	0.5	0.2
s.duckl	0.4	0.2	0.3	0.2	0.3	0.2	0.8	0.2	0.4	0.2	0.4	0.2
Probability of sustaining a population in 30 years	0.94		0		0.1				0.01		0.86	

LEGEND

m are movement probabilities by age and by source population (A or R); movement occurs after yearly survival and right before mating
s are survival probabilities by age; all are yearly survival probabilities with the exception of s.0, which is survival from duckling to 1 year old
B are breeding propensity probabilities
fem.clutch is the number of female eggs in the clutch
s.nest is nest success

s.duckl is duckling survival

fecundity is the product of B, fem.clutch, s.nest, and s.duckl

NOTES

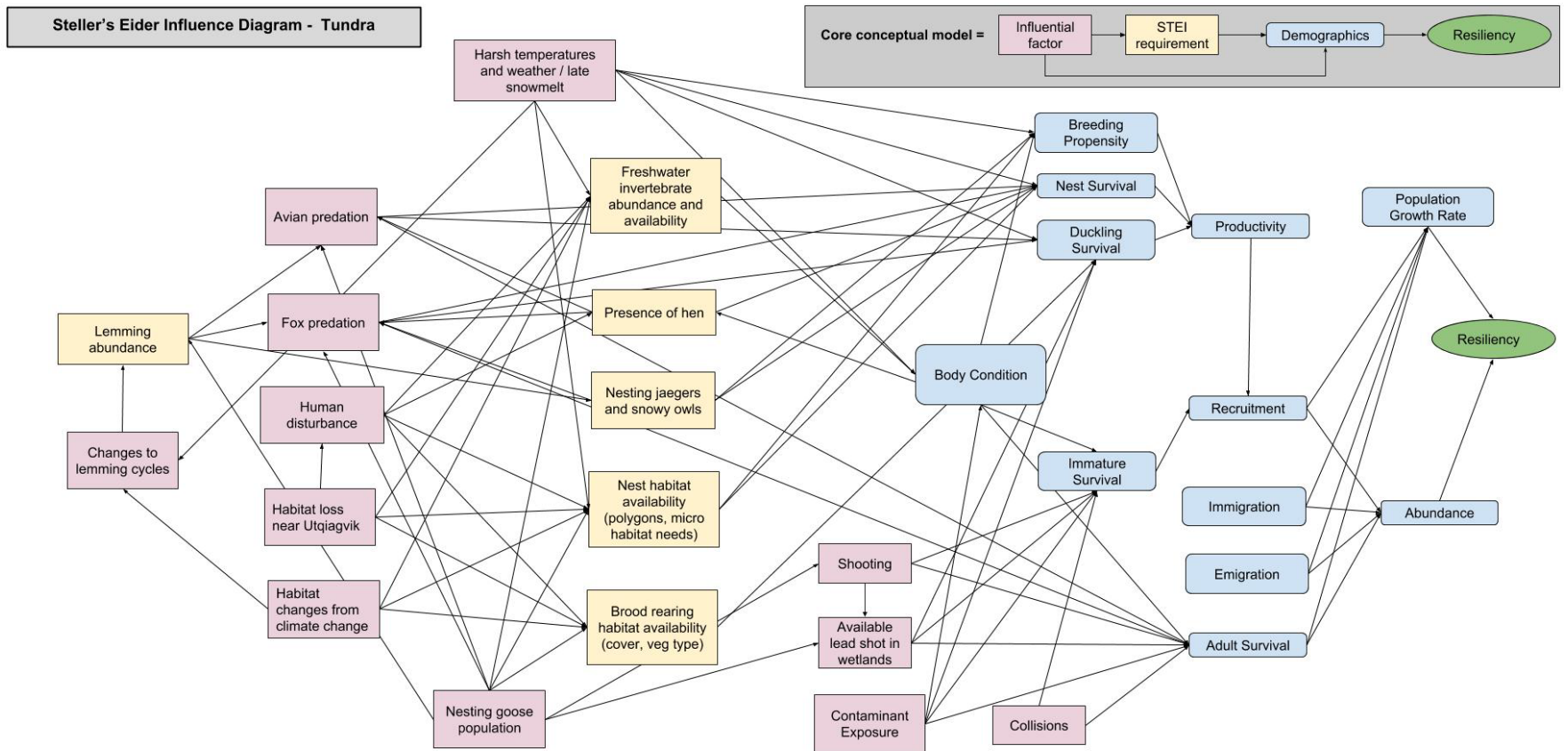
Added s.1 and s.2 and divided breeding propensity into B.2 and B.3

Clutch estimates come from Barrow project data and assuming 0.5 sex ratio

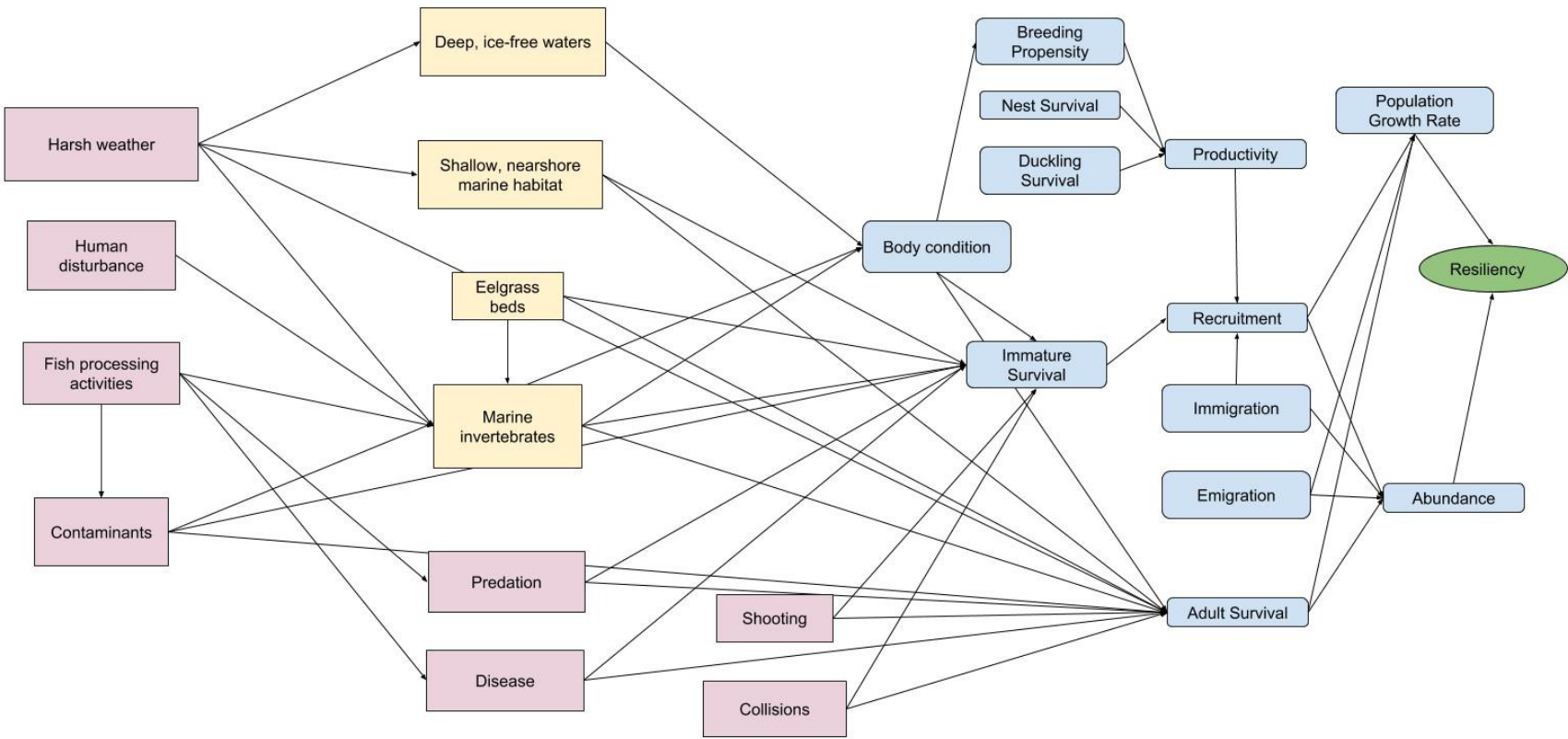
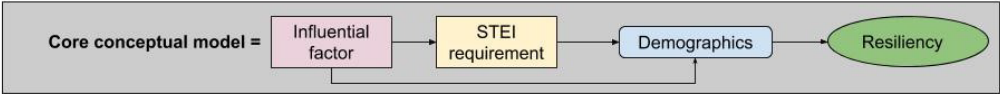
*To account for nonbreeding years, each year will have a 0.3 probability of being a breeding year. If the year is non-breeding, breeding propensity will equal 0.

**To model periodic pulses, pulse years will be modeled with a probability of 0.2. In pulse years, the vital rates in periodic.pulse will be used; otherwise, periodic.norm.

Appendix C. Influence diagrams depicting pathways of how influential factors may affect the habitat and circumstances required for individual Steller's eiders to survive and reproduce, and how those effects may influence demographic rates and, ultimately, resiliency of the population.



Steller's Eider Influence Diagram - Marine



Appendix D. Cause and Effect Tables. This appendix describes how stressors may contribute to the current condition of the northern Alaska subpopulation of Steller’s eiders.

KEY TO CAUSE AND EFFECTS TABLES		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	What is the ultimate source of the actions causing the stressor?	High Confidence (HC) = More than 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by documented accounts or research and/or strongly consistent with accepted conservation biology principles.
Activities	What actions are occurring on the ground affecting resources/birds?	Moderate Confidence (MC) = 50% to 90% sure that this relationship or assumption accurately reflects the reality in the wild as supported by some available information and/or consistent with accepted conservation biology principles.
Affected resources	What are the resources needed by the species that are being affected by this stressor? Or is it a direct effect on individuals?	Low Confidence (LC) = Less than 50% sure that this relationship or assumption accurately reflects the reality in the wild as there is little to no supporting information by some available information and/or uncertainty in its consistency with accepted conservation biology principles. Indicates areas of high uncertainty.
Changes in resources	Specifically, how has the resource changed?	
INDIVIDUAL RESPONSES		
Exposure	When and where, in terms of habitat and life stage, does the activity/stressor overlap with the resource need and/or individuals?	
Immediacy	What is the timing and frequency of the activity/stressor? Is it happening in the past, present, and/or future? Is the effect to resources or birds permanent (e.g., habitat destruction) or temporary (e.g., disturbance)?	
Conservation measures	Are there currently regulations in place or conservation measures/actions conducted that may reduce the effect of this stressor? How effective are they at minimizing impacts to individuals?	

Individual response and effects	What are individuals' responses to the stressor and how are they affected?	
Score (individual response)	1 = changes behavior but no measurable effect on survival, reproduction, body condition; 2 = may reduce reproductive success or survival; 3 = reduces reproductive success (i.e., breeding probability, nest or duckling survival); 4 = reduces survival probability of adult females; 5 = immediate mortality	
POPULATION RESPONSES		
Geographic scope	What is the geographic extent of the stressor relative to the range of the existing population? What proportion of the population is currently affected by the stressor?	
Score (geographic scope)	% of northern Alaska subpopulation affected: 0 = not currently affecting individuals; 1 = 1% or less; 2 = 1 - 25%; 3 = 25 - 50%, 4 = 50-75%; 5 = 75 - 100%	
Effect on population characteristics/resiliency	Are individual responses likely to translate to measurable effects on population characteristics, given the type of individual effect and geographic scope? What are the effects to population characteristics? (lower reproductive rates, reduced population growth rate, changes in distribution, etc.)? How large of an effect do you expect the factor to have on the population's resiliency given individual responses, immediacy and geographic scope?	
Score (Effect on resiliency)	Sum of scores for individual response, geographic scope, and overall confidence level. Low = 1-3, Moderate = 4-6, High = 7-10	
Overall confidence in analysis	Based on the confidence levels assigned in third column, how confident are we that we have strong evidence that the influential factor affects the resiliency of the population to the extent described in the above analysis?	

STRESSOR: INGESTION OF LEAD SHOT		
	Analysis	Confidence Level
Source(s)	Humans using lead ammunition for hunting and shooting.	HC
Activities	Lead is distributed in freshwater ponds within nesting, brood rearing, and pre-migration staging habitat.	HC
Affected resources	Direct effect on individuals: ingestion of lead shot	HC
Changes in resources	n/a	HC
INDIVIDUAL RESPONSES		
Exposure	<p>Steller's eiders ingest lead shot when feeding and collecting grit in wetlands. Birds are present and feeding in tundra nesting habitat from June 1 - late September. Nesting adult females overlap in time/space with stressor the most compared to other cohorts, as they remain on the breeding grounds longer than males or juveniles. Exposure is likely greatest closer to populated areas (e.g., Utqiagvik) and areas used for travel and subsistence activities (coastlines, rivers, fishing and hunting camps; Flint et al. 2016, p. 11-14). Birds may be exposed to lead from sources other than lead ammunition in other areas, such as Prudhoe Bay, but waterfowl sampled in these areas have lower exposure rates than areas with more hunting activity (Wilson et al. 2004, p. 3-4). Steller's eiders breeding near Utqiagvik showed high levels and rates of exposure (USFWS 1997, p.16; A. Matz, USFWS Biologist, pers. comm.), and 11 percent of long-tailed ducks (<i>Clangula hyemalis</i>) captured northeast of Teshekpuk Lake on the ACP in 1980 had lead shot in their gizzards (Taylor 1986, cited in USFWS 2018b, p.40). Lead shot was identified as the source of high and harmful lead levels through blood samples, radiographs, necropsy, and lead isotope analysis (A. Matz, USFWS Biologist, pers. comm). However, blood lead levels were lower in nesting female Steller's eiders (n=36) and long-tailed ducks (n=15) near Utqiagvik sampled in years 2008, and 2010-2014 (Miller et al. 2019, p. 35).</p>	<p>HC: In 1999-2000, 8/8 nesting Steller's eider females sampled near Utqiagvik exceeded blood lead concentrations of >0.2ppm (USFWS unpublished data), and a Steller's eider found dead near Utqiagvik had liver and kidney lead levels suggestive of poisoning (USFWS 1997, p. 16).</p> <p>In 2008 and 2010-2014, 36 nesting Steller's eider females were sampled for blood lead (Pb) concentrations near Utqiagvik; the mean concentrations were 0.065 ppm (SE = 0.029) and ranged from 0.002-0.996 ppm (Miller et al. 2019, p. 35). Of the 36 nesting Steller's eiders sampled for Pb levels in their blood, 4 hens had Pb levels > 0.2 ppm (M. Miller, unpublished data).</p>

Immediacy	Lead shot can be available in tundra ponds for ingestion for many years (> 25 years, Flint and Schamber 2010, p.150); thus, shot distributed in the past can still affect birds. Lead shot is still sold and may still be used in some areas (USFWS, unpublished observations). Currently, it is reasonable to assume that lead exposure occurs annually and has a permanent effect on the individual.	HC that it was used in the past and is still available for purchase. LC in the amount of lead shot currently being distributed in wetlands occupied by Steller's eiders.
Conservation measures	Waterfowl hunting with lead shot has been prohibited in Alaska since 1991. The Service intensified efforts in 1998 to enforce prohibitions against the possession and use of lead shot for migratory bird hunting. Later, the State of Alaska, at the request of regional advisory boards, passed more restrictive regulations that prohibit the use of lead shot for upland game bird hunting on the ACP and all bird and small game hunting on the Y-K Delta. There are indications compliance with these regulations improved as a result of significant outreach and education efforts. However, compliance varies spatially and temporally, and lead shot is still occasionally available in stores, hunters are found in possession of lead shot, and embedded lead shot was detected in a captured female spectacled eider in 2018 on the Y-K Delta (USFWS, unpublished observations), indicating that the factor has not been eliminated.	LC in the effectiveness of current conservation measures to reduce the use of lead shot. However, the Service has plans to expand outreach and education activities to reduce use of lead shot in waterfowl nesting areas.
Individual response and effects	The toxic effects of ingesting lead vary among individuals but include lethal and sub-lethal effects (Jordan and Bellrose 1951, p. 4-5, 15-17; Baldassarre and Bolen 2006, p. 295, Franson 2015, p. 175). Ingestion of spent lead shot was documented to reduce annual survival of spectacled eiders on the Y-K Delta (Grand et al. 1998, p. 1106; Flint et al. 2016, p. 24-25). Sub-lethal effects in waterfowl include lower fecundity (captive mallards; Elder 1954, p. 321) and increased risk of power line collisions (intermediate lead exposure levels; Kelly & Kelly 2005, p. 333). In addition, both mammal and bird species have been shown to have a reduced immunosuppression in response to lead exposure (Franson 1986, p. 107). The relationship between lead shot embedded in tissue and lead toxicosis is unclear (Eisler 1988, p. 41).	HC

Score (effect to individual)	4.5: reduces survival probability and results in immediate mortality. Not all lead exposure will lead to immediate mortality; it may have sub-lethal effects.	HC
POPULATION RESPONSES		
Geographic scope	We assume in this analysis that 1/3 of the northern Alaska subpopulation is potentially affected by anthropogenic effects near Utqiagvik, including exposure to lead shot (see Section 6.4.2). However, the true number exposed to lead depends on the number of days that individuals remain on the breeding grounds (affected by both breeding effort and success) and the number of females that actually feed in contaminated wetlands (which is unknown). We believe it is reasonable to assume that less than 25% but more than 1% of the northern Alaska subpopulation is exposed to lead at levels that affect reproduction or survival annually.	LC: Based on a set of assumptions. Abundance estimate of the northern Alaska subpopulation is highly uncertain; % of that subpopulation exposed at levels that affect reproduction and survival is even more uncertain.
Score (geographic scope)	2: 1-25%	LC
Effect on population characteristics/resiliency	Lead exposure at toxic levels reduces in survival probability and productivity. If strong breeding site fidelity, could alter nesting distribution if exposed females die. Survival of breeding females most influential to population dynamics, and they are the cohort most exposed to lead deposited in tundra ponds.	HC in the effect of lead on individuals once ingested, but MC in how many ingest lead in any given year, and how lead availability and deposition may be changing over time (i.e., human behavior component).
Score (effect on resiliency)	6.5: High	
Overall confidence in analysis	Moderate confidence	

SHOOTING (tundra)		
	Analysis	Confidence Level
Source(s)	Shooting of Steller's eiders during subsistence harvest, sport hunting, and recreational shooting activities in breeding areas.	HC
Activities	Shooting of Steller's eiders during subsistence harvest, sport hunting, and recreational shooting activities in breeding areas.	HC
Affected resources	Direct effect on individuals	HC
Changes in resources	n/a	
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders may be shot during the breeding season at nesting, brood rearing, and pre-migration staging areas near villages, hunting camps, and areas used by humans (USFWS 2018b, p. 35). Breeding adult females are at most risk of being shot because they spend more time in these areas than males and juveniles.	HC
Immediacy	Shooting of Steller's eiders near Utqiagvik has occurred in the past and may still occur annually with variable frequency, depending on the number of Steller's eiders breeding and their reproductive success, which affects the amount of time birds remain near Utqiagvik (USFWS 2018b, p. 38).	HC
Conservation measures	The Service promulgates subsistence harvest and sport hunting regulations that allow for some migratory bird species to be harvested annually (USFWS 2018b, p.4). Included in the subsistence harvest regulations are closures on shooting and collecting eggs of Steller's eiders and a closure on take of all migratory birds during the 30-day peak nesting period (USFWS 2018b, p. 5-6). An intra-agency consultation under Section 7(a)(2) of the ESA on these regulations includes conservation measures such as law enforcement, outreach, education and communication programs to minimize shooting of Steller's eiders and improve compliance with regulations (USFWS 2018b, p. 6-7). However, it is unknown how effective the regulations and conservation measures are at minimizing the amount of shooting	HC that outreach activities occur, LC that they are effective at minimizing or eliminating shooting of Steller's eiders.

	that occurs as it is difficult to monitor take (USFWS 2018, p. 36-38).	
Individual response and effects	Dead or injured birds.	HC
Score (effect to individual)	5: mortality	HC
POPULATION RESPONSES		
Geographic scope	Portion of the northern Alaska subpopulation that nests and/or stages near Utqiaġvik (1/3) are most at risk of being shot (See Section 6.4.2). USFWS (2018b) estimates that tens of Steller's eiders could be taken by hunters annually during the spring/summer subsistence hunt, when birds are on the tundra breeding area, or during migration (p. 38). The estimated annual abundance of Steller's eiders present across the entire ACP (including the area proximate to Utqiaġvik) from 2007- 2024 is 405.61 birds (95% CI: 207.67, 750.02; Appendix A). $10/406 = 2.5\%$ of the birds present annually may be shot. It is reasonable to assume that this represents more than 1% of the northern Alaska subpopulation, although the true proportion of the population present is unknown given that that breeding propensity is highly variable year to year.	LC: Abundance estimate of the northern Alaska subpopulation is highly uncertain, and % of that subpopulation exposed is based on a set of untested assumptions.
Score (geographic scope)	2: 1-25%	LC
Effect on population characteristics/resiliency	USFWS (2018b) estimates that tens of Steller's eiders may be taken annually during subsistence harvest on the ACP, but the number varies annually due in part to reproductive effort and success in given year (p. 38). The effect on individuals is death, and breeding females likely have the most exposure to shooting due to the extended time they spend in breeding areas. This is consequential given that adult female survival has been shown to influence population growth rate more than other demographic rates in sea duck species (Flint 2015, p. 85). Even a small number of mortalities of adult females may have a significant effect on the population size and growth rate, depending on the amount of recruitment due to immigration and the productivity of the population.	MC: Adult female survival shown to be influential to population growth rate of sea ducks (Flint 2015, p.85), and females near Utqiaġvik show breeding site fidelity and philopatry (Safine et al., in prep.). However, there is still uncertainty in how much immigration influences population size and growth rate relative to survival and productivity (Dunham and Grand 2017, See section 6.2.3 in text).

Score (effect on resiliency)	7: High	
Overall confidence in analysis	Moderate confidence	Uncertainty in abundance estimates of northern Alaska subpopulation, low confidence in calculations of birds exposed to risk and number of birds shot annually, and moderate confidence in what vital rates are most important to population growth rate (i.e., adult survival vs. immigration). However, effect of activity on the birds is clear, and analysis of consequences to the population is consistent with sea duck ecology and conservation biology principles.

HUMAN DISTURBANCE (Tundra)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Human presence/activity on tundra nesting areas	HC
Activities	Utqiagvik residents and tourist activity such as hiking, birding watching, photography, and hunting. Researcher activities include aerial surveys, on-tundra activities such as nest searching or captures of Steller's eiders, collection of scientific data not related to Steller's eider research, or remote aircraft landings.	HC
Affected resources	Effects on individuals: adults, ducklings, eggs	HC
Changes in resources	Some food resources or preferred nesting or brood rearing sites may be less available to individuals due to human activity in the area.	HC
INDIVIDUAL RESPONSES		
Exposure	Individuals may be disturbed when occupying terrestrial breeding habitat during breeding season (late May - late Sept), during foraging, nesting, and brood-rearing activities.	HC
Immediacy	Human disturbance to Steller's eiders has, does, and will continue to occur, particularly near Utqiagvik. Disturbance is usually a one-time, isolated and short-lived event, and not every disturbance event will result in nest or duckling depredation or nest abandonment. Repeated disturbance is of greater concern, and the frequency of disturbance is likely higher closer to Utqiagvik, where the highest concentration of humans and eiders exist. However, the amount of disturbance varies annually and throughout each breeding season due to various factors that influence human behavior - available funding for research, amount of subsistence harvest activity, etc.	HC
Conservation measures	Subsistence harvest regulations prohibit egg gathering and hunting during the 30-day peak nesting period (USFWS 2018b, p. 5-6), which may reduce some activity. Activities of Utqiagvik residents and tourists is not regulated, but outreach/education to improve awareness of disturbance on nesting Steller's eiders is conducted annually by the Service (public service announcements, newsletters, etc.). Most research activities are considered in intra-Service Section 7 consultations, consultations with the National Science Foundation, or under a programmatic consultation with the Bureau of Land Management for summer activities in the NPR-A, in which conservation measures are put in place to minimize disturbance. However, it is unclear how much these measures reduce the amount of disturbance or effects on Steller's eiders.	MC: HC that these measures occur; LC that they significantly reduce disturbance or effects of disturbance.

Individual response and effects	Disturbance may affect individuals in the following ways. First, individuals may not use preferred foraging, nesting, or brood-rearing habitats due to human activity in the area, reducing their ability to meet nutritional requirements. But the degree to which Steller's eiders can reproduce in disturbed areas or move to other less disturbed areas to reproduce, and the potential population level consequences of existing human development, are unknown. Second, nesting females may be flushed during incubation, exposing eggs or themselves to higher predation risk. The majority of nest predation is thought to occur when female waterfowl are absent (Swennen et al. 1993, p.51; Afton and Paulus 1992, p. 75-76), and waterfowl nest predation risk increases with the number of incubation recesses taken (Mallory 2015, p. 348). Disturbance may also result in nest abandonment. Grand and Flint (1997) reported 14% lower nest success for spectacled eider nests visited by researchers than those unvisited, but the difference was not statistically significant, presumably because of low sample size (p. 931). USFWS (2003) estimated that the likelihood of mortality for spectacled eider nests increased by 4% after a researcher visit (p. 13). Similarly, Meixell and Flint (2017) estimated that observer visits to greater white-fronted goose nests on the ACP were responsible for a 7-35% reduction in nest survival probability (p. 9). Likelihood of nest abandonment or depredation presumably varies with the number and frequency of disturbance events. Third, females and broods may flush and scatter in response to disturbance, reducing the ability of the female to protect ducklings and ducklings' ability to evade predation). Hens provide temperature regulation via brooding until ducklings can thermoregulate and protect ducklings from predators (Afton and Paulus 1992, p. 83, 88-89 and references therein). Finally, it is possible that disturbance could reduce an adult's probability of survival, particularly if disturbance is frequent and in conjunction with other physiological stressors such as severe weather, low food abundance, high numbers of predators, disease, or contaminants, although we have no evidence to show a significant effect of disturbance on adult survival.	MC
Score (individual response)	3: reduces reproductive success	MC
POPULATION RESPONSES		
Geographic scope	Breeding habitat (late May - late Sept). Birds nesting near human settlements/camps/development will be impacted more, which we estimated to be approximately 1/3 of the northern Alaska subpopulation (Section 6.4.2). However, only a portion of that 1/3 would be disturbed in any one year by human disturbance; thus, it is reasonable to assume that between 1-25% of the northern Alaska subpopulation is affected annually.	MC: Abundance estimate of the northern Alaska subpopulation is highly uncertain, and % of that subpopulation exposed is based on a set of untested assumptions.

Score (geographic scope)	2: 1-25%	MC
Effect on population characteristics/resiliency	A significant portion of the population may be affected by human disturbance during the breeding season, and disturbance events may occur relatively frequently in some areas with high densities of nesting Steller's eiders, particularly near Utqiagvik. Effects on reproductive rates vary by individual tolerance and the number and frequency of disturbance events. One disturbance event may increase nest mortality risk by 4-14%; the effect on duckling survival is unknown. It is unlikely that disturbance alone would measurably decrease adult survival probability. Conservation measures through Section 7 consultation may reduce probability of disturbance, but the amount of reduction is unknown. The magnitude of effect of disturbance to the northern Alaska subpopulation is moderate. Disturbance is local and short-lived but may affect a significant portion of the population. Persistent disturbance could affect reproductive rates of the population.	MC: considerable uncertainty in how disturbance affects population-level demographic parameters.
Score (effect on resiliency)	5: Moderate	
Overall confidence in analysis	Moderate confidence	

HABITAT LOSS NEAR UTQIAĠVIK (tundra)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Human population growth and resource development	HC
Activities	Road and home building, gravel extraction, expansion of infrastructure/pipelines	HC
Affected resources	Expansion of infrastructure reduces the amount of nest, brood-rearing, and foraging habitat near Utqiaġvik. It also may increase the amount of human disturbance to Steller's eiders during the nesting and brood-rearing season, which may expose eggs or small young to inclement weather and predators.	HC
Changes in resources	Nesting habitat and wetlands are destroyed, and a 200m area around development is assumed to be unusable for feeding, nesting, and brood-rearing due to disturbance (USFWS 2015, p. 35-36).	HC that wetland habitats are destroyed, LC that an additional 200m zone beyond the footprint of destroyed habitat is unusable. This is a conservative and untested assumption used to estimate incidental take in Section 7 consultations.
INDIVIDUAL RESPONSES		
Exposure	Expansion of Utqiaġvik infrastructure affects Steller's eiders and the habitat used during pre-nesting, nesting, brood-rearing, and staging for fall migration.	HC
Immediacy	The Utqiaġvik footprint has expanded in the past few decades and is expected to continue to expand gradually as the population size grows (USFWS 2018b, p. 43-44). Habitat loss is occurring in relatively small increments over time, so the effect of habitat loss in any one year may be minimal, but the impact over time is additive and permanent.	HC
Conservation measures	Many development infrastructure projects have a federal nexus and therefore require Section 7 consultation, which considers the environmental baseline and effects to listed species, and, through terms and conditions and conservation measures, minimizes impacts. For example, construction/habitat destruction is not allowed during the nesting season so active nests are not destroyed or disturbed during construction.	MC: HC that Section 7 consultation occurs in most cases, but LC that it is reducing the impact to Steller's eiders over long time periods.
Individual response and effects	Habitat destruction may force individuals to use less preferable habitat that may not meet nutritional requirements or result in lower reproductive success. Increased disturbance in the zone of influence around new	MC

	development may: 1) disturb incubating or brood-rearing hens, potentially exposing eggs or small young to inclement weather and predators (see Human Disturbance table); and/or 2) displace adults and/or broods from preferred habitats, shifting the population's distribution (USFWS 2015, p. 35). Given conservation measures that limit timing of construction to outside the nesting window, the primary effect to individuals from infrastructure development is displacement from preferred habitats after habitat is destroyed. The degree to which Steller's eiders can forage and reproduce in disturbed areas or move to other less disturbed areas to forage and reproduce is unknown. We have no evidence to suggest that foraging, nesting, or brood-rearing habitat is currently limited near Utqiagvik. However, there are indications that the habitat in the UT area are unique and perhaps preferred by Steller's eiders relative to other portions of the ACP (See Section 6.5) and that nesting distribution is shifting away from developed areas near Utqiagvik (USFWS, unpublished data).	
Score (individual response)	Unknown	MC
POPULATION RESPONSES		
Geographic scope	Expansion of the Utqiagvik footprint may affect 1/3 of the northern Alaska subpopulation that uses the area near the Utqiagvik road system (See Section 6.4.2). However, in any given year, new habitat loss affects only those individuals that may have used the area that is destroyed: currently that might be limited to a small number of acres/year and thus a small number of Steller's eiders (less than 1% of the population).	LC: Potential effects have been estimated by Section 7 consultations, but these use conservative assumptions and are untested.
Score (geographic scope)	Unknown	LC
Effect on population characteristics/resiliency	We have no evidence to suggest that foraging, nesting, or brood-rearing habitat is currently limited for Steller's eiders near Utqiagvik, so currently, this factor is unlikely to affect the population's resiliency significantly. However, as infrastructure expands and habitats change, this factor may increase in importance.	LC: Disturbance likely decreases nest success, but the number of individuals affected annually and whether habitat is limiting for Steller's eiders on the ACP are unknown.
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

OIL AND GAS DEVELOPMENT (tundra)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Oil and gas development on the ACP	HC
Activities	Pipeline and road building, oil extraction activities	HC
Affected resources	Expansion of infrastructure may reduce the amount of nest, brood-rearing, and foraging habitat on the ACP. It also may increase the amount of human disturbance to Steller's eiders during the nesting and brood-rearing season, which exposes eggs or small young to inclement weather and predators.	HC
Changes in resources	Nesting habitat and wetlands are destroyed, and a 200m area around development is assumed to be unusable for feeding, nesting, and brood-rearing due to disturbance (USFWS 2015, p. 35-36).	HC that wetland habitats are destroyed, LC that an additional 200m zone beyond the footprint of destroyed habitat is unusable. This is a conservative and untested assumption used to estimate incidental take in Section 7 consultations.
INDIVIDUAL RESPONSES		
Exposure	Industrial development affects Steller's eiders and the habitat used during pre-nesting, nesting, brood-rearing, and staging for fall migration.	HC
Immediacy	Oil and gas development on the ACP has expanded in the past few decades and is expected to continue to expand gradually. Habitat loss is occurring in relatively small increments over time, so the effect of habitat loss in any one year may be minimal, but the impact over time is additive and permanent.	HC
Conservation measures	Many development infrastructure projects have a federal nexus and therefore require Section 7 consultation, which considers the environmental baseline and effects to listed species, and through conservation measures, minimizes impacts. For example, construction/habitat destruction is not allowed during the nesting season so active nests are not destroyed or disturbed during construction.	HC that Section 7 consultation occurs.
Individual response and effects	Habitat destruction may force individuals to use less preferable habitat that may not meet nutritional requirements or result in lower reproductive success. Increased disturbance in the zone of influence around new development may: 1) disturb incubating or brood-rearing	LC - The degree to which Steller's eiders can forage and reproduce in disturbed areas or move to other less disturbed areas to forage and reproduce is unknown. We have no evidence to suggest that

	hens, potentially exposing eggs or small young to inclement weather and predators (see Human Disturbance table); and/or 2) displace adults and/or broods from preferred habitats (USFWS 2015, p. 35). Given conservation measures that limit timing of construction to outside the nesting window, the primary effect to individuals from infrastructure development is displacement from preferred habitats after habitat is destroyed. The degree to which Steller's eiders can forage and reproduce in disturbed areas or move to other less disturbed areas to forage and reproduce is unknown. We have no evidence to suggest that foraging, nesting, or brood-rearing habitat is currently limited on the ACP.	foraging, nesting or brood-rearing habitat is currently limited on the ACP.
Score (individual response)	Unknown	MC
POPULATION RESPONSES		
Geographic scope	Steller's eider density is very low near areas that have been developed for oil and gas activities in the NPR-A and Prudhoe Bay (Figure 2).	HC
Score (geographic scope)	1: < 1% of the northern Alaska breeding population	HC
Effect on population characteristics/resiliency	We have no evidence to suggest that foraging, nesting, or brood-rearing habitat is currently limited for Steller's eiders on the ACP, and, due to the very small number of Steller's eiders near areas of current oil and gas development, the likelihood of this factor affecting the population measurably is low. However, as infrastructure expands and habitats change, this factor may increase in importance.	LC
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

AVIAN PREDATION		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Some avian species, such as pomarine and parasitic jaegers, snowy owls, ravens, and glaucous gulls, naturally predate on eggs, ducklings, and adult Steller's eiders.	HC
Activities	Landfills and structures in areas such as Utqiagvik, Atkasuk, and Prudhoe Bay may artificially increase food and nest sites available to gulls and ravens and indirectly increase predation rates. Buildings have provided nest sites for ravens, allowing them to expand their range to parts of the ACP that were not inhabited prior to human development (ABR, Inc. 1998, p. 18-20; Backensto and Powell 2009, p. 12). Increased food sources from landfills and marine mammal carcasses may support higher gull and raven populations on the ACP than was historically present (ABR, Inc. 1998, p. 6-11, 13; Backensto and Powell 2009, p. 16-17).	MC
Affected resources	Direct effect of mortality of eggs, ducklings, and sometimes adult females. Also indirectly affects eggs and ducklings through disturbance (USFWS 2015, p. 32-33).	HC
Changes in resources	Gull and raven populations may have increased compared to historical numbers.	MC - Personal observations/concerns that raven population has increased have not been tested through targeted surveys (USFWS 2012b, p. 10-11,19). While glaucous gulls may be surveyed more adequately, the 90% CI of the growth rate of the aerial population index of glaucous gulls in the ACP aerial survey from 1992 - 2011 surrounds 1.0, suggesting stability rather than an increase (USFWS 2012b, p.8 and 25).
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders are at risk of predation during the nesting and brood rearing season. The risk may be greater near human habitation such as Utqiagvik, Atkasuk, Wainwright, and Prudhoe Bay because of higher gull and raven densities than areas uninhabited by humans.	HC
Immediacy	Nest predation by avian species is a relatively constant threat during nesting and brood rearing but may vary annually depending on the predator and lemming populations. For example, predation pressure on	MC

	Steller's eider nests by jaegers may be highest in years of moderate lemming abundance, when jaegers are present but lemming numbers are not adequate. In years with many lemmings, jaegers will focus on lemmings, and in years with low lemmings, few jaegers choose to nest; in low lemming years, the few jaegers that do nest may be more likely to depredate Steller's eider eggs or ducklings.	
Conservation measures	The Service destroys raven eggs/young annually in Utqiagvik when possible to reduce the raven population and resulting predation pressure on nesting Steller's eiders. Utqiagvik uses a trash incinerator to reduce trash abundance, although occasionally the incinerator is not operational (USFWS observations).	HC
Individual response and effects	Mortality of eggs and ducklings (USFWS 2011a, p. 27-28; USFWS 2018a, p. 22; USFWS unpublished data), and, in some cases, possibly nesting females (USFWS 2011a, p. 23-24). Avian predators may also flush incubating females from their nest, indirectly increasing risk of predation from other predators, nest abandonment, or egg viability from inclement weather.	HC
Score (individual response)	3: reduces reproductive success	HC - chose not to use "mortality" of adults because that effect is rare; mostly concerned with eggs/ducklings
POPULATION RESPONSES		
Geographic scope	All incubating females, eggs, and ducklings are at risk of mortality by avian predators, but not all nests are taken by them, and not all birds in the northern Alaska subpopulation nest in every year. Therefore, it is reasonable to assume that between 1 - 25 % of the population is affected annually.	LC - based on a set of untested assumptions
Score (geographic scope)	2: 1- 25%	MC
Effect on population characteristics/resiliency	Nest predation by avian predators could result in lower nest and brood survival rates, and therefore lower productivity, of the northern Alaska subpopulation. Depending on the factors most influencing population growth rate, avian predation may negatively affect resiliency of the population.	MC
Score (effect on resiliency)	5: Moderate	

Overall confidence in analysis	Moderate confidence	
---------------------------------------	---------------------	--

FOX PREDATION		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Arctic foxes naturally depredate eggs, ducklings and adults.	HC
Activities	Fox populations may be influenced by human activities - increased via increased food resources such as trash and marine mammal carcasses (ABR Inc. 1998, p. 26; Roth 2002, p.672) or decreased through trapping (USDA 2016, p.6).	LC - Based on assumptions. It makes intuitive sense that alternative food sources and trapping influence fox populations and therefore the risk of predation to Steller's eiders; however, there is little information to support this assumption.
Affected resources	direct effect on individuals	HC
Changes in resources	n/a	n/a
INDIVIDUAL RESPONSES		
Exposure	Steller's eider eggs, ducklings, and incubating females are exposed to risk of fox predation on the breeding grounds. Predation risk may be higher near villages and the coast due to increased fox populations there, but foxes' reliance on eggs may differ spatially and temporally depending on the availability of lemmings and other prey.	HC
Immediacy	Fox predation is a risk annually, but the rate varies from year to year. When it does occur, the effect is permanent (egg/duckling mortality).	HC
Conservation measures	From 2005 - 2016, fox control was conducted near Utqiagvik with the goal of increasing nest survival of Steller's eiders (USDA 2016). However, due to several factors, including study design and high annual variation in fox and Steller's eider numbers, the Service is unable to detect a significant effect of fox control on Steller's eider nest survival. In 2017, fox control was suspended until a study could be designed to better measure the effect. Additionally, the incinerator at the Utqiagvik landfill reduces the food available for fox, but an effect of the incinerator on the fox population or on nest predation has not been measured. Therefore, there are currently no conservation measures in place that measurably reduce the risk of predation by fox.	HC
Individual response and effects	Adult, egg, or duckling mortality, but eggs and ducklings are most susceptible to predation (Sargeant and Raveling 1992, p. 401, 402, 407).	HC

Score (individual response)	3: reduces reproductive success	HC: female mortality may occur, but is rarely observed compared to fox predation of nests and ducklings
POPULATION RESPONSES		
Geographic scope	All incubating females, eggs, and ducklings present in any given year are at risk of fox predation; however, breeding propensity of the northern Alaska subpopulation is highly annually variable, and not every nest/brood is taken every year by fox. It is reasonable to assume that 1-25% of the population is affected annually.	LC
Score (geographic scope)	2: 1-25%	LC
Effect on population characteristics/resiliency	Nest predation by fox could result in lower nest and brood survival rates, and therefore lower productivity, of the northern Alaska subpopulation. Depending on the factors most influencing population growth rate, avian predation may negatively affect resiliency of the population.	MC
Score (effect on resiliency)	5: Moderate	
Overall confidence in analysis	Moderate confidence	

CHANGES TO LEMMING POPULATION CYCLES		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	The amplitude and/or frequency of brown lemming population fluctuations may have changed in the past few decades near Utqiagvik. Generally, brown lemming populations underwent dramatic fluctuations in abundance every 3-4 years near Utqiagvik (Pitelka et al. 1955, p. 86, Pitelka and Batzli 2007, p. 328-329), and, although difficult to quantify, a year with very high lemming abundance has not been observed since 2008 (K. Ott, USFWS, pers comm.). There is strong evidence that other rodent species have undergone a shift from cyclic to noncyclic dynamics in the northern hemisphere in recent decades (Ims et al. 2008, p. 81).	LC
Activities	n/a	n/a
Affected resources	The number of nesting pomarine jaegers and snowy owls.	MC
Changes in resources	Fewer jaegers and snowy owls nest in years with low lemming abundance.	MC
INDIVIDUAL RESPONSES		
Exposure	Tundra nesting areas, annually during the breeding season.	HC
Immediacy	Changes to lemming population dynamics may have occurred in recent decades and are predicted to continue due to a changing climate (Kausrud et al. 2008, p. 95).	MC
Conservation measures	none	n/a
Individual response and effects	The number of nesting avian predators such as snowy owls and pomarine jaegers seems to be positively related to number of brown lemmings in the Utqiagvik study area (Quakenbush et al. 2004, p. 177), which in turn may affect the number of Steller's eiders nesting, and their nest success, in any given year (see Section 5.1). Therefore, the loss of periodic high lemming abundance may result in (1) lower Steller's eider breeding effort; or (2) lower nest and/or brood survival because foxes and other predators switch to eider eggs when lemmings are scarce, and Steller's eiders cannot benefit from nesting near jaegers and owls that might protect nests from foxes.	MC - changes to lemming cycles, and the resulting effect on Steller's eider demographics, have not been quantified. Instead, relying on observations near Utqiagvik and in other Arctic regions, and ecological principles, to make inference.
Score (individual response)	3: reduces reproductive success	MC

POPULATION RESPONSES		
Geographic scope	We do not know if the relationship between lemmings, avian predators, and Steller's eiders occurs outside of the Utqiagvik study area, but, given similar observations on a nesting area near the Lena Delta, Russia (Solovieva 1999), we assume that this relationship and the effect of lemming abundance holds across all tundra nesting areas. Therefore, it would affect the entire northern Alaska subpopulation. However, lemming abundance varies spatially across the ACP, and therefore the effect is not constant across space and time. Also, breeding propensity of the northern Alaska subpopulation is annually variable, so the entire population is not affected annually. It's reasonable to assume that 25 - 50% of the population is affected.	LC- assumption that the entire northern Alaska subpopulation is affected by lemming abundance has not been tested.
Score (geographic scope)	3: 25-50%	LC
Effect on population characteristics/resiliency	If reproductive effort and/or success is lowered, then productivity would be negatively impacted. If populations of Steller's eiders require periodic pulses of prodigious productivity to maintain a stable or growing population growth rate, and these pulses are dependent on spikes in lemming abundance, then reductions in amplitude of lemming cycles may have serious consequences for population growth and stability of the northern Alaska subpopulation. Estimated magnitude of the effect is moderate, given uncertainty.	MC
Score (effect on resiliency)	6: Moderate	
Overall confidence in analysis	Moderate confidence	

HABITAT CHANGE DUE TO CLIMATE CHANGE (tundra)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Warmer air temperatures in the Arctic caused by global carbon emissions (IPCC 2014, p. 4). Strong near-surface air temperature warming has occurred across Alaska exceeding 1.5°F (0.8°C) over the last 30 years. Especially strong warming has occurred over the ACP during autumn. For example, Utqiagvik warming since 1979 exceeds 7°F (3.8°C) in September, 12°F (6.6°C) in October, and 10°F (5.5°C) in November (summarized in Taylor et al. 2017, p. 11).	HC
Activities	Burning fossil fuels	HC - An anthropogenic contribution to Arctic and Alaskan surface temperature warming over the past 50 years is very likely (Taylor et al. 2017, p. 11).
Affected resources	Availability of nest and brood-rearing habitat, availability and abundance of freshwater invertebrates	LC - There is significant uncertainty around the specific habitat characteristics that are required and preferred by Steller's eiders, and whether these resources are affected to a degree that makes them insufficient for the birds
Changes in resources	Increased temperatures in northern Alaska have caused ice wedge degradation, polygon drainage, and changes in vegetation community (Liljedahl et al. 2016, p. 313-314), all of which are components of nest and brood-rearing habitat. Near Utqiagvik, Lougheed et al. (2011) observed higher mean and maximum pond water temperatures, ponds are more nutrient-rich, and primary productivity is higher between the 1970s and 2007-2010 (p. 593 - 595). Additionally, paired photographs suggest that <i>Carex aquatilis</i> has increased in biomass since the 1970s (p.597). Andresen and Lougheed (2015) observed a 30.3% net decrease in pond area and a 17.1% decrease in pond abundance in the UT area from 1948 - 2010 (p. 5), and suggest that increased thaw depth, temperature, and vegetation cover play an important role in this change (p. 7-8). These observed changes may have reduced the quality and/or quantity of Steller's eider nest and brood rearing habitat and the freshwater invertebrate community.	MC - high confidence in observed habitat changes, but how that translates to changes to required resources, such as the availability of habitat, is unknown.
INDIVIDUAL RESPONSES		

Exposure	All ACP habitat may be affected, and thus all nesting adults and ducklings in the northern Alaska subpopulation may be exposed.	LC
Immediacy	Changes to habitat have been documented in the past and likely continue. Likely annual variation in habitat changes over time. Likely to occur, but changes are annually variable due to changes in weather and climate variability and interactions with other environmental factors such as lemming abundance (Villareal et al. 2012, p. 7)	MC
Conservation measures	None	HC
Individual response and effects	The individual responses of Steller's eiders to the documented habitat changes near Utqiagvik and on the ACP have not been measured. If these changes decrease habitat quantity or quality, body condition of adults and/or ducklings may be impacted, and breeding probability and reproductive success may be negatively affected, particularly if other factors are also acting on individuals (such as disease, contaminants, etc.).	LC - based on several untested assumptions.
Score (individual response)	Unknown	LC - this effect has not been tested/quantified
POPULATION RESPONSES		
Geographic scope	Unknown whether it currently affects individuals in the population	LC
Score (geographic scope)	Unknown	LC
Effect on population characteristics/resiliency	Given that affects to individuals and their responses are unknown, we have even more uncertainty about how this could translate to population-level response.	LC
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

HARSH SPRING WEATHER/ LATE SNOW MELT		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Weather patterns causing cold temperatures in late May/early June on the ACP	HC
Activities	n/a	n/a
Affected resources	Nest habitat availability, food availability, female body condition	MC
Changes in resources	Snow cover limits the availability of nesting habitat and possibly food during staging and nest initiation period; harsh weather may increase energetic demand of individuals and thus decrease body condition	MC
INDIVIDUAL RESPONSES		
Exposure	All birds present on the ACP during some years.	HC
Immediacy	Annually variable - not every year, and only affects one part of annual cycle	MC
Conservation measures	None - natural phenomenon	n/a
Individual response and effects	Later snow melt/ cold temperatures in the early breeding season may result in: 1) lower breeding propensity; 2) later nest initiation and hatch date; and/or 3) lower body condition of females leading to nest abandonment. These factors have not been measured in Steller's eiders, but Pozdnyakov (2016, p. 94, 101) observed that in cold years, eggs were laid later, clutches were smaller, and nest success was lower even with low predation pressure for Steller's eiders on the Lena Delta, Russia. In other waterfowl species, breeding propensity of snow geese was negatively affected by snow cover in spring (Reed et al. 2004, p. 40-41), and duckling survival and recruitment is negatively related to hatch date for tufted ducks and pochards (Blums et al. 2002, p. 288). It is possible that given their Arctic distribution, Steller's eiders can withstand harsh temperatures and occasional late nest initiation.	MC
Score (individual response)	2: may reduce reproductive success	MC
POPULATION RESPONSES		
Geographic scope	Harsh springs do not occur annually, only a proportion of Steller's eiders nest annually, and Steller's eiders may be able to withstand harsh weather, so we assume it affects < 1% of the population annually.	MC

Score (geographic scope)	1: < 1%	LC - unknown what proportion breeds annually
Effect on population characteristics/resiliency	May result in decreased productivity through lower breeding propensity, nest survival, and/or duckling survival. Harsh spring weather could significantly impact productivity in the year in which it occurs; however, it doesn't occur every year, and we have no data on effects to Steller's eiders.	MC
Score (effect on resiliency)	3: Low	
Overall confidence in analysis	Low	

INCREASE IN NESTING GOOSE POPULATION		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Unknown	LC
Activities	n/a	n/a
Affected resources	Nest and brood rearing habitat, freshwater invertebrate abundance and availability, indirectly affecting fox predation, avian predation, lemming population, shooting and lead shot	LC - little information on the effect of goose abundance on these resources in Arctic Alaska
Changes in resources	High nesting goose population may limit preferred nest habitat of Steller's eiders. In the extreme case of colonial-nesting snow and Ross' geese, grazing altered plant communities significantly (Abraham et al. 2005, p. 272-273). Alisauskas et al. (2006) found that vegetative cover declined with increasing nest density of light geese (p. 203) and that geese have reduced the species richness of the plant community near Karrak Lake (p.204). Ganter et al. (1997) found that the vegetative community within a lesser snow goose nesting colony changed over time, with reduction of <i>Carex-Puccinellia</i> and increase in <i>Salix spp.</i> and bare mud (p. 967). Heavy grazing removed significant amounts of vegetation, and waterfowl generally prefer nest sites with vegetative concealment. These drastic differences in above ground plant biomass from the presence of colonial-nesting geese have been linked to a negative relationship between small mammal abundance and goose numbers (Samelius and Alisauskas 2009, p.97), given that small mammals depend on vegetation for food and cover. Alisauskas and Kellett (2014) suggest that nutrient inputs from geese increase eutrophication of water bodies, resulting in a hyperabundance of invertebrate food for nesting king eiders and their ducklings (p.137); however, this hypothesis has not been tested. In addition, increased numbers of nesting geese may influence nest and brood survival probability through altered predator-prey dynamics. In a review, Flemming et al. (2016) suggest that species can benefit from predator satiation near goose colonies, however these positive effects may be negated by aggressive interactions with geese, and the greater abundance of generalist predators such as gulls and Arctic foxes elevates the risk of nest predation (p. 397 -398). For example, Baldwin et al. (2011) found that cackling geese had higher nest survival probability inside a Ross's goose colony than outside of it (p. 409-410). They suggested that this finding supported the predator swamping hypothesis. However,	LC - some information on the effects of dense goose colonies on resources, but how this applies to goose populations and habitats in Alaska, and specifically how it affects important resources for Steller's eiders, is unknown

	Samelius et al. (2011) demonstrated that geese and their eggs subsidize fox diets such that regional fox populations are larger than could be supported by small mammals alone (p. 1480-1481).	
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders nest sympatrically with greater white-fronted geese and Canada geese on the ACP. Greater white-fronted geese, cackling geese, and emperor geese nest in the central coast zone of the Y-K Delta, where Steller's eiders historically nested. Therefore, Steller's eider adults and ducklings during the breeding season, while in tundra habitats, may be affected by this influential factor.	HC
Immediacy	We currently have very little data to support the hypothesis that sympatrically nesting geese currently affect Steller's eiders – positively or negatively.	LC
Conservation measures	None	n/a
Individual response and effects	Changes to resources from population increases of colonial-nesting geese are extreme examples; density of nesting geese in western, and especially northern Alaska, have not risen as high. However, some of the changes in resources may still be applicable. It is possible that geese, which initiate nests earlier than Steller's eiders, may influence nest site selection, and individuals may choose to nest in non-preferred habitats. Body condition of nesting females and ducklings could be affected by a changing invertebrate community (positive or negative). Lemming and vole populations may decrease in areas impacted by geese, which reduces the population of nesting jaegers and owls, potentially lowering breeding probability of Steller's eiders. Nest predation may be negatively or positively affected by goose numbers.	LC - little supporting information on response and effects
Score (individual response)	Unknown	LC - little supporting information on response and effects
POPULATION RESPONSES		
Geographic scope	Aerial surveys on the central coast of the Y-K Delta indicate significant increases in breeding populations of cackling geese, greater white-fronted geese, and emperor geese from 1985-2017 (USFWS 2017a, p.14-17). Indices derived from aerial surveys on the ACP also show positive trends for greater white-fronted and Canada geese (USFWS, unpublished data). These	MC - moderate confidence in increasing trend of geese on the ACP and Y-K Delta and overlap with distribution of Steller's eiders; very little confidence in the portion of the population that is affected by goose abundance

	<p>increases overlap with current and historical distribution of Steller's eiders during the breeding season. Targeted surveys in other parts of the ACP also show increases in goose abundance. Burgess et al. (2017) documented increasing nest counts of snow geese near Ikpikpuk River delta colony along the Beaufort Sea coast, from approximately 50 nests in the 1990s to over 12,000 in 2015 (1992-2015, p.14), and the colony has expanded in area (p. 16). Also, the greater white-fronted goose molting population in the Teshekpuk Lake Special Area increased geometrically from 1976 - 2005 (Flint et al. 2008, p. 551). However, colonial-nesting geese in numbers like those seen at Ikpikpuk River delta or areas of Canada such as Karrak Lake, do not currently exist in the UT, the area with the highest nesting density of Steller's eiders. Despite observations of increasing goose populations on the ACP, given the uncertainty of whether the effects to resources described for colonial-nesting geese in other areas of the continent are occurring on the ACP, where goose abundance is lower and distribution is more dispersed, and the uncertainty regarding how those effects may impact individual Steller's eiders, we conclude that only a small portion of the northern Alaska Steller's eider population is affected by goose numbers.</p>	
Score (geographic scope)	Unknown	MC - moderate confidence in increasing trend of geese on the ACP and Y-K Delta and overlap with distribution of Steller's eiders; low confidence in the portion of the population that is affected by goose abundance
Effect on population characteristics/resiliency	Unknown how goose population abundance affects demographic rates of Steller's eiders. While high goose populations may influence resources required by Steller's eiders, there is considerable uncertainty about whether the current size of goose populations nesting sympatrically with Steller's eiders in northern Alaska are currently large enough to realize these effects. Therefore, the magnitude of this influential factor is currently low.	LC
Score (effect on resiliency)	Unknown	LC
Overall confidence in analysis	n/a	

MARINE CONDITIONS (North Pacific and Bering Sea)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Combination of climate patterns such as rapid changes in the ecosystem, called regime shifts, in the North Pacific and Bering Sea (Overland et al. 2008, p. 92-93) and global climate change from increased carbon emissions.	HC
Activities	n/a	n/a
Affected resources	Regime shifts may alter phytoplankton, zooplankton, fish (Benson and Trites 2002, p. 100-101), and other bird species (Irons et al. 2008, p. 1461), but the effect on benthic invertebrates in shallow nearshore areas and their predators (i.e., Steller's eiders) has not been measured. Climate change-induced decrease in sea ice in the Bering Sea (Stabeno et al. 2018, p. 3) and/or advection of warm water from the North Pacific into the Bering Sea (Stebano et al. 2018, p. 10-11) to Steller's eider molting and wintering areas along the Alaska Peninsula could have resulted in a decrease in eelgrass biomass and/or marine invertebrate prey associated with eelgrass, used by Steller's eiders.	LC - link between warm water and changes to eelgrass and prey has not been tested
Changes in resources	Decrease eelgrass biomass (Lefcheck et al. 2017, p. 3479 - 3480) and a change in community composition and/or abundance of benthic invertebrates.	LC - link between warm water and changes to eelgrass and prey in Bering Sea lagoons has not been tested
INDIVIDUAL RESPONSES		
Exposure	The entire Alaska-breeding population could be affected during molt, winter, and staging along the Alaska Peninsula; however, the (unknown) proportion of the population that uses areas closest molting/wintering area to the Aleutian passes from the North Pacific to the Bering Sea (Izembek Lagoon) may be most affected by the effects of warm water intrusion on eelgrass beds compared to those farther away.	LC - based on several assumptions
Immediacy	While climate change factors make it more likely for ocean temperatures to continue to increase over time, water temperature may still fluctuate in the Northern Pacific/ Bering Sea rather than reflect a linear relationship with time (e.g., regime shifts; Overland et al. 2008, p. 98-99). Annually variable.	MC
Conservation measures	None	n/a
Individual response and effects	Under the hypothesis that Steller's eiders have a flexible, diverse diet (Section 5), they may be able to shift to other prey items if those prey haven't also been affected by increased water temperature or regime shift. If Steller's eiders are not flexible, then a reduction in prey availability could affect body condition of individuals and lower their	LC - based on several assumptions

	survival probability. Alternatively, they could disperse to other areas during the winter. Although, they have limited ability to move during the fall wing molt, and regime shifts and sea surface temperatures may be at such large scales that movement doesn't alleviate the problem.	
Score (individual response)	2: may reduce reproductive success	Chose 2 rather than 5 because of the uncertainty about the relationship between the influential factor and individual response.
POPULATION RESPONSES		
Geographic scope	Due to the large-scale nature of these factors, the majority of the Alaska-breeding population could be affected. We do not know the proportion of the Pacific-wintering population that uses areas near Aleutian passes/influx of warm North Pacific water rather than areas farther east, or how much of their molting/wintering/staging range may be affected by warm ocean temperatures or shifts in regime. There is evidence that Izembek Lagoon has experienced warmer conditions in recent years (USGS unpublished data), and Maliguine (2024) documents changes in marine invertebrate community composition, biomass, and size coincident with lower numbers of molting Steller's eiders observed using Izembek Lagoon in the recent years where warmer temperatures were observed; however, the author did not investigate the drivers of changes in prey availability or investigate relationships between prey availability and Steller's eider prey selection, survival, or body condition.	LC - based on several assumptions
Score (geographic scope)	Unknown	LC - based on several assumptions
Effect on population characteristics/resiliency	Documented regime shifts in the North Pacific in 1977 and 1989 are correlated with population abundance indices of eiders (king, common, spectacled, and Steller's eiders pooled; Flint 2012, p. 61). Frost et al. (2013) found that the lowest estimate of Steller's eider adult survival, in 1999, occurred immediately after a brief warming event in the Pacific Decadal Oscillation in 1997-8 before it reversed to a cold trend (p.175). If individuals have lower body condition, logically, productivity would decrease; with more extreme changes, survival may be affected. Decreases in survival and recruitment have been reported for other avian species in the Bering Sea (Irons et al. 2008, p.1460). More recently, seabird die-offs in the Bering Sea and Gulf of Alaska have been attributed to the impact of changing oceanic conditions on food availability (USGS 2016). However, we do not have adequate information to characterize effects of shifts in marine condition specifically on Steller's eiders.	LC - based on several assumptions
Score (effect on resiliency)	Unknown	

Overall confidence in analysis	n/a	There is considerable uncertainty throughout this analysis about the links between shifting marine conditions and demographic rates of Steller's eiders.
---------------------------------------	-----	--

HARSH WEATHER (marine)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Weather patterns	HC
Activities	Cold weather in the fall, winter, and spring in marine areas that causes abundant sea ice, wind and cold temperatures. In addition, when high-frequency storm surges are combined with sea ice decline, sea level rise, and high tides, larger waves pose greater risk of coastal erosion. Barrier islands can move, erode, grow, or even disappear; therefore, the effects of coastal erosion can be long-term, everchanging, or unknown.	HC
Affected resources	Increased sea ice may affect the availability of preferred marine invertebrate prey and the availability of stopover/staging sites (particularly during spring migration). Cold temperatures and high winds may also result in higher energetic requirements during the non-breeding season. Harsh storm surges may re-shape or erode the barrier islands that protect the coastline and lagoon systems used by Steller's eiders. Nelson Lagoon is at risk of coastal erosion (Bogardus et al. 2021, p. 8-10), and the area supports the majority of the molting population of Pacific Steller's eiders (USFWS 2016c, p. 7-8). The loss of coastal barriers to wave energy leads to sedimentation into the nearshore environment, which both impacts and modifies the nearshore benthic habitats. In addition, loss of coastal barriers exposes eiders to increased wave action, which may result in higher energetic requirements for eiders during the non-breeding season, especially during molt.	HC
Changes in resources	n/a - cold temperatures, wind and storms are natural phenomena	HC
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders can be exposed to cold air temperatures, winds, and storms in all parts of their annual cycle. Sea ice extent is more likely to affect them during winter and spring staging time periods. Steller's eiders use protected lagoons and embayments during the remigial molt period and require these protected areas to feed, rest, and conserve energy during feather regrowth.	HC
Immediacy	Harsh weather is annually variable - lagoons on the north side of the peninsula do not ice up each year. Also spatially variable, and Steller's eiders are dispersed across a broad area, particularly in the winter and spring.	HC
Conservation measures	none	n/a

Individual response and effects	Harsh weather may impose higher energetic demands on individuals, requiring more food resources. If areas on the north side of the Alaska Peninsula freeze over, then Steller's eiders may be required to move to new areas for foraging and resting on the south side of the peninsula or elsewhere (Laubhan and Metzner 1999, p. 695). This may limit availability of prey resources, although if Steller's eiders are truly generalist foragers, this may be less of a concern than if they are specialists. Higher energetic demands may, particularly if coupled with other stressors, result in mortality or increased risk of predation of adult or immature birds. These effects have not been measured in Steller's eiders.	LC
Score (individual response)	Unknown	LC
POPULATION RESPONSES		
Geographic scope	Entire Alaska-breeding population could be affected by harsh weather in any given year.	HC
Score (geographic scope)	Unknown	HC
Effect on population characteristics	In a year with particularly harsh fall, winter, or spring weather, lower body condition of affected birds could result in population-level effects to immature survival, adult survival, or reduced reproductive effort the following spring. Given that harsh weather does not occur annually and must occur at a high degree to affect population-level demographic rates, this factor is moderate.	LC
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

FISH PROCESSING		
Influential Factor:	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Fish processing	HC
Activities	Dumping fish waste/offal into harbors and marine areas	HC
Affected resources	Marine invertebrates, and effects to individual Steller's eiders	HC
Changes in resources	Marine invertebrate abundance can increase near areas of increased primary productivity resulting from inputs of nutrients from fish processing offal, attracting Steller's eiders (Reed and Flint 2007, p. 130). Steller's eiders can then be exposed to increased contaminant loads, pathogens, and oily residues present in the fish waste and other harbor-related effluents from sewage and small hydrocarbon spills. Alternatively, at high levels of fish processing wastewater outfall, dissolved oxygen reduction can occur because of increased oxygen demand of plankton and microbes, to the point that invertebrate abundance is reduced or dead zones occur (Blaber et al. 2000, p. 597; Hopkins et al. 1995; p. 28-29).	MC
INDIVIDUAL RESPONSES		
Exposure	Five harbors within the range of Pacific-wintering Steller's eiders have fish processing facilities permitted to release processing effluent into marine waters (termed "mixing zones"): Akutan, Unalaska, Sand Point, Chiniak Bay (Kodiak Island), and Chignik Bay (USFWS 2011b, p. 45).	HC
Immediacy	Influential factor continues every year and is expected to continue.	HC
Conservation measures	The Service consulted with Environmental Protection Agency when they oversaw the Alaska Pollutant Discharge Elimination System (APDES) permitting process in 2011 (USFWS 2011b). The consultation included several terms and conditions aimed at minimizing exposure of Steller's eiders to contaminants and other harmful substances associated with mixing zones and conducting research to learn more about the magnitude of the problem (USFWS 2011b, p. 84-85). However, Alaska Department of Conservation has since taken responsibility for APDES permitting and is not bound by the terms of the consultation. They do inform the Service regarding new permits, but whether conservation measures to minimize effects to Steller's eiders are conducted is unknown.	LC
Individual response and effect	Food availability in these areas may increase, leading to increased body condition. However, E. coli prevalence was higher in a harbor where a large fish processing plant disposes of fish waste (Unalaska) vs. a reference site without fish waste effluent (Izembek Lagoon) in Alaska. 29% of the E. coli isolates found in Steller's eiders were potentially pathogenic (Hollmén et al. 2010, p.2-3). Based on biochemical markers, health of approximately 5% of the local population of Steller's eiders at	LC

	Unalaska Bay was impacted by E. coli exposure (Hollmén et al. 2010, p. 4, 7). See Cause/Effects: Contaminants for summary of effects of contaminants and hydrocarbons. In summary, toxicity data for contaminants is lacking for most sea ducks, and the effects of specific concentrations/exposures to these metals are unknown (Franson 2015, p.170, 205). Captive Steller's eiders show biochemical responses to hydrocarbon exposure (Miles et al. 2007, p. 2701), but effects of exposure at levels in the wild to reproduction and survival are unknown.	
Score (individual response)	Unknown	LC - has not been measured
POPULATION RESPONSES		
Geographic scope	Overall, mixing zones overlap with less than 1% of Steller's eider habitat (USFWS 2011b, p. 66). But using aerial survey data, USFWS (2011b) estimated that 30% of Pacific-wintering Steller's eiders winter in water bodies with mixing zones where fish processing effluent is discharged and concluded, based on the assumption that Alaska-breeding Steller's eiders are equally distributed throughout the wintering range, that 30% of birds in the Alaska-breeding population are exposed to one or more mixing zones during the winter annually (p. 66-67). The number of birds that are negatively affected by this exposure, however, is unknown. We assume that not all individuals will realize measurable effects, thus less than 30% are affected.	LC
Score (geographic scope)	2: 1-25%	LC
Effect on population characteristics/resiliency	Effects to population demographic rates of exposure to contaminants, hydrocarbons, and/or pathogens originating from mixing zones are unknown.	LC
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

SHOOTING (marine)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Incidental and intentional shooting of Steller's eiders during migration, staging, molt, and winter periods. These activities are regulated under the Service and Alaska Department of Fish and Game sport hunting regulations from Sept 1 - March 31 and the spring/summer Subsistence Harvest regulations from April 1 - August 31 annually.	HC
Activities	Incidental and intentional shooting of Steller's eiders	HC
Affected resources	Direct effect on individuals	HC
Changes in resources	n/a	HC
INDIVIDUAL RESPONSES		
Exposure	Shooting of adult and juvenile Steller's eiders may occur along migration corridors and in staging areas near hunting areas and villages as well as throughout wintering areas in southwest Alaska. Incidental harvest during sport hunting is probably limited to areas where other sea ducks are targeted, such as Kodiak Island, Izembek NWR/Cold Bay, Adak, and St. Paul Island.	MC
Immediacy	Shooting of Steller's eiders by sport hunters has been documented by Service law enforcement (USFWS 2018b, p. 58). Harvest surveys are not adequate to sample take of rare species in remote areas, and law enforcement efforts cannot cover the wide, remote distribution of wintering and staging Steller's eiders; therefore, there is almost certainly additional unreported take of Steller's eiders by hunters (p. 58). The Service's Biological Opinion on the 2016-2019 migratory bird sport harvest regulations estimates that approximately 24 Pacific-wintering Steller's eiders are taken annually, but as the Alaska-breeding population makes up only a small proportion of the Pacific-wintering population (0.7%, p.59), they expect less than one listed individual is taken annually. Assuming this analysis is correct, we believe mortality of Alaska-breeding Steller's eiders from shooting during the non-breeding season is annually variable and may not occur every year.	LC - We cannot accurately and precisely quantify the amount of shooting of Steller's eiders given the available information.
Conservation measures	Following identification of 24 Steller's eiders taken by sport hunters in Kodiak in 2002-2003 season, the Service implemented education and law enforcement to reduce the likelihood of take of listed eiders during the sport hunting season (p.59). It is unclear if these measures are still being conducted. Service	LC - It is unknown how effective the regulations and conservation measures are at minimizing the amount of shooting that

	outreach and law enforcement efforts on the ACP, particularly at Utqiagvik, may decrease the probability that Steller's eiders are taken during both the spring/summer and migration and staging periods there (USFWS 2018b, p. 6-7).	occurs, as it is difficult to monitor take (USFWS 2018b, p. 36-38).
Individual response and effects	Dead or injured birds	HC
Score (individual response)	2: mortality, but likelihood is low, so scored it as "may reduce survival"	HC
POPULATION RESPONSES		
Geographic scope	Steller's eiders from the Alaska-breeding population are vulnerable to shooting in northern and western Alaska during spring and fall staging and migration. Less than 1% of the Alaska-breeding population is likely to be affected by shooting annually in the molting and wintering areas. Considering both of these situations, we believe it is reasonable to assume that less than 1% of the population is shot during the non-breeding season annually.	LC - based on several assumptions because of lack of monitoring data
Score (geographic scope)	1: < 1%	LC
Effect on population characteristics/resiliency	Mortality of 1% of the population annually could have a significant effect on population growth rate, depending on whether immigration from Russia subsidizes the population and the level of productivity in a given year.	LC
Score (effect on resiliency)	While mortality earns a score of 5 for individual response, we believe that shooting of a listed Steller's eider occurs very rarely during the non-breeding season. Therefore, the effect on resilience is low.	
Overall confidence in analysis	Low confidence	

PREDATION (marine)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Avian predators, primarily bald eagles and gyrfalcons	HC
Activities	n/a	n/a
Affected resources	Direct effect on adult and juvenile Steller's eiders	HC
Changes in resources	n/a	n/a
INDIVIDUAL RESPONSES		
Exposure	All Steller's eiders are likely exposed to some risk of predation by avian predators during the non-breeding season. They may be more at risk during molt, when their only escape is to dive and they may have energetic limitations. Fish processing outfall areas could expose Steller's eiders to higher predation rates due to large bald eagle populations concentrated near processing plants (Reed and Flint, p. 130).	LC
Immediacy	Mortality from avian predators in marine areas probably occurs on an annual basis.	MC
Conservation measures	none	n/a
Individual response and effects	Steller's eiders tend to fly up at approach of a bald eagle or gyrfalcon in spring in southwestern Alaska (McKinney 1956, p.285), and they have a strong tendency to flock densely (p.289). These behaviors may have affected feeding, pairing, and breeding patterns (p.289). Bald eagles and gyrfalcons have been observed killing Steller's eiders in wintering areas (Reed and Flint 2007, p. 130; McKinney 1956, p. 287).	HC
Score (individual response)	5: mortality	HC
POPULATION RESPONSES		
Geographic scope	All of the Alaska-breeding population likely encounters avian predators, but based on very limited information/observations, we believe it is reasonable to assume that 1% or less of the population dies as a result of predation in the marine environment annually.	LC
Score (geographic scope)	Unknown	LC
Effect on population characteristics/resiliency	Adult survival and female survival, has a large effect on the population growth rate of sea ducks (Flint 2016, p. 72). However, given that we don't know the true rate of mortality or the population growth	LC - based on assumptions

	rate, it is impossible to know the effect of predation on the population. One can speculate that if mortality is less than 1%, the effect may not be significant, particularly if productivity or immigration strongly influence population dynamics.	
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

DISTURBANCE (marine)		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Human disturbance in areas used during the non-breeding season	HC
Activities	Vessel traffic, hunting activity, road development at Izembek NWR, other unknown development/activities	HC
Affected resources	Food availability (marine invertebrates)	LC - linkages between disturbance and effects to resources and Steller's eiders have not been tested
Changes in resources	Disturbance may affect access to food (marine invertebrates); repeated disturbance may impact the quality of stopover/staging site, and possibly disperse large flocks.	LC - linkages between disturbance and effects to resources and Steller's eiders have not been tested
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders are most likely to encounter marine vessel traffic near harbors and fish processing facilities such as those on Kodiak Island and Dutch Harbor. In addition, disturbance from hunting is most likely to occur at Cold Bay/Izembek Lagoon and Kodiak Island, where significant waterfowl sport hunting occurs, and during subsistence hunting activities such as seal hunting, in areas accessed by hunters from local villages. Eiders are particularly vulnerable to disturbance during pre-migration staging in spring and molt in the fall, when they may be limited to certain habitats.	LC
Immediacy	Human disturbance has, does, and will continue to occur, but is undocumented for Steller's eiders in marine areas. Frequency of disturbance is probably very low in unpopulated areas and higher in areas with more human activity. Disturbance is usually a one-time, isolated, and very short-lived event. While intermittent, disturbance events are likely to persist or even increase in some areas; for example, if a road is constructed through the isthmus between Kinzarof and Izembek Lagoons, used by Pacific-wintering Steller's eiders during the non-breeding season (USFWS 2013d, p. 4-187).	LC
Conservation measures	No known conservation measures.	LC
Individual response and effects	Disturbed molting, wintering, staging birds may cease resting or feeding behaviors or move to areas with lower quality/quantity of food, increasing energy expenditures. Disturbance	LC - linkages between disturbance and effects to

	may disperse flocks, which could increase predation rates. These may, in combination with other factors, reduce breeding probability, success, or survival of individuals.	resources and Steller's eiders have not been tested
Score (individual response)	Unknown	LC
POPULATION RESPONSES		
Geographic scope	Steller's eiders generally molt, winter, and migrate in remote areas. The amount of human disturbance to the listed population during the non-breeding season is unknown.	LC - based on untested assumptions
Score (geographic scope)	Unknown	LC
Effect on population characteristics/resiliency	Possibly reduced breeding propensity, productivity, or survival, particularly if disturbance is frequent and in conjunction with other physiological stressors such as severe weather, low food abundance, high numbers of predators, disease, or contaminants. Low, because only a small portion of the population is likely to be disturbed during the non-breeding season, effects of disturbance are temporary and isolated, and it is unlikely to measurably impact demographic rates	LC
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

DISEASE, PARASITES and TOXINS		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Naturally occurring diseases, parasites, and toxins	HC
Activities	n/a	HC
Affected resources	Direct effect on individuals	HC
Changes in resources	n/a	HC
INDIVIDUAL RESPONSES		
Exposure	<p>Steller's eiders could be exposed to a variety of viruses; for example, reoviruses (T Hollmén, unpubl. data, cited in Hollmén and Franson 2015, p. 101) and avian influenza (AI). Prevalence of AI viruses in Steller's eiders sampled at Izembek and Nelson Lagoon was 0.2% and 3.9%, respectively (Ramey et al. 2011, p.1816). Ramey et al. (2011) postulate that differences in prevalence between Izembek and Nelson could be habitat related - Steller's eiders preen and roost above high tide line at Nelson rather than exposed mudflats at Izembek, and the species composition differs (p.1820). Frequency of birds testing positive for AI antibodies in serum (evidence of current or previous infection) was higher than the frequency of birds shedding the virus (Wilson et al. 2013) in Alaska. Antibodies to AI viruses were detected in serum samples of 86% of eiders (common, spectacled, and Steller's combined; Wilson et al. 2013). Low pathogenic influenza viruses likely circulate naturally in sea duck populations, and no highly pathogenic viruses have been isolated from Steller's eider samples to date (Hollmén and Franson 2015, p. 102-104). In addition to viruses, Steller's eiders could be exposed to parasites, bacteria, algal toxins, and fungi, but likelihood of exposure varies by cohort, distribution, and other factors. Bustnes and Galaktionov (2004) found that wintering juvenile Steller's eiders in Norway, which were in poorer body condition than adults, had a significantly higher parasite load than adult Steller's eiders (p.1568). E. coli prevalence was higher at an industrial site (Unalaska, 16%) vs. a reference site (Izembek Lagoon, 2%) in Alaska, and 29% of the E. coli isolates found in Steller's eiders were potentially pathogenic (Hollmén et al. 2010, p.2-3). Based on biochemical markers, health of approximately 5% of the local population of Steller's eiders at Unalaska Bay was impacted by E. coli exposure (Hollmén et al. 2010, p. 4 and 7). Occasional deaths and health effects from algal toxins present in bivalves have been documented in sea ducks, although no known cases in Steller's eiders</p>	<p>LC; with the exception of avian influenza in the mid-late 2000s, very little disease and parasite screening has been conducted on Steller's eiders.</p>

	(Landsberg et al. 2007, in Hollmén and Franson 2016, p. 113-114). Some serologic evidence supports exposure to Aspergillus fungal spores in Steller's eiders (Hollmén, unpublished data cited in Hollmén and Franson 2016, p. 109).	
Immediacy	The timing and frequency of exposure to disease, toxins, and parasites are unknown. Exposure may occur once, or may occur annually if disease, parasites, or toxins are associated with particular locations or habitats.	LC
Conservation measures	None; although some monitoring done prior to reintroduction of Steller's eiders on Y-K Delta and occasional, opportunistic sampling done with other waterfowl in Alaska, particularly focused on AI.	HC
Individual response and effects	Effects of various disease and parasites to Steller's eiders has not been evaluated. Exposure may result in a one-time, temporary effect to individuals, or the effect may be chronic (e.g., parasites), affecting future reproductive potential and survival.	LC
Score (individual response)	2: may affect reproductive success or survival	LC
POPULATION RESPONSES		
Geographic scope	The entire population could be exposed to various diseases, parasites, and toxins; however, we don't know how many individuals are actually affected annually. Given their remote and marine distribution, we may be unlikely to detect population-level mortality events.	LC
Score (geographic scope)	Unknown	LC
Effect on population characteristics/resiliency	Studies on population-level effects of disease and parasites on sea ducks are lacking (Hollmén and Franson 2016. p. 98).	LC; high uncertainty on both individual and population-level effects of disease, parasites, and toxins.
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

COLLISIONS		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Man-made structures such as light poles, buildings, drill rigs, wind turbines, offshore oil facilities, guyed towers and poles, overhead power lines, and marine vessels.	HC
Activities	Building these structures	HC
Affected resources	Direct effect to individuals	HC
Changes in resources	n/a	n/a
INDIVIDUAL RESPONSES		
Exposure	Steller's eiders can collide with manmade structures located on the tundra breeding grounds, along migration routes, and in wintering areas. Areas with human development, such as near Utqiagvik and Prudhoe Bay, have more structures and overhead power lines; therefore, exposure to birds that use those areas during breeding season have a greater risk of exposure. Vessel traffic density is high along the coast of the Alaska Peninsula and Aleutian Islands (Silber et al. 2021, p. 182-183), in the known non-breeding range of Steller's eiders.	LC - because risk likely varies annually based on various factors, there is uncertainty in the exposure risk of individuals
Immediacy	Near Utqiagvik, opportunistic observations and reporting have documented multiple power line strike mortalities of Steller's eiders from 1991-2018 (USFWS, unpublished data). Annual variation in eider density and distribution, weather, lighting conditions, and structure configurations, such as the presence/absence of guy wires, affect the level of collision risk (Longcore et al. 2008, p. 486-489). Anderson and Murphy (1988) monitored bird behavior and strikes to a 12.5 km power line in the Lisburne area (the southern portion of the Prudhoe Bay oil fields) during 1986 and 1987. They documented line strike mortality in 18 different species of birds, including at least one eider (ABR, Inc. 1988, p. 37). Results indicated strike rate was related to flight behavior, in particular the height of flight (ABR, Inc. 1988, p.22). Similarly, ABR, Inc. (2003) estimated the mean flight altitude of 1.8 m, and maximum flight altitude of 15 m, for eider species flying past St. Lawrence Island, Alaska, in the fall (p. 14-15), and ABR, Inc. (2005) estimated the mean altitude of eiders during the day at 5.9 m, and night at 16.7 m, near Northstar Island in the Beaufort Sea during fall migration (p.81). This tendency to fly low puts eiders at risk of striking even relatively low objects in their path. However, ABR, Inc. (2003) observed all eider movements over the ocean during fall migration in the Beaufort Sea, rather than land, making it	LC - While collisions are possible and have been documented in the past, the timing, frequency and rate of collisions for Steller's eiders are unknown.

	<p>potentially less likely for eider strikes on structures on land during migration and winter (p. 9), and some ducks and geese alter flight paths to avoid offshore installations (Desholm and Kahlert 2005, p. 2). In marine areas, encountering bright lights in conjunction with large structures such as buildings or fishing boats, particularly during storm or foggy conditions, increases collision risk. Examples of bird strikes on marine vessels in published literature include: Black (2005) reported a single event with 899 seabirds striking a vessel in the Southern Ocean (p. 67). Dick and Donaldson (1978) reported a similar event with crested auklets in the north Pacific Ocean (p. 235). Both incidents involved large fishing vessels lighted at night, causing the birds to become disoriented and land or collide with vessels. Additionally, USFWS (2007b) documented several reports of Steller's eiders in the Pacific-wintering population colliding with marine vessels from 1980 - 2003 (p.23-24).</p> <p>In summary, mortality rate of Steller's eiders due to collisions is difficult if not impossible to reliably quantify. It is likely that some mortality occurs annually due to collisions, but the rate is annually variable and dependent on many interacting factors.</p>	
Conservation measures	Some power lines in Utqiagvik have been marked with diverters. The Service conducts Section 7 consultations on most ACP development and works with agencies to design structures and lighting to minimize collision risk.	LC - Effectiveness of these measures has not been quantified.
Individual response and effects	Collisions cause immediate mortality, injury leading to death, or temporary injury.	HC
Score (individual response)	5: mortality	HC
POPULATION RESPONSES		
Geographic scope	While some fishing vessels, power lines, communication towers, and wind turbines exist in Alaska-breeding Steller's eider migration, staging, molting and wintering habitat, the vast majority is devoid of such structures. However, the portion of the Alaska-breeding population that breeds near Utqiagvik (1/3) is subject to a greater risk of power line strikes (Section 6.4.2.). Although the collision rate is unknown, it is unlikely that all birds using habitat near Utqiagvik will collide with power lines in any given year - such mortality events would be observed given the level of research and human activity in the area. Thus, we assume that 1% or less of the Alaska-breeding population may be subject to collisions in any given year.	LC
Score (geographic scope)	1: 1% or less	LC

Effect on population characteristics/resiliency	It is very difficult to measure the population level effect of collisions, given the potential biases in observational studies estimating collision rates, including crippling and nocturnal biases (Murphy et al. 2016, p. 314-315), and scavenger and observer biases (Ponce et al. 2010, p. 606-607). Little quantitative information is available for collisions in Alaska, and information on mortality rates associated with collisions throughout North America remains uncertain (review by Ronconi et al. 2015, p. 36). Given that we think 1% or less of Alaska-breeding population is subject to collisions annually, we think the effect of collisions to population demographics is negligible. However, annual variation collision rate, or unobserved collision events, or collisions in combination with other stressors, could rise to a population-level effect.	LC - Little to no supporting information on population-level effects of collisions to the Alaska-breeding population of Steller's eiders.
Score (effect on resiliency)	6: Moderate	
Overall confidence in analysis	Low confidence	

CONTAMINANTS		
	Analysis	Confidence Level/Description of Uncertainties
Source(s)	Contaminants such as heavy metals (e.g., Se, Hg, Cd, Cu), hydrocarbons, and persistent organic pollutants (POPs) are produced by industrial activities around the globe and distributed into the environment through atmospheric, marine, and freshwater pathways (Lovvorn et al. 2013, p. 256-258). Sources can also be local, such as small oil spills at harbors or release of wastewater effluent into marine areas, or natural, such as oil seeps (Franson 2015, p. 169 and references therein; USGS 2024, p. 7). Note that essential trace elements also occur naturally in the environment.	HC
Activities	Extracting and burning fossil fuels, smelting, manufacturing, other industrial activities; hydrocarbon spills in marine or terrestrial environments.	HC
Affected resources	Contamination of food, affecting individual birds when consumed. Direct exposure of individuals to hydrocarbons - inhalation or external contamination of feathers.	HC
Changes in resources	Habitat or food is contaminated.	HC
INDIVIDUAL RESPONSES		
Exposure	The primary mode of exposure is through ingestion of a contaminant or external contamination after coming in contact with the substance. The secondary mode of exposure is ingesting prey items that have contaminants in their tissues (Franson 2015, p. 170). Given that Steller's eiders are considered generalized feeders (section 5), individuals should be less vulnerable to secondary contaminant exposure than more specialized feeders or those that consume prey items such as fish that are higher in the food chain and thus bioaccumulate more contaminants (Franson 2015, p. 171-172). However, bivalves, one type of prey used by Steller's eiders, can have high concentrations of both heavy metals and organic contaminants (Franson 2015, p. 171). Sea ducks seem to accumulate higher concentrations of trace elements than freshwater birds (Franson 2015, p. 197-198). While Steller's eiders could be exposed to local sources of trace elements during the breeding season, particularly near Utqiagvik or near oil development in NPR-A, most	MC - Available information on exposure rates of Steller's eiders in many parts of their distribution and over time is limited.

exposure to trace elements probably occurs in marine areas used during the non-breeding season (Miller et al. 2016, p. 304; Lovvorn et al. 2013, p.250). Miller et al. (2016) found low levels of Se, Cd, and Cu in Steller's eiders sampled from near Utqiagvik and attributed this partially to their high mass-specific metabolic rate and long migration relative to other sea duck species (p.307). While female Steller's eiders sampled from Utqiagvik had higher Hg than female long-tailed ducks, levels were still below a conservative hepatic toxicity threshold (Miller et al. 2016, p. 303). In general, other eider species had higher concentrations of trace elements than Steller's eiders collected in Alaska and Russia during the summer, with the exception of Se (Stout et al. 2002, p. 218-219, 221). Nearly all Steller's eiders sampled had liver concentrations of Se that could affect reproduction (Stout et al. 2002, p.224). Steller's eiders can be exposed to hydrocarbons in areas of industrial activity or shipping, such as boat harbors during the winter along the Alaska Peninsula (Reed and Flint 2007, p. 130) or Kodiak Island, or from oil spills in terrestrial or marine areas. Petroleum hydrocarbon levels in sediments, water, and blue mussels in Nelson Lagoon were similar to other non-industrialized marine areas in Alaska, with exception of benzo(a)pyrene, which was detected in 40% of blue mussels, one prey of Steller's eiders (Lance et al. 2012, p.2132-2133). High concentrations of polycyclic aromatic hydrocarbons were found in blue mussels at Dutch Harbor, and Steller's eiders sampled in southwest Alaska showed evidence of exposure to an array of organic contaminants in bays with commercial fishing and maritime activity (Miles et al. 2007, p.2700, 2702). However, areas with fishing and industrial activity comprise a small portion of the habitat used by Pacific-wintering Steller's eiders, and less than 1% of the Pacific-wintering population consists of birds from the northern Alaska breeding population. Most POPs in Arctic environments are from atmospheric transport and are typically biomagnified through the food chain (Franson 2015, p. 209-210); it is possible that Steller's eiders could be exposed to POPs during any part of their annual cycle. Organochlorines were below toxic thresholds in liver and kidney samples of STEI collected in 1991-1995 (Stout et al. 2012, p.217). Franson et al. (2023, p. 42) evaluated exposure of Steller's eiders to trace elements and compared trace element concentrations in blood of Steller's eiders sampled at the industrialized wintering area of Dutch Harbor (in February 2001) to

	<p>Steller's eiders sampled at a reference site, Izembek Lagoon, on the lower Alaska Peninsula (in September 2001). They detected 17 trace elements in blood of one or more Steller's eiders (Franson et al. 2023, p. 43); mean concentrations of six trace elements (As, B, Fe, Hg, Se, and Mo) were greater in wintering Steller's eiders at Dutch Harbor than in those molting at Izembek Lagoon, and mean concentrations of four trace elements (Cr, Cu, Mg, and Zn) were greater in eiders at Izembek Lagoon than at Dutch Harbor (p. 43). Authors suggested that the temporal differences in sampling could have played a role in differences in trace element concentrations, particularly for Se, which was twice as high in eiders at Dutch Harbor than Izembek Lagoon (p. 45). One Steller's eider from Dutch Harbor (and one harlequin duck) had blood Pb levels above background concentrations (> 0.2 µg/g wet weight), and Pb was detected in 95.6% of eiders at Dutch Harbor compared to 30% of eiders at Izembek Lagoon (p. 46). Overall, Franson et al. (2023) found greater exposure to several trace elements in Steller's eiders at Dutch Harbor than at Izembek Lagoon, but the authors had no reason to suspect that concentrations found may be associated with adverse effects (p. 47).</p>	
Immediacy	<p>Individual Steller's eiders have been shown to be exposed to trace elements, hydrocarbons, and POPs, but there is limited evidence showing that any of these contaminants occur at toxic levels for the species. Cumulative or synergistic effects of repeated exposure of individuals near industrial sites may be of concern.</p>	LC
Conservation measures	<p>Some opportunistic monitoring of contaminants occurs but not in a systematic way (USFWS, unpublished data). New development in Steller's eider habitat is likely to undergo Section 7 consultation that should include measures to minimize contamination of habitat. Federal and state agencies coordinate to prepare for and respond to hydrocarbon spills. Many POPs have been banned for use in developed countries (Franson 2015, p. 209).</p>	HC that these conservation measures are in place; LC that they are effective at minimizing the risk of contaminants given the uncertainty in the level of risk for Steller's eiders and that heavy metals seem to be naturally high in marine species (therefore, there may be no way to reduce exposure).
Individual response and effects	<p>Toxicity data for contaminants is lacking for most sea duck species, and the effects of specific concentrations/exposures to these metals are unknown (Franson 2015, p.170, 205). Variation in individual responses to contaminant exposure would be expected due to body condition and normal seasonal changes in physiology related to reproduction, migration, and feather molt (Franson 2015, p. 172). Trust et al. (2000) found that spectacled eiders with high concentrations of heavy metals</p>	MC - even less information is available regarding the effects of exposure on individuals.

	had subtle biochemical changes (p. 110) but were in apparent good health. It is possible that the biochemical changes could lead to poor body condition, possibly leading to lower reproductive capacity (Trust et al. 2000, p. 112). How Steller's eiders compare to spectacled eiders in that regard is unknown. Captive Steller's eiders show biochemical responses to hydrocarbon exposure (Miles et al. 2007, p. 2701), but effects of exposure at levels in the wild to reproduction and survival are unknown. Sea ducks may have higher tolerance to trace elements or other contaminants than freshwater species because of the ionic rich marine environment in which they spend the majority of their life cycle.	
Score (individual response)	2 - may reduce breeding success or survival	MC
POPULATION RESPONSES		
Geographic scope	<p>In summer of 2024, an unknown release of oil was identified in a tundra lake that drains into Avak Creek, near Utqiagvik, where the highest concentrations of Alaska-breeding Steller's eiders nest. The location of the oil occurrence was a few miles south of the UG survey area. The USGS investigated the source of oil exposure and proposed that the oil originated from natural seeps that leaked from underground reservoirs (USGS 2024, p. 1, 7). Although there was no evidence of Steller's eiders affected by this incident in 2024, this oil occurrence event presents concerns for future oil contamination originating from natural seeps in the core breeding area for Alaska-breeding Steller's eiders as permafrost thawing continues.</p> <p>While Steller's eiders are most likely to be exposed to trace elements while foraging in marine areas, and a small portion of the population (1-25%) may molt and/or winter near harbors or other areas with elevated levels of hydrocarbons, evidence showing effects of exposure to reproduction or survival of Steller's eiders is lacking. Thus, given the available information, we suspect that 1% or less of the northern Alaska subpopulation is significantly affected by trace elements, hydrocarbons, and/or POPs in the marine environment.</p>	LC - based on a series of assumptions due to lack of data on exposure rates and response.
Score (geographic scope)	Unknown	
Effect on population characteristics/resiliency	Possible reductions in survival or reproductive rate, in combination with other stressors. However, we expect that levels of exposure that may	LC - based on a series of assumptions due to lack of data on exposure rates and response.

	significantly impact survival or reproduction affects 1% or less of the population.	
Score (effect on resiliency)	Unknown	
Overall confidence in analysis	n/a	

Appendix E. Status of the Pacific-wintering population of Steller's eiders

Appendix E was added to SSA version 2.0 to provide additional information on the larger Pacific-wintering population (PWP) from work that has been conducted. The revised Recovery Plan (USFWS 2021, entire) describes demographic criteria that should be met for the PWP to assess recovery of the listed population of Alaska-breeding Steller's eiders, as the status of the PWP provides an additional measure of resiliency of the listed population (see also Section 6.2.4). In addition, this appendix summarizes information on the Pacific Russian-breeding population from Russian-published articles that are not accessible in English.

Population status and distribution

Conservation status of Steller's eiders in Russia

Both Pacific and Atlantic populations of Steller's eiders breed in Russia and are declining in numbers. While Steller's eider had been listed in regional Red Books in the Sakha Republic (Yakutia), Chukotka Autonomous Okrug, and Kamchatka, Russia, only recently was it listed at the national level; the species was listed by the Russian Federation in their national Red Book on April 2, 2020, with the category 2 status: decreasing in numbers and/or distribution (The Ministry of Natural Resources and Environment of the Russian Federation 2021, p. 42-43). However, the Steller's eider is ranked at the lowest category, 3, for the degree and priority of environmental measures taken and planned for adoption in the current Red Book. The 3rd priority category suggests that the general measures provided for by regulatory legal acts of the Russian Federation in the field of environmental protection, the organization, protection and use of specially protected natural areas, and the protection and use of fauna and its habitat are sufficient to preserve the listed species (The Ministry of Natural Resources and Environment of the Russian Federation 2021, p. 8-12). Therefore, while Steller's eiders are decreasing in numbers across Russia, limited protection and conservation measures are in place.

Population and trend

Of the whole PWP of Steller's eiders, the Pacific Russian-breeding population represents ~99% of the population (Hodges and Eldridge 2001, p. 134-135). While aerial surveys have occurred annually for counting Alaska-breeding Steller's eiders on the ACP of Alaska, limited surveys have occurred since 1995 to estimate the population size of Pacific Russian-breeding Steller's eiders. Hodges and Eldridge (2001, p. 128-131) flew aerial surveys to count breeding eiders and other waterbirds in Russia between the Lena River Delta and Cape Schmidt coast in years 1993-1995. Steller's eiders were the second most abundant breeding species detected after spectacled eiders, and were common throughout the survey area. Steller's eiders were mostly concentrated from the Indigirka River delta to the Yana River delta (Hodges and Eldridge 2001, p. 132). Between 1993-1995, the minimum size of the Pacific Russian-breeding population was estimated to be 128,760 Steller's eiders (CV = 0.13) (Hodges and Eldridge 2001, p. 133). The Service recently collaborated with Russian biologists to replicate this aerial survey effort between 2019-2021, but population estimates are not available. Preliminary findings from aerial

surveys in northern Yakutia and Chukotka between 2020-2021 found relatively low numbers of breeding Steller's eiders (Rogacheva et al. 2021, p. 594-596).

Fall surveys in Alaska

The Service's Alaska Region Migratory Bird Management (MBM) office has conducted annual fall aerial surveys in the Izembek Lagoon complex (Izembek and Kinzarof Lagoons and Bechevin and Morzhovoi Bays), Alaska. The survey provides an annual index of the entire post-breeding Pacific brant population, and Steller's eiders are incidentally observed and counted. The surveys are conducted between 23 September and 31 October, when most brant occur in Izembek Lagoon (USFWS 2019a, p. 3), overlapping with the timing that adult Steller's eiders would molt in the lagoon. The long-term (1976-2022) fall population of Steller's eiders at Izembek Complex indicates a decreasing trend of 5.5% per year (growth rate: 0.945, 95% CI: 0.936 - 0.955, R^2 : 0.76) (USFWS unpublished data). While the timing of fall aerial surveys conducted at Izembek Lagoon (i.e., Steller's eider molting surveys, Pacific black brant surveys) is variable among years and between surveys, the numbers of eiders observed in recent years are greatly reduced compared to the 1980s (Petersen 1981, p. 258; Metzner 1993, p. 45; USFWS 2016c, p. 8; USFWS 2019a, p. 6, 11), suggesting potential changes in the fall molting distribution of Steller's eiders and/or population declines.

The Yukon Delta National Wildlife Refuge (YDNWR) conducted aerial surveys in 2020-2021 and 2024 to provide an index count of the number of molting Steller's eiders at the Kuskokwim Shoals (USFWS 2020b, p. 1-2; USFWS 2022, p. 1-2; USFWS unpublished data); previous molting surveys of the Kuskokwim Shoals were conducted in 1996, 2000, 2001, and 2005 by MBM and 2013 by YDNWR (USFWS 2022, p. 1). In 2020, approximately 4,300 Steller's eiders were observed in mid-September (USFWS 2020b, p. 3); in 2021, the survey was flown twice, in late-August and in mid-September, in which approximately 850 and 3,600 Steller's eiders were counted, respectively (USFWS 2022, p. 3). Steller's eider counts in 2020 and 2021 were similar to counts in 1996, 2000, and 2001 (USFWS 2020b, p. 3; USFWS 2022, p. 4). The highest number of Steller's eiders was observed in 2024 and consisted of approximately 21,000 individuals, in which at least half of the eiders were flighted, and most birds were concentrated around the eelgrass beds on the east side of Kwigluk Island (USFWS 2024f, p. 3-4). The 2024 count was much higher than recent surveys in 2020 and 2021, though it is possible delayed arrival of migrants to the Alaska Peninsula may have played a factor in the high numbers at the Kuskokwim Shoals (USFWS 2024f, p. 3-4). Previously, the highest count at the Kuskokwim Shoals was observed in 2005, where a minimum of 11,000 Steller's eiders were observed along the southwest coast of the Y-K Delta, including along the barrier islands southwest of Kipnuk (B. McCaffery, retired USFWS Biologist, pers. comm.).

While these above-mentioned molting surveys document annual indices of Steller's eiders at important molting locations, these surveys do not provide inference on the abundance or trend of the larger PWP of Steller's eiders in Alaska due to the restricted geographical range of the surveys. However, Steller's eider surveys have occurred during the molting period across multiple locations along the Alaska Peninsula with objectives to estimate population size of the PWP (see Section 6.2.4).

Winter surveys

While there are no ongoing projects that monitor the wintering population of Steller's eiders in Alaska, the Service's Alaska Region MBM office has conducted annual wintering brant surveys in the Izembek Lagoon complex and the Sanak Islands, Alaska, where Steller's eiders are incidentally observed and counted. The survey provides an index count of Steller's eiders for the surveyed area, although the wintering range of Steller's eiders spans beyond the Izembek region (from Cook Inlet through the Aleutian Islands), and thus, inferences about the larger Pacific population from this survey alone are not possible (USFWS 2024c). In addition, the number of eiders observed may vary with annual changes in percent ice coverage and timing of surveys. Recent surveys counted on average between 19,000–27,000 eiders over the last few winters (2020-2024; USFWS 2020a, p. 5; USFWS 2021a, p. 4; USFWS 2024a, p. 4; USFWS 2024b, p. 4; USFWS 2024c, p. 4), and the long-term mean count (1981-2024, excluding 1982-1987, 1997) of Steller's eiders in the survey area is 20,100 (CI: 17,666-24,252; USFWS 2024c, p. 5). Therefore, the contemporary wintering population of Steller's eiders in the vicinity of Izembek Lagoon and the Sanak Islands are near or above the long-term average of eiders counted during the survey.

Ecology

Russian-Pacific breeding population of Steller's eiders

Nesting data on Pacific Steller's eiders on the Lena River Delta, Russia, have been collected during 1992-2008, 2010, and 2013-2018, largely at Sagastyr (73°25'N, 126°35'E, Table 1) and Nerpallaakh (72°53'N, 129°22'E, Table 2) islands (Solovieva 1999, p. 26-28; Pozdnyakov 2016, p. 81-82; Pozdnyakov 2022, p. 263-264). Steller's eiders are the last of the delta-breeding birds to arrive, and timing of arrival varies significantly from year-to-year depending on snowmelt (Pozdnyakov 2016, p. 85). The highest concentrations of nesting Steller's eiders are observed in polygonal-ridge marshy coastal tundra within 20-30 km of the coast (Pozdnyakov 2016, p. 88). In the Lena Delta, Steller's eiders most often form sparse colonies of several dozen nests, but they also nest solitary or in smaller clusters (e.g., 2-3 pairs; Pozdnyakov 2016, p. 88). Steller's eiders nest annually in places where large colonies are formed, but the nesting population varies greatly from year to year (Pozdnyakov 2016, p. 88). Solovieva (1999, p. 46) suggested that the main criterion for nesting Steller's eiders is the presence of nests of protecting species, such as the pomarine jaeger. While high densities of nesting Steller's eiders have been observed around pomarine jaeger nests (Solovieva 1999, p. 46-47; Pozdnyakov 2016, p. 91), Steller's eiders do not always nest near pomarine jaeger nests, and Steller's eiders have bred in significant numbers in years where no jaegers nested at all (Pozdnyakov 2016, p. 91). Low nest density of Steller's eiders on the Lena Delta of Russia coincides with low lemming years, and the maximum nesting density coincides with high lemming years (Pozdnyakov 2016, p. 89-91). Pozdnyakov (2016, p. 91) suggests that one of the main factors contributing to nesting effort of Steller's eiders and nest survival is the low overall pressure of predators in the years of abundant lemmings. In addition, reproduction may also be closely dependent on climatic factors; colder years were found to be less favorable years for nesting, and the combination of low lemming numbers and cold years resulted in the lowest observed nesting density on the Lena Delta among all years (Pozdnyakov 2016, p. 97, 101).

Rogacheva and Syroechkovsky (2015, p. 62-81) summarized nesting accounts from their own research and various sources on Steller's eiders collected along the Taymyr Peninsula dating back to 1843; on the Taymyr Peninsula, both the Atlantic-wintering and Russian-Pacific breeding populations occur between 100° and 104° E longitude (Rogacheva and Syroechkovsky 2015, p. 80). Within this area of overlap (Figure 1), the most favored breeding area is along the southern shore of Lake Taymyr. In the Taymyr region, the southernmost nesting site is between the Bludnaya and Popigay Rivers (Rogacheva and Syroechkovsky 2015, p. 80; Figure 1, site 15). Steller's eiders are described as a nomadic and rare species, as their breeding numbers vary greatly from year to year, and they can be a common nesting species in a few favorable years (Rogacheva and Syroechkovsky 2015, p. 69). There is high pressure from nest predators (e.g., arctic foxes, jaegers) in the Taymyr region.

Between 2022 - 2024, the Wildlife Conservation Society (WCS) conducted breeding and nesting surveys targeting spectacled eiders on the Indigirka River Delta of Yakutia, Russia to compare to surveys conducted between 1993 - 1995 by Pearce et al. (1998, p. 362-363). On the Indigirka River Delta, Steller's eiders breed along the coastal margin and are uncommon breeders farther inland (Pearce et al. 1998, p. 369). Although no nests of Steller's eiders were found in 2022 or 2023, their crew found a colony of 12 Steller's eider nests on Oleniy Island in 2024. All 12 nests were depredated by gulls and jaegers, and lemming abundance in the study area was considered moderate for all 3 years (E. Bragina, WCS Arctic Beringia Program Course Director, pers. comm.).

Table 1. Breeding season conditions and reproductive variables of the Steller’s Eider in the northern Lena Delta (Sagastyr Island). Data for 1993 - 1999 were taken from Solovieva (2000). Data for 2002–2015 were taken from Pozdnyakov (2016). Data for 2017 were taken from Pozdnyakov (2022). Data for 2000 and data on clutch size for 1993 - 2000 are taken from The Chronicles of Nature of the “Ust-Lenskiy” State Nature Reserve and were collected by D. V. Solovyeva. Years with high abundance of lemmings are indicated in bold. A dash indicates that data are absent.

Parameter	Year												
	1993	1994	1995	1996	1997	1998	1999	2000	2002	2006	2014	2015	2017
Date of average daily air temperature transition through 0°C	6/13	6/8	5/28	6/20	6/12	6/6	6/3	5/30	6/7	6/6	6/4	6/3	-
Arrival date	6/10	6/10	6/2	6/16	6/12	6/7	6/11	-	6/7	6/6	-	-	-
Mean air temperature in the pre-nesting period (°C)	3.1	1.7	7.2	-1.8	3.2	3.0	8.3	4.3	5.7	7.8	8.7	4.4	-
Duration of the pre-nesting period (days)	11	11	13	16	1	-	4	-	-	-	-	-	-
Nesting density (pairs/km ²)	57.2	6.9	7.3	3.9	0.6	1.7	10.7	34.4	3.7	1.8	32.1	0.2	16
Number of nests found	111	14	11	15	0	1	72	-	-	-	-	1	-
Date of nest initiation	6/21	6/21	6/15	7/2	6/13	-	6/15	6/10	-	-	6/14	-	-
Mean clutch size	6.1	4.8	-	-	-	-	6.0	7.1	-	-	6.9	-	-
Nest success (%)	21.6	0	0	37.5	0	0	11.4	47.7	-	-	52.4	0	-

Table 2. Breeding season conditions and reproductive variables of the Steller's eider in the northeastern Lena Delta (Nerpallaakh Island). Data from 2000 - 2008 were taken from Pozdnyakov (2016). Data from 2016 and 2018 were taken from Pozdnyakov (2022). Years with a high abundance of lemmings are indicated in bold. A dash indicates that the data are absent.

Parameter	Year										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2016	2018
Date of average daily air temperature transition through 0°C	5/30	6/6	6/7	6/7	6/10	6/8	6/6	6/10	6/12	-	-
Arrival date	-	-	6/7	6/10	6/11	6/3	6/6	-	6/14	-	-
Mean air temperature in the pre-nesting period (°C)	4.3	2.9	5.7	2.3	0.6	4.3	7.8	5.7	2.8	-	-
Duration of the pre-nesting period (days)	-	-	-	10	13	8	-	-	-	-	-
Nesting density (pairs/km ²)	70.0	16.0	3.0	14.0	20.5	26.7	6.0	2.4	2.7	7	7
Date of nest initiation	6/10	6/19	-	6/20	6/24	6/11	-	6/15	-	-	-
Mean clutch size ($M \pm m$)	6,3 ± 0,2 (n = 41)	6,1 ± 0,4 (n = 10)		6,8 ± 0,2 (n = 27)	6,3 ± 0,2 (n = 20)	7,2 ± 0,1 (n = 49)	-	-	-	-	-
Nest success (%)	95.0	62.5	0	88.0	72.7	82.1	0	0	0	-	-

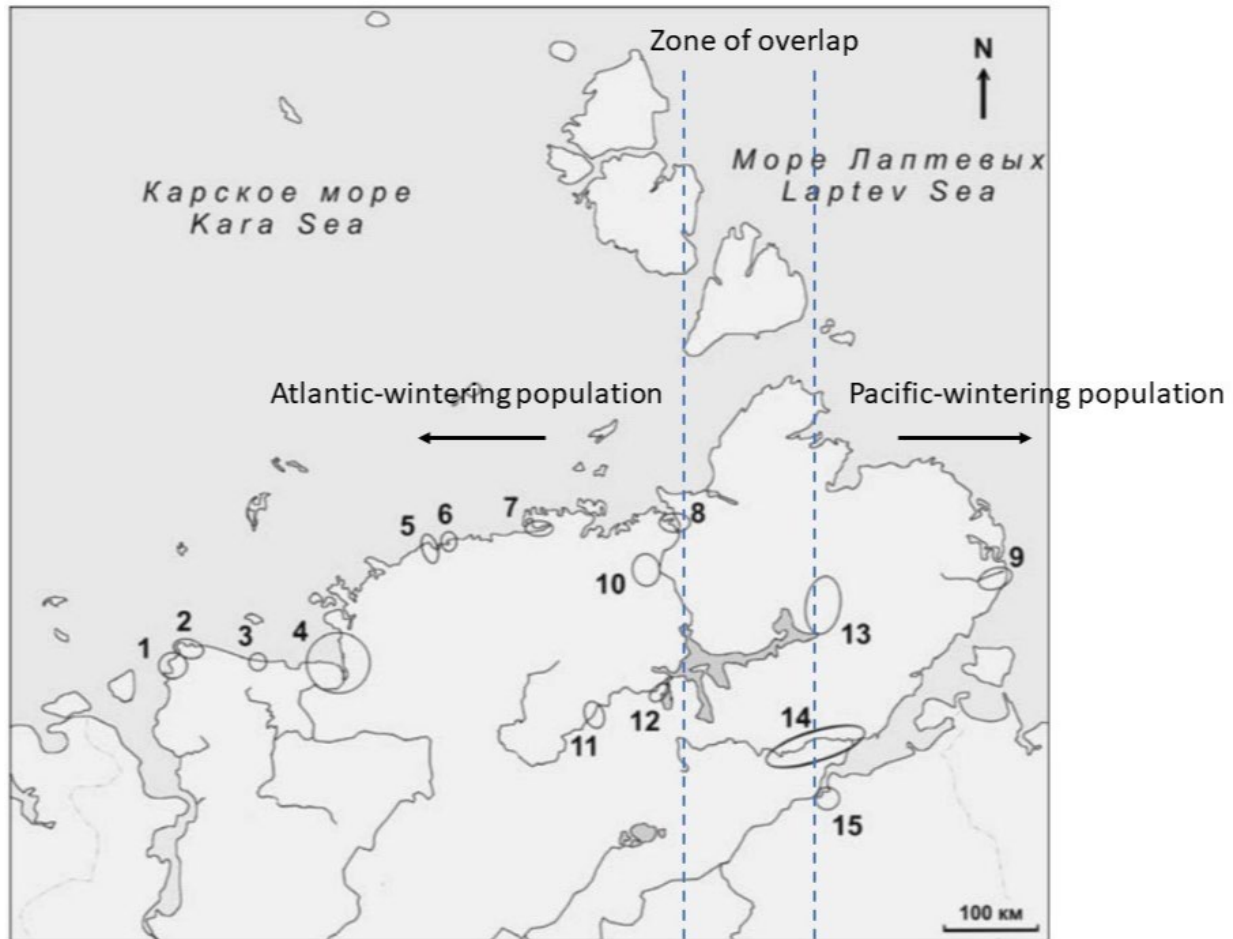


Figure 1. Surveyed territories on the Taymyr Peninsula where nesting Steller's eiders have been encountered (From: Figure 2, Rogacheva and Syroechkovsky 2015, p. 72). The zone of overlap between Pacific and Atlantic-wintering populations of Steller's eiders described by Rogacheva and Syroechkovsky (2015, p. 80) is overlaid on the map between dashed blue lines. **1** – Medusa Bay and environs **2** – environs of Dikson village **3** – mouth of Uboynaya River **4** – Pyasina River Delta and islands **5** – lower reaches and mouth of the Lenivaya River **6** – Cape Sterlegov **7** – Middendorff Bay **8** – mouth of the Nishnyaya [Lower] Taymyra River **9** – environs of Pronchischeva Lake, Kuldima River basin **10** – lower reaches of the Shrenk River **11** – middle reaches of the Verkhnyaya [Upper] Taymyra River **12** – mouth of the Verkhnyaya [Upper] Taymyra River, right bank **13** – Malakhaitari River, Bikada River basin **14** – Bolshaya Balakhnya River basin **15** – interfluve of the Bludnaya and Popigay Rivers. Nesting was assumed in areas 2, 5, and 13, and confirmed in all other areas. (See Rogacheva and Syroechkovsky 2015 p. 73, 82-86 for sources of nesting encounters).

Threats

In Russia, Russian-breeding Pacific Steller's eiders are harvested by Indigenous Peoples of the North. Hunting may be a significant contributing factor to population declines of the Pacific Russia-breeding population (Rogacheva et al. 2021, p. 594-596). Higher hunting pressure takes place in Yakutia, Russia

(Klokov et al. 2024, p. 64, 67; Rogacheva and Syroechkovsky 2015, p. 79). Rogacheva and Syroechkovsky (2015, p. 79) estimated that up to 10,000 Steller's eiders are harvested annually in Yakutia, mainly in the spring. According to Rogacheva et al. (2021, p. 594-596), harvest of eiders in Yakutia increased significantly after goose population declines in the 1990s, and coastal communities began to specialize hunting on eiders. The WCS conducted harvest surveys in 2024 in four villages from the Nizhnekolymskiy district in northeastern Yakutia, Russia and found Steller's eiders to be the most popular harvested species among eiders (WCS unpublished data). It is estimated that approximately 2,600 Steller's eiders were harvested from the Nizhnekolymskiy district within the 12-month period, primarily during spring migration to the breeding grounds. When asked about changes in long-term trends of eiders and sea duck populations, most survey respondents believed that eider and other sea duck populations have declined significantly (E. Bragina, WCS Arctic Beringia Program Course Director, pers. comm.). On the Lena and Yana River Deltas (Yakutia), locals participate in egg-ing (Rogacheva and Syroechkovsky 2015, p. 79).

Klokov et al. (2024) conducted harvest surveys at ten villages in northeastern Chukotka, Russia in fall 2022 – summer 2023 to compare hunting pressure to 2001 – 2006 (p. 2). In Chukotka, the average harvest and overall proportion of Steller's eiders among other eider species declined significantly relative to 2001 - 2006 (p. 3); Steller's eiders were harvested from the villages Uelen and Lorino in 2023, and all harvest in Chukotka took place in the spring and summer (p. 25). The estimated total harvest of Steller's eiders in Iultinskii, Providenskii, and Chukotskii districts was 141 eiders (± 163 , range: 20-304), with an average of 0.03 Steller's eiders harvested per household (p. 43).