Status Assessment

Of

The Alaska-breeding Population of Steller’s Eiders

Version 1

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EXECUTIVE SUMMARY

This species status assessment (SSA) was developed to inform a 5-year status review of the Alaska-breeding population of Steller's eiders required under the ESA (hereafter, 5-year review). 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. 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 USFWS 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 nesting season, which occurs from approximately early June to early September. Nesting in northern Alaska is concentrated in polygonal tundra wetland habitat near Utqiaġvik and occurs at lower densities elsewhere on the 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, 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 Arctic Coastal Plain (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 seem to be changing. This is demonstrated in the high annual variability in reproductive rates such as breeding propensity and nest survival near Utqiaġvik.

Several potential stressors (i.e., threats) may affect the resiliency of the northern Alaska population 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 Utqiaġvik). 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 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 Steller's eiders 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 Utqiaġvik; 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. 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 Utqiaġvik study area. 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). 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 Utqiaġvik Triangle. The wide distribution during molt, winter and staging, assuming even distribution of Alaska-breeding birds with the Pacific-Russia 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 Utqiaġvik. 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 Utqiaġvik will increase, 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 2002, 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 USFWS 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, and it is delimited by an international boundary that marks 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. 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 USFWS 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.

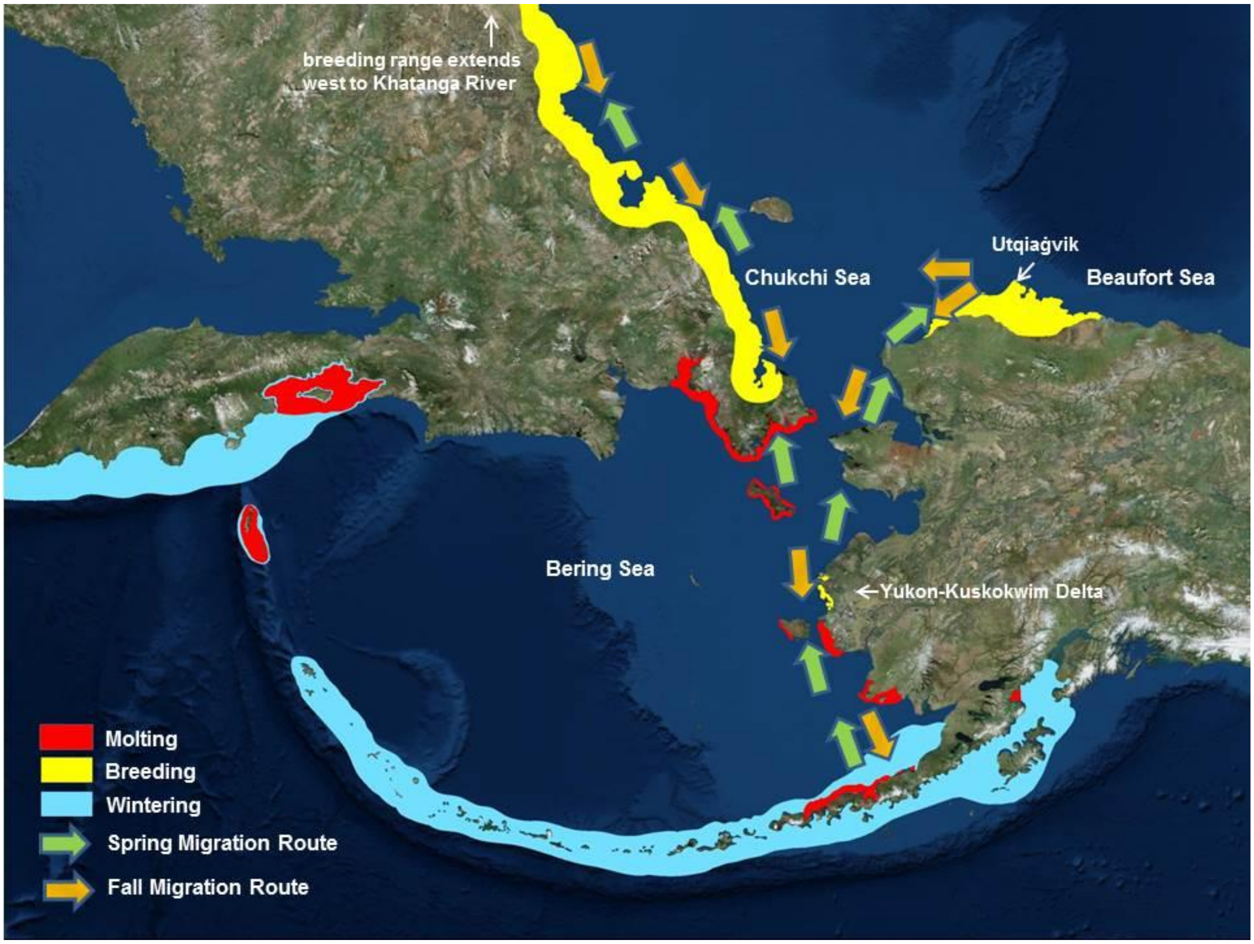


Figure 1. Distribution and general migration pathways of the Russian-Pacific breeding and Alaska-breeding populations (combined, referred to as the Pacific-wintering population).

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 Utqiaġvik (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 mi^2 (7,330 km^2) 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

This species status assessment (SSA) was developed to inform a 5-year status review of the Alaska-breeding population of Steller's eiders required under the ESA (hereafter, 5-year review). 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.

Our analysis follows the SSA guidelines developed by the USFWS (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 2002, 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 USFWS 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), prior to conducting the SSA 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 by December 2018. 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 a 5-year review, determining if reclassification is warranted typically includes comparing the current status of the species and the reclassification criteria outlined in a recovery plan. The recovery plan for Alaska-breeding Steller's eiders was signed in 2002 and defines the criteria for reclassification according to the population's probability of extinction in the next 100 years, using a population viability analysis (PVA; USFWS 2002, p. 9). Inherent in the recovery criteria is the assumption that sufficient data are available to perform a scientifically-sound PVA. During this assessment we reviewed PVAs previously developed for Steller's eiders, and evaluated whether conducting a new PVA, given available data and its associated uncertainty, was a reasonable method for producing reliable conclusions about the population's viability.

In addition to the 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 people 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've 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).

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 (*Somateria spectabilis*, and 34% of the common eider (*Somateria 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 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 the majority 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 Utqiaġvik 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 2018, 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).

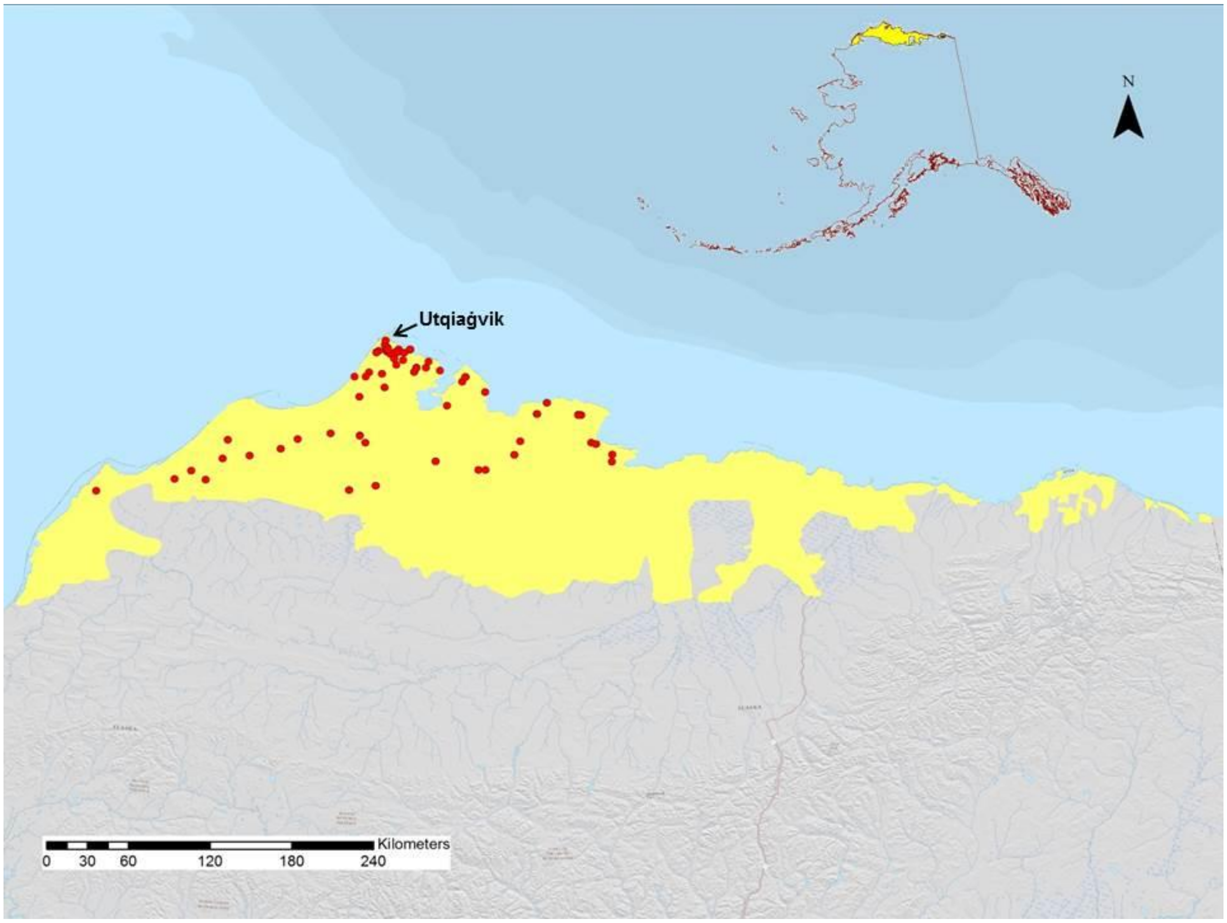


Figure 2. Observations of Steller's eider males, pairs, and flocks from the Arctic Coastal Plain (ACP) aerial survey in June 1999 - 2018.

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 Utqiaġvik, 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).

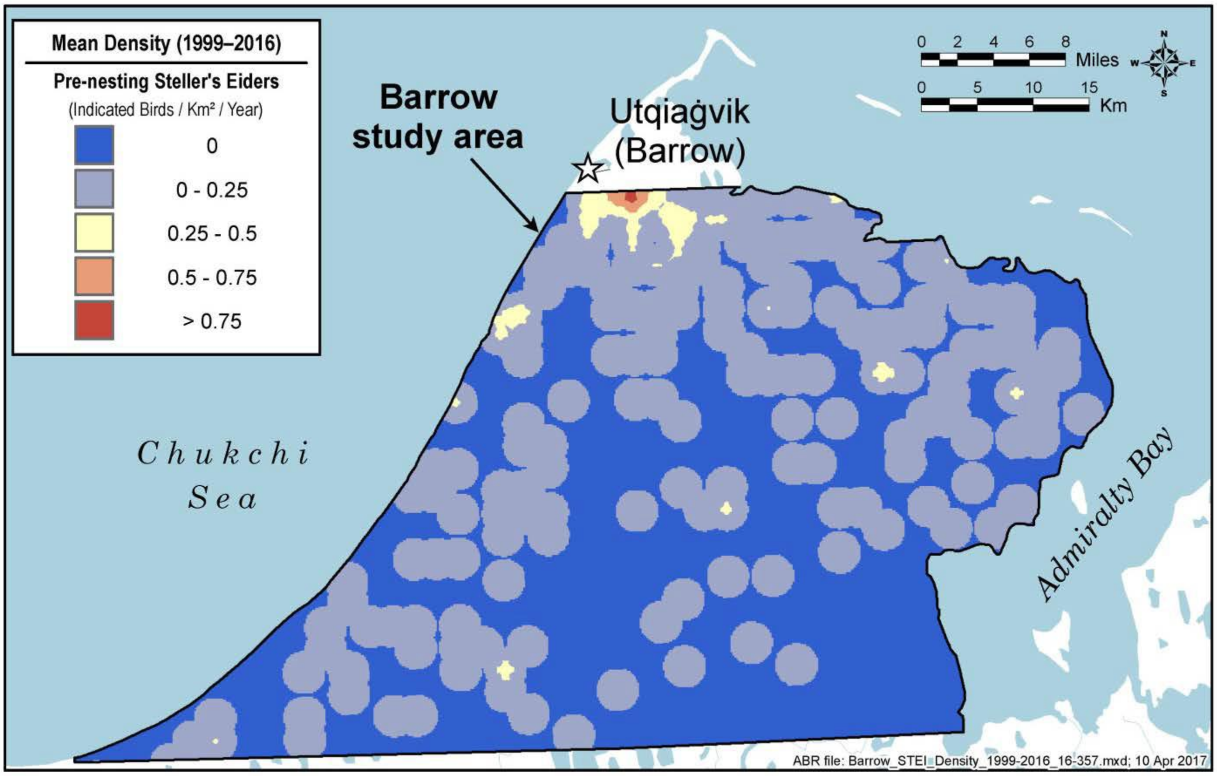


Figure 3. Mean pre-nesting densities of Steller's eiders in the Utqiaġvik Triangle, Alaska, June 1999–2016 (from ABR, Inc. 2017, p. 10).

Timing of departure from the breeding grounds near Utqiaġvik (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 Utqiaġvik (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 Utqiaġvik (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 Utqiaġvik, and observed south along the Chukchi coast near the city of Utqiaġvik (USFWS 2011a, p. 34; USFWS 2012a, p. 33). Based on these observations, females with successfully reared broods begin to depart the Utqiaġvik area in early September (USFWS 2012a, p. 33-34). In years with low breeding effort, flocks composed of both sexes occupy coastal waters near Utqiaġvik 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. T. Hollmén, ASLC, pers. comm. 2018). Here they intermix 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.

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 USFWS 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 eiders[1] 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

[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.

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 Utqiaġvik, seven molted at Kuskokwim Shoals, suggesting that Alaska-breeding birds may disproportionately use this molting area over other molting areas used by the Pacific-wintering population (Martin et al. 2015, p. 348). But, 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).

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 was lacking for that population, we used data from the Russian-Pacific breeding population, and noted it in the text. 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 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)
Egg Survival	availability of high quality polygonal tundra (micro-level – nest cover)
	adequately high presence 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
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 Utqiaġvik 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 Utqiaġvik continued to vary widely (0 - 78 nests found annually, USFWS 2018a, p. 41). 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 Utqiaġvik 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.

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). While it is unknown how much Steller's eiders rely on nutrient storage for clutch formation and incubation, their body size and behavior suggest that females rely on resources at the breeding area to a significant degree. First, the ratio of stored resources (acquired on wintering or staging grounds) to local resources used during reproduction varies by waterfowl species and individual, but seems to be positively related to body size (Sedinger and Alisauskas 2014, p. 281; Alisauskas and DeVink 2015, p. 126). Consistent with this correlation, Steller's eiders are small-bodied compared to other eider species, and take several incubation breaks daily (USFWS, unpublished data). Steller's eider females nesting near Utqiaġvik 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). Additionally, Steller's eiders typically arrive in Utqiaġvik in late May – early June (USFWS 2011a, p. 17-18; USFWS 2012a, p. 16; USFWS 2013a, p. 17; USFWS 2016b, p. 14; USFWS 2018a, p. 15), but do not initiate nests until mid to late June (USFWS 2011a, p. 22; USFWS 2012a, p. 22; USFWS 2013a, p. 22; USFWS 2015, p. 17-18; USFWS 2016b, p. 18; USFWS 2018a, p. 20). This time could allow individuals between 2-4 weeks to forage prior to laying and incubating eggs, suggesting Steller's eiders do not arrive to the nesting area with stored nutrients adequate for clutch formation and incubation, or that they need to forage to maintain body condition at nesting grounds.

Despite the potential importance of local food resources on reproduction, there is insufficient information about nutritional requirements and diet composition of Steller's eiders to determine the importance of specific taxa in their diet. Limited observations suggest that 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 Utqiaġvik (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).

Steller's eiders primarily use shallow flooded *Arctophila* and *Carex* ponds for feeding during the pre-laying, laying and early incubation periods (USFWS 2018a, p. 23) and during incubation (Solovieva 1999, p. 72). The invertebrate community in ponds sampled near Utqiaġvik 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). In summary, while the availability of freshwater invertebrates and aquatic vegetation is likely to affect Steller's eiders ability to reproduce, we lack data to identify the species, 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 Utqiaġvik, measured by the number of Steller's eider nests found, varies considerably (USFWS 2018a, p. 41, Table 2). While this could be in part due to variation in detection rate, the number of Steller's eider nests found near Utqiaġvik 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 predator switching (i.e., alternative prey hypothesis; Mallory 2015, p. 351). 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 Utqiaġvik 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 Utqiaġvik, 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 Utqiaġvik 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 Utqiaġvik. 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.

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; and, 4) availability of low-centered polygonal tundra (both macro- and micro-level characteristics).

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 nest from avian predators (N. Graff, USFWS Biologist, pers. comm.; see USFWS 2018a). 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, provides protection from wind, flooding events, and low temperatures for Steller's eider nests.

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.*

Table 2. Nesting by Steller's eiders and avian predators near Utqiaġvik, 1991-2017 (From USFWS 2018).

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

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

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

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

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

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

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

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

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 Utqiaġvik (Quakenbush et al. 2004, p. 173, 176) and 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 Utqiaġvik 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, 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, which put ducklings at risk of predation.

Finally, fresh water is an important habitat requirement for ducklings. Salt glands of common eiders begin to function at the earliest at 2 days post-hatch (DeVink et al. 2005, p. 527), and preliminary results from captive studies of Steller's eiders suggest that salt gland secretions begin around 2-3 days post-hatch and glands are functional at one week of age (T. Hollmén, Alaska Sea Life Center, 2018, pers. comm.). Prior to that time, young ducklings require a source of fresh water for survival and growth.

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 western Alaska subpopulation of Steller's eiders.

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 periods, 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 others 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 do not feed on eelgrass, but on the invertebrates associated with eelgrass habitat. 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's 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).

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).

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). 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 caloric content (Petersen 1981, p. 260-262). 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 (Zydelis 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) notes 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.

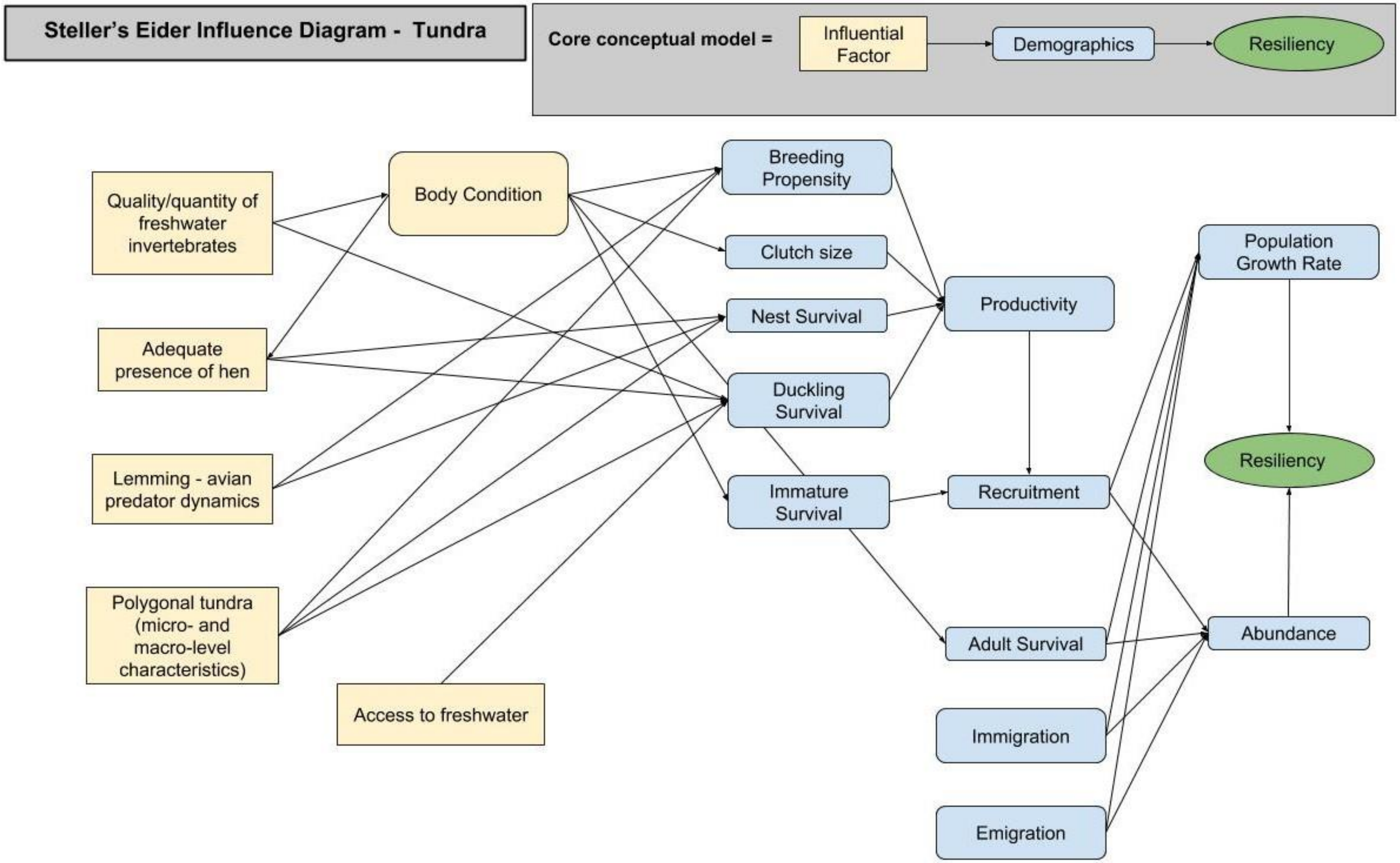


Figure 4. Influence diagram illustrating the links between required tundra habitat conditions, demographic rates, and resiliency of the northern Alaska subpopulation of Steller's eiders.

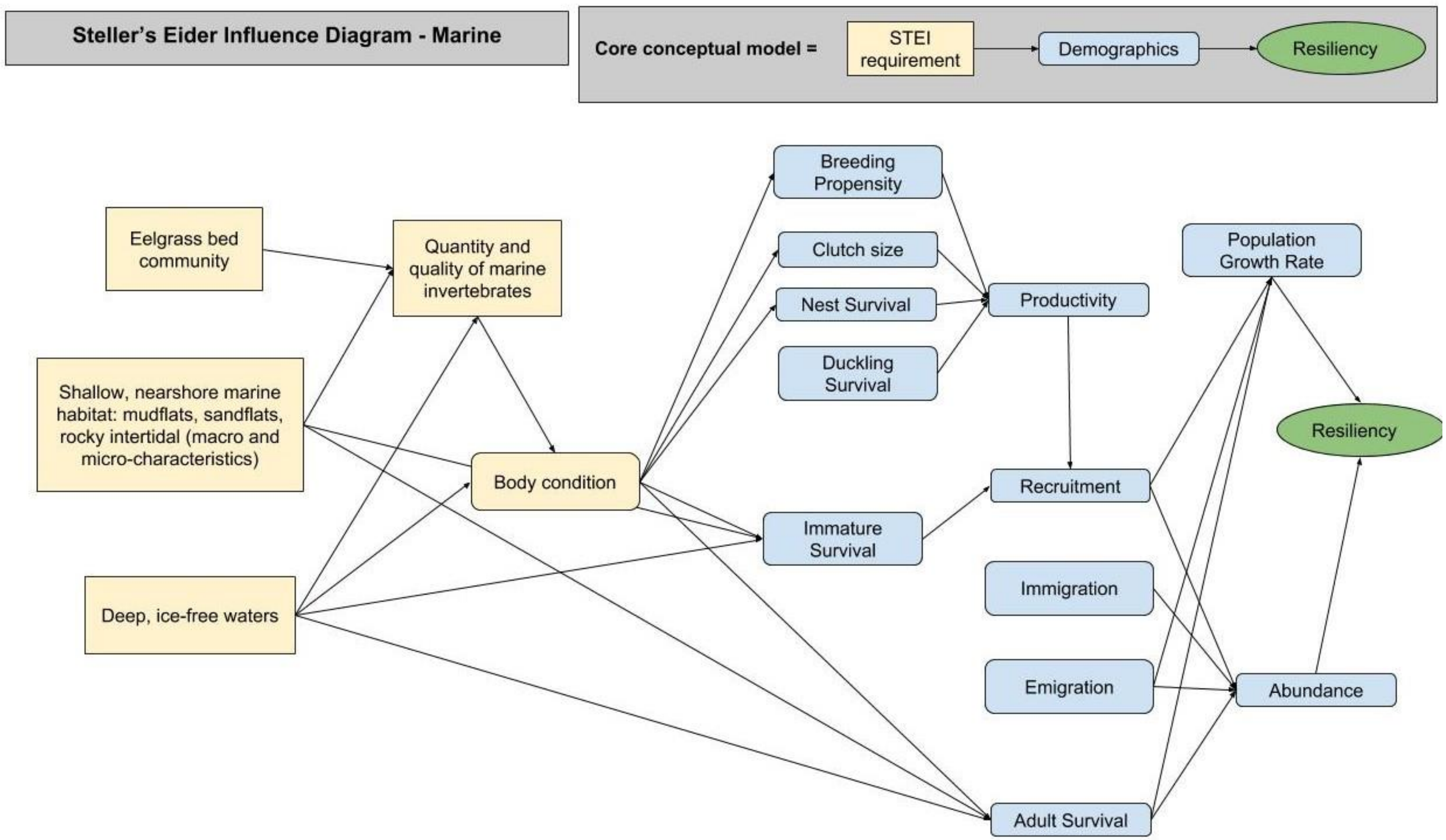


Figure 5. Influence diagram illustrating the links between required marine habitat conditions, demographic rates, and resiliency of Alaska-breeding Steller's eiders.

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; Trail 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 PVA, as required in the recovery plan (USFWS 2002).

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.

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 USFWS has conducted three breeding waterfowl surveys annually on the Y-K Delta. These include two aerial surveys, the North American Breeding Waterfowl Survey (1957-2017, USFWS 2017a) and the Yukon-Kuskokwim Delta Breeding Pair Survey (1986-2017, USFWS 2017b), and one ground survey aimed at estimating the number of waterfowl nests on the central coast of the Y-K Delta (1985-2017, USFWS 2017c). In addition, field research is conducted throughout the central coastal zone by USGS, USFWS, universities, and other government agencies. Serendipitous observations of Steller's eiders would likely be recorded during these activities given the species' rarity and the interest in the species.

No Steller's eiders were recorded during aerial surveys from 1997-2017 (J. Fischer, USFWS Biologist, pers. comm.). Observations of 44 adult Steller's eiders, and 8 nests and 1 brood, were reported during nest plot surveys and other avian research from 1997 - 2017 (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. Nests were found at Kigigak Island and near the Tutakoke and Kashunuk rivers.

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 3), 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 USFWS and Steller's Eider Recovery Team to determine its utility as a recovery tool. In 2005, at the request of the Recovery Team, the Alaska Sea Life Center established a captive flock of Steller's eiders from eggs collected near Utqiaġvik. The USFWS and the Alaska Sea Life 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 USFWS 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

Table 3. Observations of adult Steller's eiders on the Y-K Delta, 1997 – 2017.

Observations of Adult Steller's Eiders on the Yukon-Kuskokwim Delta (1997-2017)					
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
1998	Hock Slough			1	2
1998	Tutakoke River	1		2	5
1999	Kigigak Island			2	4
2000	Kigigak Island			2	4
2002	Kigigak Island		1		1
2003	Kigigak Island		1		1
2004	Kigigak Island		2		2
2005	Kigigak Island		2		2
2006	Kigigak Island	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
				Total Observations =	**44**

Table 4. Observations of Steller's eider nests and broods on the Y-K Delta, 1997 - 2017.

Nests and Broods Found on Yukon-Kuskokwim Delta (1997-2017)					
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		
2005	Kigigak Island	6	No		
2005	Kigigak Island			1	2
2013	Tutakoke River	7	Yes		
Total Reproductive Attempts Recorded (Nests + Broods) = 9					

opportunity costs of the reintroduction program, reintroduction was not a viable recovery tool at that time.

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. The number of nests found annually during ground surveys near Utqiaġvik from 1991 - 2017 ranged from 0 – 78 (USFWS 2018a, p. 41). 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. 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 survey is 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 (i.e., availability bias is not quantified). Without an estimate of availability bias, combined with the low number of annual observations, also inhibits our ability to estimate the trend of the northern Alaska subpopulation with a reasonable level of precision.

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 Survey, the Utqiaġvik Triangle Survey, and the Utqiaġvik ground-based breeding pair survey, provide some 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 - 2017, and covers 57,336 km^2 of Alaska's ACP. 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 20 geographic strata that vary in survey intensity from 0.7% to 4.0% based on waterfowl densities and physiographic and management unit characteristics (USFWS 2012b, p. 3; USFWS 2009, p. 2). Species-specific detection rates for some waterfowl species were estimated in 2015 - 2016 using a double-observer method during the ACP survey (USFWS 2017d, p. 2), improving our ability to convert aerial observations of waterfowl to estimates of the number of Steller's eiders present annually. Observations were too few to estimate a species-specific aerial detection rate for Steller's eiders;

therefore, the detection rate for long-tailed ducks (*Clangula hyemalis*), a species similar in size to Steller's eiders, was used to estimate the number of Steller's eiders present annually in northern Alaska.

A total of 13 pairs and 8 single male Steller's eiders were recorded during the ACP survey from 2007 – 2017 (Figure 7). In two years, no Steller's eiders were observed in the survey (Figure 7). Using these data, a Bayesian binomial-Poisson detection model, and detection rates estimated for long-tailed ducks on the ACP (singles = 0.43, SD = 0.03; pairs = 0.52, SD = 0.03, USFWS 2017d), the number of Steller's eiders present on the ACP from 2007 – 2017 ranged from 68 – 745 birds and the average was 308 (95% CI = 216 – 422; E. Osnas and C. Frost, USFWS Biometricians, pers. comm.; Figure 6).

In addition to the caveats regarding availability bias described at the beginning of this section, this estimate should be interpreted with caution for a number of reasons. First, it is based on a small number of observations (21 total over 11 years). Second, the small number and uneven distribution of Steller's eiders across the ACP cannot be adequately represented in the ACP survey's sampling regime, which consists of transects covering up to 4% of the area within strata, and contributes to the (unknown) bias in the estimates. In addition, the density of nesting Steller's eiders is highest in the northern-most portion of the Utqiaġvik Triangle, but ACP aerial survey transects are not flown in that area due to FAA regulations. This problem is apparent in years when Steller's eiders have been observed in relatively high numbers during ground surveys near Utqiaġvik, but estimates from the ACP aerial survey detected few or no birds (i.e., 2008, 2014, 2015).

Additionally, Steller's eider-specific detection estimates are lacking due to the small number of observations. Long-tailed ducks were used as a surrogate because their size is similar to Steller's eiders; however, the magnitude and direction of potential bias added to the estimate by the use of that particular detection estimate are unknown. While annual Steller's eider detection rates would be preferred, an estimated mean detection rate of a related species that includes a measure of uncertainty is probably an improvement on the previously-used fixed detection rate of 0.3 based on expert opinion (USFWS 2009, p. 4).

Utqiaġvik Triangle Survey. -- Intensive aerial surveys focused on Steller's eiders were conducted in a 2757 km^2 area from Utqiaġvik to the Meade River, Alaska from 1999 - 2017 following standard protocols for breeding waterfowl surveys. Coverage of the survey area varied between 25 – 50% depending on predictions of breeding effort near Utqiaġvik each year and fiscal constraints. Survey methods are described in further detail in ABR, Inc. (2017).

The number of birds observed on the survey annually from 1999 - 2016 ranged from 0 to 88 (Appendix 2 in ABR, Inc. 2017). Similar to the methods used to analyze ACP survey data, a state-space Bayesian modeling approach incorporating uncertainties associated with sampling error, stochastic variation in growth rates, and observation error, was used to analyze the Utqiaġvik Triangle Survey data (See Appendix A). The analysis also used the estimate of long-tailed duck detection (Appendix 3 in USFWS 2017d) as a surrogate for Steller's eider detection rate. Use of total counts, rather than transect-specific counts, marks the main methodological difference between the ACP survey and Utqiaġvik Triangle analyses.

The estimated average annual number of Steller's eiders in the Utqiaġvik Triangle from 1999 - 2016 is 204 (95% CI = 184-225; range 30 – 468; Appendix A; Figure 8). The population of inference for this survey is the population of Steller's eiders present in the Utqiaġvik Triangle survey area during the breeding season. It is unclear how the estimate from this survey relates to the number of Steller's eiders present in northern Alaska because the proportion of the subpopulation occupying the Utqiaġvik Triangle is unknown, and the two survey areas overlap. However, given that the highest densities of Steller's eiders in the breeding season are within the Utqiaġvik Triangle (Figures 2 and 3), this estimate represents a significant (but still unknown and annually variable) portion of the population.

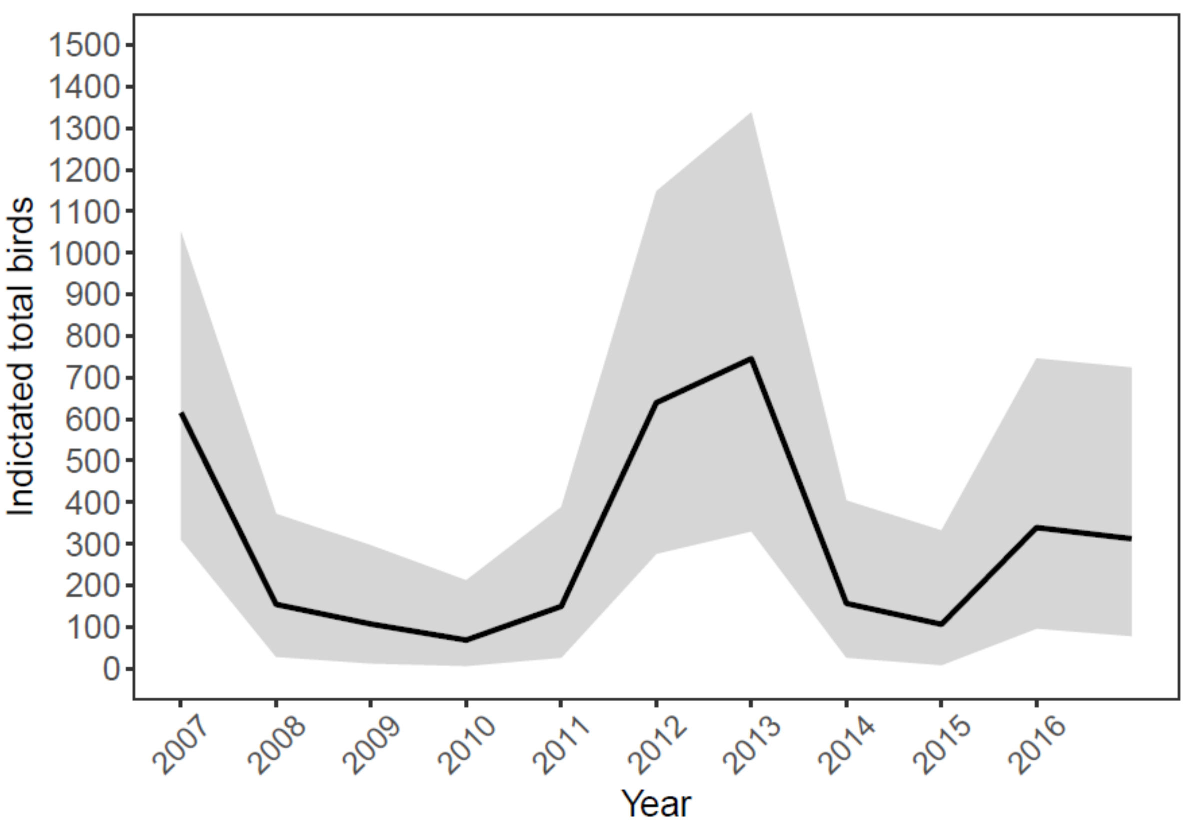


Figure 6. Annual estimate of indicated total Steller's eiders present on the ACP from ACP Survey observations from 2007 – 2017 (E. Osnas and C. Frost, USFWS Biometricians, pers. comm.). Indicated total is calculated as twice the number of males observed as singles, in pairs, and in groups of males up to four, plus birds in flocks of 5 or more regardless of sex composition (USFWS 2012b, p. 4).

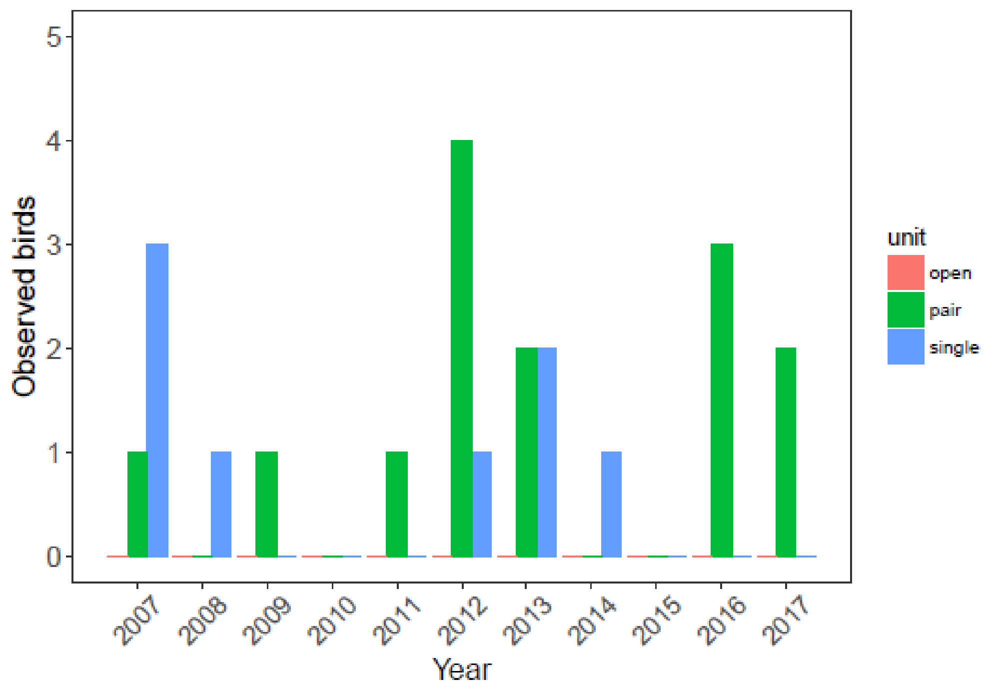


Figure 7. Number of observations of Steller's eiders during the Arctic Coastal Plain aerial survey, 2007-2017. In units, open, pair and single refer to observations of flocks, pairs of birds, and single birds, respectively (E. Osnas and C. Frost, USFWS Biometricians, pers. comm.).

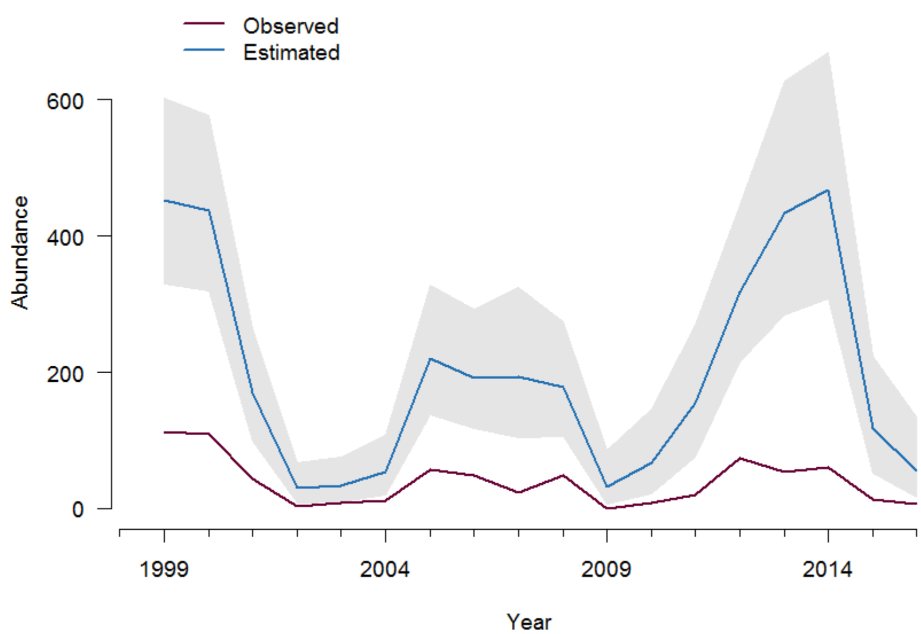


Figure 8. Observed and estimated (95% CRI) Steller's eider breeding birds in the Utqiaġvik Triangle aerial survey study area from 1999 – 2017 (Appendix A).

Utqiaġvik ground-based breeding pair survey. -- From 1999 - 2017, ground crews walked a standard survey area of 134 km^2 near Utqiaġvik and its associated road system to count the number of Steller's eiders in the area (Figure 9). Typically, males are counted and assumed to be associated with a more cryptic, and sometimes unobserved, female. The survey was designed to provide 100% spatial coverage of the study area and was conducted concurrently with the Utqiaġvik Triangle 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 estimate of the number of Steller's eiders in the study area (detection is not quantified) and identifies priority areas for nest searching. The number of Steller's eider males observed in the standard area from 1999 - 2017 ranged from 0 – 132 (mean = 52; SD = 41; Table 6).

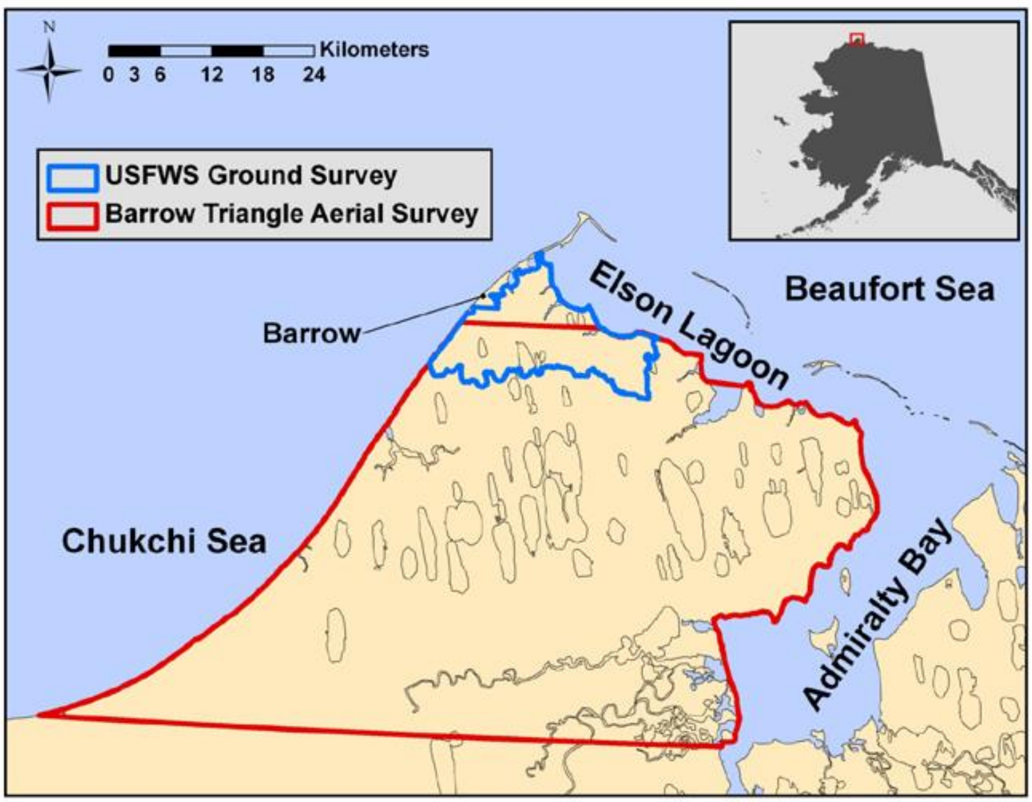


Figure 9. Steller's eider ground survey area (blue) and Utqiaġvik Triangle survey area (red; referred to in the figure as Barrow Triangle Aerial Survey).

6.1.3. Summary of population abundance data

The number of Steller's eiders observed in northern Alaska each year is variable (Table 6), and the abundance of the northern subpopulation cannot be quantified with the existing data. Existing survey data can be used to estimate the number of Steller's eiders present in northern Alaska annually, however. From data collected on the ACP aerial survey, the estimated average number of Steller's eiders present on ACP annually from 2007 – 2017 ranged from 68 – 745 (mean = 308, 95% CI = 216 – 422). The number of Steller's eiders estimated to be present annually in the Utqiaġvik Triangle ranged from 30 – 468 (mean = 204, 95% CI = 184 – 225). In some years, the point estimate of Steller's eiders from the Utqiaġvik Triangle survey was higher than that of the ACP survey, despite the significantly smaller area surveyed in the Utqiaġvik Triangle (e.g., 2008, 2014). This suggests that the ACP survey may not be appropriate for estimating abundance of Steller's eiders. Because of unquantified availability bias, we cannot estimate the abundance or trend of the northern Alaska subpopulation. Therefore, we lack adequate information to determine if abundance of the northern Alaska subpopulation has changed since listing.

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 proximal to Utqiaġvik	0.7% - 4.0% 2007 - 2017	Range = 68 – 745 Steller's eiders Mean = 308 (95% CI = 216 – 422)	- # of observations = 21 over 11 years - 2 years with 0 observations - Not designed for Steller's eiders - Bayesian analysis - Used detection rate for LTDU as surrogate
Utqiaġvik Triangle aerial survey	Birds present from Utqiaġvik to Meade River, minus birds proximal to Utqiaġvik	25 – 50%, 1999 - 2017	Range = 30 – 468 Steller's eiders Mean = 204 (95% CI = 184 – 225)	- # of observations ranged from 0 to 88 annually - Same statistical methods as ACP survey
Ground-based breeding pair survey	Birds present within 6 km of road system in Utqiaġvik	100%, 1999 - 2017	Range (observations) = 0 – 132 Mean = 52 (SD = 41)	- Conducted over 10 – 12 days, after birds have dispersed to nest areas - Not designed to estimate abundance

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 Utqiaġvik study area from 1991 – 2017. It is unclear how estimates from the Utqiaġvik 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., local fox, jaeger, gull, raven, and human populations). Nest survival near Utqiaġvik 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 Utqiaġvik, which may have artificially increased nest survival rate in the area; but the impact of fox control on nest survival is inestimable (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 Utqiaġvik, 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 – 2017 indicate that both the number of breeding pairs and nests present in the Utqiaġvik study area are highly variable from year to year. Breeding pair surveys are conducted by walking a standard 134 km^2 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 males counted annually ranges from 0 to 132 males per year (Figure 10; USFWS 2018a, p. 17). Similarly, the number of nests found in the study area annually from 1991 – 2017 ranged from 0 – 78 (Table 2; USFWS 2018a, p. 41).

Mean apparent clutch size of nests near Utqiaġvik from 1991 - 2017 is 5.7 (range 4.8 – 6.6; SD = 1.18, 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 Utqiaġvik study area from 1991-2017, and average annual nest survival probability, defined as the probability that at least one egg hatches in a nest, was estimated using

Mayfield model in program MARK. The average nest survival probability in the Utqiaġvik study area was 0.31 (SE of annual point estimates = 0.06) and ranged from 0.0 to 0.88 (USFWS 2018a, p. 40).

Steller's eider broods were monitored in five years between 2005 and 2012 near Utqiaġvik by marking a female with a radio transmitter prior to hatch, and locating the brood 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 average brood survival probability of all years of data collection is 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 average number of fledged juveniles per brood and the average number of hatched ducklings per clutch, duckling survival probability is approximately 0.44 (D. Safine, USFWS Biologist, pers. comm.).

In summary, the available measures indicate high annual variability in demographic rates related to productivity. Highly variable rates result in lower overall average rates than less variable 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.

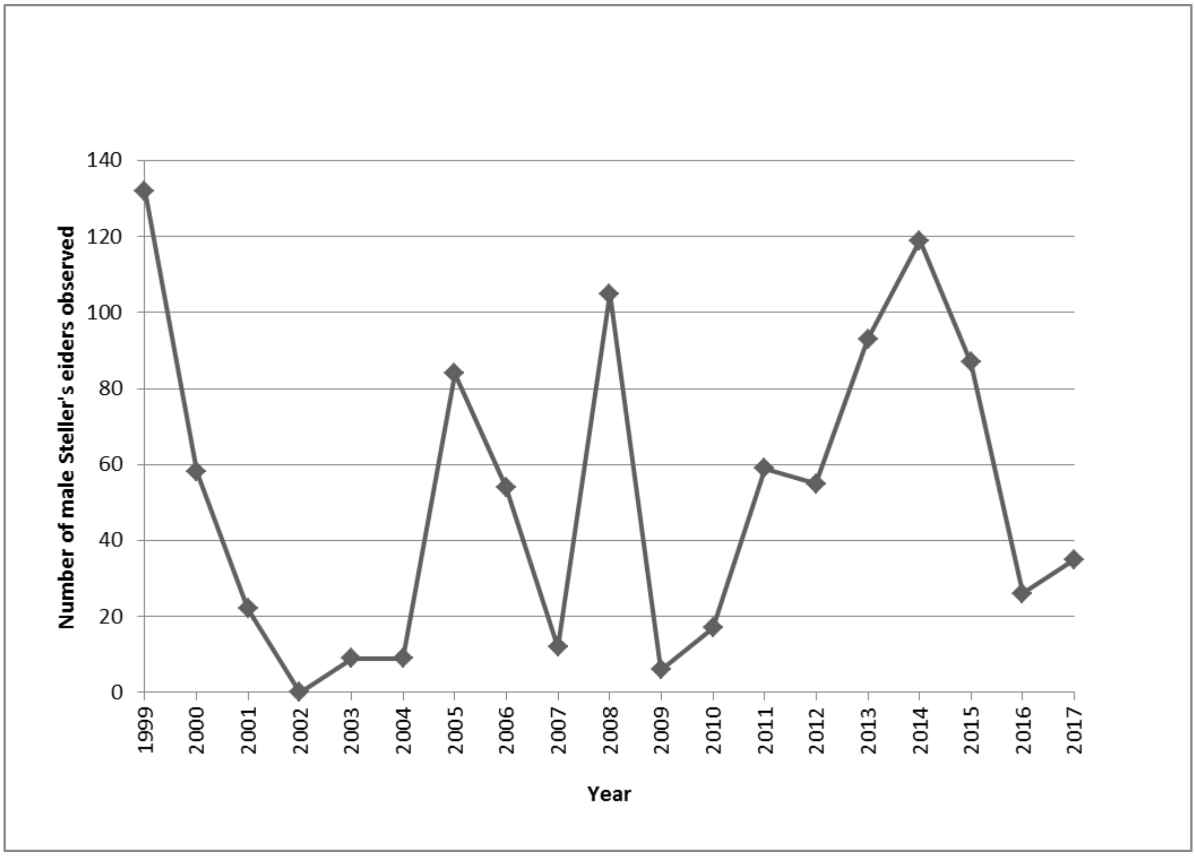


Figure 10. Number of male Steller's eiders observed during ground-based survey near Utqiaġvik, Alaska, 1999-2017.

Safine et al. (in prep) used genetic profiles of 242 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 Utqiaġvik study area from 1995 to 2016 was 0.78 (SE = 0.06; Safine et al., in prep.). 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 Utqiaġvik 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., in prep.) 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; Oppel 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 Utqiaġvik and Norway, and Utqiaġvik and Lena River, Russia breeding areas using traditional F-statistics; however, no significant difference was detected between Utqiaġvik 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. (in prep) determined the number of females that nested near their natal site in the Utqiaġvik 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 Utqiaġvik 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. (in prep.) 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 (0.4 [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), 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. (in prep.) estimated the rate of permanent emigration. 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 – (apparent survival/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, estimates of permanent emigration of Steller's eiders nesting in the Utqiaġvik study area range from 0.09 (SE = 0.07) to 0.13 (SE = 0.06; Safine et al. in prep.). 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 compliment of permanent emigration. Thus, estimates of breeding site fidelity range from 0.87 - 0.91. While this estimate applies only to the birds in the population sampled (those females that nested in the area searched near Utqiaġvik, see Safine et al., in prep.), it does suggest that female Steller's eiders in the Utqiaġvik study area have fidelity to previously used nesting areas.

Safine et al. (in prep) 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. 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- (apparent capture probability/closed capture probability) from a time-varying model, was 0.77 (SE = 0.06; Safine et al., in prep.). Safine et al. (in prep) suggests 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. We do not have information to determine the relative likelihood of either explanation. However, average distance between successive nests of individual females was 2.7 km (SE = 0.5, range 0.1 – 10 km), 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 Utqiaġvik 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 Utqiaġvik 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 Utqiaġvik in 2000 and 2001 (p. 346). Although there was a small sample size, 7/13 satellite-tagged Steller's eiders used Kuskokwim Shoals during wing molt (7/13 birds; 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, the majority of 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 Yukon-Kuskokwim 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, 11/12 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).

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 available 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 Utqiaġvik 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). The Steller's eider recovery plan bases 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 2002, 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 Utqiaġvik 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 Utqiaġvik 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 in 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, the average population size, and the 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 Utqiaġvik 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.

6.2.4. 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 philopatry in the Utqiaġvik 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 drakes with whom hens 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 bottleneck. If the eastern Russia population declines, these benefits will disappear.

However, information on demographic rates, abundance or population growth rate of the Russian-Pacific breeding population from which to infer population resilience is very limited, with the possible exceptions of estimates of adult survival (i.e., Frost et al. 2013, Section 6.2.2) and measures of minimum population abundance of Pacific-wintering Steller's eiders during the non-breeding season in southwest Alaska.

The USFWS 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 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), and averaged 81,453 (USFWS 2012c, p. 12-13). There is no measure of precision for annual counts because no replicates were conducted in most years due to weather and budget constraints, with the exception of 1992 – 1997 and 2008. The resulting count was also highly variable due to weather 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 new aerial survey was conducted during the fall molt period in five primary molting lagoons along the northern Alaska Peninsula from 2012 – 2017, using photographic and ocular methods (USFWS 2013c, p. 2). Estimates of Steller's eiders in the surveyed area ranged from 30,407 (2013) to 70,320 birds (2014; USFWS 2016c, p. 7). The ability to conduct replicate surveys in each lagoon varied annually. The new survey design reduced some sources of error, but challenges remain which limit our inferences from the data for estimating abundance or trend of the Pacific-wintering population of Steller's eiders remain. For example, annual variation in distribution, and breeding success affects the ability of the survey to consistently count the same component of the population. In addition, detection probabilities have not been estimated. This increases noise in the data and widens confidence intervals, decreasing the ability to detect trends. 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.).

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, is unknown. Therefore, we cannot evaluate the resiliency of the Russian-Pacific breeding population at this time.

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, that 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 Utqiaġvik, and loss or alteration of tundra nesting habitat from development (USFWS 2002, 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 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 Utqiaġvik. 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 Atqasuk, Nuiqsut, and Wainwright. However, the density of Steller's eiders is very low outside of the Utqiaġvik 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 Utqiaġvik 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 data sets. A thorough geospatial analysis of these data would be required for a precise estimate, which was not possible prior to the development of this SSA. However, we can approximate the proportion using the available data while making the following assumptions: 1) Steller's eiders using the area within the Utqiaġvik ground survey area will be affected by anthropogenic factors because the survey area is within 6 km of the road system; 2) the Utqiaġvik Triangle 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 Utqiaġvik Triangle and the survey has high coverage; and, 3) observations from the Utqiaġvik Triangle survey and the Utqiaġvik ground 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 Utqiaġvik ground survey area is 0.37 and ranges from 0.11 to 0.60 annually[2]. Therefore, in this analysis we assume that approximately one third of the northern Alaska subpopulation is potentially affected by anthropogenic effects near Utqiaġvik, 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 Utqiaġvik, 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 there is evidence that lead shot is still available for purchase, and is used, within Steller's eider habitat (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, and 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

[2] We calculated this number as follows: For each year 2007 – 2016, we first multiplied the number of males counted on the Utqiaġvik ground survey by 2 to account for unobserved females. We divided that number by the sum of it and the estimate from the Utqiaġvik Triangle aerial survey, and calculated the mean for the series.

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 Utqiaġvik; 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 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 near-shore habitats, the risk is low. Alaska-breeding Steller's eiders are at risk from power line strikes near Utqiaġvik, 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)[3]	Extent of subpopulation affected annually (score)[4]	Effect to resiliency (score)[5]	Confidence Level[6]
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 Utqiaġvik	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

[3] 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

[4] % 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%

[5] Sum of scores for individual response and geographic scope: Low = 1-3, Moderate = 4-6, High = 7-10

[6] **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 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 Utqiaġvik Triangle. This could indicate either strong site fidelity, or a preference for a particular habitat characteristic found in that area, or both. Additionally, there are some indications that habitat in the Utqiaġvik Triangle 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 Utqiaġvik and 40 to 50 km inland at its widest point south of Utqiaġvik (i.e., the Utqiaġvik Triangle; 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 Utqiaġvik Triangle and a few other limited northern coastal areas to the east of Utqiaġvik 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 Utqiaġvik Triangle 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 A and B). 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 Utqiaġvik, 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 Utqiaġvik, 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 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 Utqiaġvik in 2012, and all wetlands were pure freshwater (USFWS 2013a; p. 30). Currently, at least in the Utqiaġvik Triangle 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 Utqiaġvik (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 in the northern ACP. While snowy owl and pomarine jaeger nests are recorded near Utqiaġvik during the ground survey (USFWS 2018) 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. 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). Similarly, 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 murres *(Uria aalge*) and thick-billed murres (*Uria 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). Also, research is being conducted due to a concern that condition of eelgrass beds is deteriorating due to an influx of warmer water into the Bering Sea from the Pacific Ocean (T. Hollmén, Alaska Sea Life Center, pers. comm. 2018); however, at this time we have no evidence to evaluate the condition of eelgrass beds relative to Steller's eider requirements. 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 that we felt was 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 average number of Steller's eiders present on ACP per year ranges from 216 - 422 (95% CI; mean = 308; E. Osnas and C. Frost, USFWS Biometricians, pers. comm.). In the Utqiaġvik Triangle, between 184 and 225 Steller's eiders are estimated to be present per year (95% CI; mean = 204; 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 sub-population

Overall, the available information, much of which comes from the Utqiaġvik study area, suggests that the northern subpopulation of Steller's eiders has low resiliency for the following reasons. The subpopulation has a low and variable numbers of Steller's eiders are 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., in prep.), 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 seem to 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[7]
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

[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.

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 2017e, 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 Utqiaġvik Triangle. The very low densities of nesting Steller's eiders outside of the Utqiaġvik Triangle 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 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 Utqiaġvik Triangle, 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 Utqiaġvik 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 Utqiaġvik Triangle; 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 possible 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 (2014) synthesized the current state of knowledge concerning climate change science in the IPCC Fifth 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 (2014) used different CO^2 emission scenarios to project the effects of climate change on environmental factors through 2100 (p. 57). 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 2014, p. 58 - 59). 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 2014, p. 60). Near-surface permafrost extent, and spring snow cover at northern latitudes are likely to decrease (IPCC 2014, p. 62). 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 2014, p. 60 - 62). Models also project a global increase in ocean acidification for all emissions scenarios, particularly for polar marine ecosystems (IPCC 2014, p. 67).

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 2014, p.60), 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 is 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 Utqiaġvik Triangle 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 Utqiaġvik (Andresen and Lougheed 2015, p. 5), and increased coastal erosion may degrade shorelines and drain large lakes (Mars and Houseknecht 2007, p. 586). There is 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 Utqiaġvik Triangle) are dependent on many spatial and temporal variables, and thus 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 Utqiaġvik (Lougheed 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 2014, p. 60); 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 2014, p. 67). 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 western population of Steller's eiders, the potential impacts of these climate change effects on habitat suitability is unknown.

Marine environment. -- While we are still lacking 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. (in review) 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., in review). 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., in review) 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. These results highlight the high uncertainty of forage availability for Steller's eiders in molt, winter, and staging areas over the next few decades.

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 2014, p. 62). 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.

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 burden, 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.

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 National Petroleum Reserve-Alaska (e.g., GMT2 development, BLM 2018, p. 32). Future lease sales are also likely in the 1002 Area of 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 Utqiaġvik is of particular importance to Steller's eiders given that the highest densities are found in the Utqiaġvik Triangle. 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 2017f). In 2018, the Department of Interior exchanged land with the King Cove Native Corporation in order for the corporation to build a road across the Izembek-Kinzarof Lagoon isthmus to provide access to an airport. 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, for molting. 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 have 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 United States 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 2017f, p. 4). The Army Corps of Engineers (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 2017f, 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 2017f, 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 USFWS and partners. In the pessimistic scenario we assume that the present level of effort/funding focused on Steller's eider conservation near Utqiaġvik continues, and it is moderately effective. In the optimistic scenario 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 Utqiaġvik. 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 optimistic and pessimistic scenarios are the same because there is less uncertainty in the resulting effects.

	OPTIMISTIC SCENARIO	**PESSIMISTIC SCENARIO**
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 nest success and duckling survival.	Same as optimistic: Fewer thermoregulatory costs and extended time for late nests/ducklings to survive to fledge before freeze up. Increases 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.
	Lower thermoregulatory cost, and sea ice cover does not determine wintering distribution.	Same as optimistic: Lower thermoregulatory cost, and sea ice cover does not determine wintering distribution.
	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.
	Less sea ice in Arctic and North Pacific oceans results in increased shipping, resource	Same as optimistic: Less sea ice in Arctic and North Pacific oceans results in increased

	development, and infrastructure development in Steller's eider marine distribution. This increases the risk of collisions and exposure to hydrocarbons through oil spills.	shipping, resource development, and 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 pessimistic: Increases disease exposure	Increases disease exposure
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.
	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.
	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 Utqiaġvik.	No changes.
	Develop a conservation plan that protects the most important Steller's eider nesting and brood rearing habitat near Utqiaġvik.	No changes.
	Develop a plan for the landfill to consistently use incinerator, which reduces nest predator (fox, gulls) abundance near Utqiaġvik.	No changes.

7.3.2. Results

In the optimistic scenario, 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 translate into a 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 Utqiaġvik. In summary, in the most optimistic situation, 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 the pessimistic scenario 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 Utqiaġvik, may buffer the potential impact of future habitat change. We expect no increases in redundancy (current characterized as low) and 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	OPTIMISTIC SCENARIO	PESSIMISTIC SCENARIO
Tundra			
Polygonal tundra (macro)	**high**	**same as current condition**	**same as current condition**
Polygonal tundra (micro)	**unknown**	**same as current condition**	**lower condition than current condition**
Quality and quantity of freshwater invertebrates	**unknown**	**same as current condition**	**lower condition 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 impacts on resiliency are uncertain.

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 Utqiaġvik Triangle, 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 Utqiaġvik, 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 Utqiaġvik, 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.

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. 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. Lougheed. 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 esuarine 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.

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.

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 Ikpikpuk 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. Revsion v 1.7. September 2017. Anchorage, Alaska.

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.

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.

Gazeau, F., C. Quiblier, J.M. Jansen, J-P. Gattuso, J.J. Middleburg, and C.H.R. Heip. 2007. Impact of elevated CO_2 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.

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.

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.

[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.

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. Duartes, and J-P. Gattuso. 2013. Impacts of ocean acidification on marine organisms: Quantifying sensitivities and interaction with warming. Global Change Biology 19: 1884-1896.

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, AlD.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.

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. Stimmelmayr, 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. Raynolds, V.E. Romanovsky, J. Schulla, K.D. Tape, D.A. Walker, C.J. Wilson, H. Yabuki, and D. Zona. 2016. Pan-Arctic ice-wedge degredation 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.

Lovvorn, 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.

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.

McKinney, F. 1965. The spring behavior of wild Steller's eiders. The Condor 67:273-290.

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.

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., 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.

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.

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 dinoflaggelate blooms in the eastern Bering Sea in summers 2004 and 2005. PLoS ONE 12: 1-14.

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.

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., 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.

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.

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.

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.

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 prefledging 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.

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.

Traill, 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.

Traill, 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.

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. 2002. Steller's Eider Recovery Plan. Fairbanks Fish and Wildlife Field Office. Fairbanks, Alaska. 27p.

[USFWS] U.S. Fish and Wildlife Service. 2003. Impact of investigator disturbance on spectacled eiders and cackling Canada geese nesting on the Yukon-Kuskokwim Delta. Unpublished Report to Anchorage Ecological Services Office. Prepared by T. Bowman and R. Stehn. Office of Migratory Bird Management, Anchorage, Alaska. 23pp.

[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. Waterfowl population status, 2017. U.S. Department of the Interior, Washington, D.C. USA.

[USFWS] U.S. Fish and Wildlife Service. 2017b. Abundance and trend of waterbird populations on the Yukon-Kuskokwim Delta, Alaska, 1988-2016. Unpublished Report. Prepared by M.A. Swaim. Office of Migratory Bird Management, Anchorage, Alaska. 37pp.

[USFWS] U.S. Fish and Wildlife Service. 2017c. Nest population size and potential production of geese and spectacled eiders on the Yukon-Kuskokwim Delta, Alaska, 1985-2016. Unpublished Report. Prepared by J.B. Fischer, A.R. Williams, and R.A. Stehn. Office of Migratory Bird Management, Anchorage, Alaska.

[USFWS] U.S. Fish and Wildlife Service. 2017d. Aerial survey detection rates for spectacled eiders on the Arctic Coastal Plain. Unpublished Report for the Bureau of Land Management. Prepared by H.M. Wilson, R.A. Stehn, and J.B. Fischer. Office of Migratory Bird Management, Anchorage, Alaska. 23pp.

[USFWS] U.S. Fish and Wildlife Service. 2017e. 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. 2017f. 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 Utqiaġvik, 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. 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

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 Steller's eider numbers in the Barrow Triangle Aerial Survey Study Area.

Breeding Bird Population Estimates for the Barrow Triangle Aerial Survey Study Area

To: Kate Martin, Endangered Species Recovery Program Biologist

From: Catherine Bradley, FES Regional Biometrician

CC: Neesha Stellrecht, Endangered Species Recovery Program Branch Chief

March 16, 2018

In December 2017, Kate Martin requested an updated analysis of the Steller's eider count data from both the Arctic Coastal Plan (ACP) aerial survey and the Barrow Triangle aerial survey. This request stemmed from ongoing discussions to analyze the data using a state-space modeling approach, rather than the log-linear regressions used previously. Such an approach allows us to better incorporate into estimates of population size and growth rate the uncertainties associated with sampling error, stochastic variation in growth rates and observation errors due to imperfect detection.

There was also a desire to use a more informed estimate of detection probability. Previously, this had been set at a constant rate of 0.3 (see Stehn and Platte 2009 for discussion). Here, we relied on the results of a recently completed double-observer study conducted in conjunction with the ACP aerial survey (Wilson et al. 2017).

Biometricians in the Migratory Bird Management Branch have conducted the analysis on the ACP aerial survey data. Here, I will discuss the analysis of the Barrow Triangle aerial survey data. We have coordinated on our approaches. Deviations, where they occur, are noted.

Methods

Data

The Barrow Triangle aerial survey has been flown annually since 1999. Throughout this period, a standard 2757 km^2 area from Utqiaġvik to the Meade River has been covered. However, coverage intensity has varied over time (App 1). A complete summary of the survey methods is available in the annual reports prepared by ABR, Inc. (e.g., Obritschkewitsch and Ritchie 2017). From project reports the total number of lone males, paired males, and flocked males observed each year, in addition to coverage intensity, were obtained (App 1).

Use of total counts, rather than transect-specific counts, marks the main methodological difference between the ACP and Barrow Triangle analyses. At this time, transect-specific counts are not available, but I have spoken with Tim Obritschkewitsch about obtaining this data from ABR, Inc. If this information becomes available, a revised analysis will be conducted to place the two analyses in better alignment.

In addition to this data, detection probabilities from a surrogate species, the long-tailed duck, obtained through the double observer study conducted in 2015 and 2016 on the ACP were used (Wilson et al. 2017). Detection probabilities for this species were 0.43 (SE 0.0276) for lone individuals, 0.517 (SE 0.0287) for pairs, and 0.5714 (SE 0.0348) for flocks. It is not currently known how well these detection rates compare to those for Steller's eiders in the Barrow Triangle survey. It is beneficial to have specific group size probabilities and to have estimates of the error about these probabilities. However, it is important to remember that the population estimates obtained from this analysis are highly informed by the use of these values and should be interpreted with caution.

Model

Observed counts of group size *i* (where *i* = 1 for lone males, *i* = 2 for paired males, and *i* = 3 for flocked males) in year *t* is assumed to be sampled from a binomial distribution with probability equal to the detection probability, *p*, associated with the group size:

$$y_{i,t} \sim binomial\ (p_{i,t}, A_{i,t})$$

where $A_{i,t}$ is the number available for detection in the flown area.

Priors for the group size-specific detection probabilities, $p_{i,t}$, are described using beta distributions with means and standard deviations given above.

$A_{i,t}$ is assumed to be sampled from a Poisson distribution with mean $S_{i,t}$ multiplied by the proportion of the Barrow Triangle study area covered in that year, c_t.

$$A_{i,t} \sim Poisson\ (S_{i,t} c_t)$$

This completes the description of the observation process, relating the observed counts, $y_{i,t}$, to the expected population size of male breeding birds in the Barrow Triangle aerial survey area each year, $S_{i,t}$.

The state of the system describes underlying processes occurring in the population, but unobservable. Here we assume that the population in year *t* + 1 is related to the population in year *t* by the population growth rate, r_t.

$$\log S_{i,t+1} \ = \ \log S_{i,t} \ + \ r_t$$

Annual growth rate is randomly drawn from a Normal distribution centered on zero and with process error drawn from a gamma distribution.

$$\bar{r} \sim Normal\ (0, \sigma_{proc})$$

$$\sigma_{proc} \sim gamma\ (2{,}1)$$

Finally, an estimate of yearly abundance of male breeding birds in each group (lone, pair, and flock) in the Barrow Triangle study area is sampled from a Poisson distribution with mean $S_{i,t}$. These estimates are summed across groups and multiplied by 2 to provide an annual estimate of breeding birds in the Barrow Triangle study area at the time of the aerial survey.

$$N_{i,t} \sim Poisson\ (S_{i,t})$$

$$N_t = \sum_{i=1}^{3} 2N_{i,t}$$

The model was run in the R statistical environment (R Core Team 2017) and fit in a Bayesian framework with JAGS 3.30 (Plummer 2012) using the jagsUI package (Kellner 2015). Three chains were run for 30,000 iterations, a burn-in of 20,000, and a thin rate of 1. Model convergence was assessed by visual inspection of the trace plots and confirming that the Gelman-Rubin statistic was <1.1 for all estimated parameters.

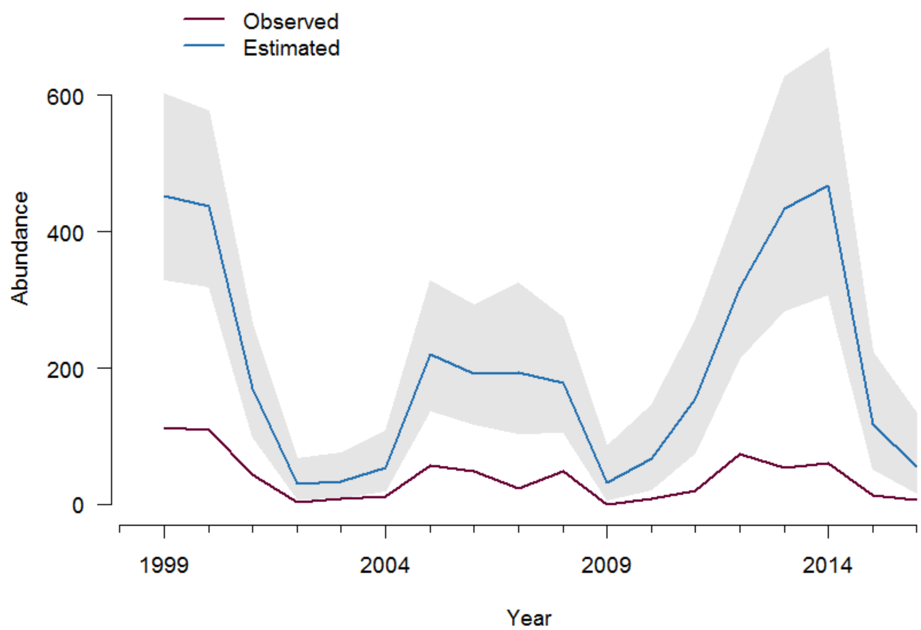
Results

The average Steller's eider breeding bird population in the Barrow Triangle study area from 1999 - 2016 is estimated to be 204 (95% CRI: 184 - 225). Annual estimates are presented in Table 1 and Figure 1.

Table 1. Annual Steller's eider breeding bird population estimates in the Barrow Triangle aerial survey study area.

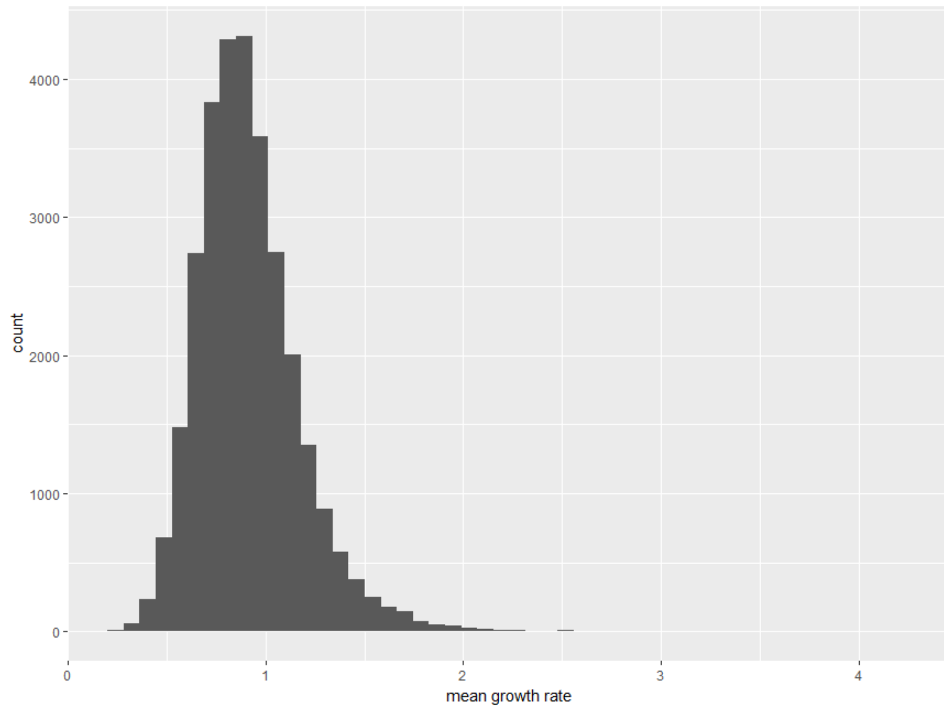
Year	Estimate	95% CRI
1999	452	330-602
2000	438	320-578
2001	170	100-264
2002	30	8-68
2003	34	10-76
2004	54	20-108
2005	220	138-328
2006	192	118-292
2007	194	104-324
2008	178	106-274
2009	32	6-86
2010	68	22-146
2011	154	76-270
2012	318	216-446
2013	434	284-628
2014	468	308-670
2015	118	52-224
2016	56	16-134

Figure 1. Observed and estimated (95% CRI) Steller's eider breeding birds in the Barrow Triangle aerial survey study area.



The estimated average growth rate is 0.88 (95% CRI: 0.56 -1.38). The variability about this estimated parameter is very wide, reflecting the uncertainty in the annual population estimates and the variability in the annual growth rates. However, 68.6% of the posterior distribution of the estimated average growth rate is below one, suggesting support for the conclusion of a declining breeding bird population in the Barrow Triangle survey area.

Figure 2. Posterior distribution of the average growth rate.



Conclusions

This represents the first formal attempt to analyze the data from the Steller's eider Barrow Triangle study area aerial survey using a state-space approach. Results are in general agreement with previous analyses: a low and highly variable population, with evidence to suggest a decline over the time period observed. Caveats to consider when interpreting these results are those associated with the use of the data from a surrogate species to estimate detection probabilities (and the assumption of constant annual mean detection probabilities), use of total count data, and the population of inference. The first two issues were discussed in the methods section. In addition to these, the population estimated here is assumed to be the number of birds present during the nesting season in the Barrow Triangle study area each year. Given the current knowledge of Steller's eider biology, population level breeding propensity may vary widely annually such that abundance and trends observed in the breeding population may not accurately reflect those of the total population. Work to collect and analyze data related to this issue is a continued activity of the Steller's eider recovery program.

Appendix 1. Data used in this analysis.

Year	Lone Males[a]	Paired Males[a]	Flocked Males[a]	Coverage[a]
1999	26	28	2	0.5
2000	15	33	7	0.5
2001	5	11	6	0.5
2002	1	1	0	0.5
2003	2	2	0	0.5
2004	5	1	0	0.5
2005	14	15	0	0.5
2006	16	8	0	0.5
2007	1	11	0	0.25
2008	3	21	0	0.5
2009	0	0	0	0.27[b]
2010	1	1	2	0.25
2011	4	6	0	0.25
2012	10	13	14	0.47
2013	11	9	7	0.25
2014	6	10	14	0.25
2015	4	3	0	0.25
2016	0	3	0	0.25

[a]Obritschkewitsch and Ritchie 2017
[b]Obritschkewitsch and Ritchie 2010

Appendix 2. The impact of unknown detection probabilities.

Because we used data from a surrogate species as a proxy for detection probability of Steller's eider in the Barrow Triangle study area, there was interest in exploring the impact of this decision. In the absence of stochasticity, detection probability (p) is a simple multiplier used to relate observed counts (C) to abundance (N). For example, if 100 individuals are observed in a survey, the table below gives abundance estimates for a range of detection probabilities.

p	N
0.1	1000
0.2	500
0.3	333
0.4	250
0.5	200
0.6	167
0.7	143
0.8	125
0.9	111
1.0	100

To see how alternative detection probabilities could affect the current analysis, three scenarios were explored. In the first two, the relative difference between lone, pair, and flock detection probabilities were kept approximately equivalent to that in the surrogate species (~ 0.1 difference between the groups), but the lowest and highest range of detection probabilities were assumed. Standard deviations were not changed from those estimated in the surrogate species. In the last scenario, a fixed rate of 0.3 was used for all group sizes as was previously assumed in past analyses of the data.

Lone	Pair	Flock	Average Pop Size (1999 - 2016)	95% CRI
0.1	0.2	0.3	669	584 - 768
0.7	0.8	0.9	129	116 - 143
0.3	0.3	0.3	332	301 - 366

References

Kellner, K. (2015). A wrapper around 'rjags' to streamline 'JAGS' analyses: Package 'jagsUI' version 1.4.9. https://github.com/kenkellner/jagsUI

Obritschkewitsch, T. and R. J. Ritchie. (2010). Steller's eider surveys near Barrow, Alaska, 2009. ABR, Inc. Fairbanks, Alaska.

Obritschkewitsch, T. and R. J. Ritchie. (2017). Steller's eider surveys near Barrow, Alaska, 2016. ABR, Inc. Fairbanks, Alaska.

Plummer, M (2012). JAGS version 3.3.0. http://sourceforge.net/projects/ mcmc-jags/files/Manuals/

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing. http://www.R-project.org/

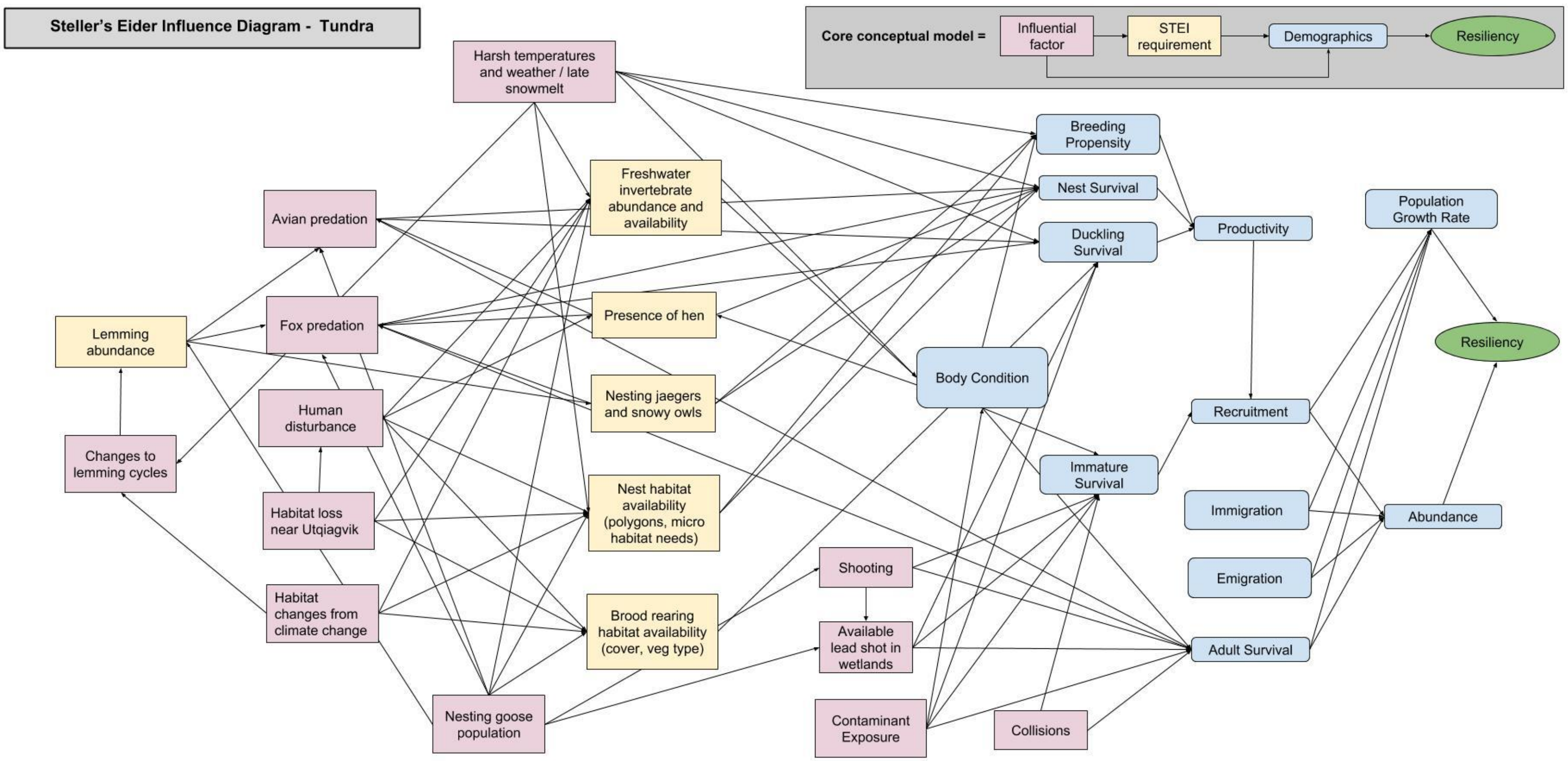
Appendix B. Five competing model structures of population process and associated vital rates used in an attempt to describe the resiliency of the northern Alaska subpopulation of Steller's eiders during this SSA analysis

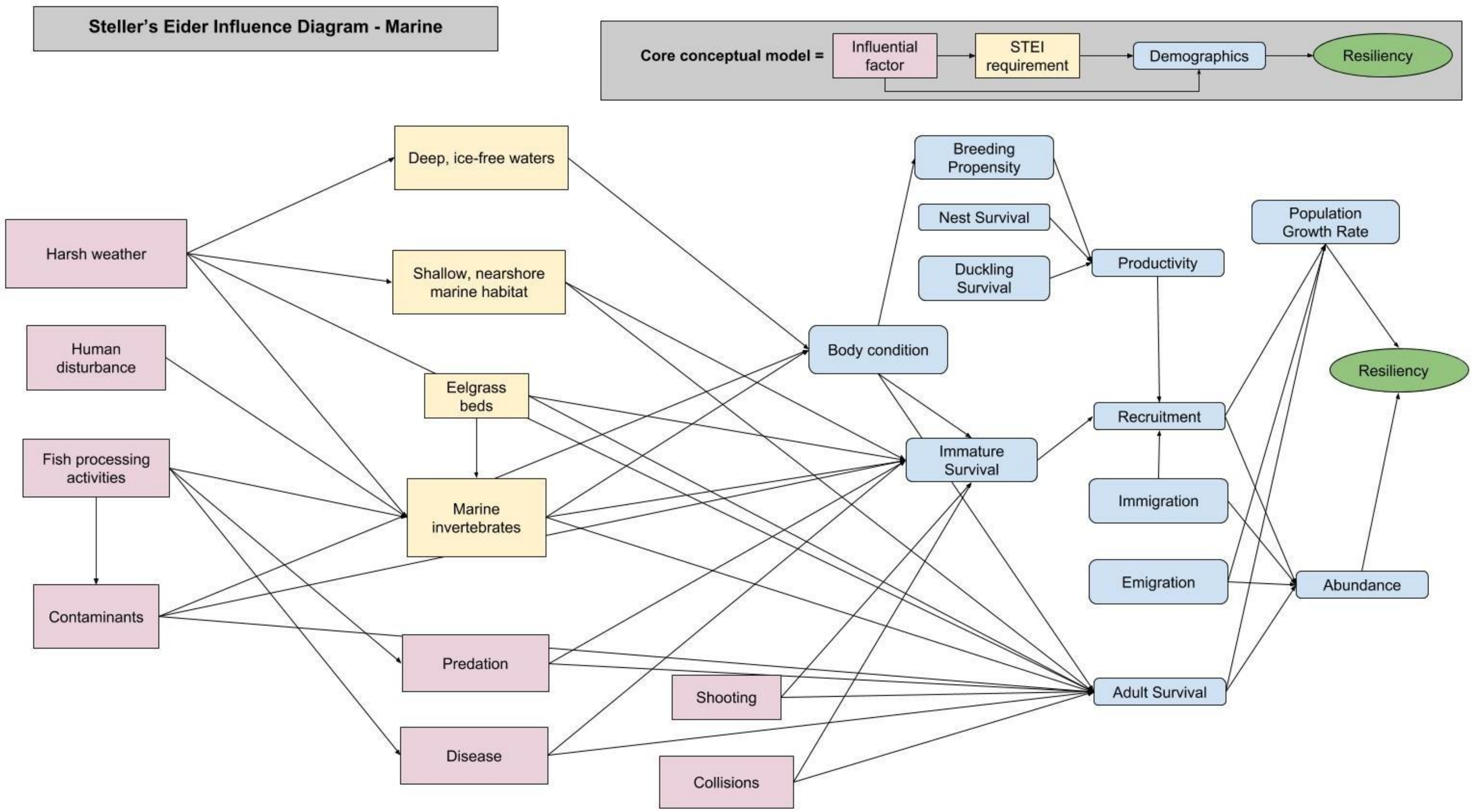
	Models											
	live.long		rescue*		periodic.norm**		periodic.pulse**		panmixia		closed	
Parameters	mu	sd	mu	sd	mu	sd	mu	sd	mu	sd	mu	sd
m.0A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.1A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	0.09	0.005	0	0
m.2A	0.001	0.002	0	0	0.001	0.002	0.001	0.002	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 non breeding 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 modelled 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
Core conceptual model =
Influential factor
STEI requirement
Demographics
Resiliency
Deep, ice-free waters
Shallow, nearshore marine habitat
Eelgrass beds
Marine invertebrates
Harsh weather
Human disturbance
Fish processing activities
Contaminants
Predation
Disease
Shooting
Collisions
Body condition
Breeding Propensity
Nest Survival
Duckling Survival
Productivity
Immature Survival
Recruitment
Immigration
Emigration
Adult Survival
Population Growth Rate
Resiliency
Abundance

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 Confident (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 resilience)	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	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., Utqiaġvik) 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 Utqiaġvik showed high levels and rates of exposure (USFWS 1997, p.16; A. Matz, USFWS Biologist, pers.comm.), and 11 percent of long-tailed ducks (*Clangula hyemalis*) 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).	HC: In 1999-2000, 8/8 nesting Steller's eider females sampled near Utqiaġvik exceeded blood lead concentrations of >0.2ppm (USFWS unpublished data), and a Steller's eider found dead near Utqiaġvik had liver and kidney lead levels suggestive of poisoning (USFWS 1997, p. 16).
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 in 2018-2019.
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 Utqiaġvik, 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	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.

	25% but more than 1% of the northern Alaska subpopulation are exposed to lead at levels that affect reproduction or survival annually.	
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 SC 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/Description of Uncertainties**
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 Utqiaġvik 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 Utqiaġvik (USFWS 2018b, p. 38).	HC
Conservation measures	The USFWS 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 that occurs, as it is difficult to monitor take (USFWS 2018, p. 36-38).	HC that outreach activities occur, LC that they are effective at minimizing or eliminating shooting of Steller's eiders.

Individual response and effects	Dead or injured birds.	HC
Score (individual response)	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 on the ACP from 2007- 2017 is 308 birds (95% CI: 216-422; E. Osnas and C. Frost 2018, USFWS Biometricians, pers. comm.). 10/308 = 3.2% 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	Utqiaġvik 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 Utqiaġvik. 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 Utqiaġvik, 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 Utqiaġvik 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 (PSA announcements, newsletters, etc.). Most research activities are considered in intra-Service Section 7 consultations, consultations with NSF, or under a programmatic consultation with the BLM 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 effected 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 Utqiaġvik. 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 UTQIAGVIK (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 development may: 1) Disturb incubating or brood-rearing hens, potentially	MC

	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 Utqiaġvik. However, there are indications that the habitat in the Utqiaġvik Triangle 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 Utqiaġvik (USFWS, unpublished data).	
Score (individual response)	Unknown	MC
POPULATION RESPONSES		
Geographic scope	Expansion of the Utqiaġvik footprint may affect 1/3 of the northern Alaska subpopulation that uses the area near the Utqiaġvik 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 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 Utqiaġvik, so currently, this factor is unlikely to affect the population's resilience 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 Utqiaġvik, Atqasuk, 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 has 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 Utqiaġvik, Atqasuk, 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 Steller's eider nests by jaegers may be highest in years of moderate	MC

	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 and therefore are not in the area to depredate Steller's eider eggs or ducklings.	
Conservation measures	USFWS destroys raven eggs/young annually in Utqiaġvik when possible to reduce the raven population and resulting predation pressure on nesting Steller's eiders. Utqiaġvik 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 inviability 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 Utqiaġvik towards 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, USFWS 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 Utqiaġvik 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 Utqiaġvik. Generally, brown lemming populations underwent dramatic fluctuations in abundance every 3-4 years near Utqiaġvik (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 is 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 Utqiaġvik 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 Utqiaġvik 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 Utqiaġvik 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, Utqiaġvik 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 Utqiaġvik, 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 *Carex aquatilis* 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 Utqiaġvik Triangle 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 Utqiaġvik 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 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 *Carex-Puccinellia* and increase in *Salix spp.* 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 2017e, 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

	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 1990's 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 Utqiaġvik Triangle, 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.	
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. However, we have no evidence that effects are currently occurring.	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	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 a higher energetic requirements during the non-breeding season.	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.	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 USFWS consulted with EPA 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 USFWS 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 STEI at Unalaska Bay	LC

	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 USFWS and ADFG sport hunting regulations, from Sept 1 - April, 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 USFWS 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). USFWS'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, USFWS 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. USFWS outreach and law enforcement efforts on the ACP, particularly at Utqiaġvik,	LC - It is unknown how effective the regulations and conservation measures are at minimizing the amount of shooting that occurs, as it is difficult to monitor take (USFWS 2018b, p. 36-38).

	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).	
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 population 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, 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 sites, 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	Steller's eiders could be exposed to a variety of viruses; for example, reoviruses (T Hollmén, unpub. 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 are 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	LC; with the exception of avian influenza in the mid-late 2000's, very little disease and parasite screening has been conducted on Steller's eiders.

	(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 YKD and occasional, opportunistic sampling done with other waterfowl in Alaska, particularly focused on avian influenza.	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, and overhead power lines.	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 Utqiaġvik 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.	LC - because risk likely varies annually based on various factors, there is uncertainty in the exposure risk of individuals
Immediacy	Near Utqiaġvik, 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 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	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.

	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 landing or colliding 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). 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.	
Conservation measures	Some power lines in Utqiaġvik have been marked with diverters. USFWS 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 Utqiaġvik (1/3) are 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 Utqiaġvik 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	LC - Little to no supporting information on population-level effects of collisions

	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.	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). Note that essential trace elements also occur naturally in the environment.	HC
Activities	Extracting and burning fossil fuels, smeltering, 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 Utqiaġvik or near oil development in NPR-A, most exposure to trace elements probably occurs in marine areas used during	MC - Available information on exposure rates of Steller's eiders in many parts of their distribution and over time is limited.

	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 Utqiaġvik, 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 Utqiaġvik 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).	
Immediacy	Individual Steller's eiders have been shown to be exposed to trace elements, hydrocarbons and POP's but there is limited evidence showing that any of these contaminants occur at toxic levels for the species.	LC

	Cumulative or synergistic effects of repeated exposure of individuals near industrial sites may be of concern.	
Conservation measures	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).	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	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 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.	MC - even less information is available regarding the effects of exposure on individuals.
Score (individual response)	2 - may reduce breeding success or survival	MC
POPULATION RESPONSES		
Geographic scope	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	LC - based on a series of assumptions due to lack of data on exposure rates and response.

	subpopulation is significantly affected by trace elements, hydrocarbons, and/or POPs at this time.	
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 significantly impact survival or reproduction affects 1% or less of the population.	LC - based on a series of assumptions due to lack of data on exposure rates and response.
Score (effect on resiliency)	unknown	
Overall confidence in analysis	n/a	