Species Status Assessment Report for the Tufted Puffin (*Fratercula cirrhata*)

Photo Credit: Service

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Executive Summary

The tufted puffin (*Fratercula cirrhata*) is a widely-distributed pelagic seabird found in the North Pacific Ocean. Tufted puffins are large alcids measuring 15.7 inches (in) (40 centimeters (cm) in length and 1.7 pounds (lb) (775 gram (g)) in weight. Males are slightly larger, otherwise both sexes are similar in appearance. The tufted puffin is a burrow-nester that commonly nests colonially on offshore islands. Tufted puffins nest along the coasts of California, Oregon, Washington, and Alaska in the United States, and in British Columbia, Russia, and Japan. The majority of tufted puffins (82 percent) nest in North America, primarily Alaska; Russia has the second largest concentration of nesting tufted puffins (18 percent). Colony size is variable, ranging from just a few birds to large colonies of greater than 100,000 tufted puffins.

In 2002, there was a range-wide estimate of 3 million tufted puffins. Since then, tufted puffin nesting has declined in Japan, Washington, Oregon, and some colonies in British Columbia and Alaska, while some colonies in Alaska have seen increased nesting, primarily those located in the Aleutian Islands. Current trends for nesting tufted puffins in Russia are unclear.

Large Marine Ecosystems (LMEs), developed by the National Oceanic and Atmospheric Administration, were used as analysis units to discuss tufted puffin colony distribution, abundance, stressors, and conservation actions throughout the range. We identified six major stressors as having potential to negatively affect tufted puffins or their habitat: (1) climate change, (2) oil spills, (3) fisheries bycatch, (4) mammalian and avian predators, (5) nonnative plants and animals, and (6) human disturbance. We carried these stressors into our analysis of current conditions, and used them to estimate potential future conditions. Of these six stressors, our analysis indicated that climate change and oil spills had the highest potential to affect tufted puffins throughout their range, while fishery bycatch may affect tufted puffins in part of their range. Table ES-1 summarizes the current condition of tufted puffins in each LME across their range.

In projecting the future viability of the tufted puffin, three scenarios were considered: (1) current influences remain constant 50 years into the future; (2) negative influences decrease due to elevated levels of conservation efforts over 50 years; and (3) negative influences increase in magnitude/intensity over 50 years. Projections to 2070 under two climate scenarios, Representative Concentration Pathway (RCP) 4.5 and RCP 8.5, indicate tufted puffins could decline in many of the LMEs, while it is highly likely the tufted puffin will disappear entirely from Japan. Table ES-2 summarizes the potential future condition of tufted puffins in each LME across their range. Our analysis indicates the species is likely to maintain the ability to withstand catastrophic events (redundancy), the adaptive potential across its range (representation), and the capability to withstand stochastic disturbance (resiliency), although at reduced abundance.

Table ES-1. Summary of the current condition of each LME in the tufted puffin range.

Analysis Unit	Population Estimates[1]	Demographic Factor	Habitat Factor	Overall Condition
		Population Trend[2]	Stressors	
California Current (CA, OR, WA, B.C.)	<60 colonies estimate 2,000 birds	Declining	Climate Change Oil Spills	Low
Gulf of Alaska (B.C., AK)	>400 colonies ~1 million birds	No statistically significant trend[3]	Climate Change Oil Spills Fishery Bycatch	Moderate
East Bering Sea (AK)	<30 colonies ~100,000 birds	No statistically significant trend	Climate Change Oil Spills	Moderate
Aleutian Islands (AK)	>150 colonies ~1.2 million birds	Increasing	Climate Change	High
North Bering and Chukchi Sea (AK)	~70-180 colonies ~40-50k birds	No statistically significant trend	Climate Change	Moderate
West Bering Sea (Russia)	~70+ colonies ~150-200k birds	Unknown	Unknown	Unknown
Sea of Okhotsk (Russia)	~40-50 colonies ~100-300k birds	Unknown	Unknown	Unknown
Oyashio Current (Japan)	1-2 colonies <20 birds	Declining	Climate Change Fishery Bycatch Mammal/Avian Predation Human Disturbance	Low

[1] Details found in individual LME discussions, summary based upon Piatt and Kitaysky 2002, entire.
[2] Based on trend data (Pearson *et al.* 2019) and documented declines across the range.
[3] The Gulf of Alaska trend should be treated with caution; 3 of 4 monitored populations show declining trends.

Table ES-2. Summary of future conditions for each LME for three potential future scenarios.

Analysis Unit	Current Condition	Scenario 1: RCP 8.5 Status Quo 2070	Scenario 2: RCP 4.5 with improved conservation/mitigation 2070	Scenario 3: RCP 8.5 with Increased Threats 2070
California Current (CA, OR, WA, B.C.)	Low	Low	Low	Low
Gulf of Alaska (B.C., AK)	Moderate	Low	Moderate	Low
East Bering Sea (AK)	Moderate	Low	Moderate	Low
Aleutian Islands (AK)	High	Moderate	High	Moderate
North Bering and Chukchi Sea (AK)	Moderate	High	Moderate	High
West Bering Sea (Russia)	Unknown	Unknown	Unknown	Unknown
Sea of Okhotsk (Russia)	Unknown	Unknown	Unknown	Unknown
Oyashio Current (Japan)	Low	Extirpated[1]	Extirpated[1]	Extirpated[1]

[1] Based on extremely low current numbers, extirpation is likely under all three scenarios.

Abbreviations and Acronyms

ACT	Endangered Species Act
ADF&G	Alaska Department of Fish and Game
AI	Aleutian Islands
AK	Alaska
AU	Analysis Unit
BC	British Columbia
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CA	California
COASST	Coastal Observation and Seabird Survey Team
EC	Ecosystem Component
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FR	Federal Register
GAL	Gallon
GHG	greenhouse gas
GIS	Geographic Information System
GOA	Gulf of Alaska
HAB	Harmful Algal Bloom
IUCN	International Union for Conservation of Nature
LME	Large Marine Ecosystem
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPFMC	North Pacific Fishery Management Council
NPSD	North Pacific Seabird Colony Data
NPS	National Park Service
NRC	National Research Council
NRDC	Natural Resources Defense Council, Inc.
NWFSC	Northwest Fisheries Science Center
NWR	National Wildlife Refuge
OR	Oregon
PAME	Protection of the Arctic Marine Environment Working Group
PFMC	Pacific Fishery Management Council
PSAT	Puget Sound Action Team
RCP	Representative Concentration Pathway
RLO	Relative Likelihood of Occurrence
SDM	Species Distribution Model
SE	Standard Error
Service	U.S. Fish and Wildlife Service
SSA	Species Status Assessment
SST	Sea Surface Temperature
SWFSC	Southwest Fisheries Science Center
TUPU	Tufted Puffin
USGS	U.S. Geological Survey
WA	Washington
WDFW	Washington Department of Fish and Wildlife
WSDE	Washington State Department of Ecology

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Chapter 1: Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U. S. Fish and Wildlife Service (Service) for the tufted puffin (*Fratercula cirrhata*) (Figure 1-1). We use the SSA framework to conduct an in-depth review of the species' biology and the various factors that influence the tufted puffin (both negative and positive), evaluate its current biological status, and predict the potential future status of resources and conditions as a means of assessing the tufted puffin's viability. This SSA report is a living document and is not an exhaustive list of everything known about the tufted puffin, but rather summarizes the results of our analysis using this framework. As new information becomes available, we intend to update this SSA report as needed so that it can support all functions of the Endangered Species program, if merited, such as candidate assessments, listing, consultation, and recovery.

This SSA report is not a decisional document; rather, it provides the biological and scientific foundation for our decision on whether to list the tufted puffin as an endangered or threatened species under the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq.*). If we determine listing the tufted puffin is warranted, we may also use this SSA report to aid us in designating critical habitat for the species (if found to be prudent and determinable), and as required by the Act.

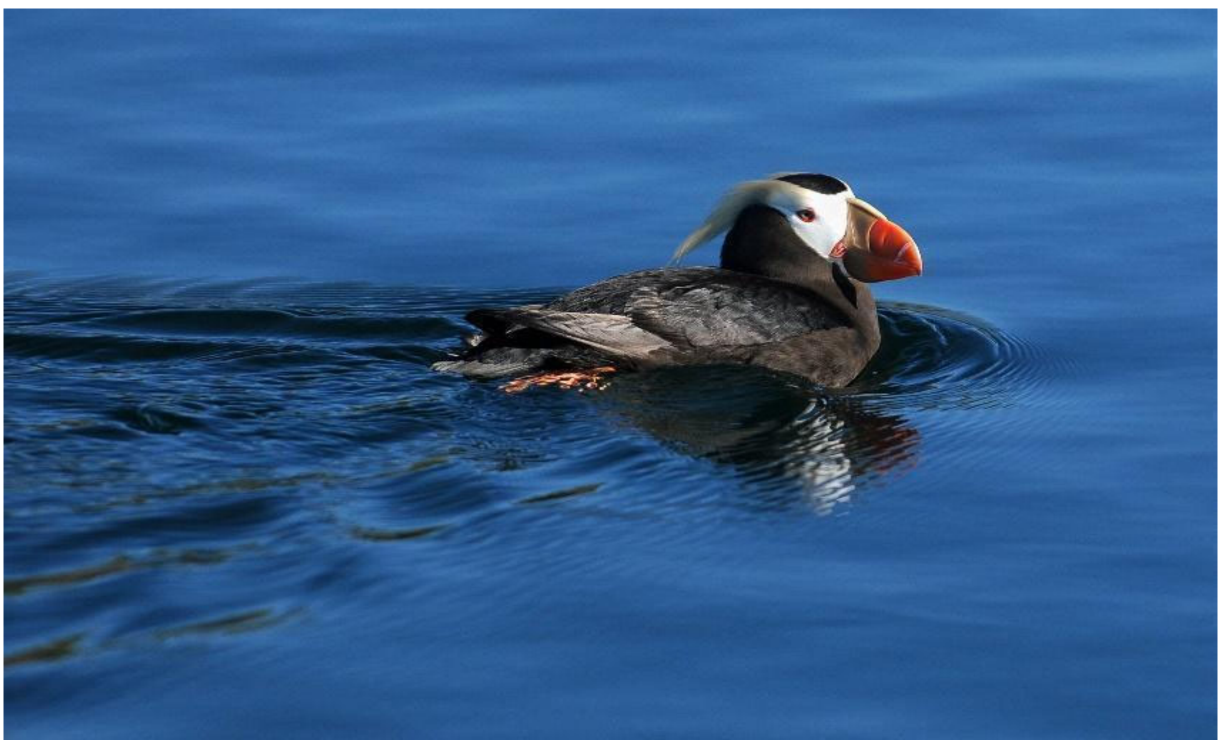
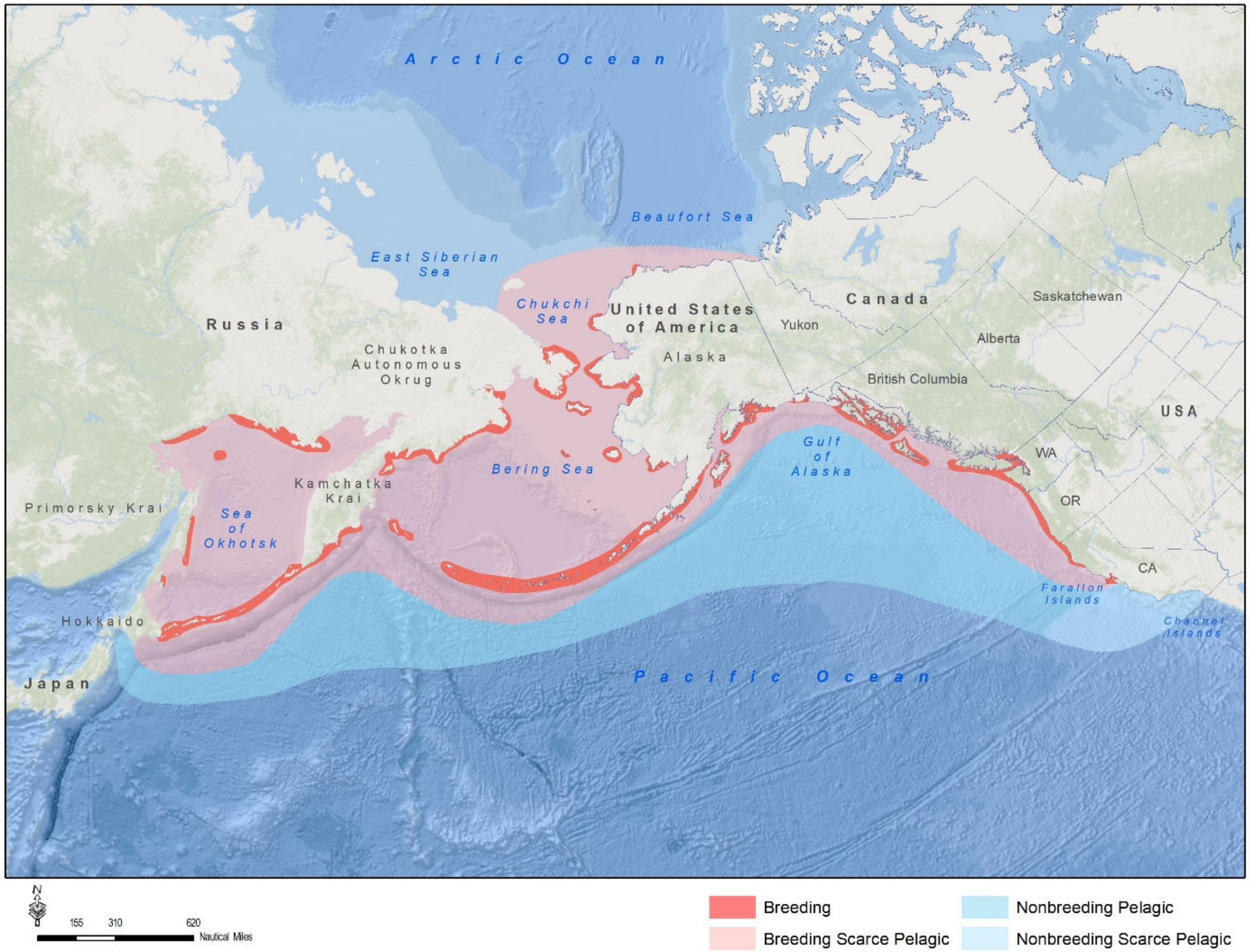


Photo Credit: Peter Davis, Service

Figure 1-1. Adult tufted puffin, Protection Island National Wildlife Refuge, Washington, U.S.A.



Source: Adapted from Piatt and Kitaysky 2002

Figure 1-2. Tufted puffin range map, including breeding and non-breeding distribution. "Pelagic" refers to distribution of tufted puffins in the open ocean, and "scarce pelagic" refers to distribution of tufted puffins in the open ocean at low numbers.

1.1 Species Basics and Taxonomy

The tufted puffin is a pelagic seabird that nests along the coasts of the northern Pacific Ocean, including California, Oregon, Washington, British Columbia, Alaska, Russia, and Japan (Figure 1-2). During the non-breeding season, adult and juvenile tufted puffins return to the deep waters of the North Pacific Ocean (Piatt and Kitaysky 2002, pp. 1–2).

The currently accepted classification of the tufted puffin is:

- Phylum: Chordata
- Class: Aves
- Order: Charadriiformes
- Family: Alcidae
- Tribe: Fraterculini
- Genus: Fratercula
- Species: cirrhata

Tufted puffins belong to the Alcidae family, a family of seabirds known for "flying" underwater to forage (Friesen *et al.* 1996, p. 359). The Alcidae family is based on the analysis of both morphological and ecological characteristics, along with a comparison of allozymes and sequences of mitochondrial deoxyribonucleic acid. The family is made up of six major lineages, each identified by their own tribe (Piatt and Kitaysky 2002, p. 4). The tufted puffin classified tribe, Fraterculini, includes all puffins (genus *Fratercula*), and the rhinoceros auklet (*Cerorhinca monocerata*; genus *Cerorhinca*). The tufted puffin was formerly placed in the monotypic genus *Lunda* because it was initially thought to be more closely related to the rhinoceros auklet than other species of puffins (Piatt and Kitaysky 2002, p. 4).

1.2 Methodology

1.2.1 The Species Status Assessment (SSA) Framework

This report, which is a summary of the analysis, entails three iterative assessment stages: species (resource) needs, current species condition, and future species condition (Figure 1-3). Using this framework, we considered what the tufted puffin needs to maintain viability (i.e., sustain populations in the wild over time); we characterized the current and future status of the species using the concepts of resiliency, redundancy, and representation (the "3Rs") from conservation biology (Shaffer and Stein 2000, pp. 308–311; Service 2016, p. 12).

- **Resiliency** is the ability of populations to tolerate natural, annual variation in their environment and to recover from periodic or random disturbances, known as stochastic events. Resiliency can be measured using metrics like vital rates, such as annual births and deaths, and population size. In general, populations with high abundance and stable or increasing population trends are more resilient than those with limited resources or declining populations. Populations with high resiliency can better withstand stochastic changes in demography or their environment due to natural or anthropogenic disturbances.

- **Redundancy** is the ability of a species to withstand catastrophic events, such as a rare, destructive natural event that affects multiple populations. Redundancy is measured by the duplication and distribution of populations across the range of the species. The more redundant a species, or the greater number of populations a species has distributed over a larger landscape, the better able it is to recover from catastrophic events. Redundancy helps "spread the risk" and ensures all populations are not extirpated at once due to a catastrophic event.

- **Representation** is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. Representation can be measured by looking at the genetic, morphological, behavioral, and ecological diversity within and among populations across a species' range. The more representation, or diversity, a species has, the more likely it is to adapt to and persist with natural or human-caused changes to its environment.

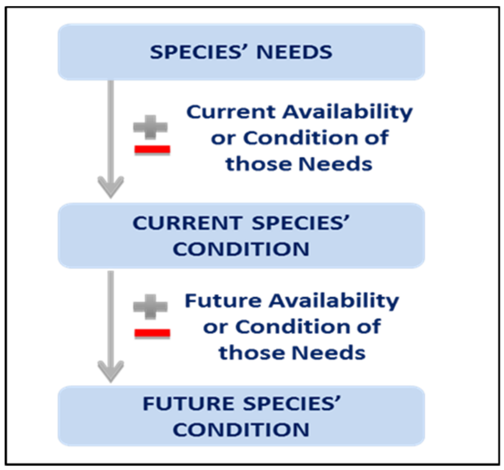


Figure 1-3. The three phases (blue boxes) of the SSA Framework used to guide this analysis (Service 2016, entire).

1.2.2 Species Needs

We evaluated the best available scientific information on the tufted puffin's life history. To identify individual- , population-, and species-level needs, we used published literature, unpublished reports, information from experts and consultants, and data from current agency surveys and research projects. Major sources of information on population demographics and abundance include Kondratyev *et al.* 2000, entire; Piatt and Kitaysky 2002, entire; Hanson and Wiles 2015, entire; and unpublished Service data. Major sources of information for population status and trends include Hanson and Wiles 2015, entire; Goyert *et al.* 2017, entire; Hart *et al.* 2018, entire; Hanson *et al.* 2019, entire; and Pearson *et al.* 2019, entire.

The majority of information presented in this SSA is specific to the tufted puffin. Occasionally, information for a closely related, conspecific, or surrogate species such as the horned puffin (*Fratercula corniculata*), Atlantic puffin *(Fratercula arctica),* or rhinoceros auklet (*Cerorhinca* *monocerata*) is presented. In these instances, we explicitly identify the species used as a surrogate for the tufted puffin, and describe the similarities and differences between the conspecific species and the tufted puffin.

1.2.3 Current Conditions

We considered the tufted puffin's distribution, abundance, and factors currently influencing the viability of the species. We identified known historical and current distribution and abundance, and examined factors that negatively and positively influence the species. Threats (stressors) were identified by reviewing current literature on tufted puffins (e.g., Piatt and Kitaysky 2002, pp. 17, 20–22; Hanson and Wiles 2015, pp. 20–32; Hanson *et al.* 2019, p. 2; Pearson *et al.* 2019, p. 2) and evaluated for their likely impacts on tufted puffin, and then described for each analysis unit. Finally, known conservation actions were identified for each analysis unit. Large Marine Ecosystems (LME) were used as analysis units (Section 3.2) to discuss tufted puffin colony distribution, abundance, stressors, and conservation actions throughout the range.

We relied on Pearson *et al.* (2019, entire) to understand changes in the occurrence of breeding tufted puffins in North America. Pearson *et al.* (2019, p. 4) used data from select LMEs in the North American breeding range of the tufted puffin, which included 11 datasets spanning 112 years, to model trends; data included at-sea density or encounter estimates, and on-colony counts. To assess trends, Pearson *et al.* (2019, p. 4) conducted a meta-analysis for the California Current, Gulf of Alaska, and Aleutian Island/East Bering Sea LMEs using a negative binomial generalized linear mixed effects regression model (Pearson *et al.* 2019, p. 7). Population trends in these LMEs, along with the magnitude and scale of potential impacts to the tufted puffin or its habitat by a given stressor or a given conservation measure, are described using a High/Moderate/Low category scale (Chapter 3, Table 3-6).

For the purposes of this SSA, we considered tufted puffins extant in an analysis unit if there is evidence they nested or attempted to nest. We considered tufted puffins extirpated in an analysis unit when there is no longer evidence they nested or attempted to nest. Since many tufted puffin colonies are not regularly monitored, identifying active tufted puffin nesting colonies is difficult. For this reason, if census data is lacking, we assumed tufted puffins were extant until confirmed extirpated.

Range-wide, there is no standardized monitoring or census of tufted puffin colonies. Along the west coast of the U.S., many (but not all) tufted puffin colonies are regularly monitored. In British Columbia, monitoring of most tufted puffin colonies is sporadic, with the last large-scale monitoring project in the 1980s (Wilson 2019, pers. comm.); however, ongoing tufted puffin monitoring on Triangle Island is conducted at 5-year intervals. In Alaska, eight out of several hundred tufted puffin colonies are regularly monitored using established plots. In Russia, the amount and type of tufted puffin monitoring is unknown. In Japan, tufted puffin colonies were last counted in 2013, although breeding was confirmed in 2016 (Sato *et al.* 2018, pp. 1, 3).

1.2.4 Future Conditions

Using the SSA framework (Figure 1-3), we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (Wolf *et al.* 2015, entire; Service 2016, entire). To examine the potential future condition of tufted puffins, we developed three future scenarios that focus on a range of conditions based on projections for ways stressors could negatively affect the species into the future; we also considered beneficial conservation actions. We describe the range of what may happen in each future scenario based on the current condition, and how resilience, representation, and redundancy may change. We chose a timeframe of 50 years (to 2070) for our analysis based on the availability of trend information, planning documents, climate modeling that helps inform future conditions, and the generation time of the tufted puffin, which is reported as 21.6 years (Birdlife International 2018, p. 1).

Major sources of information used to forecast future conditions for the SSA include Goyert *et al.* (2017, entire), Hart *et al.* (2018, entire), Bradley (2019, pers. comm.), and Pearson *et al.* (2019, entire). When data were lacking for tufted puffin, we used information for a closely related, conspecific, or surrogate species, such as horned puffin, Atlantic puffin, or rhinoceros auklet, where appropriate.

1.3 Conservation Status

1.3.1 Global Status

The International Union for Conservation of Nature (IUCN) lists the global status of the tufted puffin as a species of "Least Concern" (Birdlife International 2018, p. 1). According to the IUCN, tufted puffin "…has a very large range, and hence does not approach the thresholds for Vulnerable under the range size criterion (Extent of Occurrence [less than] 20,000 [square kilometers] combined with a declining or fluctuating range size, habitat extent/quality, or population size and a small number of locations or severe fragmentation). Despite the fact that the [global] population trend appears to be decreasing, the decline is not believed to be sufficiently rapid to approach the thresholds for Vulnerable under the population trend criterion ([greater than] 30 [percent] decline over ten years or three generations). The population size is extremely large, and hence does not approach the thresholds for Vulnerable under the population size criterion ([less than] 10,000 mature individuals with a continuing decline estimated to be [greater than] 10 [percent] in ten years or three generations, or with a specified population structure)." (Birdlife International 2018, p. 1).

1.3.2 Local Status

Several location-specific regulatory protections are in place to protect the tufted puffin. In some areas of its range that are currently experiencing declining population trends (as described in Chapter 3), tufted puffins have been designated as a species of special concern, sensitive, endangered, or as vulnerable by state, provincial, or constitutional governments (Table 1-1). Specific laws and regulations that protect the tufted puffin across its range are listed in more detail in Appendix A). Each of these designations provides the tufted puffin with some degree of protection, although not necessarily the same level of protection that listing under the Act would provide. In Alaska and Russia, where a large percentage of tufted puffins breed (Piatt and Kitaysky 2002, pp. 3, 18), local governments have not designated regulatory protections for tufted puffins.

Table 1-1. Existing classification status of tufted puffins across their range.

California	Listed as a species of special concern by the State of California[1]
Oregon	Listed as sensitive by the State of Oregon[2]
Washington	Listed as endangered by the State of Washington[3]
Canada ***British Columbia***	Listed as a priority species in the North Pacific Rainforest Bird Conservation Region Strategy[4] Listed as a species of special concern (imperiled/vulnerable) in British Columbia[5]
Alaska	Not listed
Russia	Not listed
Japan	Listed as a vulnerable species (endangered) by Japan[6]

[1] CDFW 2019; [2] ODFW 2019; [3] WDFW 2019; [4] Government of Canada 2014; [5] Government of British Columbia 2019; [6] Government of Japan 2019.

Chapter 2: Species Ecology and Needs

In this chapter, we provide basic biological information about the tufted puffin, including its taxonomic history and relationships, morphological description, physical environment, and reproductive and other life history traits. We then outline the needs of the tufted puffin at the individual, population, and species levels. This is not an exhaustive review of the species' natural history; rather, it provides the ecological basis for the SSA analyses summarized in this report.

2.1 Life History

2.1.1 Species Description

Tufted puffins are large alcids, averaging 15.7 inches (in) (40 centimeters (cm)) length and 1.7 pounds (lb) (775 gram (g)) weight, identified by their large laterally compressed triangular bill. Males are slightly larger than females, but both sexes are similar in appearance. Adult breeding birds are brown-black, with a white face-mask and long golden head plumes that drape down their neck (Figure 1-1 and Figure 2-1). Their bill is bright orange and their legs and feet are bright yellowish-orange. Adult non-breeding birds are also brown-black, but their white face-mask becomes gray-brown and they lose their golden plumes. Non-breeding birds also shed their bill plates resulting in their bills becoming slightly smaller with no ridges, but still orange in color (Piatt and Kitaysky 2002, p. 2).

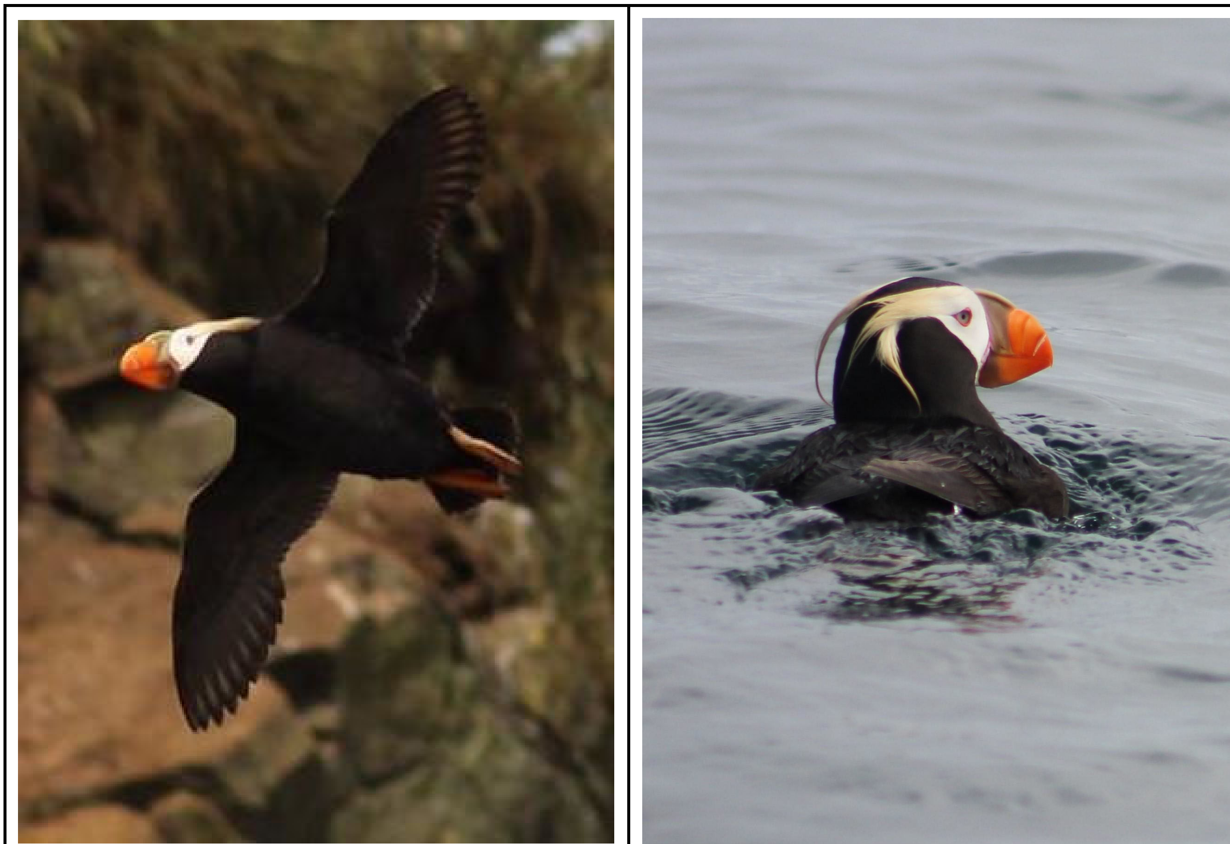


Photo Credit: Service

Figure 2-1. Adult tufted puffins in flight (Haystack Rock at Cannon Beach, photo on left), and on the water (Three Arch Rocks, photo on right) in Oregon, U.S.A.

Juvenile tufted puffins are similar in appearance to non-breeding adult birds, but their bill is shorter, narrower, and brownish gray in color; their feet and legs are charcoal black (Piatt and Kitaysky 2002, p. 23). The iris of a juvenile tufted puffin is charcoal black with a black orbital ring, while adults have a yellow or pale cream color iris and coral red orbital ring (Piatt and Kitaysky 2002, pp. 2, 22-23). Hatchlings are covered in long down that is typically uniformly black or black-brown in color (95 percent of birds), but some hatchlings (5 percent) can have a gray or white belly (Piatt and Kitaysky 2002, p. 22). Hatchlings typically have a dark gray upper mandible and pink-gray lower mandible and their feet are a dark gray (Piatt and Kitaysky 2002, p. 22).

2.1.2 Genetics

Information is limited on range-wide genetic structuring of the tufted puffin. Preliminary studies have examined population differentiation among four breeding colonies in Alaska (Buldir Island, Aiktak Island, Chowiet Island, and East Amatuli Island) and one breeding colony in British

Columbia, Canada (Triangle Island, Figure 2-1; Graham *et al.* 2019, pers. comm.). Microsatellite loci and allele frequencies from 271 individual tufted puffins were used to compare genetic differences among the five colonies. Pairwise tests for genetic differentiation (Fst) were significant between Triangle and Aiktak, and Triangle and Buldir, but not between any other pairs of islands (Table 2-1).

The southern-most sampled population, Triangle Island, was genetically distinct from the northernmost islands of Aiktak and Buldir (Figure 2-2), suggesting an isolation by distance pattern. Overall, results from this preliminary study indicate limited gene flow among the colonies of tufted puffins sampled.

Table 2-1. Pairwise Fst* (lower diagonal) and P values (upper diagonal) for pairwise tests of population differentiation.

Island	Aiktak	Buldir	Chowiet	East Amatuli	Triangle
Aiktak (N=67)	-	0.399	0.426	0.493	**0.002**
Buldir (N=34)	0.001	-	0.883	0.343	**0.013**
Chowiet N=26)	0	0	-	0.512	0.627
East Amatuli (N=8)	0	0	0	-	0.088
Triangle (N=136)	**0.01**	**0.01**	0	0.1	-

Source: Graham *et al.* 2019, pers. comm.

*Fst is a measure of average pairwise distances between pairs of individuals (haplotypes) in terms of allele frequencies. For between population comparisons Fst is a "difference" between allele frequencies of two populations.

Source: Graham *et al.* 2019, pers. comm.

Figure 2-2. Islands sampled for tufted puffin genetic analyses. Tufted puffin sampled from Buldir Island and Aiktak Island (White) are genetically distinct from tufted puffin from Triangle Island (Black). East Amatuli Island and Chowiet Island are not genetically distinct enough (grey) to be considered different from either Buldir Island and Aiktak Island, or Triangle Island.

2.1.3 Habitat

Tufted puffins are pelagic seabirds, spending most of their life great distances from land (Piatt and Kitaysky 2002, p. 2). In the winter and the non-breeding season, juvenile and adult tufted puffins are widespread in the North Pacific Ocean, reportedly occupying an area from approximately 35 degrees north latitude to the Beaufort Sea (Udvardy 1963, p. 104; Piatt and Kitaysky 2002, p. 2). Non-breeding tufted puffins are also regularly observed during the spring and summer months in the deep waters of the North Pacific (Piatt and Kitaysky 2002, p. 3).

In the spring and summer months, tufted puffins breed colonially on land. They prefer steep, rocky islands and mainland cliffs, and typically breed in excavated cavities of vegetated turf on steep slopes or plateaus (Piatt and Kitaysky 2002, p. 5). Burrow densities are the highest along cliff edges and steep slopes with a deep layer of soil and dense vegetation. Vegetation in nesting colonies is often lush and consists of forbs, grasses, and sedges. In lower densities, tufted puffins also nest in cliff crevices and sea caves (Piatt and Kitaysky 2002, p. 13).

All tufted puffins, regardless of life stage, rely on oceanic habitats for feeding and resting, whether in the open water of the North Pacific, or in coastal and deeper waters near their breeding colonies.

2.1.4 Feeding Habits

Tufted puffins capture and consume prey underwater during wing-propelled "flight." They can forage throughout the water column, but spend most of their time searching for prey in midwater during the day and at dusk. Tufted puffins forage either alone, or in small groups of 10 to 20 individuals, with their foraging group either a monospecific or mixed species flock (Sealy 1973, pp. 797, 800; Hoffman *et al.* 1981, pp. 441–443, 449–451; Wehle 1982, p. 51; Ostrand *et al.* 1998, p. 295). An adult diet consists of invertebrates and fish, typically whatever pelagic species are most abundant or available. The diet of adult tufted puffins consists primarily of invertebrates such as squid, polychaetes (bristle annelid worms), and euphausiids (small shrimp-like crustaceans, such as krill); invertebrates make up approximately 50–70 percent of their diet (Piatt and Kitaysky 2002, p. 5). The remainder of their diet consists of forage fish such as anchovy (Family Engraulidae), capelin (*Mallotus villosus*), lanternfish (Family Myctophidae), pollock (*Gadus* sp.), rockfish (*Sebastes* sp.), greenling (Family Hexagrammidae), and sand lance (Family Ammodytidae) (Wehle 1982, p. 56; Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5).

During the breeding season, when tufted puffins have chicks, both parents carry fish in their bills when returning to their burrow. Their bill is adapted for capturing and carrying many fish at a time, routinely carrying 5 to 20 fish in a single delivery to their chick (Piatt and Kitaysky 2002, p. 6). They have a large foraging range, even during the breeding season. Tufted puffins in Washington have been documented flying up to 31 miles (mi) (50 kilometers (km)) one-way from coastal breeding colonies to forage along the offshore shelf-break, then returning to feed their young (Menza *et al.* 2015, pp. 16, 22). The species composition of prey that tufted puffin feed their young can vary by location and year; the variation and relative importance of prey type (i.e., fish, squid, crustaceans, polychaetes) among years and colonies is indicative of the tufted puffin's opportunistic foraging ability (Wehle 1982, p. 56). Tufted puffin pairs may display preference for certain prey species to feed their chicks (Golubova and Nazarkin 2009, pp. 601–602); individual foraging strategies and target prey can vary among tufted puffins, even in the same colony, which can have measurable impacts on chick development (Hipfner *et al.* 2007, pp. 1,150–1,151).

2.1.5 Life Cycle and Reproduction

Pelagic seabirds, such as the tufted puffin, exhibit several distinctive life history characteristics including low reproductive rates, delayed onset of reproduction, longer periods of development and growth, and relatively long lifespans (Ricklefs 1990, p. 1; Schreiber and Burger 2001, p. 46). Tufted puffin populations inter-mix during the non-breeding season in the North Pacific Ocean, although the amount of interaction between individuals from different colonies during the non-breeding season is poorly understood. They spend their entire life dependent on the marine environment and only come "onshore" to breed (Schreiber and Burger 2001, p. 46). Tufted puffin generation time is reported as approximately 21.6 years (Birdlife International 2018, p. 2).

Tufted puffins can have high nesting-site fidelity, often returning to the same breeding colony to lay a clutch of only one egg; some adults are known to return to the same burrow year after year (Wehle 1980, pp. 46–47). The phenology of the tufted puffin breeding season typically starts earlier at lower latitudes than higher latitudes. Four events distinguish arrival at breeding colonies: 1) adults arrive in the vicinity of the colony; 2) colony visits begin; 3) continuous occupancy is established; and 4) egg-laying is initiated; this pre-egg stage averages 3.5 weeks (Wehle 1980, pp. 24, 26). Adult tufted puffins either arrive at their breeding grounds already in pairs, or form pairs shortly after their arrival, with the timing of arrival near breeding colonies relatively constant, usually within the same 1-2 week time-period each year (Piatt and Kitaysky 2002, p. 12). Courtship and mating begins shortly after arrival at the breeding colonies (Wehle 1980, p. 27).

Adults use their clawed feet and occasionally their bill to excavate a crevice or burrow in the soil or mud at their breeding colony. The mean height of a burrow entrance is 5.3–5.7 in (13.5–14.5 cm), mean width is 0.4–6.7 in (1–17 cm), and mean length is 34 in (86.4 cm) but can be as deep as 63 in (160 cm) (Piatt and Kitaysky 2002, p. 13). Adults collect nesting material such as dry grass, small twigs, or feathers from around their burrow, and may also collect nesting materials floating in the ocean, such as algae, scraps of plastic, or gill nets (Piatt and Kitaysky 2002, p. 13). Nests vary from well built with a defined egg cup to simply a few grass straws on the floor of their burrows (Piatt and Kitaysky 2002, p. 13).

The interval between the beginning of colony visits and egg laying is about 2 weeks (Piatt and Kitaysky, p. 12). Timing of egg laying is late April through early May (in lower latitudes) and late May through early July (in higher latitudes; Table 2-2). All parental care duties are shared between the male and female. They begin incubation immediately after egg laying, and both sexes have brood patches. The female lays a single egg with a thick shell, between 2.8 and 2.9 in (71 to 74 millimeters (mm)) in length (Piatt and Kitaysky 2002, p. 13), and dull white or creamy white in color. The mean incubation period is approximately 45-46 days (Amaral 1977, p. 45; Wehle 1980, p. 71). Chicks may hatch as early as June in lower latitudes and as late as August in higher latitudes (Table 2-2). Most tufted puffins brood their chick for 1-3 days after hatching;

both sexes participate in brooding (Wehle 1980, p. 74). Both sexes also participate in feeding the chick during daylight hours (Piatt and Kitaysky 2002, pp. 13–15). The period from hatching to fledging is between 38–59 days (Piatt and Kitaysky 2002, p. 15).

Table 2-2. Timing of incubation, hatching of eggs, and fledgling stages for tufted puffin within three representative areas (California Current, Gulf of Alaska, and Aleutian Islands) across the species range. Specific breeding phenology for other distinct areas within the range are unknown, but are likely to occur in a similarly staged manner according to latitude. In general, tufted puffins initiate breeding earlier in lower latitudes and later in the season with increasing latitude.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
California Current												
Incubation												
Hatch												
Fledge												
Gulf of Alaska												
Incubation												
Hatch												
Fledge												
Aleutian Islands												
Incubation												
Hatch												
Fledge												

Source: Developed from information contained in Piatt and Kitaysky 2002, entire; and Rojek 2019a, pers. comm.

Fledgling dates vary, depending on latitude (Table 2-2). Chicks may fledge as early as July and as late as September; chicks are completely independent from their parents after fledge (Piatt and Kitaysky 2002, pp. 12–13). The fledgling departs the nest at dusk or at night by simply walking or flying from the burrow directly to open water. Parents do not accompany the fledgling or provide any additional parental care once the fledgling leaves the burrow (Piatt and Kitaysky 2002, pp. 13–15).

Egg laying, hatching, and fledgling at tufted puffin colonies is fairly synchronous between individual pairs, so fledgling departure from the colony typically occurs over a 2- to 4-week period. Tufted puffins disperse to their wintering areas in the North Pacific Ocean immediately after fledgling, although some may remain near their breeding colonies (Piatt and Kitaysky 2002, p. 5). Juvenile tufted puffins experience delayed sexual maturation, remaining in the North Pacific Ocean for 1 to 2 years after post breeding dispersal; they may then return to breeding areas, but still might not breed until their fourth or fifth years (Piatt and Kitaysky 2002, pp. 4, 16).

Once adult tufted puffins are of breeding age, it is unknown how many return to their natal colony to breed, and how many select a different breeding colony location. Once tufted puffins select a breeding colony (either their natal colony or different colony), they have been documented to exhibit nest site fidelity, returning to that breeding colony, and sometimes the same burrow, every year (Wehle 1980, pp. 46–47). It is likely that tufted puffin occasionally emigrate to non-natal colonies; the closely related Atlantic puffin has been shown to disperse away from their natal colony, with up to 23 percent of Atlantic puffins permanently emigrating to breed on a new colony (Harris 1983, p. 56). Movement between colonies may be widespread among alcids, and has been documented for other seabirds (Harris 1983, p. 69). There is also evidence that tufted puffins can recolonize a breeding area after being absent for several decades, such as on San Miguel Island (Channel Islands) in southern California in 1991 and 1994 (McChesney *et al.* 1995, entire).

2.2 Tufted Puffin Needs

A species can only be viable if its basic ecological needs are met. In this section, we translate our knowledge of the tufted puffin's biology and ecology into its needs at the individual, population, and species levels.

2.2.1 Individual Needs

Individual needs for tufted puffin vary during the non-breeding and breeding seasons, and by life stage (Figure 2-3; Appendix B). Non-breeding adults in the marine environment (the Pacific Ocean) need access to sufficient forage fish and invertebrates to live during the non-breeding season (Wehle 1982, p. 56; Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5).

During the breeding season, tufted puffin adults and their mates return to breeding colonies; once there, tufted puffin pairs need protective rocks, reefs, sea caves, mainland cliffs, a crevice, or a burrow with suitable soils and vegetation that can be excavated to provide nesting habitat (Piatt and Kitaysky 2002, p. 13). Ideally, burrows or crevices should be spaced to reduce conflicts (Piatt and Kitaysky 2002, p. 10), with a sufficient supply of nesting materials available (Piatt and Kitaysky 2002, p. 13). Breeding adults need access to a sufficient amount of forage fish and invertebrates in marine waters near the colony to feed themselves (Wehle 1982, p. 56; Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5). In addition, adults need access to suitable prey to feed their chick once it hatches (Sealy 1973; Baird 1990, p. 225; Hatch and Sanger 1992, pp. 1, 4; Hipfner *et al.* 2007, p. 1,151; Williams and Buck 2010, pp. 42–43).

Once an egg is produced, tufted puffin adults must brood the egg and protect it from predators, with an average incubation time of 42 to 46 days (Piatt and Kitaysky 2002, p. 14). After hatching, an adult remains with the chick approximately 1 to 3 days (Wehle 1980, p. 225), while continuing to provide protection from predators. Adults must provide chicks sufficient food resources for consumption, such as suitable forage fish and invertebrates of an appropriate size and nutritional value, allowing them to grow and thrive until they fledge. Once fledged, juveniles are completely independent of their parents and need access to a sufficient amount of forage fish and invertebrates in marine waters to feed themselves until they reach maturity and become a breeding adult (Wehle 1982, p. 56; Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5).

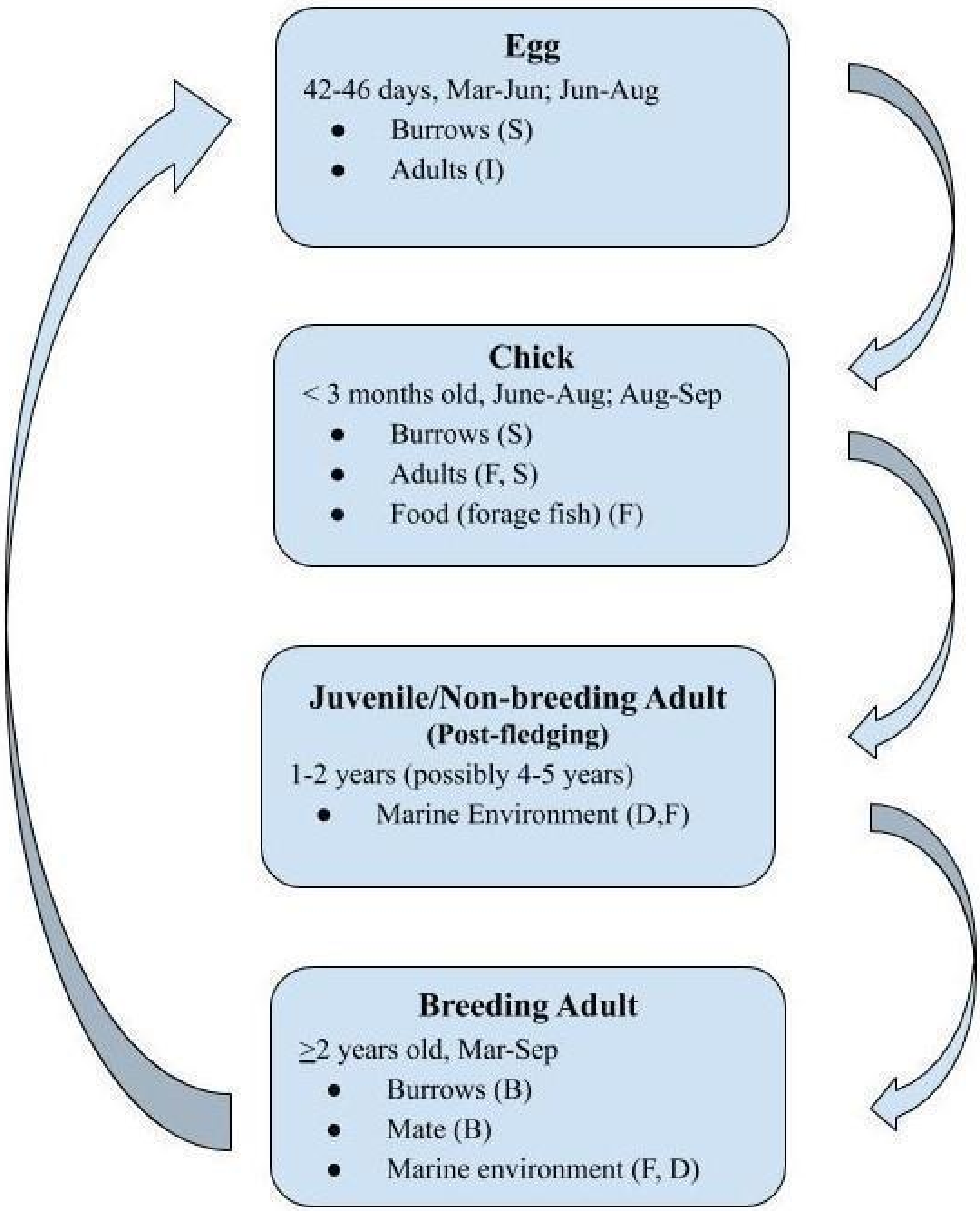


Figure 2-3. Life cycle diagram with the resource needs of tufted puffin eggs, chicks, juveniles and non-breeding adults, and breeding adults. Tufted puffin need these resources to breed (B), feed (F), disperse (D), shelter (S), and incubate (I). Phenology for higher latitudes is represented as later months for each life stage.

2.2.2 Population Needs

For the purposes of this SSA report, we define a population of tufted puffins as a complex of breeding colonies located within a similar geographic area. To remain ecologically functional, these populations need high levels of adult and juvenile survival and low levels of negative influences (stressors). High levels of adult survival, reproductive success, and juvenile survival can drive population growth and allow colonies to recover from stochastic events such as extreme weather events that may flood burrows; extreme heat stress causing reproductive failure; human disturbance that may lead tufted puffins to abandon their nest or chick; or food resource limitations that may make it difficult to provision their chick.

2.2.3 Species Needs

As a species, the tufted puffin needs multiple resilient, well-distributed populations that display ecological, behavioral, and genetic diversity across its range. Information on genetic variability of tufted puffins is limited, and genetic exchange between populations is poorly understood, although preliminary genetic analysis indicates that tufted puffins show a strong genetic differentiation related to their breeding colonies (section 2.1.2 Genetics) (Graham *et al.* 2019, pers. comm.). In general, the tufted puffin's viability is based on resiliency (represented by their populations' ability to withstand stochastic events and their relatively high abundance), redundancy (represented by the wide distribution of their breeding colonies and number of resilient populations), and representation (represented by variations they display in selecting nesting habitat and prey species, and in genetic differentiation related to breeding colonies) (Figure 2-4).

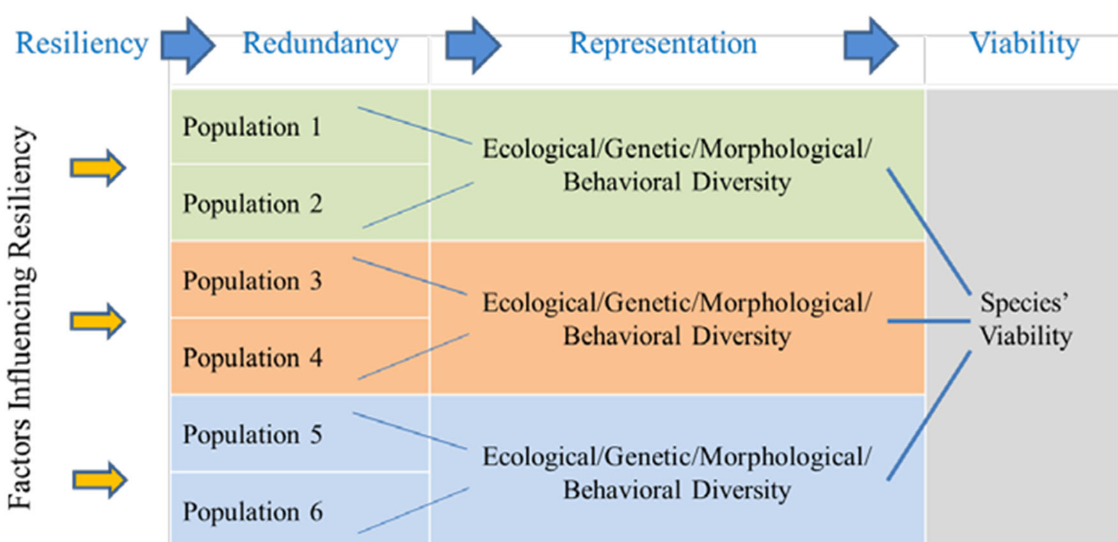


Figure 2-4. General overview illustration of how resiliency, redundancy, and representation influence what a species needs for viability.

2.2.4 Summary of Species Needs in Terms of the 3Rs

In order to maintain resilient populations, tufted puffins need sufficient resources (forage fish and other prey, burrow habitat) to support abundance, survival rate, and reproductive success (Figure 2-5). In order to adapt to changing physical and biological conditions, the species needs to maintain a certain number or distribution of resilient populations across its range (redundancy), and its ecological, behavioral, and genetic diversity (representation) (Figure 2-6).

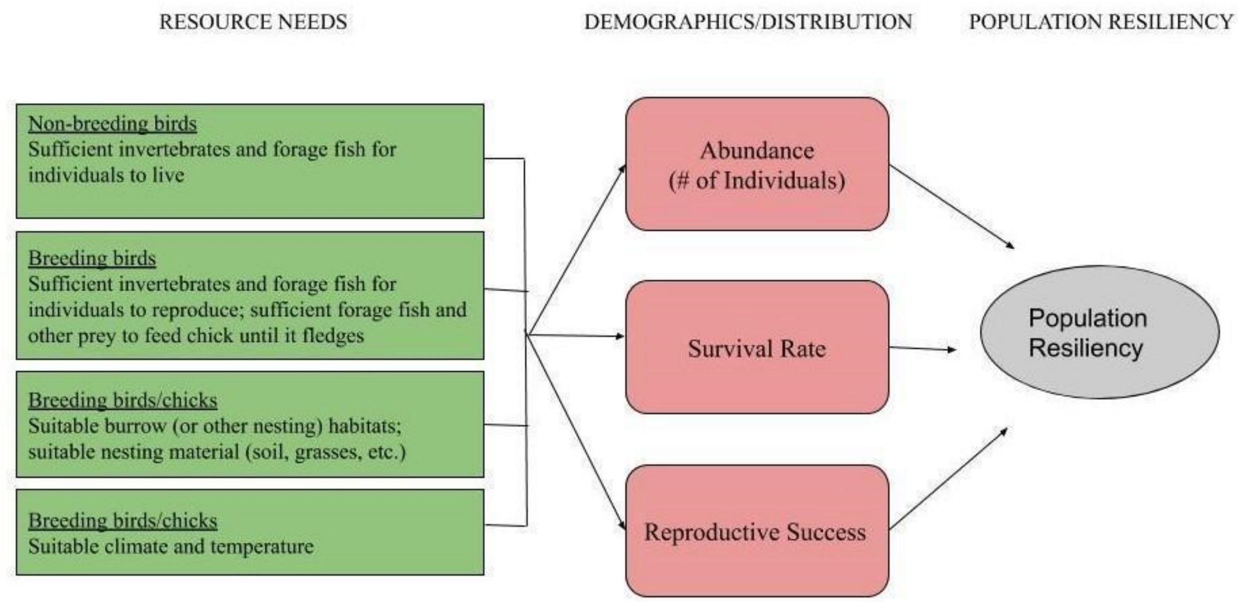


Figure 2-5. Conceptual diagram of what tufted puffins need for population resiliency.

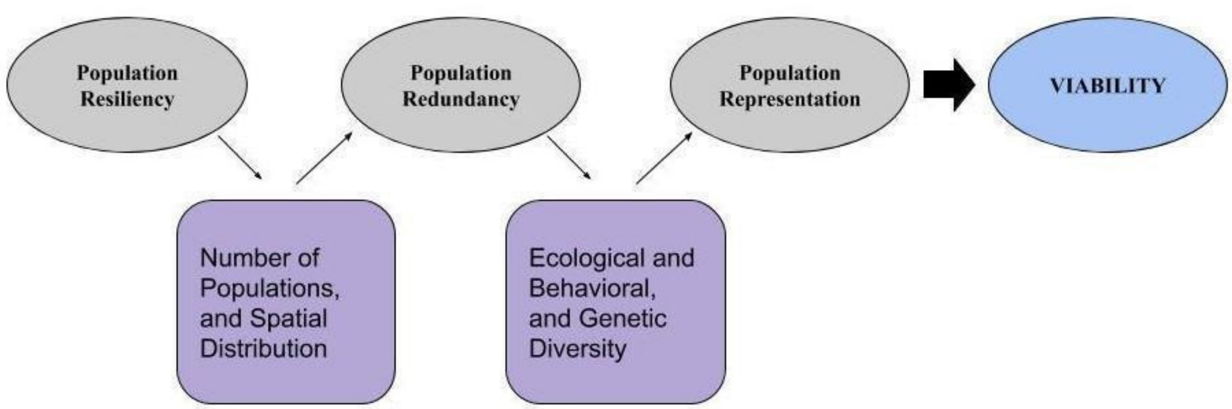


Figure 2-6. Conceptual diagram of what tufted puffins need for population redundancy, representation, and viability.

Chapter 3: Current Conditions

In this chapter, we describe historical and current distribution of tufted puffin across their range, discuss stressors that influence the species' condition, and summarize the tufted puffin's current condition across its range. We also discuss the species' existing regulatory protections, including existing management and conservation actions that benefit the species. Finally, we put the species' current conditions in the context of the 3Rs.

Tufted puffins spend the majority of the year (non-breeding and wintering) in the marine waters of the North Pacific Ocean. At-sea surveys off the coasts of Oregon, Washington, and Alaska provide some information on tufted puffins in these areas; however, their large numbers and wide-ranging distribution make it difficult to monitor tufted puffins in the ocean. Instead, this species is more often described and monitored at their breeding colonies.

3.1 Unknowns and Assumptions

Following our review of the best available scientific and commercial information on the ecology, abundance, distribution, etc. of the species, we identify the following list of unknowns and assumptions for this analysis:

3.1.1 Unknowns

- We do not have a current range-wide population estimate of tufted puffins. This species is a burrow-nester that often nests in inaccessible locations, is easily disturbed while nesting, and is distributed across a wide range. Because of these factors, it is difficult to get a precise count of tufted puffins within their colonies.
- Similar to other alcids, there is evidence that tufted puffins exhibit nest-site fidelity (i.e., return to the same colony, even the same burrow) each year (Wehle 1980, pp. 46–47; Piatt and Kitaysky 2002, pp. 16–17); however, we do not know what percentage of breeding tufted puffins exhibit nest-site fidelity, nor what percentage seek new nest locations in any given year.
- Distribution within the North Pacific Ocean during their wintering and non-breeding season is unknown.
- The amount of gene flow among tufted puffins and colonies is unknown; however, preliminary results of a recent genetic study indicate limited gene flow among colonies of tufted puffins sampled (Graham *et al.* 2019, pers. comm.).

3.1.2 Assumptions

- Range-wide, we assume the information in Piatt and Kitaysky (2002, entire), a comprehensive compilation of tufted puffin ecology, accurately describes the tufted puffin life history, distribution and abundance. We also rely on peer-reviewed research reports and journal articles to inform our understanding of the life history, distribution, and abundance of tufted puffin, with all sources referenced accordingly.
- The population estimates in Piatt and Kitaysky (2002) came from a number of sources, including information provided from the Alaska Maritime National Wildlife Refuge (NWR) and the Beringian Seabird Colony Catalog, now the North Pacific Seabird

Colony Database (NPSD). Many tufted puffin colonies (the majority of Alaska and Russia, some British Columbia colonies) have not been surveyed since the 1970s or 1980s. Piatt and Kitaysky (2002, p. 31) is used to inform our discussion of abundance and distribution. We recognize that the information contained within is a snapshot in time; however, we view this information as the best available scientific and commercial information for many of the tufted puffin colonies and populations range-wide.

- We assume the compilation of colony estimates we received for Russia (Artukhin 2019, pers. comm.) are representative of tufted puffin populations that nest in Russia.
- We have adopted a global tufted puffin population estimate of approximately 3 million tufted puffins range-wide[1] (Kondratyev *et al.* 2000, p. 68; Piatt and Kitaysky 2002, p. 31; Naughton *et al.* 2007, p. 3; Kocourek *et al.* 2009, p. 14; Warzybok *et al.* 2018, pp. 14, 21; Hanson *et al.* 2019, p. 3; NPSD 2019, entire; Renner 2019, pers. comm.), based upon the best available scientific and commercial information. However, this estimate may overstate the current tufted puffin population, due to previously discussed difficulties in counting tufted puffins, and variability of range-wide surveys.

3.2 Large Marine Ecosystems (LMEs)

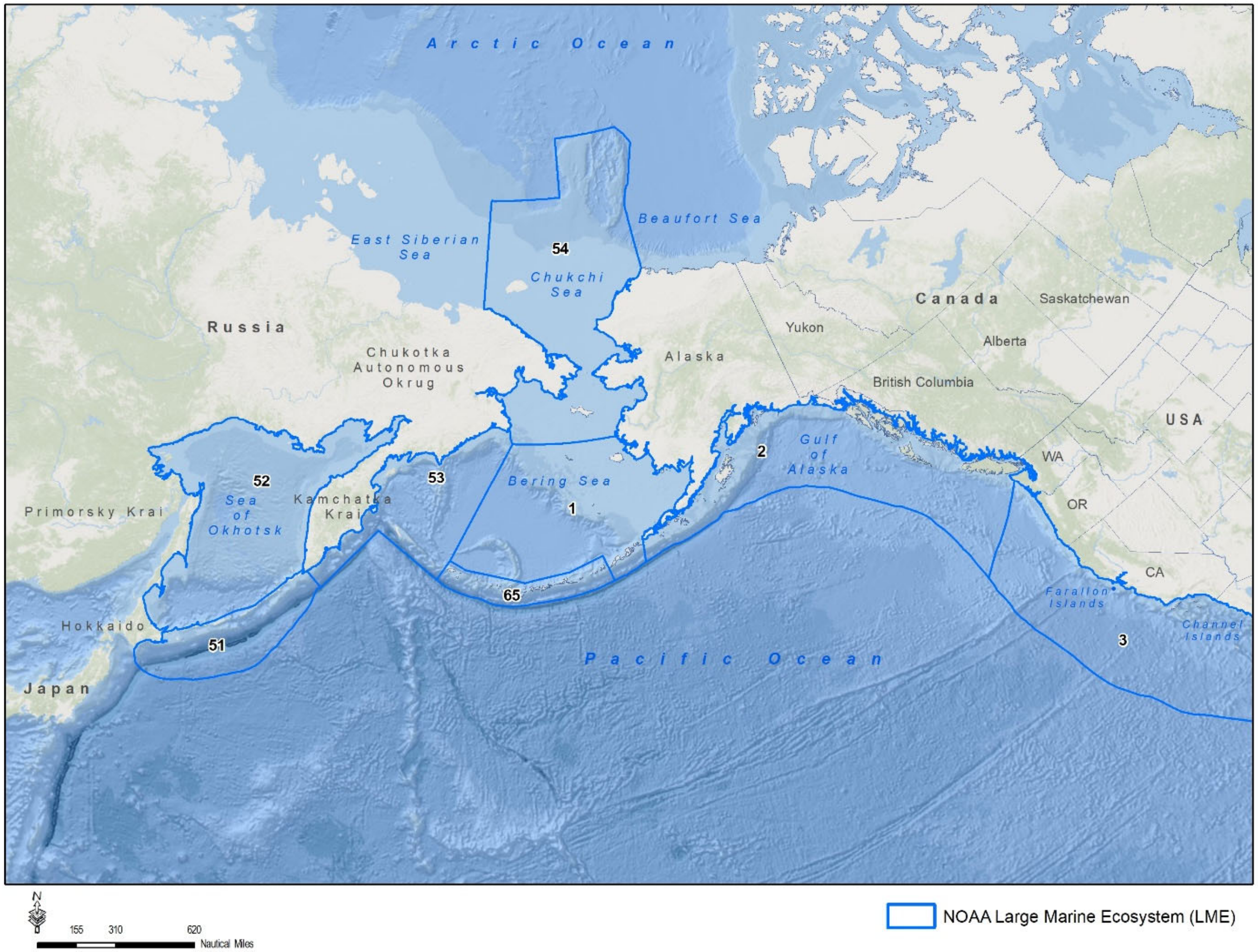
The LMEs are used as analysis units to discuss tufted puffin colony distribution, abundance, stressors, and conservation actions throughout the range. The LMEs were developed by the National Oceanic and Atmospheric Administration (NOAA) to enable ecosystem level management of ocean resources, in accordance with the United Nations Convention for the Law of the Sea; LMEs are regional units for the conservation and management of living marine resources (Sherman 1991, p. 349). LMEs are relatively large areas of the ocean that are approximately 77,220 square miles (mi^2) (200,000 square kilometers (km^2)) or greater, adjacent to the continents in coastal waters where primary productivity is generally higher than in open ocean areas. The LME boundaries are based on four ecological criteria: bathymetry (i.e., the depths and shapes of underwater terrain), hydrography (the science of measuring and describing physical features of bodies of water), productivity (i.e., the production of organic matter by phytoplankton), and trophic relationships (i.e., connections between organisms within an ecosystem that determine which organisms eat and which are eaten). In addition, NOAA uses a five-module strategy to assess changes in the LMEs based on: productivity and oceanography; fish and fisheries; pollution and ecosystem health; socioeconomics; and governance (NOAA 2019a, no page number). The LMEs found within the range of the tufted puffin, and used as analysis units in this SSA report, are included below in Table 3-1, Figure 3-1, and Appendix C.

[1] Birdlife International (2018, p. 4) estimates the global population at 3,500,000 tufted puffins.

Table 3-1. Large Marine Ecosystems (LMEs) found within the range of the tufted puffin.

Geographic Area	Large Marine Ecosystem[1] (LME) Analysis Unit
California, Oregon, Washington, and British Columbia	California Current (LME #3)
British Columbia and Alaska	Gulf of Alaska (LME #2)
Alaska	East Bering Sea (LME #1)
Alaska	Aleutian Islands (LME #65)[2]
Alaska	North Bering and Chukchi Sea (LME #54)[2]
Russia	West Bering Sea (LME #53)
Russia	Sea of Okhotsk (LME #52)
Japan	Oyashio Current (LME #51)

[1] NOAA 2019a; [2] Protection of the Arctic Marine Environment (PAME) 2013.



Source: NOAA 2019b.

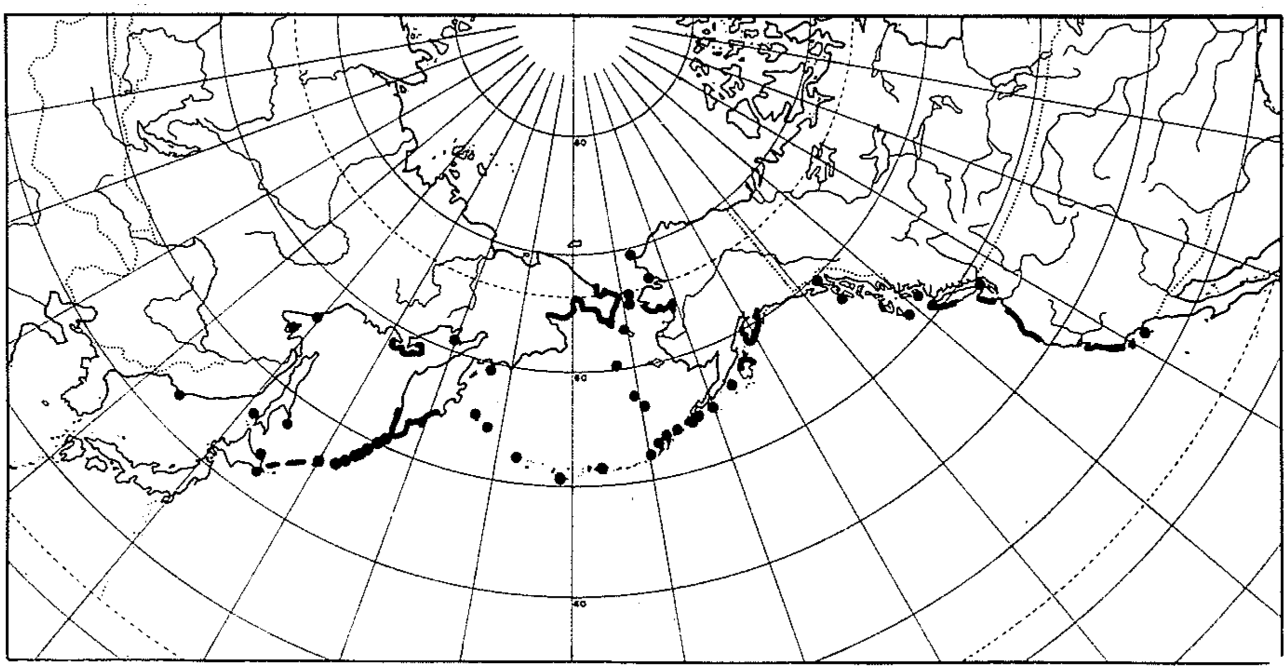
Figure 3-1. Large Marine Ecosystems (LME) within the range of the tufted puffin, and used as analysis units, are: (1) East Bering Sea; (2) Gulf of Alaska; (3) California Current; (51) Sea of Oyashio; (52) Sea of Okhotsk; (53) West Bering Sea; (54) North Bering and Chukchi Sea; and (65) Aleutian Islands (NOAA 2019b, entire).

3.3 Distribution and Population

Tufted puffins nest along the coasts of California, Oregon, Washington, British Columbia, Alaska, Russia, and Japan (Figure 1-2). During the non-breeding season, adult and juvenile tufted puffins can be found in the waters of the North Pacific Ocean (Piatt and Kitaysky 2002, pp. 1–2). The tufted puffin is a relatively abundant, wide-ranging species (Birdlife International 2018, p. 1), spending a majority of its time in the marine waters of the North Pacific Ocean and returning to land only to breed. This life history characteristic makes it difficult to develop accurate population estimates or determine population trends for the species.

3.3.1 Historical Distribution and Population

The breeding distribution of the tufted puffin was described in Udvardy (1963, p. 104); however, estimates were not given for tufted puffin colony populations. One of the first known maps of tufted puffin breeding distribution is shown in Figure 3-2 (Udvardy 1963, p. 104).



Source: Udvardy 1963, p. 104.

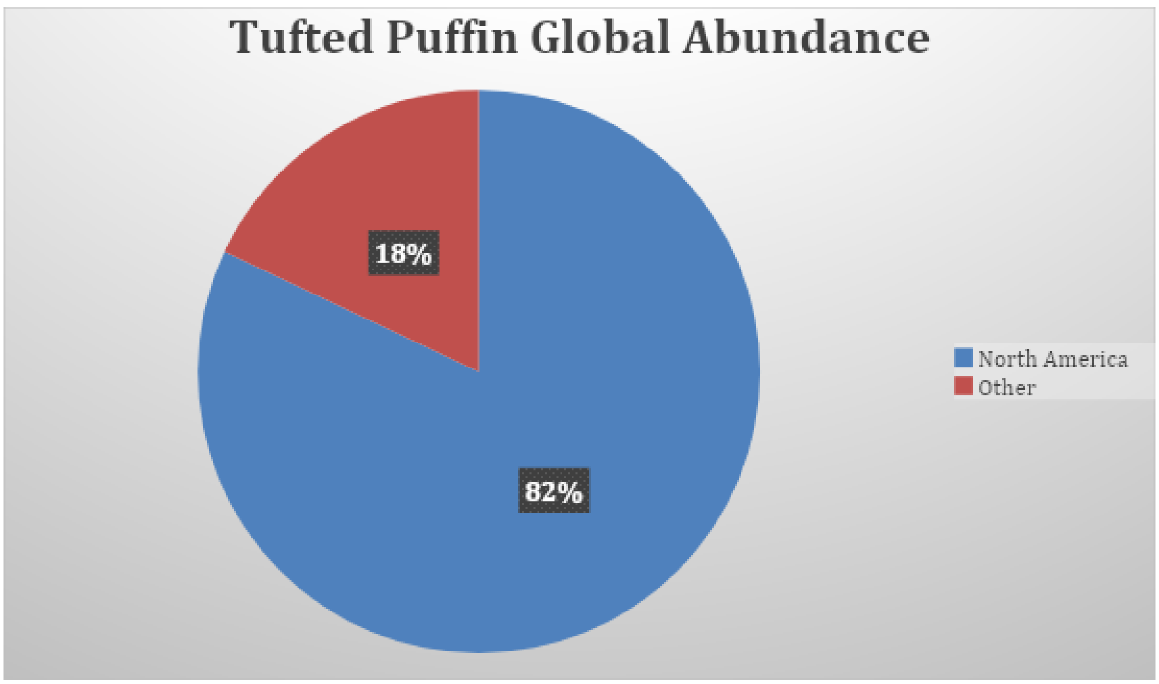
Figure 3-2. Breeding distribution of the tufted puffin, as originally described in Udvardy 1963. Black dots indicate nesting data or colonies.

Piatt and Kitaysky (2002) wrote the Birds of North America species account[2] for the tufted puffin in 2002, describing tufted puffins and summarizing information known at that time for the species distribution in North America and range-wide (Piatt and Kitaysky 2002, entire).

[2] Piatt and Kitaysky's (2002) Birds of North America account is a compilation of the tufted puffin life history and its distribution, and still informs our current understanding of tufted puffins range-wide.

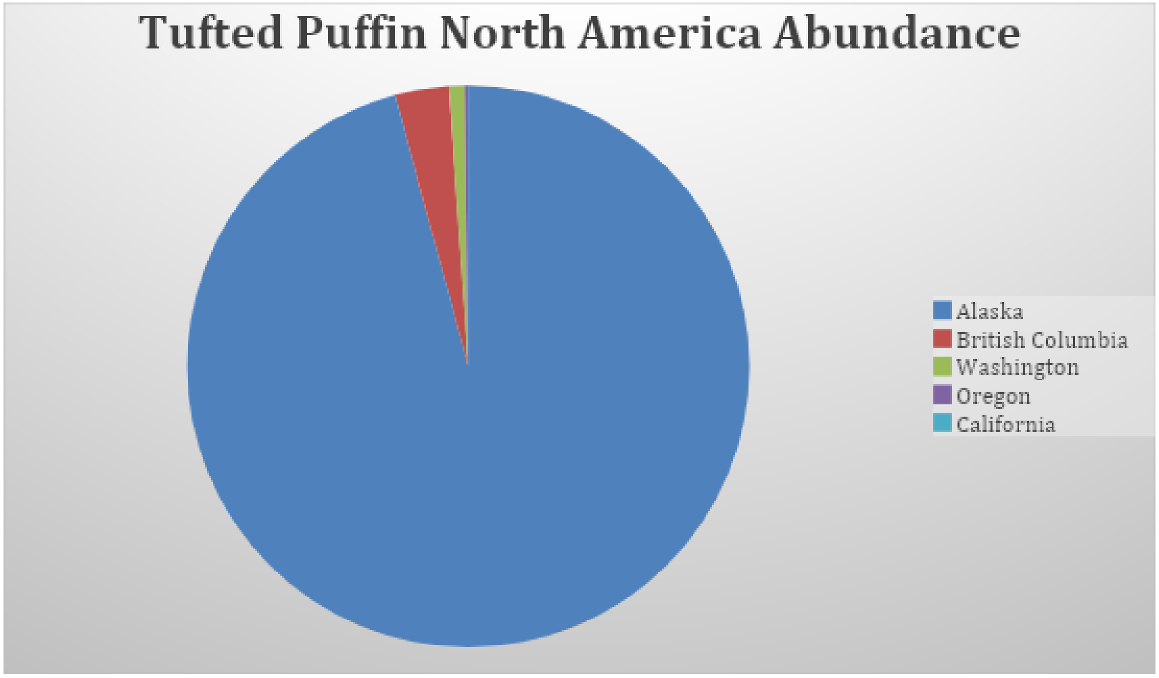
Population estimates for the species primarily rely upon breeding colony counts because it is difficult to develop population estimates from at-sea counts of non-breeding tufted puffins.

In 2002, the total colony population estimate was approximately 3 million birds (2,970,000) (Piatt and Kitaysky 2002, p. 31; Appendix D). Approximately 82 percent or 2,440,000 of tufted puffins breed in North America, of which small percentages breed in California (0.01 percent), Oregon (0.2 percent), Washington (0.9 percent), and British Columbia (3.1 percent) (Piatt and Kitaysky 2002, p. 18; Appendix D) (Figures 3-3 and 3-4). The remaining North American tufted puffins were found to breed in Alaska (96 percent), with the largest concentrations of North American breeding tufted puffins along the Alaska Peninsula (36 percent) and the eastern Aleutian Islands (45 percent). Additional scattered populations occur throughout the remaining Aleutian Islands (7.3 percent), the Bering Sea (4.6 percent), and the Chukchi Sea (less than 0.01 percent) (Piatt and Kitaysky 2002, p. 18). The remaining 18 percent of the worldwide population breed in Asia, almost exclusively in Russia (Piatt and Kitaysky 2002, p. 3).



Source: Piatt and Kitaysky 2002, pp. 3, 18.

Figure 3-3. Tufted puffin global abundance.

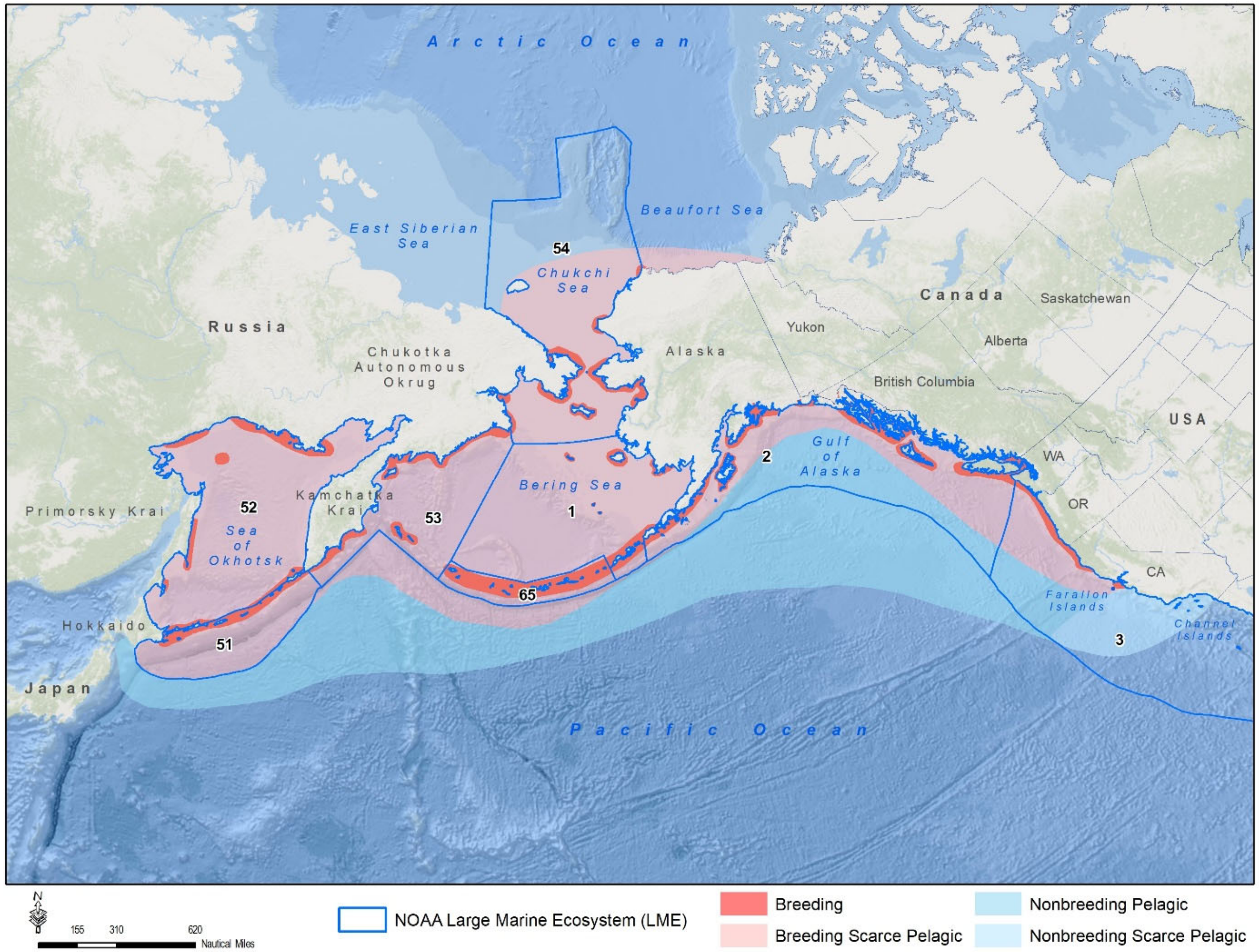


Source: Piatt and Kitaysky 2002, p. 18.

Figure 3-4. Tufted puffin North America abundance.

North American colonies were thought to be well-distributed, with the median colony size including approximately 140 birds (Piatt and Kitaysky 2002, p. 18). For this 2002 estimate, roughly 50 colonies with greater than 10,000 tufted puffin individuals may have accounted for more than 75 percent of the North American population of tufted puffins (Piatt and Kitaysky 2002, p. 18). In 2002, 802 known breeding colonies were calculated to occur throughout its range in North America (Piatt and Kitaysky 2002, p. 18; Appendix D). There is less historical information available for tufted puffin abundance and distribution in Russia (Kondratyev *et al.* 2000, p. 68). Russia population estimates included in Piatt and Kitaysky (2002, entire) attempted to reconcile differences calculated from the colony catalog and Kondratyev *et al.* (2000, pp. 66–68), and may overestimate the actual population; Russian population numbers were derived from rough estimates of tufted puffins, and were often rounded up (Piatt and Kitaysky 2002, p. 31; Appendix D).

Finally, more than 250 individual tufted puffins were observed breeding on Japan's Moyururi Island in the 1960s, with scattered nesting found on several other islands (Sato *et al.* 2018, p. 5). Since that time, tufted puffin colonies in Japan have experienced declines (Kondratyev *et al.* 2000, p. 33), with 30 tufted puffins found in Japan in 2002 (Piatt and Kitaysky 2002, pp. 3, 31).



Source: Adapted from Piatt and Kitaysky 2002; NOAA 2019b.

Figure 3-5. Estimated current breeding and non-breeding range of the tufted puffin, shown by LME. (1) East Bering Sea; (2) Gulf of Alaska; (3) California Current; (51) Sea of Oyashio; (52) Sea of Okhotsk; (53) West Bering Sea; (54) North Bering and Chukchi Sea; and (65) Aleutian Islands (NOAA 2019b, entire).

3.3.2 Current Distribution and Population

Tufted puffins currently occur throughout the majority of their historical range (Figure 3-5), with two notable exceptions: (1) active breeding colonies in Japan are now found only on Yururi and Moyururi Islands (Sato *et al.* 2018, p. 1), and (2) many of the colonies on the West Coast of the U.S. and British Columbia have declined or disappeared entirely (Naughton *et al.* 2007, p. 3; Kocourek *et al.* 2009, entire; Hanson and Wiles 2015, p. 1; Service 2018, p. 1; Warzybok *et al.* 2018, pp. 14, 21; and Hanson *et al*. 2019, p. 2). Tufted puffins appear to be undergoing a range contraction, with breeding colonies on the southernmost extent of its range (i.e., California, Oregon, Washington, select colonies in British Columbia, and Japan) experiencing declining numbers of breeding birds (Hanson and Wiles 2015, p. 13; Hanson *et al.* 2019, p. 2; Pearson *et al.* 2019, p. 1).

In contrast to the declining numbers of breeding birds in the southernmost extent of their range, breeding birds in some areas of Alaska (i.e., the Aleutian Islands) appear to be increasing in number (Pearson *et al.* 2019, p. 1). Although information on Russian colonies is limited, anecdotal information indicates that large numbers of breeding tufted puffins continue to nest in Russia at or above their historical breeding numbers in some areas. In summary, tufted puffins continue to breed throughout their historical range and all analysis units currently contain extant colonies of tufted puffins. However, the best available information suggests that breeding tufted puffins may soon be extirpated from Japan based on documented declines between the 1960s and present, with fewer than 20 tufted puffins confirmed on islands in Japan in 2013 (Kondratyev *et al.* 2000, p. 33; Piatt and Kitaysky 2002, pp. 3, 31; Sato *et al.* 2018, pp. 1, 5). In addition, tufted puffins on the West Coast of the U.S. (the California Current LME #3) are experiencing steep declines (Hanson and Wiles 2015, p. 1; Hanson *et al*. 2019, p. 1), with Hart *et al.* (2017, entire) predicting extirpation in the California Current LME. In addition, monitored tufted puffin colonies in the Gulf of Alaska LME appear to be in decline, with a population viability analysis by Goyert *et al.* (2017, entire) predicting quasi-extinction[3] within 100 years, and a trend analysis by Pearson *et al.* (2019, entire) showing declines in 3 of 4 monitored populations.

Additional discussion on the number of birds or colonies within individual analysis units (LMEs) will be discussed with available trend and threats information in section 3.6.

3.4 Existing Land Ownership

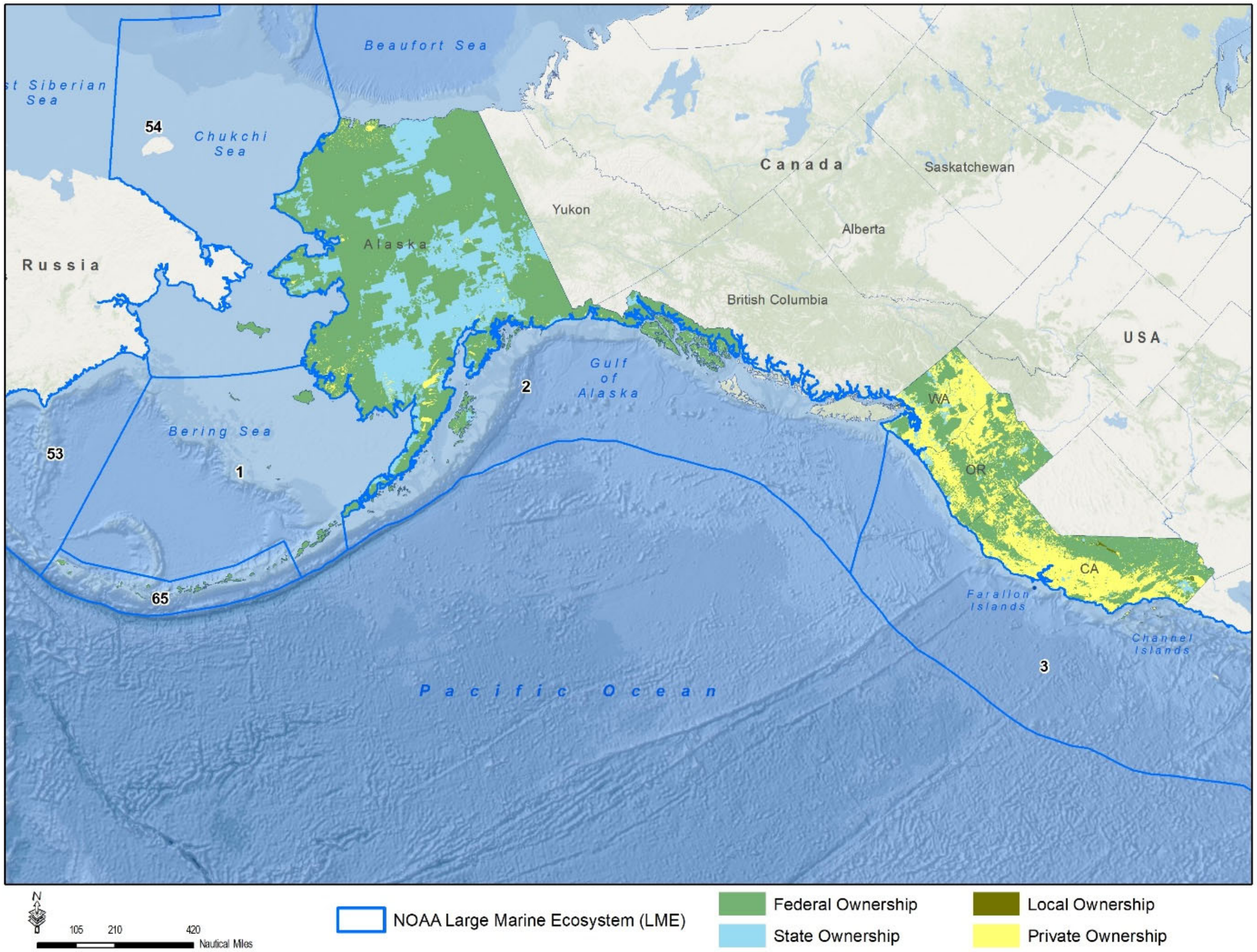
Tufted puffins prefer to nest on steep, rocky islands and mainland cliffs (section 2.1.3), areas that provide a degree of protection from predators. Many tufted puffin breeding colonies are currently protected by Federal, State, Provincial, or local governments, either through land ownership, or management as recreational areas or wildlife reserves. In North America, most colonies and all large colonies are located on lands owned by Federal, State, Provincial, or Territorial governments, which provides tufted puffin colonies some protection through land management actions and ownership status. For example:

[3] Quasi-extinction threshold is the level at which the number of adults in a population may be insufficient to assure persistence of the species. Quasi-extinction is defined to occur when the population size reaches the quasi-extinction threshold.

- In the United States, most colonies are located on land managed by the Service's NWR system, National Park Service (NPS) lands, and U.S. Forest Service (USFS) lands (Piatt and Kitaysky 2002, p. 22).
- In Canada, most colonies are located on lands managed as Ecological Reserves or National Park Reserves (Government of Canada 2014; Government of British Columbia 2019).

Land ownership and management are further described as follows (with general landowner information for colonies in the United States shown in Figure 3-6):

- California—All current, active colonies are located on the Farallon Islands NWR or Castle Rock NWR.
- Oregon—All colonies are located on the Oregon Islands NWR, which is managed by the Service's Oregon Coast NWR Complex.
- Washington—Most documented colonies are included in the Washington Maritime NWR Complex and associated wilderness areas (Hanson and Wiles 2015, Hanson *et al.* 2019, p. 4).
- British Columbia—Most of the colonies are within protected areas (Ecological Reserves, National Park Reserves), including the largest tufted puffin colony at Triangle Island (Anne Vallee Ecological Reserve and Scott Islands Provincial Park).
- Alaska—Most colonies occur on NWR-managed lands, the majority of which are found within the Alaska Maritime NWR; USFS lands (e.g., Tongass National Forest); and NPS lands (e.g., Glacier Bay and Kenai Fjords National Parks).
- Russia—Some colonies could be included in Russia's Regional Protected Areas, but the number of colonies actually protected is unknown.
- Japan—The currently known occupied colonies in Japan occur on Yururi and Moyururi Islands, which have been designated as National Wildlife Reserves by the government, and Natural Monuments by Hokkaido (Sato *et al.* 2018, p. 1).



Source: NOAA 2019b.

Figure 3-6. General land ownership of known tufted puffin breeding colonies in the United States, with LMEs: (1) East Bering Sea; (2) Gulf of Alaska; (3) California Current; (51) Sea of Oyashio; (52) Sea of Okhotsk; (53) West Bering Sea; (54) North Bering and Chukchi Sea; and (65) Aleutian Islands (NOAA 2019b, entire).

3.5 Threats

This section discusses the external factors (stressors) that may negatively influence the 3Rs, and thus the viability, of the tufted puffin. We also take into consideration positive influences on the species and its habitat, such as beneficial management implemented through land management plans and strategies. Through careful review of the best available scientific and commercial information on tufted puffin, including information on conspecific or surrogate species when applicable, we evaluate stressors with the potential to negatively affect the species either through direct mortality, injury, habitat alteration of their breeding colonies, or reducing their ability to feed themselves or their young. We identify six major stressors as having high potential to negatively affect tufted puffins or their habitat: (1) climate change, (2) oil spills, (3) fisheries bycatch, (4) mammalian and avian predators, (5) nonnative plants and animals, and (6) human disturbance (Piatt and Kitaysky 2002, pp. 17, 20–22; Hanson and Wiles 2015, pp. 20–32; Hanson *et al.* 2019, p. 2; Pearson *et al.* 2019, p. 2) (Figure 3-7). For major stressors, we include a description, a current quantification of the magnitude of the stressor (if possible) for each LME, and a summary of ongoing or potential conservation actions that may lessen these impacts (see section 3.5 Current Condition (Including Stressors and Conservation Actions) of Analysis Units). In addition to the major stressors carried forward, we identified two "minor" stressors (i.e., those stressors likely to have limited or localized effects on tufted puffins): (1) wind and wave energy development, and (2) human subsistence harvest. These six major and two minor stressors are described in the following sections of this report.

Several stressors were also identified as likely to have an unknown level of adverse effects on tufted puffin populations or their habitat, possibly contributing to tufted puffin declines. These stressors with "unknown" levels of impact include toxins, plastics, microplastics, and commercial fishing of prey species. While there is information available on each of these potential stressors, there is little to no information on how these stressors could affect individual tufted puffins, or if these stressors have population-level effects on tufted puffins. Therefore, these stressors were considered to have unknown effects on tufted puffin populations, and were removed from further consideration.

It is important to note that stressors categorized as "unknown" may have negative effects on the tufted puffin population resiliency, both currently or in the future. However, at this time information is not available on whether these stressors are adversely affecting the species to the degree that they are reducing its long-term viability.

As stated in the introduction to Chapter 3, stressors are described first in sections 3.5.1 (Major Stressors) and 3.5.2 (Minor Stressors), detailing what the stressor is, and how it impacts tufted puffins or their habitat, including some examples when relevant. Details about the immediacy and magnitude of each stressor within each of the individual LMEs are described in section 3.6.

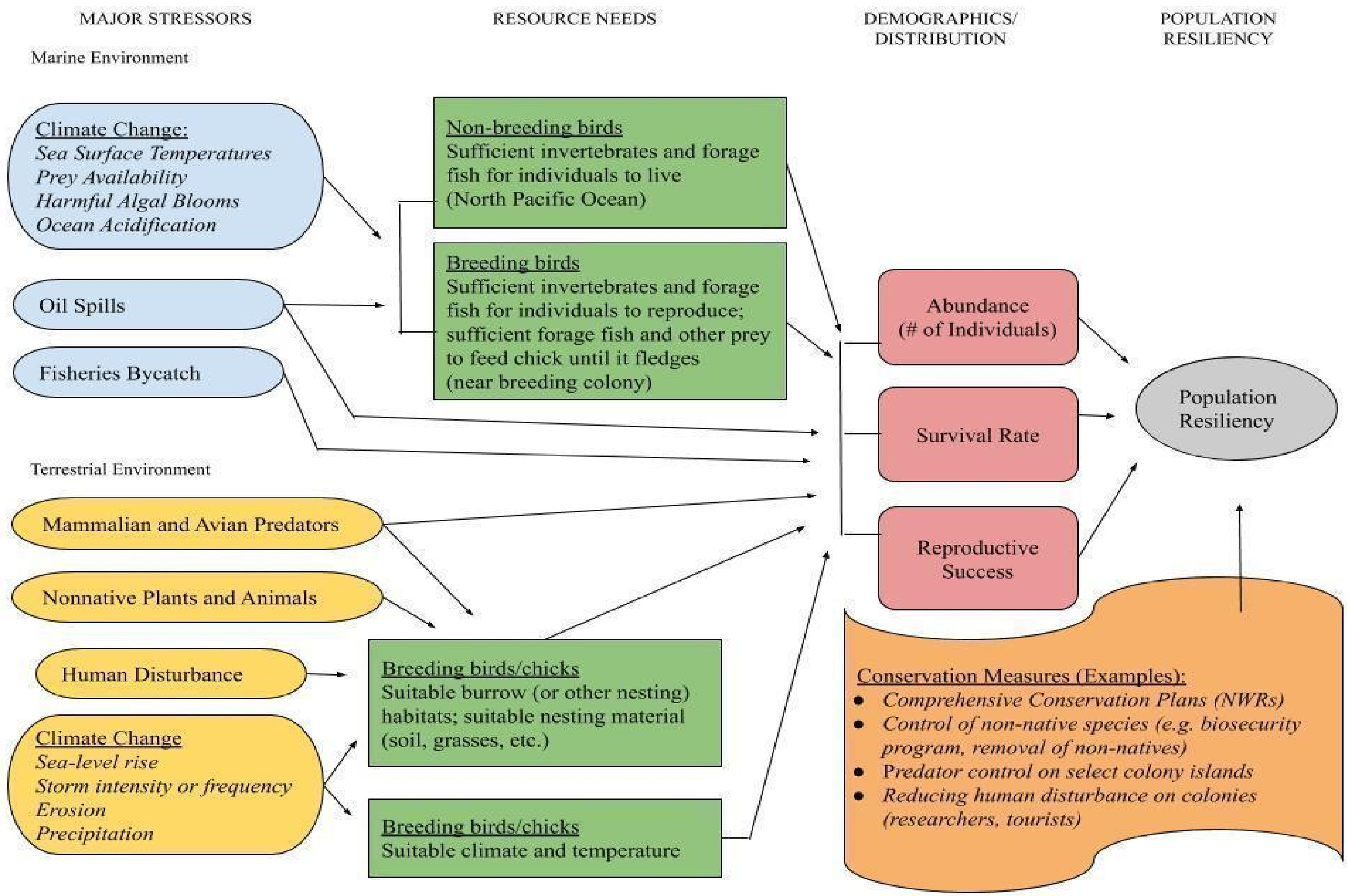


Figure 3-7. Influence diagram model, showing how stressors can impact population resiliency of the tufted puffin.

3.5.1 Major Stressors – Range-wide Effects on Tufted Puffin Populations

3.5.1.1 Climate Change

Measurements spanning several decades demonstrate that changes in climate are occurring globally, and that the rate of change since the 1950s is unprecedented (Intergovernmental Panel on Climate Change (IPCC) 2014, p. 40). Examples include warming of the atmosphere and the oceans, melting of glaciers and sea ice, and substantial increases in precipitation in some regions of the world with decreases in other regions (e.g., IPCC 2014, pp. 40–42; Solomon *et al.* 2007, pp. 35–54, 82–85). Analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "extremely likely" (defined by the IPCC as 95 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from fossil fuels (IPCC 2014, pp. 47–49; Solomon *et al.* 2007, pp. 21–35). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 is caused by human activities.

The IPCC uses climate models to predict future climate change, with Representative Concentration Pathways (RCPs) used to describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use; these RCPs are the accepted standard of predicting future GHG emissions and associated climate effects (IPCC 2014, pp. 56–57). The RCPs represent the range of GHG emissions in the wider literature, and include a stringent mitigation scenario (2.6), two intermediate scenarios (4.5 and 6.0), and one scenario with relatively high emissions (8.5) (IPCC 2014, p. 57).

There are several ways climate change may affect species at higher trophic levels (i.e., consumers). Changing physical conditions, such as increasing temperatures, hypoxia, or acidification will have direct effects on some species. Other consumers will be affected via changes in the abundance, distribution, or other characteristics of their competitors or prey species. Changes in the timing of seasonal events may lead to mismatches in the timing of consumers' life history requirements with their habitat conditions (including prey availability as well as physical conditions; Mackas *et al.* 2007, p. 249). The combination of these effects is likely to cause changes in community dynamics (e.g., competitive interactions, predator-prey relationships), but the magnitude of these effects cannot be predicted with confidence (Busch *et al.* 2013, pp. 827–831).

Ongoing climate change includes complex, interrelated changes in temperatures, weather patterns, and ocean conditions. Changes in ocean conditions can lead to changes in the availability and quality of forage fish and invertebrates that tufted puffins rely on to feed themselves and provision their chicks during the breeding season. Loss of access to suitable forage fish and other prey can cause reproductive failure.

We provide further discussion of specific climate-related changes in the marine environment that have the potential to impact tufted puffin populations: increasing sea surface temperatures, reduced prey availability, harmful algal blooms, and ocean acidification. Climate-related changes in the terrestrial environment such as sea-level rise, storm intensity or frequency, erosion, and precipitation, although not well-documented, also have the potential to impact nesting tufted puffins. Nesting colonies may be subject to habitat changes such as soil erosion brought on by increased precipitation events, sea-level rise, and increased storm intensity and frequency. Although we do not discuss changing terrestrial climate change conditions in detail here, terrestrial climate change is discussed further in those LMEs likely to experience changing conditions in the terrestrial environment (e.g., the California Current).

Increasing Sea Surface Temperatures (SST)

Increasing SST in the northeastern Pacific Ocean corresponds to decreased growth rates and fledging success of puffin nestlings (Gjerdrum *et al.* 2003, p. 9,377). Additionally, increasing SSTs have been negatively correlated with tufted puffin prey, including capelin, sand lance, and rockfish abundance (Thayer *et al.* 2008, p. 1,616). Puffins and other alcids may be at higher risk of mortality from increasing SST, in part due to adverse effects that increasing SST has on prey availability (Hanson *et al.* 2019, p. 7). Parrish *et al.* (2017, p. 24) documented five mass mortality events of seabirds between 2013 and 2017, with more than 15,000 seabird carcasses, mostly alcids, found on beaches from California to Alaska.

In the winter of 2013–2014, a large area of anomalously warm water (nicknamed “the Blob”) developed in the North Pacific Ocean off the coast of Alaska, and subsequently stretched south to Baja California (Bond *et al.* 2015, entire; Cavole *et al.* 2016, pp. 273–274). During this anomalous event, SSTs were up to 4 degrees (Celsius) higher than average in those areas affected (Cavole *et al.* 2016, p. 275). Higher SSTs corresponded with unusual biological events such as sightings of marine species further north than usual, mass strandings of marine mammals and seabirds, reduced forage fish availability, and harmful algal blooms (Cavole *et al.* 2016, pp. 274, 279).

On September 5, 2019, NOAA released a report that SSTs were once again higher than average in areas of the North Pacific Ocean, and the risks are high for formation of another anomalous warm water event (NOAA 2019c, entire). Although it is unknown whether these high SSTs will follow the same trajectory as the 2013–2014 event, increasing SSTs and anomalous warm water events could have climate-related impacts to forage fish and could in turn impact tufted puffins ability to forage for themselves and provision their chicks.

Reduced Prey Availability

Prey abundance, quality, and timing of availability all play an important role in survival and reproductive success of tufted puffins. A recent study found widespread reproductive failure in 14 seabird species (including rhinoceros auklets, common murres, and Atlantic puffins) across seven ecosystems when forage fish and krill populations were depleted below one-third of their observed maximum (Cury *et al.* 2011, p. 1,704). In addition, there is evidence that climate change can “shift” the timing of a species’ breeding phenology, although the effect of this shift varies by species (Walther *et al*. 2002, entire; Visser and Both 2005, p. 2,161). In tufted puffins, these shifts can lead to a mismatch in peak prey availability and chick growth, which can impact reproductive success (Gjerdrum *et al.* 2003, p. 9,379). Tufted puffin breeding phenology may also advance in response to climate-induced changes in the availability of prey species, although their responses to climate induced prey changes are still poorly understood (Gjerdrum *et al.* 2003, p. 9,379).

A mass starvation mortality event, the majority of which were tufted puffins, in the Bering Sea in 2016 and 2017 appeared to be caused by shifts in the zooplankton community and forage fish distribution following a period of elevated sea surface temperature (Jones *et al.* 2019, entire). A separate mass starvation of tufted puffin chicks occurred in the Sea of Okhotsk in a year when herring were abundant, but of a size class too large for the chicks to ingest (Golubova 2002, entire). In years of weak marine primary production, tufted puffins experienced near total breeding failure (less than 10 percent successful); most rhinoceros auklets did not breed, and those that did experienced their worst breeding season in 20 years (Gaston *et al.* 2009, p. 271). Research on thick-billed murres (*Uria lomvia*) showed that each bird had an energy expenditure cap that did not vary across years, activity, age, sex, or environmental conditions, even though body mass and daily energy expenditure did vary. However, in order to not exceed their cap, birds reduced time spent flying, diving, and provisioning chicks, and increased time resting on the water (Elliott *et al.* 2014, pp. 140–141). Similarly, in years of limited food availability, tufted puffins adjust the size and frequency of food loads they deliver to their chicks, which is thought to result in higher instances of reproductive failure (Vermeer and Cullen 1979, p. 26).

The nutritional value of tufted puffin prey varies greatly among prey species, and by age class (Anthony *et al.* 2000, entire; Iverson *et al.* 2002, entire; Becker *et al.* 2007, p. 272; Ball *et al.* 2007, pp. 702–703; Beaubier and Hipfner 2013, entire). In a study with captive tufted puffins, Romano *et al.* (2006, pp. 410–411) determined that dietary shifts to less nutritious species reduced chick growth rates. Research on alcids with life histories similar to the tufted puffin indicates that poor or inadequate diets and low prey availability can result in poor body condition of adults at the end of the breeding season (Harding *et al.* 2011, pp. 54–55). Adults may try to compensate by bringing more fish (i.e., make more provisioning trips) to feed their chicks (Kadin *et al.* 2016, p. 174). In addition, in years when chicks are fed lower quality prey, there is decreased fledgling success (Kadin *et al.* 2012, pp. 243–244).

<u>Harmful Algal Blooms</u>

Harmful algal blooms are large growths of algae that can have detrimental effects on marine organisms through the production of algal toxins (U.S. Geological Survey (USGS) 2018, p. 1). Algal toxins are produced by certain species of dinoflagellates and have been linked to severe illness and mortality of marine organisms (e.g., invertebrates, fish, seabirds, and marine mammals). Exposure to algal toxins can result from ingestion of food, water, and or aerosols (Lopez *et al*. 2008, pp. 19, 22). Tufted puffin prey species, such as forage fish and squid, tolerate and bioaccumulate higher levels of these biotoxins, thus becoming lethal vectors when consumed (Shumway *et al.* 2003, pp. 10–11). Additionally, some dinoflagellates can produce compounds that reduce feather waterproofing, which can result in hypothermia in birds (Jessup *et al*. 2009, p. 2; Phillips *et al*. 2011, p. 120). Ecosystems can be degraded through the formation of large harmful algal blooms that can alter habitat quality through overgrowth, shading, or oxygen depletion (Lopez *et al.* 2008, p. 8). Algal blooms are a natural phenomenon, but recently have increased in frequency and biomass as a result of warmer ocean conditions (Wells *et al.* 2015, pp. 70–73; Lopez *et al.* 2008, p. 19).

Alexandrium spp. and *Pseudo-nitzschia* spp. are two common harmful algal bloom organisms that occur throughout the California Current LME and along the coast of British Columbia and Alaska (Alaska Sea Grant 2019, entire; NWFSC 2019, pp. 1–2). *Alexandrium* spp. are dinoflagellates that produce neurotoxins (e.g., saxitoxin), commonly known as paralytic shellfish poisoning in humans (Gibble and Hoover 2018, p. 224; NWFSC 2019, pp. 1–2). These toxic dinoflagellates are inadvertently consumed by zooplankton, which in turn are ingested by organisms at higher trophic levels (Doucette *et al.* 2005, pp. 2,769–2,775). *Pseudo-nitzschia* spp. produce domoic acid, a neurotoxin that can lead to permanent brain damage, reproductive failure, and death; commonly observed effects include seizures and head weaving (Lopez *et al.* 2008, p. 18). Domoic acid can also have significant chronic effects, such as epilepsy and behavioral changes due to repeated exposures at sublethal levels (Lopez *et al.* 2008, p. 4). Shellfish and fish can accumulate this toxin without apparent ill effects, but transfer the toxin when consumed (NOAA 2009, entire). *Pseudo-nitzschia* spp. blooms are recurrent along the entire coasts of California, Oregon, Washington, British Columbia, and Alaska and have been linked to large numbers of seabird and marine mammal deaths annually since 1998 (Lopez *et al.* 2008, p. 28).

An outbreak of *Pseudo-nitzschia* spp. in the spring and summer of 2015 stretched from southern California to the Aleutian Islands, Alaska (NOAA Climate 2015, p. 1; Du *et al*. 2016, pp. 2–3; National Ocean Service (NOS) 2016, p. 2). Rather than lasting a few weeks, as is typical, this event persisted from May to October (NOS 2016, p. 1) and produced extremely high concentrations of domoic acid (NOAA Climate 2015, p. 2). This harmful algal bloom was preceded by anomalous ocean conditions (lack of southwesterly storms and warm sea surface temperatures) associated with "the Blob" (Du *et al*. 2016, pp. 4–7). Although relatively large numbers of forage fish, seabird, and marine mammal mortalities were reported, there was no direct evidence that domoic acid was the cause of death (NOAA Climate 2015, p. 2; NOS 2016, p. 2).

Mortality related to harmful algal blooms may be an underreported cause of seabird mortality worldwide, in particular because mass mortality events occur offshore and are typically only reported when prevailing winds carry weakened and dead seabirds toward land (Shumway *et al.* 2003, p. 14). This may be particularly true for tufted puffins that spend a majority of their time farther offshore, thus sick or dead birds would not be found on shore, which is the method by which geographic extent, duration, and magnitude of mortality events are measured. However, should the frequency and duration of a harmful algal bloom event occur during the breeding season or fall when birds are undergoing molt and are less mobile, there is an expectation that puffins would be negatively affected as documented in other seabirds.

Ocean Acidification

A wide variety of marine species are directly affected by ocean acidification. Similar to their phytoplankton counterparts, foraminiferans (amoeboid protists) and other planktonic consumers that form calcium carbonate shells are less able to form and maintain their shells in acidified waters (Feely *et al*. 2004, pp. 356–366). Relatedly, chemical changes associated with acidification interfere with shell development or maintenance in pteropods (sea snails) and marine bivalves (Busch *et al*. 2014, pp. 5, 8; Waldbusser *et al*. 2015, pp. 273–278). These effects on bivalves can be exacerbated by hypoxic conditions (i.e., deprived of adequate oxygen supply at the tissue level; Gobler *et al*. 2014, p. 5), or ameliorated by very high or low temperatures (Kroeker *et al*. 2014, pp. 4–5); thus, it is not clear what the effect is likely to be in a future that includes acidification, hypoxia, and elevated temperatures. Acidification negatively affects crustaceans, for example, slowing growth and development in Pacific krill (*Euphausia pacifica*) and Dungeness crabs (*Cancer magister*) (Cooper *et al*. 2016, p. 4; Miller *et al*. 2016, pp. 118–119).

We are not aware of data that support a direct link between ocean acidification and population level mortality effects on tufted puffin. However, increases in ocean acidification could affect calcium-dependent organisms such as krill, which would negatively influence tufted puffins given that krill and other invertebrates make up approximately 50–70 percent of the tufted puffin's diet (Piatt and Kitaysky 2002, p. 5).

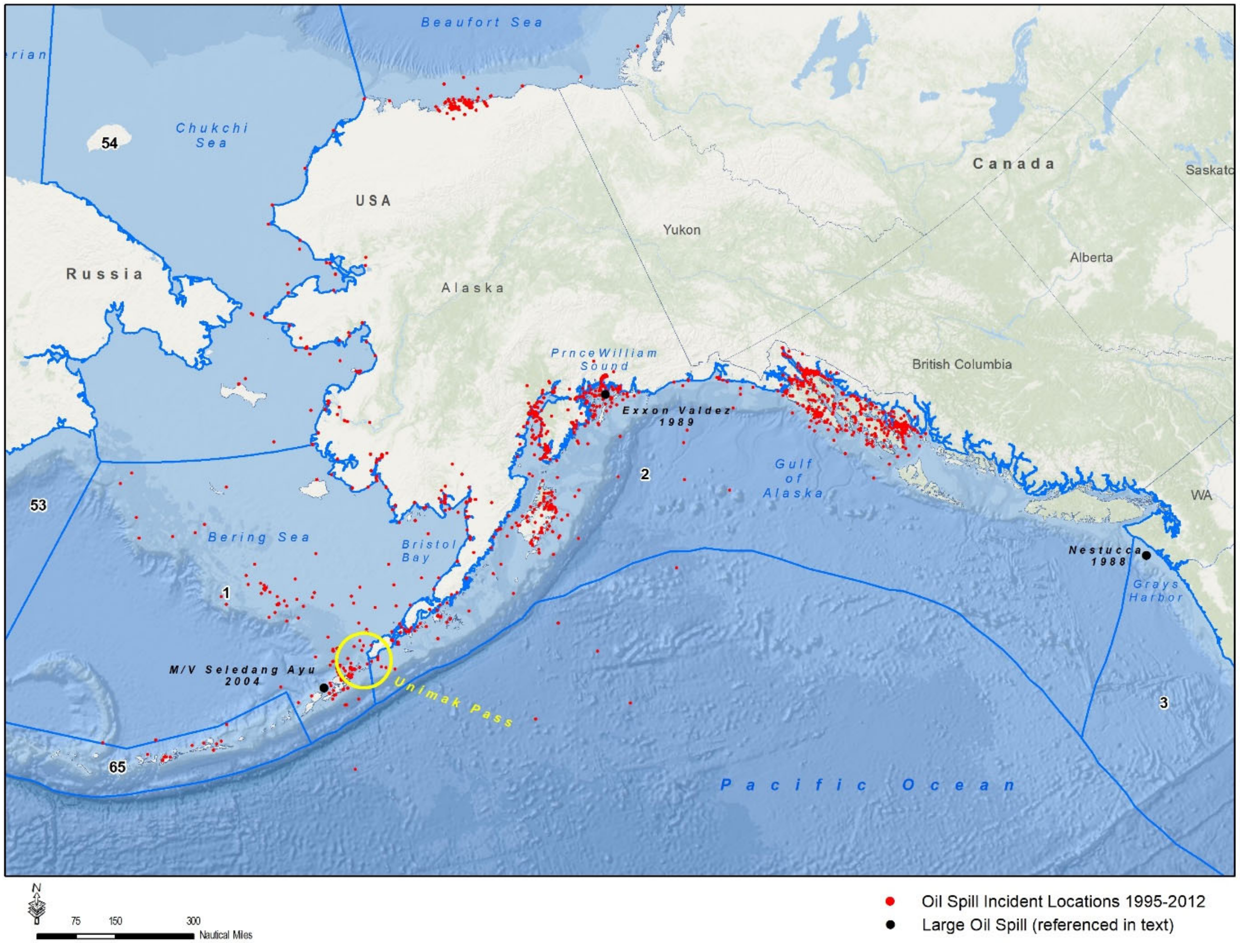
3.5.1.2 Oil Spills

Oil spills are a form of human-caused pollution defined as the release of liquid petroleum hydrocarbon into the environment. Offshore and particularly, nearshore oil spills have the potential to injure or kill tufted puffins at individual, local, and regional scales. Oiling kills adult birds directly through hypothermia, drowning, or ingestion when they try to preen oil off their feathers (American Trader Trustee Council 2001, p. 10), and has the potential to cause immediate negative effects on seabird population demographics. In addition, the reproductive capacity of surviving birds may be permanently impaired (Barros *et al.* 2014, pp. 2–3). When the *Exxon Valdez* spilled oil in Prince William Sound, Alaska, in 1989, it is estimated that 100,000 to 300,000 birds were killed, and approximately 14 percent of these were thought to be puffin species (Piatt *et al.* 1990, p. 1).

Little is known about the risk of oil spills on wintering tufted puffins, particularly since they winter well offshore, beyond the continental shelf in the central north Pacific Ocean (Piatt and Kitaysky 2002, p. 1). Though rare, deep-water spills have occurred due to ship-to-ship collisions or human error. Tournadre (2014, p. 7,930, Renner and Kultez 2015, entire) highlighted the central North Pacific Ocean as a medium to high traffic shipping corridor from Asia to the west coast of North America; therefore, spills could occur within tufted puffin wintering habitat. Although the potential threat exists for oil spills within the tufted puffin's overwintering habitat, the likelihood of recovering an oiled tufted puffin or any other pelagic seabird carcass from such a vast region and great distance from shore are improbable.

Many variables can significantly influence the magnitude of exposure to seabirds from an oil spill, including volume of oil, proximity to breeding colonies or other seabird concentration areas, prevailing currents, and season of spills. For the purposes of this SSA, and following McCrary *et al.* (2003, p. 46), large spills are defined as spills greater than 1,000 barrels (42,000 gallons (gal)), and small spills are defined as less than 1,000 barrels (42,000 gal).

Although mapped oil spill data is not available for all areas of tufted puffin distribution, the geographic distribution of oil spills reported from 1995–2012 in British Columbia and Alaska, (Figure 3-8), demonstrates that many oil spills, most small but a few major, are reported offshore of tufted puffin nesting islands each year (NOAA 2014, p. 51). Incident rates are considered small oil spills and defined as, "events involving vessels or facilities (including onshore facilities, pipelines and offshore wells) that could potentially result in the spillage of oil, such as casualties, accidents, discharges, and leakages" (NOAA 2014, pp. 50–51). Most spill volumes associated with incidents in Alaska and British Columbia during 1995–2012, as shown in Figure 3-8, were small, with many incidents not involving any spillage (NOAA 2014, p. 54). Eighty-five percent of spills reported involved less than 1 barrel of oil (42 gal) (NOAA 2014, p. 54). Over 99 percent of the spills involved less than 50 barrels (2,100 gal), and only 0.1 percent involved more than 500 barrels (21,000 gal) of oil (NOAA 2014, p. 54). Specific oil spills are discussed in more detail for each LME in section 3.6.



Sources: NOAA 2019b; NOAA 2014, p.51

Figure 3-8. Geographic distribution of oil spill incidents from 1995–2012, shown with known, monitored tufted puffin colonies. An individual red dot may represent multiple incidents. LMES shown: (1) East Bering Sea; (2) Gulf of Alaska; Oyashio; (52) Sea of Okhotsk; (53) West Bering Sea; (54) North Bering and Chukchi Sea; and (65) Aleutian Islands (NOAA 2014, p. 51; NOAA 2019b, entire).

3.5.1.3 Fisheries Bycatch

Bycatch is a fish or other marine species caught unintentionally by fishing vessels. Bycatch can be either a different species (such as tufted puffins, which can become hooked or entangled in fishing gear) than the target species; or the wrong sex, size, or life stage of the target species.

Historically, bycatch from commercial fisheries is thought to have led to rapid declines in tufted puffin populations, especially in Japan (Ono 2009, p. 1; Ono 2012, p. 28). The Japanese driftnet fishery was responsible for the death of hundreds of thousands of seabirds every year in the waters off Japan and Russia (DeGange and Day 1991, pp. 251–258; Artukhin *et al.* 2010, pp. 200–202). Diving and pursuit-foraging species have been found to be especially vulnerable to gillnet fisheries (Tasker *et al.* 2000, p. 533; Zydelis *et al.* 2013, p. 78). Coastal gillnet fisheries are considered a major source of seabird mortality worldwide, with an estimated 400,000 seabirds killed annually (Zydelis *et al.* 2013, pp. 84–85).

Bycatch as a whole has been greatly reduced by laws and regulations implemented to protect seabirds, particularly the United Nations ban on large-scale, high seas driftnet fisheries in 1992 (Zydelis *et al.* 2009, p. 1,270), and the Russian ban on the use of driftnets in their Economic Exclusion Zone in 2015. Coastal gillnet fisheries remain active, including mostly small vessels operated by subsistence fishers, but monitoring these vessels is difficult. As a result, few studies have focused on documenting seabird bycatch in these fisheries and the impacts they may have on seabird populations (Zydelis *et al.* 2009, p. 1,270).

Currently, there are few tufted puffins reported as bycatch in U.S. groundfish and halibut commercial fisheries, with yearly reports of tufted puffins caught in trawls, hook and line, and net pot fisheries each year ranging from zero to the low single digits (Eich *et al.* 2017, p. 15; Jannot *et al.* 2018, p. 70; Kingham 2019, pers. comm.).

3.5.1.4 Mammalian and Avian Predators

Native and nonnative predators are known to kill individuals at any life stage. Tufted puffins are a colonial species (see section 2.1.3); they are more concentrated in specific areas (colonies) during the breeding season. Mammalian predators can destroy tufted puffin eggs and burrows, or kill tufted puffin chicks and adults. Predators that may occur within breeding colonies are either native or nonnative species, such as (but not limited to): rats (*Rattus* spp.; nonnative), mice (*Mus sp*.), foxes (*Vulpes* sp. and *Urocyon* sp.; native and nonnative species), voles (*Microtus* sp.; native and nonnative species), ground squirrels (*Urocitellus* sp.; native and nonnative species), mink (*Neovison* sp.; native and potentially nonnative), raccoons (*Procyon lotor*; native), and river otters (*Lontra canadensis*; native) (Amaral 1977, p. 81; Bailey 1993, pp. 33–35; Taylor *et al.* 2000, p. 151; Towns *et al.* 2011, pp. 14, 25; Service 2013a, pp. 1, 7, 8).

Avian predators found attending tufted puffin colonies include bald eagles (*Haliaeetus leucocephalus*), Steller's sea eagles (*H. pelagicus*), gulls (multiple species, including the slaty-backed gull (*Larus schistisagus*) and glaucous-winged gull (*L. glaucescens*)), snowy owls (*Bubo scandiacus*), eagle owls (*B. bubo*), common ravens (*Corvus corax*), and peregrine falcons (*Falco peregrinus*) (Murie 1940, pp. 199, 200; Amaral 1977, p. 81; Trapp 1979, pp. 413, 416; Wehle

1980, p. 84; Piatt and Kitaysky 2002, p. 11). In addition to direct mortality of tufted puffin adults, chicks, and eggs, avian predators can also affect tufted puffins by: (1) kleptoparasitism (i.e., stealing food that adults bring to feed a chick in their burrow) (Blackburn *et al.* 2009, pp. 412, 414; Frazer 1975, pp. 37, 38; St. Clair *et al.* 2001, p. 934); and (2) altering adult puffin behavior and attendance of the nest (Addison *et al.* 2007, p. 69). Kleptoparasitism may make it more difficult to provision chicks during lean years, but does not measurably affect reproductive success (Piatt and Kitaysky 2002, p. 11; Hanson and Wiles 2015, p. 10).

3.5.1.5 Nonnative Plants and Animals

Tufted puffins may have to compete for burrow habitat space with other species, such as nonnative European rabbits (*Oryctolagus cuniculus*). Native and nonnative mammals, birds, and plants can alter or degrade habitat available to burrow-nesting seabirds, such as tufted puffins.

For example within the California Current LME, overgrazing by introduced rabbits on Destruction Island, Washington, has altered the plant community, resulting in significant soil erosion and land slippage that has caused loss of burrowing habitat (Hanson and Wiles 2015, p. 29). Native species can likewise alter burrow habitat, such as on Castle Rock, California and Flatiron Rock, Oregon, where soil loss and erosion caused by nonbreeding Aleutian cackling geese, California sea lions (*Zalophus californicus*), and cormorants (*Phalacrocorax* spp.) may have degraded burrowing habitat (Jaques 2007, p. 38; McChesney and Carter 2008, p. 215).

In the Aleutian Islands and on islands in the Bering Sea, nonnative mice, voles, rats, ground squirrels, rabbits, hares, cats, foxes, caribou, reindeer, elk, horses, and domestic sheep and cattle have been introduced (Gotthardt *et al.* 2015, entire). Some colonies are at risk more than others; rat introduction is a constant threat in the Pribilof Islands (the East Bering Sea LME) because of seafood processing, boat tie-ups, and the possibility of shipwrecks. The Norway rat is a particular threat in Alaska; it is widespread and a good swimmer, which allows it to spread easily (Fritts 2007, p. 7).

Nonnative plants such as cheatgrass and scotch broom can also alter habitat, making nesting areas unsuitable (Hanson *et al.* 2019, p. 18). Replacement of native perennial tuft or bunch forming grasses by nonnative and invasive grasses accelerates erosion on tufted puffin nesting sites like Protection and Smith Island, Washington.

3.5.1.6 Human Disturbance

Human activities and disturbance can affect tufted puffin colonies across its range (Pearson *et al.* 2019, pp. 1–2). Tourism (e.g., sightseeing boats near Yururi Island and Moyururi Island in Japan) may cause disturbance to nesting tufted puffins (Sato *et al.* 2018, p. 3). Additionally, when researchers reach into burrows during incubation or chick-brooding stages, the egg or chick is often abandoned (Pierce and Simons 1986, p. 214). Reproductive success varies based on the level of disturbance, including a reproductive success rate (chicks fledged per egg laid) estimated at 94 percent for a relatively undisturbed site, and 18 percent for a “heavily disturbed” site (visited every 5 days as hatching approached) (Pierce and Simons 1986, p. 214). In addition, disturbance was found to increase the incubation period[4] (Pierce and Simons 1986, p. 214). Across the species range, human disturbance from tourism is likely restricted by land management practices and closure of nesting islands, while human disturbance from research activities is likely limited to those colonies that are part of an ongoing, active monitoring program.

3.5.2 Minor Stressors – Limited or Localized Effects on Tufted Puffin Populations

3.5.2.1 Wind and Wave Energy Development

For areas where wind and wave energy development may occur (i.e., the California Current LME, and parts of the Gulf of Alaska and Oyashio Current LMEs), there may be risks to tufted puffins, depending upon the proposed location and type of equipment required. In some cases the negative effects may be direct mortality from collision or indirect impacts from displacement (Best and Halpin 2019, p. 3); the collision risk at sea is likely to be higher than on land (Exo *et al.* 2003, p. 51). In other cases, projects may degrade marine habitat, cause long-term habitat loss through disturbance, and create barriers between suitable breeding, roosting, and feeding habitats (Exo *et al.* 2003, pp. 51–52). Alternatively, a wind or wave energy project may have little or no impact to tufted puffins.

At this time, the best available information suggests that only a few colony locations within the range of tufted puffin may be negatively affected by this stressor. The future of any offshore wind or wave energy project is unclear at this time; however, on October 7, 2015, California's Governor Edmund G. Brown, Jr. signed legislation to require 50 percent of California's electricity to come from renewable energy by December 31, 2030 (California Energy Commission 2017, entire). Due to this legislation, wind and wave energy development in the future could result in an increased risk of mortality or result in habitat degradation within the California Current LME. Construction of offshore wind farms near the Japanese coast (Oyashio Current LME) may also present a threat to nesting tufted puffins (Sato *et al.* 2018, p. 4).

3.5.2.2 Human Harvest for Subsistence

The Aleutian Islands and St. Lawrence Island in Alaska, and the Diomede Islands in Russia and Alaska, are some of the few places in the tufted puffin range where human harvest of seabirds for subsistence still occurs (Naves 2018, pp. 1,217–1,236). Alaska Native and indigenous peoples in Alaska and Russia have used seabirds and their eggs as subsistence and cultural resources for thousands of years (Naves 2018, p. 1,217). Between 2002–2015, an average of 248 puffins were harvested each year in Alaska, with an average of 452 eggs collected each year for all puffin species (Naves 2018, pp. 1,227, 1,229, 1,231). Naves (2018, pp. 1,217–1,236) does not identify puffins harvested for subsistence to species; it is likely that fewer tufted puffins were harvested for subsistence than these numbers suggest, given both tufted and horned puffins occur in these areas.

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[4] These observations were made at East Amatuli Island (Gulf of Alaska LME) and the authors concluded that "sensitive colonies should not be disturbed at all during the incubation period." Similar abandonment was observed from handling birds during incubation at Ugaiushak Island, off the Alaska Peninsula (Wehle 1980, p. 26).

3.6 Current Condition (Including Stressors and Conservation Actions) of Analysis Units

For our analysis of current conditions summarized in this report, we evaluated each LME (analysis unit) for any identified population trend, the number and magnitude of stressors, and the effectiveness of any conservation actions.

We evaluated threats found within each LME based upon the potential of each threat to impact tufted puffin population resiliency. Using the best available scientific and commercial information, we categorized threats as having low, moderate, or high impacts to tufted puffins. A threat categorized as LOW was considered to pose limited risks to tufted puffin resiliency within an analysis unit; that is, tufted puffins were still able to tolerate natural, annual variation (stochasticity) in their environment, and to recover from periodic disturbance. A threat categorized as MODERATE was considered to pose a medium amount of risk to tufted puffin resiliency within an analysis unit; that is, moderate threats could reduce the degree to which tufted puffins can tolerate natural, annual variation in their environment, and to recover from periodic disturbance. Finally, a threat categorized as HIGH was considered to pose a large risk to tufted puffin resiliency, further reducing their ability to tolerate natural, annual variation, and inhibiting their ability to recover from periodic disturbance (Table 3-2).

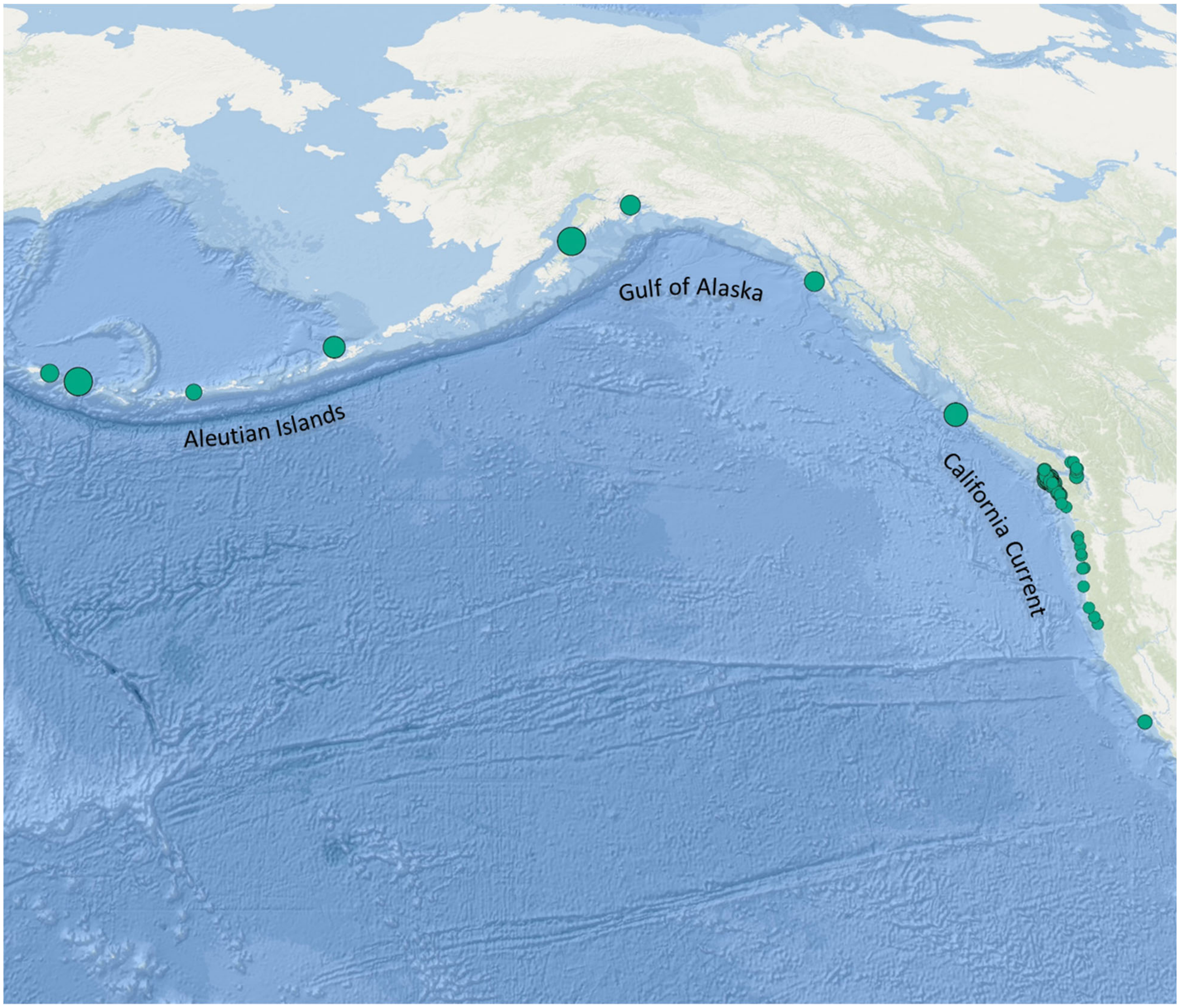
Table 3-2. Definitions used to evaluate threats to tufted puffin resiliency.

LOW	Limited risk to tufted puffin resiliency
MODERATE	Medium risk to tufted puffin resiliency
HIGH	Large risk to tufted puffin resiliency

It is important to recognize that threats occurring within each analysis unit are not uniformly distributed throughout any given LME. In fact, one tufted puffin colony within an LME may experience threats from multiple sources (e.g., climate change, predation, nonnatives), while another colony may only experience threats from a single source (e.g., climate change), or not at all. Therefore, we relied on the best scientific and commercial information available for each LME to evaluate how threats to tufted puffins impacted colonies across the entire LME, and used that information to determine an overall threat level for each LME, taking into account how (or if) a given threat affected many of the colonies within that LME, or merely a few.

We relied on Pearson *et al.* (2019, entire)[5] to understand changes in the occurrence of breeding tufted puffins in North America. Trends were modeled using information from select colonies and at-sea data in the California Current, Gulf of Alaska, and Aleutian Islands LMEs (Figure 3-9), and specifically focused on 11 datasets spanning 112 years. Further, trends were used to discuss increases or decreases in the abundance of tufted puffins within the California Current, the Gulf of Alaska, and the Aleutian Islands LMEs.

[5] Updated November 2019, to include additional datasets for the Gulf of Alaska LME



Source: Pearson *et al*. 2019, in prep., p.27

Figure 3-9. Map of the tufted puffin colonies included in Pearson *et al*. 2019 trend analysis (excluding Bogoslof Island). Green colony location circles were graduated to display the maximum count for each colony across the time series (excerpted from Pearson *et al*. 2019, in prep., p. 25).

Finally, we used the known population trend, the number of population-level threats found in each LME, and known conservation measures for each LME to assign a current condition category (i.e., HIGH, MODERATE, LOW) to each analysis unit (Table 3-3). We then use these current condition categories to discuss the current status of tufted puffins across the range.

Table 3-3. Condition category table, defining high, moderate, and low conditions used to analyze tufted puffin current and future conditions[6].

Analysis Unit Condition	***Demographic Factor***	***Habitat Factors***	
	Population Trend	**Number of Major Stressors**	**Conservation Actions**
High	Population exhibits a statistically significant, increasing trend	0-1 Stressors	Active, ongoing implementation of conservation actions to address most stressors
Moderate	Population exhibits a stable trend	2-3 Stressors	Some implementation of conservation actions to address stressors
Low	Population exhibits a statistically significant, declining trend	>3 Stressors	Limited implementation of conservation actions to address stressors

[6] Please note, if an LME is found to be in "HIGH" condition, tufted puffins found within are considered to be highly resilient; that is, able to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance. An LME in "MODERATE" condition means tufted puffins found within have some resiliency, although potentially to a lesser degree. An LME in "LOW" condition is considered to be more vulnerable to natural, annual variation, with a reduced ability to recover from periodic disturbance.

3.6.1 California Current (LME #3)[7]

The coastal portion of the California Current LME (Figures 3-10a, Figure 3-10b, and Figure 3-11) extends approximately 190 mi (300 km) offshore from southern British Columbia, Canada, to Baja California, Mexico, and is dominated by a southward surface current of colder water from the North Pacific (Dailey *et al.* 1993, pp. 8–10; Miller *et al.* 1999, p. 1). The system is characterized by upwelling, particularly in spring and summer. This is an oceanographic phenomenon involving wind-driven movement of dense, cooler, and usually nutrient-rich water towards the ocean surface, which replaces warmer and usually nutrient-depleted surface water (Smith 1983, entire). Coastal upwelling replenishes nutrients near the surface where photosynthesis occurs, resulting in increased productivity (Batchelder *et al.* 2002, p. 37).

The Strait of Juan de Fuca is where deep in-flowing oceanic waters mix with outflowing surface waters from Puget Sound and the Georgia Basin (Figure 3-11). The incoming ocean water can fluctuate between high-density waters with low oxygen and high nutrient content, versus low-

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[7] The boundary between the California Current and Gulf of Alaska LMEs in most publications is mapped at 48º N latitude. However, this boundary does not equate to the flow of the currents and ecosystems these LMEs are supposed to represent. The California Current moves south along the western coast of North America, beginning off southern British Columbia, flowing southward past Washington, Oregon, and California, and ending off southern Baja California. The California Current is part of the *North Pacific Gyre* (a large system of circulating ocean currents) and brings cool waters southward. In addition to the California and Alaska Currents, the Davidson current flows northward along the nearshore of western North America.

There is not a definitive demarcation that separates the California and Alaska Currents. The transition zone between the two LMEs, on the westside of Vancouver Island, varies throughout the year in response to the currents. In addition, the flow northward versus southward along the coasts of southern British Columbia, Washington, Oregon, and California depends upon the season and whether the California or Davidson Current is dominant. In the summer, the California Current is the stronger current, running southward. In the winter, the Davidson Current shifts the California Current offshore and the predominant flow is northward along the coasts.

In addition to the offshore currents, the tidal-driven waters from the Puget Sound and southern Georgia Straits (British Columbia; an area also referred to as the Salish Sea) flow through the Straits of Juan de Fuca into the California/Davidson Currents. The northern Georgia Straits tidal exchange is northward into Queen Charlotte Sound, a part of the Alaska Current.

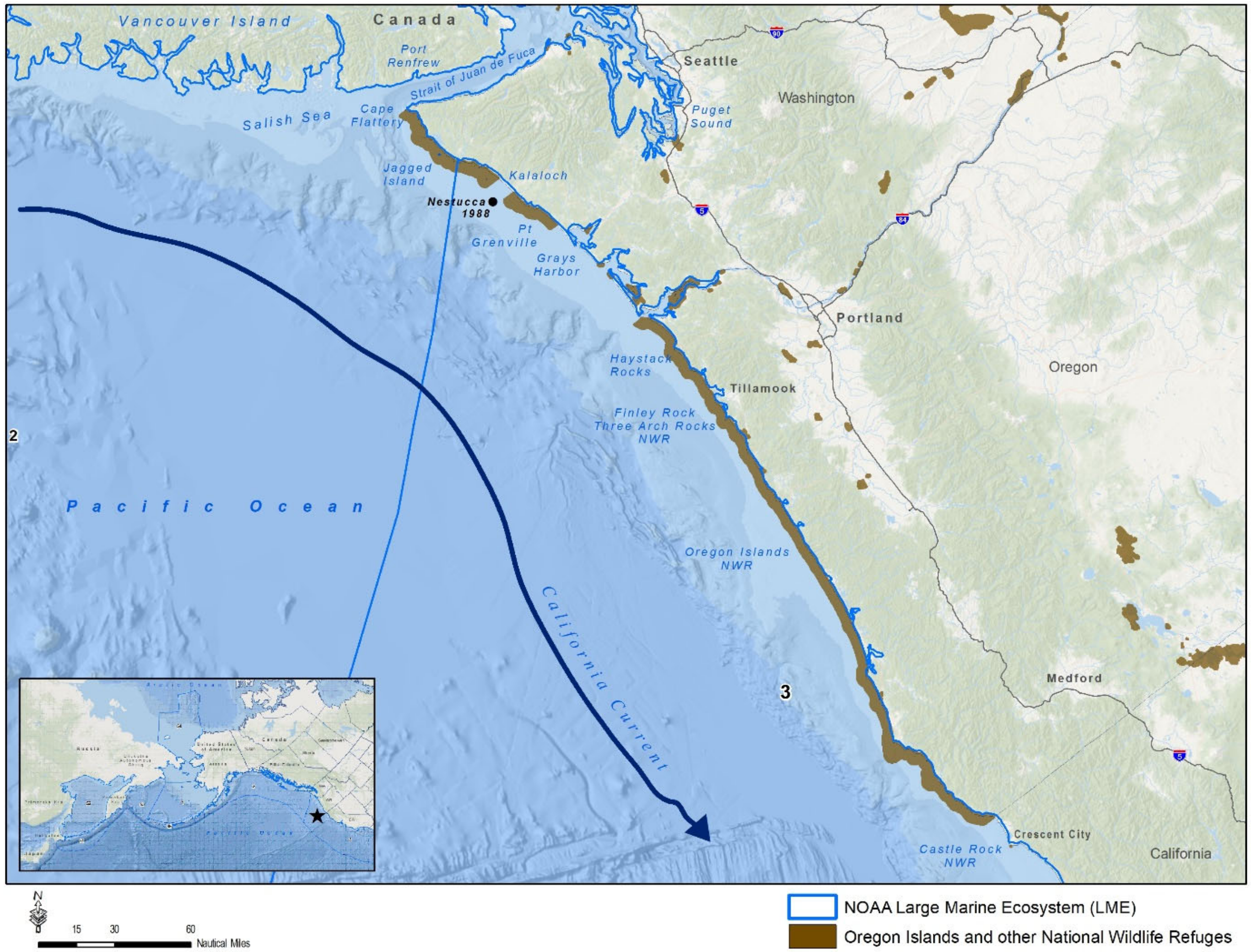
Use of the LMEs as they are mapped at 48º N latitude divides the coast of Washington into two LMEs at approximately Jagged Island. Using this boundary would result in tufted puffin colonies along the outer Washington coast being analyzed in two separate LMEs, but which are not exposed to different threats, climate variables, or food resources north and south of that boundary. In addition, this would place the tufted puffin colonies that are located in the Salish Sea into the Alaska LME, which does not represent the marine resources being used by the puffins.

Also, the data that this SSA relies upon also does not define the California/Alaska Currents at 48º N latitude. All of the Washington tufted puffin colonies used in the meta-analysis conducted by Pearson *et al*. (2019, entire) are considered to be a part of the California Current. Hart *et al.* (2018) uses a boundary demarcation at 48.5º N latitude. Hart *et al.'s* (2018) demarcation of 48.5º N latitude (approximately the town of Port Renfrew, British Columbia) does not account for the influence of the flow out of the Strait of Juan de Fuca, thus applying a demarcation at 48.9º N latitude (approximately at the town of Ucluelet, British Columbia) would account for a better representation of the marine resources attributable to the California versus Alaska Current and would be a better fit for the data to be used in the SSA analysis. Thus, all tufted puffin colonies on the outer Washington and southern British Columbia coasts and those in the Salish Sea are attributed to the California Current LME for this analysis.

density waters with high oxygen and low nutrient content (Puget Sound Action Team (PSAT) 2007, p. 116). The marine conditions in the Strait of Juan de Fuca are in response to upwelling and downwelling patterns generated by coastal winds and changes in coastal circulation.

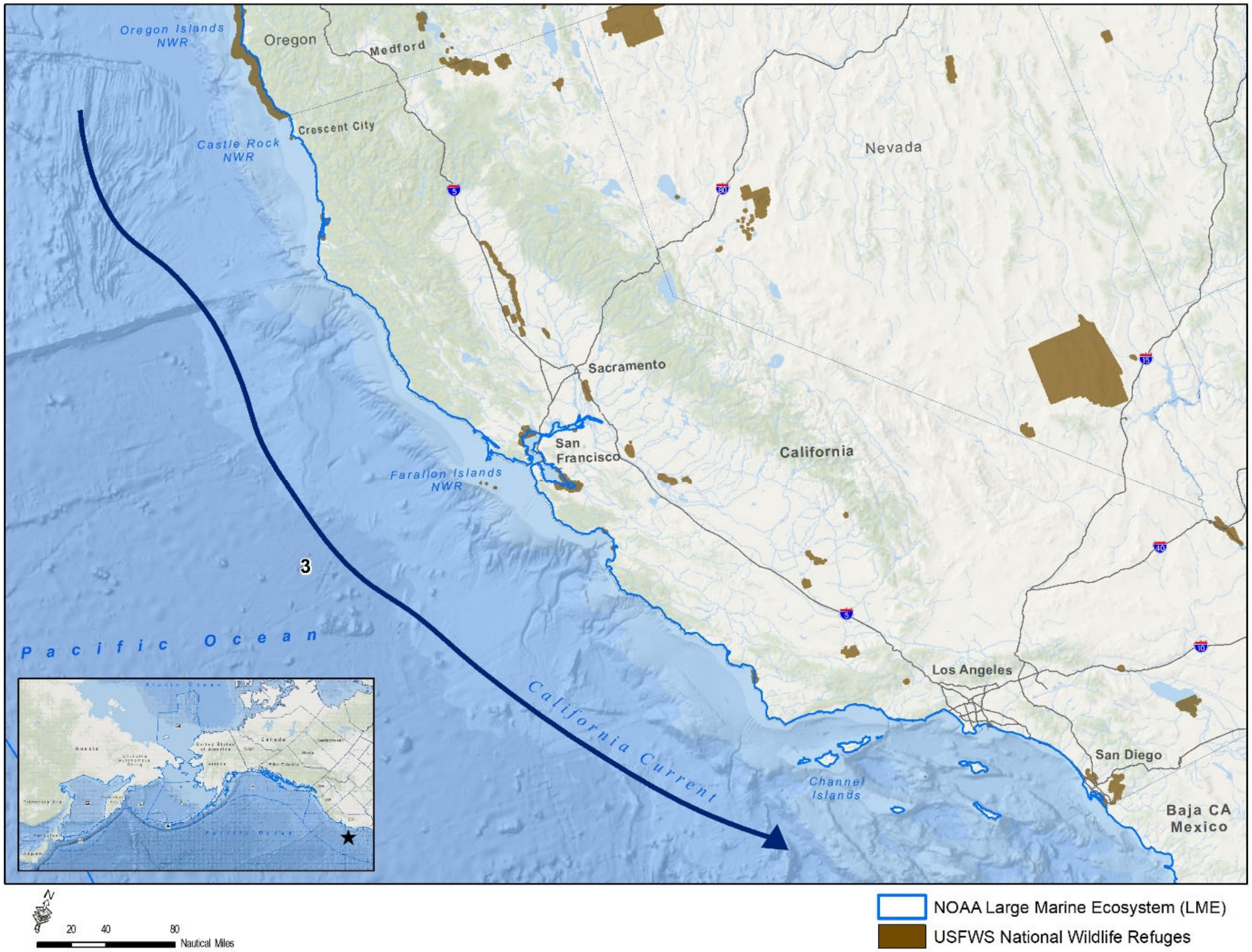
Puget Sound is unique among North American estuaries because of its geologically young, deep, narrow, and fiord-like structure. The subtidal circulation of Puget Sound is largely driven by the differences in salinity between fresher waters within Puget Sound and the saltier waters in the Strait of Juan de Fuca. The Olympic and Cascade mountain ranges provide freshwater inputs; however, several shallow sills restrict the entry of deep oceanic water into Puget Sound, which reduces flushing of these inland marine and estuarine waters compared to the other urbanized estuaries of North America. This hydrologic isolation puts Puget Sound's aquatic organisms at higher risk because toxic chemicals, nutrients, and pathogens that enter Puget Sound remain in the system longer, resulting in increased exposure (PSAT 2007, p. 129).

The California Current LME includes tufted puffin colonies in California, Oregon, and Washington. In addition, British Columbia colonies in the Salish Sea were included in the California Current for this analysis (Figure 3-11) because the LME boundary is fluid in this area, and impacts from stressors for those colonies closely mirror those in Washington.



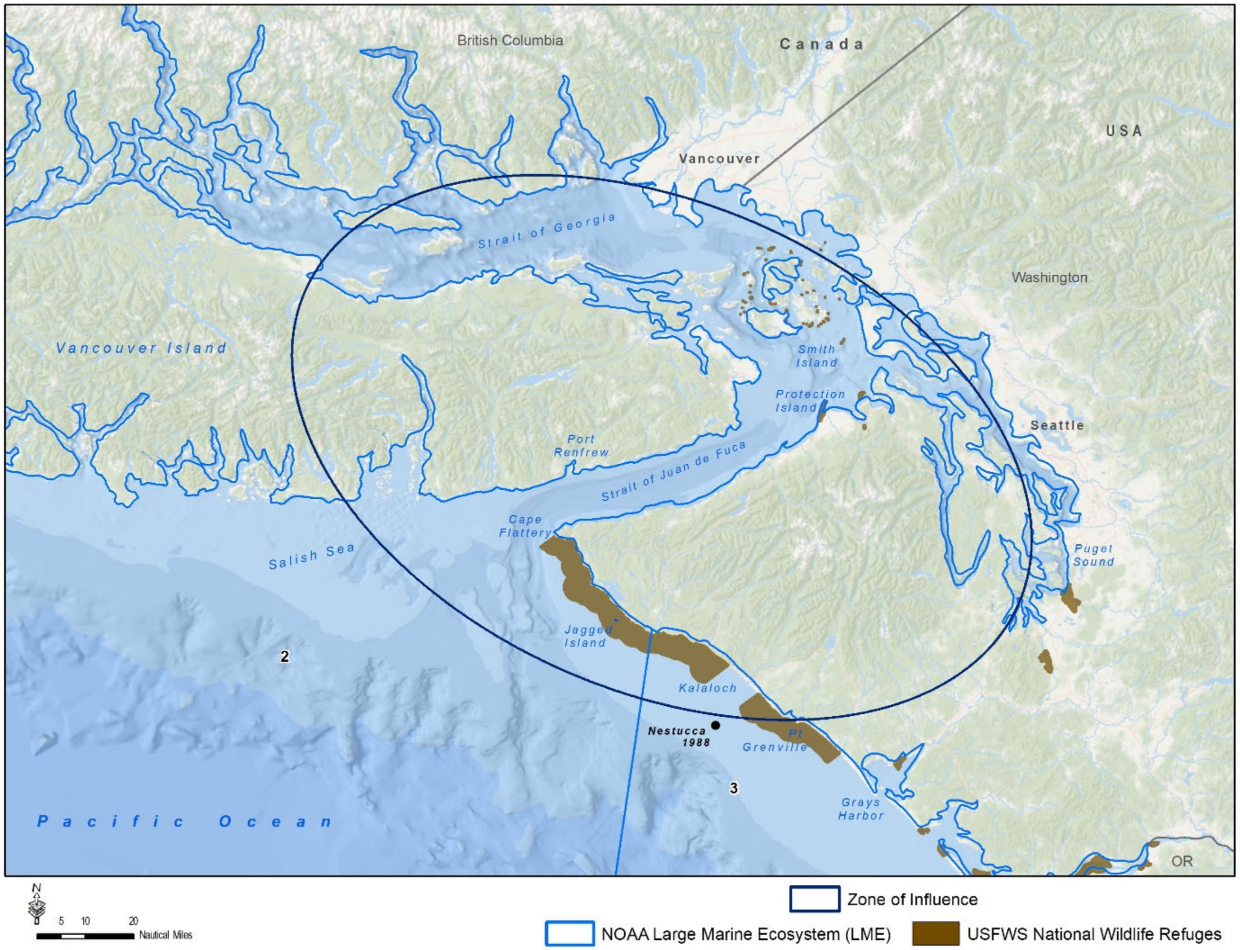
Source: NOAA 2019b, entire.

Figure 3-10a. The northern part of the California Current LME #3, as mapped by NOAA (2019b, entire).



Source: NOAA 2019b, entire.

Figure 3-10b. The southern part of the California Current LME #3, as mapped by NOAA (2019b, entire).



Source: NOAA 2019b.

Figure 3-11. The Salish Sea: the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound area influences the California Current LME (the map refers to this area as the "zone of influence" for the California Current). Tufted puffin colonies in this area are included in the California Current LME for our analysis.

3.6.1.1 Population Size and Trend

Piatt and Kitaysky (2002, p. 31; Appendix D) identified approximately 60 colonies in the California Current LME, with an estimated population of 27,610 tufted puffins. More recently, tufted puffin populations in the California Current LME have been declining, with colonies in the state of Washington, in particular, experiencing precipitous declines of up to 95 percent (Hanson *et al.* 2019, p. 3). It is thought fewer than 2,000 tufted puffins now nest in the California Current LME (Pearson 2019a, pers. comm.), with the trend analysis performed by Pearson *et al.* (2019, entire) confirming this decline.

Current estimates of abundance of tufted puffins in this LME include:

- California—Several small colonies may exist; however, only the two largest known colonies (Farallon Islands NWR and Castle Rock NWR) have been recently surveyed. These two colonies were counted in 2017, and had a combined estimated total of 405 birds; this represents an increase from the 280 birds counted in 2002, with all but 9 tufted puffins reported from the Farallons (Piatt and Kitaysky 2002, p. 31; Service 2018, p. 1; and Warzybok *et al.* 2018, pp. 14, 21).

- Oregon—All tufted puffins in Oregon nest within the Oregon Coast NWR complex, which includes Three Arches and Oregon Islands NWRs. In 1979, 38 active tufted puffin colonies were documented with a coastwide total breeding population of 6,632 birds; the 1988 survey documented 49 colonies and 4,858 breeding birds; and only 15 colonies and 142 breeding birds were observed during the 2008 survey (Naughton *et al.* 2007, entire; Kocourek *et al.* 2009, entire), an order of magnitude decline compared to previous coastwide surveys (Stephensen 2019, pers. comm.). The last time a complete survey of the Oregon Coast was conducted was 2008, as described in Kocourek *et al.* (2009, entire). However, a survey for tufted puffins at Three Arch Rocks in July 2019 documented 220 birds (compared to only 16 birds during the 2008 survey), while monitoring for tufted puffins at Haystack Rock at Cannon Beach for the past 10 years estimates the population there at 120 birds (Stephensen 2019, pers. comm.). Here, we discuss two studies that attempted to estimate tufted puffins along the Oregon coast, each using different methodologies, and each with vastly different results (Naughton *et al.* 2007, entire; Kocourek *et al.* 2009, entire).

    1) Using survey data from 1901–2004, Naughton *et al.* (2007, p. 3) estimated the number of breeding tufted puffins in Oregon at 4,600 (rounded estimate), with most of the birds nesting on Finley Rock within the Three Arches NWR, and the two northernmost Haystack Rocks within Oregon Islands NWR (Naughton *et al.* 2007, p. 5). Tufted puffins were estimated using direct nest counts whenever possible; however, because they are burrow-nesters, estimated counts of tufted puffins were thought to be less reliable than estimates for other Oregon seabirds (Naughton *et al.* 2007, p. 12).
    2) The Oregon Coast NWR Complex conducted a burrow-nesting seabird species census during June, July, and August 2008 of all rock, reef, island, and mainland colonies along the Oregon coast (Kocourek *et al.* 2009, entire). Tufted puffin numbers at that time were found to be greatly reduced compared to the 1988 survey, with only 142

tufted puffins counted in 2008 compared to 4,858 in the 1988 survey (Kocourek *et al.* 2009, pp. iv–vii). Tufted puffins were counted using the direct count method, in which individual birds were counted at colonies from a boat or from mainland vantage points (Kocourek *et al.* 2009, p. 8). Reported breeding population estimates are the total number of individual adult birds observed at the colony; no conversion factors were used to adjust the population estimates, and birds hidden in crevices or burrows, or absent from the colony, were not accounted for in the 2008 survey (Kocourek *et al.* 2009, p. 8). The 2008 methodology used for estimating tufted puffin breeding populations differed somewhat from previous survey methods; thus, while the 2008 tufted puffin breeding population estimate likely represents a decline, differences in survey methodology and survey timing between years may exaggerate the decline (Kocourek *et al.* 2009, pp. 17–18). In addition, Kocourek *et al.* (2009, p. 18) indicate that surveys conducted in 2008 may have taken place after breeding birds had dispersed from some colonies, and recommended additional surveys to confirm the low numbers observed.

In summary, results from the two most recent range-wide surveys in Oregon were mixed, and it is unclear how many tufted puffins currently nest at breeding colonies along the Oregon coast. However, Pearson *et al.* (2019, p. 28) indicates that the rate of decline in Oregon is comparable or even exceeds that seen in Washington.

- The current size of the existing tufted puffin population in Washington is unclear. Tufted puffin colonies in Washington are primarily on islands along the outer coast from Point Grenville north to Cape Flattery (Speich and Wahl 1989, pp. 80–82). Historically, tufted puffins also nested in small numbers at sites throughout the San Juan Islands, but are now restricted to Protection Island and Smith Island (Hanson and Wiles 2015, pp. 3–4). Tufted puffins in Washington declined 4 percent per year from 2001–2017 (Hanson *et al.* 2019, p. 4). It should also be noted that 2015 was a year with unusually high ocean temperatures (the anomalous warm water "Blob" was reported during that year), and many colonies had little nesting activity that year (Hanson *et al.* 2019, p. 3).

Once more numerous, tufted puffin colonies in the California Current LME, which represents the southernmost extent of the species range, are now smaller in size, and the number of birds in each colony now range from single pairs to several hundred birds. Colonies are located along the coastlines of California, Oregon, Washington, and in the Strait of Juan de Fuca, and are spread across a wide geographical range. Most colonies in this LME were included in the Pearson et al. (2019, entire) trend analysis, which confirmed tufted puffin populations in the California Current LME have undergone significant declines (Pearson et al. 2019, p. 8). Notably, approximately half (or more) of previously identified tufted puffin colonies in Washington and Oregon are no longer occupied (Pearson 2019b, pers. comm.).

3.6.1.2 Threats

Climate Change[8]

Climate change events such as increased SSTs, which can lead to reduced prey availability, are thought to have contributed to historical and recent declines in tufted puffins in California (Ainley and Lewis 1974, p. 442; Hunt *et al.* 1981, entire; Agler *et al.* 1999, entire). Specifically, tufted puffins in the Farallon Islands may have never recovered from the loss of Pacific sardine (*Sardinops sagax*) populations in the 1940s (Ainley and Lewis 1974, p. 442).

California fisheries[9] for anchovy have undergone a pattern of expansion and collapse in response to fishing pressure and changes in ocean climate. Anchovy populations grew throughout the 1970s but then declined in the 1980s as the area off southern and central California warmed. The abundance of adult-stage anchovy off central California has declined in recent years (Ralston *et al*. 2015, pp. 29–30) with a major decline documented between 2005 and 2006, and between 2008 and 2009. Thayer *et al.* (2017, pp.1, 4) reported continued declines. However, Thayer (2018, entire) updated 2015-2017 estimates for northern anchovy; the anchovy biomass for 2017 was estimated at 1,289,043 tons (1,169,400 metric tons), the first time in more than 11 years that the biomass has been higher than the long-term mean (Thayer 2018, entire).

Pacific herring (*Clupea pallasii*) stocks in California fluctuate above and below the historical (1979 to present) average biomass of 50,300 tons (45,631 metric tons) (CDFW 2016, pp. 2, 4). The below average biomass reported over the last 2 years may be attributed to conditions not favorable to herring survival as a result of the recent poor oceanic and estuarine conditions (CDFW 2016, p. 2) that are associated with record high sea surface temperature anomalies and the development of a large El Niño event (NMFS 2016, p. 1). In 2014 and 2015, this resulted in the California Current LME having lower productivity at nearly every trophic level (NMFS 2016, p. 1). In addition, the ongoing drought has resulted in atypical estuarine conditions with reduced freshwater influence into the San Francisco Estuary, which may negatively influence both spawning herring and young herring in the estuary (CDFW 2016, p. 2).

Climate change has also been linked to increased algal blooms in the California Current LME. Two harmful algal bloom events resulting in the mortality of seabirds occurred in 2007 in California, and 2009 in Washington and Oregon (Jessup *et al*. 2009, entire; Phillips *et al*. 2011, entire). Both of these events were caused by the dinoflagellate *Akashiwo sanguinea*, which produces a foam that coats the feathers of birds. This coating resulted in reduced waterproofing, ultimately resulting in hypothermia (Jessup *et al*. 2009, p. 2; Phillips *et al*. 2011, p. 120). Of the birds examined from the Washington and Oregon event, 58 percent were undergoing molt of the primary feathers, making them more susceptible to plumage fouling owing to their reduced

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[8] Within this section, we include an abbreviated discussion of the impacts of climate change on the California Current LME. However, because the California Current LME has climate change stressors that are unique among the analysis units in scale and magnitude, we include a more robust discussion of climate change in the California Current LME in Appendix E.

[9] We include a discussion of forage fish and their responses to changing ocean conditions in the California Current LME in Appendix F.

ability to move away from areas where algal blooms were occurring (Phillips *et al*. 2011, pp. 123–124). While tufted puffins were not specifically identified in these events, other alcid species were affected (Jessup *et al.* 2007, entire; Phillips *et al.* 2011, entire).

The seasonal fluctuations of the Juan de Fuca Eddy, a nutrient-rich area within the Puget Sound (Figure 3-10), serves as an incubator for algae, which can then be deposited along the Washington coastline (Lopez *et al*. 2008, p. 18). While there is limited direct evidence of paralytic shellfish poisoning related impacts reported in tufted puffins, it has been implicated in the death of one tufted puffin in a 1942 harmful algal bloom event along the Washington coast, and has been documented as the cause of mortality in other alcid species (McKernan and Scheffer 1942, entire; Shumway *et al*. 2003, p. 5).

Blooms of *Pseudo-nitzschia* spp. have been linked to large numbers of seabird and marine mammal deaths annually and have been reportedly increasing over the last 15 years (Lopez *et al.* 2008, p. 28; Lewitus *et al.* 2012, p. 45). In 1991, along the beaches of Monterey Bay, California, dead and dying seabirds were observed and many of the sick birds displayed unusual symptoms suggesting exposure to a neurological toxin. Examination of the contents of dead bird's stomachs revealed high levels of domoic acid. The birds had been eating anchovies that had been consuming the diatom *Pseudo-nitzschia australis* (NOAA 2009, entire). An outbreak of *Pseudo-nitzschia* spp. during the spring and summer of 2015 stretched from southern California to the Aleutian Islands, Alaska (NOAA Climate 2015, p. 1). Within Monterey Bay, California, this harmful algal toxin produced the highest particulate concentrations of domoic acid recorded in more than two decades of monitoring (Ryan *et al.* 2017, p. 5,575).

Finally, the California Current LME has documented impacts from terrestrial climate changes on nesting tufted puffins and their habitat. While the erosion rates are generally low on the coastal cliffs where tufted puffins nest, the highest erosion rates occur where wave exposure is high (Shipman 2004, p. 89). In addition, slope failures occur episodically, generally tied to heavy precipitation (Shipman 2004, p. 89).

Sea-level rise and wave action are the two processes that most influence the evolution of coastal cliffs (Hampton *et al.* 2004, pp. 11, 14). Sea level rise is a consequence of the melting of glaciers and ice sheets combined with the expansion of water as it warms. At regional and local scales, numerous factors affect sea level rise, including ocean currents, wind patterns, and plate tectonics (Mauger *et al.* 2015, p. 4–1; Dalrymple 2012, p. 81; Petersen *et al.* 2015, p. 21). While sea levels have been rising in the eastern North Pacific (Mazzotti *et al.* 2008, p. 7, Figure 4; Zervas 2009, pp. 23–24; Miller *et al.* 2013, p. 27), the change in sea level height has not been consistent across the range of the tufted puffin because of vertical land movements (uplift or subsidence) that has mitigated or exacerbated the rise (Hampton *et al.* 2004, pp. 11–12; Mazzotti *et al.* 2008, entire; Zervas 2009, p. 20). For example, in Washington, the areas of the coastline that are uplifting (northwest tip of Olympic Peninsula) have experienced a declining sea level height; in addition, areas along the outer coasts of California, Oregon, and Washington and most areas in the Gulf of Alaska have experienced falling sea levels due to vertical land uplifting (Zervas 2009, pp. 20, 23, 24).

Since the 1970s, wave heights and periods have increased, particularly in the northern portions of the eastern North Pacific; for example, within the California Current LME, the highest rate of increase has been off the coast of Washington where winter wave heights have increased by 6.6 feet (2 meters) (Hampton *et al.* 2004, p. 15). Storm events magnify the wave action on beaches and bluffs by increasing wave energy, wave height, and wind speed, which results in increased coastal erosion, and these can be exacerbated by high tides and El Niño events (Hampton *et al.* 2004, p. 12; Shipman 2004, p. 89).

Due to documented occurrences of elevated SSTs affecting forage fish availability, seabird mortality events, along with HAB events, we categorized risks to tufted puffins from climate change as moderate for the California Current LME.

Oil Spills

Throughout the California Current LME, frequent oil spills have been implicated in historical tufted puffin population declines in the Farallon Islands in California (Ainley and Boekelheide 1990, p. 341). Because of their pelagic distribution, tufted puffins oiled by a spill may not wash ashore to be counted (McChesney and Carter 2008, p. 215). Within the California Current LME, a breeding season crude oil spill from a tanker of more than or about 10,000 barrels (420,000 gal) would likely have wide-ranging, catastrophic impacts to nearby seabird colonies. Fortunately, spills that large are relatively rare (Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) 2012, p. 17). The vast majority of oil spills in this LME are less than 1 barrel (42 gal) and are primarily of diesel oil/marine gas oil (Oil Spill Task Force 2019, pp. 5–7). These small spills should be considered a low but chronic level of exposure because they are not contained or cleaned up.

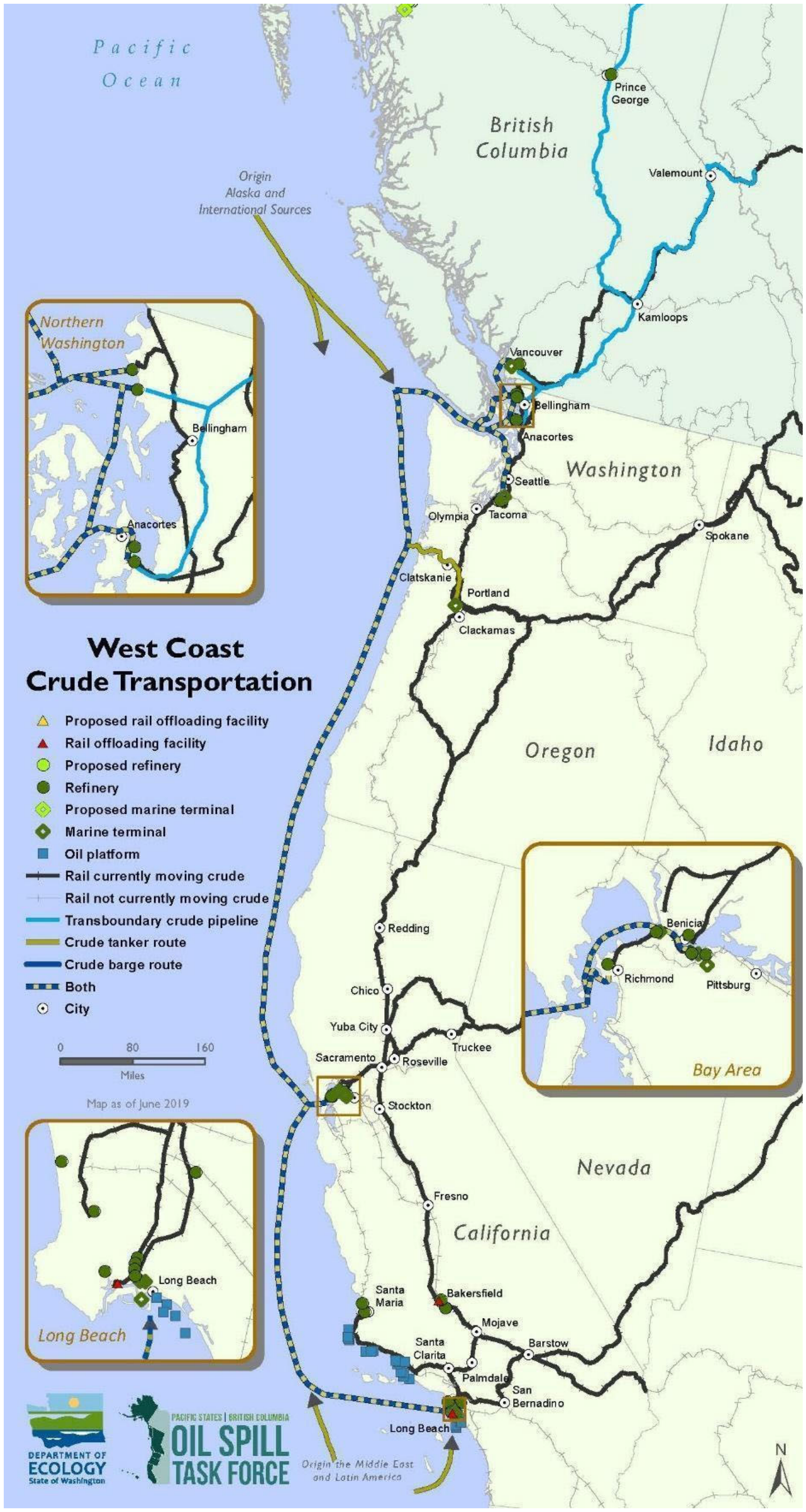
Of the five Natural Resource Damage Assessments from Washington, Oregon, and northern California in the last 30 years that have resulted in known tufted puffin deaths (Table 3-4), three of the four known sources were from groundings or collisions of non-tank vessels (e.g., container, freighter, fishing, or cruise ships). One spill, *The Nestucca*, was a fuel oil barge that collided with its tug near Grays Harbor, Washington (Ford *et al.* 1991, p. 13). Non-tank vessels are not required to have double hulls and other safety features per the Oil Pollution Act of 1990 (33 U.S.C. 2706(b)); therefore, they remain vulnerable to fuel oil spills following groundings or collisions. Typically, these larger regional spills are still significantly smaller than the volume of oil a tanker can hold and thus spill. The five incidents reported to have killed tufted puffin spilled approximately 48 to 8,400 barrels (2,000 to 350,000 gal) of fuel oil each, whereas the *Exxon Valdez* in the Gulf of Alaska spilled approximately 262,000 barrels (11 million gal) of crude oil (Cartwright 1991, p. 451).

Table 3-4. List of oil spills that have Natural Resource Damage Assessment reports within the California Current LME, including spill statistics.

Incident Name	Type of Vessel	State	Season/ Year	Volume and Material Spilled	Puffins killed[1]
Nestuca Oil Spill	Oil Barge	WA	Winter 1988–1989	231,000 gal #6 Fuel Oil	4 TUPU 5 PU sp.
Tenyo Maru Oil Spill	Fishing	WA	Summer 1991	≤354,800 gal Intermediate Fuel Oil and ≤97,800 gal Diesel Fuel	127 TUPU
M/V New Carissa Oil Spill	Cargo	OR	Winter 1999	25,000 to 140,000 gal Fuel Oil	3 TUPU
OR/WA Mystery Spill	Unknown	OR/WA	Winter 1999	Unknown amount of Fuel Oil	1 TUPU 2 PU sp.
Stuyvesant/ Humboldt Coast Spill	Dredge	CA	Fall 1999	2,100 gal Intermediate Fuel Oil	1 TUPU

[1]Number represents actual puffin carcasses collected, which is unlikely to be the extent of the total numbers killed. Natural Resource Damage Assessments generally combine all alcids into one estimate. TUPU = tufted puffin; PU = unidentified puffin species.

Upon evaluation of shipping traffic, large ship traffic has increased fourfold from 1992–2012 (Tournadre 2014, p. 7,929). The trend has been roughly a 6 percent increase per year from 1992–2002, and an increasing rate of 10 percent per year from 2002–2011, with the exception of 2008–2009, when the rate remained stable, possibly due to the economic downturn (Tournadre 2014, p. 7,929). Marine vessels (tankers and barges) have historically been and are currently still the primary mode of transporting oil along the west coast (Figure 3-12). In 2013, approximately 700 vessels entered the Salish Sea (excluding those going to Canada, though Canadian tankers are also traveling the same route into and out of the Salish Sea) and 264 entered the Columbia River (Washington State Department of Ecology (WSDE) 2015, p. 271). However, as U.S. and Canadian crude oil production has increased, the type and mode of transporting oil to refineries and terminals is changing (WSDE 2015, p. 18). Trends are shifting toward more rail and pipeline transport (WSDE 2015, pp. 25–26). In Washington, this may result in more transfers from Columbia River and Grays Harbor terminals to Puget Sound refineries by barge; thus, tufted puffins that nest near the Strait of Juan de Fuca may be at increased risk for potential oil spills.



Source: Oil Spill Task Force 2019.

Figure 3-12. West Coast crude oil transportation and potential sources of oil spills.

California supports small numbers of wintering tufted puffins, as well as nesting tufted puffins on the Farallon Islands and Castle Rock, and is considered a high traffic shipping, oil producing and refining region. In addition to high volume of tanker and non-tank shipping traffic, southern California has approximately 23 offshore oil platforms in Federal waters and 10 in State waters and their associated pipelines. McCrary *et al.* (2003, p. 45) estimated the risk of a spill greater than or equal to 1,000 barrels (42,000 gal) over the following 28 years to be approximately 41.2 percent for Federal offshore oil operations and 8.4 percent for state operations. For tankering Alaskan and foreign oil through the southern California region, there is an estimated 99 percent chance of a spill of greater than 1,000 barrels (42,000 gal) (McCrary *et al.* 2003, p. 46).

Oil and other fuel spills can and do occur in this LME, although most are considered small spills; however, spills of any size can impact reproductive success of nesting tufted puffins, and are known to have other chronic effects on seabirds. In addition, shipping traffic has steadily increased in this LME, leading to an increased probability that a large spill could impact tufted puffins. Therefore, we categorized risks from oil spills as moderate for this LME.

<u>Fisheries Bycatch</u>

From 2002–2016, there was no known tufted puffin mortality in the West Coast groundfish fisheries (Jannot *et al*. 2018, p. 2) in the California Current LME. This includes fisheries using hook-and-line, trawls, pots, and strikes on trawler cables. One non-lethal interaction (Jannot *et al*. 2018, p. 70, App. B) was documented, in which a tufted puffin was entangled in gear in the hook and line fishery during that time (Jannot *et al*. 2018, p. 2).

The NMFS research fishery documented two tufted puffin mortalities in 2011: one approximately 20 mi (32 km) offshore of Kalaloch, Washington, and one approximately 17 mi (27 km) offshore of Tillamook, Oregon (Catelani 2017, pers. comm.). Prior to 2015, NMFS had no systematic protocol for documenting seabird bycatch. NMFS data includes other closely related pursuit-diving seabird species, such as common murres and rhinoceros auklets, being killed by surface trawl gear (Catelani 2017, pers. comm.).

Although comprehensive observer data do not exist for Salish Sea gill net fisheries (Hamel *et al.* 2009, p. 42), there is evidence of a tufted puffin being killed in a treaty[10] gillnet fishery (Beattie and Lutz 1993, p. 9). However, multiple studies have documented mortality of common murres and rhinoceros auklets, in purse seine and gillnet fisheries (National Research Council (NRC) 1993, pp. 5, 7; Craig and Cave 1994, p. 4; NRC 1995, pp. 14, 17; Melvin *et al.* 2001, p. 170; Smith and Morgan 2005, p. 24; Hamel *et al.* 2009, p. 51). Seabirds that engage in kleptoparasitism and scavenging may experience a cost and a benefit from interactions with fisheries; pursuit-diving species are likely to bear only costs, including both direct mortalities and indirect effects. Fishing vessel discards may lead to increases in populations of kleptoparasites and scavengers, which in turn prey on pursuit-divers, their eggs, and their young at breeding colonies, and which may contribute to mortalities (Wagner and Boersma 2011, p. 163).

[10] Treaty fishery refers to those governed by the Pacific Salmon Treaty between the United States and Canada, first signed in 1985 and renewed in 2018. The treaty provides a framework for both countries to work together to conserve and manage all five species of Pacific salmon (Pacific Salmon Commission 2019, entire).

Historically, fishery bycatch killed large numbers of seabirds, including tufted puffins. However, the United Nations ban on large-scale, high seas driftnet fisheries in 1992 (Zydelis *et al.* 2009, p. 1,270) greatly reduced seabird bycatch. Currently, very few tufted puffin deaths are reported from fishery bycatch in this LME; therefore, we categorized risks to tufted puffins from fishery bycatch as low for this LME.

<u>Mammalian and Avian Predators</u>

Native predators that occur in the California Current LME that could affect individual puffins or an entire colony include bald eagles, peregrine falcons, gulls (western and glaucous-winged), common ravens, river otters, mink, and raccoons. In addition to predation, gulls are known to displace puffins at burrow sites and kleptoparasitize adult puffins bringing food to chicks (Speich and Wahl 1989, p. 81; Jaques and Strong 2001, p. 18). On islands where small numbers of puffins nest among dense aggregations of gulls, such as Castle Rock and South Farallon Island, California, this could lead to reduced fledging success for tufted puffin (Speich and Wahl 1989, p. 81; McChesney and Carter 2008, p. 215).

Although some tufted puffin colonies in this LME may be negatively impacted by predation, colonies are distributed across a wide range and the effects of predation on population distribution or trends remains unclear. However, predation is not thought to greatly impact tufted puffins in this LME; therefore, we categorized risks from mammalian and avian predators in the California Current LME as low.

<u>Nonnative Plants and Animals</u>

Nonnative European rabbits were introduced to a number of islands in Washington, including Destruction, Smith, Colville, Flattop, Matia, and Skipjack (Couch 1929, pp. 334, 336; Aubry and West 1984, p. 82). Studies have not been conducted, thus there is no direct correlation of the impacts from introduced rabbits and tufted puffin declines; however, puffins have disappeared from Colville, Flattop, Matia, and Skipjack islands (Hanson and Wiles 2015, p. 29). On Destruction Island, European rabbits persist and have been observed occupying rhinoceros auklet burrows and may have contributed to the declining trend of auklets through direct competition for burrow sites (Hanson and Wiles 2015, p. 29).

Nonnative mammals, birds, and plants can alter or degrade habitat available to burrow-nesting seabirds. Overgrazing by introduced rabbits has altered the plant community on Destruction Island resulting in significant soil erosion and land slippage, which has caused loss of burrowing habitat (Hanson and Wiles 2015, p. 29).

Invasive nonnative plants compete with native plants and can degrade burrow habitat by blocking access/egress from burrows. Introduced plant species are present at many seabird nesting sites in Washington, particularly on the San Juan Islands and Strait of Juan de Fuca. At Protection Island, for example, nonnative grasses (e.g., cheatgrass (*Bromus tectorum*)) are common on sandy bluff habitat used by nesting tufted puffins (Service 2010, pp. 4–17, 4–18). Non-native plants can alter fire regimes because they senesce early and are more prone to fires. In addition, they enhance soil moisture deficits, which can ultimately lead to instability of steep slopes (Service 2010, p. 2-23). Invasive plant control measures and restoration of native vegetation are being implemented by the NWR.

In California, the last remaining invasive mammal species, the house mouse, still remains on the Farallon Islands NWR; however, efforts are underway to remove this nonnative mammal (Service 2019a, p. 91).

The effects of nonnative plants and animals on tufted puffin population distribution or trends remains unclear; however, risks to tufted puffins from nonnative species appear to be limited to a select number of colonies rather than widespread. In addition, ongoing efforts to remove nonnative species on tufted puffin nesting islands in this LME appear to be successful. Therefore, we categorized risks from nonnative plants and animals as low.

Human Disturbance

In the California Current LME, nearly all documented former and current breeding locations are managed by the Service's NWR system, including the Washington Maritime NWR Complex, Oregon Coast NWR Complex, Castle Rock NWR, and Farallon Islands NWR. Most of the islands are designated as wilderness and do not have humans residing on them. The exceptions are Protection Island in Washington, which has a private residence and resident caretakers, and Farallon Island in California, which provides housing for researchers and restoration personnel. All of the islands may receive periodic/sporadic visitation from researchers and refuge managers; however, on most islands access is limited, especially to tufted puffin nesting habitat. Research on tufted puffins, in particular work that involves capturing, handling, banding, or application of transmitters, is rare because of the lack of accessibility of the breeding habitat. In Oregon, for example, there are no tufted puffin colonies where research can occur that would not cause unacceptable levels of disturbance (Stephensen 2017, p. 2). The known exceptions where research is conducted on puffins or other species in the vicinity of puffins includes Protection, Tatoosh, and Destruction islands in Washington (Good *et al.* 2014, entire; Pearson and Hodum 2018, entire).

The NWR system manages the islands and cliffs where tufted puffin colonies are found in this LME. Access is limited during the nesting season, although a few colonies may be visited by researchers, which may cause disturbance to nesting tufted puffins. However, researchers are aware of the potential to disturb nesting tufted puffins, and have developed methods to mitigate disturbance, such as using remote sensing and cameras, and monitoring puffin attendance from a distance. Overall, land management by the NWR system limits human disturbance to colonies; therefore, we categorized risks from human disturbance as low for this LME.

3.6.1.3 Conservation Actions

Nearly all colonies are located on land managed by the Service's NWR system.

Within California, Castle Rock NWR and Farallon Islands NWR (specifically, southeast Farallon Island) are the largest and most important seabird colonies in the State (Service 2009a, p. 6). Current management under both NWR's respective Comprehensive Conservation Plans include closure of the NWRs to the public due to the sensitive nature of the wildlife and habitat with only limited access for research, monitoring, and management (Service 2009a, p. 6; Service 2009b, p. 62). Such closures result in reduced human disturbance, potential for crushing burrows, and introducing invasive plant and animal species. No other active management is occurring on Castle Rock NWR. Additional management occurring on the southeast Farallon Island under the Farallon Islands NWR Comprehensive Conservation Plan includes restoration of degraded habitat through reduction of nonnative vegetation (Service 2009b, p. 22), which should benefit burrow nesting seabirds by providing more nesting substrate rather than a thick mat that interferes with nesting. An Environmental Impact Statement (Service 2019a, entire) has been produced for a South Farallon Islands Invasive House Mouse Eradication Project. Once implemented, the removal of house mice is likely to contribute to an increase in seabirds inhabiting the island by reducing the spread of nonnative seeds, reducing herbivory on native plants that are better suited for burrowing seabirds, the possible direct mortality of eggs or young, and through reducing a prey source for avian predators that may otherwise leave the island in the absence of an artificial prey resource. However, it remains unknown which species will ultimately benefit from these management actions.

The Oregon Islands, Three Arch Rocks, and Cape Meares NWR Comprehensive Conservation Plan (Service 2009c, entire) includes management goals for protecting tufted puffin colonies. The goals include maintenance and protection of native coastal habitats for the benefit of rare plants, migratory birds, and other native wildlife; collecting scientific information (inventories, monitoring, feasibility studies, assessments, and research) to support adaptive management decisions; promoting protection, stewardship, and enjoyment of Oregon's seabirds and their wilderness habitats; and preserving and protecting the wilderness character of Oregon Islands Wilderness and Three Arch Rocks Wilderness, including the areas' untrammeled nature, naturalness, and undeveloped condition (Service 2009c, entire).

The Washington National Maritime Refuge Complex's Comprehensive Conservation Plan states one of the goals of the refuge complex is to minimize or eliminate disturbance to wildlife (Service 2007, p. 1-22). The refuge complex's islands and rocks are extremely important habitat for seabirds, including tufted puffins (Service 2007, p. 2-2); gaining safe access to these rocks and islands is difficult due to dangerous surf conditions (Service 2007, p.1-22). Therefore, all of the islands of the Washington National Maritime Refuge Complex are closed to public use and access (Service 2007, p. 2-2).

3.6.1.4 Summary

Tufted puffin colonies in the California Current LME are well-studied, and the tufted puffin population in this LME is well-documented (NRDC 2014, entire; Hanson and Wiles 2015, entire; Hart *et al.* 2018, entire; Hanson *et al.* 2019, entire; Pearson *et al*. 2019, entire).

- In this LME, the tufted puffin population is declining (Pearson *et al.* 2019, p. 8). It is thought fewer than 2,000 tufted puffins now nest in the California Current LME (Pearson 2019a, pers. comm.).
- The most significant threats that are or are likely affecting tufted puffins or their habitat in this LME are climate change (increasing SSTs leading to reduced availability of forage

fish, and the potential for increased HAB implicated in mortality events), along with oil spills. Climate change and oil spills are both categorized as moderate risks to tufted puffins and their habitat. Fishery bycatch, mammalian and avian predators, nonnative plants and animals, and human disturbance are categorized as low risk to tufted puffins and their habitat in this LME.
- Conservation actions include management by the NWR system, restricting access to tufted puffin nesting areas during the breeding season, and control of nonnative plants and animals.

3.6.2 Gulf of Alaska (LME #2)

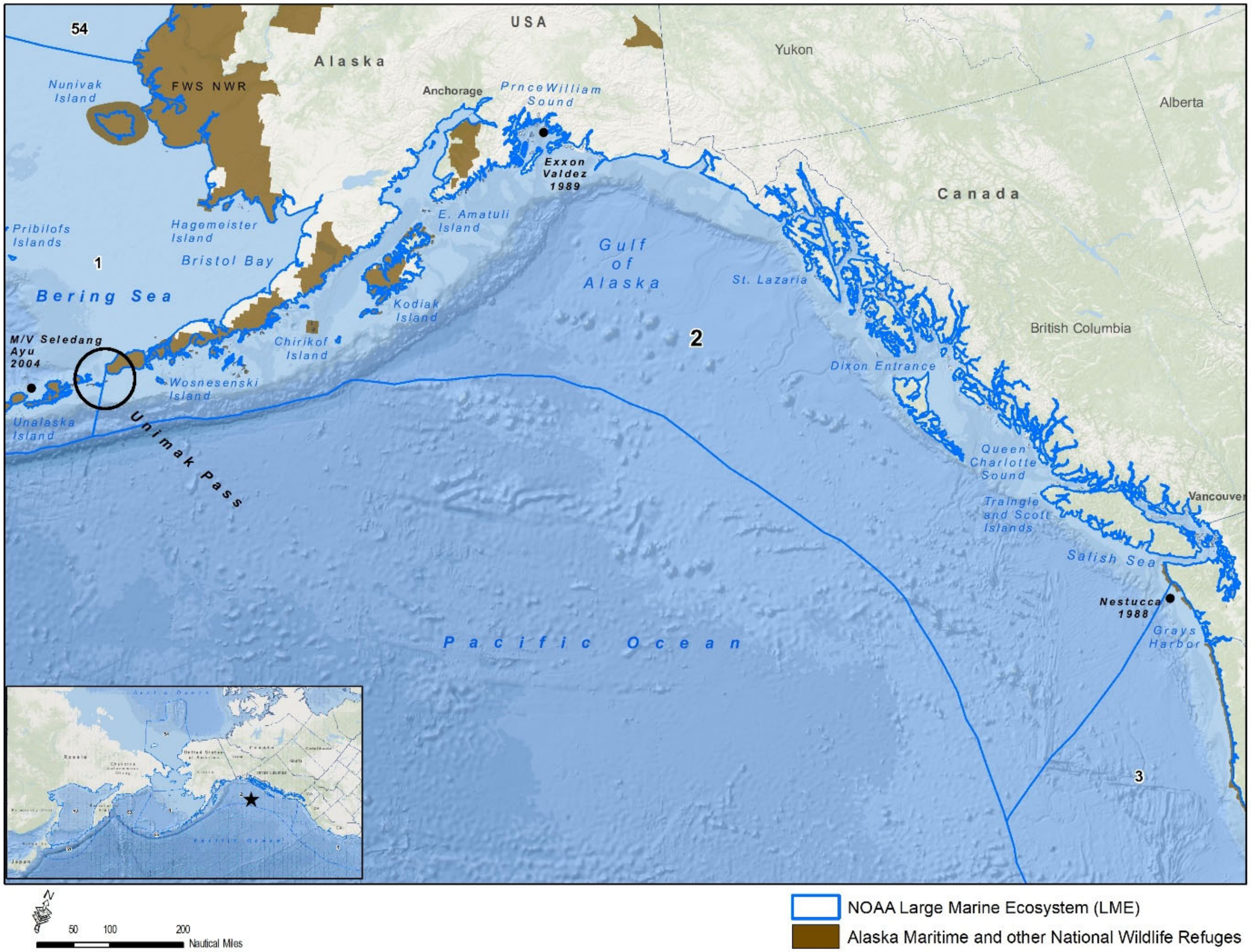
The Gulf of Alaska LME (Figure 3-13) lies off the southern coast of Alaska and the western coast of Canada, and is separated from the East Bering Sea LME by the Alaska Peninsula. The cold Subarctic Current serves as the boundary between the Gulf of Alaska LME and the California Current LME (NOAA 2019a, entire).

3.6.2.1 Population Size and Trend

The Gulf of Alaska LME includes tufted puffin colonies in Southeast Alaska, the Northern Gulf of Alaska, the East Alaska Peninsula, the West Alaska Peninsula, and colonies in British Columbia, with the exception of those in the Salish Sea, which are included in the California Current LME (section 3.6.1). Notably, the largest tufted puffin colony in British Columbia, Triangle Island, is included in this LME.

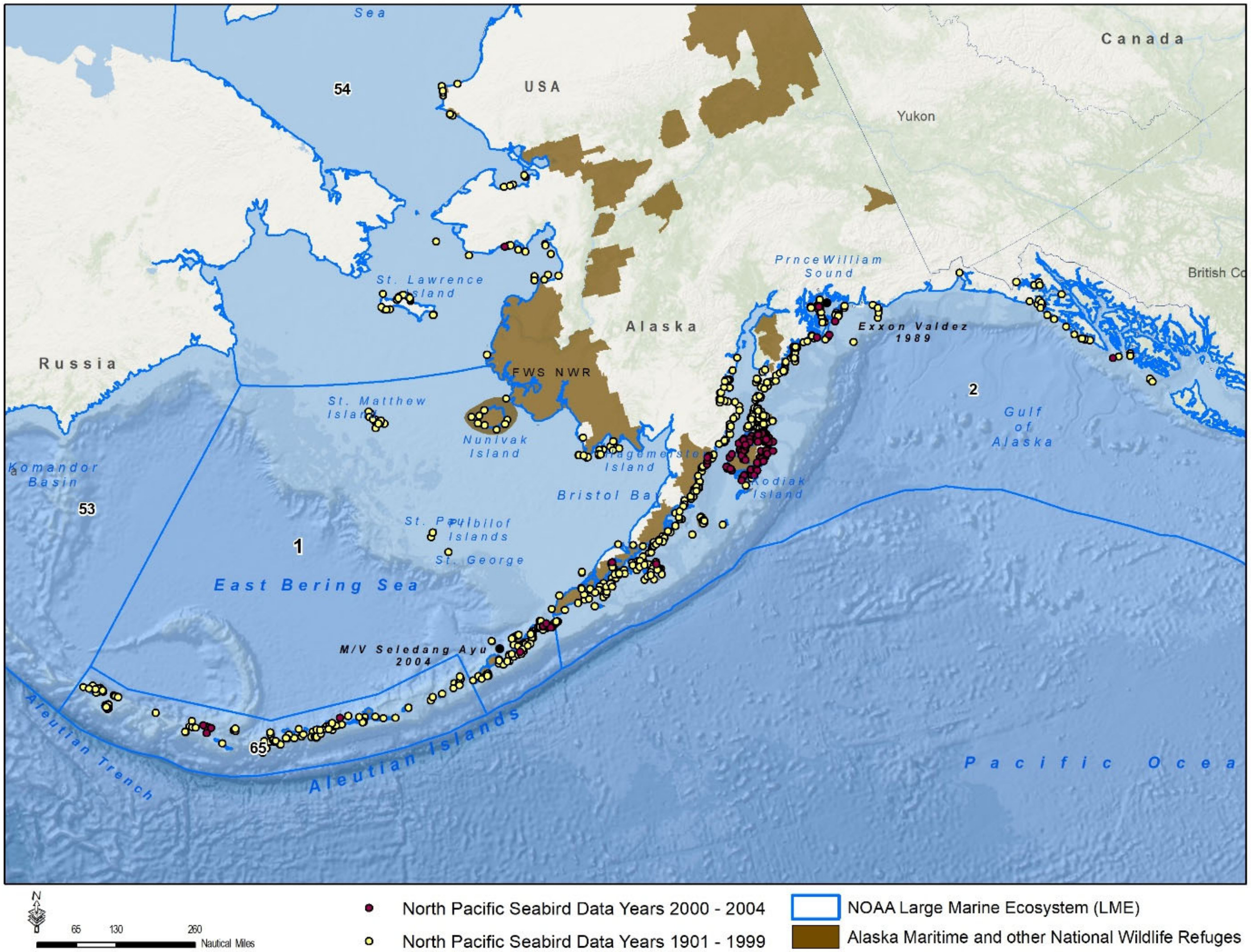
Piatt and Kitaysky (2002, p. 31; Appendix D) document approximately 447 colonies in the Alaska portion of this LME, and approximately 31 colonies in British Columbia. The estimated tufted puffin population in 2002 was 952,330 individuals in the Alaska portion, and 76,730 individuals in British Columbia (Piatt and Kitaysky 2002, p. 31; Appendix D). Colony size in this LME ranges from small (a few pairs of tufted puffins) to large (greater than 100,000 tufted puffins). Colonies are well-distributed across the LME, with a majority of the colonies off the coast of Alaska, and smaller numbers of colonies along the coast of British Columbia. Tufted puffin colonies found in Alaska are mapped in Figure 3-14.

We consider the Piatt and Kitaysky (2002, p. 31) population size estimate, which includes data from the NPSD (2019, entire) catalog, to be the most comprehensive scientific information available for tufted puffin in the Gulf of Alaska LME.



Source: NOAA 2019b

Figure 3-13. Gulf of Alaska LME # 2



Source: NPSD 2019, entire; NOAA 2019b, entire

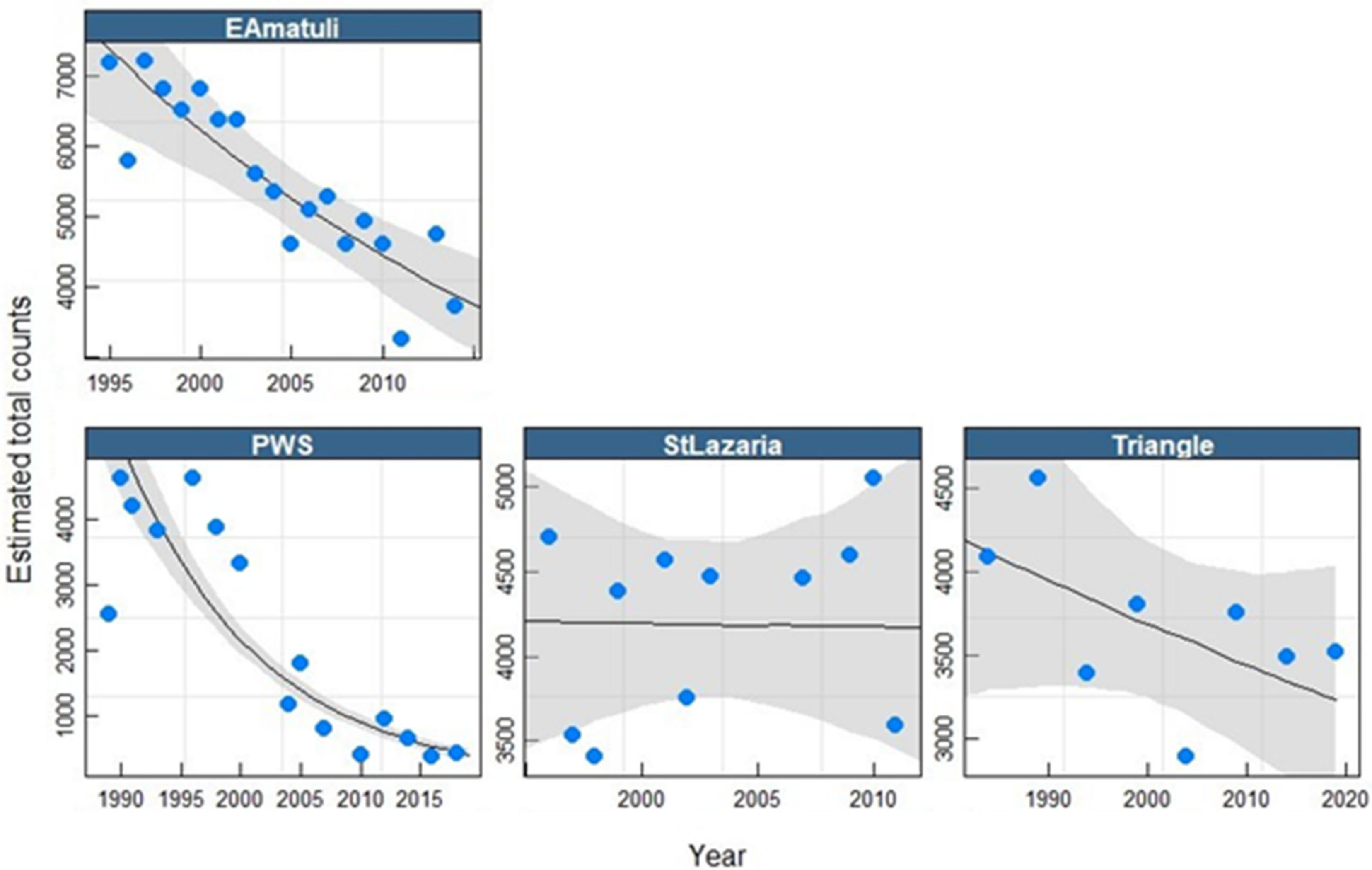
Figure 3-14. Tufted puffin colonies in Alaska.

Of the hundreds of tufted puffin colonies that occur in the Gulf of Alaska LME, only three colonies are monitored with enough long-term data to include in the trend analysis (Pearson *et al.* 2019, p. 4)[11]. In addition, Prince William Sound at-sea surveys were included in the range-wide analysis for the Gulf of Alaska LME (Pearson *et al.* 2019, p. 5). This means the trend data for this LME was drawn from a small subset of the total active tufted puffin colonies along with at-sea surveys. The best available information suggests:

- The Triangle Island colony, which is the largest tufted puffin colony in British Columbia, is experiencing a declining trend (Pearson *et al.* 2019, pp. 2, 8); this decline appears to be a continuation from a 1.7 percent per year decline observed between 1984 and 2004 (Gaston *et al.* 2009, p. 271).
- The East Amatuli colony (Figure 3-15), in the Gulf of Alaska, shows a decline in tufted puffins between 1995 and 2014, based on analysis of monitored burrow counts (Pearson *et al.* 2019, pp. 7, 8).
- The St. Lazaria colony population numbers show high variability and no overall trend (Pearson *et al.* 2019, p. 8).
- The Prince William Sound at-sea surveys are not associated with colony attendance, and show strong downward trends over time (Pearson *et al.* 2019, pp. 7-8).

Overall, there is a slight, but statistically insignificant decline of tufted puffins in the Gulf of Alaska System from 1972–2019 (Pearson *et al.* 2019, p. 7). Because the declines seen in the Gulf of Alaska LME were not statistically significant, we consider the population trend for this LME to be stable for the purposes of this SSA. However, these results should be treated with caution. When the datasets are examined independently, three are declining, and one colony is not exhibiting a trend (Pearson 2019c, pers. comm.). In addition, a population viability analysis conducted by Goyert *et al.* (2017, entire) predicted extirpation in the Gulf of Alaska LME within 100 years, and a trend analysis by Pearson *et al.* (2019, entire) found declines in three of four monitored populations.

[11] Updated November 2019 to include additional datasets in the Gulf of Alaska LME, including additional information on Prince William Sound surveys, and



Source: Pearson *et al*. 2019, p. 28.

Figure 3-15. Trend analysis of the four monitored colonies in the Gulf of Alaska from 1972 to 2019. Note the differences in scale for each colony (excerpted from Pearson *et al*. 2019, p. 30).

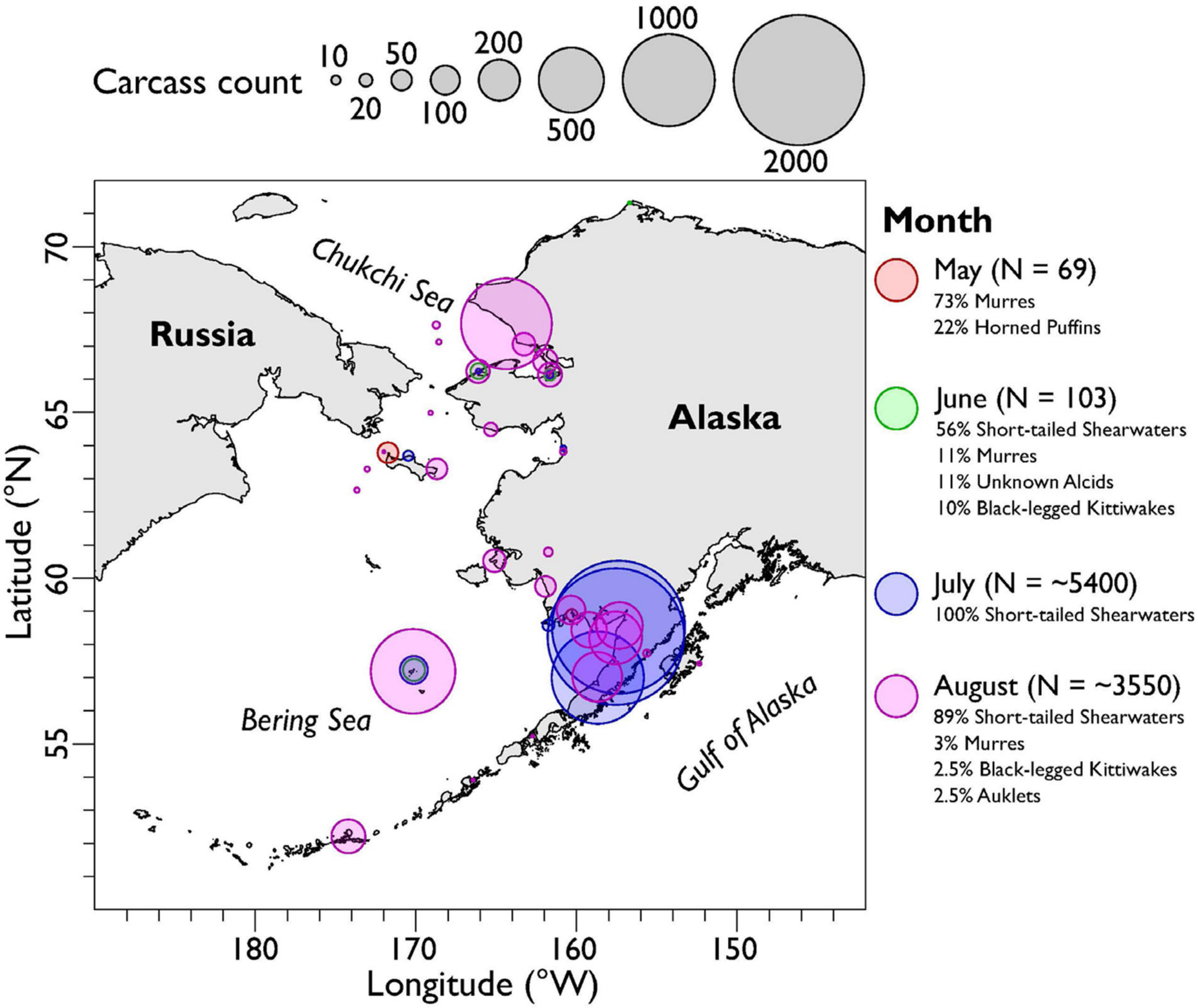
3.6.2.2 Threats

Climate Change

In the 1970's, the Gulf of Alaska's ocean climate shifted, resulting in a reorganization of the epibenthic (organisms that live on or just above the ocean's bottom sediments) community structure (Anderson and Piatt 1999, pp. 121–122). Such shifts affected the seabirds that rely on forage fish for food resources (Anderson and Piatt 1999, p. 121). Extreme variation in tufted puffin reproductive success was documented at Triangle Island during 1975–2002 and was related to changes in SST, both within and among seasons (Gjerdrum *et al.* 2003, entire). In many ways, the Gulf of Alaska LME shares the California Current LME's climate regime and vulnerability to warming ocean temperatures (see "Climate Change" under section 3.6.1.2). Gaston *et al.* (2009, p. 271) likewise found burrow counts declined at Triangle Island between 1984–2004 by approximately 1.7 percent per year, and that poor growth conditions for tufted puffins were associated with warm SST and poor recruitment of sand lance (Gaston *et al.* 2009, p. 271).

The 2013–2014 warm water anomaly ("the Blob") and high SSTs that impacted the waters off the coast of Alaska, including the Gulf of Alaska (Bond *et al.* 2015, entire; Cavole *et al.* 2016, pp. 273–274), corresponded to increased seabird mortality events. It is unknown if the recently identified 2019 summer/fall anomalous SSTs (NOAA 2019c, entire) will follow a similar trajectory, or have similar impacts to seabirds.

Unusually large numbers of dead seabirds have been found along coastal areas of the Gulf of Alaska since 2015. During routine beach surveys in 2015–2016, 45,000 dead common murres were counted in the Gulf of Alaska (USGS 2018, p.1). Other seabirds were also documented in this morality event, including northern fulmar (*Fulmarus glacialis*) and black-legged kittiwake (*Rissa tridactyla*). Necropsy information from a subset of these birds determined that the cause of death was starvation (USGS 2018, p. 1). Although mortality was directly attributed to starvation, saxitoxin was detected in some birds and prompted further study of how harmful algal toxins may have contributed to seabird deaths (USGS 2018, p. 1). Saxitoxin was detected in both dead and healthy seabirds, but the concentrations varied by species and tissue type. Domoic acid was also detected in seabird tissues, but in trace amounts (1 of 86 samples) (USGS 2018, p. 2). Forage fish and invertebrates also contained saxitoxin (approximately 27 of 85 samples) and domoic acid (approximately 4 of 34 samples) (USGS 2018, p. 2). In 2011 and 2012, saxitoxin was identified as the cause of up to 21 percent of Kittlitz's murrelet (*B. brevirostris*) nestling mortalities at Kodiak Island, Alaska; likely resulting from being fed sand lance (*Ammodytes* spp.) infected with *Alexandrium* spp. (Shearn-Bochsler *et al*. 2014, p. 935). Although saxitoxin was determined to be the cause of death of two of the Kittlitz's murrelet nestlings, detectable levels of saxitoxin were found in seven of the eight nestlings tested (Shearn-Bochsler *et al*. 2014, p. 935). During May–August 2019, approximately 5,400 short-tailed shearwaters were reported dead along coastal beaches within the Gulf of Alaska (Service 2019b). Although tufted puffin mortalities related to algal toxins have not been reported for this LME, the increase in harmful algal blooms and potential impacts to tufted puffin and their prey remains a concern.



Source: Service 2019b.

Figure 3-16. Distribution of seabird carcasses counted during the 2019 mortality event in Alaska.

Because there have been documented occurrences of elevated SSTs in this LME, including "the Blob", along with several seabird mortality events, we categorized risks to tufted puffins from climate change as moderate for this LME.

Oil Spills

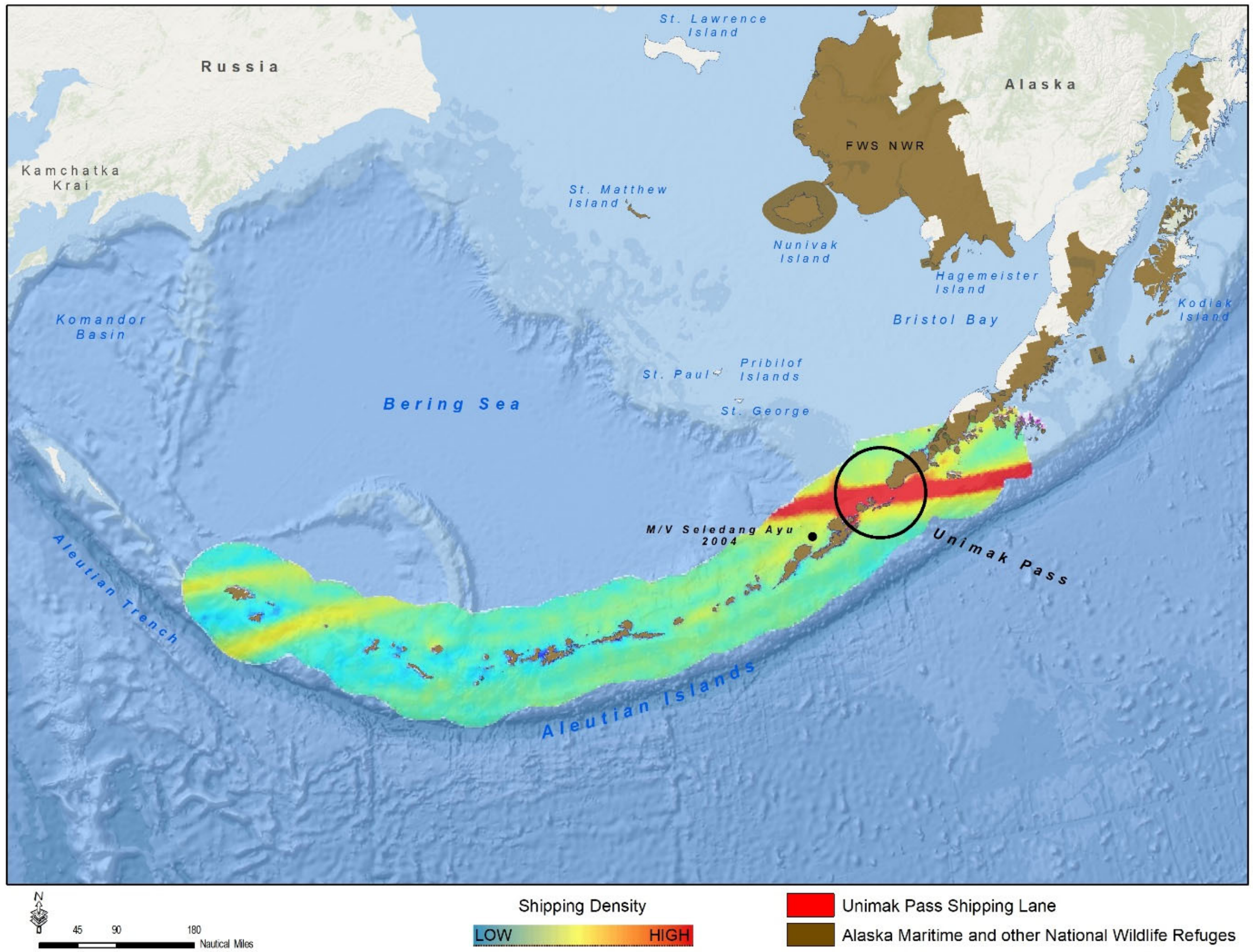
One large oil spill has been documented within the Gulf of Alaska LME. In March 1989, the Exxon Valdez oil spill occurred in Prince William Sound, releasing over 262,000 barrels (11 million gal) of crude oil into the marine environment (Cartwright 1991, p. 451; Piatt *et al.* 1990, p. 387). Approximately 600–700 tufted puffin and horned puffin carcasses were recovered in the aftermath of the *Exxon Valdez* oil spill (Piatt *et al.* 1990, p. 393). Based on recovery rates, number of puffins killed may have been as high as 13,000 (Piatt and Kitaysky 2002, p. 21), although many apparently died of starvation long after the initial oil spill (Piatt *et al.* 1990, p. 393). Due to the timing of the *Exxon Valdez* oil spill, just prior to when tufted puffins typically arrive at colonies, it is assumed that population level mortality effects were likely avoided (Piatt *et al.* 1990, p. 395). However, Goyert et al. (2017, p.183) estimated a significant decrease in tufted puffin burrow density (47 percent) following the 1989 Exxon Valdez oil spill.

Small oil spills and chronic oil pollution as a result of unintentional or illegal discharges, can lead to cumulative impacts to sensitive marine species (Wiese and Robertson 2004, p. 635). To our knowledge, no data are available that specifically document the effects of small, but chronic oil spills on tufted puffin population resiliency. However, incident rates of small oil spills reported within this LME from 1995–2012 indicate they are relatively common, especially within areas near tufted puffin and other seabird colonies (NOAA 2014, p. 51; Figure 3-8). Incident rates are defined as "events involving vessels or facilities (including onshore facilities, pipelines, and offshore wells) that could potentially result in the spillage of oil, such as casualties, accidents, discharges, and leakages" (NOAA 2014, p. 50).

A recent study focused on using vessel traffic as a proxy for the probability of shipping accidents and subsequent oil spill impacts to seabirds (Renner and Kuletz 2015, entire). Renner and Kuletz (2015, entire) estimate the probability of shipping accidents and oil spills based on modeled density of shipping traffic within the western part of the Gulf of Alaska LME, the Aleutian Islands LME, and the West Bering Sea LME (Renner and Kuletz 2015, p. 128; Figure 3-17).

Results from Renner and Kuletz (2015, entire) indicate that within the Gulf of Alaska LME, the areas of greatest risk to shipping accidents and potential oil spills is around Unimak Pass (Figure 3-17), an area where tufted puffin colonies currently exist (Renner and Kuletz 2015, p. 134).

Given the history of a large oil spill (Exxon Valdez) within this LME and its subsequent and ongoing impacts to the marine environment, the relatively frequent incident rate of small oil spills, and the areas identified as at risk based on modeled data, we categorize oil spills as a moderate threat for this analysis unit.



Source: Renner and Kuletz 2015, p. 132; NOAA 2019b

Figure 3-17. Modeled areas of greatest shipping density (a proxy of risk of oil spill; from Renner and Kuletz 2015, p. 132), shown with LMEs used for current conditions analyses. (1) East Bering Sea; (2) Gulf of Alaska; (52) Sea of Okhotsk; (53) West Bering Sea; (54) North Bering and Chukchi Sea; and (65) Aleutian Islands (NOAA 2019b, entire).

Fisheries Bycatch

Historically, fishery bycatch killed large numbers of seabirds, including tufted puffins. Although the United Nations ban on large-scale, high seas driftnet fisheries in 1992 (Zydelis *et al.* 2009, p. 1,270) has greatly reduced seabird bycatch, the impact of gillnet fisheries on seabird mortality remains largely unknown. Salmon gillnet fisheries in Alaska generally occur in State territorial waters. Monitoring and observer coverage in the salmon gillnet fisheries has not been regular or widespread, and to date has been limited to single (two year) studies in four general areas within this LME: Prince William Sound and Copper River Delta, Cook Inlet, Kodiak Island, and Yakutat Bay. Most gillnet fishing boats are relatively small (less than 32 feet) and observer coverage for seabird bycatch is logistically difficult and limited in opportunity. Existing observer programs for gillnet fisheries are implemented as part of the Marine Mammal Protection Act, which directs the Secretary of Commerce to monitor marine mammal and seabird mortality, and serious injury occurring incidentally to commercial fishing. Different regions throughout the U.S. compete for funds to implement these surveys, which are focused on marine mammals at risk; thus, coverage in Alaska has been sporadic and not designed for estimating seabird bycatch.

Two salmon fisheries within the Gulf of Alaska LME were monitored for seabird bycatch in 1990 and 1991. In 1990, the Prince William Sound driftnet fishery took an estimated 1,468 birds (95 percent Confidence Interval (CI) = 836–2,100 birds); Wynne *et al.* 1991; p. 34); none of these were tufted puffin. In the South Unimak driftnet fishery that year 3.5 percent of the fishery was sampled and an estimated 336 birds (95 percent CI = 158–516 birds) were taken (Wynne *et al*. 1991; p. 35), with tufted puffin being 7 percent of the total (2 of 29 birds), for a mean estimate of 24 tufted puffins that year. In 1991, Wynne *et al*. (1992) sampled 5 percent of the Prince William Sound salmon driftnet fishery and estimated 993 birds killed (95 percent CI = 334–2097), with no record of tufted puffin taken (Wynne *et al*. 1992, p. 48). The salmon drift gillnet fishery in Unimak Pass fishery estimated 337 seabirds were killed annually (Bakken and Falk 1998, pp. 7–8). Bakken and Falk 1998 (pp. 7–8) reported that 63 percent of seabirds taken in the Unimak Pass fishery were murres, and that other species, including tufted puffins and auklets were taken.

During 2002, tufted puffins were estimated as the second most common seabird taken as bycatch in the salmon set gillnet fishery off Kodiak, Alaska, with an estimated 110 tufted puffins (CI = 7–266) killed (Many 2007, p. 27), and 7 tufted puffin takes were actually observed (Manly 2007, pp. 5–6). During 2005, an estimated 96 (CI = 13–179) tufted puffins were taken as bycatch (Manly 2007, p.37). Salmon gillnet fisheries operate during the tufted puffin breeding season (roughly, June through August), when adults are near colonies (during incubation) and foraging for themselves, or during chick rearing when they forage for themselves and their young. Although the estimated tufted puffin bycatch was only reported for a few years and locations, these numbers likely reflect approximate numbers of tufted puffin taken annually in gillnet fisheries in their respective regions. If breeding adults are regularly removed from these populations, it could have cumulative level effects for the affected tufted puffin colonies. Furthermore, areas of higher tufted puffin density occur in areas where these fisheries remain active (e.g., Kodiak Island, Figure 3-18).

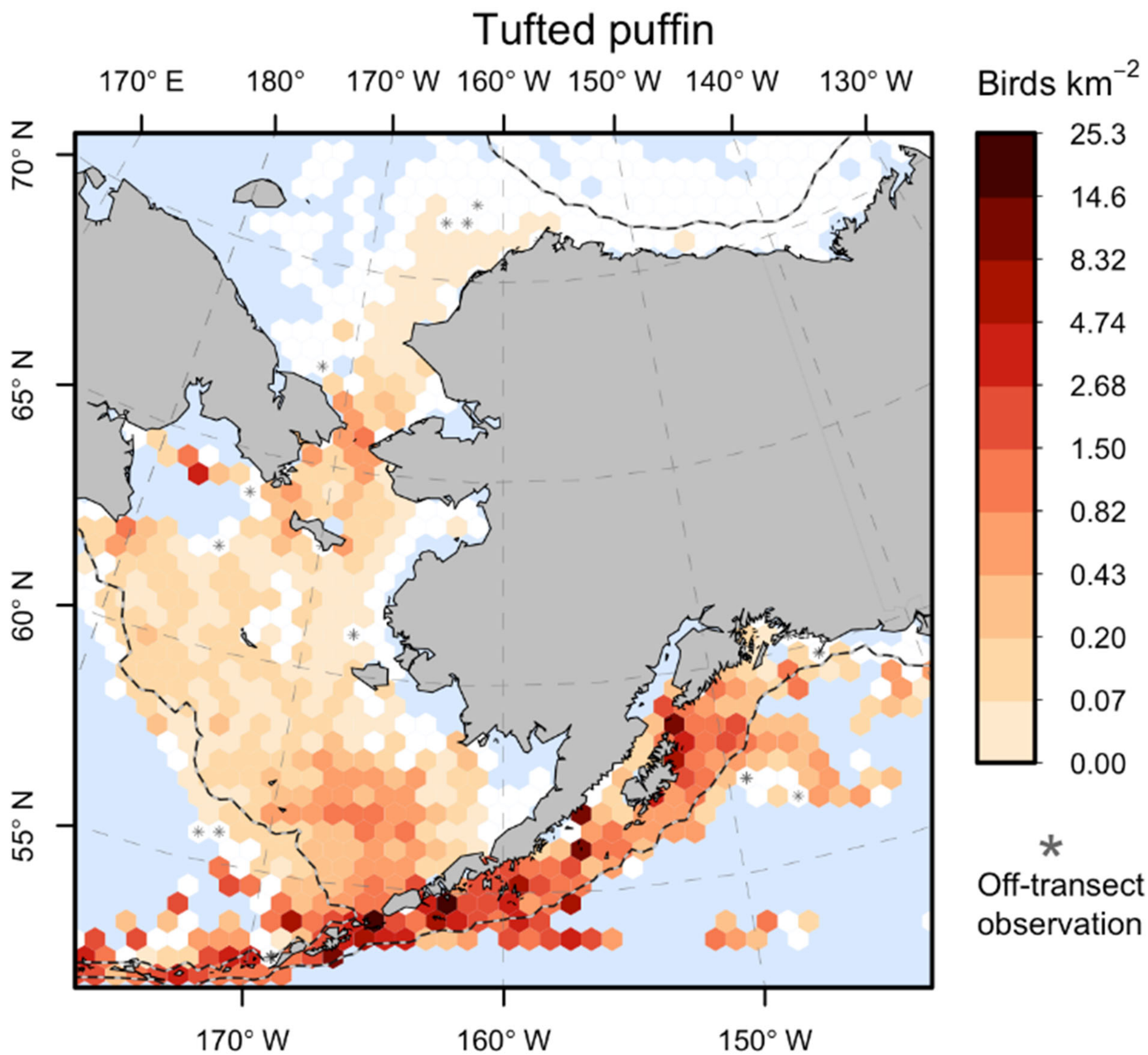


Figure 3-18. Tufted puffin at-sea density derived from vessel-based surveys in Alaska, with data combined from 2006–2018 (Kuletz 2019, pers. comm.).

According to gillnet seabird bycatch information from British Columbia, on average, approximately 12,085 seabirds were caught annually between 1995 and 2001 (Smith and Morgan 2005, p. 24). Tufted puffins were not reported as bycatch in this assessment, but a similar species, rhinoceros auklet, accounted for 23 percent of all bycatch (Smith and Morgan 2005, p. 24).

During 2007–2015, there were no reported tufted puffins caught within the Federal groundfish and halibut fisheries. Based on observer coverage data, extrapolated tufted puffin bycatch was estimated at nine during 2010 and zero for all other years (Eich *et al.* 2017, p. 15; Kingham 2019, pers. comm.).

Because tufted puffins are reported as bycatch in fisheries within this LME (especially gillnet fisheries), and because the cumulative impacts of tufted puffin bycatch could have population level effects, we categorized risk from bycatch as moderate for this LME.

Mammalian and Avian Predators

On the Alaska Peninsula, native river otters and brown bears (*Ursus arctos*) are known to depredate tufted puffin nests (Amaral 1977, p. 83; Piatt and Kitaysky 2002, p. 11). However, this predation occurs in low numbers and does not appear to influence breeding success. Kleptoparasitism has been documented at colonies in the Barren Islands (the northernmost islands of the Kodiak Archipelago), although there is no evidence that tufted puffin breeding success was affected (Amaral 1977, p. 60). Amaral (1977, p. 83) also found direct predation by peregrine falcons and bald eagles, though once again, there was no evidence that predation affected tufted puffin breeding success.

Tufted puffin colonies in this LME are well-distributed, and impacts from predation are likely limited to a select number of colonies; the effects of predation on population distribution or trends in this LME remains unclear. However, predation is not thought to greatly impact tufted puffins in this LME; therefore, we categorized risks from mammalian and avian predators in the Gulf of Alaska LME as low.

Nonnative Plants and Animals

Rabbits were introduced on Middleton Island (approximately 80 mi (130 km) southwest of Cordova) in the 1950s, but it is unknown whether or how they affect tufted puffins (O'Farrell 1965, pp. 525–527). Similarly, foxes, voles, mice, and ground squirrels have been introduced on other islands where tufted puffins breed, but the impacts from these introduced species to tufted puffins and their habitat is unknown (Bailey 1993, pp. 33–37). Feral cattle on Wosnesenski and Chirikof islands (Alaska Maritime NWR) cause erosion that may negatively affect tufted puffins; although it is known that feral cattle on these islands negatively impact nesting seabirds, ongoing litigation prevents the Service from removing them at this time (Service 2013b, entire). Finally, plant introductions in this LME are poorly documented.

Because few tufted puffin colonies in this LME are monitored, the effects of nonnative plants and animals on tufted puffin population distribution or trends remains unclear. However, tufted puffin colonies in this LME are well-distributed, most nesting islands are uninhabited and rarely visited; therefore, we categorized the risks of nonnative species impacting tufted puffin nesting islands in the Gulf of Alaska LME as low.

Human Disturbance

Researcher disturbance has been documented on monitored islands in the Gulf of Alaska LME. Accidental crushing of burrows by researchers at East Amatuli Island has been observed (Kettle 2019, pers. comm.). It appears that burrows are rarely used again once crushed, and that new burrows rarely replace those lost (Kettle 2019, pers. comm.). Over the long term, this negative effect can cause a decrease in the number of burrows in permanent-boundary study plots.

Additionally, if researchers reach into burrows during the incubation or chick-brooding stages, the egg or chick is often abandoned (Pierce and Simons 1986, entire). Reproductive success can be significantly impacted when considering a relatively undisturbed reproductive success rate of 94 percent compared to a "heavily disturbed" reproductive success rate (visited every 5 days as hatching approached) of 18 percent (Pierce and Simons 1986, p. 214). In addition, disturbance increased the incubation period (Pierce and Simons 1986, p. 215); thus, they conclude, "Sensitive colonies should not be disturbed at all during the incubation period." In both the Pierce and Simons (1986, entire) and the Wehle (1980, pp. 50–51) studies, excavation of an artificial entrance was necessary to allow arm-length access to the nest chamber of long burrows. At East Amatuli, most study burrows require such an excavation (Kettle 2019, pers. comm.), which appears to weaken the integrity of study burrows.

No documentation has been found regarding negative effects of tourism disturbance to tufted puffins in the Gulf of Alaska LME. Visitation to St. Lazaria Island (20 mi (32 km) west of Sitka, Alaska) is allowed, but visitors are cautioned not to go ashore to avoid crushing seabird burrows and tunnels (Service 2019c, no page number); in the Barren Islands, visitation is allowed but access is difficult.

The magnitude and intensity of human disturbance at most of the colony locations within this LME are unknown. Researcher disturbance has been recorded, but since very few colonies in this LME are monitored by these researchers, we categorized the risks of human disturbance in as low.

3.6.2.3 Conservation Actions

Many, but not all, of the Alaskan colonies in the Gulf of Alaska LME are managed by the Service's NWR system. Triangle Island, the largest tufted puffin colony in British Columbia, is in the Scott Islands Marine Wildlife Area and the Anne Vallée Triangle Island Ecological Reserve, with access to the island regulated by the British Columbia Ministry of Environment.

The Alaska Maritime NWR, approximately 4.9 million ac (1.9 million ha) was established by the Alaska National Interest Lands Conservation Act of 1980. This act added 1.9 million ac (768,903 ha) of additional lands to 11 pre-existing refuges, and combined a majority of Alaska's seabird habitat into one refuge. Alaska Maritime NWR is divided into five distinct geographic refuge units: the Chukchi Sea Unit, the Bering Sea Unit, the Aleutian Islands Unit, the Alaska Peninsula Unit, and the Gulf of Alaska Unit (Service 1988, p. xiii). Alaska Maritime NWR was established to "conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to marine mammals, marine birds and other migratory birds, the marine resources upon which they rely, bears, caribou, and other mammals (Service 1988, p. xiii)." Alaska Maritime NWR is home to approximately 80 percent of Alaska's seabirds, including the majority of tufted puffins that nest off the coast of Alaska (Service 2017a, p. 15). Protection of seabirds is one of the management priorities of the NWR. The Alaska Maritime NWR provides protection for nesting tufted puffins through land management practices, as well as the fact that many nesting areas are inaccessible to the public and remote.

At the Barren Islands, there is an attempt to rely on time-lapse photography (from a distance) of roosting tufted puffin adults, to allow for monitoring population trend and, possibly, reproductive output while limiting researcher disturbance. In addition, chick diet is being monitored with photography rather than burrow visits, in an attempt to further reduce researcher disturbance at monitored colonies (Kettle 2019, pers. comm.).

Finally, the Alaska NWR has strengthened its island biosecurity program for islands that it manages, including those in this LME.

3.6.2.4 Summary

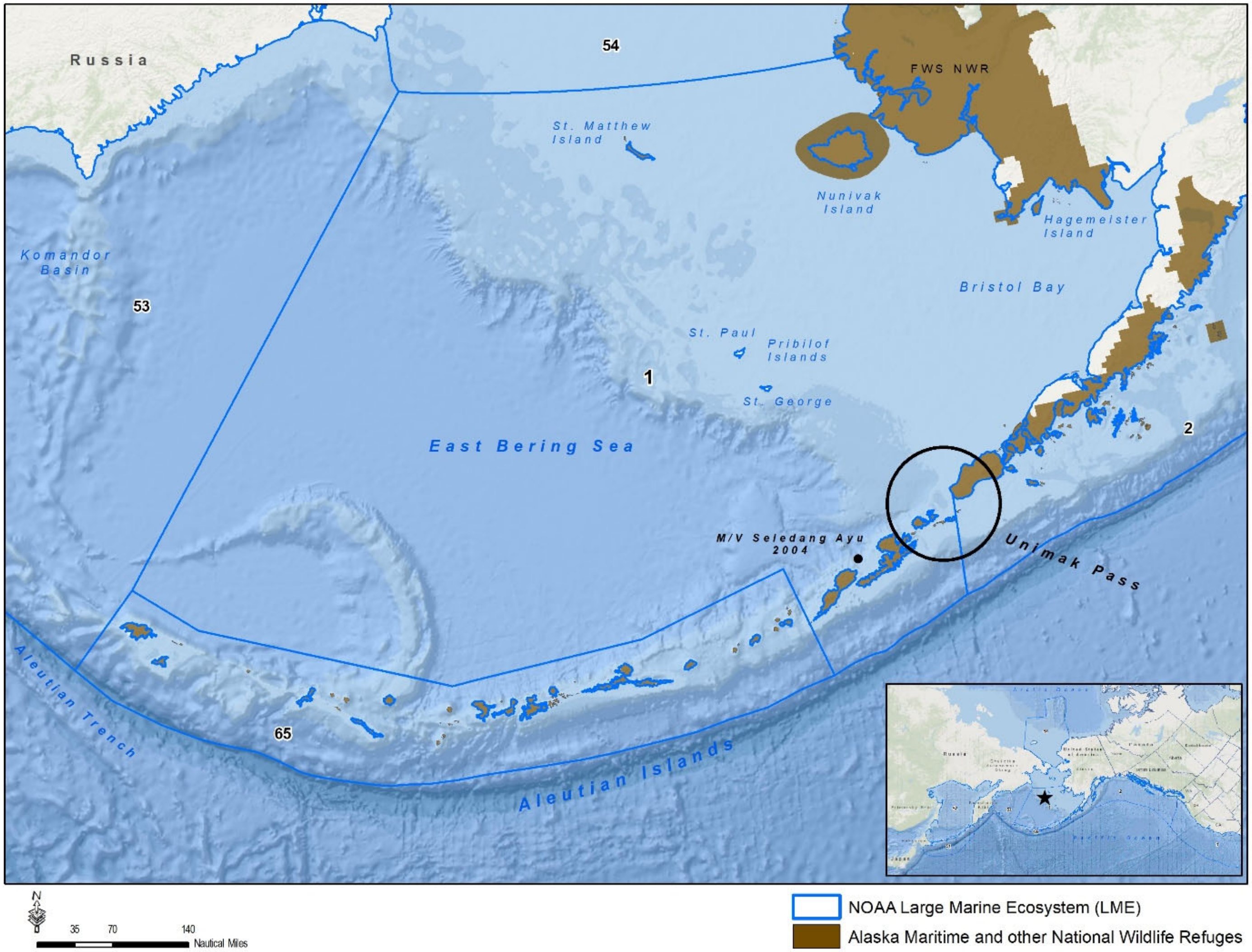
- The population trend for the Gulf of Alaska LME is considered stable because the declines noted in Pearson *et al.* (2019, p. 7-8) were not statistically significant when evaluated as a whole. However, declines found at individual colonies and at-sea data are concerning. At a minimum, some colonies in the southern portion of the LME are experiencing declines (e.g., Triangle Island in British Columbia) (Gaston *et al*. 2009, p. 271; Pearson *et al.* 2019, p. 1).
- The most significant threats are climate change, oil spills, and fishery bycatch, which are considered moderate threats to tufted puffins. All other threats to tufted puffin in this LME are considered low.
- Ongoing conservation actions in this analysis unit include Alaska Maritime NWR protection of seabird colonies through land management practices. In addition, Alaska Maritime NWR's biosecurity program is designed to prevent the introduction of nonnative species. Finally, Alaska Maritime NWR is investigating ways to reduce disturbance by researchers (through photography and remote monitoring, when feasible) (Kettle 2019, pers. comm.).

3.6.3 East Bering Sea (LME # 1)

The East Bering Sea LME (Figure 3-19) is characterized by an extremely wide, gradually sloping shelf; seasonal ice cover, which once extended over most of the East Bering Sea, is now found on approximately half of the sea found in this LME. The LME is bounded by the Bering Strait to the north, by the Alaskan Peninsula and Aleutian Islands to the south, and by a coastline to the east, thousands of miles in length (NOAA 2019a, entire).

3.6.3.1 Population Size and Trend

The East Bering Sea LME includes tufted puffin colonies just north of the Aleutian Islands and Alaska Peninsula. Piatt and Kitaysky (2002, p. 31; Appendix D) referred to this area as the "S. Bering Sea," with approximately 23 colonies and an estimated population of 96,170 tufted puffins. This estimate is the most recent and best scientific information available at this time.



Sources: NOAA 2019b.

Figure 3-19. East Bering Sea LME # 1

Pearson *et al.* (2019, entire) included two East Bering Sea colonies in the trend analysis for the Aleutian Islands LME, so they are discussed in the Aleutian Islands LME, as well. These two colonies, on Bogoslof and Aiktak islands, display different trends when examined individually (Figure 3-22). Bogoslof Island had a positive trend in the analysis. However, Bogoslof Island experienced a volcanic eruption in 2016, and tufted puffin colonies on the island were displaced (Pearson *et al.* 2019, p. 6; Rojek 2019b, pers. comm.). A visit to the island in 2018 by the Service confirmed the presence of tufted puffins on the island, but could not confirm nesting activity (Rojek 2019b, pers. comm.). Due to the loss of Bogoslof, and lack of trend in the Aiktak data, the population trend for the East Bering Sea LME is considered unknown. Tufted puffin colonies found in Alaska are mapped in Figure 3-14.

3.6.3.2 Threats

Climate Change

During October 2016 through January 2017, approximately 350 seabird carcasses were recovered on St. Paul Island (Jones *et al.* 2019, p.1; Figure 3-19). Seabird carcasses were not found on the nearby island of St. George (Figure 3-19). Tufted puffin constituted the majority of seabirds found dead (275 individuals) and most were adults that were undergoing flight feather molt (Jones *et al.* 2019, pp. 8, 11). The number of dead tufted puffins documented in this mortality event is considered unusually high, with approximately 60–80 times higher encounter rate than baseline data (Jones *et al.* 2019, p. 11). The timing of this die off event was also unusual given that it occurred during late fall and early winter (Jones *et al.* 2019, p. 15), which happened to coincide with flight feather molt in adult tufted puffins. Tufted puffins undergo complete flight feather molt, which can last for up to 40 days and can render birds flightless during this time.

Based on modeled data, all seabird mortalities during the 2016–2017 mortality event were estimated at 3,150–8,800 individuals (Jones *et al.* 2019, p. 8). The estimated population size of tufted puffins on the Pribilof Islands is around 7,000 birds. Jones *et al.* (2019, p. 14) estimated that approximately 39 to 109 percent of the population would have been impacted by this mortality event. However, little is known about tufted puffin dispersal after the breeding season, and it is possible that birds from colonies outside of the Pribilof Islands were included in this mortality event.

A subset of dead carcasses from the 2016–2017 mortality event were tested for saxitoxin and domoic acid (Dusek 2019, pers. comm.). While no domoic acid was detected, saxitoxin was present in trace levels in stomach contents, cloacal contents, or liver tissue in 35 percent (6 out of 17) of individuals tested, indicating exposure of these seabirds to saxitoxin in the marine environment (Dusek 2019, pers. comm.). Although saxitoxin was present in some of the sampled tissues, a direct link with mortality of seabirds and levels of saxitoxin remains unclear. For all birds necropsied, emaciation was determined as the proximate cause of death (Dusek 2019, pers. comm.). The three years leading up to this mortality event had unusually warm air and ocean temperatures (even in winter), and little to no sea ice over the Bering Shelf (Stabeno *et al*. 2017, entire).

We are not aware of data that support a direct link between harmful algal blooms and population level mortality effects on tufted puffin. The significance of low dose neurotoxin exposure and how it may influence behavior and feeding, particularly in malnourished birds, remains unknown. However, algal toxins could be a contributing factor in mass seabird mortality events by reducing prey availability and quality, and weakening autoimmune response and disease resistance owing to reduced body quality associated to exposure to a biotoxin (Dusek 2019, pers. comm.). Immediately prior to this mortality event, shifts in zooplankton community composition and in forage fish distribution and energy density were documented in the eastern Bering Sea following a period of elevated sea surface temperatures, evidence cumulatively suggestive of a bottom-up shift in seabird prey availability (Jones *et al.* 2019, entire).

Because there were documented elevated SSTs, along with reduced forage fish availability, and a seabird mortality event that directly affected tufted puffins, we categorized risks to tufted puffins from climate change as moderate for this LME.

<u>Oil Spills</u>

Two large oil spills have been documented within the East Bering Sea LME. In July 1989, the *M/V Milos Reefer* was confirmed as grounded near St. Matthew Island (DEC 1998, p. 1). An unknown amount of fuel was spilled as a result of the initial grounding, but is estimated at around 7,527 barrels (237,000 gal) (Alaska Shipwrecks 2019, p.5). Due to severe weather and remoteness of the area, the grounded vessel was never removed and no subsequent studies were conducted to evaluate impacts to the marine environment.

In December 2004, the *M/V Selendang Ayu* experienced engine failure, then grounded and split in two near Unalaska Island. More than 7,142 barrels (300,000 gal) of heavy bulk fuel spilled into the marine waters off Unalaska Island (Ritchie and Gill 2008, pp. 184–185). After the *M/V Selendang Ayu* spill, more than 600 live oiled birds were recovered and over 1,600 dead birds were documented, including puffins, murres, auklets, seaducks, gulls, and bald eagles. Records indicate 6 tufted puffins and 11 unidentified puffins were found dead (Service 2008, p. 5).

During February 1996, the *M/V Citrus* collided with a crab fishing vessel. As a result of the collision, it is estimated that approximately 14 barrels (600 gal) of oil were introduced into the marine environment (Renner, 2019 pers. comm.). An estimated 1,000 oiled birds and carcasses were subsequently documented on St. Paul Island (IRBC 1996, p. 1). An additional few hundred oiled birds, carcasses, and live birds were documented with 157 live birds collected for rehabilitation. Most of the live birds were king eiders (*Somateria spectabilis*; 144 individuals), but other species including murres, auklets, and guillemots were represented (IRBC 1996, p. 1).

Based on oil spill incident rate data from 1995–2012, small oil spills have occurred frequently throughout this LME, including areas with known tufted puffin colonies (NOAA 2014, p. 51; Figure 3-8). The level of negative effects on tufted puffins from these small oil spills is unknown. Although small, numerous spills could result in cumulative effects that could pose population level threats to marine birds (Wiese and Robertson 2004, pp. 627, 635), we are not aware of data documenting tufted puffin declines related to oil spills within this LME. Results from Renner and Kuletz (2015, entire; see Figure 3-17) indicate that, similar to the Gulf of

Alaska LME, the area within the East Bering Sea LME with the greatest risk to shipping accidents and potential oil spills include Unimak Pass (separating the Gulf of Alaska from the East Bering Sea; Figure 3-17), which is an area where tufted puffin colonies currently exist (Renner and Kuletz 2015, p. 134).

Given two large oil spills have occurred within this LME, Unimak Pass represents an area of high shipping traffic, and because small spills have been documented and the incidence of small oil spills is relatively frequent, we categorized the risks of oil spills in this LME as moderate.

<u>Fisheries Bycatch</u>

Tufted puffins are near shore foragers, which makes them less likely to interact with offshore groundfish and halibut fisheries. Tufted puffins were not reported as bycatch in the Federal groundfish and halibut fisheries based on observer coverage data collected from 2007–2015 (Eich *et al.* 2015, p. 15). Based on all seabird bycatch data, the extrapolated estimate of puffin bycatch (tufted puffin and horned puffin combined) was estimated at nine during 2010, and zero for all other years (Eich *et al.* 2015, p. 15). Estimated tufted puffin bycatch data were not available for specific LMEs, so values presented here represent combined estimates for the entire Gulf of Alaska, Bering Sea, and Aleutian Islands; however, it is important to note that the majority of documented seabird bycatch has occurred within this LME (Eich *et al.* 2016, p. 16).

Information on coastal gillnet salmon fisheries are not available, but the majority of salmon gillnet fisheries occur within the Bristol Bay region, an area where tufted puffin colonies are less common (Alaska Department of Fish and Game (ADF&G) 2019, entire).

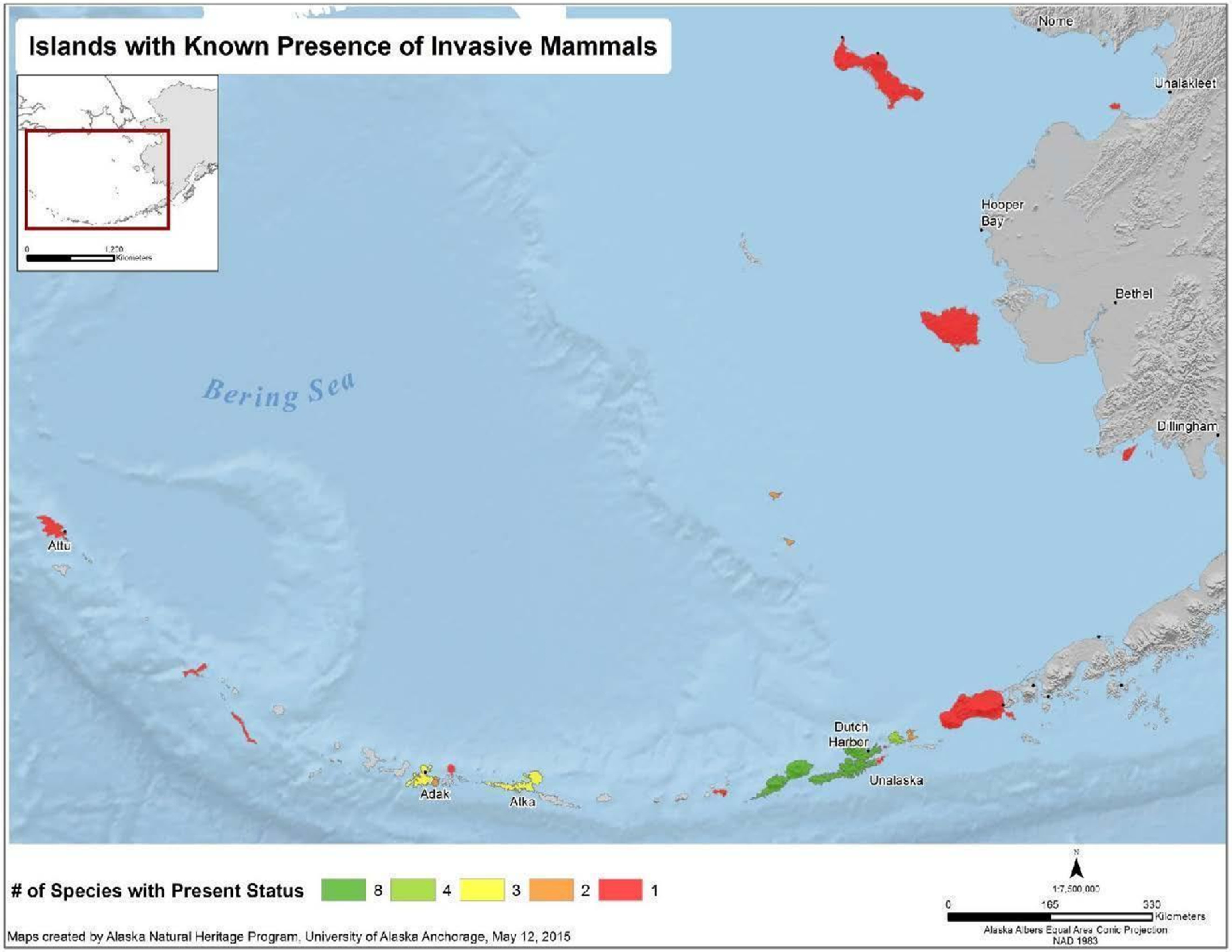
Due to the low numbers of reported and extrapolated puffin bycatch data in the Federal groundfish and halibut fisheries, and because the majority of gillnet fisheries occur outside of tufted puffin breeding habitat, we categorized the risks of fishery bycatch in this LME as low.

<u>Mammalian and Avian Predators</u>

Mammalian predators in the East Bering Sea LME include native foxes in the Pribilof Islands; avian predators include eagles and gulls. The effects of predation on population distribution or trends remains unclear. Overall, we categorized the risks of mammalian and avian predators in this LME as unknown.

<u>Nonnative Plants and Animals</u>

The leading source of nonnative plant and animal introductions to islands within the East Bering Sea LME (as well as the Aleutians LME and the North Bering and Chukchi Sea LME) is humans (Gotthardt *et al*. 2015, p. 20; Figure 3-20). Norway rats (*Rattus norvegicus*) and fox were found to be extremely invasive, while roof rats (*R. rattus*), house mice, and domestic cats (*Felis catus*) were ranked as highly invasive (Gotthardt *et al.* 2015, p. 20). Rats are a constant threat to islands with nesting tufted puffins, often transferring to land from ships (Gotthardt *et al.* 2015, entire). Plant introductions in this LME are poorly documented.



Source: Gotthardt *et al*. 2015, p. 17.

Figure 3-20. Islands in the Aleutians LME, East and West Bering Sea LMEs, and North Bering and Chukchi Sea LMEs, with nonnative mammal species, from Gotthardt *et al.* (2015, p.17).

The effects of nonnative plants and animals on tufted puffin population distribution or trends remains unclear; however, there are efforts to detect and remove nonnative species on tufted puffin nesting islands in this LME. Therefore, we categorized risks from nonnative plants and animals as low.

Human Disturbance

Human disturbance of tufted puffins and their habitat is limited in the East Bering Sea LME. Most tufted puffin colonies are inaccessible, there is very little tourism, and tufted puffin burrows are not routinely monitored or visited by researchers (Kettle 2019, pers. comm.). The exceptions are the Pribilof Islands, St. Matthew Island, and Hall Island. The Pribilof Islands have human settlements, tourist access, and visitation. St. Matthew Island and Hall Island are experiencing an increase in cruise ship traffic, which could potentially increase human disturbance on these islands (Romano 2019, pers. comm.). We categorized the risks of human disturbance on tufted puffin as low for this analysis unit.

3.6.3.3 Conservation Actions

Many, but not all, of the Alaskan colonies in the East Bering Sea LME are managed by the Service's Alaska Maritime NWR, Yukon Delta NWR, and Togiak NWR. The Alaska Maritime NWR provides protection for nesting tufted puffins through land management practices, and many nesting areas in this LME are inaccessible and remote. The Alaska NWR's strengthened island biosecurity program is designed to prevent nonnative plants and animals from becoming established.

3.6.3.4 Summary

- The population trend for this analysis unit is considered unknown. The most recent population estimate from 2002 is 96,170 tufted puffins in this LME (Piatt and Kitaysky 2002, p. 31)
- The most significant threats in this LME are oil spills and climate change, which was implicated in a seabird mortality event near St. Paul in 2016, with the cause of death thought to be starvation (Jones *et al*. 2019, entire). Mammalian and avian predators were categorized as an unknown threat to tufted puffins in this LME; all other threats were categorized as a low risk to tufted puffins.
- Islands in the East Bering Sea LME are managed by the Alaska NWR to ensure that fish and wildlife populations, including seabirds, and ecological relationships necessary to conserve natural diversity, are maintained (Service 1988, p. xv). The Alaska NWR's strengthened island biosecurity program is designed to prevent nonnative plants and animals from becoming established.

3.6.4 Aleutian Islands (LME #65)

The Aleutian Islands LME (Figure 3-21) is recognized by distinct features of productivity and trophic structure that are shaped by the interaction of currents and bottom topography of the many passes between volcanic islands of the archipelago (Protection of the Arctic Marine Environment (PAME) 2013, entire).

3.6.4.1 Population Size and Trend

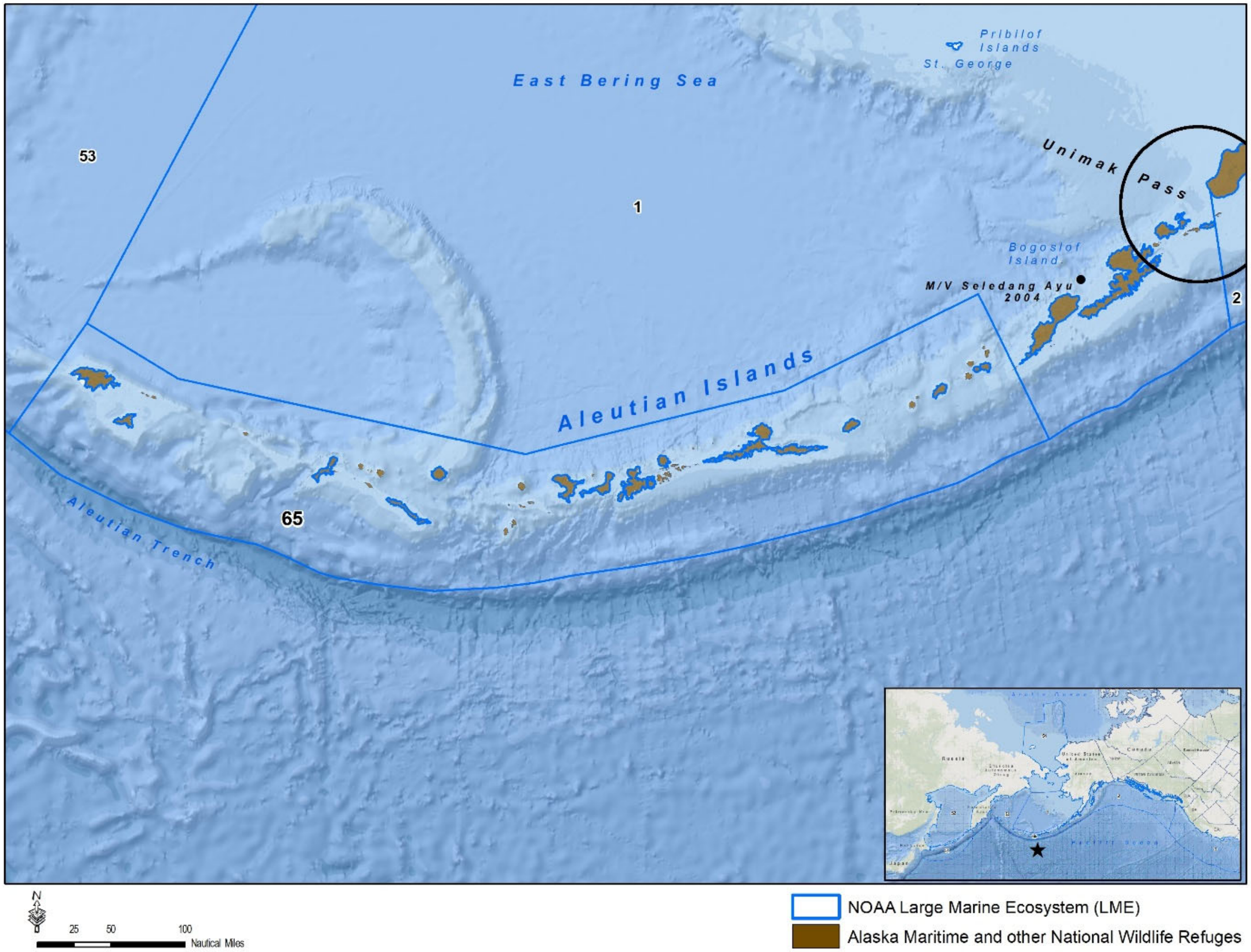
In 2002, approximately 167 colonies were known to exist across the LME with an estimated population of 1,271,800 tufted puffins (Piatt and Kitaysky 2002, p. 31; Appendix D). These colonies are widely distributed across the LME, and represent almost half (45 percent) of the breeding population of tufted puffins in North America (Piatt and Kitaysky 2002, p. 18). Colony size in this LME ranges from small (a few pairs of tufted puffins) to large (greater than 100,000 tufted puffins). The Piatt and Kitaysky (2002, p. 31) estimates are the most recent, best scientific information available for this LME. Tufted puffin colonies found in Alaska are mapped in Figure 3-14.

Five monitored colonies were included in the recent range-wide analysis for this LME. Two of these colonies, Bogoslof and Aiktak, are actually located in the East Bering Sea LME; however, because Pearson *et al*. (2019, entire) grouped these two colonies in the Aleutian Islands LME, we discuss them here as well. A trend analysis from 1973 to 2016, based upon the five monitored colonies in this LME, shows a strong long-term increase in tufted puffin population size (Figure 3-22) (Pearson *et al.* 2019, pp. 6–7). It is unknown if this increase represents emigration from areas with declining populations, although it is unlikely given ongoing research showing strong genetic structuring within colonies (Graham *et al.* 2019, pers. comm.; Pearson *et al.* 2019, p. 7).

3.6.4.2 Threats

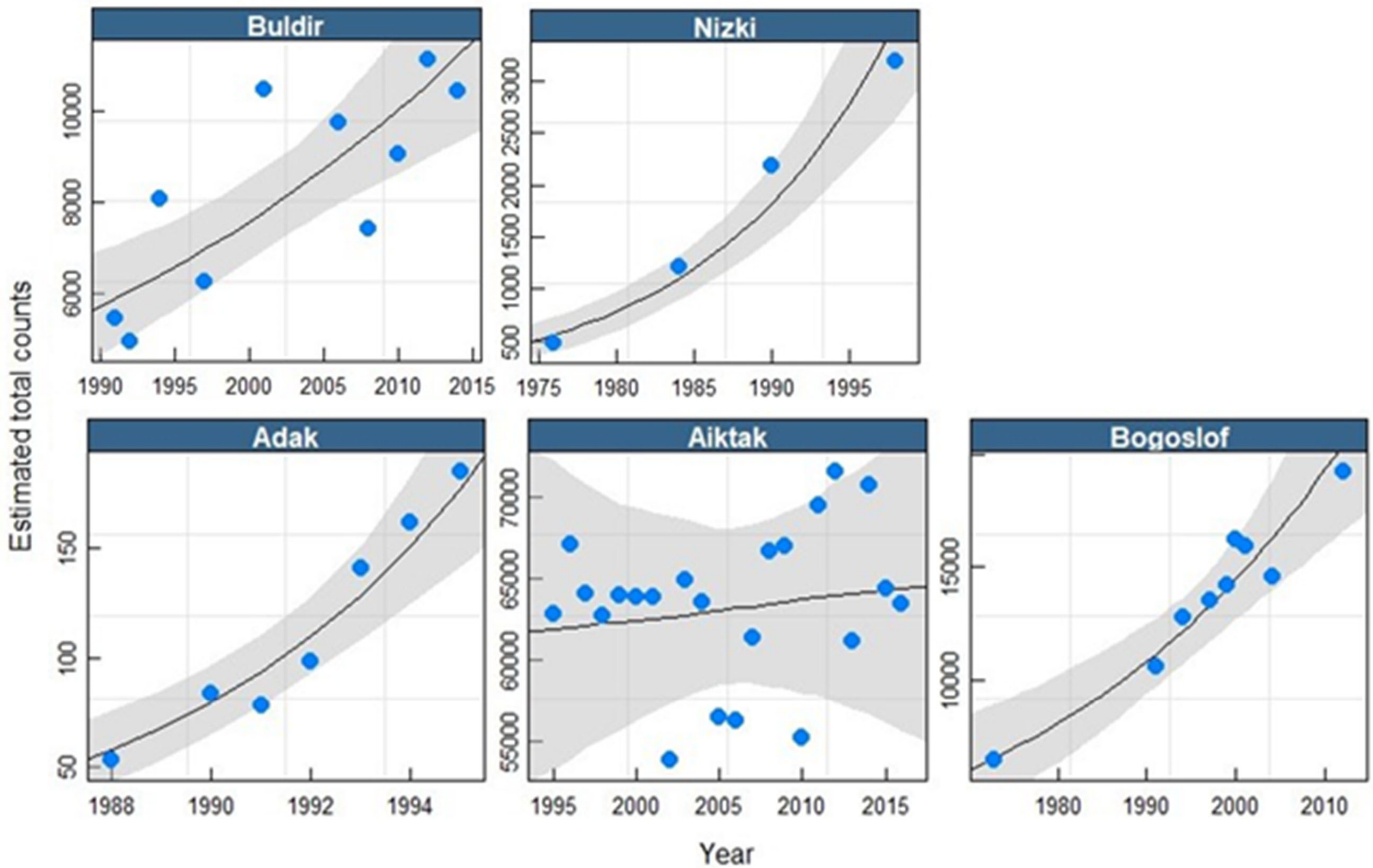
<u>Climate Change</u>

Recent seabird mortality events have been documented near Buldir Island (Service 2017b) and Atka Island (Service 2019b) (Figure 3-16; Figure 3-23). The majority of seabirds in both of these mortality events were primarily northern fulmars, shearwaters, and kittiwakes; to a lesser extent, murres, auklets, gulls, and puffins were also reported. Both of the recent Aleutian Islands mortality events are considered within the range of normal observations of seabird die-offs for this region (Kaler 2019, pers. comm.).



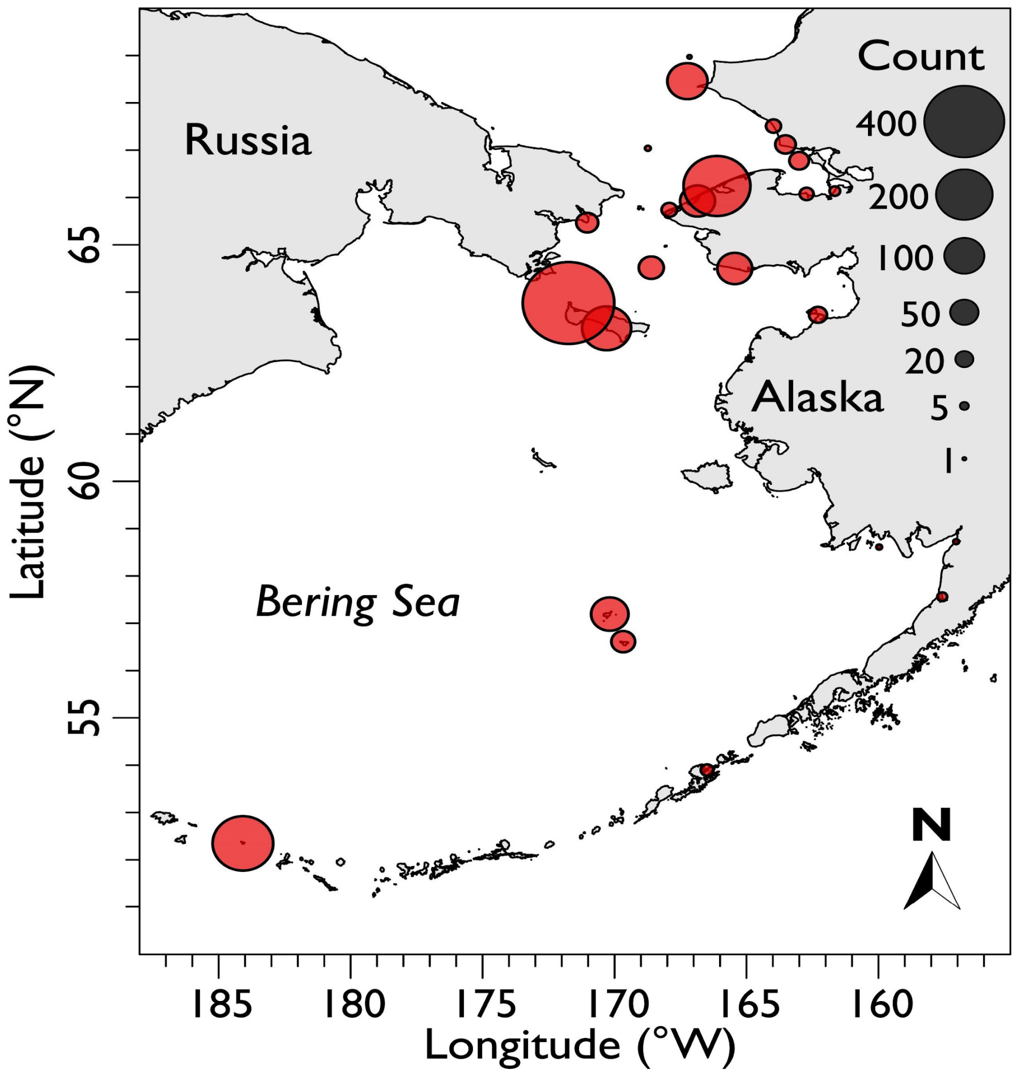
Sources: NOAA 2019b, entire.

Figure 3-21. Aleutian Islands LME # 65



Source: Pearson *et al.* 2019, p. 27.

Figure 3-22. Trend analysis of five monitored colonies in the Aleutian Islands from 1973 to 2016; please note the differences in scale for each colony (excerpted from Pearson *et al*. 2019, p. 29).



Source: Service 2017b.

Figure 3-23. Distribution of seabird carcasses counted during the 2017 seabird mortality event in Alaska.

Oil Spills

No known large oil spills have been documented within the Aleutian Islands LME. Based on oil spill incident rate data from 1995–2012, small oil spills have occurred within this analysis unit, most commonly near the central Aleutian Islands (NOAA 2014, p. 51; Figure 3-8).

The best available information suggests that currently, the areas of greatest risk to shipping accidents and potential oil spills are outside of this analysis unit (Figure 3-17) (Renner and Kuletz 2015, p. 134). Thus, the potential for oil spills resulting in population-level threats to tufted puffin within this analysis unit are considered to be low. Overall, we categorized oil spills as low for this LME.

Fisheries Bycatch

Historically, gillnet fisheries likely had a significant impact on tufted puffin populations within this LME. Beginning around 1952 and up until 1988, the Japanese mothership salmon fishery operated drift gillnets near the western Aleutian Islands. Up to 38,000 tufted puffins were estimated as annual bycatch mortality from 1981 to 1985 (Degange and Day 1991, p. 253). Fishing effort was concentrated during June and July and concern was expressed that local breeding populations of puffins, as well as other seabirds within the area were being adversely affected (Ainley *et al*. 1981, p. 805, Byrd *et al.* 1992, p. 3). Since 1988, the Japenese salmon drift gillnet fisheries has been banned within this LME.

In general, reported seabird bycatch for the Federal groundfish and halibut fisheries within this LME are relatively low, especially compared to the Bering Sea and Gulf of Alaska (Eich *et al.* 2016, p. 16). Based on observer coverage data collected from 2007 to 2015, there have been no reported tufted puffin bycatch in either of these fisheries (Eich *et al.* 2015, p. 15). Furthermore, the extrapolated estimate of puffin bycatch (tufted puffin and horned puffin combined) for the Aleutian Islands, Bering Sea, and Gulf of Alaska regions was estimated at nine during 2010, and zero for all other years (Eich *et al.* 2015, p. 15). Information on coastal gillnet salmon fisheries are not available, but the majority of salmon gillnet fisheries occur outside of this analysis unit (ADF&G 2019, entire).

Due to the ban on gillnet fisheries in 1988, the low numbers of reported and extrapolated puffin bycatch data in the Federal groundfish and halibut fisheries, and because the majority of gillnet fisheries occur outside of tufted puffin breeding areas, we categorized the risks of fishery bycatch in this LME as low.

Mammalian and Avian Predators

There are few native mammalian predators in the Aleutian Islands, with the notable exception of ground squirrels on Unimak Island (Gotthardt *et al.* 2015, p. 22). Native avian predators include eagles and gulls, both of which are known to kill tufted puffins and chicks (Amaral 1977, p. 81; DeGange and Nelson 1978, pp. 5-6; Wehle 1980, pp. 84, 95-96). However, predation on tufted puffins is not thought to be unusually high, especially given the large number of tufted puffin colonies in the Aleutians Islands. Therefore, we characterized risks from mammalian and avian predators as low for the Aleutian Islands LME.

Nonnative Plants and Animals

A variety of nonnative animals, including mice, voles, rats, ground squirrels, rabbits, hares, cats, foxes, sheep, caribou, reindeer, elk, horses, and cattle, have been introduced to some of the islands that comprise the Aleutian Islands LME (Figure 3-20) (Gotthardt *et al.* 2015, entire). Of these, Norway rats and foxes were found to be extremely invasive, while roof rats, house mice, and domestic cats were ranked as highly invasive (Gotthardt *et al*. 2015, p. 20). Rabbits and hares may compete with tufted puffins for burrow habitat and change vegetation of habitat. Sheep, caribou, reindeer, elk, horses, and cattle negatively affect burrow habitat by trampling, removing vegetation, and increasing erosion (Gotthardt *et al.* 2015, entire). Nonnative plant introductions in this LME are poorly documented.

Both historically and currently, some islands in the Aleutians have nonnative species on them, while many do not. Currently, the best available information suggests that nonnative plants and animals are a low risk to tufted puffins and their habitat given the number of islands in this LME. However, we also note some degree of uncertainty regarding nonnative animal impacts on tufted puffins (as a whole) in the Aleutian Islands LME.

<u>Human Disturbance</u>

At some locations within the Aleutian Islands LME, tufted puffin burrows, eggs, or chicks are accessed for annual or less-frequent studies by the Service or USGS researchers. There is little or no documented impact from researcher disturbance in the Aleutian Islands (Kettle 2019, pers. comm.). However, it can be assumed that some negative impacts from researchers do occur at monitored colonies in the Aleutian Islands, given documented researcher disturbance at tufted puffin colonies across the range. There is little human disturbance from tourism given the remoteness of these islands.

Access is limited during the nesting season, although a few colonies may be visited by researchers, which may cause disturbance to nesting tufted puffins. However, overall, few colonies in this LME are monitored, and disturbance from tourism is rare; therefore, we categorized risks from human disturbance as low for this LME.

3.6.4.3 Conservation Actions

The Alaska Maritime NWR manages many of the islands and cliffs where tufted puffin colonies are found in this LME. The Alaska Maritime NWR has strengthened its island biosecurity program to prevent nonnative plants and animals from becoming established, and which includes all islands within the Aleutian Islands LME.

3.6.4.4 Summary

- There is an increasing population trend of monitored colonies in the Aleutian Islands LME (Pearson *et al.* (2019, pp. 6–7).
- The most significant threat in this LME is climate change, which we categorized as a moderate threat. All other threats were categorized as low.
- Management by the Alaska Maritime NWR provides protection of nesting islands, Alaska Maritime NWR's strengthened island biosecurity program is designed to prevent nonnative plants and animals from becoming established on the refuge. Additional conservation actions in this LME include nonnative species control, fox removal, and rat removal, when deemed prudent.

3.6.5 North Bering and Chukchi Sea (LME #54)

The North Bering and Chukchi Sea LME (Figure 3-24) is a shallow shelf environment with depths of 164 to 230 feet (50 to 70 meters) or less, and extending for more than 0.62 mi (1 km) from the shelf edge in the North Bering Sea to the shelf edge of the northern Chukchi Sea. This area is characterized by a persistent northward flow of water driven by higher water level in the Bering Sea than in the Arctic Ocean.

3.6.5.1 Population Size and Trend

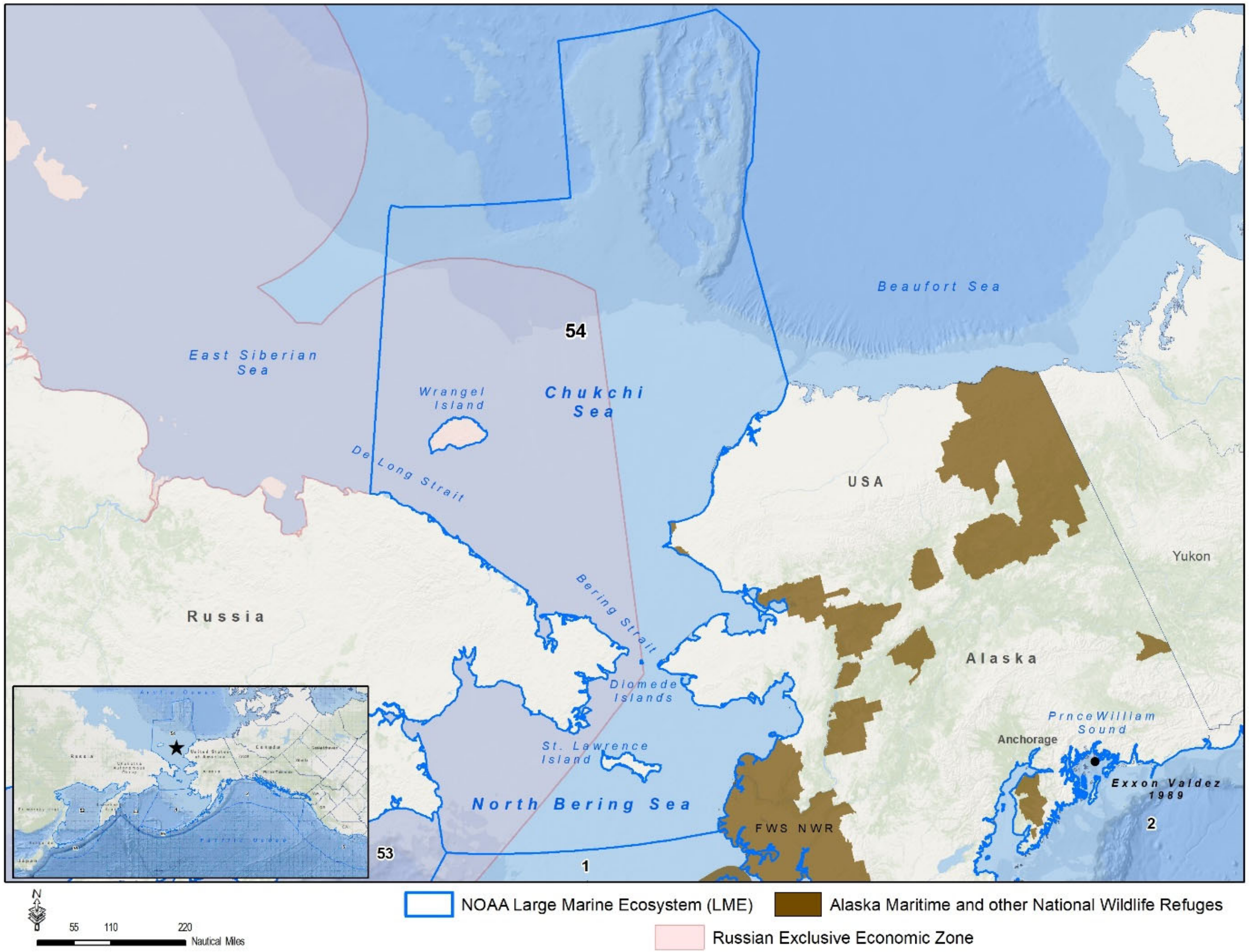
The North Bering and Chukchi Sea LME includes tufted puffin colonies located north of the East Bering Sea LME, in Alaska. In 2002, approximately 74 colonies of unknown size occurred in this LME in the United States, with an estimated population of 16,480 tufted puffins; an additional 106 colonies of unknown size were found in Russia, in the Chukchi and North Bering Sea, with an estimated 32,030 tufted puffins (Piatt and Kitaysky 2002, p. 31; Appendix D). These estimates are the most recent, best scientific information available for this LME. There are no monitored colonies in this LME, so the population trend for the North Bering and Chukchi Sea LME is unknown. Tufted puffin colonies found in Alaska are mapped in Figure 3-14.

3.6.5.2 Threats

<u>Climate Change</u>

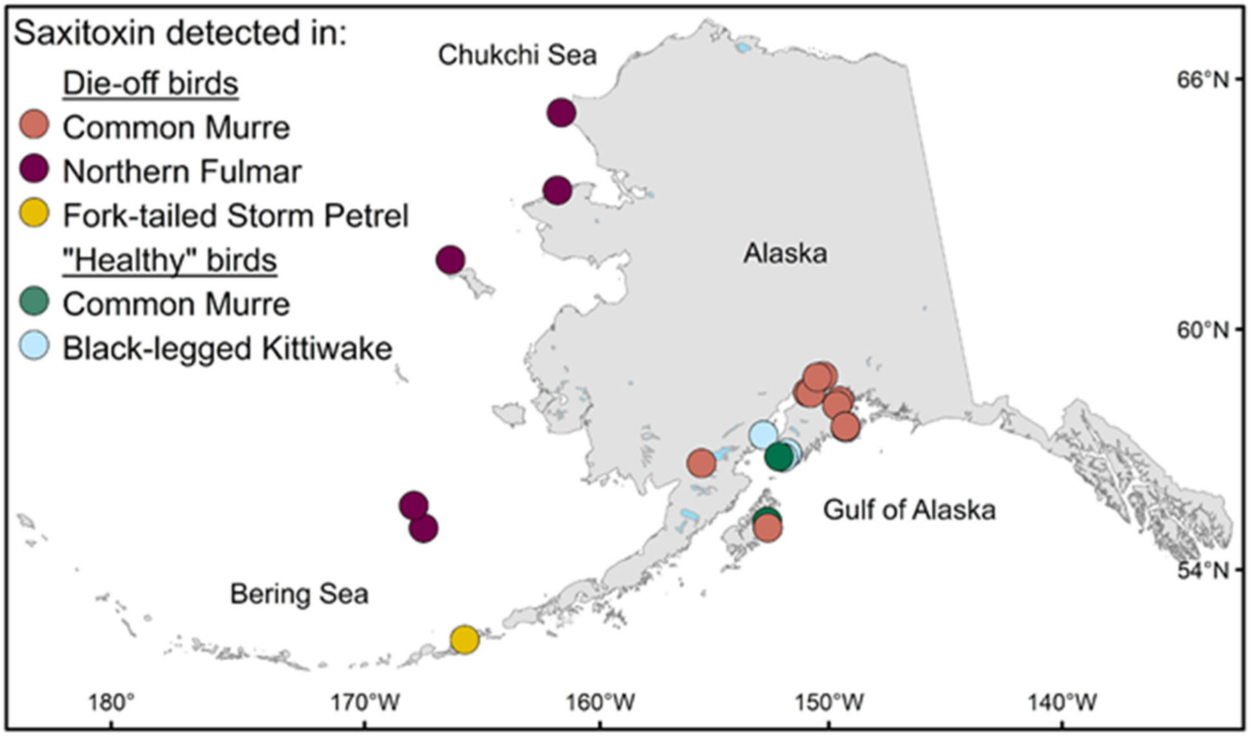
From July to September 2017, nearly 1,600 seabird carcasses were counted during beach surveys within the Bering Sea and Chukchi Sea regions (Figure 3-23). The majority of birds reported in this mortality event were northern fulmars, shearwaters, and kittiwakes. To a lesser extent, murres, auklets, gulls, and puffins (including tufted puffins) were also reported (Service 2017b, entire). While seabird mortality events have occurred annually throughout Alaska since 2015, the 2017 mortality event within this LME is considered unusual in geographic scope, duration, and number of birds affected (Kaler 2019, pers. comm.).

Based on 200 necropsied birds, starvation was determined to be the cause of death and was presumably related to warm ocean temperatures that may have affected prey availability (USGS 2018, p. 1). Saxitoxin was detected in some of the carcasses, which prompted further testing of necropsied birds. Healthy birds were also sampled in areas where mortality events occurred (Figure 3-25). Detectable levels of saxitoxin were found in both die-off (31 of 69) and "healthy" (22 of 63) birds (Figure 3-25; USGS 2018, p. 1). Although the proximate cause of death was starvation, algal toxins, such as saxitoxin, could be a contributing factor to recent unusual seabird mortality events within this LME (Kaler 2019, pers. comm.).



Sources: NOAA 2019b, entire.

Figure 3-24. North Bering and Chukchi Sea LME #54.



Source: USGS 2018, p. 1.

Figure 3-25. The distribution of sampled seabirds with detectable levels of saxitoxin in Alaska from 2015–2017.

Although large numbers of tufted puffins were not reported during the 2017 mortality event, the fact that 2017 represented an unusual seabird mortality event warrants attention. Furthermore, with warming waters, less sea ice cover, and longer growing seasons, the occurrence of harmful algal blooms may increase in the future (Alaska Sea Grant 2019, p. 2).

Due to documented occurrences of elevated SSTs affecting forage fish availability, seabird mortality events, and documentation of saxitoxin in carcasses collected during the mortality events, we categorized risks to tufted puffins from climate change as moderate for this LME.

Oil Spills

No large oil spills are known to have occurred within this analysis unit and few incidents of small oil spills are documented (Figure 3-8). Thus, we categorize risks from oil spills as low for this analysis unit.

Fisheries Bycatch

Most observed seabird bycatch in commercial fisheries occurs in the hook-and-line fisheries; however, small numbers of bycatch have been observed in trawl and other fisheries. The most common fishery within this LME is the Federal pollock trawl fishery (Eich *et al.* 2016, p. 28).

Trawl vessels differ from hook and line vessels in that they do not use bait that would attract seabirds. Instead, they may attract seabirds to vessels with offal discharge (Eich *et al.* 2016, p. 26). Birds foraging near the trawl vessel are sometimes caught in the trawl net as it is brought back on board.

Based on observer coverage data (and extrapolated estimates based on observer data), tufted puffins were not reported as bycatch within this LME during 2007 to 2015 (Eich *et al.* 2016, p. 28). However, trawl bycatch typically results from birds striking the third wire or trawl wrap cables and can be difficult to document because birds that strike the cables may fall into the water and go unobserved.

Because very few tufted puffin deaths have been reported from fisheries in this LME, we categorized risks to tufted puffins from fishery bycatch as low for this LME.

<u>Mammalian and Avian Predators</u>

Mammalian predators in this LME include native foxes, which can limit tufted puffin nesting to cliffs and crevices. Winter sea ice may allow predators, such as foxes, to cross from the mainland and access nesting colony islands to prey on tufted puffins (Renner 2019, pers. comm.), potentially causing mortality to adults and chicks, or causing tufted puffins to abandon their nests. Overall, we categorized the risks of mammalian and avian predators in this LME as unknown.

<u>Nonnative Plants and Animals</u>

Gotthardt *et al.* (2015, pp. 7, 9) found at least one nonnative animal species present on St. Lawrence Island, although they did not specify what species it was (Figure 3-20). Nonnative plant introductions in this LME are poorly documented. Overall, we categorized the risk of nonnative plants and animals to tufted puffins as low for this LME.

<u>Human Disturbance</u>

Human disturbance of tufted puffins or their habitat is limited in the North Bering and Chukchi Sea LME. Tufted puffin colonies are remote and difficult to access, there is very little tourism, and tufted puffin burrows are not routinely monitored or visited by researchers (Kettle 2019, pers. comm.). Therefore, we categorized the risk of human disturbance to tufted puffins as low for this LME.

3.6.5.3 Conservation Actions

The Alaska Maritime NWR manages many of the islands and cliffs where tufted puffin colonies are found in this LME, and provides long-term protection of tufted puffin nesting colonies through ownership, as well as land management practices. The Alaska Maritime NWR's biosecurity program was designed to prevent nonnative plants and animals from becoming established.

3.6.5.4 Summary

- There are no monitored tufted puffin colonies in the North Bering and Chukchi Sea LME, so the population trend for the North Bering and Chukchi Sea LME is unknown.
- Climate change was categorized as the most significant threat in this LME; mammalian and avian predators were categorized as an unknown threat; all other threats were categorized as low for this analysis unit.
- Conservation actions include the Alaska Maritime NWR's long-term protection of tufted puffin nesting areas through land management practices, and a biosecurity program to address nonnative species concerns.

3.6.6 West Bering Sea (LME #53)

The West Bering Sea LME (Figure 3-26) lies off Russia's northeast coast and borders the Aleutian Trench. The bottom topography includes the deep Aleutian Basin, Kamchatka Basin, and Bowers Basin (NOAA 2019a, entire).

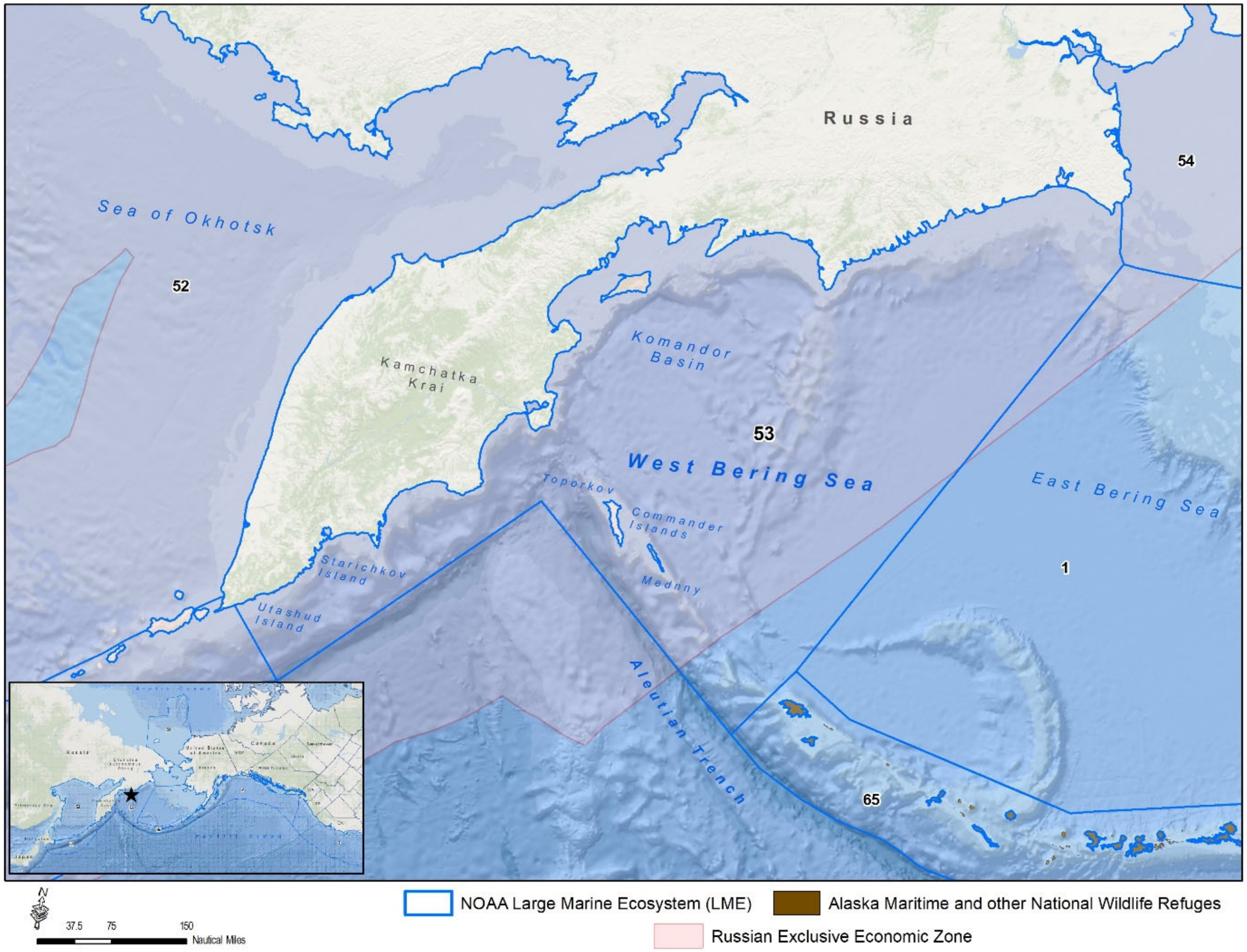
3.6.6.1 Population Size and Trend

The West Bering Sea LME includes tufted puffin colonies just west of the Aleutian Islands in the West Bering Sea, and in the Commander Islands. Piatt and Kitaysky (2002, p. 31; Appendix D) referenced this area as the "S. Bering Sea" and Commander Islands in Russia, with approximately 72 colonies and an estimated population of 172,500 tufted puffins in the LME in 2002. Population estimates and anecdotal evidence suggest that tufted puffins in the large colonies on Toporkov Island, Starichkov Island, and Utashud Island have increased, while the relatively small puffin colonies in the Tri Brat Islands have declined (Artukhin 2019, pers. comm.). A recent estimate of select tufted puffin colonies in this LME suggests there are currently at least 197,000 tufted puffins in this analysis unit (Artukhin 2019, pers. comm.).

There are no monitored colonies in this LME, so the population trend for the West Bering Sea LME is unknown.

3.6.6.2 Threats

Existing threats to tufted puffins in those analysis units that occur wholly in Russia, such as the West Bering Sea LME, are poorly understood. There is limited information on climate change, oil spills, mammalian and avian predators, nonnative plants and animals, and human disturbance.



Sources: NOAA 2019b, entire.

Figure 3-26. West Bering Sea LME #53.

Fisheries Bycatch

The information provided below encompasses fisheries bycatch data provided for three LMEs combined: Sea of Oyashio (LME #51), West Bering Sea (LME #53), and Sea of Okhotsk (LME #52). Although information provided was relevant to an individual LME, data on actual numbers of tufted puffin bycatch were reported for all three LMEs combined. Only general information was described regarding the frequency of tufted puffin reported as bycatch for a particular area within an LME (e.g., the Kuril Islands, within the Sea of Oyashio LME, had higher tufted puffin bycatch compared to areas within the Sea of Okhotsk LME, but actual values were not reported). Thus, we were unable to provide specific bycatch numbers for an individual LME. Instead, we summarize all tufted puffin reported as bycatch for the three LMEs combined.

Use of driftnets within these LMEs was introduced by the Japanese in the 1920s (Artukhin *et al.* 2010, p. 200). Following the United Nations ban in 1992, high-seas driftnet fisheries within these LMEs were no longer active (DeGange *et al.* 1993, p. 204). Prior to that time, tens of thousands of seabirds, including tufted puffins, were reported taken as incidental bycatch. Although high-seas driftnet fisheries were banned in the 1990s, coastal (or inshore) driftnet fisheries remained active. Coastal gillnet fisheries operated at a smaller scale than the high-seas driftnet fisheries, but may have had a proportionately greater impact on seabird populations (Ogi 1983, p. 193; Tasker *et al.* 2000, p. 534; Zydelis *et al.* 2013, p. 77).

During 1993–2001, the Japanese driftnet salmon fishery, operating within the Russian Exclusive Economic Zone (EEZ)[12], documented approximately 183,464 dead seabirds, of which 19.3 percent (approximately 35,408) were tufted puffins (Artukhin *et al.* 2010, p. 200). The Russian EEZ encompasses a total area of 5,030,547 mi^2 (8,095,881 km^2) and overlaps with three of the tufted puffin LMEs (Figures 3-24, 3-25, 3-26). Overall, more seabirds were incidentally caught in salmon driftnets within the Sea of Oyashio and West Bering Sea LMEs, compared to Sea of Okhotsk LME (Artukhin *et al.* 2010, p. 200).

Between 1996–2005, the Russian driftnet salmon fishery, operating within the Russian EEZ, documented a total of 18,698 marine birds, of which 18.3 percent (3,421) were tufted puffins (Artukhin *et al.* 2010, p. 201). Similar to the Japanese salmon driftnet fishery, more seabirds were incidentally taken with salmon driftnet fisheries operating in Sea of Oyashio LME and West Bering Sea LME, compared to Sea of Okhotsk LME (Artukhin *et al.* 2010, p. 201). Tufted puffin was one of the most common species documented as bycatch in these fisheries and declines of the tufted puffin within these LMEs have been directly linked to impacts from gillnet fisheries (Ogi 2008, p. 193; Artukhin *et al.* 2010, p. 201).

Since the 1992 ban of large-scale high seas driftnet fisheries within these analysis units, the impacts to tufted puffin are assumed to be greatly reduced. However, given the overall small population numbers of tufted puffins that occur within these LMEs, fishing practices that still

[12]An exclusive economic zone (EEZ) is a sea zone that was prescribed by the United Nations Convention on the Law of the Sea, an international agreement signed/concluded on December 10, 1982. A state has special rights regarding the exploration and use of marine resources within their designated zone, including energy production from water and wind. The distance is from the coast out to 200 nautical mi (322 km).

employ the use of gillnets may be causing population level effects to the species, although the magnitude of continued fishery bycatch is unknown (Piatt and Kitaysky 2002, p. 21).

Due to the historical impacts of gillnet fisheries on tufted puffin population declines, we categorized fisheries bycatch as high for this analysis unit.

3.6.6.3 Conservation Actions

Conservation actions that benefit tufted puffins in this analysis unit are unknown.

3.6.6.4 Summary

Updated population, distribution, and threats information for those tufted puffin colonies located in Russian LMEs is difficult to find. We made several attempts to collect more recent tufted puffin information from Russia, with limited success. The information contained in this SSA for those LMEs located in Russia is the best scientific information we were able to gather.

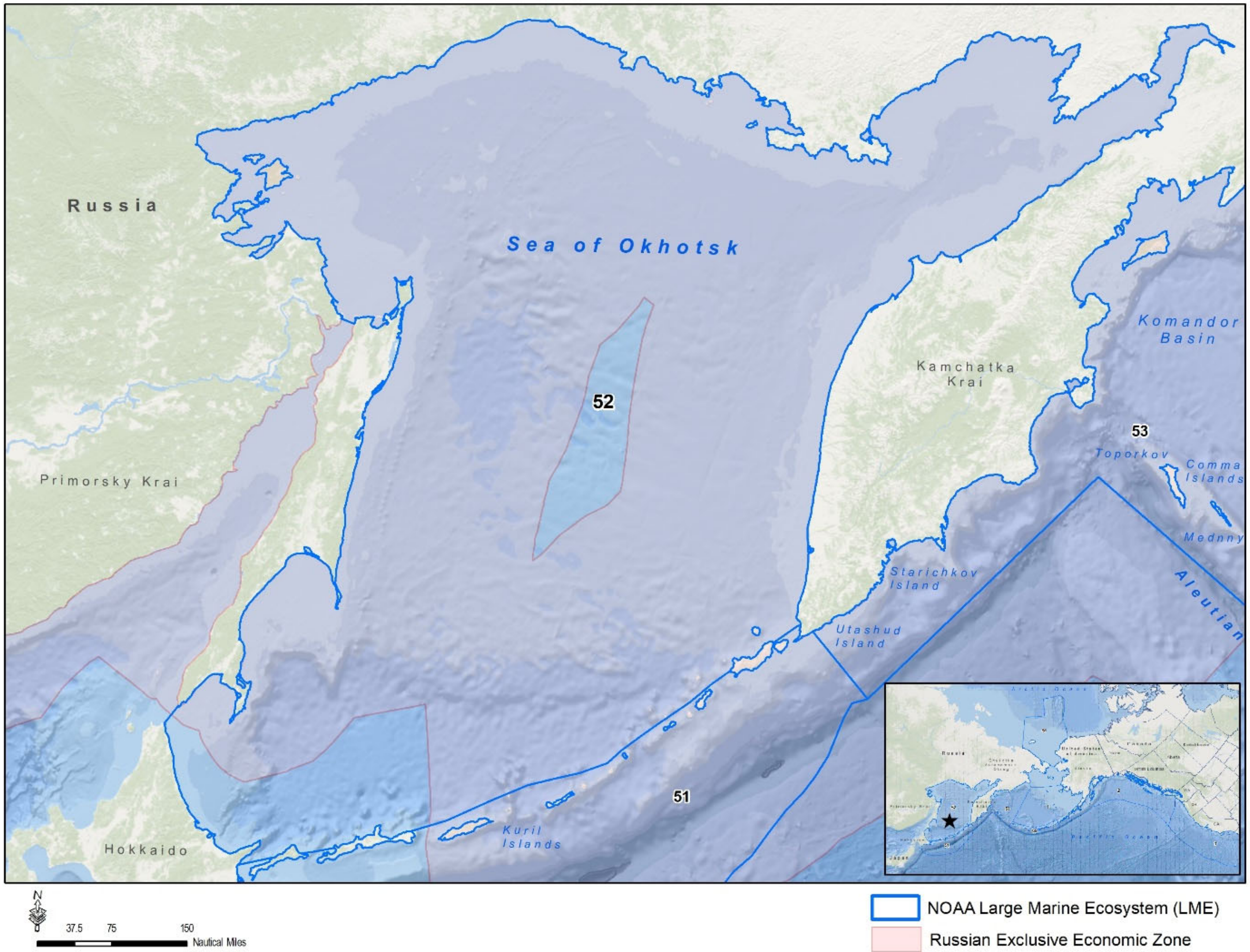
- There are no monitored colonies in the West Bering Sea LME, so the population trend for the West Bering Sea LME is unknown.
- The number and magnitude of threats in this LME are unknown (although historical fishery bycatch is thought to be high for this LME).
- Conservation actions that benefit tufted puffins in this LME are unknown.

3.6.7 Sea of Okhotsk (LME #52)

The Sea of Okhotsk LME (Figure 3-27) is bordered by Russia and northern Japan, and the entire sea is located in the cold temperate zone, with intense ice formation in almost all areas of the sea. There are marked differences in climate, hydrography, and biology between its northern and southern parts. Variations in climate and hydrography are related to atmospheric processes over the northwest Pacific (NOAA 2019a, entire).

3.6.7.1 Population Size and Trend

The Sea of Okhotsk LME includes tufted puffin colonies west of Kamchatka, Russia, and in the Kuril Islands, which is under Russian jurisdiction; however, some of the islands are part of Japan's disputed claim. Piatt and Kitaysky (2002, p. 31; Appendix D) referenced this area as the Sea of Okhotsk and the Kuril Islands, with approximately 46 colonies and an estimated population of 325,580 tufted puffins in 2002. Population estimates and anecdotal evidence suggest the large breeding population on Talan Island has declined, possibly by 30 to 40 percent, in the last 3 decades (estimated population in 1998 was 140,000 tufted puffins, with the estimated population falling to 103,000 in 2007) (Kondratyev *et al*. 2010, p. 67; Artukhin 2019, pers. comm.). Estimates for a select number of individual colonies (with variable survey data, ranging from 2005 to 2015) in this LME suggest there are currently at least 111,000 tufted puffins in this analysis unit (Artukhin 2019, pers. comm.).



Source: NOAA 2019b, entire.

Figure 3-27. Sea of Okhotsk, LME # 52.

There are no monitored colonies in this LME. Other than anecdotal evidence described, the population trend for the Sea of Okhotsk LME is unknown.

3.6.7.2 Threats

Existing threats to tufted puffins in the Sea of Okhotsk LME, which occurs off the coast of Russia, are poorly understood. There is limited information on climate change, oil spills, mammalian and avian predators, nonnative plants and animals, and human disturbance.

<u>Fisheries Bycatch</u>

Fishery bycatch information provided below encompasses fisheries bycatch data provided for three LMEs combined: Sea of Oyashio (LME #51), West Bering Sea (LME #53), and Sea of Okhotsk (LME #52). Although information provided was relevant to an individual LME, data on actual numbers of tufted puffin bycatch were reported for all three LMEs combined. Only general information was described regarding the frequency of tufted puffins reported as bycatch for a particular area within an LME (e.g., the Kuril Islands, within the Sea of Oyashio LME, had higher tufted puffin bycatch compared to areas within the Sea of Okhotsk LME, but actual values were not reported). Thus, we were unable to provide specific bycatch numbers for an individual LME. Instead, we summarize all tufted puffin reported as bycatch for the three LMEs combined.

Use of driftnets within these LMEs was introduced by the Japanese in the 1920s (Artukhin *et al.* 2010, p. 200). Following the United Nations ban in 1992, high-seas driftnet fisheries within these LMEs were no longer active (DeGange *et al.* 1993, p. 204). Prior to that time, tens of thousands of seabirds, including tufted puffins, were reported taken as incidental bycatch. Although high-seas driftnet fisheries were banned in the 1990s, coastal (or inshore) driftnet fisheries remained active. Coastal gillnet fisheries operated at a smaller scale than the high-seas driftnet fisheries, but may have had a proportionately greater impact on seabird populations (Ogi 1983, p. 193; Tasker *et al.* 2000, p. 534; Zydelis *et al.* 2013, p. 77).

During 1993–2001, the Japanese driftnet salmon fishery, operating within the Russian EEZ, documented approximately 183,464 dead seabirds, of which 19.3 percent (approximately 35,408) were tufted puffins (Artukhin *et al.* 2010, p. 200). The Russian EEZ encompasses a total area of approximately 5.0 million mi^2 (8.1 million km^2) and overlaps with three of the tufted puffin LMEs (Figures 3-24, 3-25, and 3-26). Overall, more seabirds were incidentally caught in salmon driftnets within Sea of Oyashio LME and West Bering Sea LME, compared to the Sea of Okhotsk LME (Artukhin *et al.* 2010, p. 200).

Between 1996–2005, the Russian driftnet salmon fishery, operating within the Russian EEZ, documented a total of 18,698 marine birds, of which 18.3 percent (3,421) were tufted puffins (Artukhin *et al.* 2010, p. 201). Similar to the Japanese salmon driftnet fishery, more seabirds were incidentally taken with salmon driftnet fisheries operating in Sea of Oyashio, LME 51 and West Bering Sea, LME 53, compared to Sea of Okhotsk, LME 52 (Artukhin *et al.* 2010, p. 201). Tufted puffin was one of the most common species documented as bycatch in these fisheries and declines of tufted puffin within these LMEs have been directly linked to impacts from gillnet fisheries (Ogi 2008, p. 193; Artukhin *et al.* 2010, p. 201).

Since the 1992 ban of large-scale high seas driftnet fisheries within these analysis units, the impacts to tufted puffin are assumed to be greatly reduced. However, given the overall small population numbers of tufted puffins that occur within these LMEs, fishing practices that still employ the use of gillnets may be causing population level effects to the species, although the magnitude of continued fishery bycatch is unknown (Piatt and Kitaysky 2002, p. 21).

Due to the historical impacts of gillnet fisheries on tufted puffin population declines, we categorized fisheries bycatch as high for this analysis unit.

3.6.7.3 Conservation Actions

Conservation actions that benefit tufted puffins in this analysis unit are unknown.

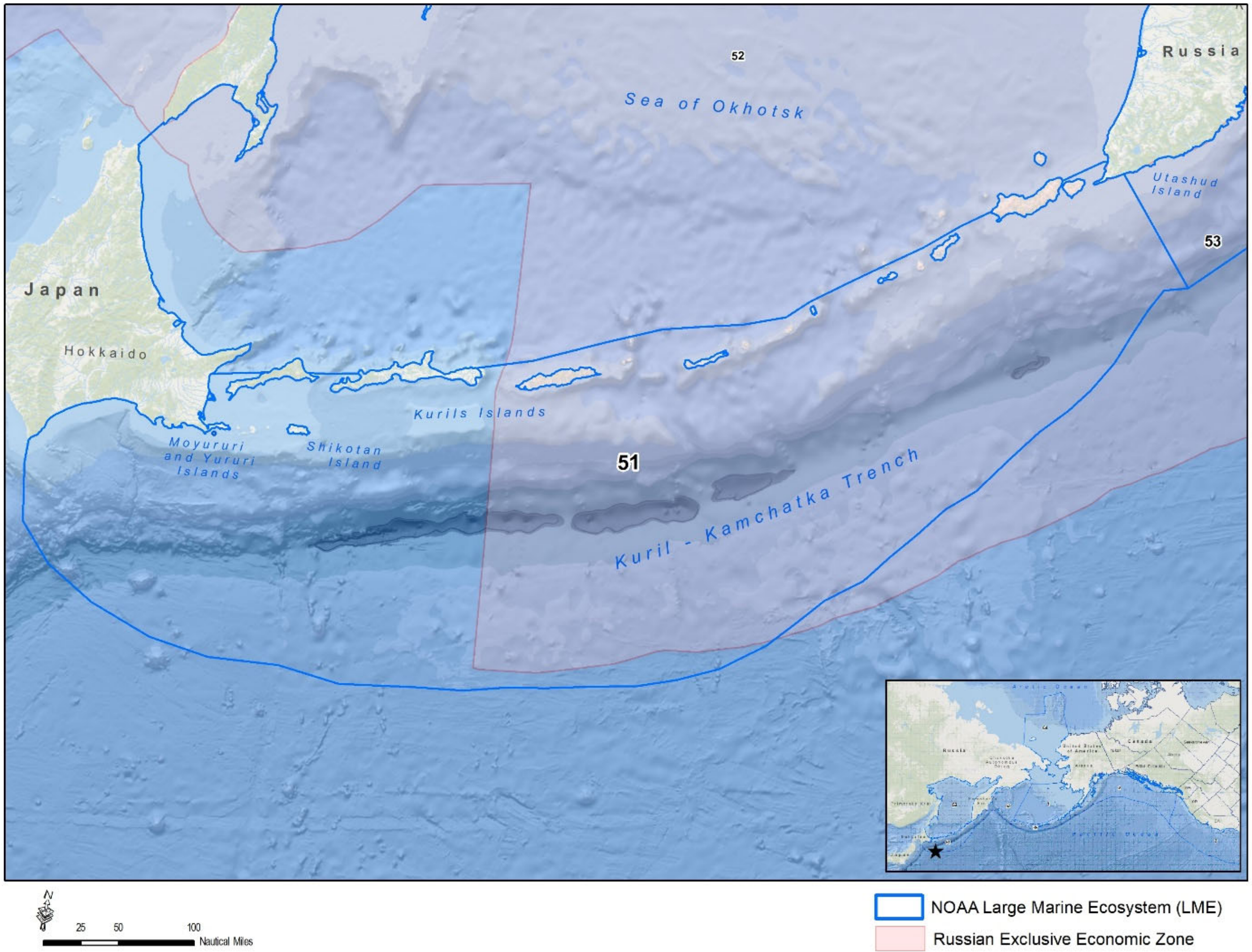
3.6.7.4 Summary

Updated population, distribution, and threats information for those tufted puffin colonies located in Russian LMEs is difficult to find. We made several attempts to collect more recent tufted puffin information from Russia, with limited success. The information contained in this SSA for those LMEs located in Russia is the best scientific information we were able to gather.

- There are no monitored colonies in the Sea of Okhotsk LME, so the population trend for this LME is unknown.
- The number and magnitude of threats in this LME are unknown (although historically, fishery bycatch was thought to be high).
- Conservation actions that benefit tufted puffins in this analysis unit are unknown.

3.6.8 Oyashio Current (LME # 51)

The Oyashio Current LME (Figure 3-28) is located in the northwest Pacific Ocean and is bordered by Russia (the Kamchatka Peninsula and Kuril Islands) and the Japanese island of Hokkaido. A subarctic climate characterizes this LME (i.e., winters that are long and usually cold, and summers that are short and cool to mild). The geographic remoteness and inaccessibility of the Kuril Islands, combined with the extreme environmental conditions have discouraged human settlement and contributed to making the Kuril Archipelago one of the least known regions of the world (NOAA 2019a, entire).



Source: NOAA 2019b, entire.

Figure 3-28. Oyashio Current, LME # 51.

3.6.8.1 Population Size and Trend

Once more abundant in Japan, with more than 250 individual tufted puffins observed breeding on Japan's Moyururi Island in the 1960s and scattered nesting on several other islands (Sato *et al.* 2018, p. 5), tufted puffins have experienced notable declines (Kondratyev *et al.* 2000, p. 33). As few as 30 tufted puffins were thought to breed in Japan in 2002 (Piatt and Kitaysky, p. 20); between 12 and 19 tufted puffins were counted in 2013 (Sato *et al*. 2018, entire), which is the most recent estimate available. Breeding is now limited to Yururi Island and Moyururi Island off the coast of Japan, near Hokkaido (Sato *et al.* 2018, entire). Breeding tufted puffins were confirmed in 2016, but individual birds were not estimated (Sato *et al.* 2018, entire). The tufted puffin population in the Oyashio Current LME displays greatly reduced population numbers, and a strong downward trend (Sato 2018, entire).

3.6.8.2 Threats

<u>Climate Change</u>

Evidence suggests climate change plays a part in tufted puffin declines in the Sea of Oyashio LME, although to what degree is unclear. Decline of food sources are thought to be negatively affecting the population of rhinoceros auklet in Hokkaido, and similarly may be making it difficult for tufted puffins to forage or provision their chicks (Sato *et al.* 2018, p. 4). However, since the tufted puffin population in this LME has been reduced to just a few individuals, all threats have an unusually large impact on the remaining population, either through direct mortality, habitat degradation, or changes in prey availability. Using the rhinoceros auklet as a proxy, and due to documentation that forage fish the rhinoceros auklet rely on are declining in this LME, we consider the risks of climate change on tufted puffins in this LME to be moderate.

<u>Oil Spills</u>

The risks of oil spills on tufted puffins in this LME are unknown.

<u>Fisheries Bycatch</u>

The information provided below encompasses fisheries bycatch data provided for three LMEs combined: Sea of Oyashio (LME 51), West Bering Sea (LME 53), and Sea of Okhotsk (LME 52). Although information provided was relevant to an individual LME, data on actual numbers of tufted puffin bycatch were reported for all three LMEs combined. Only general information was described regarding the frequency of tufted puffins reported as bycatch for a particular area within an LME (e.g., the Kuril Islands, within the Sea of Oyashio LME, had higher tufted puffin bycatch compared to areas within the Sea of Okhotsk LME, but actual values were not reported). Thus, we were unable to provide specific bycatch numbers for an individual LME. Instead, we summarize all tufted puffin reported as bycatch for the three LMEs combined.

Use of driftnets within these LMEs was introduced by the Japanese in the 1920s (Artukhin *et al.* 2010, p. 200). Following the United Nations ban in 1992, high-seas driftnet fisheries within these LMEs were no longer active (DeGange *et al.* 1993, p. 204). Prior to that time, tens of thousands of seabirds, including tufted puffins, were reported taken as incidental bycatch. Although high-seas driftnet fisheries were banned in the 1990s, coastal (or inshore) driftnet fisheries remained active. Coastal gillnet fisheries operated at a smaller scale than the high-seas driftnet fisheries, but may have had a proportionately greater impact on seabird populations (Ogi 1983, p. 193; Tasker *et al.* 2000, p. 534; Zydelis *et al.* 2013, p. 77).

During 1993–2001, the Japanese driftnet salmon fishery, operating within the Russian EEZ, (Figures 3-24, 3-25, 3-26), documented approximately 183,464 dead seabirds, of which 19.3 percent (approximately 35,408) were tufted puffins (Artukhin *et al.* 2010, p. 200). Overall, more seabirds were incidentally caught in salmon driftnets within Sea of Oyashio (LME #51) and West Bering Sea (LME #53), compared to Sea of Okhotsk (LME #52) (Artukhin *et al.* 2010, p. 200).

Between 1996–2005, the Russian driftnet salmon fishery, operating within the Russian EEZ, documented a total of 18,698 marine birds, of which 18.3 percent (3,421) were tufted puffins (Artukhin *et al.* 2010, p. 201). Similar to the Japanese salmon driftnet fishery, more seabirds were incidentally taken with salmon driftnet fisheries operating in Sea of Oyashio (LME #51) and West Bering Sea (LME #53), compared to Sea of Okhotsk (LME #52) (Artukhin *et al.* 2010, p. 201). Tufted puffin was one of the most common species documented as bycatch in these fisheries and declines of tufted puffin within these LMEs have been directly linked to impacts from gillnet fisheries (DeGange and Day 1991, pp. 251–258; Ogi 2008, p. 193, Artukhin *et al.* 2010, p. 201).

Since the 1992 ban of large-scale high seas driftnet fisheries within these analysis units, the impacts to tufted puffin are assumed to be greatly reduced. However, given the overall small population numbers of tufted puffins that occur within this LME, fishing practices that still employ the use of gillnets may be causing population level effects to the species, although the magnitude of continued fishery bycatch is unknown (Piatt and Kitaysky 2002, p. 21).

Sato *et al.* (2018, pp. 1, 4) considered fisheries bycatch to be one of the main causes of tufted puffin decline within the Sea of Oyashio LME, especially along the coast near Hokkaido Island. The salmon driftnet fisheries that operated during the 1960s may have particularly affected the wintering tufted puffin population in this area (Sato *et al.* 2018, p. 4).

It is unknown if fisheries bycatch continues to impact tufted puffins in this analysis unit. Due to historical impacts of driftnet and gillnet fisheries on tufted bycatch mortality and the documented population decline, we categorized the threat of fisheries bycatch as high for this analysis unit.

<u>Mammalian and Avian Predators</u>

Marked increases on Teuri Island and in Hamanaka Town of the carrion crow (*Corvus corone*), the jungle crow (*C. macrorhynchos*), and the slaty-backed gull, have necessitated protective measures against predation of eggs and chicks by these predators (Ogi 2008, p. 193). Increased predation by slaty-backed gulls and white-tailed sea eagles (*Haliaeetus albicilla*) are thought to be negatively affecting the few remaining tufted puffins in this LME through direct mortality of adults and chicks (Sato *et al.* 2018, p. 1). We consider the risks of mammalian and avian predators on tufted puffins in this LME to be high.

<u>Nonnative Plants and Animals</u>

The Kushiro District Bureau of the Ministry of the Environment reportedly eradicated brown rats (Norway rats), which depredate tufted puffin eggs and chicks, from Yururi Island and Moyururi Island in 2017 (Sato *et al.* 2018, p. 3). We are unaware of information indicating nonnative plants have negative impacts on tufted puffins in this LME. The risks of nonnative plant and animal introductions (or re-introductions) on nesting tufted puffins in this LME are unknown.

<u>Human Disturbance</u>

Human disturbance to breeding tufted puffins from sightseeing boats passing too close to their nests on Yururi Island and Moyururi Island may cause nesting puffins to flush temporarily, or even abandon their nests (Sato *et al.* 2018, p. 3). Because tufted puffins are sensitive to nesting disturbance (Wehle 1980, p. 26; Pierce and Simons 1986, p. 214), and there are few tufted puffins remaining in this LME, we consider the risks of human disturbance on tufted puffins in this LME to be moderate.

3.6.8.3 Conservation Actions

The nesting islands allow limited access to people, and have been designated as National Wildlife Reserves by the Japanese government, and a Natural Monument by Hokkaido (Sato *et al.* 2018, p. 2). The Kushiro District Bureau of the Ministry of the Environment eradicated brown rats (Norway rats) from Yururi Island and Moyururi Island in 2017 (Sato *et al*. 2018, p. 3), although the long-term benefits of this eradication, especially considering the tufted puffin population in Japan is greatly reduced, is unclear.

3.6.8.4 Summary

- The tufted puffin population in the Sea of Oyashio LME displays greatly reduced population numbers, and a strong downward trend (Sato 2018 *et al.*, entire).
- The most significant threats in this LME are climate change; the potential continuation of gill net and driftnet fisheries, which could cause direct mortality; mammalian and avian predation; and human disturbance. The tufted puffin population has declined dramatically, which means all threats have an unusually large impact on the remaining population (Sato 2018 *et al.*, entire). The risk of oil spills and nonnative plants and animals on tufted puffins in this LME are unknown.
- Although some conservation actions have been implemented (designation of nesting islands as national wildlife reserves, eradication of brown rats), it is uncertain if the tufted puffin population can rebound, given their low numbers. The effectiveness of conservation actions that benefit tufted puffins in this analysis unit are unknown.

3.7 Current Conditions Summary

3.7.1 Summary of Threats

While we evaluated numerous threats, only those major threats causing, or potentially causing, population-level effects within each of the analysis units were carried forward into this report. Minor threats, those we identified as having limited or localized effects on tufted puffin populations, were wind and wave energy development (California Current LME) and human subsistence harvest (Aleutian Islands LME and North Bering and Chukchi Sea LME). Additionally, several threats whose negative influence on tufted puffin populations are unknown (i.e., toxins, plastics, microplastics, and commercial fishing of prey) were identified as possibly contributing to tufted puffin declines. However, while there is information available on how each of these "unknown" threats could negatively influence the species or its habitat, the best available information on the species (or surrogate species) at this time does not indicate these threats are significantly affecting tufted puffin resiliency.

After evaluating each of the LMEs for impacts from the major threats (i.e., climate change, oil spills, fisheries bycatch, mammalian and avian predators, nonnative plants and animals, and human disturbance) (see section 3.6), we categorized each threat for its likely impact on the resiliency of the tufted puffin using a high, moderate, low scale[13]. Using this evaluation, we determined that climate change and oil spills were the threats most likely to have population-level impacts on tufted puffins throughout their range (Table 3-5).

The California Current, Gulf of Alaska, East Bering Sea, Aleutian Islands, North Bering and Chukchi Sea, and Oyashio Current LMEs were considered to have moderate risks related to climate change (Table 3-5). Climate change includes complex, inter-related changes in air and water temperatures, weather patterns, and ocean conditions. Increasing SST and an associated reduction in prey availability have been shown to impact tufted puffins' ability to forage, feed themselves, and provision their chicks (Gjerdrum *et al*. 2003, p. 9,377; Mackas *et al.* 2007, p. 249; Parrish *et al.* 2017, entire; Hanson *et al.* 2019, p. 7; Pearson *et al*. 2019, entire).
The California Current, Gulf of Alaska, and East Bering Sea LMEs were considered to have moderate risks related to oil spills (Table 3-5). Oiling kills adult birds directly through hypothermia, drowning, or ingestion when they try to preen oil off their feathers (American Trader Trustee Council 2001, p. 10), and has the potential to cause immediate impacts on seabird populations through mortality, sublethal injury, interfering with their ability to feed and provision chicks. In addition, the reproductive capacity of surviving birds may be permanently impaired (Barros *et al*. 2014, pp. 2–3).

[13] A threat categorized as LOW was considered to pose limited risks to tufted puffin resiliency within an analysis unit; that is, tufted puffins were still able to tolerate natural, annual variation (stochasticity) in their environment, and to recover from periodic disturbance. A threat categorized as MODERATE was considered to pose a medium amount of risk to tufted puffin resiliency within an analysis unit; that is, moderate threats could reduce the degree to which tufted puffins can tolerate natural, annual variation in their environment, and to recover from periodic disturbance. Finally, a threat categorized as HIGH was considered to pose a large risk to tufted puffin resiliency, further reducing their ability to tolerate natural, annual variation, and inhibiting their ability to recover from periodic disturbance

Oyashio Current LME (off the coast of Japan) notably had a much reduced population (under 20 individual puffins at last count, in 2013 (Sato *et al.* 2018 p.1). Because of their low numbers, this LME was considered to have high risks related to fisheries bycatch, mammalian and avian predators, and human disturbance (Sato 2018, entire); risks from oil spills and nonnative plants and animals were considered unknown (Table 3-5).

The West Bering Sea and the Sea of Okhotsk LMES (off the coast of Russia) were considered to have unknown risks for all threats evaluated (Table 3-5), due to difficulty gathering information on tufted puffin populations and their current threats in Russia.

3.7.2 Summary of Current Conditions

Based upon the population estimates found in Piatt and Kitaysky (2002, pp. 3, 18), we summarized the percentage of estimated tufted puffins currently found in each LME (Figure 3-29).

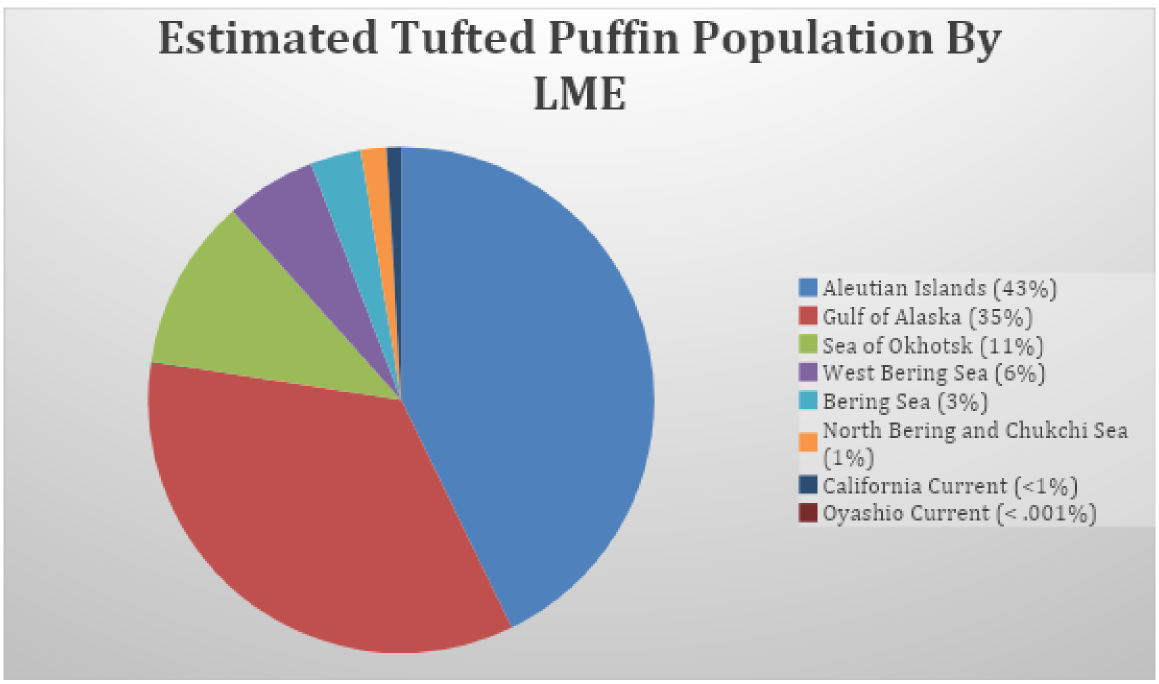


Figure 3-29. The percentage of tufted puffins currently found in each LME, based upon Piatt and Kitaysky (2002, p. 3, 18).

Table 3-5. Summary of current threats to tufted puffin resiliency.

Analysis Unit	*Summary of Current Condition Threats*						
	Climate Change	*Oil Spills*	*Fisheries Bycatch*	*Mammalian and Avian Predators*	*Nonnative Plants and Animals*	*Human Disturbance*	*Overall Number/ Magnitude of Threats*
California Current	Moderate	Moderate	Low	Low	Low	Low	Moderate
Gulf of Alaska	Moderate	Moderate	Moderate	Low	Low	Low	Moderate
East Bering Sea	Moderate	Moderate	Low	Unknown	Low	Low	Moderate
Aleutian Islands	Moderate	Low	Low	Low	Low	Low	Low
North Bering and Chukchi Sea	Moderate	Low	Low	Unknown	Low	Low	Low
West Bering Sea	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Sea of Okhotsk	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Oyashio Current	Moderate	Unknown	High	High	Unknown	High	High

We used the best available scientific and commercial information, including (but not limited to) trend analysis by Pearson *et al*. (2019, entire), to determine the current condition (HIGH, MODERATE, LOW)[14] of the tufted puffin throughout its range. We considered known threats, accounting for the number and magnitude of their effects on tufted puffin populations and their habitat for each analysis unit, as well as conservation actions that could limit how those threats may negatively influence the species or its habitat in each analysis unit (Table 3-6).

In general, the population trend appeared to accurately reflect the current condition of each analysis unit; the number of threats in each LME was similar across the range, with the exception of the additive threats in the Oyashio Current LME; and conservation actions were similar for each LME, and did not appear to clearly correlate with each LME's current condition.

- In the California Current LME, there are two threats (i.e., climate change and oil spills), with some ongoing conservation actions, and a statistically significant declining population trend. The overall condition of the California Current LME was determined to be low.
- In the Gulf of Alaska LME, there are three threats (i.e., climate change, fishery bycatch, and oil spills), with some ongoing conservation actions, and a statistically insignificant declining population trend. The overall condition of the Gulf of Alaska LME was determined to be moderate.
- In the East Bering Sea LME, there are two threats (i.e., climate change and oil spills), with some ongoing conservation actions, and a stable population trend. The overall condition of the East Bering Sea LME was determined to be moderate.
- In the Aleutian Islands LME, there is one threat (i.e., climate change), with some ongoing conservation actions, and a statistically significant increasing population trend. The overall condition of the Aleutian Islands LME was determined to be high.
- In the North Bering and Chukchi Sea LME, there is one threat (i.e., climate change), with some ongoing conservation actions, and a stable population trend. The overall condition of the North Bering and Chukchi Sea LME was determined to be moderate.
- In the West Bering Sea and the Sea of Okhotsk LMEs, there are unknown threats, unknown conservation actions, and an unknown population trend. The overall condition of the West Bering Sea and the Sea of Okhotsk LMEs was determined to be Unknown.
- Finally, in the Oyashio Current, there are four known threats (i.e., climate change, fisheries bycatch, mammalian and avian predators, and human disturbance), and two unknown threats (oil spills and nonnative plants and animals); there are some conservation actions, and a statistically significant declining trend. The overall condition of the Oyashio Current LME was determined to be low.

[14] If an LME is in "HIGH" condition, tufted puffins found within are considered to be highly resilient; that is, able to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance. An LME in "MODERATE" condition means tufted puffins found within have some resiliency, although potentially to a lesser degree. An LME in "LOW" condition is considered to be more vulnerable to natural, annual variation, with a reduced ability to recover from periodic disturbance.

Table 3-6. Summary of current conditions for each analysis unit.

Analysis Unit	Population Estimates	Demographic Factor	Habitat Factor	Overall Condition
		Population Trend[1]	Stressors	
California Current	<60 colonies estimate 2,000 birds	Declining	Climate Change Oil Spills	Low
Gulf of Alaska	>400 colonies ~1 million birds	No statistically[2] significant trend	Climate Change Oil Spills Fishery Bycatch	Moderate
East Bering Sea	<30 colonies ~100,000 birds	No statistically significant trend	Climate Change Oil Spills	Moderate
Aleutian Islands	>150 colonies ~1.2 million birds	Increasing	Climate Change	High
North Bering and Chukchi Sea	~70-180 colonies ~40-50k birds	No statistically significant trend	Climate Change	Moderate
West Bering Sea	~70+ colonies ~150-200k birds	Unknown	Unknown	Unknown
Sea of Okhotsk	~40-50 colonies ~100-300k birds	Unknown	Unknown	Unknown
Oyashio Current	1-2 colonies <20 birds	Declining	Climate Change Fishery Bycatch Mammal/Avian Predation Human Disturbance	Low

[1] Based on trend data (Pearson *et al.* 2019) and documented declines across the range.
[2] The Gulf of Alaska trend should be treated with caution; three of four monitored populations show declining trends.

Our analysis indicates that tufted puffins appear to be undergoing a range contraction on the southern end of their range (e.g., California Current and Oyashio Current LMEs). Concurrently, one part of the range (i.e., the Aleutian Islands LME) has seen increasing populations. Overall, the areas of the tufted puffin's range with the largest number of colonies and nesting tufted puffins (Aleutian Islands and Gulf of Alaska LMEs) are found to be in moderate to high condition (Figure 3-30).

In summary, we found one analysis unit (Aleutian Islands LME) in high condition; three analysis units (Gulf of Alaska, East Bering Sea, and North Bering and Chukchi Sea LMEs) are in moderate condition; two analysis units (California Current and Oyashio Current) are in low condition; and two analysis units (West Bering Sea and Sea of Okhotsk) are in unknown condition.

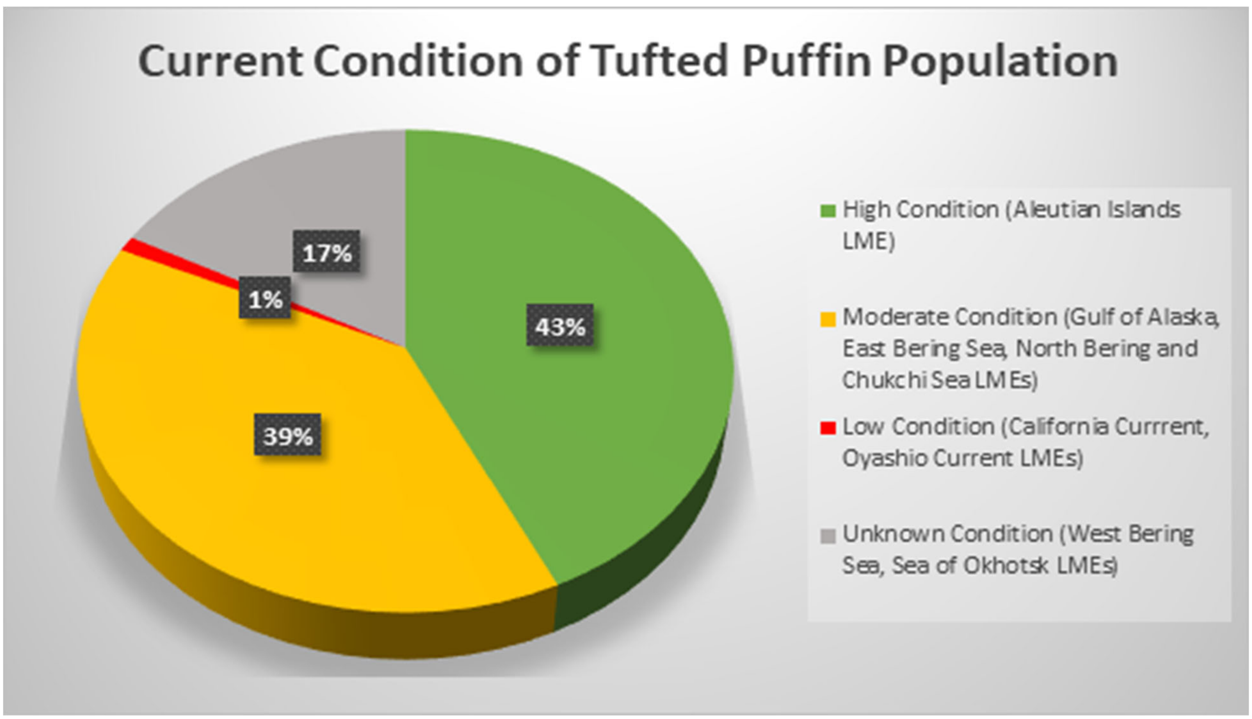


Figure 3-30. Current condition of the tufted puffin population, based upon analysis of population trend, threats, and conservation actions.

Chapter 4: Future Conditions

Based upon our current condition analysis, we determined that two threats were most likely to have moderate impacts to tufted puffins across their range: climate change and oil spills. One threat, fishery bycatch, was found to have moderate impacts in the Gulf of Alaska LME. The other threats evaluated (avian and mammalian predators, nonnative plants and animals, and human disturbance) are currently considered to pose low risks to tufted puffins at the LME and population level, although they may have larger impacts on individual colonies. However, as climate change continues to impact tufted puffin populations, these "low-risk" threats could increase, potentially playing a larger role in the future condition of tufted puffin populations.

Of the threats evaluated, climate change and oil spills are expected to be the main drivers of population changes into the future. Additionally, the current population trend of each LME predicts how tufted puffins will respond to changing future conditions. The anticipated future conditions of tufted puffins in each LME are examined in more detail in sections 4.1–4.5.

4.1 Future Climate Conditions

Global climate change has been driven primarily by increasing concentrations of "greenhouse" gases that trap heat in the earth's atmosphere. Higher concentrations lead to greater warming and other climate anomalies. Evaluations of many potential future scenarios have shown that greenhouse gas concentrations could range from approximately 430 to more than 1,000 parts per million of CO_2 equivalent gases by the end of the century (usually expressed as a range of decades, such as 2080–2100) (IPCC 2014, entire). Many strategies have been identified as possible ways to reduce or limit increases in emissions of greenhouse gases, and infinite combinations of these strategies (or "pathways") are conceivable, each leading to different outcomes.

The IPCC (2014, entire) has identified four "representative concentration pathways" (RCPs) that lead to distinctly different warming levels by 2100. Each of these four RCPs is identified by the warming effect it would produce, expressed as an average net increase in radiative energy relative to pre-industrial levels in joules (watts per square meter) by century's end. The four RCPs currently in use have replaced the "emission scenarios" used in IPCC assessments prior to 2014. They range from aggressive mitigation to reduce emissions to a level that would maintain average global temperatures within 2°C of pre-industrial temperatures to meet the goals of the Paris Agreement (RCP 2.6) to unabated continuation of recent emission rates, with corresponding increases in atmospheric greenhouse gases and rises in global temperatures (RCP 8.5). An intermediate pathway (RCP 4.5) would require prompt and prudent mitigation in the coming decades and potentially result in relatively stable emissions after gradual increases in greenhouse gas emissions through mid-century, while another intermediate pathway (RCP 6.0) would require less aggressive mitigation and result in warming intermediate between RCPs 4.5 and 8.5 (van Vuuren *et al.* 2011, pp. 5–26; IPCC 2014, p. 57) (Figure 4-1). The RCPs are not forecasts, absolutes, or prescriptive, and none was considered more likely than another when developed (van Vuuren *et al.* 2011, p. 26).

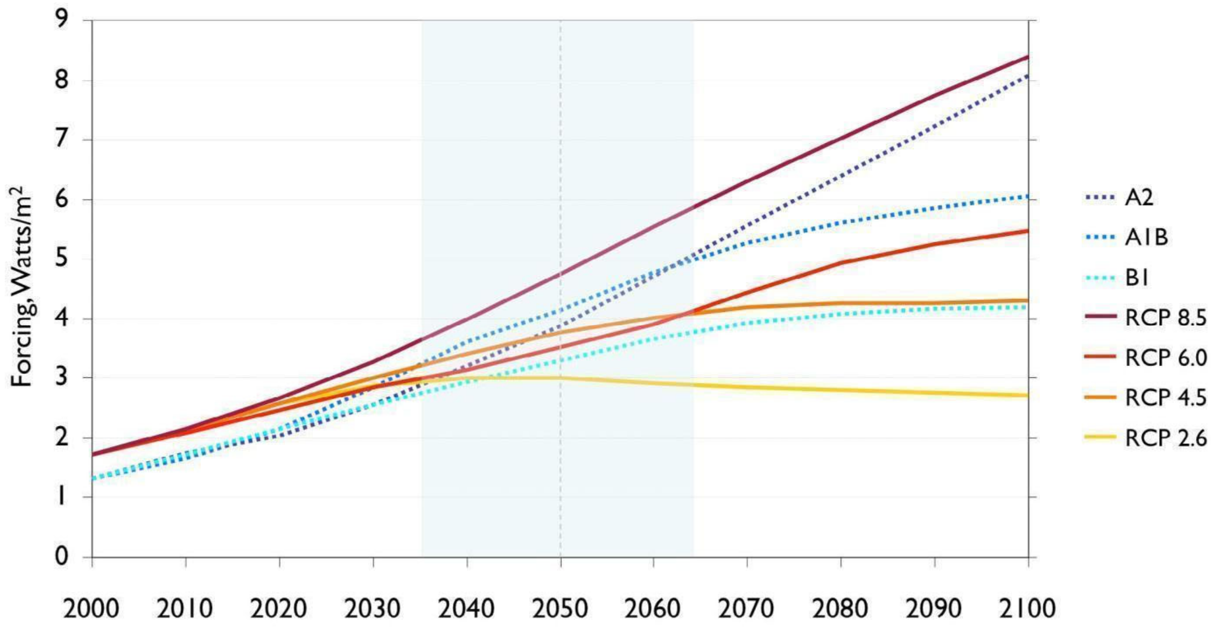


Figure 4-1. Changes in atmospheric radiation energy (or "radiative forcing") resulting from various Representative Concentration Pathways (RCPs) used in IPCC climate modeling since 2014 and emission scenarios used prior to 2014 (A1B, A2, and B1). Each pathway or scenario represents a different level of greenhouse gas emissions from various sources, and human activity to reduce emissions, resulting in different rates of atmospheric warming. From Lukas *et al.* 2014, p. 41.

The best available scientific information related to potential changes in climate are included below (sections 4.4.1, 4.4.2, and 4.4.3) related to RCPs 4.5 and 8.5. Attainment of RCP 2.6 would require unprecedented global commitments and technologies, which has led to widespread doubts about its relative likelihood (Tollefson 2015, p. 436). For this reason, we have dismissed it as a plausible scenario for the purposes of evaluating potential future scenarios for tufted puffin. Reductions in greenhouse gas emissions as a result of global mitigation efforts do seem feasible, though, given commitments and actions by many governments, corporations, and non-profit groups. We therefore consider the more intermediate RCP 4.5 a plausible future scenario that could have impacts on the species distinct from continuation of the status quo, which is approximately represented by RCP 8.5.

Climate change impacts tufted puffin populations directly and indirectly, through changes in temperatures, weather patterns, and ocean conditions, and through increased SST, reduced prey availability, ocean acidification, increased harmful algal blooms, sea level rise, changes in storm intensity or frequency, and changes in precipitation.

4.2 Future Oil Spills

Forecasting patterns of future oil spills is challenging; there are a large number of economic and environmental factors to consider, and a great deal of uncertainty (NOAA 2014, p. 57). Long-term trends in oil transport will vary with fluctuations in national and international costs of oil, including transportation costs; however, currently it is projected to stay the same or increase (WSDE 2017, p. 95).

In the California Current LME, for example, the recently approved Trans Mountain Expansion Project would significantly increase the amount of oil delivered to terminal facilities in Burnaby, B.C., Canada, from approximately 300,000 to 890,000 barrels per day (Canada 2019, p. 3). This is estimated to increase the number of tankers departing Burnaby through the Salish Sea and the Strait of Juan de Fuca from 5 to 34 tankers per month (Canada 2019, p. 3). It is unknown how much oil will go to refineries in Puget Sound or California, how much would be exported overseas, and additionally how the increase will impact the amount of oil currently imported to Washington refineries from Alaska, and outside of North America. However, we can anticipate an increase in crude and fuel oil and other refined petroleum product tanker and barge traffic around the Salish Sea and through the Strait of Juan de Fuca, due to the doubling of volume from the Trans Mountain Pipeline.

The NOAA Assessment of Marine Oil Spill Risk and Environmental Vulnerability for the State of Alaska (2014, entire) modelled risk of potential future oil spills in Alaska's waters. The risk model consisted of three elements: 1) vulnerability of the environment to oil spill impacts; 2) probability of a spill based on past and projected future incident rates; and 3) potential maximum most probable discharge and worst-case discharge volumes that could result from an incident now or in the future (NOAA 2014, p. 4). Future spill risks were modelled to the year 2025. The report found the Aleutian Islands (Aleutian Islands LME) to have the second highest relative risk for a future oil spill, based upon a high environmental vulnerability due to the species diversity found in the region (NOAA 2014, p. 62, 77). Southeast Alaska (Gulf of Alaska LME) had the third highest relative risk for a future oil spill (NOAA 2014, pp. 77–78).

In the last decade, the number of vessels operating in waters within the U.S. Arctic (including the North Bering and Chukchi Sea LME) has increased by 128 percent and is now 2.3 times larger than the number of ships passing through the region in 2008 (CMTS 2019, p. iv). Based on recent projections, it's possible that the number of vessels operating in the U.S. Arctic in 2030 is likely to be more than triple the activity in 2008 (CMTS 2019, p. 116).

Again, the potential for future oil spills is heavily dependent on whether cargo shipping or shipping routes increase, future economic conditions, and mitigation measures that may be implemented (e.g., double hull tanks) are implemented (NOAA 2014, p. 58).

4.3 Additional Future Threats

As the climate continues to change, nonnative plants and animals species are expected to increase on nesting islands across the tufted puffin's range; the IPCC's Special Report on the Ocean and Cryosphere in a Changing Climate found, with high confidence, that nonnative species will pose increased risks to Arctic marine ecosystems and coastal communities (IPCC 2019a, p. SPM-17). Anticipated range expansions of species in response to climate change may allow alien species brought into an area by human activities to become invasive and outcompete native species (IPCC 2019b, p. 3-73). Increases in Arctic marine transportation, in particular, pose risks for introduction of nonnative species (IPCC 2019b, p. 3-83); increased marine traffic could increase the risks of nonnative plants and animals on tufted puffin nesting colonies.

Increased future threats from fisheries bycatch, mammalian and avian predators, and human disturbance, are unknown.

4.4 Modelled Future Conditions for Tufted Puffins

Two relatively recent papers (Goyert *et al.* 2017; Hart *et al.* 2018) model tufted puffin populations dynamics and develop future population projections from these models. The papers differ in the data used and the modeling approach taken, to include: (1) a population viability analysis for five Alaskan seabirds, including tufted puffins (section 4.4.1) (Goyert *et al*. 2017, entire); and projected range-wide distribution for tufted puffins (section 4.4.2) (Hart *et al*. 2018, entire).

4.4.1 Goyert *et al.* 2017: Population Viability Analysis for Alaska

Goyert *et al.* (2017, pp. 178–187) examined density dependence and changes in the carrying capacity of five Alaskan seabirds, including the tufted puffin, using LMEs (ecoregions) as analysis units. Using data collected from 1973–2014 (and noting that all colonies were not monitored in all years), Goyert *et al.* (2017, pp. 179–183) used existing colony counts (estimated from 1988–2014) to model projections for future estimated tufted puffin populations. These models projected tufted puffin populations 30 years (to the year 2045) and 100 years (to the year 2115) into the future (Goyert *et al.* 2017, pp. 178–187). The Goyert *et al*. (2017, entire) models estimate strong rates of decline, particularly in the Gulf of Alaska LME, and predicts extirpation of tufted puffins from the Gulf of Alaska LME within 100 years.

The authors themselves recommend treating their tufted puffin projections with caution (Goyert *et al.* 2017, p. 185). They acknowledge that the tufted puffin data used in this model was sparse relative to the spatial ranges of interest. Six monitored colonies and two at sea data locations informed the population dynamics in Alaska (two monitored colonies and one at sea location from the Gulf of Alaska LME, two monitored colonies from the East Bering Sea LME, and two monitored colonies and one at sea location within Aleutian Islands LME). In addition, estimates of the carrying capacity across Alaska derived from the models are not consistent with the Beringian Seabird Colony Catalog (now known as the North Pacific Seabird Colony Database) or current estimates of the global population size.

4.4.2. Hart *et al*. 2018: Range-wide Species Distribution Model

Hart *et al.* (2018, pp. 1–26) used approximately 50 years of nesting-habitat distribution information, ranging from California to the Bering Sea, to map tufted puffin nesting habitat in North America, with particular emphasis on the California Current LME (Hart *et al.* 2018, pp. 1–26). Species distribution data (presence/absence) was obtained from State and Federal agencies, as well as non-profit organizations. Current presence was defined as the most recent survey observation between 1950 and 2009 (Hart *et al.* 2018, p. 5). With respect to environmental drivers of observed distributions, the authors focused on temperature (air temperature, which was highly correlated with sea surface temperature), citing Gjerdrum *et al.* (2003, entire) and Hipfner *et al.* (2007, entire) to link temperature, prey availability, and tufted puffin fledgling success and growth rates. Current climate data (1950–2000) was obtained from WorldClim and future climate data was averaged over eight climate models for two emissions scenarios defined by the IPCC 5th Assessment Report (IPCC 2014, entire), RCP 4.5 and RCP 8.5, representing intermediate and status quo scenarios, respectively. Species Distribution Models (SDMs) were used to relate climate variables to the probability of observing *at least one* breeding tufted puffin at a given site, with data extrapolated across the entire species range. Annual temperature range and mean temperature of the warmest quarter were the most predictive environmental variables.

Models predict an overall 22 percent contraction in the North American range of tufted puffin under RCP 4.5, and a 26 percent contraction in range under RCP 8.5 by 2050 (Hart *et al.* 2018, pp.1–26). Most of this range contraction is estimated to occur due to a projected loss of observed colonies in the California Current LME north into southeastern Alaska (i.e., the Gulf of Alaska LME). These overall contraction rates also account for possible northward range expansion (Hart *et al.* 2018, pp. 1–26), although the best available scientific information currently does not show that this northward projection has occurred, and there is no guarantee that northward range expansion will occur (e.g., habitat may not be suitable for nesting). The projected southern range contraction as well as the possible northward range expansion are consistent with the hypothesized relationship between puffin habitat and temperature (Hart *et al.* 2018, pp. 11), and the southward range contraction is in line with the declines seen in the California Current and Oyashio Current LMEs. Hart *et al.* (2017, entire) predicted the extirpation of tufted puffin in the California Current LME.

Hart *et al.* (2018, entire) was published in an open source journal, which made the data and code available for replication. To expand our understanding of potential future distribution across the tufted puffin's range, we took the data and model used by Hart *et al.* (2018, entire) and extrapolated out to the year 2070. We selected 2070 as our time horizon to account for the reported tufted puffin generation time of 21.6 years (Birdlife International 2018, p. 2), and to evaluate future conditions for at least two generations. The results of the extrapolated analysis can be found in Appendix G.

The SDM model extrapolated to 2070 showed consistent declines across the range in response to two climate change scenarios, the RCP 4.5 scenario and the RCP 8.5 scenario. The SDM model shows declines in the California Current LME, and a strong correlation between continued warming and increasing availability of tufted puffin habitat in the North Bering and Chukchi Sea LME. This potential range expansion should be treated with caution, as there is no indication that suitable tufted puffin habitat would be available in the North Bering and Chukchi Sea LME to allow a northward expansion of tufted puffins.

4.5 Plausible Future Scenarios

We examined three plausible future scenarios to estimate tufted puffin populations into the future. We chose to forecast to 2070, since tufted puffin generation time is approximately 21.6 years (Birdlife International 2018, p. 2). This allows us to make inferences on tufted puffin populations for at least two generations. For our Future Scenarios evaluation, we chose two RCP trajectories: RCP 8.5, which is now considered business-as-usual, or status quo; and RCP 4.5, now considered a moderated scenario, in which extraordinary measures would need to be implemented globally to slow the warming trajectory.

4.5.1 Scenario 1: Status Quo Scenario - RCP 8.5 (2070)

Under the Status Quo scenario, we assume that the projected increase in greenhouse gas emissions under RCP 8.5, would continue to result in exacerbated climate change impacts to tufted puffin (SSTs, reduced prey availability, harmful algal blooms, ocean acidification, etc.). Under this scenario, we assume that all other threats would remain the same (Table 4-1).

4.5.2 Scenario 2: Improved Conservation Scenario – RCP 4.5 (2070)

For this scenario, we assume that management and conservation actions would be implemented to reduce some of the current threats to tufted puffin. Greenhouse gases would follow the RCP 4.5 trajectory, which would presumably help to slow or stop current climate change impacts to tufted puffin. In addition, under this scenario, there would be reduced oil spills (through adoption of new technologies, for example, or changes in shipping traffic to avoid nesting islands), and reduction or removal of non-native species due to implementation of management actions (Table 4-1).

4.5.3 Scenario 3: Increased Threats Scenario – RCP 8.5 (2070)

For this scenario, we assume there would be an increase in threats (Table 4-1) to the tufted puffin, and management actions would not be implemented. Greenhouse gases would follow the RCP 8.5 trajectory, which would presumably lead to increased impacts from climate change. In addition, under this scenario there would be:

- Increased oil spills (continued or increased shipping traffic; exploration)
- No change in bycatch
- An increase in nonnative plants and animals on nesting colonies (IPCC 2019a, p. SPM-17; IPCC 2019b, pp. 3-73 and 3-83).
- Commercial fishing of prey

4.6 Future Conditions Analysis and Summary

As shown in Goyert *et al.* (2017, entire), Hart *et al.* (2018, entire), and our extrapolation of Hart *et al.* (2018), RCPs were predictive of future population trends, in line with our finding that climate change (including SSTs and reduced prey availability) was one of the most influential threats for the tufted puffin. All models showed agreement that with increasing greenhouse gases, the population trend for all analysis units declined. In addition, Hart *et al.* (2018, pp. 12–13) found that summer temperature was a strong predictor of tufted puffin breeding habitat, including the southern range contraction.

Table 4-1. Anticipated changes in threats to tufted puffins for each plausible future scenario

Future Scenarios	RCP Trajectory	Climate Change	Oil Spills	Nonnative Plants and Animals
Scenario 1 – Status Quo	RCP 8.5	Increased SSTs; reduced prey availability; harmful algal blooms; ocean acidification; increased tufted puffin mortality	Increased oil spills; higher tufted puffin mortality due to oil spills	Increased nonnative predators; increased competition from nonnative species, for food and burrow habitat
Scenario 2- Improved Conservation	RCP 4.5	Slower increases in SSTs; fewer harmful algal blooms; reduced tufted puffin mortality	Reduced oils spills; decreased tufted puffin mortality due to oil spills	Fewer nonnative predators; decreased competition from nonnative species, for food and burrow habitat
Scenario 3- Increased Threats	RCP 8.5	Increased SSTs; reduced prey availability; harmful algal blooms; ocean acidification; increased tufted puffin mortality	Increased oil spills, higher tufted puffin mortality	Increased nonnative predators; increased competition from nonnative species, for food and burrow habitat

Based upon modelled population declines for all analysis units other than the North Bering and Chukchi Sea LME, all three scenarios had similar outcomes. The two RCP 8.5 scenarios (Scenario 1 and 3) can be expected to result in the condition of each LME declining, and the moderated RCP 4.5 scenario (Scenario 2) can be expected to result in the condition of each LME either staying the same or declining slightly. For the purpose of discussing future conditions, LMEs were considered to exhibit no change in their condition under the moderated RCP 4.5 scenario (Scenario 2), with the exception of the Oyashio Current LME.

The northward range expansion shown by Hart *et al.* (2018, pp. 12–13), and reflected in the future condition table, specific to the Northern Bering and Chukchi Sea LME, should be treated with caution; there is no guarantee that continued warming will lead to increased availability of tufted puffin habitat in the North Bering and Chukchi Sea LME. The summary of future conditions for three plausible scenarios forecast to 2070 is shown in Table 4-2.

Table 4-2. Summary of potential future conditions[15] of LMEs under three plausible future scenarios forecast to 2070: (1) Status Quo (RCP 8.5); (2) Improved Conservation (RCP 4.5 with mitigation), and (3) Increased Threats (RCP 8.5).

Analysis Unit (LME)	Current[1] Condition	Scenario 1: RCP 8.5 Status Quo 2070	Scenario 2: RCP 4.5 with improved conservation/ mitigation 2070	Scenario 3: RCP 8.5 with Increased Threats 2070
California Current	Low	Low	Low	Low
Gulf of Alaska	Moderate	Low	Moderate	Low
East Bering Sea	Moderate	Low	Moderate	Low
Aleutian Islands	High	Moderate	High	Moderate
North Bering and Chukchi Sea	Moderate	High	Moderate	High
West Bering Sea	Unknown	Unknown	Unknown	Unknown
Sea of Okhotsk	Unknown	Unknown	Unknown	Unknown
Oyashio Current	Low	Extirpated[2]	Extirpated[2]	Extirpated[2]

[1] Based on trend data (Pearson *et al.* 2019) as well as current stressors, documented and modelled current and future declines across the range; Goyert *et al.* 2017; Hart *et al.* 2018; updated Species Distribution Model to 2070, using Hart *et al.* 2018 data and code (Appendix G).
[2] Based on extremely low current numbers, extirpation is likely under all three future scenarios.

Chapter 5: Viability

We considered what the tufted puffin needs for viability (Chapter 2) and have evaluated the species' current condition in relation to those needs (Chapter 3). We also forecast how the species' condition may change in the future under three different scenarios (Chapter 4). In this chapter, we synthesize the results from our historical, current, and future analyses, and discuss the potential consequences for the future viability of the tufted puffin. We assess the viability of the species by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophic events (redundancy), and changes in its environment (representation) into the future.

[15] Please note, if an LME is found to be in "HIGH" condition, tufted puffins found within are considered to be highly resilient; that is, able to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance. An LME in "MODERATE" condition means tufted puffins found within have some resiliency, although potentially to a lesser degree. An LME in "LOW" condition is considered to be more vulnerable to natural, annual variation, with a reduced ability to recover from periodic disturbance.

5.1 Resilience

Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance.

For this analysis, we used the eight LMEs across the range of the species as analysis units. Based upon the relevant factors evaluated in our analysis, one of the LMEs (Aleutian Islands) is currently in overall high condition, and three LMEs (Gulf of Alaska, East Bering Sea, Northern and Chukchi Sea) are in moderate condition (Table 4-2). The best available information suggests that the Oyashio Current LME will lose its tufted puffins in the near-term future; this was predicted by Piatt and Kitaysky (2002, p. 20) almost two decades ago. The status of the two LMEs in Russia (West Bering Sea and Sea of Okhotsk) is unknown. The California Current LME is currently in low condition based on a declining population trend and threats from climate change and oil spills. This LME has experienced an estimated 92 percent population decline between 1905 and recent estimates (Pearson *et al. 2019*, p. 8).

Our predictions of future conditions were similar for all LMEs; the condition of most LMEs are expected to decline under Scenario 1 (RCP 8.5, status quo) and Scenario 3 (RCP 8.5, increased threats), with the exception of the North Bering and Chukchi Sea LME. Two populations, the Gulf of Alaska and East Bering Sea LMEs, will join the California Current LME in low condition. The Aleutian Islands LME will have an increased risk of decreasing from high to moderate condition; the North Bering and Chukchi Seas LME may move into high condition from moderate condition as warming temperatures potentially make this area more suitable for nesting tufted puffins (it is also possible it will remain in moderate condition; the models do not agree) (Hart *et al.* 2018, p. 12). Under the moderated RCP 4.5 scenario (increased mitigation), most of the LMEs are expected to retain their current condition into the future. Finally, the Oyashio Current LME is likely to be extirpated in the near-term future in all three scenarios. In general, we predict the species will maintain a mixed resiliency into the future (Table 4-2).

The Aleutian Islands LME, widely considered to have the largest breeding population of tufted puffins in North America (45 percent; Piatt and Kitaysky 2002, p. 18) is currently in high condition and predicted to maintain at least moderate condition under all three future scenarios. There was very little difference between the future scenarios on the tufted puffin's estimated resilience. Even with population declines forecast for two of the three future scenarios, the tufted puffin is expected to maintain populations in every part of its range, although at lower abundance, with the exception of the Oyashio Current LME, which is predicted to be extirpated. Maintaining its presence throughout most of its current range (excluding Japan) will allow the tufted puffin to withstand annual environmental variation and stochastic events.

5.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication or distribution of populations across the range of the species.

Historically, the tufted puffin ranged from Southern California to the East Bering Sea in Alaska and Russia, then south to Japan. The tufted puffin has maintained its wide distribution across most of its historical range, and maintains relatively high abundance. The tufted puffin remains distributed across the spatial extent and ecological settings of its historical range, with the exception of the Oyashio Current LME off the coast of Japan, likely to be extirpated in the near future.

While the species' redundancy is likely lower than in the past, tufted puffins still have high duplication and distribution of populations across the species' range. Tufted puffin colonies located in the core of its range (i.e., the Aleutians and the Alaska Peninsula) (Piatt and Kitaysky 2002, p. 18) are often large (some colonies have more than 100,000 birds); some large colonies also occur in other portions of its range. This redundancy makes it unlikely that a catastrophic event could extirpate all of the populations.

Under all of our future scenarios, we predict the tufted puffin will retain at least two of the eight analysis units across its range in moderate to high condition (two of the analysis units; those in Russia, remain in unknown condition).

The Aleutian Islands LME, which is currently in high condition, has a low risk of falling below moderate condition in two of three future scenarios, and is comprised of multiple colonies that contain almost half of the breeding population of tufted puffins in North America (45 percent; Piatt and Kitaysky 2002, p. 18). The North Bering and Chukchi Seas LME may increase its tufted puffin population under two of the three future scenarios, as warming climate conditions make more of the area suitable for nesting. However, this possible northward range expansion is uncertain, and should be treated with caution (Hart *et al.* 2018, entire).

While the extirpation of the Oyashio Current LME, and declines in the Gulf of Alaska, East Bering Sea, and California Current LMEs would indicate a decrease in the species' redundancy, tufted puffins would remain extant in most LMEs within their range, but at significantly lower abundance. The exception would be the Oyashio Current LME, which is predicted to be extirpated in all future scenarios. As stated previously, it is also important to recognize that the current and future condition of the two analysis units in Russia is unknown. Anecdotal evidence suggests that at least one, if not both, of the Russia LMEs (West Bering Sea and Sea of Okhotsk) have an increasing population trend, similar to the positive trend observed in the Aleutian Islands.

5.3 Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. It can be thought of as the 'adaptability' of the species.

A species' representation is measured by looking at the genetic, morphological, behavioral, and ecological diversity within and among populations across its range. The more representation, or diversity, a species has, the more likely it is to persist in changing environments. Historically, the tufted puffin has been distributed over a large latitudinal range, spanning the United States, British Columbia, Russia, and Japan. Within this range, the tufted puffin displays varying phenology, typically breeding earlier in the lower latitudes and later in the higher latitudes. In addition, tufted puffins across the range may adapt to local conditions by selecting different types of breeding habitat. For instance, although tufted puffins are primarily burrow nesters, in areas that have shallow soils, frozen ground, or predators, tufted puffins are more likely to nest in cracks and crevices that are inaccessible to predators (Piatt and Kitaysky 2002, p. 5; Renner 2019, pers. comm.). Food availability and species can also vary across the range, with some tufted puffins repeatedly and preferentially selecting specific forage fish to feed their chicks. We know of no morphological differences between tufted puffins across their range.

Information on population genetics and range-wide genetic structuring of the tufted puffin is limited. Recent studies have examined population differentiation among four breeding colonies in Alaska (Buldir Island, Chowiet Island, Aiktak Island, and East Amatuli Island) and one breeding colony in British Columbia, Canada (Triangle Island) (Graham *et al.* 2019, pers. comm.). Preliminary results show strong genetic differences among the northern most colonies (Buldir and Chowiet) compared to the southernmost colony sampled (Triangle), which increases their adaptability to changing conditions.

Tufted puffins still occupy most of their historical range and all of the varied habitats within it. In all of our future scenarios, we predict the tufted puffin will continue to occupy most of its full range and ecological settings, remaining widely distributed, with the exception of the population in Japan (the Oyashio Current LME). Climate models predict the tufted puffin's southern range will contract, but also indicate a possible northern range expansion (Goyert *et al.* 2017; Hart *et al.* 2018).

5.4 Summary

The consensus among experts (Goyert *et al.* 2017, pp. 178–187; Hart *et al.* 2018, pp. 1–26; Hanson *et al.* 2019, p. 2; Pearson *et al.* 2019, p. 1) is that tufted puffins are undergoing a range contraction, particularly on the southern end of its range (i.e., the California Current LME along the West Coast of the U.S, and the Oyashio Current LME along the coast of Japan). However, the species continues to be widely distributed across its northern historical range, and maintains high abundance overall. The most recent range-wide estimate is approximately 3,000,000 (Piatt and Kitaysky 2002, p. 31; NPSD 2019, entire), though it is important to note that estimate was based on information gathered nearly two decades ago. Despite the potential for future population declines (as modelled by Goyert *et al.* 2017, entire; Hart *et al.* 2018, entire; and Bradley 2019, entire), tufted puffins are expected to maintain their resiliency, redundancy, and representation, albeit at reduced abundance, throughout most of their range, and into the foreseeable future.

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Appendix A: Summary of Existing Regulatory Mechanisms

California	Listed as a species of special concern by the State of California[1]
Oregon	Listed as sensitive by the State of Oregon[2]
Washington	Listed as endangered by the State of Washington[3]
Canada ***British Columbia***	Listed as a priority species in the North Pacific Rainforest Bird Conservation Region Strategy[4] Listed as a species of special concern (imperiled/vulnerable) in British Columbia[5]
Alaska	Not listed
Russia	Not listed
Japan	Listed as a vulnerable species (endangered) by Japan[6]

[1] CDFW 2019; [2] ODFW 2019; [3] WDFW 2019; [4] Government of Canada 2014; [5] Government of British Columbia 2019; [6] Government of Japan 2019.

<u>Regulatory Mechanisms in the United States</u>

The United States has several laws that provide protection of tufted puffins. These include the Migratory Bird Treaty Act, which protects tufted puffins from direct, intentional harm; the Organic Act of 1916, which established the National Park Service; and the National Wildlife Refuge Administration Act, which consolidated U.S. Fish and Wildlife Service lands into the National Wildlife Refuge System, for the conservation and protection of natural and cultural resources. National Park Service and National Wildlife Refuge System lands, managed by the Federal government for conservation of natural resources, provide a degree of protection for nesting tufted puffins.

- The Migratory Bird Treaty Act (16 U.S.C. 703-712) makes it illegal to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, their parts, nests, or eggs except under the terms of a valid Federal permit.

- The Organic Act of 1916 (16 U.S.C. l, 2, 3 and 4) created the National Park Service, whose stated mission is"…to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

- The National Wildlife Refuge Administration Act (16 U.S.C. 668) consolidated areas administered by the Secretary of Interior, including, "…all lands, waters, and interests therein administered by the Secretary as wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas are hereby designated as the 'National Wildlife Refuge System'…"

- The Wilderness Act (16 U.S.C. 1131-1136) established the National Wilderness Preservation System and instructed federal land management agencies, including the National Park Service, to manage wilderness areas and preserve wilderness character.

Additional Regulatory Mechanisms in the State of California

The State of California includes the tufted puffin on the California Bird Species of Special Concern list. "Species of special concern" is an administrative designation to focus attention on animals at conservation risk, and carries no formal legal status (CDFW 2019, entire). Species of special concern are included in the State Wildlife Action Plan, which provides threat assessments for habitats that support these species, and provides conservation goals and actions for these habitats (CDFW 2019, entire).

Additional Regulatory Mechanisms in the State of Oregon

The State of Oregon lists the tufted puffin as a "sensitive" species. The State of Oregon developed a "sensitive" species classification under Oregon's Sensitive Species Rule (OAR 635-100-0040), to prioritize conservation actions and prevent species from becoming eligible for listing as endangered or threatened on the state Threatened and Endangered Species list (OAR 635-100-0080). Species listed as "sensitive" have no formal legal status under the rule.

The State of Oregon also lists the tufted puffin in their Oregon Conservation Strategy, a strategy developed by the State to conserve fish and wildlife. The goals of the strategy are "to maintain healthy fish and wildlife populations by maintaining and restoring functioning habitats, preventing declines of at-risk species, and reversing declines in these resources where possible" (ODFW 2019, entire).

Additional Regulatory Mechanisms in the State of Washington

The State of Washington listed the tufted puffin as "endangered" in 2015, under the State of Washington's Wildlife Classification, and the Endangered, Threatened, and Sensitive Wildlife Species Classification Rules (RCW 77.12.020 and WAC 220-610-110). The state published the Washington State Recovery Plan and Periodic Status Review for the Tufted Puffin (Hanson et al 2019, entire), which identifies conservation actions and reclassification criteria for the species.

Regulatory Mechanisms in Canada/British Columbia

Canada protects migratory birds, including the tufted puffin, under the Migratory Birds Convention Act of 1994 and its implementing regulations, which prohibits the hunting of migratory nongame birds, and the possession or sale of "migratory birds, their nests, or eggs".

Canada lists the tufted puffin as a priority species in Environment and Climate Change Canada's North Pacific Rainforest Bird Conservation Region Strategy, which lists bird conservation priorities for Canada's migratory birds programs. Priority species are species vulnerable due to population size, distribution, population trend, abundance and threats, and are of conservation concern.

The British Columbia Wildlife Act of 1996 protects virtually all vertebrate animals from direct harm, except as allowed by regulation (e.g., hunting or trapping). Tufted puffins are listed as a species of special concern (imperiled/vulnerable) because of characteristics that make them particularly sensitive to human activities or natural events. However, this does not afford any additional protections.

Regulatory Mechanisms in Russia

The Conservation of Migratory Birds and their Environment, signed by the Union of Soviet Socialist Republic and the United States in 1976 and 1978, protects migratory birds including the tufted puffin, and establishes cooperative conservation. This agreement automatically renews every fifteen years, and remains in place.

Regulatory Mechanisms in Japan

In Japan, the Wildlife Protection and Hunting Law protects birds and mammals in Japan. In 1991, the Wildlife Protection Division initiated a study on threatened flora and fauna of Japan, resulting in the publication of the "Red Data Book of Japan". The tufted puffin is listed as a species of special concern (imperiled/vulnerable) in the Red Data Book (Government of Japan 2019).

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Appendix B: Resource Needs of the Tufted Puffin by Life Stage

Life Stage	Resource Needs
Egg	● Adult(s) to incubate egg 42–46 days and protect from predators (Piatt and Kitaysky 2002, p. 14). ● Rock, reef, boulders, island, sea cave, or cracks and crevices of sea or mainland cliffs that can provide nesting habitat (crevice or burrow) (Piatt and Kitaysky 2002, pp. 5, 13). ● Nesting habitat including soil and vegetated turf to enable a burrow to be excavated (Piatt and Kitaysky 2002, p. 13). ● Nesting materials (dry grass, small twigs, feathers) in vicinity of nests or at sea, along with algae and other floating materials, including scraps of plastic line and gillnets (Piatt and Kitaysky 2002, p. 13). ● Adequate soil depth (Kettle 2019, pers. comm.). ● At E. Amatuli Island, gradual slope burrows had a depth of 43 cm; burrow density was higher near the cliff edge, and burrows near the cliff edge measured 1.5 in (39 cm) in depth (Amaral 1977, p. 33). ● Burrow/crevice microclimate approximately 48.2–51 ^{o}F (9–10.5 ^{o}C) for egg-laying and 55.4–60 ^{o}F (13–15.5 ^{o}C) for hatching (Wehle 1980, p. 54).
Chick	● Rock, reef, island, sea cave, or mainland cliffs that can provide nesting habitat (crevice or burrow). Some nesting habitat require soil and vegetated turf to enable a burrow to be excavated (Piatt and Kitaysky 2002, p. 13). ● One parent usually spends night in nesting burrow until chick is about 6 week old (Piatt and Kitaysky 2002, pp. 5–6, 13, 15). ● Food resources comprised of predominantly fish species (i.e., small schooling fishes such as (but not limited to) anchovy, capelin, lanternfish, juvenile pollock, rockfish, greenling, sand lance) (Piatt and Kitaysky 2002, pp. 5–6; Wehle 1983, p. 440). ● Enough food resources provided by adults to grow at about 2.5% of adult weight/day to attain weight and wingspan necessary for fledging (approximately 1.09 lb (496 g)) (Wehle 1983, pp. 431, 439). ● Adult to remain with chick until chick can thermoregulate (approximately day 6) (Wehle 1980, p. 74).
Juvenile	● Marine environment (Pacific Ocean) with available prey. Diet consists of 50–70% invertebrates and remainder fish (Wehle 1982, p. 56; Wehle 1983, p. 440). ● Invertebrates include squid, polychaetes, and euphausiids; fish include mainly anchovy, capelin, lanternfish, pollock, rockfish, greenling, and sand lance (Piatt and Kitaysky 2002, p. 5; Wehle 1983, p. 440).

Life Stage	Resource Needs
Non-breeding Adult (summer or winter)	● Marine environment (Pacific Ocean) with available prey. Diet consists of 50–70% invertebrates and remainder fish (Wehle 1982, p. 56; Wehle 1983, p. 440). ● Invertebrates include squid, polychaetes, and euphausiids; fish include mainly anchovy, capelin, lanternfish, pollock, rockfish, greenling, and sand lance (Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5).
Breeding Adult (nesting)	● Rock, reef, island, sea cave, or mainland cliffs that can provide nesting habitat (crevice or burrow). Burrow nesting habitats require proper soils and vegetated turf to enable a burrow to be excavated (Piatt and Kitaysky 2002, p. 13). ● Spacing between burrows/crevices to reduce conflicts with neighbors (Piatt and Kitaysky 2002, p. 10). ● Sufficient supply of nesting materials, particularly in areas predominantly crevice nests (Piatt and Kitaysky 2002, p. 13). ● Marine environment (Pacific Ocean) with available prey. Diet consists of 50–70% invertebrates and remainder fish (Wehle 1982, p. 56; Wehle 1983, p. 440). ● Invertebrates include squid, polychaetes, and euphausiids; fish include mainly anchovy, capelin, lanternfish, pollock, rockfish, greenling, and sand lance sand lance (Wehle 1983, p. 440; Piatt and Kitaysky 2002, p. 5). ● Sufficient prey within 197 ft. (60 m), 361 ft. (110 m) maximum, of surface (Piatt and Kitaysky 2002, pp. 5–6).

Appendix C: Excerpted Descriptions of Large Marine Ecosystems (LME) Analysis Units

Summary descriptions of the LMEs used as analysis units in this SSA, excerpted from NOAA 2019a, entire. Additional information for LMEs available at h*ttp://lme.edc.uri.edu/* or *https://www.pame.is/index.php/projects/ecosystem-approach/arctic-large-marine-ecosystems-lme-s*.

California Current (LME #3)
The California Current LME is bordered by the USA and Mexico, between subtropical and subarctic LMEs. The shoreline is more than 2,000 mi (3,219 km) long, and the LME features more than 400 estuaries and bays, including the Columbia River, San Francisco Bay, and Puget Sound, which constitute 61 percent of the estuary and bay acreage. This LME is characterized by its temperate climate, and strong coastal upwelling (NOAA 2019a, entire).

Productivity and Oceanography
Coastal upwelling, the El Niño Southern Oscillation and the Pacific Decadal Oscillation contribute to strong inter-annual variability in the productivity of the ecosystem (NOAA 2019a, entire). The Pacific Decadal Oscillation is a 20- to 30-year cooling and warming cycle between a cool and productive ocean regime and a warm and unproductive ocean regime. The latest warm regime was in 2003–2006. These cycles lead to changes in primary and secondary production, and changes in the abundance of eastern Pacific fish stocks (NOAA 2019a, entire). Seasonal upwelling of cold, nutrient-rich water contribute to areas of high primary productivity that support fisheries for sardines, anchovy, and other pelagic fish species (NOAA 2019a, entire).

Fish and Fisheries
Fisheries resources include salmon, pelagic fisheries, groundfish, and invertebrates. Small pelagic resources in the LME are Pacific sardine, northern anchovy, jack mackerel, chub (Pacific) mackerel, and Pacific herring (NOAA 2019a, entire). The collapse of the Pacific sardine stock has affected other ecosystem components, including marine birds (NOAA 2019a, entire).

Pollution and Ecosystem Health
The major factors affecting ecosystem health in this LME are the effects of shifting oceanic climate regimes, the intensive harvesting of commercial fish, releases of captive-bred salmon, and low-level, and chronic pollution from multiple sources (NOAA 2019a, entire).

Socioeconomics
Three major estuaries, the San Francisco Bay, the Columbia River, and Puget Sound, contribute to the local economy and enhance the quality of life of the inhabitants. Human population pressures are increasing in Puget Sound, the Seattle-Tacoma region, San Francisco Bay, and southern California (NOAA 2019a, entire).

Governance
The Pacific Fishery Management Council is responsible for managing fisheries off the coasts of California, Oregon, and Washington, along with state and tribal fishery agencies. Chinook and

coho salmon within Puget Sound and the Columbia River are managed by the states and tribes (NOAA 2019a, entire).

Gulf of Alaska (LME #2)
The Gulf of Alaska LME lies off the southern coast of Alaska and the western coast of Canada, and is separated from the East Bering Sea LME by the Alaska Peninsula. The cold Subarctic Current serves as the boundary between the Gulf of Alaska and the California Current LMEs (NOAA 2019a, entire).

Productivity and Oceanography
The Gulf of Alaska LME is considered a moderately productive ecosystem, with nutrient-rich waters that support a biologically diverse ecosystem (NOAA 2019a, entire). Large-scale atmospheric and oceanographic conditions affect productivity; changes in zooplankton biomass have been observed (NOAA 2019a, entire). Pacific herring is the major pelagic species harvested in the LME. The groundfish complex (walleye pollock, Pacific cod, flatfish, sablefish, rockfish, and Atka mackerel) is an abundant fisheries resources in the Gulf of Alaska LME but less so than in the neighboring East Bering Sea LME (NOAA 2019a, entire).

Fish and Fisheries
This LME supports a number of commercially important fisheries for crab, shrimp, scallops, walleye pollock, Pacific cod, rockfishes, sockeye salmon, pink salmon, and halibut. The largest fisheries for sockeye salmon, the salmon species of highest commercial value in the U.S. portion of the LME, occur in Cook Inlet, Kodiak Island, and Prince William Sound (NOAA 2019a, entire).

Pollution and Ecosystem Health
Problems affecting the LME include predation by invasive species, discharges of oil products, and industrial and agricultural contaminants that enter the LME through a variety of pathways including ocean currents and prevailing winds (NOAA 2019a, entire).

Socioeconomics
The LME coastal population is low relative to the length of the coastline, with the exception of the city area of Vancouver in the Canadian province of British Columbia. Native peoples have a long and rich tradition of relying on salmon for economic, cultural, and subsistence purposes. The coastal native communities rely for their subsistence largely on hunting and the harvesting of marine resources. The economy of the coastal communities is based on commercial fishing of pink and red salmon, fish processing, timber, minerals, agriculture, and tourism (NOAA 2019a, entire).

Governance
The Gulf of Alaska LME is bordered by the U.S. and Canada, each with separate government actions and management plans (NOAA 2019a, entire).

East Bering Sea (LME #1)
The East Bering Sea LME is characterized by an extremely wide, gradually sloping shelf, and by seasonal ice cover in March that extends over most of this LME. The LME is bounded by the Bering Strait to the north, by the Alaskan Peninsula and Aleutian Island chain to the south, and by a coastline to the east, thousands of miles in length (NOAA 2019a, entire).

Productivity and Oceanography
Temperature, currents, and seasonal oscillations influence the productivity of this LME. The East Bering Sea is a moderately high productivity ecosystem that is undergoing climate driven changes in some species' abundance and distribution. For example, there have been nearly ice-free conditions in the mid shelf from January to May in 2000–2004. Accompanying this change are shifts in the trophic structure, with walrus (*Odobenus rosmarus*) populations moving northward with the ice, and Alaska pollock moving east (NOAA 2019a, entire).

Fish and Fisheries
The LME's thousands of miles of coastline support populations of five species of salmon (pink, sockeye, chum, Coho, and Chinook). Sockeye salmon (in Bristol Bay, Alaska Peninsula, and Aleutian Islands) is the most valuable of the salmon species but has had recent declines. Chum salmon have seen similar recent declines; in some years, significant numbers of chum salmon are caught as bycatch in fisheries that target pollock and other groundfish. Despite relatively stable Chinook stocks, there is concern over abundance trends. Groundfish (Pacific halibut, Walleye pollock, Pacific cod, flatfish, sablefish, and Atka mackerel) are the most abundant fisheries resources off the East Bering Sea LME. The dominant species harvested are pollock and cod (NOAA 2019a, entire).

Pollution and Ecosystem Health
The coastal resources in this LME are generally in pristine condition. Coastal habitats are favorable to the high abundance of salmon, with minimal impact from extensive development. Salmon are anadromous and depend on freshwater streams, rivers, and lakes. Their health is directly influenced by land management practices. The conservation of the region's salmon resource requires conservation of the thousands of miles of riparian habitat that support salmon production (NOAA 2019a, entire). Competing uses for this habitat include logging, mining, oil and gas development, and industrial and urban development. Concerns for the health of this LME focus on petroleum hydrocarbons found in the tissue of marine mammals, and the effects of the growing industrialization of the region. The East Bering Sea LME has low levels of toxic contaminants, but these have been rising over the last 50 years due to increased human activities (e.g., mining, fishing, and oil exploration). This increase has been linked to the long-range transport of contaminants through the ocean and atmosphere from other regions (NOAA 2019a, entire).

Socioeconomics
The Alaskan coast east of the East Bering Sea LME has a low population relative to its size, and is distant from major urban or industrial areas. Native Alaskans live on the shores of this LME, with a long tradition of relying on salmon and other marine resources for economic, cultural, and subsistence purposes. Pacific salmon plays an important and pivotal role, along with mining, timber, and furs, keystone natural resources that led to the settling and development of the U.S.'s

49th state by nonnative peoples. Many Alaskans still depend heavily on salmon for recreation, food, and industry. Recent declines in chum and sockeye salmon runs have added to the hardships experienced by fishermen in Bristol Bay. The value of the salmon catch has declined over the past decade, along with a rising trend in total worldwide salmon production with the rapid growth of farmed salmon especially in Norway, Chile, and the United Kingdom. Nearshore fishery resources provide important subsistence and recreational fishing opportunities for Alaskans in the East Bering Sea LME. Subsistence fishing occurs all along the coastline of the LME (NOAA 2019a, entire).

Governance

The East Bering Sea LME is bordered by the State of Alaska, USA. The Alaska Board of Fisheries deals with the allocation of fish resources and quotas among various fisheries. The North Pacific Fishery Management Council (NPFMC) has primary responsibility for groundfish management within the U.S. Exclusive Economic Zone (EEZ) (3 to 200 nautical miles) off the coasts of the East Bering Sea and Aleutian Islands, with the goal of maintaining stable yields by regulating harvest allocations among species. The Alaska native populations benefit from individual fishing quotas and community development quotas. Lastly, pelagic and salmon fisheries within three nautical miles of the coast are managed by the Alaska Department of Fish and Game (NOAA 2019a, entire).

Aleutian Islands (LME #65)

This LME consists of the Aleutian Islands with the surrounding deep waters (PAME 2013, entire). Originally part of the East Bering Sea LME, the Aleutian Islands LME recognizes distinct features of productivity and trophic structure that are shaped by the interaction of currents and bottom topography of the many passes between volcanic islands of the archipelago (PAME 2013, entire).

Productivity and Oceanography

This ecosystem includes two major current systems: the Alaska Stream flowing westwards along the southern side, and the Aleutian North Slope Current flowing eastward on the northern side. These two currents flow along the slopes of the Aleutian Islands range, with some connecting flows through passages between island groups. The boundaries for the Aleutian Islands LME are located at Samalga Pass in the east, and is bounded to the north and south of the archipelago by a pair of lines each about 31 mi (50 km) seaward of the islands, approximating the LME criteria of bathymetric features and trophic relationships. Samalga Pass has been identified as an ecological boundary between the adjacent Gulf of Alaska and eastern Bering Sea ecosystems. The western boundary is at the eastern end of Near Strait, which represents a major oceanographic divide to the West Bering Sea LME (PAME 2013, entire).

The main flow into the Bering Sea is through the deep Near Strait between the westernmost Aleutian Islands (the Near Islands group) and the Commander Islands on the Russian side. A part of this water turns east and forms the beginning of the Aleutian North Slope Current, which receives further inflows through Amchitka and Amukta Passes. The productivity of these waters is high due to high content and availability of nutrients through physical processes. Steller sea lions from many rookeries feed on different fish and squid in these waters (PAME 2013, entire).

Fish and Fisheries
The basic productivity and advection of oceanic copepods and other zooplankton in the two currents on each side of the Aleutian Islands chain represent defining characteristics of the ecology in this area. The Aleutian Islands have limited ecological connectivity to the East Bering Shelf and so they constitute a very special environment with many local fish stocks, seabird colonies and Steller sea lion rookeries. Fish stocks spawn and live along the archipelago nourished by the productivity associated with the current systems. Large numbers of seabirds from many breeding colonies along the Aleutians forage in passages between the islands and in the currents out over deeper waters (PAME 2013, entire).

Pollution and Ecosystem Health, Socioeconomics, and Governance
Please refer to the East Bering Sea LME for information on these modules. The Aleutian Islands LME shares many of the same characteristics as the East Bering Sea LME.

North Bering and Chukchi Sea (LME #54)
This LME is referenced as LME #12 by PAME (2013, entire). This LME is a shallow shelf environment with depths of 164–230 ft. (50–70 m) or less extending for more than 0.62 mi (1 km) from the shelf edge in the northern Bering Sea, to the shelf edge of the northern Chukchi Sea. The area is characterized by a persistent northward flow of water driven by higher water level in the Bering Sea than in the Arctic Ocean. The mean transport or flushing time is of the order of 1 year or less (PAME 2013, entire).

Productivity and Oceanography
The Pacific water is nutrient-rich (about 3-fold compared to North Atlantic water), and the combination of northward flow and shallow topography drives very high primary production rates in the Bering Strait region (from northern Gulf of Anadyr to the southern Chukchi Sea) (PAME 2013, entire).

Fish and Fisheries
Transport of oceanic copepods and other zooplankton in this productive water is an important characteristic as is a high energy input to the benthic part of the ecosystem. Polar cod is an important fish species and occurs possibly with one or more migratory populations. The LME is ice-covered in winter but clears of ice in summer except for the northern part of the Chukchi Sea in cold years. The area on the eastern shelf between St. Lawrence and St. Matthews islands is a transition zone between boreal and Arctic conditions, characterized by large interannual variation. The chosen boundary approximates the average position of the southern extent of the "cold pool," which is a characteristic but variable feature of the northeastern Bering shelf. The boundary separates the main areas of distribution for the major commercial fish species in the East Bering Sea LME to the south, and core wintering areas for ice-associated marine mammals to the north (PAME 2013, entire).

Pollution and Ecosystem Health, Socioeconomics, Governance
Please refer to the East Bering Sea LME for information on these modules. The North Bering and Chukchi Sea LME shares many of the same characteristics as the East Bering Sea LME.

West Bering Sea (LME #53)
The West Bering Sea LME lies off Russia's northeast coast and borders the Aleutian Trench. The bottom topography includes the deep Aleutian Basin, Kamchatka Basin and Bowers Basin (NOAA 2019a, entire).

Productivity and Oceanography
This LME is considered a moderately high productivity ecosystem, and contains a variety of biological resources adapted to sea ice, including 450 species of fish, crustaceans and molluscs, and marine mammals, such as polar bears, whales, walruses, and sea lions. The Bering Sea provides an important habitat for grey whales (*Eschrichtius robustus*), the federally endangered Western Distinct Population Segment of Steller sea lions (*Eumetopias jubatus*), and a variety of seabirds. Most climate regime shifts in this LME are thought to be linked to the Pacific Decadal Oscillations (NOAA 2019a, entire).

Fish and Fisheries
The West Bering Sea LME has the largest biomass of cod-like fishes in the world. Other species include Alaskan pollock, Pacific saury, salmon, flatfish, rockfish, halibut, flounder, herring, squid, and a variety of crab species and other crustaceans. There have been large and sudden population fluctuations in the stocks of these species. Evidence of illegal fishing in prohibited area and increased industrial fishing have had major impacts on fish species in this LME (NOAA 2019a, entire).

Pollution and Ecosystem Health
Signs of ecosystem stress include the decline of the pollock catch and in numbers of the Steller sea lion and sea otter (*Enhydra lutris*) populations. The poaching of sockeye salmon for their eggs is preventing the salmon from reaching their spawning grounds in the Pacific. Petroleum and other contaminants have been found in marine mammals, a result of the growing industrialisation of the region. The West Bering Sea LME has low levels of toxic contaminants, but these have been rising over the last 50 years due to increased human activities (mining, fishing and oil exploration). This increase has been linked to the long-range transport of contaminants through the ocean and atmosphere from other regions (NOAA 2019a, entire).

Socioeconomics
Fish and game have supported the lives of people of the West Bering Sea LME for many centuries. Marine mammal hunting has been a part of the traditional economy of the indigenous coastal populations, who are provided with an annual quota to harvest whales, ringed seals (*Pusa hispida*), and walruses. Marine mammals are used for food, skins, and fat. In recent years, people have begun to migrate away from this region. Most of the area's population are immigrants from Russia and Ukraine (NOAA 2019a, entire).

Governance
The West Bering Sea LME is bordered by Russia. Other users of the marine environment include the U.S. and Japan, and who also impact the rich biological resources of the LME. Issues and challenges include conservation strategies, legal issues, fisheries economics, and scientific monitoring (NOAA 2019a, entire).

Sea of Okhotsk (LME #52)
The Sea of Okhotsk LME is bordered by Russia and northern Japan. The entire sea is located in the cold temperate zone, with intense ice formation in almost all areas of the sea. There are marked differences in climate, hydrography, and biology between its northern and southern parts. Variations in climate and hydrography are related to atmospheric processes over the northwest Pacific (NOAA 2019a, entire).

Productivity and Oceanography
The Sea of Okhotsk LME is considered a moderately productive ecosystem. Plankton and benthic species are unevenly distributed throughout the LME as a result of complex circulation patterns. The most productive zones are in the upwelling areas and waters off Kamchatka; the northern and western areas are especially rich in plankton. High plankton concentrations in the areas of downwelling are attributed to mechanical accumulation (NOAA 2019a, entire).

Fish and Fisheries
The Sea of Okhotsk LME is rich in fisheries resources, with approximately 300 commercially exploited species. Species of commercial importance include Alaska pollock, Pacific herring, Pacific saury, flounders, Pacific salmon, halibut, cod, capelin, South American pilchard (a.k.a sardine), king crab, and shrimp. Fluctuations in the abundance of some fish stocks (e.g., pollock and herring) have been attributed primarily to overfishing, and secondarily to climatic and oceanographic factors (NOAA 2019a, entire).

Pollution and Ecosystem Health
The exploitation of oil and natural gas off Sakhalin's east coast and shelf and throughout the LME increases the risk of pollution. Contrary to prohibitions under Russian laws, the toxic waste products of drilling and oil production on the Sakhalin shelf are discharged into the sea. Tanker traffic and extreme weather conditions in the LME increase the risk of oil spills and vessel collisions on the Northern Sea Route (NOAA 2019a, entire).

Socioeconomics
Beginning in 1992, Russia experienced a human population decline in this LME due to death and migration. Major industries in this LME include fisheries, oil and gas extraction, coal mining, sea transport, and ship repair. Oil and natural gas deposits were discovered off Kamchatka's west coast, and the peninsula is also rich in deposits of gold, silver, copper, and coal. However, the remoteness of this area and its lack of infrastructure hinder large-scale regional development (NOAA 2019a, entire).

Governance
The LME is governed by Russia, although the issue of sovereignty over the south Kuril Islands involves Japan. Because of its great natural resource wealth (i.e., petroleum, gas, and fish), the LME is of geo-political interest to a number of countries, including the USA and Japan (NOAA 2019a, entire).

Oyashio Current (LME # 51)
The Oyashio Current LME is located in the northwest Pacific Ocean and is bordered by

Russia (the Kamchatka Peninsula and Kuril Islands) and the Japanese island of Hokkaido. A sub-arctic climate characterizes this LME. The geographic remoteness and inaccessibility of the Kuril Islands, combined with the extreme environmental conditions have discouraged human settlement and contributed to making the Kuril Archipelago one of the least known regions of the world (NOAA 2019a, entire).

Productivity and Oceanography
The Oyashio Current LME is a moderately productive ecosystem. The confluence zone of the cold Oyashio Current and the warm Kuroshio Current off northern Japan gives rise to some of the most productive marine areas of East Asia, with many species of fauna and flora, and rich fishing grounds (NOAA 2019a, entire).

Fish and Fisheries
The Oyashio Current flows off the Pacific coast of the Kuril Islands, an important fishing ground for the Russian Federation. In addition to the capture fisheries, a large number of kelp, scallop, abalone, and algae are cultured in the region. Japan and Russia have the largest footprint in this LME. Russia sells the rights to fish inside its EEZ, a large number of foreign fleets, mainly those from China and South Korea, as well as a number of flag-of-convenience ships (i.e., a ship is registered as a merchant ship in a ship register of a country other than that of the ship's owners), operate within the LME. Illegal fishing is a concern, although its extent in Russian territorial waters is unknown (NOAA 2019a, entire).

Pollution and Ecosystem Health
Solid waste is of concern in areas close to human settlements, including seasonal camps. Numerous navigation routes are used by thousands of vessels year-round, which increases the potential for oil pollution in this LME. There is some concern over radioactive contamination from old, decommissioned nuclear submarines and other sources in this LME. Coastal development contributes to habitat modification (e.g., port construction and operation). The release of chum salmon fry from hatcheries may lead to competition with other fish larvae for food, resulting in community modification. Global climate change is expected to influence the El Niño-Southern Oscillation phenomenon, winter monsoon, western boundary currents, and upper ocean stratification, with biological consequences on coastal and marine habitats (NOAA 2019a, entire).

Socioeconomics
In the north of the peninsula, the indigenous people of Kamchatka, the Koryaks, the Itelmen, the Chukchies, and the Evenks have maintained their traditional way of life. The LME is rich in natural resources, including fish, minerals, and potentially large oil and gas reserves. Fishing and fish processing, fuel, and energy (e.g., geothermal, wind-driven, and hydroelectric power plants), ship repair, and tourism are the major economic activities of the Kamchatka region (NOAA 2019a, entire).

Governance
The long-term dispute between Russia and Japan over sovereignty of the South Kuril Islands resulted in a dispute over fishing rights in the Oyashio Current LME (NOAA 2019a, entire).

Appendix D: Tufted Puffin Colonies and Populations in the North Pacific

Appendix 4. Tufted Puffin colonies and populations in the North Pacific.[1]

	Number of colonies	Number of individuals	Percentage of colonies	Percentage of individuals
West coast south of Alaska				
California	13	280	1.3	0.0
Oregon	31	5,030	3.0	0.2
Washington	16	22,300	1.6	0.8
British Columbia	31	76,730	3.0	2.6
Total south of Alaska	91	104,340	8.8	3.5
Gulf of Alaska				
Se. Alaska	28	18,200	2.7	0.6
N. Gulf of Alaska	104	63,650	10.1	2.1
E. Alaska Peninsula	232	475,660	22.5	16.0
W. Alaska Peninsula	83	394,820	8.1	13.3
Total Gulf of Alaska	447	952,330	43.4	32.1
Aleutians				
East Aleutians	80	1,092,710	7.8	36.8
Central Aleutians	53	84,470	5.1	2.8
West Aleutians	34	94,620	3.3	3.2
Total Aleutians	167	1,271,800	16.2	42.8
Bering/Chukchi Seas (U.S.)				
S. Bering Sea	23	96,170	2.2	3.2
N. Bering Sea	62	16,400	6.0	0.6
Chukchi Sea	12	80	1.2	0.0
Total Bering/Chukchi Seas	97	112,650	9.4	3.8
Total North America	802	2,441,120	77.8	82.2
Russia				
Chukchi Sea	13	320	1.3	0.0
N. Bering Sea	93	31,710	9.0	1.1
S. Bering Sea	66	45,500	6.4	1.5
Commander Is.	6	127,000	0.6	4.3
Kuril Is.	17	175,000	1.6	5.9
Sea of Okhotsk	29	150,580	2.8	5.1
Japan	5	30	0.5	0.0
Total Asia	229	530,140	22.2	17.8
Total world	1,031	2,971,260	100.0	100.0

[1]Data compiled from: Alaska and Russia-Beringian Seabird Colony Atlas, U.S. Fish and Wildlife Service, Anchorage, AK, and Kondratyev *et al*. 2000. Note that estimates for Russia attempt to reconcile differences in numbers calculated from the Colony Atlas and Kondratyev *et al*. 2000. Japan—Watanuki *et al*. 1988, Brazil 1991, Osa and Watanuki 2002. British Columbia—Campbell *et al*. 1990. Washington—Speich and Wahl 1989, U. Wilson unpubl., R. T. Paine unpubl. Oregon: Hodder 2002. California—Carter *et al*. 1992, McChesney *et al*. 1995.

Source: Piatt and Kitaysky 2002, p. 31.

Please note: These estimates represent data from different years and methodologies but were the best available information at the time of publication. However, the southern range (the California Current) has a more recent population estimate of approximately 2,000 tufted puffins, as documented in the SSA.

Appendix E: Additional Information on Stressors for the California Current

Toxins

Within the California Current, no specific studies have been conducted on tufted puffins; however, studies in other LMEs have found relatively low levels of organochlorine (Ricca *et al*. 2008, p. 316), mercury, and heavy metal concentrations (Burger *et al*. 2007, p.100; Ricca *et al.* 2008, p. 310; Burger and Gochfeld 2009, pp. 599–600). The mercury, lead, and cadmium levels detected in the feathers were below levels known to cause adverse effects; however, selenium levels may have been within the range that could result in sublethal adverse effects and mortality, but the authors caution more studies are needed (Burger and Gochfeld 2009, pp. 603–604). In these studies, mercury levels were associated with trophic levels and foraging habitat, such that birds foraging at higher trophic levels had higher mercury levels, as did species that foraged closer to shore (Burger *et al*. 2007, p. 100). Thus, tufted puffins may be less susceptible, as they generally forage farther from shore.

Several studies looked at contaminant levels in tufted puffin prey, in particular Pacific herring and Pacific sand lance. Pacific sand lance collected from nine locations throughout Puget Sound were collected and sampled for toxic contaminants (such as polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ether (PBDE), and polychlorinated biphenyl (PCBs)). PCBs, PBDEs, PAHs, and some organochlorine pesticides were broadly detected; including banned chemicals such as PBDE flame retardants and dichlorodiphenyltrichloroethane (DDT). Higher concentrations were found in fish collected from urbanized embayments; however, the widespread occurrence of toxic contaminants in tissues suggests persistent exposure (PSEMP Toxics Work Group 2017a, p. 16). Contaminant levels in Pacific herring in Puget Sound have been monitored since 1994. While PCBs have declined in areas with low development, they continue to be problematic in developed areas, such as south and central Puget Sound (PSEMP Toxics Work Group 2017a, p. 29). PCBs appear to persist in the environment, despite prohibitions on production and use; however, PBDEs declined or remained static, suggesting that source controls and mitigation efforts have been somewhat successful (PSEMP Toxics Work Group 2017a, p. 29).

Good *et al*. (2014, entire) measured contaminant levels in forage fish comparing sites within Puget Sound to sites on the outer Washington coast. Good *et al*. (2014, pp. 5–7) found PCBs were higher (1.8 to 4.9 times) for Pacific sand lance, Pacific herring, surf smelt (*Hypomesus pretiosus*), and chinook salmon (*Oncorhynchus tshawytscha*) collected at Protection Island in Puget Sound than for fish collected at Tatoosh and Destruction Islands on the outer coast and PBDEs were higher (1.5–3.5 times) for Pacific sand lance, Pacific herring, surf smelt, and chinook salmon at Protection Island than Tatoosh or Destruction Islands. Forage fish collected in Puget Sound were much more likely to be contaminated than those collected on the outer coast, which results in potentially higher contaminant burdens in the birds that are consuming these fish (Good *et al*. 2014, p. 8). Based on diet composition, Good *et al*. (2014, p. 10) estimated the dietary PCB exposure for rhinoceros auklet chicks to be 4.5 times greater in Puget Sound than the outer coast and PBDE exposure to be 4.5–7.5 times greater in Puget Sound.

Microplastics
Tufted puffins ingest plastic debris, directly (Day 1980, p. 35; Wehle 1982, pp. 52, 55; Day *et al.* 1985, p. 347; Blight and Burger 1997, pp. 323, 324; Goldberg 1997, p. 106) and indirectly through consumption of prey that contain microplastics. Within the alcid community, the species that consume zooplankton, such as puffins, may be at more risk of consuming plastic debris because they cannot easily distinguish the zooplankton from the small-sized plastic particles (Day 1980, p. 45; Day *et al*. 1985, p. 359; Avery-Gomm *et al*. 2013, p. 258). In addition, puffins (adults or chicks) may consume prey that contain microplastics; for example, in a study in Haro Strait, British Columbia, 85 percent of Pacific sand lance collected contained colored plastic filaments (PSEMP Toxics Work Group 2017a, p. 22). Microplastics are also ingested by zooplankton species (Desforges *et al.* 2015, entire) that are prey for puffins. Ingestion of plastic debris by puffins may directly cause mortality by blocking or damaging the intestinal tract or can affect species by slower sub-lethal physical and chemical effects. Once ingested by the tufted puffin, the microplastics remain in the gizzards, rather than passing through the intestinal track to be excreted in feces (Day *et al.* 1985, p. 345). Data from coastal Oregon, Washington, and British Columbia found that 89 percent of the tufted puffins sampled had plastics in their stomachs, and while the amount of microplastics was sufficiently low enough to be unlikely to impede digestion (Blight and Burger 1997, pp. 323, 324), the partial blockage may contribute to poor nutrition or dehydration. While specific effects of plastic ingestion on puffins has not been studied, there is evidence that the plastics can release toxins, such as PCBs and heavy metals, directly into the bloodstream (Teuten *et al*. 2009, pp. 2,037, 2,038).

A study comparing data from two time periods (1969–1978 and 1988–1990) in the subarctic North Pacific Ocean found that the amount of plastics found in tufted puffin stomachs had increased from about 15 percent to 25 percent (Goldberg 1997, p. 106). While concentrations vary across the globe, high concentrations have been found in nearshore coastal British Columbia (Desforges *et al.* 2014, entire), with some of the highest concentrations found in this study overlapping the known tufted puffin breeding colonies (see Desforges *et al*. 2014, Fig 1). Microplastic concentrations in the marine environment continued to increase between 1993 and 2008 and are predicted to increase 50-fold by 2100, which will most likely lead to more ingestion in the future (Everaert *et al.* 2018, pp. 1,933, 1,934).

Harmful Algal Blooms
Some algal species cause harm to animals and the environment through toxin production or excessive growth. These algal species are known as harmful algae and can include microalgae that live suspended in the water or macroalgae that live attached to plants or other substrates. Harmful algal blooms (HABs) are a natural phenomenon, but human activities are thought to contribute to the increased frequency of some HABs, for example increased nutrient loading is a factor that contributes to increased occurrence of high biomass HABs (Lopez *et al.* 2008, p. 19). All coastal states in the United States have experienced HAB events and "it is generally believed that the frequency and distribution of HABs and their impacts have increased considerably in recent years" (Lopez *et al.* 2008, p. 19).

The consequences of HABs can include the death of whales, sea lions, dolphins, manatees, sea turtles, birds, fish, and invertebrates from direct exposure to toxins; exposure to toxins via contaminated food, water, or aerosols; damaged gills; starvation due to low or poor food quality (Lopez *et al.* 2008, pp. 19, 22); and by producing compounds that reduce feather waterproofing, which can result in hypothermia (Jessup *et al.* 2009, entire). HABs can also exacerbate impacts of other stressors and indirectly lead to mortalities. Ecosystems can be degraded through the formation of such large blooms that they alter habitat quality through overgrowth, shading, or oxygen depletion (see dead zone section, below). In addition, HAB-inflicted mortalities can degrade habitat quality indirectly through altered food webs or hypoxic events caused by the decay of dead animals (Lopez *et al*. 2008, p. 22).

The types of HABs known to occur along the Pacific coast that can impact seabirds are *Heterosigma akashiwo,* macroalgae, *Alexandrium catenella*, and *Pseudo-nitzschia* (Lopez *et al*. 2008, p. 8). Blooms of *Heterosigma akashiwo*, a raphidophyte known to kill fish, have been documented in the Pacific Northwest annually since the 1960s, and blooms of *Chanttonella*, another raphidophyte, have also killed fish along the Pacific coast. Macroalgal blooms along Washington's coast harm seagrasses, fish, and invertebrates due to hypoxia and potentially due to the production of bioactive compounds (Lopez *et al.* 2008, p. 28). Tufted puffin prey species, such as forage fish and squid, tolerate/bioaccumulate higher levels of the biotoxins, thus become lethal vectors when consumed (Shumway *et al*. 2003, pp. 10–11).

The dinoflaggelate *Alexandrium catenella* and some other members of this genus (NWFSC 2019, HAB website) produce neurotoxins, commonly known as the paralytic shellfish poisoning suite of marine biotoxins when consumed by humans. These toxic dinoflagellates are taken up by zooplankton, which in turn are ingested by organisms at higher trophic levels (Doucette *et al*. 2005, pp. 2,769-2,775). *A. tamarense* has also been observed in waters off the west coast of Canada (British Columbia) and in northern Puget Sound in Washington State (NWFSC 2019, HAB website). Within Puget Sound, 18 of 29 sampling sites (62 percent) had at least some paralytic shellfish poisoning impact in 2005 (PSAT 2007, p. 197). While there is limited direct evidence of neurotoxin impacts reported in tufted puffins, it has been implicated in a 1942 mortality event that included puffins along the Washington coast (McKernan and Scheffer 1942, entire; Shumway *et al.* 2003, p. 5) and it has been documented as the cause of mortality in other alcid species. McShane *et al*. (2004, p. 3–67), reported two juvenile murrelets were killed by paralytic shellfish poisoning in 1989. In 2011 and 2012, paralytic shellfish poisoning was identified as the cause of up to 21 percent of Kittlitz's murrelet (*Brachyramphus brevirostris*) nestling mortalities; likely resulting from being fed sand lance (*Ammodytes* species) infected with *Alexandrium* (Shearn-Bochsler *et al*. 2014, p. 935). Moore *et al*. (2015, entire) used a mechanistic approach to model the potential growth response (*i.e.*, proliferative phase) of *Alexandrium* species to climate-driven changes in Puget Sound. Moore *et al*. (2015, pp. 7–8) project that future conditions in Puget Sound will result in higher growth rates and a longer bloom season as a result of increased sea surface temperatures. The largest increases (up to 30 more days) were projected to occur in the northern portions of Puget Sound and the eastern Strait of Juan de Fuca (Moore *et al*. 2015, p. 7). Because the areas where blooms are projected to be larger and longer are where the two currently-active puffin nesting colonies occur, there may be an increasing risk of nestling mortality due to paralytic shellfish poisoning.

Pseudo-nitzschia blooms are recurrent along the entire Pacific coast. Recent research indicates that the seasonal fluctuation of the Juan de Fuca Eddy serves as an incubator for growth for this algae and other algae and when it gets disrupted, these algae are deposited along the Washington coastline (Lopez *et al.* 2008, p. 28). In California, blooms of *Pseudo-nitzschia* are recurrent and have caused large numbers of seabird and marine mammal deaths annually since 1998 (Lopez *et al.* 2008, p. 28). Diatoms in the genus *Pseudo-nitzschia* produce domoic acid. Exposure to domoic acid can lead to permanent brain damage, reproductive failure, and death; commonly observed effects include seizures and head weaving. Domoic acid can also have significant chronic effects, such as epilepsy and behavioral changes due to repeated exposures at sublethal levels (Lopez *et al.* 2008, p. 28). Shellfish and fish can accumulate this toxin without apparent ill effects, but transfer the toxin when consumed (NOAA 2009, entire). In 1991, along the beaches of Monterey Bay, CA, dead and dying seabirds were observed – many of the sick birds displayed unusual symptoms suggesting a neurological toxin. Examination of the contents of the dead bird's stomachs revealed high levels of domoic acid. The birds had been eating anchovies that had been consuming the diatom *Pseudo-nitzschia australis* (NOAA 2009, entire). Prior to 2003, within Puget Sound domoic acid had not been detected at levels high enough to cause beach closures, although *Pseudo-nitzschia* and domoic acid had been documented in Hood Canal (Horner *et al*.1996 cited in PSAT 2007, p.220). In 2007, domoic acid levels in water samples from southern California were reported as some of the highest ever recorded in natural samples (Lopez *et al.* 2008, p.28).

An outbreak of *Pseudo-nitzschia* in the spring/summer of 2015 stretched from southern California to the Aleutian Islands (NOAA Climate 2015, p. 1) and rather than lasting a few weeks, as is typical, this event persisted from May to October (NOS 2016, entire) and produced extremely high concentrations of domoic acid (NOAA Climate 2015, p. 2). This HAB was preceded by anomalous ocean conditions (lack of southwesterly storms and warm sea surface temperatures) in January and February associated with "the Blob" (Du *et al*. 2016, pp. 4–7). In Monterey Bay, California, this HAB produced the highest particulate concentrations of domoic acid ever recorded (Ryan *et al*. 2017, p. 5,575).

Two HAB events resulting in the stranding of live and dead seabirds occurred in California (2007) and Washington/Oregon (2009) (Jessup *et al*. 2009, entire; Phillips *et al*. 2011, entire). Both of these events were caused by the dinoflagellate *Akashiwo sanguinea* which produces a proteinaceous foam that coated the feathers of the birds. This coating resulted in reduced waterproofing, ultimately resulting in hypothermia (Jessup *et al*. 2009, p. 2; Phillips *et al*. 2011, p. 120). Both of these events occurred during the fall/winter months and of the birds examined from the event in Washington/Oregon, 58 percent were undergoing molt of the primary feathers, making them more susceptible to plumage fouling (Phillips *et al*. 2011, pp. 123–124). While puffins were not specifically identified in these events, other alcid species (e.g., rhinoceros auklets) were affected.

There is limited direct evidence of tufted puffins experiencing harmful effects of biotoxins or feather fouling. However, HABs may be an underreported cause of seabird mortality worldwide, in particular because mortality events that occur offshore are rarely observed (Shumway *et al.* 2003, p. 14). This may be particularly true for puffins that spend a majority of their time farther offshore, thus sick or dead birds would not be found on shore, which is the method by which most mortality events are documented. When a HAB event occurs during the winter months, tufted puffins may be less susceptible because the birds are farther offshore. However, should a

HAB event occur during the breeding season or fall when birds are undergoing molt, there is no expectation that puffins would not be similarly affected as documented in other seabirds. Within the California Current LME, most HAB events occur during the months of April to October (Lewitus *et al*. 2012, pp. 137–140) and outbreaks may be increasing in frequency and distribution (Lewitus *et al*. 2012, p. 136).

Dead Zones. Ecosystems can be degraded through the formation of such large algal blooms that they alter habitat quality through overgrowth, shading, or oxygen depletion (hypoxia or anoxia) (Lopez *et al*. 2008, pp. 21–22). Hypoxia or anoxia (low or no dissolved oxygen) can suffocate fish and bottom-dwelling organisms and can sometimes lead to hydrogen sulfide poisoning (Lopez *et al*. 2008, p. 22; Grantham *et al*. 2004, p. 750; Chan *et al*. 2008, entire). In addition, HAB-inflicted mortalities can degrade habitat quality indirectly through altered food webs or hypoxic events caused by the decay of dead animals (Lopez *et al*. 2008, p. 22).

Hypoxic and anoxic events along the Pacific Coast can also be caused by large-scale changes in ocean conditions on near-shore upwelling ecosystem dynamics. Upwelling is part of the California Current coastal ecosystem, but typically, northerly winds alternate throughout the summer with southerly winds. The wind shifts suppress upwelling, mix the water, and prevent nutrient overload. However, most summers since 2002 the Oregon Coast has experienced an hypoxic/anoxic event (also referred to as "dead zone") (Grantham *et al*. 2004, entire; Chan *et al*. 2008, entire; Oregon State University (OSU) 2017, entire) due to changes in typical summer wind patterns along with upwelling of nutrient rich, but oxygen poor waters. While hypoxic conditions are known to be related to upwelling events, the hypoxic events off Oregon's coast extend from the shallowest reaches (inshore of 30 meter isobath) to the nearshore stations (2 to 5 kilometers offshore), which is unusual and hypoxic events along the coast have expanded upward into shallower water depths (Somero *et al*. 2016, p. 15). Further complicating matters, phytoplankton are two to three times more abundant, resulting in increased respiration (expiration of carbon dioxide) exacerbating the dissolved oxygen deficits (Grantham *et al.* 2004, pp. 751–752). The severe hypoxic event in 2006, extended into Washington at least as far north as the Quinault River (Science News 2019, entire), and affected crabs in pots at depths of about 45 to 90 feet. Hypoxic events have continued to occur along the outer coast of Washington (PSEMP Marine Waters Workgroup 2017b, p. 22).

In addition to unusual summer wind patterns, researchers are also interested in large phytoplankton blooms that occur in the late spring and early summer in the waters off Washington and Vancouver Island. The large blooms in the north might explain why waters off the Oregon coast that now well up at the coastal shelf break are unusually low in oxygen. The change in wind patterns and the response of the marine ecosystem may be an interlude in a natural cycle or may signal a more permanent shift in the regional climate and the health of the ecosystem (Chan *et al*. 2008, entire).

The Hood Canal is a 60 mi (100 km) long, highly productive estuary within Puget Sound that has a strong seawater density stratification and slow circulation (months to a year). These conditions are conducive to seasonal hypoxic events, which have been observed in records dating back to the 1930s. While this phenomenon, or even anoxia is not new in Hood Canal, research suggests that this problem has increased in severity, persistence, and spatial extent (Curl and Paulson 1991 *cited in* PSAT 2007, p. 107; Newton *et al.* 1995; 2002). The most severe low dissolved oxygen conditions occur in the southern end of the canal, at the point furthest from water exchange with the rest of Puget Sound. A comparison of oxygen data from 1930 through the 1960s with data from 1990 through 2000s shows that, in recent years, the area of low dissolved oxygen is growing and spreading northwards and periods of hypoxia are persisting longer through the year (Collias *et al*. 1974 *cited in* PSAT 2007, p. 107; Newton *et al*. 2002, entire). Dissolved oxygen levels measured during 2004 were at the historical low point for any recorded observations (PSAT 2007, p. 107). Although records of fish kills in Hood Canal date as far back as the 1920s, repetitive fish kills during 2002, 2003, and 2004 indicate that the increasing hypoxia may be having biological consequences (PSAT 2007, p. 107). Unfortunately, the cause(s) of the increasing hypoxia in Hood Canal have not been identified as yet.

These hypoxic events in Oregon and Washington occur within the marine areas used by tufted puffins. These seasonal dead zones begin as early as June and generally wrap up in September; therefore, these events encompass most of the tufted puffin breeding season. These events result in significant mortality of fish and invertebrates (Grantham *et al*. 2004, p. entire; Chan *et al*. 2008, p. entire). These "dead zone" events may be contributing to low food availability during the tufted puffin breeding season and may be contributing to low reproductive success. Impacts to water chemistry and marine life are expected to grow rapidly in intensity and extent in the California Current System over the coming decades (Chan *et al*. 2016, p. 5). Therefore, it is reasonable to predict that the impacts to tufted puffins may also grow, resulting in lower prey availability and reproductive success.

Wave and tidal energy

Section 23(b) (1) of the Federal Power Act of 1920 grants jurisdiction to the Federal Energy Regulatory Commission (FERC) for the licensing of hydropower development (for example, wave energy projects) in offshore waters of the United States. FERC licensing procedures include analyzing potential project effects on natural resources including, but not limited to, water quality, water use, marine mammals, fish, birds, geology, land use, ocean use, navigation, recreation, aesthetics, and cultural resources.

The threat(s) these projects may pose to tufted puffins varies greatly, depending upon the proposed location and type of equipment. In some cases, such as tidal energy projects that will use underwater turbines, the threat may be mortality. In other cases, the projects may degrade marine habitat through shading, collision/entanglement obstacles, night-lighting, changes in prey abundance, or increased human presence. In some cases, the project may have little or no impact to tufted puffins.

While multiple tidal and wave energy projects have been proposed in Washington, none have been permitted or installed and there are no actively operating or proposed facilities. Likewise, there are no actively operating or proposed facilities in California; however, on October 7, 2015, Governor Edmund G. Brown, Jr. signed legislation to require 50 percent of the state's electricity to come from renewable energy by December 31, 2030 (California Energy Commission 2017), leaving the future for offshore wave energy uncertain.

In Oregon, an OSU/U.S. Department of Energy wave energy test site has been permitted for installation approximately seven nautical miles offshore between Newport and Waldport, Oregon, with underwater transmission lines coming ashore just north of Waldport (PacWave 2019, website). To our knowledge that are no actively operating or proposed tidal energy facilities in British Columbia.

Offshore Wind Projects. A report generated by Adams *et al*. (2016, entire), using a comprehensive database to quantify marine bird vulnerability to potential offshore wind energy infrastructure covers 81 regularly occurring seabirds to the California Current System, including the tufted puffin. Three vulnerability indices were created: Population Vulnerability, Collision Vulnerability, and Displacement Vulnerability. Population Vulnerability was used as a scaling factor to generate two comprehensive indices: Population Collision Vulnerability (PCV) and Population Displacement Vulnerability (PDV). The tufted puffin had a PCV best estimate score of 57, ranking it "low" among the suite of species; however there was high uncertainty around the population and collision vulnerabilities (Adams *et al.* 2016, p. 36) due to the unknown estimates for the amount of time spent flying in the areas of the rotors and any avoidance or attractant behaviors that might occur. The PDV best estimate score of 152 puts the ranking "high" among the suite of species (Adams *et al*. 2016, pp. 1, 34, 61) with a low uncertainty ranking (Adams *et al*. 2016, p. 36). More detailed information is available in Adams *et al.* (2016, entire).

At this time we are unaware of any offshore wind energy projects proposed along the coasts of Washington or Oregon.

California. In January 2016, the Bureau of Ocean Energy Management (BOEM) received an unsolicited request for a commercial lease from Trident Winds LLC (Trident Winds). To determine competitive interest, BOEM published a notice in the Federal Register, "Potential Commercial Lease for Wind Power on the Outer Continental Shelf (OCS) Offshore California - Request for Interest (RFI) in Docket No. BOEM-2016-0051 on August 18, 2016. BOEM received one expression of interest from Statoil Wind US, LLC. The responses to the RFI indicated competitive interest in offshore California and therefore, BOEM established the BOEM/California Intergovernmental Renewable Energy Task Force to promote planning and coordination, and to facilitate effective and efficient review of requests for commercial and research leases and right-of-way grants for power cables on the Federal outer continental shelf (OCS), which encompasses the marine areas between 3 and 200 nautical miles offshore.

In September 2018, BOEM received a lease request from Redwood Coast Energy Authority for a proposed project in the Humboldt Call Area. On October 19, 2018, BOEM published a call for information and nominations from companies interested in commercial wind energy leases within areas off central and northern California (Docket No. BOEM-2018-0045). The comment period closed on January 28, 2019. The future of any offshore wind project is unclear at this time; however, on October 7, 2015, Governor Edmund G. Brown, Jr. signed legislation to require 50 percent of the state's electricity to come from renewable energy by December 31, 2030 (California Energy Commission 2017).

British Columbia. Canadian Federal and Provincial regulatory approvals are in place for a 400-megawatt project to be constructed in the northern portion of Hecate Strait between Haida Gwaii and the British Columbia mainland. Tufted puffin nesting colonies are located on the northwestern tip, along the west coast, southern tip of Haida Gwaii, and on islands on the southeastern end of the Hecate Strait (Hipfner 2015; Bird Studies Canada 2019, website). Thus, there is a likelihood of tufted puffins to be exposed to the offshore wind project when it is constructed. There are no windfarms currently constructed on the west coast, such that the exposure and impacts have been observed for seabirds, or tufted puffins specifically. However, tufted puffins may be at high risk of displacement from using the area occupied by a windfarm (based on Adams *et al.* 2016) or that birds could be killed as a result of collisions with turbines.

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Appendix F: Summary of Forage Fish and Other Prey in the California Current

Prey

Prey abundance, quality, and timing of availability all play an important role in survival and reproductive success of tufted puffins. A recent study found widespread reproductive failure in 14 seabird species (including rhinoceros auklets, common murres, and Atlantic puffins) across seven ecosystems when forage fish and krill populations were depleted below one-third of their observed maximum (Cury *et al*. 2011, p. 1,704). A mass starvation mortality event, the majority of which were tufted puffins, in the Bering Sea in 2016/2017 appeared to be caused by shifts in the zooplankton community and forage fish distribution following a period of elevated sea surface temperature (Jones *et al*. 2019, entire). A separate mass starvation of tufted puffin chicks occurred in the Sea of Okhotsk in a year when herring were abundant, but of a size class too large for the chicks to ingest (Golubova 2002, entire). In years of very weak marine primary production, tufted puffins experienced near total breeding failure (less than 10 percent successful) and most rhinoceros auklets did not breed and those that did experienced their worst breeding season in 20 years (Gaston *et al*. 2009, p. 271). Research on thick-billed murres (*Uria lomvia*) showed that each bird had an energy expenditure cap that did not vary across years, activity, age, sex, or environmental conditions, even though body mass and daily energy expenditure did vary; however, in order to not exceed their cap, birds reduced time spent flying, diving, and provisioning chicks, and increased time resting on the water (Elliott *et al*. 2014, pp. 140–141). However, in good marine condition years, these long-lived seabirds can bounce back, unless there are several years of poor marine conditions and declining prey populations.

The nutritional value of prey varies greatly among species and ages classes (Anthony *et al.* 2000, entire; Iverson *et al*. 2002, entire; Ball *et al*. 2007, pp. 702–703; Becker *et al*. 2007, p. 272; Beaubier and Hipfner 2013, entire). In a study with captive tufted puffins, Romano *et al.* (2006, pp. 410–411) determined that dietary shifts to less nutritious species reduced chick growth rates. Research on alcids with similar life histories to the tufted puffin indicates that poor or inadequate diets/low prey availability can result in poor body condition of adults at the end of the breeding season (Harding *et al*. 2011, pp. 54–55) because they try to compensate by bringing more fish (*i.e.*, made more provisioning trips) to feed chicks (Kadin *et al*. 2016, p. 174). In addition, in years when chicks are fed lower quality prey, there is decreased fledgling success (Kadin *et al*. 2012, pp. 243–244).

Data on the status of prey in the offshore areas used during the winter and by nonbreeding puffins during the summer is limited. The following discussion will focus on prey status in the nearshore areas used by tufted puffins during the breeding season. Adult tufted puffins feed on a variety of prey, including fish and invertebrates but generally provision their young with fish of high nutritional quality within the 20 to 200 mm size range (Hanson and Wiles 2015, p. 21). Within the California Current LME, these would include Pacific herring, Pacific sand lance, juvenile rockfish, Eulachon, Pacific sardine, and northern anchovy. Additional species that are within the preferred size range include surf smelt, night smelt, popeye blacksmelt, whitebait smelt, juvenile kelp greenling, Pacific saury, and juvenile salmon (Hanson and Wiles 2015, pp. 21–22).

Pacific herring. As of 2012, the aggregate of all herring stocks in Puget Sound, except for Cherry Point and Squaxin Pass stocks which are genetically different, was considered to be moderately healthy (Stick *et al*. 2014, p. 61). A recent synthesis of 40 years of trawling efforts in Puget Sound indicate significant Pacific herring declines in south and central Puget Sound (Greene *et al.* 2015, p. 162), while at the same time the proportion of jellyfish have increased from 27 to over 90 percent in south Puget Sound and from 10 to 92 percent in central Puget Sound (Greene *et al*. 2015, p. 163). Within the Washington and Oregon coastal areas of the California Current LME, there is very little abundance or distribution information. As of 2016, herring stocks in California continued to fluctuate above and below the historical (1979-present) average biomass of 50,300 tons (45,631 metric tons), (CDFW 2016, pp. 2, 4). The below average biomass reported over the last two years may be attributed to conditions not favorable to herring survival as a result of the recent poor oceanic and estuarine conditions (CDFW 2016, p. 2) associated with record high sea surface temperature anomalies and the development of a large El Niño (NMFS 2016a, p. 1). In 2014-2015, this resulted in the California Current Ecosystem having lower productivity at nearly every trophic level (NMFS 2016a, p. 1). In addition, the ongoing drought has resulted in atypical estuarine conditions with reduced freshwater influence into the San Francisco Estuary, which may have negative impacts on both spawning herring and young herring in the estuary (CDFW 2016, p. 2). There is limited commercial and recreational fishing for herring in Washington (Stick *et al*. 2014, p. 67; Stick and Lindquist 2009, p. 71), Oregon (ODFW 2016, pp. 40–41), and California (CDFW 2017, website).

Pacific sand lance. There are no population assessments of sand lance in Washington, Oregon, or California. In 2016, the NMFS published a final rule prohibiting directed commercial fisheries for Shared Ecosystem Component (EC) Species, including sand lance, in federal waters; however, four coastal tribes in Washington are excluded from the prohibition (NMFS 2016b). This final rule also prohibits, with limited exceptions, at-sea processing of Shared EC Species for all three west coast states (NMFS 2016b). Recreational fisheries are allowed and sand lance may be incidentally taken during herring fishing (ODFW 2016, p. 40). Until there is sufficient data available, Oregon has prohibited development of new directed commercial harvest of forage fish, including Pacific sand lance (ODFW 2016, p. 41).

Anchovy (*Engraulis mordax*). In Washington, there is no northern anchovy stock abundance information; however, there are commercial fisheries that provide live and packaged bait for recreational and commercial fisheries (Wargo and Hinton 2016, p. 14). These fisheries occur in State waters on the southern Washington coast, Grays Harbor, Willapa Bay, and lower Columbia River (Wargo and Hinton 2016, p. 14). Since 2000, the highest reported landings were in 2009 with over 880 tons (800 metric tons) being harvested; however, since 2010 the harvest levels have been below 330 tons (300 metric tons) (Wargo and Hinton 2016, p. 15). We have no information on the status of this species in Oregon.

California fisheries for anchovy have undergone a pattern of expansion and collapse in response to fishing pressure and changes in ocean climate. Anchovy populations grew throughout the 1970s but then declined in the 1980s as the area off southern and central California warmed. The abundance of adult-stage anchovy off central California has declined in recent years (Ralston *et al*. 2015, pp. 29–30) with a major decline seen between 2005–2006 and 2008–2009. Thayer *et al.* (2017, pp.1, 4) reported continued declines. However, Thayer (2018, entire) updated 2015-2017 estimates for northern anchovy; the anchovy biomass for 2017 was estimated at 1,289,043 tons (1,169,400 metric tons), the first time in more than 11 years that the biomass has been higher than the long-term mean (Thayer 2018, entire). Northern anchovy populations are monitored under the Coastal Pelagic Species Fishery Management Plan (Pacific Fishery Management Council (PFMC) 2011, entire).

Eulachon. The Pacific eulachon (*Thaleichthys pacificus*) occurs in coastal waters and spawns in rivers along the eastern Pacific Ocean from northern California to the southeastern Bering Sea (Gustafson *et al.* 2010, p. 10). After an abrupt decline in abundance, the NMFS listed the southern DPS (Nass River in British Columbia to Mad River in California) as threatened (75 FR 13012) in 2010. Although abundance numbers appeared to improve between 2013-2015, sharp declines were observed again in 2016 and 2017 and have been projected to continue as poor ocean conditions and bycatch in offshore shrimp fisheries persist into the future (NMFS 2017, pp. 18–19).

In British Columbia, there is harvest of eulachon by First Nations in the lower Fraser River (DFO 2019a, p. 2)

Pacific sardine (*Sardinops sagax caerulea*). In 2015, the PFMC closed the 2015–2016 west coast sardine fishing season due to very low sardine numbers (PFMC 2015) and due to continued populations below cutoff thresholds, the non-tribal commercial west coast sardine fishing season remain closed through 2019 (PFMC 2015; PFMC 2019, pp. 70–71). While non-treaty fisheries are closed, a small harvest amount was allocated to the Quinault Indian Nation (PFMC 2019, pp. 70–71) that has conducted a commercial purse-seine fishery within their usual and accustomed fishing grounds directly off Westport/Grays Harbor, Washington since 2012 (Wargo and Hinton 2016, p. 5). There are continues to be limited bycatch of sardine in other fisheries (PFMC 2019, pp. 70–71).

In British Columbia, there are a total of 50 licenses for the commercial Pacific sardine fishery that utilizes purse seine gear (DFO 2018a, p. 2).

Market squid: The market squid fishery is one of California's largest fisheries and authority for management of this fishery is through the California Fish and Game Commission, which adopted a Market Squid Fishery Management Plan in 2004 (PFMC 2019, pp. 75–76). There are no directed fisheries for market squid in Washington and in Oregon the fisheries are very limited, due to lack of squid available (PFMC 2019, p. 24). However, market squid are bycatch in other fisheries, such as for Pacific sardine (PFMC 2019, p. 22). The market squid fishery in California could potentially impact tufted puffins associated with the Farallon Islands. The Market Squid Fishery Management Plan includes management measures to reduce some of the impacts, such as a prohibition on the use of lights at night within the Greater Farallones National Marine Sanctuary (PFMC 2019, p. 41).

Market squid are very sensitive to the warm water trends of El Nino, such that abundance declines during El Nino and increase during La Nina phases (PFMC 2019, p. 23).

Zooplankton (Euphausiids/Krill): There is very limited information on the distribution and abundance of zooplankton species (euphausiids/krill), except for areas of California where information indicates the abundance levels of krill within the coastal areas that would support the tufted puffins using the Farallon Islands have been fairly high since 2008 (PFMC 2019, p. 65). Within the U.S. waters of the California Current LME, there are no directed krill fisheries in federally-managed waters and Washington, Oregon, and California state laws prohibits krill landings by state-licensed fishing vessels in state-managed waters (PFMC 2019, p. 12). Thus, there is currently a complete ban on commercial fishing for all species of krill (PFMC 2019, p. 12; also see 74 FR 33372). Due to the lack of information, NMFS designated Essential Fish Habitat for krill in 2008 (PFMC 2019, pp. 90–91).

In British Columbia there is a limited entry commercial fishery for euphausiids that primarily takes place in the upper Strait of Georgia and a few mainland inlets on the south coast (DFO 2018b, p. 2).

Rockfish. Rockfish are an important part of the food web, including as prey for tufted puffins. Rockfish are vulnerable to overfishing because they are long-lived and may not begin to reproduce until they are 5-20 years old and very few young survive to adulthood. Within the interior waters of Washington and southern British Columbia (Puget Sound/Georgia Basin), rockfish populations have declined (Palsson *et al.* 2009, pp. 6-51 to 6-54) and two species have been listed by NMFS under the Act, Puget Sound/Georgia Basin bocaccio (*Sebastes paucispinis*) and Puget Sound/Georgia Basin yelloweye rockfish (*Sebastes ruberrimus*) (75 FR 22276 and 82 FR 7711), while 13 rockfish species are designated by the State of Washington as candidates for listing (WDFW 2019).

All rockfish fisheries in federally-managed waters of Washington, Oregon, and California fall under the Pacific Coast Groundfish Fishery Management Plan. Rockfish are caught in fisheries off the coast of British Columbia; however, since 2002, there have been catch restrictions, monitoring and conservation areas in place to protect and conserve rockfish in British Columbia (DFO 2019b).

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Appendix G: Range-wide Species Distribution Model Extrapolated to 2070

Extension of the Tufted Puffin Species Distribution Model Presented in Hart *et al.* (2018) to Inform the Future Conditions Section of the Species Status Assessment

To: Catherine Yeargan, Anchorage Fish and Wildlife Conservation Office, Fish and Wildlife Biologist

From: Catherine Bradley, Fisheries and Ecological Services, Biometrician

6.19.2019

To aid the development of the Future Conditions section of the tufted puffin (*Fratercula cirrhata*) Species Status Assessment (SSA), I adapted and revised the Species Distribution Model (SDM) presented in Hart *et al.* (2018). Major changes include:

1) Projecting the SDM to the year 2070, rather than the 2050 projection presented in Hart *et al.* (2018). The SSA team determined that this was a more relevant time horizon on which to project the species distribution largely due to tufted puffin generation time.

2) The number of background absence datasets was increased from two to 10 following the recommendations of Barbet-Massin *et al.* (2012) given that the number of background absences is roughly equivalent the number of observations (1000 and 781, respectively), models were fit using generalized linear, generalized boosting, and random forest approaches, and it is appropriate to assume climatically-biased sampling (i.e., northerly latitudes were less extensively sampled than were southerly latitudes).

3) The presentation of results, both in the text and figures, was revised to more accurately reflect the inferences that can be made from this SDM. Specifically, the probability of occurrence, as presented in Hart *et al.* (2018), cannot be ascertained from the presence-background dataset available for analysis (Yackulic *et al.* 2013; El-Gabbas and Dorman 2018). This is because the probability of site inclusion (an observation) in a presence-background dataset is comprised of the probability that a site is sampled, the probability of occurrence at the site, and the conditional probability of detection given occurrence. These components cannot be disentangled from one another without additional information or strong assumptions (Yackulic *et al.* 2013). Following the guidance of Guillera-Arriota *et al.* (2015), by asserting the strong assumptions that detection probability was constant across observed sites and that the method of background absence selection accounts for climatically-biased sampling, the results of the SDM may be described as relative likelihoods. Relative likelihoods are obtained directly from the SDM output and are proportional to the actual probability of occurrence, but to an unknown degree. Under these assumptions, the relative likelihood can be used to assess the impact of climate change on species distribution on a relative, but not absolute, scale (Guillera-Arriota *et al.* 2015). I discuss

the tufted puffin relative likelihood of occurrence (RLO) across space and time using the Large Marine Ecosystems as relevant spatial units.

Species distribution models of the type presented here provide an assessment of potential species distribution (Wittman *et al.* 2016) and rely on the assumption of niche conservatism (Pearman *et al.* 2008), such that a species can move into geographic areas with similar environmental conditions as its native range. Prey distribution, interspecific competition, propensity for dispersal or other ecological factors can greatly affect the realized species distribution, particularly in future projections (Pulliam 2000, Holt 2009, Boulangeat *et al.* 2012). This limitation should be kept in mind.

Results

Results concerning model performance and variable contribution were consistent with those reported in Hart *et al.* (2018) and will not be discussed here. The forecasts made to 2070 using the ensemble models, derived from a weighted average of all fitted models (see Hart *et al.* 2018 for details), are the focus.

Across the species range examined here, the relative likelihood of occurrence (RLO) in 2070 decreases 18.7 percent under RCP 4.5 conditions and 28.0 percent under RCP 8.5 conditions, with the greatest decreases in RLO observed in the Gulf of Alaska LME (Figure F-1; Table F-1). Among the LMEs, only the North Bering - Chukchi Seas exhibits an increasing RLO between current and 2070 scenarios (Table F-1). Between emission scenarios, the East Bering Sea (-15 percent) and the Aleutian Islands (-11.5 percent) LMEs are most strongly effected by business-as-usual (RCP 8.5) conditions continuing into the future.

Table F-1. Species Distribution Model (SDM) estimates (relative likelihoods of occurrence, RLO) and the percent change between current and future scenarios for tufted puffins are presented by Large Marine Ecosystem (LME) and across the total range.

	Current	**2070 RCP 4.5 Emissions Scenario**		**2070 RCP 8.5 Emissions Scenario**	
LME	SDM estimate	SDM estimate	Percent Change	SDM estimate	Percent Change
California Current	68,758	49,851	-27.5%	46,725	-32.0%
Gulf of Alaska	1,883,580	1,240,465	-34.1%	1,065,713	-43.4%
Aleutian Islands	283,495	261,107	-7.9%	228,388	-19.4%
East Bering Sea	680,443	614,696	-9.7%	512,183	-24.7%
North Bering - Chukchi Seas	369,164	505,333	36.9%	511,556	38.6%
Total Range	3,285,440	2,671,452	-18.7%	2,364,565	-28.0%

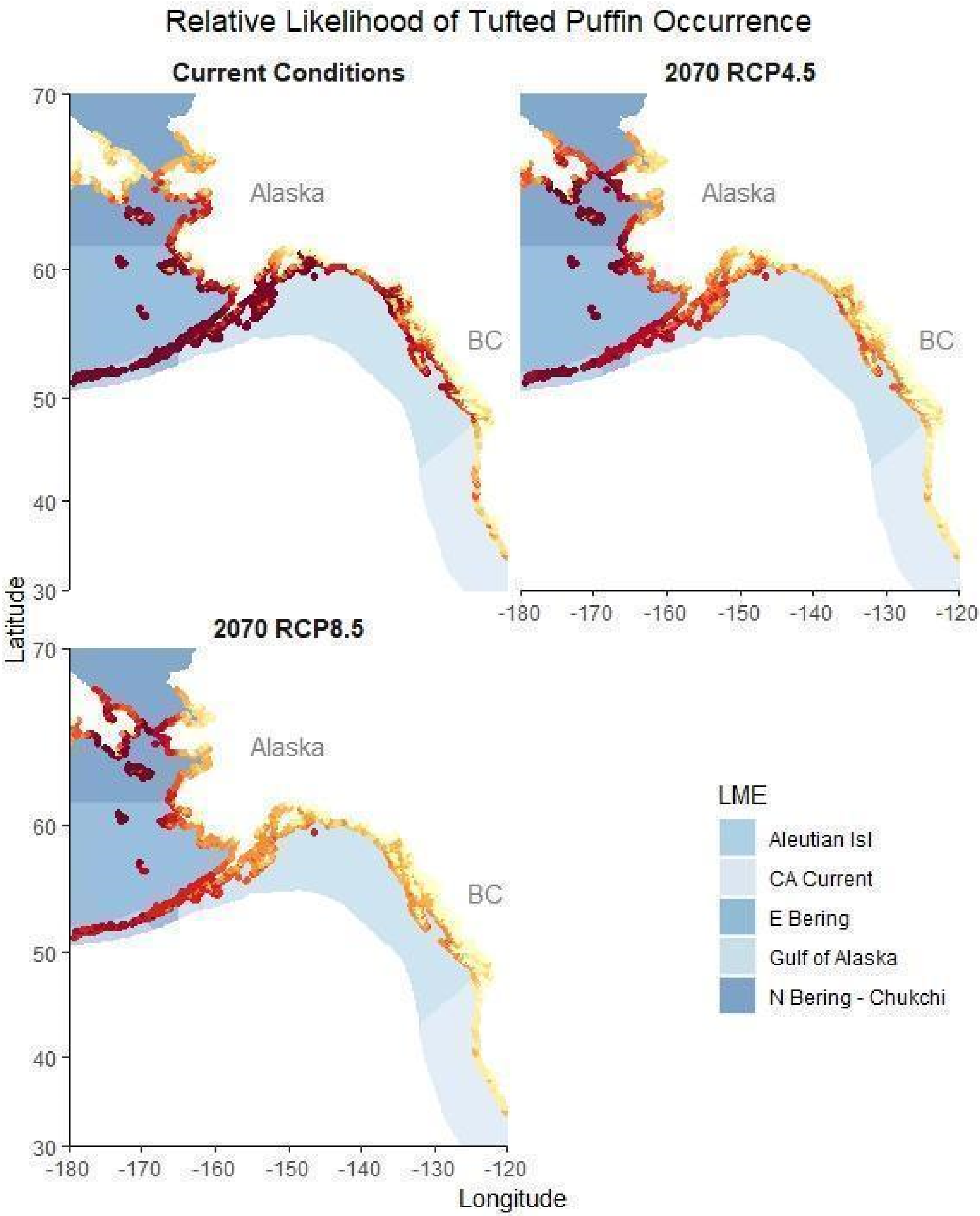

Figure F-1. Relative likelihood (Species Distribution Model, SDM, estimates) of tufted puffin occurrence under current, 2070 moderated (RCP 4.5) and 2070 business-as-usual (RCP 8.5) projected environmental conditions. Relative likelihood increases from yellow to dark red colors.

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