

Present-Day Assemblage of Birds and Mammals in the Islands of Four Mountains, Eastern Aleutians, Alaska

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Abstract

We compiled present-day observations and survey data of the avian and mammal fauna in the Islands of Four Mountains, Alaska, which primarily consist of marine-adapted species, to provide insight into the prehistoric fauna found in the archaeological record. We documented 63 bird species, mainly seabirds (67%). The majority (71%) of the estimated number of breeding birds are ledge nesters, predominately murre, and most (68%) spend the majority of their lives in the offshore environment. We lack good estimates for burrow and crevice nesters, which were impacted by and are still recovering from a period of arctic fox farming in the twentieth century. Marine mammals, predominately Steller sea lion, harbor seal, and sea otter, primarily use accessible land as haul-outs and are found in low numbers compared with the rest of the Aleutians. Red fox, the only land mammal, presently only reside on Chuginadak Island. While the present-day fauna is similar to the fauna recorded in the archaeological record, we found no indication of nesting by ancient murrelets and northern fulmars in the Island of Four Mountains, whereas both species were present in midden sites on Carlisle and Chuginadak Islands, with the possibility of prehistoric breeding colonies on Carlisle Island.

Keywords: Aleutian Islands; Aleuts; Avifauna; Islands of Four Mountains; Marine mammals; Seabirds

INTRODUCTION

The Islands of Four Mountains, originally established as the Aleutian Islands Reservation in 1913, became part of the Alaska Maritime National Wildlife Refuge (AMNWR) in 1980. AMNWR lands are managed by the U.S. Fish and Wildlife Service (USFWS), and the refuge was established to conserve marine mammals, seabirds and other migratory birds, and the marine resources upon which they rely (Alaska National Interest Lands Conservation Act of 1980). Given the vastness and remoteness of AMNWR lands, particularly in the Aleutian Islands, limited information exists on both the historical and present-day species assemblages on many of these islands. The refuge does conduct periodic monitoring of wildlife, primarily of marine birds and mammals, to understand species presence, abundance, and distribution, but these site visits have been limited in the Islands of Four Mountains. The information that has been obtained does serve as a baseline for understanding the fauna that would have been available to prehistoric Aleutian hunter-gatherers who occupied this island

group from ca. 4000 years ago to Russian contact (Hatfield et al., 2016; Krylovich et al., forthcoming).

As in the rest of the Aleutians, there are no amphibians or reptiles present in the Islands of Four Mountains, and the islands are naturally treeless. The tundra vegetation consists of two plant communities, a herbaceous *Elymus*–umbel community in more protected areas and a dwarf shrub *Empetrum*–*Vaccinium* community at higher elevations and in areas with wind exposure (Byrd, 1984; Talbot et al., 2010). The island landscapes are dominated by steep, snowcapped stratocone volcanos (Cameron and Schaefer, 2016), with lava flows of various ages. Few ponds or permanent flowing streams exist due to the porous volcanic soil, and along the coastlines there are few protected coves or sand beaches (Bailey, 1990; Thomson, 1993; Thomson and Wraley, 1994; Byrd, 1995).

The present-day assemblage of birds and mammals in the Islands of Four Mountains is shaped by various factors, either occurring presently or resulting from responses to past influences. Wildlife populations are dynamic, and in the Aleutians the distribution of native biota is determined by availability of appropriate habitat (e.g., breeding, foraging) and also influenced by additional factors such as hunting pressure, volcanism, and introductions of invasive species, which result in changes over time. Examples of hunting

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pressure include Steller's sea cow (*Hydrodamalis gigas*), which became extinct in the Aleutians by 1768 (Domning et al., 2007), and sea otters (*Enhydra lutris*), which were hunted to near extinction by 1911, when commercial hunting ceased (Doroff et al., 2003). Aleutian maritime hunter-gatherers used the most available offshore and inshore resources, including birds and mammals (Krylovich et al., forthcoming), for food as well as for skin, feathers, and bones to provide raw material for clothing and tools and for religious purposes (Corbett, 2016). While the prehistoric record indicates most faunal populations remained stable throughout the history of occupation in the Islands of Four Mountains, there is evidence of overexploitation of storm-petrels (*Oceanodroma* spp.) on Carlisle Island (Krylovich et al., forthcoming).

In the Aleutian Islands, on the northern edge of the Pacific Ring of Fire, volcanism has a major influence on island flora and habitat available for fauna, particularly as eruptive events result in disturbances to the landscape (DeGange et al., 2010). In the Islands of Four Mountains, Carlisle Island (last potential eruption 1987), Herbert Island (last eruption date unknown), and Kagamil Island (last eruption 1929) each has one historically active volcano. Chuginadak Island has two volcanos, including Cleveland, which is still intermittently active and exhibits explosive activity that can produce lava flows down to sea level (last significant event with lava flowing to sea level in 2001). Herbert Island has fumaroles and possibly historical eruptions. Geologic information is limited for Uliaga Island, but there is no evidence of a caldera (Cameron et al., 2016). Eruptive events can result in direct mortality of wildlife, particularly terrestrial species such as passerines, and can eliminate foraging and nesting habitat (Williams et al., 2010). While recovery for some species will be slower and dependent on formation of soil and recovery of terrestrial plant communities, other species, such as seabird species not dependent on soil substrates, can recover rapidly (Byrd et al., 1980; Walker et al., 2013). For example, tephra can create new talus slopes and rock rubble that provide beneficial habitat for species such as crevice-nesting auklet species (Major et al., 2006) that may actually be dependent on disturbance (Renner et al., 2017).

No terrestrial mammals are known to be native west of Umnak Island (Murie, 1959; Buskirk and Gipson, 1980; Bailey, 1993), with one exception. Red fox (*Vulpes vulpes*), potentially native but previously considered possibly introduced by Russians in the 1800s, were noted as present on Chuginadak Island in 1840 (Veniaminov, [1840] 1984). Krylovich et al. (forthcoming) recently documented red fox bones in prehistoric levels on Carlisle Island, which indicates red fox were present in the Islands of Four Mountains before Russian contact. Arctic fox (*Alopex lagopus*) were introduced to all of the Islands of Four Mountains for fox farming between 1921 and 1930 (Bailey, 1993). As observed throughout the Aleutian Islands where fox were introduced, the native avifauna was negatively affected, with many species reduced to low levels, particularly ground- and burrow-nesting birds, and some breeding populations, including

Aleutian cackling goose (*Branta hutchensii leucopareia*), extirpated from many islands (Bailey, 1993; Byrd, 1995). Since the fox farm-leasing days, arctic fox have disappeared or been eradicated from all of the islands in this group to restore nesting habitat for native birds (Bailey, 1990, 1991, 1993; Thomson, 1993; Thomson and Wraley, 1994). Red fox still exist on Chuginadak Island (Gotthardt et al., 2016), which may represent the western extent of their range. While the avifauna have responded to some extent to the release from arctic fox predation pressure, the difference in avifauna and flora assemblages and relative abundance between present-day and precontact periods is difficult to evaluate, but some differences may be inferred by comparing the present species assemblages with those found in the prehistorical records (Krylovich et al., forthcoming). For example, seabirds are long-lived and have low productivity; thus, in recent history, species that were impacted by or prevented from nesting by foxes are likely still recovering after the fox eradications of the 1990s.

The present-day assemblage of marine birds and mammals in the Islands of Four Mountains is also influenced by oceanographic conditions and the availability of food, particularly availability within the foraging range of species breeding on these islands. The Islands of Four Mountains are located on the west side of Samalga Pass, which is the first deep pass west of the Alaska Peninsula and, as a result, is very productive due to strong current movement and upwelling that creates cold, salty, and nitrate-rich surface water that concentrates prey such as zooplankton (Coyle, 2005; Hunt and Stabeno, 2005; Stabeno et al., 2005). Samalga Pass, 29 km in width, is considered to form a physical and biogeographic boundary between the eastern and central Aleutian marine ecosystems (Ladd et al., 2005a). The flow of water through this pass is dominated by strong tidal currents and net flow that primarily moves northward (Ladd et al., 2005a, 2005b). In addition, strong tidal currents and tide rips set through all of the passes between islands within the Islands of Four Mountains (National Oceanic and Atmospheric Administration [NOAA], 2016) (Fig. 1).

METHODS

Wildlife surveys of the Islands of Four Mountains have been limited but have been conducted in recent history. AMNWR conducted nearshore boat-based circumnavigation surveys in 2013 and 2015 (see paragraphs 3-5, this section) that provide the most recent snapshot of marine bird and marine mammal presence and relative abundance on the islands. Additional observations, which usually focused on marine birds, were made by biologists during boat surveys or site visits through the Aleutians in 1936 (Murie, 1936), 1972 (Sekora, 1973), and 1982 (Bailey and Trapp, 1986). During arctic fox eradication work on Carlisle, Herbert, and Kagamil Islands from 1990 to 1994, observations of wildlife were recorded and provide the best record of terrestrial and more difficult to detect species, as crews were present on land for extended periods of time

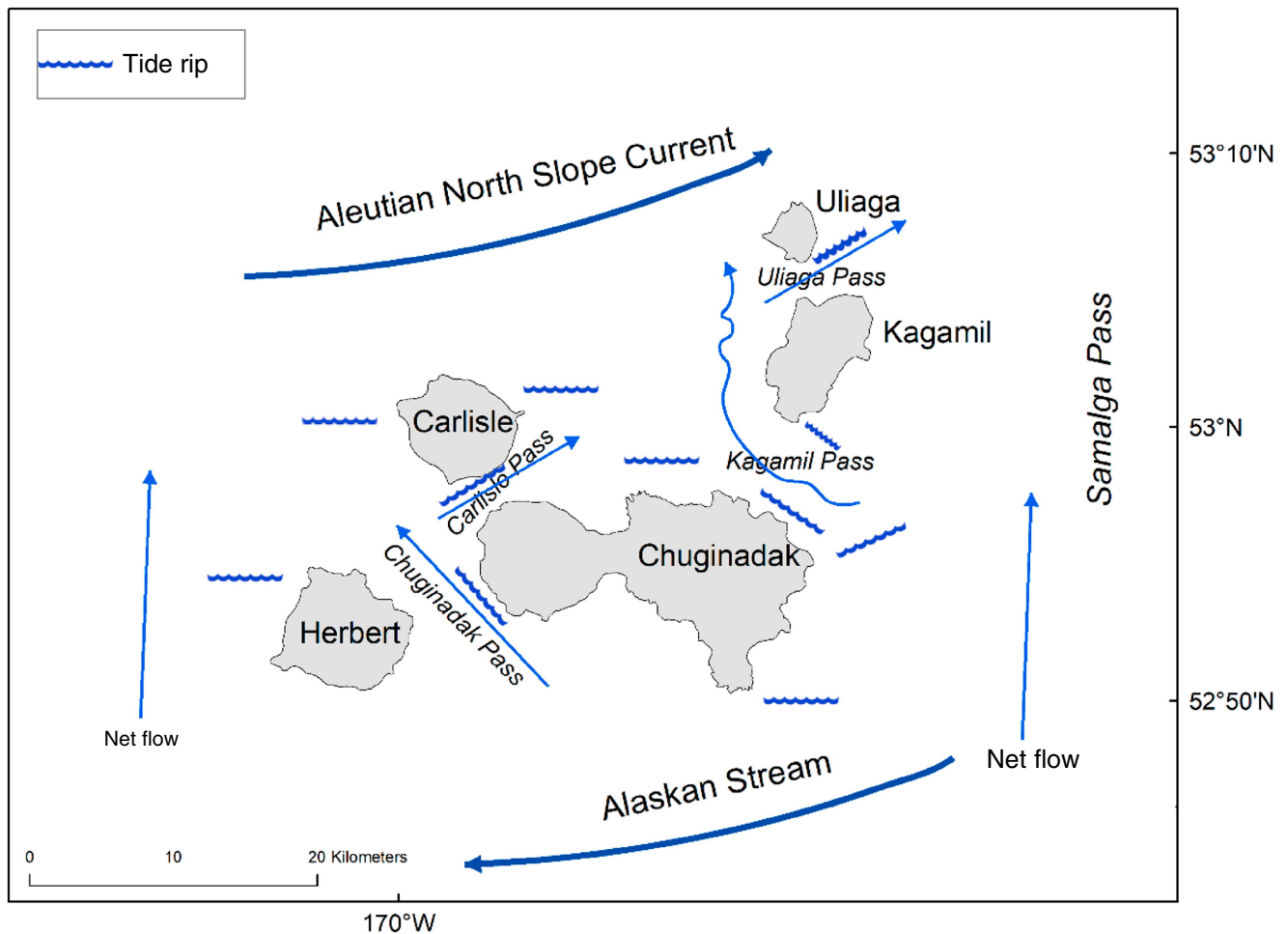


Figure 1. Map of the Islands of Four Mountains showing island passes, direction of currents, and areas with strong tidal rips. The indications of currents, net flow, and tidal rips shown in blue come from publications describing the oceanography of the Aleutians (Hunt and Stabeno, 2005; Ladd et al., 2005a), and local details within the Islands of Four Mountains come from descriptions in NOAA (2016) and personal observations of the authors and other AMNWR staff. (For interpretation of the reference to color in this figure legend, the reader is referred to the web version of this article.)

(Bailey, 1990, 1991; Thomson, 1993; Thomson and Wraley, 1994). In 1994, Byrd (1995) conducted both nearshore circumnavigation surveys using methodology similar to that of the 2013 and 2015 surveys and goose habitat surveys on each island. Additionally, incidental observations have been recorded by AMNWR personal from the R/V *Tiglatx* while transiting past these islands. All of these observations were between May and August of their respective years.

Pinnipeds and sea otters have been counted and haul-outs sites have been identified in the Islands of Four Mountains by species specialists using the most appropriate survey methods for detecting these species (as described in Doroff et al., 2003; Small et al., 2008; Fritz et al., 2016). In the Islands of Four Mountains, aerial surveys of sea otters were conducted in 1960, 1992, and 2000 (Doroff et al., 2003). Since 1985, Steller sea lions (*Eumetopias jubatus*) have been counted on a regular basis at terrestrial rookery and haul-out sites in the breeding season during aerial, ship, and/or land-based surveys conducted by the Marine Mammal Laboratory of NOAA Alaska Fisheries Science Center (Sweeney et al., 2016). Aerial surveys for

harbor seals (*Phoca vitulina*) at haul-out sites were conducted by the Marine Mammal Laboratory of NOAA Alaska Fisheries Science Center in 1999 and 2011 (NOAA, unpublished data; Small et al., 2008).

AMNWR nearshore boat-based circumnavigation surveys are one of the main techniques that the refuge uses to periodically collect information on species presence, abundance, and distribution throughout the Aleutian chain. The surveys were conducted with a 4.5 m inflatable skiff operated approximately 100 m offshore around the coastline of each island; however, distance from shore exceeded 100 m when extensive kelp beds were encountered. Two surveyors, in addition to a boat operator, used binoculars to scan and count all wildlife observed along the coast, on the water, or flying out to 200 m offshore. In addition, when possible, locations and numbers of nests observed (i.e., for surface- and ledge-nesting species, such as eagles, cormorants, kittiwakes, gulls) were recorded. Island coastlines were subdivided into contiguous survey segments for data recording. Due to logistical constraints, sections were counted just once during a survey

trip, and weather or ocean conditions prevented some segments from being completed. Ideal conditions were winds less than 15 knots, seas less than 1 m, clear visibility, and little to no precipitation; however, less than optimal conditions were often encountered, which affected the ability to detect and count wildlife. In general, surveys are conducted during summer months, ideally between late June and early July, to maximize detection of nesting seabirds, and during daylight hours, regardless of tide stage.

The circumnavigation surveys are designed to detect presence and relative abundance of nearshore marine birds and marine mammals, as well as locations of major seabird colonies and marine mammal haul-outs and rookeries. This survey type is not adequate for land birds and terrestrial mammals, other than detecting their presence if they are observed along the coastline. It also is not adequate for verifying presence or absence of difficult to detect species, such as seabirds that are only nocturnally active at breeding colonies, or for determining absolute abundance of most species. More secretive species, such as crevice- and burrow-nesting seabird species that are less likely to be observed, will either not be detected or will be underestimated. Even for diurnally active species, activity periods onshore and nearshore vary both daily and seasonally, which also affects numbers observed. For example, peak numbers of pigeon guillemots (*Cephus columba*) (a crevice nester) are visible near colonies in early mornings (Byrd et al., 1997); harbor seals are more likely hauled out close to low tide, and peak haul-out numbers occur during molting in August to September (Small et al., 2008).

The most recent AMNWR nearshore boat-based circumnavigation surveys of the Islands of Four Mountains (single survey per island) were conducted on July 26–29, 2013, for all but Herbert Island, which was surveyed on July 29, 2015 (inclement weather prevented completion in 2013). Each island was surveyed only once. Some segments were only partially completed: Uliaga (1 segment), Kagamil (2 segments), Chuginadak (1 segment); and some segments were compromised by fog. Two segments on the southeast end of Chuginadak Island were not completed due to extreme tidal currents.

In this paper, we present results of the most recent nearshore surveys conducted in 2013 and 2015 by AMNWR as totals for each island and for the island group as a whole. We combined counts of adult and immature individuals in our totals. For a more complete picture of the present-day avifauna, we compiled an avian species list from all the pre-1936 accounts discussed earlier, and we indicate which species have been confirmed breeding in the Islands of Four Mountains and include information on nesting (for the breeding species) and foraging habitat, as well as known residency status of these avian species in the Aleutians as determined by criteria in Gibson and Byrd (2007). For marine mammals, we also present the most recent specific marine mammal survey results for sea otters (Doroff et al., 2003), Steller sea lion (Sweeney et al., 2016; NOAA Alaska Fisheries Science Center, unpublished data), and harbor seals (NOAA Alaska Fisheries Science Center, unpublished data).

Using the information from these survey counts, annotated lists, USFWS Marine Mammal Management (MMM) data, NOAA Alaska Fisheries Science Center data, and personal observations collected by staff of the AMNWR, we generated our best estimates of present-day relative abundance of each species in the Islands of Four Mountains, in some cases using best professional judgment when considering available data along with knowledge of species' biology and habitat preferences.

RESULTS

Nearshore circumnavigation surveys of 2013 and 2015

Avian species

During the 2013 and 2015 nearshore boat-based circumnavigation surveys, 27 avian species (plus an unidentified *Brachyramphus* murrelet) and five marine mammal species were observed, and more than 70,000 individual birds and 578 marine mammals were counted (Table 1). The avifauna observed consisted primarily of seabirds (67%) with a small number of species of sea ducks, shorebirds, raptors, and passerines. Twenty-one of these bird species, including 69% of the seabirds, were documented (i.e., nests observed) or suspected as probably breeding in the island group.

On the islands themselves, terrestrial habitat is used primarily by seabirds during the summer breeding season and by a small assemblage of land birds. Three species of passerines known to be year-round residents in this region of the Aleutians were detected (Table 1). Two raptor species, bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*), were seen in small numbers on all islands, along with small numbers of common ravens (*Corvus corax*).

The most predominant seabirds in the Islands of Four Mountains are common and thick-billed murre (*Uria aalge* and *U. lomvia*), with a total count of 56,520 individuals (Fig. 2, Table 1). One large breeding colony is found in the island group, along 4 km of cliff habitat on the southwestern side of Kagamil Island. Murres were observed in other nearshore locations as the birds transited to and from the colony to forage. Bailey and Trapp (1986) estimated 80% of murres in this colony are thick-billed.

Three species of cormorants, double-crested (*Phalacrocorax auritus*), red-faced (*P. urile*), and pelagic (*P. pelagicus*), also use cliff habitat for nesting, with more than 2000 individuals observed in the island group, with the largest number observed at Chuginadak Island (Fig. 2, Table 1). Surveys included many unidentified cormorants due to challenges with discerning species at a distance, particularly for similar-looking red-faced and pelagic cormorants. Two-hundred sixty nests were observed: 56 double-crested, 116 red-faced, 49 pelagic, and 39 unknown. The majority (57%) of cormorant nests were found on Kagamil (57%) and Chuginadak (33%) Islands, with small numbers on Uliaga (7%) and Carlisle (3%) Islands.

Table 1. Bird and marine mammal species counted in the Islands of Four Mountains using nearshore boat-based circumnavigational surveys conducted by AMNWR in July 2013 and 2015, with counts presented as totals for each island and total for all islands combined.

Common name	Species	Uliaga	Kagamil	Chuginadak	Carlisle	Herbert	Total
Birds							
Common eider	<i>Somateria mollissima</i>	91	342	620	101	1	1155
Harlequin duck	<i>Histrionicus histrionicus</i>	11	52	81	13	44	201
Red breasted merganser	<i>Mergus serrator</i>	0	0	0	0	1	1
Black oystercatcher	<i>Haematopus bachmani</i>	5	27	15	11	29	87
Rock sandpiper	<i>Calidris ptilocnemis</i>	0	1	0	0	3	4
Parasitic jaeger	<i>Stercorarius parasiticus</i>	0	0	1	0	0	1
Common murre	<i>Uria aalge</i>	0	4	7	1	13	25
Thick-billed murre	<i>Uria lomvia</i>	1	47	5	3	0	56
Murre sp.	<i>Uria</i> sp.	29	56,301	79	17	13	56,439
Pigeon guillemot	<i>Cephus columba</i>	49	116	61	99	100	425
Brachyramphus murrelet	<i>Brachyramphus</i> sp.	1	0	0	0	0	1
Ancient murrelet	<i>Synthliboramphus antiquus</i>	0	0	0	0	2	2
Parakeet auklet	<i>Aethia psittacula</i>	0	0	0	2	0	2
Whiskered auklet	<i>Aethia pygmaea</i>	0	0	8	0	0	8
Horned puffin	<i>Fratercula corniculata</i>	211	245	394	144	302	1296
Tufted puffin	<i>Fratercula cirrhata</i>	1251	1431	1138	309	391	4520
Black-legged kittiwake	<i>Rissa tridactyla</i>	0	0	0	0	28	28
Glaucous-winged gull	<i>Larus glaucescens</i>	199	770	809	484	508	2770
Laysan albatross	<i>Phoebastria immutabilis</i>	0	0	2	0	0	2
Northern fulmar	<i>Fulmarus glacialis</i>	500	0	3	1	352	856
Double-crested cormorant	<i>Phalacrocorax auritus</i>	7	152	103	76	59	397
Red-faced cormorant	<i>Phalacrocorax urile</i>	46	129	246	50	21	492
Pelagic cormorant	<i>Phalacrocorax pelagicus</i>	49	48	108	88	43	336
Cormorant sp.	<i>Phalacrocorax</i> sp.	168	147	387	192	225	1119
Bald eagle	<i>Haliaeetus leucocephalus</i>	3	11	15	6	11	46
Peregrine falcon	<i>Falco peregrinus</i>	10	2	16	4	6	38
Common raven	<i>Corvus corax</i>	12	27	16	7	18	80
Pacific wren	<i>Troglodytes pacificus</i>	8	17	12	4	9	50
Gray-crowned rosy finch	<i>Leucosticte tephrocotis</i>	12	31	27	23	18	111
Song sparrow	<i>Melospiza melodia</i>	0	1	3	15	2	21
<i>Total birds</i>		2663	59,901	4156	1650	2199	70,569
Marine mammals							
Sea otter	<i>Enhydra lutris</i>	0	3	21 ^a	1	4	29
Northern fur seal	<i>Callorhinus ursinus</i>	0	0	1	0	0	1
Steller sea lion	<i>Eumetopias jubatus</i>	196	4	41	6	68	315
Harbor seal	<i>Phoca vitulina</i>	5	82	90	17	28	222
Orca	<i>Orcinus orca</i>	0	0	0	11	0	11
<i>Total marine mammals</i>		201	89	132	35	100	578

^aIncludes four pups.

Tufted puffin (*Fratercula cirrhata*), a burrow nester, was the most abundant seabird observed after murrees and was found in small colonies on all islands in soil habitat on steep slopes, particularly on Kagamil and Uliaga Islands and Corwin Rock off of Chuginadak Island (Fig. 2).

Among the crevice nesters, horned puffins (*Fratercula corniculata*) (Fig. 2) and pigeon guillemots were less abundant than tufted puffins and were assumed to be nesting in multiple locations on all islands. Only a few crevice-nesting parakeet (*Aethia psittacula*) and whiskered auklets (*A. pygmaea*) were observed on the most recent survey.

Of the ground- or surface-nesting marine birds, glaucous-winged gulls (*Larus glaucescens*) were observed in the largest numbers and were present on all islands, with

breeding confirmed by the presence of immature birds, as well as by nesting observations from past accounts (Fig. 2). Black oystercatchers (*Haematopus bachmani*), which nest on rocky shorelines, were found in small numbers on all islands. Common eider (*Somateria mollissima*), a sea duck that nests along shorelines, was observed on all islands, particularly on Kagamil and Chuginadak Islands, and breeding was confirmed by the presence of ducklings (Fig. 2).

Several other species were observed in small numbers, primarily using nearshore waters, including harlequin ducks (*Histrionicus histrionicus*), which are not known to nest in the Aleutians (Gibson and Byrd, 2007). Northern fulmars (*Fulmarus glacialis*) were observed only on the water or in flight, particularly off Herbert Island and an islet off

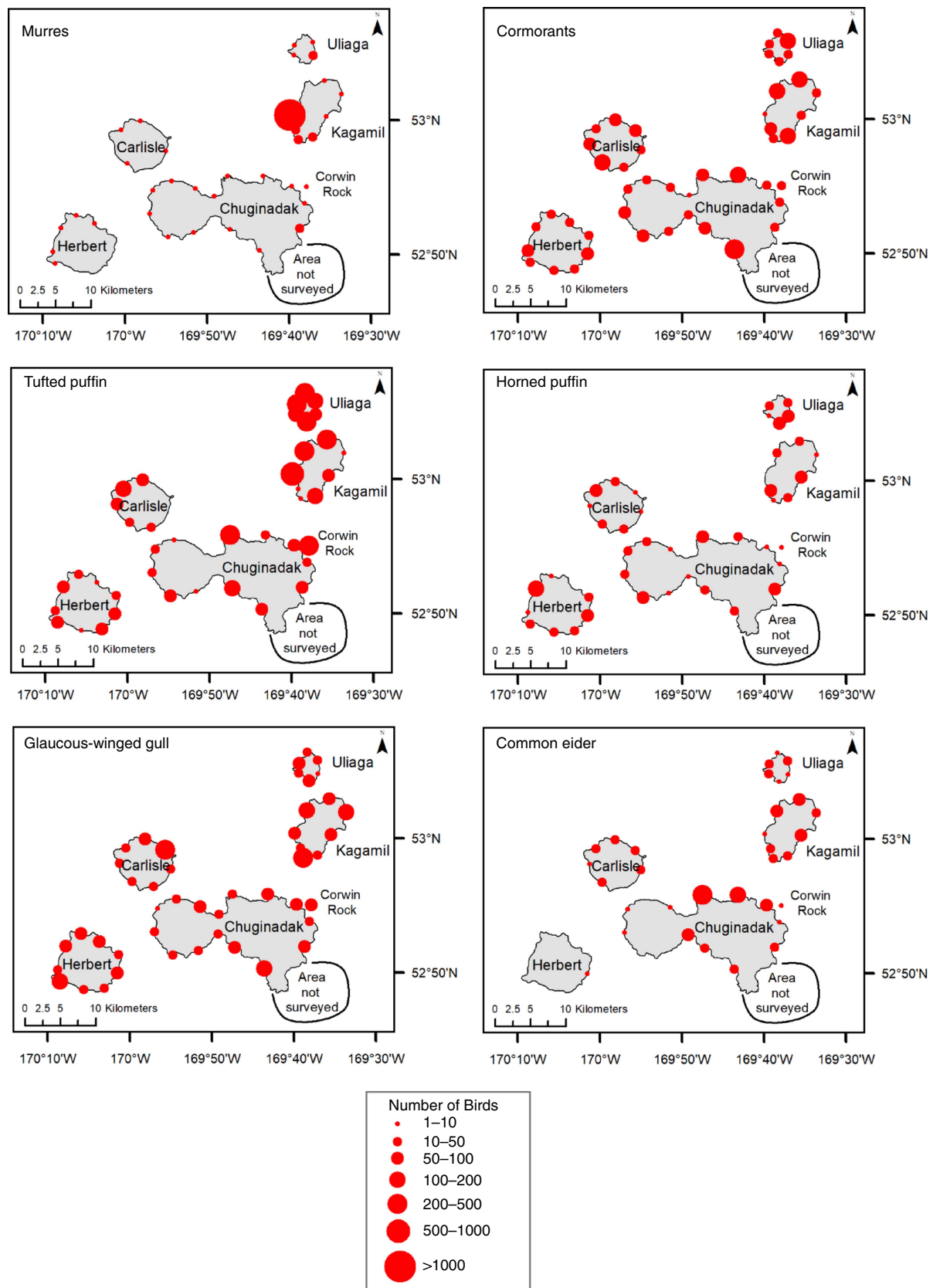


Figure 2. Maps showing distribution of murres, cormorants, tufted puffin, horned puffin, glaucous-winged gull, and common eider in the Islands of Four Mountains from observations in 2013 and 2015 nearshore circumnavigation boat surveys. Counts are presented by survey segment, with the location of each segment count presented at the midpoint of the segment.

Uliaga Island, but no breeding colony was detected in this island group.

Marine mammal species

Five marine mammal species were observed in nearshore waters or hauled out on shorelines, totaling 578 individuals. Steller sea lions and harbor seals were observed around all the islands in the group, with Steller sea lions being the most numerous. The majority of the Steller sea lions were observed at Uliaga (62%) and Herbert (22%) Islands, and no pups were noticed, while harbor seals were most numerous at Chuginadak (41%) and Kagamil (37%) Islands, with no sightings of young. Sea otters were observed in smaller numbers at all but Uliaga Island, with the majority (72%) around Chuginadak Island, including four pups. A pod of 11 orcas (*Orcinus orca*) were seen nearshore of Carlisle Island, and one northern fur seal (*Callorhinus ursinus*) was seen at Chuginadak Island.

Additional accounts of avian species

From the additional accounts since 1936 of birds observed in the Islands of Four Mountains, 37 additional species have been documented for a total of 63 species (Table 2). This includes an additional 10 breeding species, 5 of which are land birds (rock ptarmigan and four passerines), 1 duck (Aleutian green-winged teal), and red-necked phalarope (Table 2). Three additional burrow-nesting seabirds were confirmed or likely breeding, including one Cassin's auklet (*Ptychoramphus aleuticus*) on Carlisle Island (Bailey, 1990) and both fork-tailed (*Oceanodroma furcata*) and Leach's storm-petrels (*O. leucorhoa*) on all islands (Murie, 1936; Bailey and Trapp, 1986; Bailey, 1990; Thomson and Wraley, 1994). While only a few whiskered auklets were observed on the most recent nearshore boat survey, this crevice-nesting species has been confirmed breeding in the Islands of Four Mountains (Murie, 1936; Sekora, 1973; Bailey and Trapp, 1986; Thomson, 1993; Thomson and Wraley, 1994) and larger numbers have been documented from additional sightings. All of these burrow- and crevice-nesting species would be difficult to detect during a daytime survey or island visit, because they are only nocturnally active at colony sites. These species were more often observed foraging offshore, with sightings of hundreds of parakeet auklets (Bailey, 1991) and up to 10,000 whiskered auklets in island passes in the Islands of Four Mountains (Byrd and Gibson, 1980).

Additional nonbreeding birds include several species of waterfowl, including emperor (*Anser canagica*) and Aleutian cackling geese and shorebirds. Most of the shorebirds would be migrants, and thus short-term visitors, as shorebird nesting habitat is lacking on these islands. Seabird species that are not breeding in this island group have been documented in these additional accounts, including least and crested auklets (*Aethia pusilla*, *A. cristatella*), black-legged kittiwake (*Rissa tridactyla*), and northern fulmar, as well as species that typically would be found offshore of the islands, foraging

or passing through, including albatross (*Phoebastria* spp.) and shearwaters (*Ardenna* spp.). Short-tailed albatross (*Phoebastria albatrus*) have been recorded by the R/V *Tigllax* while transiting south of the islands (USFWS, unpublished data).

Additional surveys of marine mammals

Marine mammals, such as sea otters, harbor seals, and Steller sea lions primarily use portions of the accessible land as haul-outs (Fig. 3) and forage nearshore. Marine mammal counts by USFWS MMM, and NOAA were higher for sea otters and Steller sea lions than those detected in a 1-day circumnavigation (Table 3). Relative abundance of species is similar and hierarchy of island use in the group is the same. These surveys have documented that no Steller sea lion rookeries are present in the Islands of Four Mountains, although an occasional one or two pups have been born there. We counted more harbor seals in our circumnavigation survey than were counted by NOAA's most recent haul-out survey in 2011 (Table 3). However, harbor seal counts are known to be variable, and the NOAA survey had large variances in abundance estimates, but overall the population of harbor seals in the Islands of Four Mountains is characterized by NOAA at 100–200 seals (London, J. M., personal communication, 2017).

We are not aware of any dedicated cetacean surveys in the Islands of Four Mountains, but species with known ranges that include oceanic waters surrounding this island group include species that may be present in coastal waters such as minke whale (*Balaenoptera acutorostrata*), humpback whale (*Megaptera novaeangliae*), orca, and harbor porpoise (*Phocoena phocoena*). Pelagic species include blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*), Dall's porpoise (*Phocoenoides dalli*), sperm whale (*Physeter macrocephalus*), Baird's beaked whale (*Berardius bairdii*), and the now-rare North Pacific right whale (*Eubalaena japonica*) (Wynne, 2012). Humpback whales, orcas, and fin whales have been recorded by the R/V *Tigllax* while transiting north of the islands (USFWS, unpublished data).

Estimates of present-day relative abundance of avian species

Based on our surveys and all historical accounts, we estimated present-day relative abundance of each species in the Islands of Four Mountains. The majority (71%) of the estimated number of breeding birds in the Islands of Four Mountains are ledge-nesting seabirds (Table 4), which are predominately murre nesting on cliffs of Kagamil Island. However, we do not have good estimates for most of the burrow- and crevice-nesting seabirds, and numbers for these species are suspected to be much higher than we can currently evaluate. The majority (92%) of total birds present in this island group are Aleutian residents and predominately spend the majority (68%) of time (away from breeding colonies)

Table 2. Avian species observed in the Islands of Four Mountains from various sources.

Common name	Species	Residency status ^a	Foraging habitat ^b	Nesting habitat ^c	Estimated relative abundance ^d	Observation sources ^e
Known or suspected breeder						
Aleutian green-winged teal	<i>Anas crecca nimia</i>	Resident	Inshore and nearshore	Surface	<100	2, 5, 6, 7
Common eider	<i>Somateria mollissima</i>	Resident	Nearshore	Surface	1000s	
Rock ptarmigan	<i>Lagopus muta</i>	Resident	Onshore	Surface	<500	1, 2, 3, 4, 5, 6, 7
Black oystercatcher	<i>Haematopus bachmani</i>	Resident	Nearshore	Surface	<100	
Rock sandpiper	<i>Calidris ptilocnemis</i>	Resident	Nearshore	Surface	P	
Red-necked phalarope	<i>Phalaropus lobatus</i>	Summer	Inshore, nearshore, and offshore	Surface	<100	5
Parasitic jaeger	<i>Stercorarius parasiticus</i>	Summer	Inshore and nearshore	Surface	<100	
Common murre	<i>Uria aalge</i>	Resident	Offshore	Ledge	>10,000	
Thick-billed murre	<i>Uria lomvia</i>	Resident	Offshore	Ledge	>45,000	
Pigeon guillemot	<i>Cepphus columba</i>	Resident	Nearshore	Crevice	<1000	
Cassin's auklet	<i>Ptychoramphus aleuticus</i>	Summer	Offshore	Burrow	P	3, 5, 6, 7
Parakeet auklet	<i>Aethia psittacula</i>	Summer	Nearshore	Crevice	P	
Whiskered auklet	<i>Aethia pygmaea</i>	Resident	Nearshore	Crevice	10,000	
Horned puffin	<i>Fratercula corniculata</i>	Summer	Nearshore	Crevice	>1000	
Tufted puffin	<i>Fratercula cirrhata</i>	Resident	Offshore	Burrow	>1000	
Glaucous-winged gull	<i>Larus glaucescens</i>	Resident	Nearshore	Surface	>1000	
Fork-tailed storm-petrel	<i>Oceanodroma furcata</i>	Resident	Offshore	Burrow	P	1, 2, 3, 6
Leach's storm-petrel	<i>Oceanodroma leucorhoa</i>	Summer	Offshore	Burrow	P	2
Double-crested cormorant	<i>Phalacrocorax auritus</i>	Resident	Nearshore	Ledge	<1000	
Red-faced cormorant	<i>Phalacrocorax urile</i>	Resident	Nearshore	Ledge	<1000	
Pelagic cormorant	<i>Phalacrocorax pelagicus</i>	Resident	Nearshore	Ledge	<1000	
Bald eagle	<i>Haliaeetus leucocephalus</i>	Resident	Onshore	Surface	<100	
Peregrine falcon	<i>Falco peregrinus</i>	Resident	Onshore	Ledge	<100	
Common raven	<i>Corvus corax</i>	Resident	Onshore	Ledge	<100	
Pacific wren	<i>Troglodytes pacificus</i>	Resident	Onshore	Surface	>1000	
American pipit	<i>Anthus rubescens</i>	Summer	Onshore	Surface	<1000	5, 6
Gray-crowned rosy finch	<i>Leucosticte tephrocotis</i>	Resident	Onshore	Surface	>1000	
Lapland longspur	<i>Melospiza melodia</i>	Summer	Onshore	Surface	>1000	1, 3, 5, 6, 7
Snow bunting	<i>Plectrophenax nivalis</i>	Resident	Onshore	Surface	>1000	1, 3, 5, 6, 7
Savannah sparrow	<i>Passerculus sandwichensis</i>	Summer	Onshore	Surface	<1000	1, 5, 6, 7
Song sparrow	<i>Melospiza melodia</i>	Resident	Onshore	Surface	>1000	
Nonbreeders, migrants, or winter visitors						
Emperor goose	<i>Anser canagica</i>	Winter	Onshore		P	1
Aleutian cackling goose	<i>Branta hutchinsii leucopareia</i>	Summer	Onshore		<100	5, 7
American wigeon	<i>Anas americana</i>	<Annual	Inshore and nearshore		<100	7
Northern shoveler	<i>Anas clypeata</i>	Migrant	Inshore and nearshore		<100	7
Northern pintail	<i>Anas acuta</i>	Resident	Inshore and nearshore		<100	5, 7
King eider	<i>Somateria spectabilis</i>	Winter	Inshore and nearshore		<100	8
Harlequin duck	<i>Histrionicus histrionicus</i>	Resident	Nearshore		<500	
White-winged scoter	<i>Melanitta fusca</i>	Winter	Nearshore		<100	3, 6, 7
Bufflehead	<i>Bucephala albeola</i>	Winter	Nearshore		<100	6
Red breasted merganser	<i>Mergus serrator</i>	Resident	Nearshore		<100	
Sandhill crane	<i>Antigone canadensis</i>	Summer	Onshore		<100	2, 6
Semipalmated plover	<i>Charadrius semipalmatus</i>	Summer	Nearshore		<100	3
Whimbrel	<i>Numenius phaeopus</i>	Migrant	Nearshore		<100	6
Ruddy turnstone	<i>Arenaria interpres</i>	Migrant	Nearshore		<100	3, 5
Least sandpiper	<i>Calidris minutilla</i>	Summer	Nearshore		<100	3
Wandering tattler	<i>Tringa incana</i>	Migrant	Nearshore		<100	5, 6
Long-tailed jaeger	<i>Stercorarius longicaudus</i>	Migrant	Offshore and nearshore		<100	6
Marbled murrelet	<i>Brachyramphus marmoratus</i>	Resident	Nearshore		<100	7
Ancient murrelet	<i>Synthliboramphus antiquus</i>	Resident	Offshore		P	
Least auklet	<i>Aethia pusilla</i>	Resident	Offshore		<100	5
Crested auklet	<i>Aethia cristatella</i>	Resident	Offshore		<100	1, 5
Black-legged kittiwake	<i>Rissa tridactyla</i>	Resident	Offshore		P	
Mew gull	<i>Larus canus</i>	Winter	Nearshore		<100	6
Common loon	<i>Gavia immer</i>	Resident	Inshore and nearshore		<100	6
Laysan albatross	<i>Phoebastria immutabilis</i>	Summer	Offshore		<100	
Black-footed albatross	<i>Phoebastria nigripes</i>	Summer	Offshore		P	5, 8
Short-tailed albatross	<i>Phoebastria albatrus</i>	Summer	Offshore		<100	8
Northern fulmar	<i>Fulmarus glacialis</i>	Resident	Offshore		>1000	

Table 2. (Continued)

Common name	Species	Residency status ^a	Foraging habitat ^b	Nesting habitat ^c	Estimated relative abundance ^d	Observation sources ^e
Shearwater spp.	<i>Ardenna</i> spp.	Summer	Offshore		>1000	5, 8
Short-eared owl	<i>Asio flammeus</i>	Summer	Onshore		<10	3, 4, 7
Bank swallow	<i>Riparia riparia</i>	Summer	Onshore		<10	2, 3, 5, 6
Unsubstantiated vagrant						
Rufous hummingbird	<i>Selasphorus rufus</i>	Vagrant	Onshore		<10	1, 5
American golden-plover	<i>Pluvialis dominica</i>	Vagrant	Nearshore		<10	4, 5

^aResidency status as determined in Gibson and Byrd, 2007: appendix 4. Species with residency status in bold are noted in Gibson and Byrd as confirmed to breed in the Aleutians.

^bForaging habitat is defined as the location a species is likely to be found while foraging, either onshore, inshore, nearshore, or offshore.

^cFor breeding species, nesting habitat is defined as a burrow (eggs laid in tunnels excavated in soil), crevice (eggs laid inside crevices), ledge (eggs laid on cliff ledges), or surface (eggs laid on ground).

^dEstimated relative abundance (number of individual birds) of each species based on all accounts. "P" indicates present but no estimate available.

^eSources of observation if not observed in the most recent USFWS 2013/2015 nearshore boat survey. Sources: 1, Murie, 1936; 2, Bailey and Trapp, 1986; 3, Bailey, 1990; 4, Bailey, 1991; 5, Thomson, 1993; 6, Thomson and Wraley, 1994; 7, Byrd, 1995; 8, USFWS, unpublished data.

in the offshore environment (Table 5), followed in numbers by species that use the nearshore environment (22%) and a smaller number (10%) remain on land.

DISCUSSION

Avian species

The present-day assemblage of birds and mammals in the Islands of Four Mountains primarily consists of marine-adapted species, such that most species use the terrestrial environment for breeding and/or resting (e.g., haul-out site for marine mammals) but forage and spend the majority of their lives in the ocean environment. Inland habitat suitable for breeding birds requiring vegetation, soil, or access to freshwater is limited, given the presence of porous volcanic soil and few permanent flowing streams or ponds on most of

the islands. The majority of the coastlines of these islands consist of rugged lava flows that rise steeply on all sides of cone volcanos; thus only a coastal fringe provides suitable habitat for most birds (Bailey, 1990). Few protected coves or sand beaches exist, which also limits use by species such as shorebirds that would prefer this habitat.

The introduction of arctic fox to these islands certainly impacted avian species, and we do not have many observations pre-fox introduction to compare changes. Surface- and burrow-nesting birds, which include waterfowl, shorebirds, seabirds, and ptarmigan, would have been most heavily impacted (Bailey, 1993; Ebbert and Byrd, 2002). What we do know is that some recovery has occurred since the days of fox farming. Bailey (1990) noted that birds had largely vanished from Carlisle Island by 1949 and only about 500 seabirds (puffins) were recorded there in 1972 by Sekora (1973), while in our most recent survey we observed 22 species and counted 1650 birds. Bailey also found no seabird colonies on Herbert Island in 1990, compared with six species and an estimated 400 birds observed in 1982, while we documented four species of seabirds nesting in our most recent surveys.

There are several challenges to determining the complete assemblage and absolute abundance of species present in the Islands of Four Mountains using nearshore boat surveys or even short-term island visits. Logistical constraints have

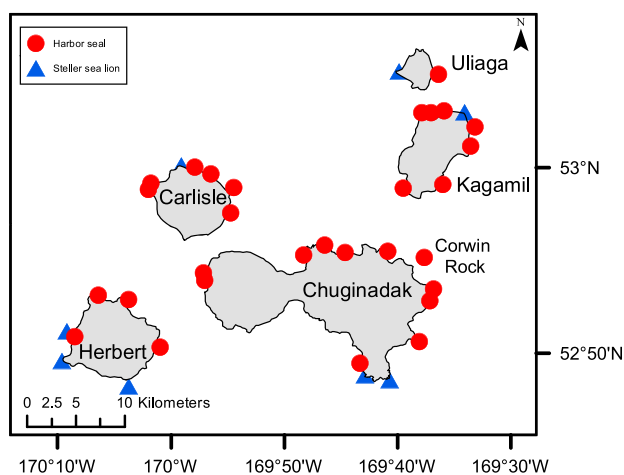


Figure 3. Map showing known haul-out sites for harbor seals (red) and Steller sea lions (blue) in the Islands of Four Mountains. Location data from Marine Mammal Laboratory, NOAA Alaska Fisheries Science Center. (For interpretation of the reference to color in this figure legend, the reader is referred to the web version of this article.)

Table 3. Most recent marine mammal counts in the Islands of Four Mountains from surveys conducted by USFWS Marine Mammal Management and NOAA Alaska Fisheries Science Center.

Species	Year of count	Year of					Total
		Uliaga	Kagamil	Chuginadak	Carlisle	Herbert	
Sea otter ^a	2000	3	3	16	6	12	40
Steller sea lion ^b	2014	164	13	112	20	114	423
Harbor seal ^c	2011		46 ^d	47	18	8	119

^aDoroff et al. 2003.

^bFritz et al. 2016.

^cNOAA Alaska Fisheries Science Center, unpublished data.

^dData for Uliaga and Kagamil combined into one survey unit in NOAA abundance estimate

Table 4. Number of breeding avian species and estimated minimum numbers of breeding birds by nesting habitat type in the Islands of Four Mountains.

Habitat	Breeding birds	
	No. species	No. birds
Burrow ^a	4	>1000
Crevice ^b	4	>12,000
Ledge	7	58,000
Surface	16	10,000
Total	31	>81,000

^aMore than 1000 burrow nesters are present, but likely <10,000. We lack good estimates for these species, in particular for storm-petrels and Cassin's auklets. Byrd et al. (2005) estimated 6500 storm-petrels and no Cassin's auklets nesting in the island group.

^bThe estimate for crevice nesters is a minimum and does not include an estimate for parakeet auklets, which are present but in unknown numbers. Bailey and Trapp (1986) estimated 50 parakeet auklets on Carlisle Island and 40 on Chuginadak Island based on a brief reconnaissance.

prevented frequent site visits to the island group and replicate surveys in a particular year have not been possible. Passerines, such as snow bunting (*Plectrophenax nivalis*) that nest in upland scree, and other land birds, such as rock ptarmigan (*Lagopus muta*) that typically nest at higher elevations, and waterfowl using inland habitat would be better detected with land surveys. While several of these inland species have been documented in this island group, few dedicated surveys of land birds have been conducted, none of which would have estimated populations. Thus our estimates of relative abundance are limited and based on knowledge of expected numbers, given what is known on other Aleutian islands.

We have high confidence that surveys have detected all of the present-day ledge-nesting seabird colonies in the Islands of Four Mountains, because all coastal cliff habitat can be identified and these colonies would be noticeable. Similarly, most surface-nesting seabirds (e.g., glaucous-winged gull) and the presence of raptor species would be detected. No northern fulmar colonies were documented. This conspicuous surface-nesting seabird that nests on steep, grassy, sea-facing hillsides would have been detected on our surveys if present. While the predominant seabirds breeding in the Islands of Four Mountains in the present-day are murre, the archaeological record from Carlisle and Chuginadak Islands indicates that prehistoric Aleuts rarely hunted them

(Krylovich et al., forthcoming). This may be due to the colony being located on Kagamil Island, on steep cliff ledges that would be difficult to access. Murres have been considered a species preferred by Aleuts in historical times for use of skins in clothing (Turner, 2008; Corbett, 2016), but these birds would need to be accessible to hunters. Small numbers of cormorants nest in the Islands of Four Mountains, particularly on Chuginadak and Kagamil Islands. Based on the archaeological record of the Islands of Four Mountains, prehistoric Aleuts hunted cormorants in small numbers, with the largest percentage (9%) of the avian assemblage on Carlisle Island, at the Ulyagan site unit 4, dated between 2900 and 1850 cal yr BP (Krylovich et al., forthcoming). In historical times, cormorants have been considered preferred birds for hunting by Aleuts for food and for use of skins and feathers in clothing and parts for toolmaking (Jochelson, 2002; Turner, 2008; Corbett, 2016). Cormorants have low nest-site fidelity and frequently move nesting locations from year to year; however, they tend to be nonmigratory and are present near-shore year-round, including spending time roosting on rocky shorelines (Causey, 2002; Hobson, 2013; Dorr et al., 2014).

All crevice- and burrow-nesting seabirds are extremely difficult to count and often difficult to detect. Additionally some of these species are only nocturnally active at breeding sites (e.g., ancient murrelet, whiskered auklet, storm-petrels) and thus were detected in small numbers or not at all using boat surveys during daylight hours. Even diurnally active species such as puffins have periods of activity at colonies when swarms of birds can be observed flying erratically overhead or standing near burrow entrances, while the same colony locations can appear uninhabited at other times of the day. Our surveys document species presence, colony locations, and relative abundance or minimum numbers of these species but certainly lack the ability to estimate absolute abundance.

After murre, the most abundant seabird we observed on surveys was tufted puffins. Both tufted and horned puffins are found in small percentages in the archaeological record from both Carlisle and Chuginadak Islands, except for Ulyagan site unit 2, dated approximately 150 years ago, where puffin species comprised 21% of the avian assemblage (Krylovich et al., forthcoming). In historical times, puffins have been considered preferred birds for hunting by Aleuts for use of skins in clothing (Veniaminov, [1840] 1984; Turner, 2008; Corbett, 2016). Chicks and/or adults of both species could have been easily extracted from their burrow and crevice nests.

Table 5. Seasonality of avian species in the Islands of Four Mountains and estimated minimum numbers.

Season	Nearshore		Offshore		Land		Total	
	No. spp.	No. birds	No. spp.	No. birds	No. spp.	No. birds	No. spp.	No. birds
Resident	15	17,100	9	57,200	8	4800	32	79,100
Summer	6	>1400	6	>1200	7	3220	19	>5820
Winter	4	300	0	0	1	<1000	5	1,300
Spring/fall migrant	5	410	1	100	1	10	7	520
Total	30	>19,210	16	>58,500	17	>9030	63	>86,740

Whiskered auklets, a small nocturnally active crevice nester, are an example of a species for which few individuals are detected during daytime surveys, yet they have been documented to nest in the Islands of Four Mountains. This auklet forages mainly in tide rips (Byrd and Williams, 1993), which are present between all island passes in this island group. Whiskered auklets occur in small colonies throughout the Aleutians and were considered heavily impacted by fox predation (Bailey, 1993; Byrd and Williams, 1993; Williams et al., 2003). Following fox removal, Williams et al. (2003) noted evidence of recovery, with increasing numbers of whiskered auklet observations, including large numbers in the passes of the Islands of Four Mountains, the largest being a single flock of 10,000 individuals observed in 1972 (Byrd and Gibson, 1980). The current estimated population of 10,000 whiskered auklets in the Islands of Four Mountains is based on these observations (Williams et al., 2003; Byrd et al., 2005). The archaeological record of the Islands of Four Mountains indicates that prehistoric Aleuts hunted whiskered auklets, and evidence from bones indicates nesting during that time period. On north Chuginadak Island, at the Tanaã Agunaã site, dated between 2800 and 2000 cal yr BP (Krylovich et al., forthcoming), whiskered auklet was the most common species at 54% of the avian assemblage, which suggested they were hunted for their skins as well as for food (Krylovich et al., forthcoming). Whiskered auklet was also identified in archaeological layers at a prehistoric village site located on Carlisle Island. It is possible whiskered auklets are one of the most abundant bird species found in these midden sites because of the now-confirmed documentation that these auklets are nonmigratory and are resident at some colonies year-round, roosting on land at night year-round (Schacter, 2017); thus they were available to be hunted year-round, while most other seabird species are entirely offshore during the nonbreeding season. Additionally, whiskered auklets have ornate facial crests and plumes and possibly could have been selected for collection of facial ornamentation for clothing, as was suggested by Lefevre et al. (1997) at Buldir Island; the use of bird head plumes in general as clothing ornaments has been documented by Turner (2008).

Ancient murrelets (*Synthliboramphus antiquus*), nocturnally active burrow nesters on steep sea-facing slopes (Gaston and Shoji, 2010), were not detected nesting in the Islands of Four Mountains. The closest colony is located at Chagulak Island, estimated at 5000 birds (Gibson and Byrd, 2007). As burrow nesters, which depart the breeding colony within a few days of chicks hatching, ancient murrelets are believed to have been heavily impacted by foxes. Currently their largest concentrations are on islands where foxes were never introduced (Gibson and Byrd, 2007). It is thought that historically colonies must have occurred on more islands (Byrd et al., 2005), and their population in present times is expected to increase following removal of fox from various islands (Ebbert and Byrd, 2002). The archaeological record of the Islands of Four Mountains indicates that prehistoric Aleuts hunted ancient murrelets, with indication of skinning for use in clothing. On north Chuginadak Island, at the Tanaã

Agunaã site, dated between 2800 and 2000 cal yr BP, ancient murrelet comprised 34% of the avian assemblage (Krylovich et al., forthcoming). Multiple ancient murrelet bones were also identified in archaeological layers located on Carlisle Island over a long period of time, from prehistoric village sites and a village site from the Russian contact period (Krylovich et al., forthcoming), which provides evidence that ancient murrelets were formerly present in larger numbers in the Islands of Four Mountains than observed in recent surveys. Ancient murrelets comprised 16% of the avian assemblage found at Ulyagan site unit 4 (dated between 2850 and 1850 cal yr BP) (Krylovich et al., forthcoming), 14 % of the avian assemblage at Ulyagan site unit 5 (400 years ago), and 39% of the avian assemblage at Ulyagan site Unit 2 (150 years ago). Two ancient murrelet bones found at the Tanaã Agunaã site were identified to be from chicks (i.e., bones not fully formed), which suggests that breeding possibly occurred locally during that time period (Krylovich et al., forthcoming). Recent research on the postbreeding movements of ancient murrelets from breeding colonies in British Columbia (which starts in June) indicates that they move long distances, including spending a molting period in the eastern Aleutian Islands (Gaston et al., 2017). This indicates that ancient murrelets could be present offshore in certain seasons, even if not breeding in the island group.

Fork-tailed and Leach's storm-petrels, also nocturnally active burrow nesters, are suspected of breeding on all islands in the Islands of Four Mountains, but unfortunately present-day numbers are difficult to determine. The archaeological record of the Islands of Four Mountains indicates that prehistoric Aleuts hunted storm-petrels, particularly on Carlisle Island, at the Ulyagan site unit 5, where storm-petrels comprised a remarkable 41% of the avian assemblage, and the presence of many chick bones ca. 500–300 cal yr BP suggests a nesting colony occurred on the island (Krylovich et al., forthcoming). Storm-petrels are long-lived seabirds with fidelity to breeding colonies. In addition, they have a protracted incubation and chick-rearing period (Huntington et al., 1996; Boersma and Silva, 2001), during which time adults, eggs, or chicks could be obtained by extraction or digging out of burrows. Krylovich et al. (forthcoming) and Kuzmicheva et al. (forthcoming) found evidence suggesting a rapid decline in the storm-petrel colony, likely due to human harvesting, during one period of human occupation on Carlisle Island. Storm-petrel species also would be impacted by presence of predators such as fox (Bailey, 1993). In the present day, storm-petrels in the Islands of Four Mountains are suspected to have been heavily impacted during the fox-farming period and have been in a period of recovery since that time.

Nearshore or land surveys will not generally detect species such as northern fulmar that do not presently nest in the Islands of Four Mountains but are using offshore waters for foraging. Northern fulmars, cliff nesters, are known to nest on only eight islands in the Aleutians (Mallory et al., 2012). The closest fulmar colonies to the Islands of Four Mountains are approximately 70 km west at Chagulak and Amukta Islands. The Chagulak colony is estimated at 500,000 birds,

97% of the entire Aleutian breeding population (Byrd et al., 2005). Fulmars traveling from those colonies to and from Samalga Pass, where large aggregations have been observed foraging (Jahncke et al., 2005; Ladd et al., 2005b), would result in movement of many birds through the Islands of Four Mountains; thus fulmars would have been encountered by Aleuts hunting offshore. The archaeological record of the Islands of Four Mountains indicates that prehistoric Aleuts hunted northern fulmars, particularly on Carlisle Island, at the Ulyagan site unit 4, dated between 2850 and 1850 cal yr BP, where fulmars comprised 22% of the avian assemblage; while at the other sites and in more recent time periods, they comprised less than 3% of the avian assemblage (Krylovich et al., forthcoming). The presence of the bones of fulmar chicks, which comprised 67% of fulmar remains at the Ulyagan site unit 4, would indicate that a colony could have been present during that prehistoric period on Carlisle Island, but by approximately 400 cal yr BP (Krylovich et al., forthcoming) fulmars were less common, indicating perhaps a decline or disappearance of a breeding colony. Fulmars are known to exhibit strong fidelity to individual nest sites and they are long-lived (mean life expectancy of more than 40 yr) (Mallory et al., 2012); thus, if a local colony existed prehistorically on Carlisle Island, continual hunting pressure could have resulted in eventual decline of the colony. Presence of predators such as fox could also reduce or eliminate a fulmar colony, as has been noted for some Aleutian islands, and a volcanic eruption was noted for disturbing a fulmar colony on Gareloi Island (Murie, 1959; Mallory et al., 2012).

Chagulak Island has one of the largest seabird colonies in the Aleutian islands (Byrd et al., 2004) and is thus a close source for several other seabird species, some of which have not been documented to breed, or breed only in limited numbers, in the nearby Islands of Four Mountains, including ancient murrelets, least and crested auklets, black-legged kittiwake, northern fulmar, and fork-tailed and Leach's storm-petrels. Some of these seabirds may be present in the Islands of Four Mountains, foraging in tide rips in the island passes or passing through to forage in Samalga Pass. Perhaps the observation of daily foraging trips of seabirds helped the prehistoric Aleuts know islands existed further west, even if the next adjacent island could not be observed from shore. The present-day distribution of birds would indicate that these species could be encountered when traveling in offshore waters, even if no breeding colonies for these species occurred in the island group.

Summertime, nonbreeding visitors to the Aleutians may not be detected (or in small numbers) in our surveys, because these species are typically found offshore. Three species of albatross have been observed offshore of the islands: Laysan (*Phoebastria immutabilis*), black-footed (*P. nigripes*), and short-tailed albatross, and this part of the Aleutians is within their long-distance foraging range (Piatt et al., 2006; Fischer et al., 2009), while they breed elsewhere. Shearwaters, short-tailed (*Ardenna tenuirostris*) and sooty (*A. grisea*), have been observed foraging on zooplankton in tide rips in island passes (USFWS, unpublished data) and can be present in large

aggregations in the eastern Aleutians during the summer and fall months (Jahncke et al., 2005), then migrating south to breeding colonies in the Southern Hemisphere. These species can be encountered while traveling in offshore waters. The archaeological record of the Islands of Four Mountains indicates that prehistoric Aleuts hunted these species, which represent a small percentage of the avian assemblage, with evidence of human toolmaking incorporating parts of the short-tailed albatross (Krylovich et al., forthcoming). Turner (2008) indicated that Aleuts use the sinew from short-tailed albatross wings to wrap around spearheads, and Jochelson (2002) noted the use of short-tailed albatross beak as pincers to extract arrows from wounds. Short-tailed albatross are considered to have been formerly more common visitors to the Aleutians, but unlikely to have ever bred there (Yesner, 1976). The species declined to near extinction due to exploitation for feather collection in the late 1800s and early 1900s (Yesner, 1976) and is currently slowly recovering as a result of conservation measures (Piatt et al., 2006), with more frequent observations recorded by the R/V *Tiglax* while transiting the Aleutian chain (USFWS, unpublished data).

Timing of surveys also affects detection, with summer surveys not typically detecting migrants that may pass through during spring and fall migration periods, and certainly not detecting species present only in winter months. Besides species that are expected to be present on the islands year-round (e.g., passerines, raptors, ptarmigan, common eider), non-nesting season species that could occur include shorebirds and waterfowl. Emperor geese winter in the Aleutian Islands, and small numbers may occur in the Islands of Four Mountains in winter or more likely stop over for short periods of time during spring and fall migration. For example, Kenyon (1961) conducted an aerial survey in the eastern Aleutians in spring of 1961 and estimated 1020 emperor geese in the Islands of Four Mountains during a time period when many geese wintering in the Aleutians had likely started migrating eastward. The total wintering population of emperor geese in the Aleutians in that year was estimated at 25,000 to 37,000.

Small numbers of Aleutian cackling geese likely stop over for short periods of time during spring and fall migration as they travel to breeding sites to the west. Chagulak Island, approximately 70 km east of Islands of Four Mountains, has a small breeding population and was the site of the relict breeding population of geese in the eastern Aleutians, as fox farming resulted in the elimination of geese from other islands in that region (Bailey, 1993; Byrd, 1993, 1994, 1995). Small numbers of Aleutian cackling geese could potentially nest or may have nested in the past in the Islands of Four Mountains. Veniaminov ([1840] 1984) noted that Kagamil Island had "tundra geese, which arrive from the southeast and here molt, and hatch their young," and Jochelson (2002) also indicated that some bred in this island group. In recent times, as arctic fox removal was underway, Byrd (1995) conducted a survey of this island group to determine potential for nesting geese. He found that only Kagamil Island has substantial amounts of preferred nesting habitat for cackling

geese, with some scattered small patches available on other islands, and concluded that the nesting habitat available in the island group was adequate for 40–50 pairs of geese. Both emperor and cackling geese were found in small numbers in the archaeological record on Carlisle and Chuginadak Islands (Krylovich et al., forthcoming), which does indicate the species was present but perhaps infrequently, given the likelihood they would have been hunted if present (Jochelson, 2002; Turner, 2008; Corbett 2016).

Avian species found in the archaeological record of the Islands of Four Mountains that have not been documented in present-day records include several species of waterfowl, including swan (*Cygnus* sp.), tufted duck (*Aythya fuligula*), greater scaup (*Aythya marila*), long-tailed duck (*Clangula hyemalis*), and common goldeneye (*Bucephala clangula*), and one seabird species, rhinoceros auklet (*Cerorhinca monocerata*) (Krylovich et al., forthcoming). All of these species have been documented to occur in the Aleutians (Gibson and Byrd, 2007). Swans, both tundra (*Cygnus columbianus*) and whooper (*C. cygnus*), are uncommon visitors in the Aleutians in fall, winter, and spring, with limited records of breeding by tundra swans in the eastern Aleutians (Gibson and Byrd, 2007). Tufted ducks are observed in winter and spring during their migration (Gibson and Byrd, 2007). Greater scaup, long-tailed ducks, and common goldeneyes are mainly winter visitors, with limited records of summer breeding by greater scaup (Gibson and Byrd, 2007). Rhinoceros auklets are nocturnally active burrow nesters, with few observation records in the Aleutians, and are considered possibly a casual local breeder in very small numbers (Gibson and Byrd, 2007). This species has been observed in small numbers at Aiktak Island in the eastern Aleutians, with nesting by one pair confirmed in 2017 and suspected nesting of small numbers at Buldir Island in the western Aleutians, but no certain record (Gibson and Byrd, 2007; Youngren et al., 2018).

Marine mammal species

Sea otters, Steller sea lions, and harbor seals are found in small numbers around the Islands of Four Mountains, and northern fur seals are rarely observed. In recent decades, declines have been documented for all of these species in the Aleutians (Doroff et al., 2003; Small et al., 2008; Fritz et al. 2016). It is possible these species may have been more abundant in the past or that they were always in low abundance in this island group. In the archaeological record of the Islands of Four Mountains, these marine mammals are present but represent the smallest category of fauna at all midden sites (Krylovich et al., forthcoming). While there is haul-out habitat available and used by marine mammals in this island group, habitat (flat shoreline areas) is limited for Steller sea lion and fur seal rookeries, which likely limits numbers and reliability of attendance of these pinnipeds at these sites. In the present day, there is only one known fur seal rookery in the Aleutians, at Bogoslof Island (Wynne, 2012), but there is evidence in the archaeological record of

rookeries or nursery haul-outs in the Aleutians in prehistoric times (Crockford, 2012).

Sea otters require kelp-bed habitat. Bailey (1990) found extensive kelp beds around Carlisle Island but observed few sea otters. He speculated that the deep waters surrounding these volcanic islands that rise rapidly from the sea in this island group do not provide good habitat for sea otters. Given that sea otters were rarely found in the archaeological sites in the island group, despite the abundance of sea urchins (*Strongilocentrotus* sp.), a favored prey item (Krylovich et al., forthcoming), it is thought they have always occurred here in low numbers.

Spotted seal (*Phoca largha*) was found in the archaeological record of the Islands of Four Mountains at the Ulyagan site on Carlisle Island, dated approximately 150 years ago (Krylovich et al., forthcoming). This species has not been documented in present-day records in the Islands of Four Mountains. Spotted seals are primarily associated with sea ice. In the present day, within Alaska, this seal breeds in the Bering Sea, and its known extent does not include the Aleutians west of Unimak Island (Boveng et al., 2009).

CONCLUSIONS

Despite the remoteness of Aleutian Islands and limited access to the Islands of Four Mountains for biological work, these surveys have revealed the suite of avian and mammal species inhabiting the present-day land and waters surrounding the Islands of Four Mountains. As observed throughout the Aleutian Islands, the diversity of terrestrial species is limited, and the majority of species, which are seabirds, are marine adapted, primarily using the terrestrial environment for limited times for breeding and resting, while spending the majority of their lives at sea.

The majority of species present in the Islands of Four Mountains in modern times are also represented in the archaeological record. What is difficult to compare is the absolute population numbers of species in the present day versus numbers in prehistoric times. While we are fairly confident in our estimates of ledge-nesting seabirds, we lack good estimates for burrow- and crevice-nesting species, as well as for land birds. The archaeological record provides insight on species presence in the past, as well as some indication of abundance, but it must be acknowledged that the faunal assemblage from midden sites reflects selection of species by hunters that may or may not reflect absolute abundance or presence/absence of various species (Lefevre et al., 1997). For example, the most abundant birds in the island group currently are murre, with a large breeding colony on the cliffs of Kagamil Island. While murre are present in the archaeological record, the evidence indicates low use by prehistoric hunters. This could be interpreted to mean that murre were present in lower numbers prehistorically or that the colony at Kagamil was not easily accessible by Aleuts living on Carlisle and Chuginadak Islands (both due to needing to travel to Kagamil to access larger numbers of murre and due to the difficulty in accessing breeding murre on their steep cliff ledges).

The major differences between the present-day and prehistoric avian fauna in the Islands of Four Mountains is the evidence in the archaeological record of the presence of ancient murrelets and northern fulmars, as well as indications of a higher abundance of storm-petrels. Ancient murrelets, in fact, were one of the most abundant fauna found in the midden sites (Krylovich et al., forthcoming). Additionally the archaeological records indicate prehistoric Aleuts hunted chicks of ancient murrelets and northern fulmars, which suggests breeding colonies for both species formerly existed that were accessible to hunters. While neither of these species is known to currently nest in this island group, large colonies exist nearby at Chagulak Island, where foxes were never introduced. Both of these species could have nested in the island group in the past, and the most plausible explanation for the loss of these colonies is elimination (particularly for ancient murrelet) resulting from the introduction of arctic fox.

There is certainly evidence that the introduction of arctic fox for fox farming had a major impact on birds on these islands and that a recovery has been underway since fox removal. What is intriguing is the discovery in the archaeological record of red fox in the Carlisle Island midden, dating 1900 to 1850 cal yr BP (Krylovich et al., forthcoming). It is interesting to consider the coexistence of red fox and birds on Carlisle Island, given Bailey's (1990) documentation that birds had largely vanished 20 yr after the introduction of arctic fox to the island. Perhaps the difference was in the numbers of foxes present on the island; it is possible fox trappers provided supplemental food during the fox-farming days that could have kept the arctic fox population size above normal, resulting in a larger impact on nesting birds. Klein and SOWLS (2015) recently proposed that the stronger territoriality and larger home-range size of red foxes limits their population density on islands compared with arctic foxes, which would result in less overall predation on birds. Certainly in the present day, red fox (numbers unknown) still occur on Chuginadak Island, along with many breeding birds. Seabirds successfully breeding on Chuginadak Island today must nest in areas inaccessible to red foxes in order to coexist.

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