MARINE ASSOCIATED BIRD AND MAMMAL HABITAT USE AT THE FIVE FINGER LIGHTHOUSE ISLAND

By

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Abstract

In summer 2017 I studied the abundance and distribution of marine associated birds and mammals from four observational points on the southernmost of the Five Finger Islands (FFI). My objectives were (1) to identify the areas of highest habitat use by species of conservation concern, and (2) to use this information to make recommendations for an ecosystem-based management plan at the Five Finger Lighthouse Island (FFLI). I found higher relative abundance and higher biodiversity of both birds and marine mammals on the South and West facing sectors compared to the North and East facing sectors. I attribute this to the greater habitat complexity that comprises a near-shore reef, a mixed kelp forest, and a channel between the reef and the side of the island with the highest cliff, areas used extensively for foraging, nesting, traveling, socializing, and resting by many of the documented species. I therefore recommend avoiding development and minimizing anthropogenic disturbance on the southern and western portions of the island including the adjacent reef and channel between the reef and island. As both the FFI ecosystem and the Five Finger Lighthouse (FFL) management continue to evolve in response to changing environmental conditions and human needs, this study provides a useful baseline for future comparison. Continued study and monitoring is also recommended at this site to inform future adaptive management, document changes over time, and engage community stakeholders in science and conservation.

Chapter 1. Introduction

Centered in an area of high biological productivity, the Alexander Archipelago of Southeast Alaska possesses a long and varied history of human influences including indigenous occupation and Euro-American settlement, resource exploitation, and tourism; however, our understanding of the ecological patterns, processes and linkages in the area is limited (Muto et al., 2017; Szabo & Batchelder, 2014; Weingartner et al., 2009). The surrounding landscape encompasses mountains, rivers, glaciers, bogs, rainforests and over 30,000 miles of coastline that all contribute nutrients to the marine environment (Figure 1). This nutrient rich environment provides critical habitat for many resident and migratory birds as well as important foraging areas for numerous species of marine mammals (Dahlheim et al., 2009; Womble et al., 2009).

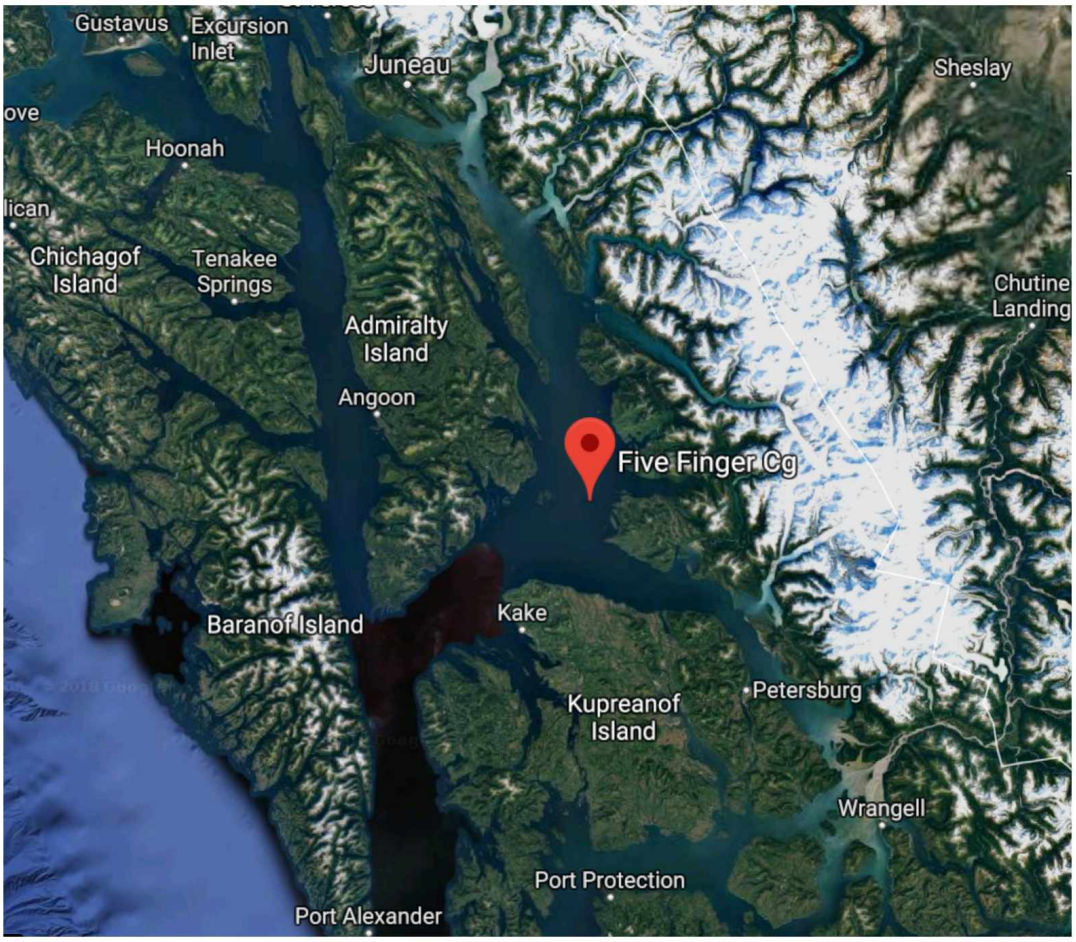

Figure 1. Map showing survey area in Frederick Sound, SE Alaska, including glaciated mountains to the east and the location of Five Finger Lighthouse Island (Google Earth 2018).

On a smaller scale, the three-acre island on which the FFL sits is historically unique from surrounding islands and the mainland in terms of human influences and geophysical attributes, and yet it is connected with sites throughout the Arctic, the Subarctic and globally through the birds and marine mammals that utilize this area on their annual migrations. For example, North Pacific humpback whales (*Megaptera novaeangliae*) journey from their tropical wintering grounds in Hawaii, Central America and elsewhere to feed in the nutrient rich waters of Southeast Alaska (Calambokidis et al., 2001; Muto et al., 2017; Jensen et al., 2018). Likewise, numerous migratory birds, including species observed at the FFLI, depend on the Southeast Alaskan portion of the Pacific Flyway as part of a diverse network of habitats, linking Arctic tundra and northwestern rainforest ecosystems to tropical beaches and mangroves to the south (Audubon 2017). Rufous Hummingbirds (*Selasphorus rufus*), documented during the 2017 FFLI surveys, for example, may travel 4,000 miles between breeding grounds in Alaska to wintering sites in Central America (All About Birds 2017-b). Wandering Tattlers (*Tringa incana*) that breed in the Alaskan Arctic Tundra and migrate along the East Asian-Australasian flyway to Australia, New Zealand and various Pacific islands (Audubon 2018; Gill 2002; Higgins & Davies 1996) have also been documented at FFLI prior to and during the 2017 survey.

Research data on breeding, foraging and migratory patterns is critical for both the science and conservation of bird populations however, detailed studies of stopover locations are lacking (Skagen 2006). Rapid environmental changes in the marine environment also necessitate integrated management approaches that recognize the full array of interactions within an ecosystem including human interests (NOAA n.d.-a). For this reason, my study was designed to contribute to science and conservation by both establishing a baseline to inform immediate recommendations for ecosystem-based management decisions, and by providing a template for future study. My primary research questions were (1) what species of marine associated birds and mammals use the FFLI during the summer, and (2) which parts of the island receive greatest use, and would be most sensitive to development?

To address these questions my primary objectives were to:

1. Document the relative abundance and diversity of bird and mammal species at the Five Finger Lighthouse Island and surrounding marine waters.
2. Document how relative abundance and diversity of marine-associated birds and mammals changed temporally between June, July and August 2017, and spatially at North, East,

South and West –facing quadrants (north, east, south and west intentionally capitalized to indicate reference to observational sight locations).

Following the objectives outlined above, Chapter 2 provides a context for the study in terms of the Five Finger Lighthouse location and management needs, as well as the birds and marine mammals known to occur in the area. Chapter 3 describes the methods I used. Chapter 4 details my results in terms of bird and mammal abundance and distribution at the four island sectors (North, East, South and West) across the summer surveys months (June, July and August). In Chapter 5 I discuss the relative abundance and distribution of bird and mammal species in relation to tidal stage. Individual species are further discussed in terms of behaviors, habitat associations, and conservation status as deemed relevant. In Chapter 6 I present recommendations to the Juneau Lighthouse Association both for current management and for future study based on the 2017 field results and insights gained from this initial study.

Chapter 2. Background

2.1 Five Finger Lighthouse Study Site

Built in 1901, the Five Finger Lighthouse is situated on the southernmost of the five islands that make up the FFI group (Figure 2). It is located at the northern extreme of Fredrick Sound between Keku Straight and Stephen's Passage (57°16′13″N133°37′54″W) (Figure 3). The lighthouse is a National Historic Landmark that is currently managed and operated by the non-profit Juneau Lighthouse Association (JLA), which is mandated to preserve the historic and cultural significance of the lighthouse while facilitating its continued function as a navigational aide to mariners. In addition to guiding commercial and recreational vessels through the archipelago, the lighthouse continues to serve as a destination for small cruise ships and recreational boaters, receiving several hundred visitors each summer (Five Finger Lighthouse 2017). Tourism and other environmental impacts are expected to increase with new cruise ship terminals in the vicinity (personal communication with JLA Board Members, August 30, 2016). Maintenance of building structures, forestry and trails, and a small boat dock on the Five Finger Lighthouse Island (FFLI) is ongoing and performed largely by board members and volunteers of the JLA. Currently the JLA seeks to determine the best location for the construction of a new boat dock at the FFLI.

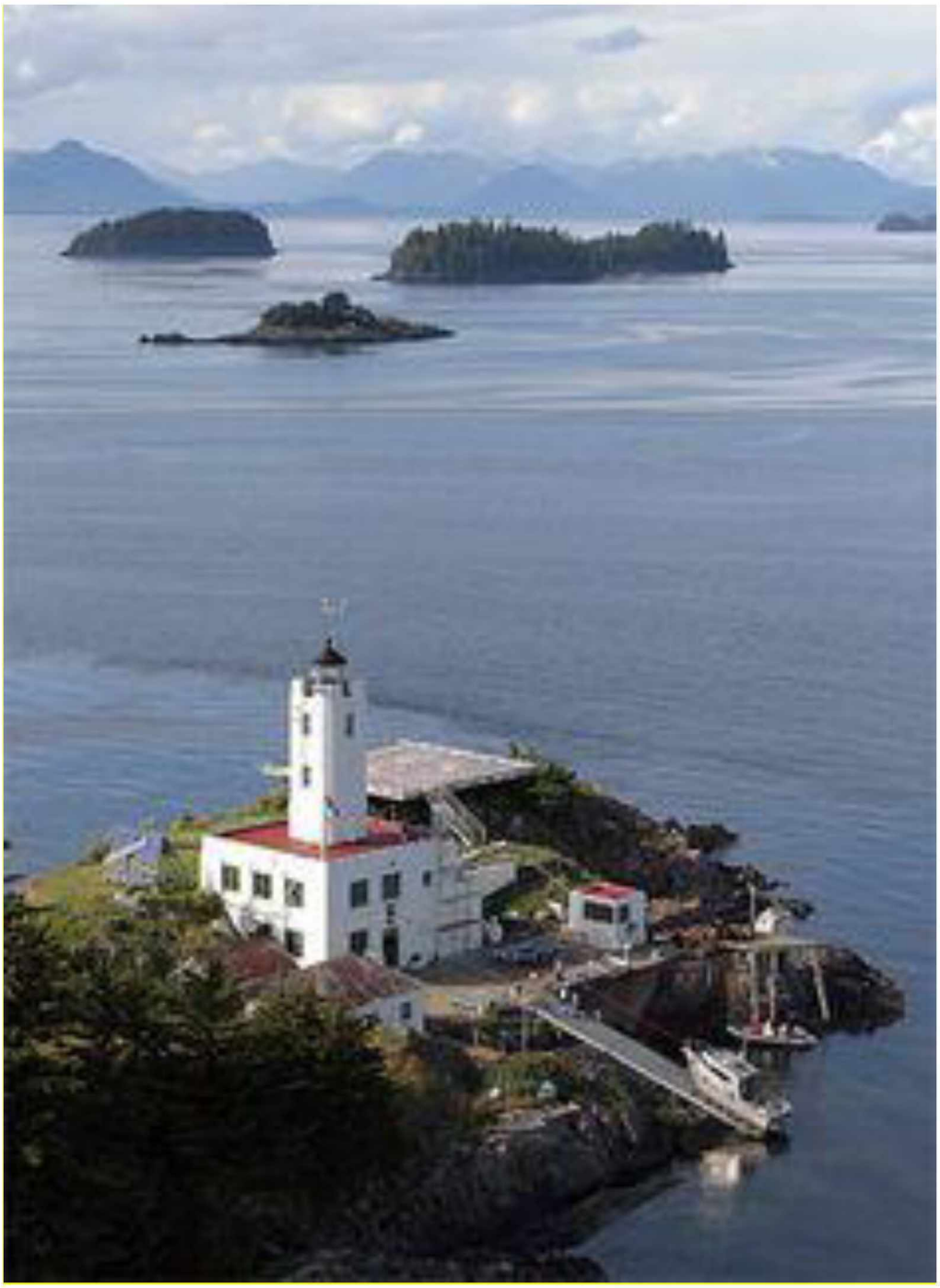

Figure 2. FFLI in the foreground looking north towards the other islands in the FFI group (photo courtesy Five Finger Light).

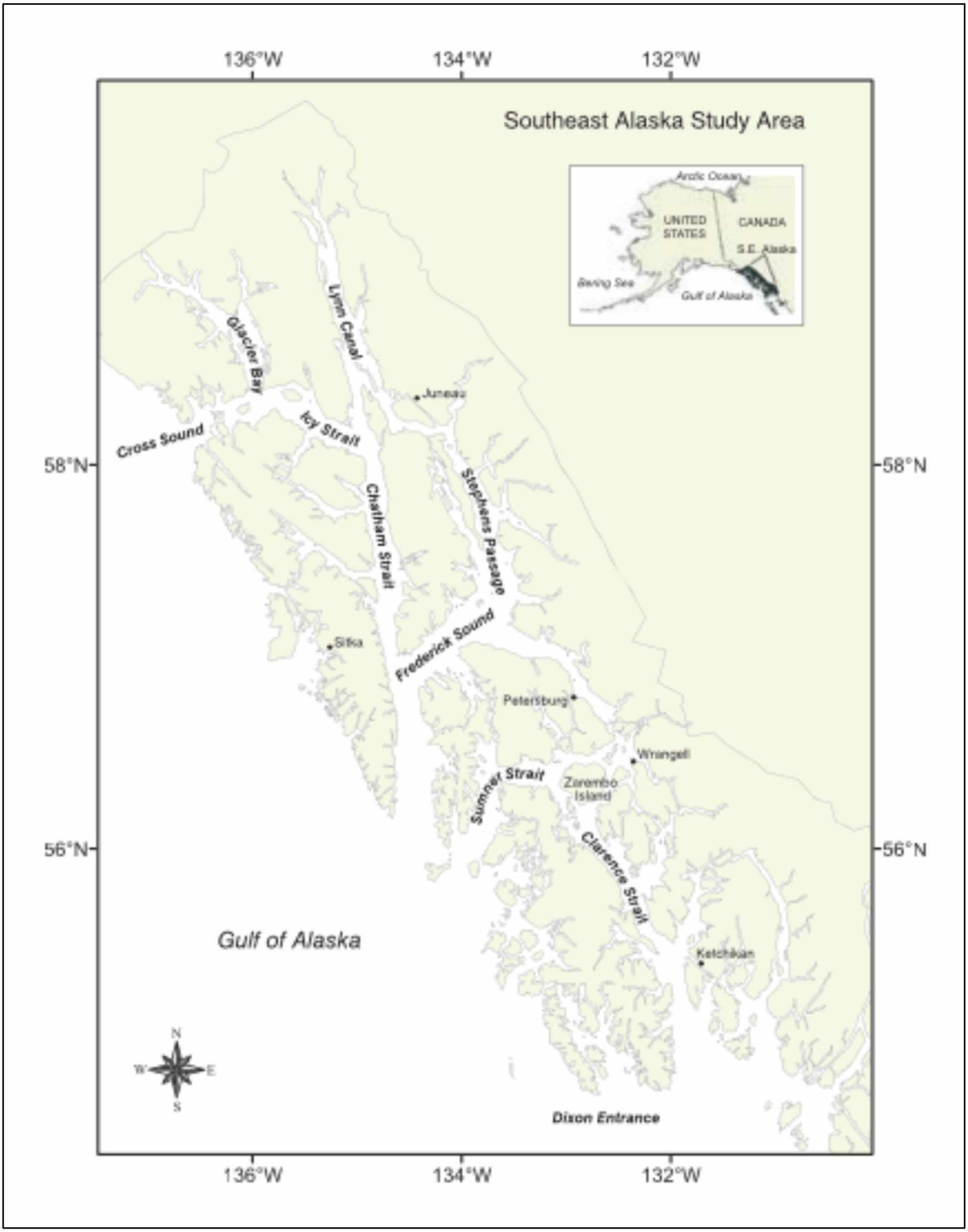

Figure 3. Greater Southeast Alaska Study Area (Journal of Biogeography 2008).

2.2 Birds at the Five Finger Islands

Alaska's marine ecosystems support one of the world's largest concentrations of seabirds and shorebirds. The extensive shoreline and moderate temperatures of Southeast Alaska provide an ice-free habitat for both resident and migratory bird species (Lance et al., 2001). Several million individual birds and hundreds of bird species depend on these coastal habitats for summer breeding, feeding and stop-over rest sites (Hodges et al., 2014). Three Important Bird Areas (IBA), areas that hold a significant proportion of the population of one or more bird species (Birdlife International 2009), have been recognized within 100 miles of the FFI (Figure 4).

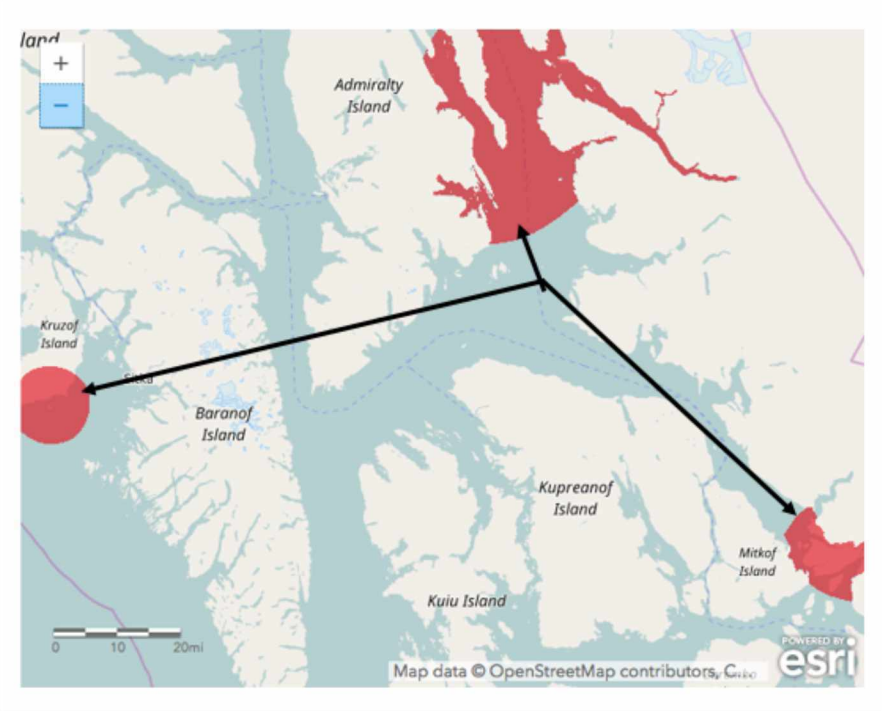

Figure 4. The FFI in Stephen's Passage are bordered by three Important Bird Areas (IBA).

Global and continental population declines have been observed in many bird species, including several found at the FFI including Rufous Hummingbirds (*Selasphorus rufus*), Long-tailed Ducks (*Clangula hyemalis*), Marbled Murrelets (*Brachyramphus marmoratus*), and Belted Kingfishers (*Megaceryle alcyon*) (Barnard et al., 2017; Faaborg et al., 2010; Warnock 2017) (Table 1). These declines stem primarily from loss of habitat, fisheries interactions, climate change, and pollution (Hodges et al., 2014; Lance et al., 2001). Seabirds are often seen as "indicators" of ecosystem health in research and applied management contexts as they can provide "real time sensors" of ecosystem variability (Kissling & Garton 2008). As birds face

increased threats, continued monitoring of populations is critical to inform better conservation and management (Smith et al., 2012) including detailed studies of habitat use (North Pacific Research Board 2018).

Table 1. Species and conservation status of birds that regularly occur at the FFI.
Listed in taxonomic order as with *eBird* (www.birds.cornell.edu/clementschecklist 2017).
Conservation Status according to the International Union for Conservation of Nature (http://www.iucnredlist.org/) and \\ 2017 Audubon Alaska Watchlist (http://ak.audubon.org/conservation/alaska-watchlist).
BOLD indicates species seen during summer 2017 survey.
An asterisk following common name indicates species seen less than 3 times during summer 2017 surveys (not an indication of rare species).

Common Name	Scientific name	Conservation Status
Harlequin Duck	*Histrionicus histrionicus*	AK species of conservation concern; Endangered in Canada & elsewhere
White-winged Scoter	*Melanitta fusca*	Least concern
Long-tailed Duck	*Clangula hyemalis*	Vulnerable \\ Declining
Rufous Hummingbird	*Selasphorus rufus*	Declining in some areas
Black Oystercatcher	*Haematopus bachmani*	Least concern
Whimbrel	*Numenius phaeopus*	Possible decline
Black Turnstone	*Arenaria melanocephala*	Least concern
Surfbird	*Calidris virgata*	Least concern
Wandering Tattler	*Tringa incana*	Least concern
Greater Yellowlegs	*Tringa melanoleuca*	Least concern
Red-necked Phalarope	*Phalaropus lobatus*	Declining in some areas
Common Murre*	*Uria aalge*	Least concern
Pigeon Guillemot	*Cepphus columba*	Some concern in Alaska
Marbled Murrelet	*Brachyramphus marmoratus*	Endangered \\ Depressed
Cassin's Auklet	*Ptychoramphus aleuticus*	Near threatened
Red-throated Loon	*Gavia stellata*	Declining in some areas
Pelagic Cormorant	*Phalacrocorax pelagicus*	Least concern
Bonaparte's Gull	*Chroicocephalus philidelphia*	Least concern
Mew Gull	*Larus canus*	Least concern
Glaucous-winged Gull	*Larus glaucescens*	Least concern
Black-legged Kittiwake	*Rissa tridactyla*	Least concern
Arctic Tern	*Sterna paradisaea*	Least concern
Northwestern Crow	*Corvus caurinus*	Least concern
Bald Eagle	*Haliaeetus leucocephalus*	Least concern
Belted Kingfisher*	*Megaceryle alcyon*	Declining in some areas
Merlin	*Falco columbarius*	Least concern

2.3 Marine Mammals at the Five Finger Islands

The FFI are located in an area of high biological productivity that supports one of the largest summer feeding aggregations of humpback whales in the Northern Hemisphere (Calambokidis et al., 2008; Muto et al., 2017). The Juneau Lighthouse Association is partnered with the Alaska Whale Foundation (AWF) and facilitates the use of the lighthouse as a platform for research on acoustic and behavioral studies of humpbacks whales. Several other species of cetaceans (whales, dolphins, and porpoises), as well as pinnipeds (seals and sea lions), and mustelids (river and sea otters), utilize this region of Southeast Alaska and the FFI specifically, for resting, socializing, and foraging. Resident and migratory marine mammal species at the FFI and throughout the world are subject to increasing anthropogenic disturbances including underwater noise, entanglement in fishing gear, ship strikes, competition with fisheries, pollution, and climate change. Harbor seals in Alaska for example, are currently listed as a species of conservation concern due to long term declines resulting from combined factors (Alaska Department of Fish and Game 2018). By contrast, some populations of Humpback whales, Stellar sea lions, and Northern sea otters are declining or listed as threatened and endangered by the Endangered Species Act (ESA) and the International Union for Conservation of Nature (IUCN) in some parts of their range however, the populations that use the FFLI for resting, socializing and foraging are mostly stable or recovering (Table 2). Analogous to birds, marine mammals are important sentinels of ecosystem health, and documenting population trends may contribute important data to broader studies in population dynamics and species adaptation to environmental change (di Sciara et al., 2016).

Table 2: Species and conservation status of marine mammals that regularly occur at the FFI.
Conservation status according to:
Alaska Department of Fish and Game (ADFG, www.adfg.alaska.gov; International Union on the Conservation of Nature, (IUCN, www.iucnredlist.org), and NOAA Fisheries (www.fisheries.noaa.gov).
BOLD indicates species documented during 2017 FFLI survey.
An asterisk following common name indicates species seen less than 3 times during summer 2017 surveys (not an indication of rare species)

Marine mammal species observed at FFI	Local population status	Status in other regions
Northern sea otter* *Enhydra lutris kenyoni*	Expanding in Southeast Alaska	Endangered or threatened (IUCN, NOAA)
Steller sea lion *Eumetopias jubatus* (Eastern stock)	Eastern stock population segment Stable/ delisted 2013	Western distinct population segment endangered/depleted (NOAA/ ADFG)
Harbor seal *Phoca vitulina*	Declining; Alaska Species of Special Concern (ADFG)	Mostly stable outside Alaska (NOAA Fisheries)
Humpback whale *Megaptera novaeangliae* (North Eastern Pacific population segment)	Recovered in Southeast Alaska (as of 2016)	Endangered
Killer whale* *Orcinus orca* (3 Ecotypes: Resident, Transient, Offshore)	Varies widely with ecotype and pod, Conservation Dependent (IUCN)	'Resident' ecotype threatened in British Columbia and Washington Data deficient
Harbor porpoise *Phocoena phocoena*	Least Concern (ADFG/IUCN)	Threatened in some areas
Dall's porpoise *Phocoenoides dalli*	Least Concern (ADFG/IUCN)	Data Deficient (IUCN)
Partial list of other marine mammals recorded in Southeast Alaska		
Northern Fur seal *Callorhinus ursinus*	All populations declining, Vulnerable (IUCN)	
Gray whale *Eschrichtius robustus* (Eastern North Pacific)	Recovered, Conservation Dependent (IUCN)	Western North Pacific: Endangered (NOAA) Atlantic population: Extinct
Rorqual (Blue, Fin, Sei, Minke) *Balaenoptera species*	Varies	
Sperm whale *Physeter microcephalus*	Endangered throughout its range (NOAA)	

Chapter 3. Methods

Data collected during the summer 2017 field season included 37 surveys conducted between 2-9 June, 41 surveys conducted between 13-21 July, and 32 surveys conducted between 16-23 August totaling 110 surveys. The island was sub-divided into four island sectors looking out from the island interior as follows: (North) north facing, (East) east facing, (South) south facing, and (West) west facing (Figure 5). Each survey included a 10-minute scan from observational locations at each of the four island sectors resulting in 440 total scans.

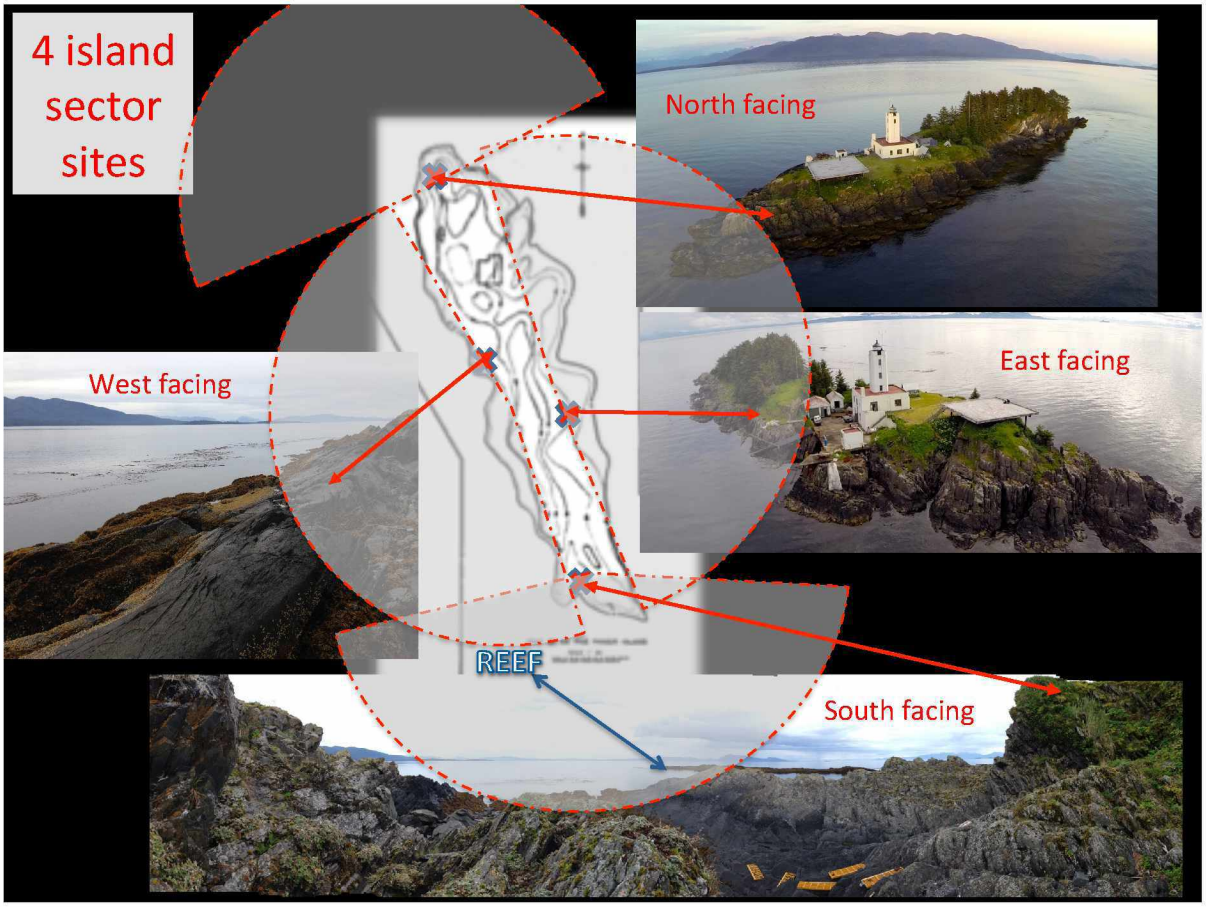

Figure 5. Diagram of the FFLI observational sites at the four island sectors clockwise from top: North facing, East facing, South facing and West facing.

For two consecutive days before initial surveys began, a rangefinder was used to train my eye to approximate a 300-meter distance from each observational station to (1) landmarks on the island and exposed reef, and (2) to points on the water with the aid of opportunistic boat traffic. During each 10-minute scan I counted all birds and mammals observed on the water, on land, and in the

air. In order to account for seasonal changes in hours of daylight over the three summer months, the night before each daily survey I identified 5 surveys windows, spaced within 30-120 minutes of sunrise, sunset and in between the 5 daily surveys. The order in which island sectors were surveyed each day was intentionally randomized to reduce possible observer bias and species habituation.

The methodology for an estimated population index followed standard protocols adapted to the FFLI terrain as follows. Each day I conducted five surveys which included four scans at each of the four island sectors (North, East, South and West). The five surveys conducted each day captured at least one high, one low, one rising, and one falling tide for that day. Environmental data recorded included the tidal height (high, low, rising, falling); precipitation (none, light rain, fog, steady rain); cloud cover (0-100%); and Beaufort sea state (0-4) which is an empirical measure of wind speed on the water (Encyclopaedia Britannica 2018).

During each 10-minute scan I recorded all bird and mammal species seen inside a 180-degree arc, out to approximately 300 meters. Each of the five daily surveys averaged about one hour in total including the four 10-minute scans, and travel time between them. I scanned repeatedly in the air and on the water with my naked eye and used a wide angle Brunton macroscope (7 x 40 magnification) for species and number verification.

Data were recorded on waterproof data sheets (Figure 6). Surveys were conducted in weather conditions rating four and under on the Beaufort scale. Comments were also noted on data sheets regarding other causes of limited visibility such as strong sun glare on the water or fog. Compromised scans were discarded and not included in the 110 surveys analyzed. Behavioral codes were assigned to both marine mammal and bird habitat use at each location including sitting/standing, resting, foraging/feeding, traveling/swimming/flying, socializing, predator/prey interactions, courtship/nesting displays, and fleeing or displacement from other species including humans. Habitat associations recorded included: on the water; on the island (including rocky intertidal, shoreline rocks, and shoreline cliffs); on or within three meters of the reef; on or within three meters of the kelp bed; or noted as 'mixed' associations if the animals moved between two or more habitat associations during a single 10-minute scan. Other visual and acoustic observations were noted in comments, including anthropogenic activities such as passing boats, visitors to the island, and obvious observer caused disturbances. Additional

quantitative and qualitative observations were noted including plankton blooms, noteworthy currents, or unusual weather conditions.

Date: / / 17	#	Tide: R H S L F	NORTH Start/finish	EAST Start/finish	SOUTH Start/finish	WEST Start/finish
Time	Assoc: W=water		AM / PM	AM / PM	AM / PM	AM / PM
Beaufort SS	RK=rock/isle		1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Air/W Temp	RF=reef		F°/C°	F°/C°	F°/C°	F°/C°
Cloud /Preci	KP=kelp MO=mixed/other		% N LR F SR	% N LR F SR	% N LR F SR	% N LR F SR

Type	Species	Assoc-iation	Be-havor	Type: MM=mammal SB=seabird SH=shorebird R=raptor SO=songbird H=humm U=unknown	Tally/Count: Lo/Hi/Best	Behavior: St=sit/standing T=travel (fly/swim) F= feed/foraging R=rest So=socializing N=nest/mate/court E= Escape(flee) H=human O=other/unknov

Cloud cover (Cloud)=numeric percentage (0 – 100) indicating the of amount of the sky covered by clouds

Precipitation (Preci)= N – none; L R– light rain; F – fog; SR – steady rain

Beaufort Sea State (Wind)= 0-4

Behaviors for both birds and mammals: St=standing on water/rock/reef; T=traveling on land/water/air; F= obvious foraging or feeding; So=socializing/non-aggressive group interaction; N=obvious courtship, mating or nesting behaviors; E=escaping or fleeing from human or non-human causes; O= other or unknown

Habitat association W=in/on the water; RK= on the main island rocks or cliffs; Rf: within 3 meters of reef including submerged reef; Kp= within 3 meters of floating kelp; MO= mixed association

Figure 6: Example of 2017 FFLI summer field data sheet and key.

Chapter 4. Results

The following results derive from the 110 surveys (440 scans) conducted in summer 2017. Each survey included four 10-minute scans conducted at the four island sectors (North, East, South, and West). The words *sightings* and *counts* refer to the number of individual animals recorded during a single 10-minute scan. Note that a total of 100 sightings or counts at a particular location or during a particular time period for example, does not equal the number of animals seen over all, but rather the sum of sightings recorded for the stated animal/s.

4.1. Mammals

Six species of marine mammals (all scientific names listed in Table 1) and one marine-associated mammal (river otter, *Lutra canadensis*) were observed during the summer 2017 field season. These included three species of cetaceans (humpback whale, killer whale and Dall's porpoise), two species of pinnipeds (Stellar sea lion and harbor seal), and two species of mustelids (sea otter and river otter). Five of the seven observed mammal species were documented during surveys and entered into the data analysis (Table 3). In total, 1350 marine mammal sightings were counted during the 110 summer surveys (or 440 scans). The distribution by sector was: North 173 sighting), East 187 sightings, South 602 sightings, and West 388 sightings (Figure 7).

Table 3: Number of mammal sightings counted by site location and month.

	North				East				South				West				
	June	July	Aug.	**Total N**	June	July	Aug.	**Total E**	June	July	Aug.	**Total S**	June	July	Aug.	**Total W**	**Grand Total**
Sea Otter	0	0	1	**1**	0	0	0	**0**	0	0	1	**1**	0	0	0	**0**	**2**
Dall's Porpoise	5	3	2	**10**	25	14	0	**39**	3	0	0	**3**	0	0	0	**0**	**52**
Humpback Whale	11	6	21	**38**	14	7	29	**50**	3	0	20	**23**	1	7	5	**13**	**124**
Harbor Seal	8	5	0	**13**	17	1	1	**19**	251	21	26	**298**	135	12	10	**157**	**487**
Stellar Sea Lion	20	45	46	**111**	26	43	10	**79**	71	97	109	**277**	60	47	111	**218**	**685**
Totals	**44**	**59**	**70**	**173**	**82**	**65**	**40**	**187**	**328**	**118**	**156**	**602**	**196**	**66**	**126**	**388**	**1350**

(Table colors correspond to pie chart in Figure 7.)

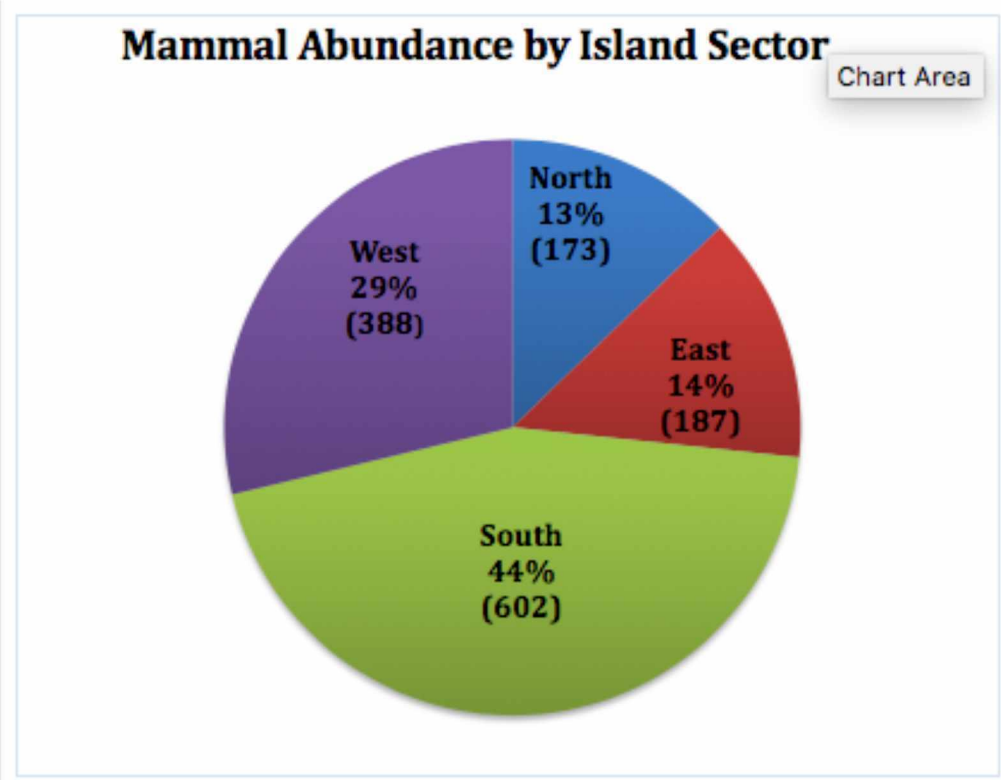

Figure 7. Relative marine mammal abundance by island sector.

In terms of relative mammal abundance by island sector (Figure 8), Northern sea otters were observed twice, once from the North and once from the South facing sectors. Dall's porpoises were counted a total of 52 times, with no counts from the West, three counts from the South, 10 counts from the North, and the highest count of 39 was recorded on the East. Humpback whales counted within the 300-meter radius were counted 23 times from the South, 38 times from the North, 50 times from the East, and the highest count of 124 sightings was from the North. In addition, many humpback whales were seen and heard both during and outside of surveys times and outside survey areas throughout the summer surveys and were noted in comments during surveys but not quantified. Harbor seals were counted a total of 487 times: 13 times from the North, 19 times from the East, 157 times from the West and again the highest count of 298 sightings from the South facing sector. Harbor seals on the South and West were strongly associated with both the reef while hauling out, and with the kelp forest while resting at high tide. The 13 harbor seal counts on the North represented an estimated one or two individuals often displaying curiosity towards the observer and lighthouse keepers, and on one occasion an individual was observed eating a large fish while in physical contact with rocks on the north side

of the island. Stellar sea lions were observed from all four island sectors a total of 685 times including 79 counts from the East, 111 from the North, 218 from the West, and the highest count of 277 from the South. Stellar sea lions were most often seen traveling or resting in the water in small groups of 5-10 individuals. Stellar sea lions were never observed hauled out on either the island or the exposed reef, but on one occasion an individual was observed eating a large halibut in the water to the East. Small groups of three to ten Stellar sea lions were often observed resting, traveling, or socializing in the water within 100 meters of the island. A single river otter was observed once climbing onto the dock area on the northeastern side of the island but was not observed or recorded during survey windows and therefore not included in data analysis. Killer whales were observed on several occasions to the south and west outside the 300-meter limit for survey areas and loosely associated with sport fishing boats. Because they were not observed during the 10-minute scans nor within the 300-meter radius of the study locations, they are not included in the data analysis. In sum, Stellar sea lions were seen from all island sectors however they were observed more than twice as frequently on the South and West than on the North and East. Harbor seals were also observed on all sides of the island however the vast majority of sightings were from the South and West due to their association with the reef and kelp forest. Humpbacks whales in contrast were observed more frequently on the North and East as were the Dall's porpoises.

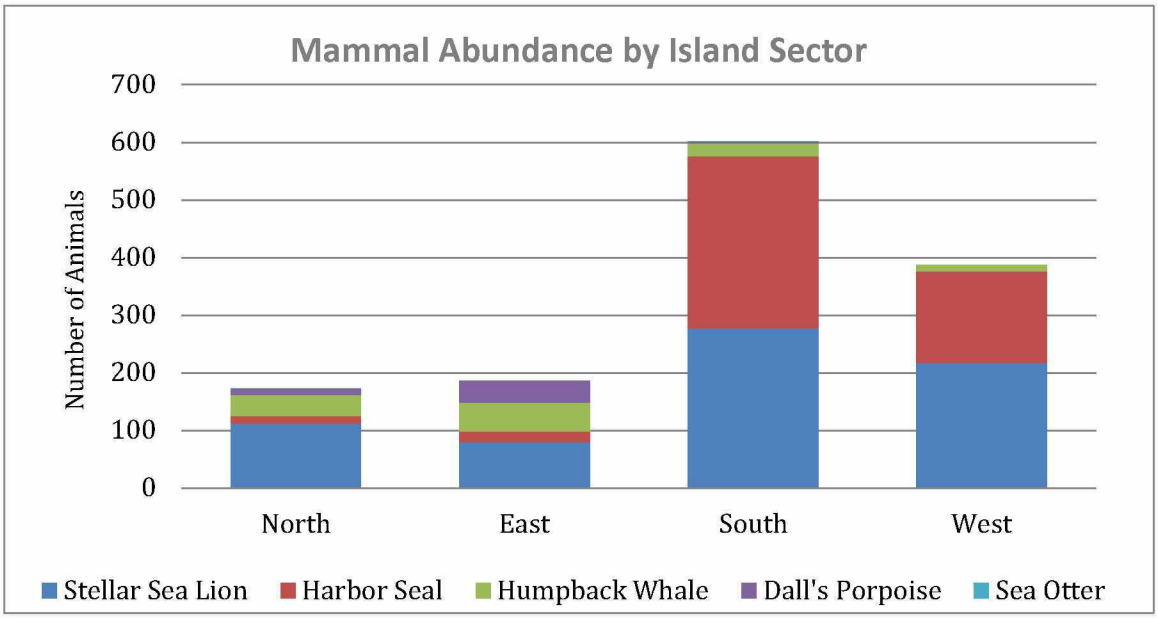

Figure 8. Mammal abundance by island sector.

In terms of relative mammal abundance by summer months, June, July and August (Figure 9), two sea otter observations occurred in August, (believed to be the same individual based on time, location and movement). Out of a total of 52 Dall's porpoise sightings, the lowest count of two was in August, followed by 17 sightings in July, with the highest count of 33 sightings occuring in June. Humpback whales were counted within the 300-meter observational site parameters a total of 124 times. The lowest count of 20 sightings was in July, followed by 29 sightings in June, with the highest count of 75 sightings occurring in August despite the month of August having the lowest number of surveys. Harbor seals were counted 37 times in August, 39 times in July, and the much higher count of 411 sightings in June represents many mothers with pups hauled out on the reef. Stellar sea lions were counted 177 times in June, 232 times in July, and the highest count of 276 sightings was recorded in August. More marine mammals were counted in June than either July or August, with harbor seals largely accounting for the difference (Figure 9). In contrast, whales and sea lions were most abundant in August.

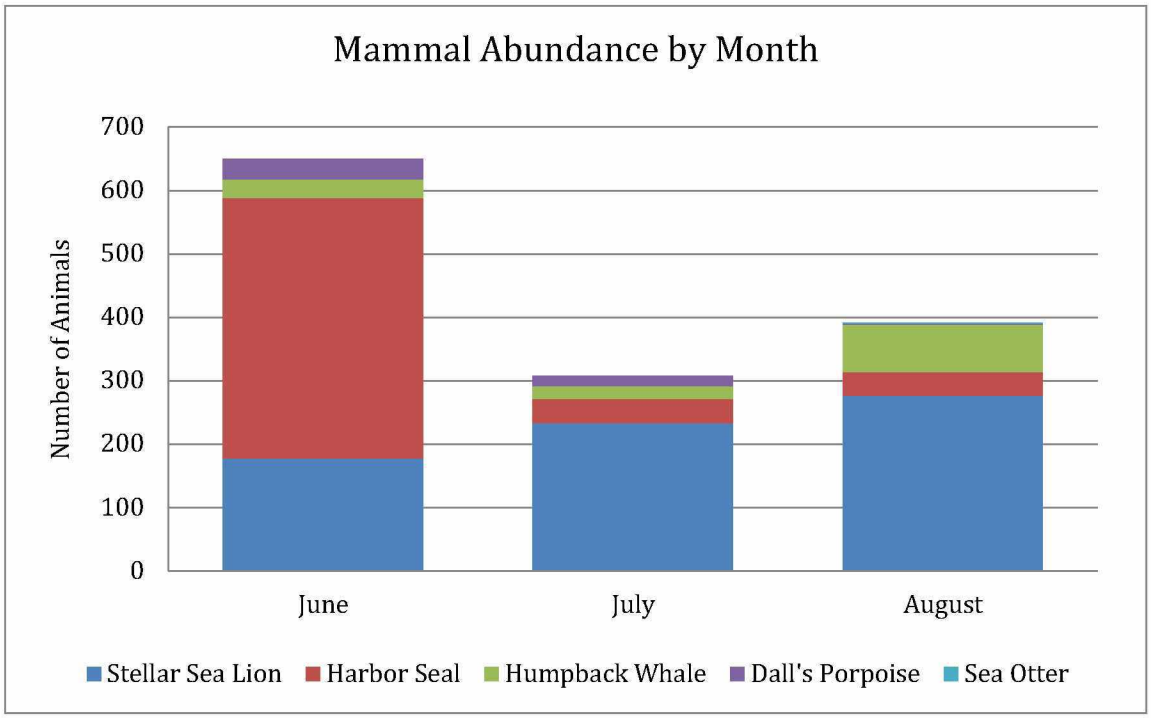

Figure 9. Mammal abundance by month: June (n=37), July (n=41) and August (n=32).

In sum, the most abundant marine mammals documented at the FFLI were the pinnipeds. Steller sea lions were seen during all summer months without great variation in counts, and on all island sectors with highest counts on the South and West facing sectors as compared to the North and

the East (Figure 10). Steller sea lions were mainly observed traveling, socializing and resting in the water on the South side between the island and the reef, and on one occasion a single adult male sea lion was observed feeding from the East facing sector approximately 250 meters from the island. Steller sea lions were never observed hauled out on either the island or the adjacent reef however there are several known Steller sea lion rookeries in the area (Loughlin, 1997; Raum-Suryan et al., 2002). Pacific harbor seals were also seen in all summer months at the FFLI with peaks in June on the South and West island sectors (Figure 10). Again, the much greater number of harbor seals counts in June reflects numerous observations of females with pups hauled out on the reef during exposed tides and viewable from the South and West island sectors. In July and August there were far fewer counts of harbor seals and when counted they were mostly resting in the kelp, also observable from the South and West facing island sectors. By far the highest total counts for harbor seals were on the South and West facing sectors as compared with the East and the North during any summer month.

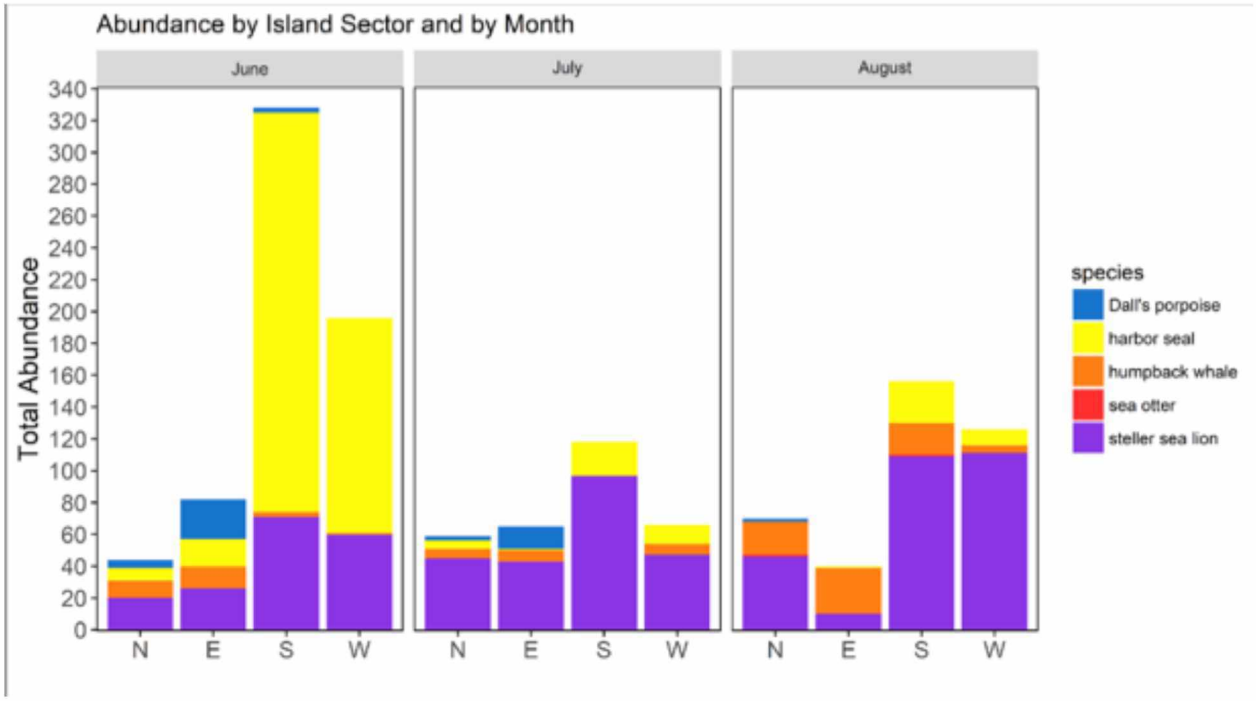

Figure 10. Mammal abundance by month (June, July, and August) and island sector (North, East, South, and West).

As for the cetaceans, humpback whales were counted during all summer months on all sides of the island with the highest counts on the East. Dall's porpoise sightings were concentrated on the

East as well, followed by the North and the South and no sightings from the West island sector. They were also counted more frequently in June and July than in August. A single mustelid, the Northern sea otter, was sighted twice in August, once on the North and once on the South island sectors.

4.2. Birds

Twenty taxa of marine associated birds were observed during the 2017 field season (all scientific names listed in taxonomic order in Table 1). These included fourteen avian taxa identified to the species, four avian taxa identified to the family (Alcidae, Gaviidae, Laridae and Phalacrocoracidae), and two avian taxa identified to the order (Charadriiformes, and Passeriformes).

In addition, to simplify graphic illustration, the 20 avian taxa were separated into four broader bird subgroups as follows: 'Sea Birds' included Pigeon Guillemot, Marbled Murrelet, Common Murre, Harlequin Duck, White-winged Scoter, and unidentified seabird (family Alcidae). 'Marine-associated Birds' included gulls (family Laridae), loons (family Gaviidae) and cormorants (family Phalacrocoracidae). 'Shore Birds' included Black Oystercatchers, Black Turnstones, Surfbirds, Red-necked Phalaropes, Wandering Tattlers, and unidentified shorebirds (order Charadriiformes). 'Land Birds' included Bald Eagles, Northwestern Crows, Rufous Hummingbirds, Belted Kingfishers and unidentified songbirds (order Passeriformes) (Table 4).

In total, 15,377 bird sightings were recorded during the 2017 summer surveys. By far the greatest number of birds were counted on the South island sector which included the reef (42%), followed by the West island sector which included a kelp forest and part of the reef (31%). Far fewer bird sightings as well as avian taxa were counted on the East (19%), with the lowest counts on the North (8%) where the island habitat was more uniform (Figure 11).

Table 4: Bird sightings counted by site location and month.

		North				East				South				West				
		June	July	Aug.	Total N	June	July	Aug.	Total E	June	July	Aug.	Total S	June	July	Aug.	Total W	Grand Total
Sea Birds	Pigeon Guillemot	112	79	51	**242**	59	227	188	**474**	231	336	215	**782**	387	463	279	**1129**	**2627**
	Marbled Murrlet	158	5	0	**163**	1	1	0	**2**	5	2	0	**7**	0	8	1	**9**	**181**
	Common Murre	0	0	0	**0**	0	0	0	**0**	0	1	0	**1**	0	0	0	**0**	**1**
	Harlequin Duck	4	0	0	**4**	11	3	4	**18**	57	242	116	**415**	41	108	54	**203**	**640**
	White-winged Scoter	0	0	0	**0**	0	0	0	**0**	0	0	122	**122**	0	0	40	**40**	**162**
	Seabird sp	9	7	4	**20**	41	1	0	**42**	0	1	4	**5**	15	8	0	**23**	**90**
	Sea Bird Totals	**283**	**91**	**55**	**429**	**112**	**232**	**192**	**536**	**293**	**582**	**457**	**1332**	**443**	**587**	**374**	**1404**	**3701**
Marine Assoc. Birds	Gull sp	31	27	508	**566**	28	16	1798	**1842**	621	207	1464	**2292**	454	185	1290	**1929**	**6629**
	Cormorant sp	1	0	0	**1**	1	0	0	**1**	0	0	12	**12**	0	0	9	**9**	**23**
	Loon sp	2	0	0	**2**	0	0	0	**0**	0	0	0	**0**	2	0	0	**2**	**4**
	Marine Assoc. Bird Totals	**34**	**27**	**508**	**569**	**29**	**16**	**1798**	**1843**	**621**	**207**	**1476**	**2304**	**456**	**185**	**1299**	**1940**	**6656**
Shore Birds	Black Oystercatcher	10	26	10	**46**	24	29	0	**53**	39	42	195	**276**	46	16	103	**165**	**540**
	Black Turnstone	0	59	15	**74**	0	112	0	**112**	0	1297	0	**1297**	0	389	0	**389**	**1872**
	Surfbird	0	21	0	**21**	0	28	0	**28**	0	544	0	**544**	0	49	0	**49**	**642**
	Red-necked Phalarop	0	0	6	**6**	0	0	0	**0**	0	0	0	**0**	0	0	0	**0**	**6**
	Wandering Tattler	0	3	0	**3**	0	0	0	**0**	0	0	1	**1**	0	0	1	**1**	**5**
	Shorebird sp	0	0	25	**25**	0	13	0	**13**	0	16	0	**16**	0	0	15	**15**	**69**
	Shore Bird Totals	**10**	**109**	**56**	**175**	**24**	**182**	**0**	**206**	**39**	**1899**	**196**	**2134**	**46**	**454**	**119**	**619**	**3134**
Land Birds	Bald Eagle	2	1	1	**4**	3	2	2	**7**	29	37	29	**95**	24	37	30	**91**	**197**
	Northwest Crow	16	29	9	**54**	119	77	85	**281**	169	145	215	**529**	247	129	298	**674**	**1538**
	Songbird sp	9	6	3	**18**	17	7	9	**33**	1	7	7	**15**	17	18	9	**44**	**110**
	Hummingbird Sp	0	9	3	**12**	0	7	1	**8**	0	0	0	**0**	0	11	8	**19**	**39**
	Belted Kingfisher	0	0	0	**0**	0	0	0	**0**	0	0	1	**1**	0	0	1	**1**	**2**
	Land Bird Totals	**27**	**45**	**16**	**88**	**139**	**93**	**97**	**329**	**199**	**189**	**252**	**640**	**288**	**195**	**346**	**829**	**1886**
	Grand Totals	**354**	**272**	**635**	**1261**	**304**	**523**	**2087**	**2914**	**1152**	**2877**	**2381**	**6410**	**1233**	**1421**	**2138**	**4792**	**15377**

(Table colors correspond to pie chart in Figure 11).

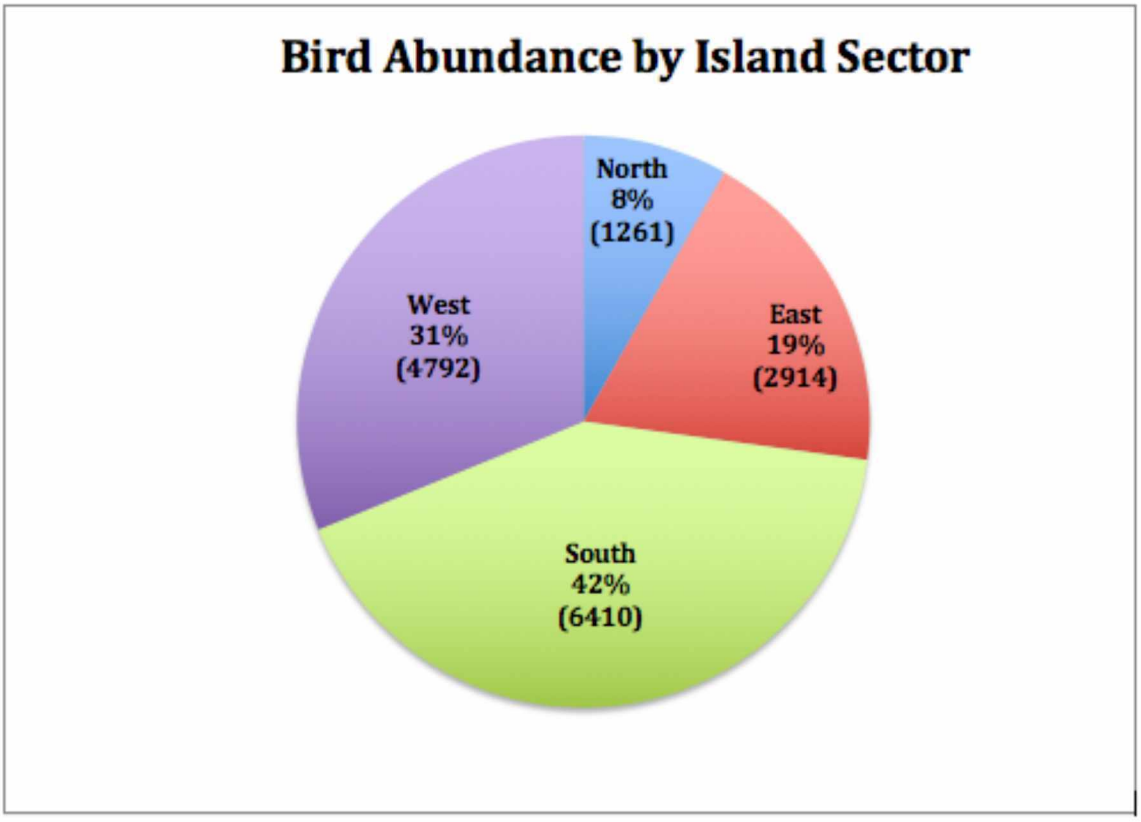

Figure 11. Bird abundance by island sector showing counts and percentages.

Relative abundance across the four island sectors was as follows (Figure 12):
'Sea Birds' were counted a total of 3701 times with the greatest counts observed on the West (1404 sightings) and the South island sectors (1332 sightings) followed by the East (536 sightings) and North (429 sightings) island sectors. The vast majority of 'Sea Bird' sightings were of Pigeon Guillemots (2627) at all island sectors, followed by Harlequin Ducks (640), Marbled Murrelets (181), White-winged Scoters (162), unidentified seabirds (90) and a single sighting of a Common Murre.
'Marine Associated Bird' counts totaled 6,656 sightings and were almost exclusively represented by several gull species (Glaucous-winged Gulls, Mew Gulls, Bonaparte's Gulls and others) (6,629 sightings), but also included 23 unidentified cormorant and 4 unidentified loon sightings. 'Marine Associated Bird' sightings were also highest on the South (2304), followed by the West (1940), the East (1843) with the smallest number of sightings of was on the North (569).
'Shore Birds' were sighted a total of 3,134 times and their distribution by sector was: North 175 sightings, East 206 sightings, West 619 sightings, with the greatest count on the South amounting to 2134 sightings and attributed to having the greatest rocky intertidal habitat. The highest count in the 'Shore Bird' subgroup was for Black Turnstones (1,872) which were almost entirely sighted in July on the South island sector. The second highest count was for Surfbirds (642) which were closely associated with Black Turnstones both in terms of spatial habitat use and temporal presence with the majority of sightings concentrated on the South in July. Black Oystercatchers were the third most frequently sighted 'Shore Bird' (540), and in contrast to the Black Turnstones and Surfbirds, Black Oystercatchers were present throughout the three-summer month survey periods however were rarely counted more than 10 times during a single 10-minute scan. 'Shore Bird' sightings also included 69 counts of unidentified shorebirds, 6 counts of Red-necked Phalaropes, and 5 counts of (possibly a single) Wandering Tattler.
'Land Bird' counts totaled 1886 with the highest count on the West (829 sightings), followed by the South (640 sightings), the East (329 sightings), and the lowest counts on the North (88 sightings). The most commonly sighted 'Land Bird' was the Northwestern Crow (1538) followed by the Bald Eagle (197). Both species nested on the FFLI and were observed throughout the three-summer month survey period with increased numbers in August. 110 unidentified songbirds were observed mostly on the supratidal rocks. 39 Rufous Hummingbird sightings were almost always associated with flowering plants at the upland border of the survey

area. Belted Kingfishers were observed on just 2 occasions, both in August, once on the South and once on the West.

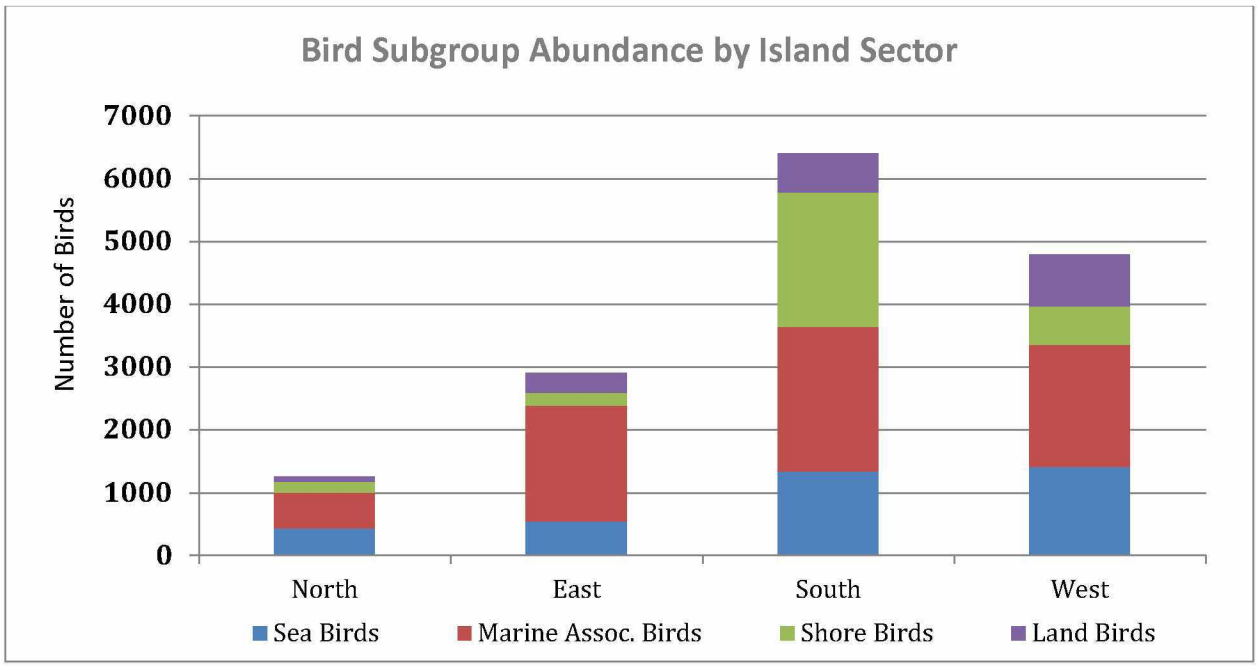

Figure 12. Bird abundance by island sector.

Relative abundance of birds by subgroup across survey month (note in June n=37 surveys, in July n= 41 surveys, and in August n= 32 surveys) (Figure 13) are as follows:
'Sea Birds' were counted 1131 times in June, 1492 times in July, and 1078 times in August, and again were mostly represented by Pigeon Guillemots which were present throughout the summer season. 'Marine Associated Birds' were counted 1140 times in June, 435 times in July, and 5081 times in August. The peak in August was across all island sectors and represented different gull species. 'Shore Birds' were counted 119 times in June, 2,644 times in July, and 371 times in August. 'Shore bird' spikes in July are largely represented by Black Turnstones and Surfbirds which were concentrated on the South island sector where they were observed feeding and resting in the rocky intertidal. 'Land Birds' were counted 653 times in June, 522 times in July, and 711 times in August. Higher counts in August may largely be attributed to Bald Eagle and possibly Northwest Crow fledglings, the former often observed from the South island sector perched on the adjacent reef.

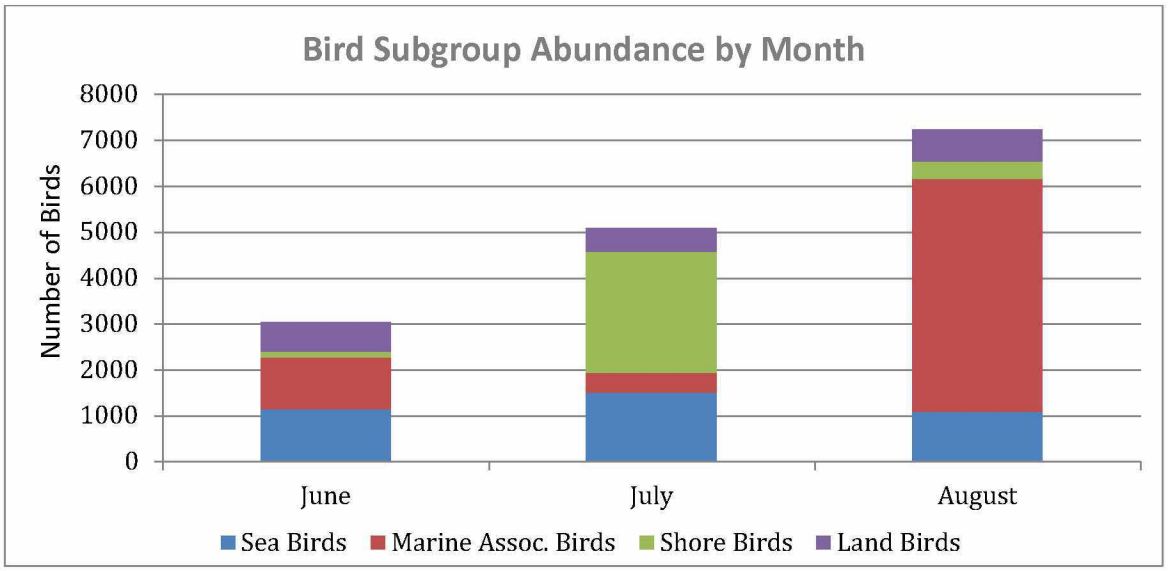

Figure 13. Relative bird abundance by month: June (n=37), July (n=41) and August (n=32).

Relative abundance of the 20 taxa of birds (14 species, 4 families and 2 orders) across island sector and month vary considerably however, results show that the South and West island sectors are used by a higher number of species as well as individual birds than either the North or East island sectors during all survey periods (June, July and August) (Figure 14).

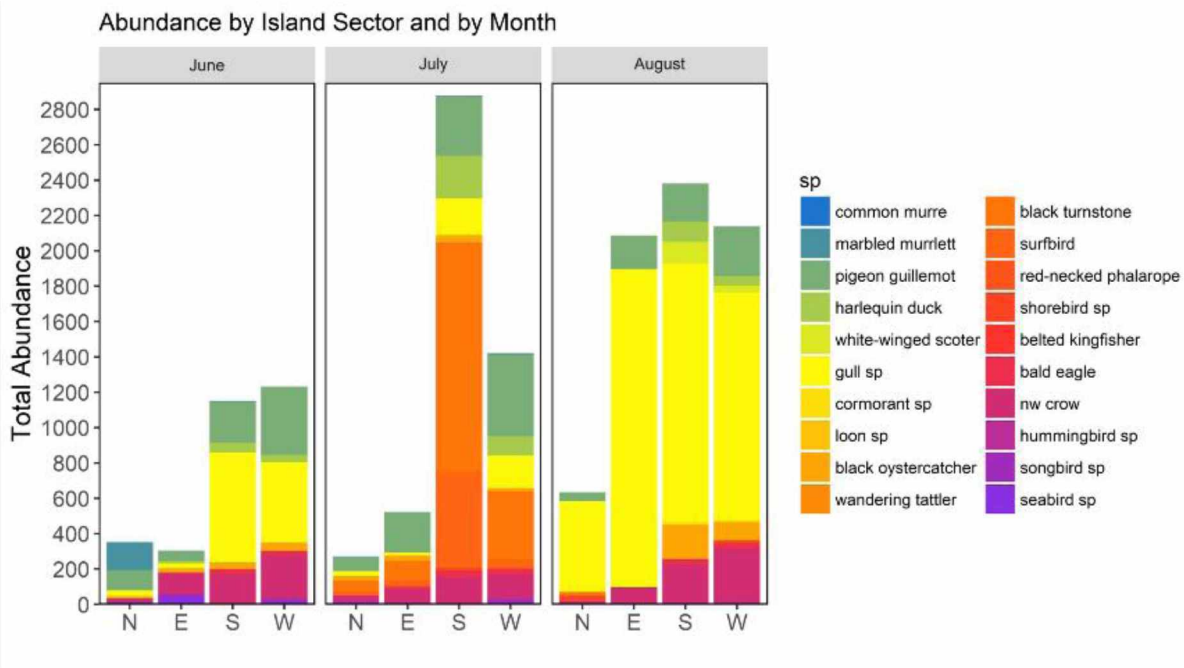

Figure 14. Relative bird abundance (all taxonomic groups) by month and island sector.

The most abundant of the 20 avian taxa documented at the FFLI was the 'gull species' or family Laridae. 'Gull species' included three main species of various ages. Mew Gulls and Glaucous-winged Gulls were primarily associated with the exposed reef off the South and West island sectors during all summer months. Bonaparte's Gulls were mainly counted sitting on the water from the North and East facing sectors in August. Combined, gull counts were highest on the South, second highest on the West, and mainly consisted of Mew and Glaucous-winged Gulls. The third highest gull count of was on the East in August and consisted mainly of Bonaparte's Gulls. The lowest gull count was on the North and again consisted mostly of Bonaparte's Gulls. Bonaparte's Gulls also accounted for the vast majority of gulls counted on the North in August. Gull numbers were considerably higher in August at all island sectors despite the smaller number of surveys in August.

The second most abundant bird taxa were the species Pigeon Guillemot. Pigeon Guillemots were seen during all summer months and at all island sectors however their counts were highest on the West followed by the South. On the West they were mostly observed in association with the rocky cliff and near-shore waters. They were often engaged in courtship behaviors on both the South and West island sectors. In August, individual birds were observed sitting on the water carrying a fish but not consuming it or sharing with other adults- a behavior possibly associated with waiting to feed chicks at concealed nest sites (Litzow et al., 2000).

Black Turnstones, one of several shorebird species that use the FFLI for summer foraging, were the third most abundant bird species during the 2017 study. Black Turnstones were observed mainly on the South island sector during the eight survey days in July, mainly in the rocky intertidal habitat on the island and on the reef. Black Turnstones were also recorded on the East and West exclusively in July and to a lesser degree on the North in July and August.

Northwestern Crows were the fourth most common bird counted at the FFLI. During the 2017 summer survey, Northwestern Crows used much of the island's forested interior for nesting and socializing. They were also observed on several occasions being fed by the island's volunteer lighthouse keepers in summer 2017. For the purposes of this study Northwestern Crows were only documented during marine associated survey times within the 300-meter by 180-degree radius arc survey areas, consistent with other documented species. The highest counts were on the West and South with much lower counts recorded on the East and North.

Surfbirds were the fifth most frequently sighted bird and all sightings were recorded during the July survey days. The vast majority were documented on the South island sector and the fewest counts were on the North.

Harlequin Ducks were the sixth most frequently counted bird species and occurred mostly on the South followed by the West facing island sectors with highest counts in July. On the East and North, Harlequin Ducks were counted far fewer times, mostly in June.

Black Oystercatchers were the seventh most frequently counted bird with the majority observed on the South and West in August however, on the North and East facing sectors, highest counts were in July. Black Oystercatchers were mostly observed foraging in the rocky intertidal on the South including the adjacent reef when exposed at lower tides. Counts on the South side should be considered minimums as they were well camouflaged and hard to see on the reef. Nesting and courtship behavior was also observed on the South side of the island however no confirmed nests were documented.

Contrary to the predominant trend of relatively higher species abundance at the FFLI on the South and West facing sectors, Marbled Murrelets were most commonly sighted sitting on the water to the North. Of the 181 Marbled Murrelet sightings, the highest counts were on the North though many more were seen to the northeast beyond the 300-meter survey area. This was not surprising as they are pursuit diving birds and take advantage of high productivity in upwelling zones as compared with the shorebirds for example that forage in the rocky intertidal.

The ninth most abundant bird species was the White-winged Scoter with the majority of sightings documented on the South side in August, and a small portion observed on the West also in August. These birds were entirely associated with the reef and kelp habitat and none were observed on either the North or East during any month.

The tenth most commonly observed species was the Bald Eagle which was counted a total of 197 times, and represented just four individual birds (two adults and two juveniles). A pair of Bald Eagles has been nesting in the same tree in the interior forested segment of the FFLI for more than 10 years. The highest counts for Bald Eagle sightings were on the South and West. Although the adults and juveniles were sometimes visible on the island forest interior and were heard throughout the island, they were only counted when observed within the survey areas during the 10-minute scans. Most often they were observed perching at the reef or flying

between the reef and the island nest, but on occasion they were also observed foraging on the water.

Chapter 5. Discussion

The overarching goal of this thesis project was to promote ecosystem conservation through science and stewardship. The science component was accomplished through wildlife surveys that result in recommendations for ecosystem-based management at the FFLI. Ideally ecosystem-based management should be place-based, flexible, adaptive and responsive to monitoring and research results (NOAA n.d.-a). By definition it is precautionary and proactive and is most effective when collaborative and inclusive of multiple stakeholders (NOAA n.d.-a). The stewardship component therefore was executed through the design of field protocols that would accommodate futures surveys by citizen scientists and other stakeholders. These future surveys could in turn contribute ongoing data for adaptive management and provide a baseline to measure changes over time. Therefore, in addition to establishing a benchmark for future comparison, the 2017 research design provides a template for continued study.

The main focus of the summer 2017 fieldwork was the establishment of a benchmark of marine associated bird and mammal abundance and distribution at the FFLI, and a preliminary understanding of how the habitat is being used spatially and temporally by the documented species. In the previous chapter I summarized survey findings in terms of marine mammals and birds across both space (North, East, South and West) and time (June, July and August). Here I provide a discussion highlighting how bird and mammal species combined used the island spatially, temporally, and in relation to variations in tide (high, falling, low, and rising). Because this study aimed to identify not only which parts of the island habitat would be most sensitive to disturbance, but also which species might be impacted the most by future development and change, here I provide further context of individual bird and mammal species that were documented during the 2017 field study and generally known to occur at the FFLI. Finally, this chapter concludes with the motivations for continuing the research at the FFI as a citizen science project because the sustainable management and conservation of marine and other natural resources depends on adaptive ecosystem-based management approaches that explicitly incorporate stakeholder interests and human impacts on biodiversity (Domínguez-Tejo et al., 2016).

5.1 Limitations of the Study

The 2017 study was exploratory by nature with the primary aim of acquiring a preliminary understanding of how species of birds and mammals use the FFLI and the surrounding marine waters. The results provide the basis for recommendations to minimize disturbances to resident and migratory species. Limitations to the study included the lack of a dedicated boat to conduct surveys at near islands in the FFI group for comparison of habitat and habitat use. In addition, due to a mixed terrain, observational locations for conducting scans out 300 meters at 180-degree radius arc were limited by several blind spots. For example, the southern side of the reef was not observable from the South facing island observation spot. Also, rocks at all fours island sectors did obstruct to a limited degree a complete 180-degree view from sea level to sky, therefore all counts should be considered minimums. In addition, in order to maximize survey effort during the limited survey days, it was not possible to conduct surveys at equivalent tides across survey days but rather the analysis of habitat use by tidal state is evaluated here in terms of relative daily tidal fluctuations (high, low, rising, and falling). Other limitations of the study are discussed in the context of specific species in Sections 5.3 and 5.4, and in terms of recommendations for future study in Chapter 6.

5.2 Spatial and temporal habitat use

Understanding how the four island sectors at the FFLI are used spatially and temporally is critical to determine areas of high importance and potential sensitivity to disturbance for the different birds and mammals. Study results show clear spatial differences both in terms of species diversity and total abundance (Figure 15). Combined, marine mammal and bird presence at the South and West facing sides of the island was notably higher than at the North and East facing island sectors at all tidal states. The median number of individual animals counted on the South during each scan was between 40 and 65 animals. On the West the median was between 25 and 41 animals. On the East side the median was between 10 and 18 individuals. The lowest median of between 5 and 10 individual animals per scan were recorded on the North. In sum, the South and West island sectors had nearly twice the abundance of species combined (bird and mammal) than the North or East facing sectors at any tidal state (outliers greater than 230 excluded here for visual clarity).

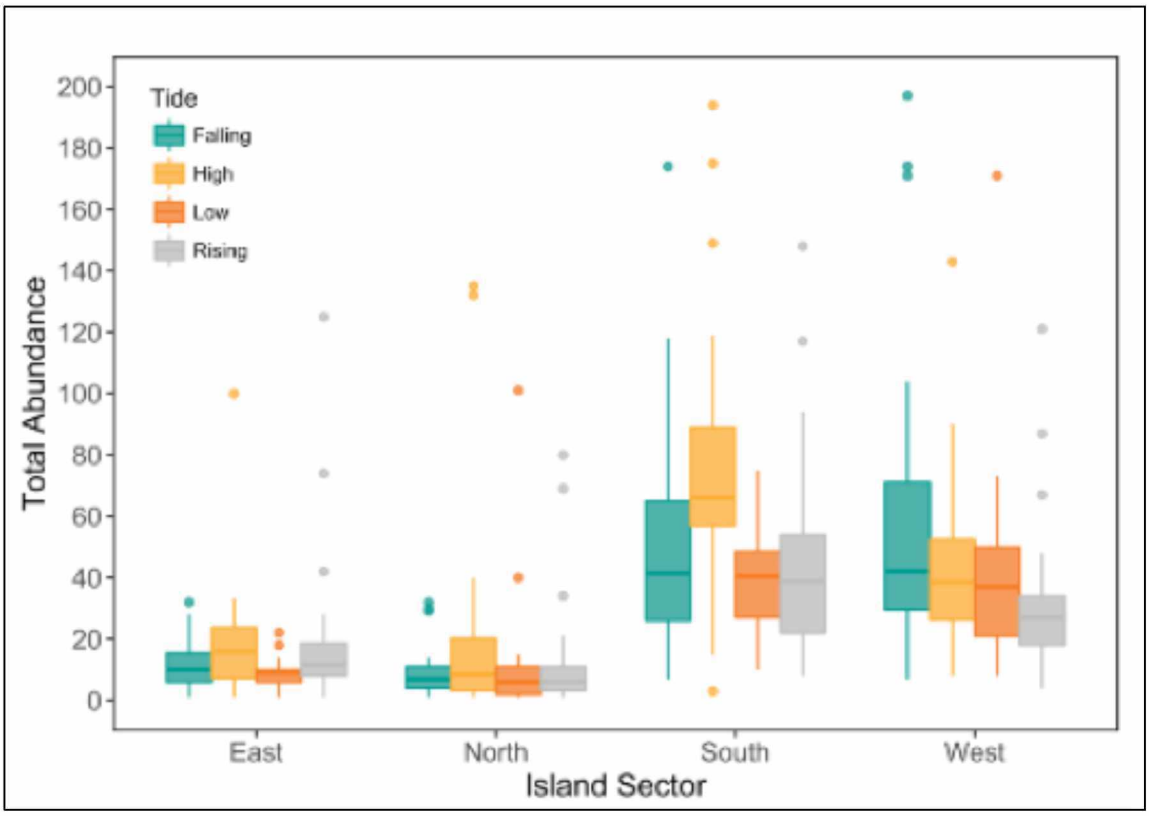

Figure 15. Relative index of abundance surveyed across island sector and tide (birds and mammals combined).

The mean species richness in terms of marine associated birds and mammals documented was also greater on the South and West than on the North and East across all tidal states (Figure 16). The mean number of species per scan was highest on the West at just above five and a half and on the South at just above five. In contrast, the mean number of species on the East was just above three and on the North the mean was slightly below three.

Higher overall abundance as well as higher diversity on the West and South island sectors may be largely attributed to greater habitat complexity. To the southwest is an adjacent reef and extensive rocky intertidal habitat. Surveys documented use of the reef as a resting area for harbor seals and their pups, a protected species under the Marine Mammal Protection Act, and a species of conservation concern in Alaska due to continued declines in population (Womble et al., 2009). The reef was also used for foraging by Northwestern Crows, Black Oystercatchers, Black Turnstones, Surfbirds, Bald Eagles, Harlequin Ducks, White-winged Scoters, multiple gull

species and others. The West island sector, in addition to rocky intertidal habitat, includes a mixed kelp forest which was used for resting and foraging by numerous species. The West facing island sector also included a cliff face that is used for nesting by Pigeon Guillemots and perching by Pelagic Cormorants. In addition, the channel that occurs between the island, the reef, and the kelp forest was used extensively by various species of birds and mammals including Steller sea lions, harbor seals, Northern sea otters, humpback whales and courting Pigeon Guillemots. Future studies focused on this southwestern island segment alone would contribute to a deeper understanding of the FFLI ecosystem dynamics.

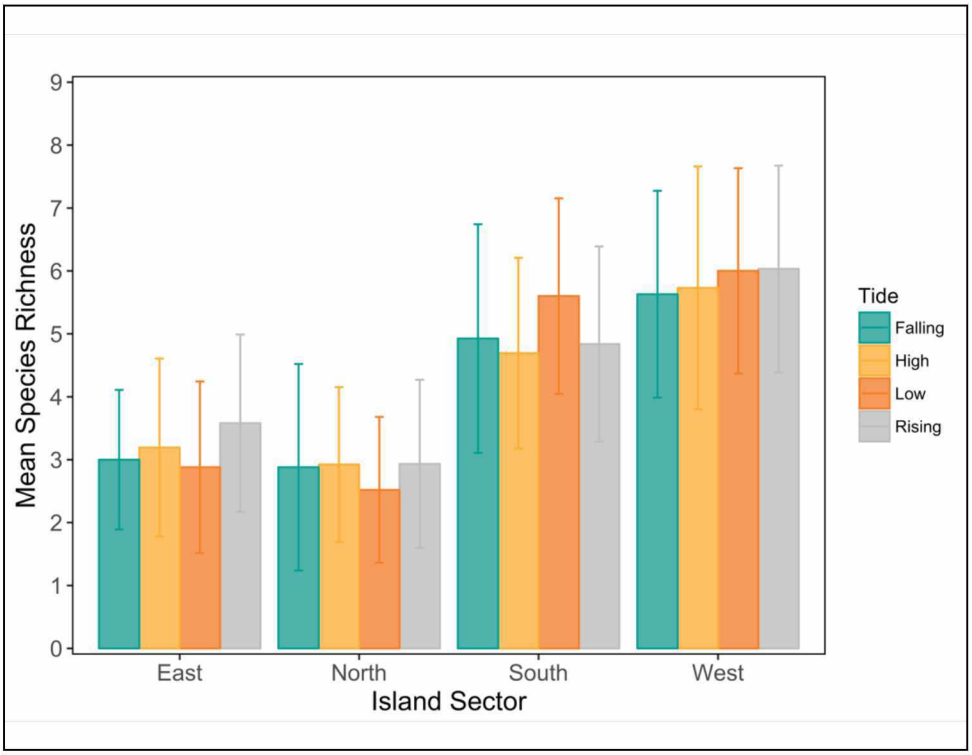

Figure 16. Mean species richness surveyed across island sector and tide.

Tidal height described as high, low, falling, and rising varied both within and across island sectors as well as for different species. Future studies might benefit from targeted research questions addressing relationships between tidal variation and individual species abundance. In terms of the immediate aim of this project to understand the comparative use of the four island sectors to inform future development, tidal state did not appear to be a major driving factor for spatial or temporal (June, July August) presence and use. In sum, further investigation of both

spatial and temporal use of the channel between the island and the reef during the various tidal states for individual species would provide a more detailed evaluation of the importance of this FFLI hotspot.

5.3 Mammals

The Steller sea lions that occur in this region are part of the 'eastern distinct population segment' and have been delisted from the Endangered Species Act list since 2013 (NOAA n.d.-d). Observations made during the 2017 surveys lead me to conclude that the FFLI serves mostly as an area of rest, socializing, and refuge from predation for transiting Steller sea lions during summer. The South side of the island and channel between the island and reef in particular were FFLI hot spots for this species, and the FFI location may provide an important and strategic rest stop within the local population's range.

Harbor seals, although widely distributed, are currently listed as a species of conservation concern in Alaska due to long-term declines (NOAA n.d.-b). Harbor seals are also an important cultural and subsistence food for Alaska Natives, and despite ongoing research in some areas, causes for decline are not well understood (Womble et al., 2009). Harbor seals may also serve as good indicators of environmental change such as ocean warming and contamination as they are sensitive to various habitat disturbances and perturbations (NOAA n.d.-b). For all of these reasons, and the limited research on the harbor seal population in the immediate area, protection of the South and West portions of the FFLI including the adjacent reef and kelp forest, is advocated as is continued monitoring of harbor seal presence and use of the FFI habitat.

Regarding humpback whales, it is difficult to gauge the importance of the FFLI as habitat using the 300-meter distance. Many humpback whales were seen outside the 300-meter mark while some individuals were observed within 50 meters. It is also presumed that humpback whale presence and absence is more closely associated with local currents, upwellings, and the availability of food which were not measured by this survey. The location of the FFLI, between Stephens Passage and Fredrick Sound, is known as an important feeding ground for the North Pacific distinct population segment however, there is growing concern in the area regarding both increased competition with commercial fisheries and disturbances from increased whale watching tourism (Calambokidis et al., 2001; Szabo & Batchelder, 2014; Teerlink 2017). Results from the 2017 fieldwork show a temporal increase in humpback whales with 75 out of 124 total

counts occurring in August, compared with 29 in June and 20 in July. This data is consistent with increased observations of humpback whales and the increased availability of humpback whale food by other researchers in Southeast Alaska in previous years and during August 2017 (Straley et al., 2018; Szabo & Batchelder, 2014).

The presence or absence of Dall's porpoise on the various island sectors is not well understood from limited studies on this local population but is probably related to food availability and the species' preference for deeper water (Dahlheim et al., 2009; NOAA n.d.-c). Data collected during the 2017 survey together with future monitoring of this species at the FFLI may help fill knowledge gaps on population trends by sharing with web-based open sourced databases and scientific data repositories such as the Ocean Biogeographic Information System (OBIS-SEAMAP) (Halpin et al., 2009) or the Global Biodiversity Information Facility (GBIF) (Global Biodiversity Information Facility 2018).

Currently listed as endangered, sea otters throughout their range are known as a keystone species for having a great influence on their environment (Estes, 2015; Estes & Duggins, 1995). Although Northern sea otter counts at FFLI were minimal during the 2017 study, it will be important to monitor their presence and use at the FFI in future years because as both their population in the Southeast Alaska region increases, so does their potential competition and conflict with local fisheries (Carswell et al. 2015; Hoyt 2015; Marine Mammal Commission 2018).

5.4 Birds

Gulls were the most abundant group of birds however, they were not individually identified to species level due to the large flock sizes, including juveniles, and they were not considered species of high conservation concern. Future surveys should reconsider protocols for accurately counting various species of gulls if they become species of targeted interest.

The second most abundant bird species was the Pigeon Guillemot which was seen during all summer months and at all island sectors. Counts were highest on the West where they were mostly observed in association with the high rocky cliffs and near-shore waters, and they were often observed engaged in courtship behaviors on both the South and West island sectors. In August, individual birds were observed sitting on the water carrying a fish but not consuming it or sharing with other adults- a behavior possibly associated with waiting to feed chicks at

concealed nest sites (Litzow et al., 2000). Because Pigeon Guillemots are present all summer and nest on the FFLI, they would be an ideal species to monitor for documenting changes in the abundance, nesting success, and phenology over time at this site. Future studies could also contribute to comparative and collaborative studies of Pigeon Guillemots in other parts of their range in Alaska for example (Golet et al., 2000; Oakley & Kuletz, 1996), or throughout the Pacific Northwest through the sharing of collected data on web-based citizen science applications such as *eBird* or other open sources databases.

Black Turnstone and Surfbird presence during the 2017 survey was significant however, counts should be considered minimum estimates as these birds may be discrete in low light, at a distance, and in flight. They are also well camouflaged and at the FFLI were often obscured behind rocks. As a result, Black Turnstones were sometimes indistinguishable from Surfbirds with whom they were closely associated (best estimates were recorded). Furthermore, data on Black Turnstone use of nearby island habitats and the population percentage that relies on FFLI for summer foraging is lacking, so continued surveys may help fill knowledge gaps. Likewise, although Surfbirds are considered a species of least concern by the International Union on the Convention on Nature (IUCN Redlist 2018), much is unknown about their winter breeding. Prince William Sound in the Gulf of Alaska has been identified as a principal spring staging area where much of the world Surfbird population gathers (Cornell Lab of Ornithology 2018). With one of the longest and narrowest shorebird breeding ranges, Surfbirds are listed as a species of special concern by *Partners in Flight* (USGS 2018) due to their vulnerability to oil pollution and increased coastal development (Birdweb 2018).

Harlequin Ducks are listed by the IUCN as a species of least concern (IUCN Redlist 2018) however, they are listed as endangered in Canada, threatened in Maine, and a species of special concern in western states (All About Birds 2018-a). In Alaska, Harlequins have also been heavily impacted by the 1989 Exxon/Valdez oil spill (Birdweb 2018). At the FFLI they were easily flushed and observer-caused disturbances were noted on several occasions.

Future investigation focused on Black Oystercatcher habitat use at the FFLI would be an interesting project as there is evidence that Black Oystercatcher numbers may have increased in some areas as a result of decreased human presence as lighthouses have become fully automated (Birdweb 2018). Although not listed by the IUCN as endangered, they were recognized in 2000

as a species of high regional concern by the Northern Pacific Coast Regional Shorebird Management Plan due to combined anthropogenic impacts and life history (Birdweb 2018; Shorebird Plan 2000).

Marbled Murrelets are listed as threatened globally (Datazone 2018; IUCN 2018) and are considered flagship species throughout their range because they represent a strong conservation link between the importance of protecting old growth forests and protecting the marine environment. As with Harlequin Ducks, Surf Scoters were sensitive to human presence and fleeing from the observer was noted on the South side on several occasions.

Although Bald Eagles were delisted in 2007 by the Endangered Species Act (ESA), they are protected in Alaska by the 1940 Bald Eagle Protection Act (Alaska Department of Fish and Game 2018). Future studies focused on Bald Eagles and their influence on other bird species at the FFLI would surely add to our understanding of the FFI ecosystem complexity.

No Long-tailed Ducks, a species in steep decline (All About Birds 2018-c), were observed during the 2017 surveys however, over one thousand Long-tailed Ducks were seen within 100 meters of the FFLI just a week before surveys started (personal communication with JLA board member June 2017). Future studies will help understand the importance of the FFLI habitat to these threatened birds.

5.5 Citizen Science

Research shows that citizen science projects around the world are expanding at an exponential rate and are proving to be especially useful for large scale biodiversity monitoring (Aceves-Bueno et al., 2015; Cooper et al., 2014; Follett & Strezov, 2015; Jordan et al., 2015). Innovations in new technologies, changing perceptions of scientists, and development of toolkits for appropriate matching of projects needs to volunteer interests is leading to continued improvements (Kobori et al., 2016; van der Velde et al., 2017; Wang et al.,2015). Likewise, citizen science, the practice of public participation in research (National Geographic 2018), has made, and continues to make contributions to science through peer review literature. This in turn affects management and adaptive management policies and decisions (Kays et al., 2017; Snäll et al., 2011; Sullivan et al., 2017) and can contribute significantly to conservation through scientific discovery. When employing best practices and intentional design, citizen science may also inspire innovation through collaborative processes and feedback loops (Chandler, Rullman, et

al., 2017; Chandler, See, et al., 2017; Couvet & Prevot, 2015; Crain et al., 2014; McKinley et al., 2017; Newman et al., 2017). Citizen science has also been shown to increase public stewardship by increasing scientific literacy and sharing of knowledge as well as action and behavioral changes including voting (Cooper et al., 2014; Danielsen et al., 2014; Johnson et al., 2014; Kays et al., 2017; Schmeller et al., 2017; Toomey & Domroese, 2013). Therefore, continuing small scale, detailed, and place-based projects such as the FFLI study have the potential to involve the greater community in research that can contribute to broader understandings of how species and ecosystems are linked and interdependent at multiple scales.

Future research protocols and volunteer training at the FFLI could be adapted to accommodate prime tourist visitation peaks, proposed development needs, concurrent research projects, volunteer availability and interests, and other logistics. Participation in on-going research may provide added incentive to enlist volunteers, including seasonal lighthouse keepers, in scientific inquiry. By participating in on-going research, volunteers can make immediate contributions to adaptive management and local conservation efforts. Continuing monitoring of wildlife species at the FFI can also provide supplementary and comparative data for collaborations across scales and with related organizations such as the Alaska Shorebird Group and Alaska Fisheries for species of high conservation concern. Moreover, viewing marine mammals and birds, such as those found at the FFIs, as ‘sentinel', ‘umbrella’ and ‘flagship’ species, can inspire interest in the conservation of broader marine ecosystems while benefiting local wildlife and human populations (di Sciara et al., 2016).

Chapter 6. Conclusions and Recommendations

In summer 2017 I conducted an exploratory study of marine associated bird and mammal habitat use on the southern-most of the Five Finger Islands that also houses the Five Finger Lighthouse. The data were intended to inform a subsequent ecosystem-based management plan for the island and provide a benchmark for future study. The methods were designed to suit a future citizen science project that might reveal changes over time, as well as a means to engage stakeholders in ongoing research, conservation, and stewardship.

6.1 Key findings

This research documented the presence of over 27 species of marine associated birds and mammals at the FFLI over the course of 25 survey days. The 2017 results show that the South facing island sector was used by nearly twice as many taxa as the North or East facing sectors. Furthermore, the 2017 study showed even higher species diversity at the West facing island sector which was not anticipated based on preliminary observations in 2016. Total abundance was also markedly highest on the South facing island sector for the majority of species documented including harbor seals which are a species of high conservation concern in Alaska. In addition to the documented use of the southern reef by resting harbor seal females with pups, the reef was used extensively for foraging by multiple species of birds including Black Oystercatchers, Black Turnstones, Surfbirds, Northwestern Crows, Bald Eagles, Harlequin Ducks, White-winged Scoters and several gull species throughout the summer survey period. The West facing side of the island which includes a mixed kelp forest, also proved to be important habitat for resting harbor seals when the reef was submerged at high tide, and especially important for cliff nesting Pigeon Guillemots. The channel between the island, the reef, and the kelp forest, which is incorporated in both South and West facing survey areas, was also used by resting and socializing Steller sea lions much more frequently on the South and the West than on the North or East. Results of this research clearly show that the South and West facing sectors are used by more species as well as greater numbers of individual birds and marine mammals, and these results serve to inform recommendations for immediate ecosystem-based management decisions. The 2017 pilot study also provides salient information for the design of continued studies including surveys to be conducted by citizen scientists.

6.2 Recommendations

The 2017 research entailed an observational study of birds and marine mammals at the FFLI which currently serves as habitat for various species of birds and marine mammals. With a predicted increase in anthropogenic disturbances, a comprehensive inventory of species abundance, distribution, and habitat use at the FFI was critical to inform future development, as well as serve as a benchmark for future comparison. The 2017 study also identified the island sectors of highest habitat use during the specified period and demonstrate a much greater need to safeguard the habitat on the southern and western segments of the FFLI. These data and analyses form the basis for recommendations to inform both immediate and future ecosystem-based management decisions. Likewise, the 2017 study provides a point of departure for future study at the FFI.

6.2.1 Management Recommendations

Analysis of the 2017 research results provide the foundation for management recommendations aimed at minimizing disturbances to birds and mammals at the FFLI. Data results indicate future development should avoid the southern and western portions of the FFLI in order to protect resting, nesting, and foraging areas for documented species. Boat traffic or landing at the adjacent reef and channel between the southwestern side of the island and reef should be avoided altogether. In addition, efforts to minimize boat access from the South end of the island at any tide and during any month are strongly encouraged.

6.2.2. Recommendation for Future Study and Citizen Science

The 2017 study serves as an initial benchmark documenting three points in time at the FFLI: eight days in June, nine days in July, and seven days in August. Adapting 2017 protocols for future citizen science would allow not only a cost-effective means for continuing to survey, but an important means to engage the community in environmental stewardship and science. Successful citizen science projects require appropriate investments including matching scientific and volunteer goals; involving a diversity of stakeholders; and providing training and meaningful interactions and engagement for volunteers (Chandler, Rullman, et al., 2017; Chase & Levine, 2016; McKinley et al., 2017).

Given the current level of investment feasible for continued study of habitat use at the FFLI, I recommend using current web-based applications for continued documentation or birds,

mammals and other species. Engaging volunteers in this type of data collection may also advance scientific understanding in ecology and improve species conservation and management both locally and across larger scales (Wood et al. 2007). For this reason, I have initiated the *iNaturalist Five Finger Islands Ecological Survey* (iFFIES). Encouraging casual visitors to the island to contribute to the Five Finger Islands Ecological Survey via the citizen science platform (Citisci 2017) and *iNaturalist* app (iNaturalist 2017), the 2017 survey data may be incorporated, complemented and verified with future data collection. Additional benefits of using these crowd-sourcing platforms include the potential to increase visitation to the historic monument as mandated by the JLA, while engaging local and non-local visitors in scientific discovery.

Necessary investments for future surveys at the FFLI include an upgrade in field equipment including a higher quality scope or binoculars with reticles for accurately measuring distance; a professional grade digital camera with telephoto capacity; and a field computer for data entry and storage. Future scans on the North and West island sectors could be validated by conducting point counts from the top of the lighthouse by a second observer. In addition, periodic small boat-based surveys around the island and reef as well as to neighboring islands could both uncover blind spots and provide comparisons of habitat use and availability.

Increased investment in logistics and budget should include reliable transportation, heating, provisioning, insurance and emergency evacuation protocols. An on-sight lighthouse keeper and/or dedicated JLA board member could provide volunteer supervision, coordination, and training as well as study site and website maintenance. Planned and unplanned visitors might include local school groups, fishers, charter boats, and cruise ship passengers. On-sight workshops or a *Bioblitz*, a communal citizen science effort to record as many species as possible within a given time and place (*iNaturalist* 2018), would be possible. Likewise, regularly scheduled tourist boats could be prepped with information on downloading the *iNaturalist* app and species identification guides on passengers' personal devises. And finally, because the iFFIES incorporates an area that includes the FFLI, other islands in the group, and surrounding waters, disembarking from boats would not be necessary to participate and contribute to the study, therefore minimizing impacts on the FFLI habitat and maximizing coverage in multiple weather conditions.

In summary, this research project has resulted in two major outcomes: (1) baseline data to inform ecosystem-based management decisions to the non-profit Juneau Lighthouse Association (JLA), and (2) the initiation of a citizen science web-based platform that may contribute both past and future data to open source biodiversity assessment. It is inevitable that this environment will continue to change and develop as a response to both internal and external forces and influences. The ability to adapt to these changes will be improved through continued study and community engagement in both the science and the stewardship. Incorporating citizen science therefore can contribute to increased socio-ecological resilience through capacity building at all levels (Meek et al, 2008; Pocock et al., 2015).

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