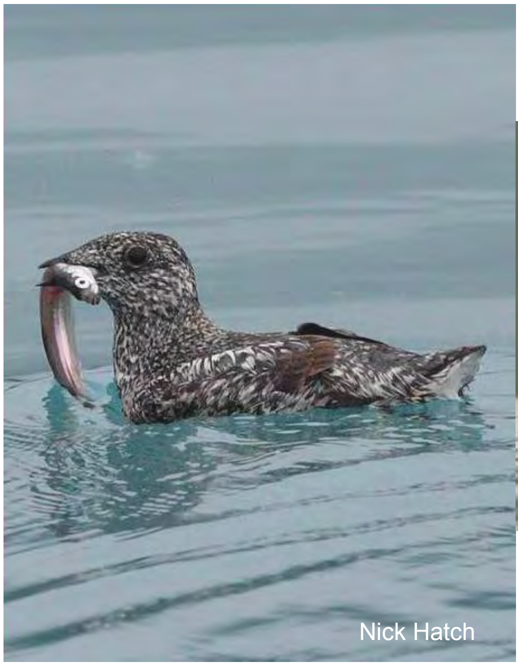
A MONITORING PLAN FOR BRACHYRAMPHUS MURRELETS IN ALASKA



Nick Hatch

Milo Burcham

USFWS and NPS Monitoring

Report #

June 2015

ACKNOWLEDGEMENTS

This project was funded through grants from the U.S. Fish and Wildlife Service, Migratory Bird Management office in Anchorage, Alaska and the National Park Service, Glacier Bay Field Station, Juneau, Alaska to Oregon State University, Department of Fisheries and Wildlife in Corvallis, Oregon. Many thanks to K. Maas-Hebner and K. Raum-Suryan for helping write sections of this monitoring plan. C. Rose created the maps. The plan benefited greatly from edits and input from A. Wilson, xx, and xx.

The ideas and outline for this monitoring plan were based on meetings and input from the following people and agencies (but see Appendix A):
Kathy Kuletz, U.S. Fish and Wildlife Service
Scott Gende, National Park Service
David Irons, U.S. Fish and Wildlife Service
John Piatt, U.S. Geological Survey
Michelle Kissling, U.S. Fish and Wildlife Service
Robb Kaler, U.S. Fish and Wildlife Service
Kim Nelson, Oregon State University
James Lawonn, Oregon State University

This publication should be cited as: Nelson, S.K., K.J. Kuletz, and S.M. Gende. 2015. A monitoring plan for *Brachyramphus* murrelets in Alaska. USFWS and NPS Monitoring Report no. XX.

For more information please contact:

USFWS, Migratory Birds
1011 E Tudor Road
Anchorage, AK 99503
ak_mbm@fws.gov
http://www.fws.gov/alaska/mbsp/mbm/

NPS, Glacier Bay Field Station
3100 National Park Road
Juneau, AK, 99801
scott_gende@nps.gov
http://www.nps.gov/glba/

TABLE OF CONTENTS

1. INTRODUCTION

Marbled (*Brachyramphus marmoratus*) and Kittlitz's (*Brachyramphus brevirostris*) murrelets are small diving seabirds (Family Alcidae) that generally occur in sheltered marine waters of the North Pacific. Marbled Murrelets breed in older-aged coastal forests from Alaska to central California, but also nest on the ground and on rock ledges in parts of Alaska, British Columbia, and Washington (Nelson 1997, Bradley and Cooke 2001, Carter and Sealy 2005, Bloxton and Raphael 2008). Kittlitz's Murrelets are endemic to coastal Alaska and the Russian Far East and breed on talus slopes often near glaciers (Day et al. 1999). Murrelets in the genus *Brachyramphus* (i.e., Marbled, Kittlitz's, and Long-billed *B. perdix*) fly long distances inland to their solitary nests (generally up to 40 km), are cryptic and secretive at nest sites, and active primarily at dawn and dusk (Nelson 1997, Day et al. 1999, Lawonn 2012). These species are thought to be declining over much of their ranges due to numerous anthropogenic threats including habitat loss, oil spills, interactions with commercial fisheries, predation, human disturbance, and climate change. Marbled Murrelets are listed as threatened in California, Oregon, Washington, and British Columbia. Both Marbled and Kittlitz's Murrelets are species of conservation concern in Alaska (USFWS 1992, 1997, 2009), 'Priority Species' in the draft Landscape Conservation Cooperative plans (LCC 2014), and on the American Bird Conservancy and National Audubon watch lists (ABC 2007).

Brachyramphus murrelets are poorly understood, difficult to monitor, and declining throughout much of their ranges. Evaluating the status and trends of a species is vital to their conservation and management yet determining *Brachyramphus* murrelet productivity and status and trends is challenging because they spend most of their lives at sea; most breed in isolated areas where they nest in cryptic or difficult areas to access, they tend to be long-lived with low fecundity and deferred maturity, and may not breed every year. Because of these life history traits, populations of these murrelets are highly susceptible to small changes in adult mortality rates.

Both of these species nest inland and are non-colonial, thus their population abundance and trends are measured and monitored at sea. Because these two *Brachyramphus* murrelets co-occur at-sea in Alaska and are difficult to distinguish on the water, a high proportion of murrelets observed during at-sea surveys are categorized as 'unidentified *Brachyramphus* murrelets', which was particularly a problem in surveys prior to the 2000s. In addition, body size, life history, diet, and foraging patterns are similar between these species (with notably more specialized and ice-associated Kittlitz's Murrelet habits), both show evidence of declining population trends, and both are similarly distributed in some regions of Alaska. Therefore it is appropriate and necessary to consider both species together in this monitoring plan.

Evaluating the status and trends of a species is vital to their conservation and management yet determining *Brachyramphus* murrelet productivity and status and trends is challenging because they spend most of their lives at sea; most breed in isolated areas where they nest in cryptic or difficult areas to access, they tend to be long-lived with low fecundity and deferred maturity, and may not breed every year. Because of these life history traits, populations of these murrelets are highly susceptible to small changes in adult mortality rates. Since the early 1970s, *Brachyramphus* murrelets in Alaska have been monitored both inland and at sea at various scales, by varying methods, and with different intensities, however no comprehensive and standardized monitoring program has been established to determine productivity, distribution, and long-term population trends.

A comprehensive and standardized monitoring program is needed to determine long-term population trends and provide early warning of significant declines. Seabirds, including murrelets, are excellent indicators of marine and coastal environmental impacts, especially from introduced predators, fisheries, pollution, habitat loss, and disturbance. As global climate change progresses, monitoring seabird populations also can help elucidate impacts of climate change to marine ecosystems. In addition, rare, threatened and endangered species require specialized monitoring to more carefully track trends and determine factors causing declines, especially possible effects of climate change. However, to achieve all of these goals, baseline monitoring is needed to discover the natural factors leading to annual variation in population size, reproduction, survival, and recruitment.

The primary objective of this project is to develop a monitoring plan which summarizes existing survey information, identifies data gaps, and provides general guidelines for standardized protocols at inland and at-sea locations to assess productivity, threats, and population status and trends of *Brachyramphus* murrelets in Alaska. Given the difficulty of distinguishing between Marbled and Kittlitz's Murrelets during surveys, a comprehensive plan for both species, with species-specific recommendations (e.g., location of surveys), was deemed appropriate. In addition, *Brachyramphus* Murrelets require a monitoring plan because they are not adequately covered under the existing Seabird Monitoring Plan (USFWS 2009), which is primarily directed towards colonial nesting seabirds. This manual will include the following for both inland and at-sea sites: (1) a summary of existing survey information and protocols; (2) identification of survey gaps; (3) priorities for monitoring strategies; (4) identification and rationale for the selection of population parameters and monitoring sites; (5) recommendations for targeted studies and analyses needed to aid protocol development; and (6) recommendations for development of standardized protocols. This plan will be the first step in developing a detailed monitoring protocol that can be implemented across agencies for monitoring *Brachyramphus* murrelet populations and trends. This plan will not include a detailed survey protocol, which is the next step in fully implementing a monitoring program in Alaska.

Development of this monitoring plan is a cooperative effort between Oregon State University (OSU), National Park Service (NPS) and the U.S. Fish and Wildlife Service (USFWS). This manual was prepared under contract by Oregon State University (OSU) in conjunction with USFWS and NPS, with input from many other agencies and groups, as a first major step towards developing a scientifically sound monitoring plan for *Brachyramphus* murrelets in Alaska. This plan is designed primarily to give decision-makers and resource managers a framework from which to implement monitoring methods for assessing population status and trends using science-based, standardized protocols for data collection. It may also serve to help coordinate *Brachyramphus* murrelet conservation efforts with other federal, state, and international entities, non-governmental organizations (NGOs), and academia. It may also allow the USFWS to be proactive in proposing management and conservation actions that will reduce the risk to murrelets from shipping and fishing activities, coastal development, oil and gas exploration, and changes in the marine environment due to climate change. This plan will be made available to all interested parties, including State and Federal agencies, non-governmental organizations and the general public. This is a living document; monitoring recommendations will be evaluated at regular intervals and modified after careful review.

2. OBJECTIVES

Following many discussions about developing a monitoring plan for Kittlitz's Murrelets in Alaska, USFWS convened several meetings with research partners in Anchorage, Alaska (Appendix A) to discuss goals and objectives for developing a monitoring plan for this species. The goals and objectives evolved over the course of those discussions to include developing a broader monitoring plan, for both *Brachyramphus* murrelets that occur in Alaska (Kittlitz's and Marbled), and focusing on (1) integrating existing information on populations and surveys; and (2) creating a foundation for the future development of specific monitoring protocols.

Goal: Create a monitoring plan for *Brachyramphus* murrelets in Alaksa

Objectives:

- Outline a comprehensive strategy for creating a monitoring plan by summarizing and integrating existing population and survey information on murrelets in Alaska
- Address issues specific to each species as appropriate
- Provide the foundation for the future development of specific monitoring protocols
- Collaborate with partners to achieve and advance all objectives (see 4. PARTNERS below)

3. JUSTIFICATION

Under the authorities of the Fish and Wildlife Conservation Act of 1980 (amended 1988), among other legislation (see USFWS 2009), the USFWS is responsible for monitoring the status and trends of nongame migratory birds and identifying the effects of environmental changes and human activities on these species. Therefore, the USFWS has trust responsibility for seabirds and must gather and maintain reliable seabird colony data to effectively monitor populations and suggest management actions. The recent North American Waterbird Conservation Initiative (Kushlan et al. 2002) identified as high priority the development of monitoring manuals with standardized population monitoring sufficient for trend analysis. In addition, the Alaska Seabird Conservation Plan (USFWS 2009) outlined a number of goals for managing seabird populations in Alaska, including restoring and maintaining the natural abundance, diversity, and distribution of breeding seabird populations in Alaska. The objectives of this goal included: (1) tracking changes in seabird populations, productivity, diets, and survivorship; (2) inventorying at-sea distribution and abundance of seabirds at specific spatial and temporal (seasonal) scales to assist management decisions in the face of global climate change; (3) monitoring seabird distribution and abundance at-sea in selected oceanographic areas; (4) updating colony inventories; (5) conducting basic research that assists in the management of seabird species; and (6) identifying adverse effects of natural events and human activities to seabirds and protect populations. Development of this monitoring plan is one step in the process for USFWS to meet these responsibilities.

In response to documented population declines, the Kittlitz's Murrelet was listed as a candidate for protection under the Endangered Species Act (ESA) with Listing Priority Number 5 in 2004 (69 FR 24875). In 2008, the USFWS upgraded the Listing Priority Number from 5 to 2 because threats to the species had increased from non-imminent to imminent (72 FR 69038). In 2013, the USFWS found that listing the Kittlitz's Murrelet was not warranted based on the scientific evidence (78 FR 61764). The Kittlitz's Murrelet remains a species of conservation concern in Alaska (USFWS 2009) and is a 'Priority Species' under the Landscape Conservation Cooperative (LCC) plans being developed.

The Marbled Murrelet is listed as threatened under the ESA in Washington, Oregon and California, and is a species of concern in Alaska as well as a Priority Species under LCC plans.

Based on at-sea survey data, both *Brachyramphus* species show long-term declines and underwent alarming declines in Alaska during the 1980s and 1990s, with estimated declines of 70% for Marbled Murrelets (Piatt et al. 2007) and declines of 70-85% for Kittlitz's Murrelets (Kuletz et al. 2003, 2008, Van Pelt and Piatt 2003, Drew and Piatt 2008, USFWS 2010). The causes of these declines are not entirely known, but for both species likely involve changes in nearshore foraging conditions and prey availability during summer and winter, and for Marbled Murrelet some loss of old-growth forest nesting habitat. Increased predation due to increased predator populations (eagles, falcons, corvids) is also suspected to affect both species. Marbled Murrelets are experiencing major declines in population, primarily due to the loss and fragmentation of nesting habitat by clearcut logging in

British Columbia and the Pacific Northwest (McShane et al. 2004, Burger 2002, Piatt et al. 2007).

The monitoring plan will help inform land managers and regulators about strategies for species surveys and resource protection. As for many species of concern that eventually fall under scrutiny of state and federal endangered species legislation, reliable methods of estimating populations and detecting trends are critical for sound management. This project will benefit the public by contributing information that will help conserve rare and declining species.

4. PARTNERS

Collaborators in this project include the U.S. Fish and Wildlife Service, National Park Service, U.S. Forest Service, Alaska Department of Fish and Game, Audubon Alaska, Birdlife International (2012), and the Pacific Seabird Group. Broader goals of USFWS and others include: (1) collaboration with Canada and Russia to help integrate seabird monitoring in the U.S. with marine areas adjacent to Alaska (USFWS 2009); and (2) integration of this plan with the North American Colonial Waterbird Plan (Kushlan et al. 2002) and other international efforts to coordinate management and monitoring of seabirds in North America and globally.

5. STUDY AREA

The geographic scope of this monitoring plan includes the coastline and nearshore islands, and inland nesting habitat within 65 km of the coast, encompassed within USFWS Region 7, Alaska Region. The area extends from the Chukchi and Beaufort seas, south to the Aleutian Islands, and east to the Canadian border. Piatt and Springer (2007) defined 30 oceanographic ecoregions in Alaska, 21 of which include coastal waters that are foraging habitat to murrelets. Estuarine areas adjacent to these major divisions are strongly affected by inlet conditions and freshwater input, especially in Cook Inlet, Prince William Sound, and other major inlets and estuaries. Given that ecosystem differences likely affect murrelet population dynamics, we used the following sub-regions to provide the basis for potential geographic stratification of population monitoring, from north to south and east (Figure 1):

- Beaufort and Chukchi seas (ecoregions 27-29)
- Bering Sea (ecoregions 22-25)
- Aleutian Islands (ecoregions 14-17)
- Northern Gulf of Alaska (ecoregions 7-13)
- Southeast Alaska (ecoregions 4-6)

This plan seeks to integrate monitoring throughout these regions, but, in the future, the hope is that coordination can occur if similar efforts are implemented in Canada and Russia.

6. METHODS

Development of this monitoring plan was accomplished through: (1) an extensive literature review of published and peer-reviewed sources for existing monitoring plans and programs; (2) a review of gray literature and personal contacts with seabird biologists conducting ongoing monitoring programs; and (3) a review of USFWS, NPS, and other databases that summarize *Brachyramphus* murrelet monitoring conducted in Alaska since the early 1970's.

7. BACKGROUND

The distributions of Marbled (hereafter MAMU) and Kittlitz's (hereafter KIMU) murrelets overlap much of Alaska, with the exception of some islands in the Aleutians and in the Chukchi and Beaufort seas.

MAMU and KIMU are similar in appearance, but KIMU are heavier (average about 236g), have longer wings and tails, and smaller bills than MAMU (average about 219g; Pitocchelli et al. 1995, Kuletz et al. 2008). See below for a more detailed discussion of differentiating these species in the field. They have two distinct plumages: a full, pre-basic molt in fall (September–October) and a partial, prealternate molt in spring (April–May) (Day et al. 1999). During the pre-basic molt, individuals transition from their mottled, cryptic breeding plumage to a conspicuous black and white plumage of the non-breeding season.

These *Brachyramphus* murrelets (hereafter BRMU) nest in dispersed and cryptic habitats and rely on cryptic coloration and behavior to avoid predator detection, making nests difficult to locate. Unlike other seabirds which are easily studied and monitored at nesting colonies, getting accurate estimates of the numbers, distribution and long-term trends of these non-colonial, secretive birds is extremely difficult. At-sea monitoring in near-coastal habitat is the best way to track abundance and distribution. Monitoring productivity at nesting areas will be difficult and costly for KIMU and near impossible for MAMU.

There are no reliable censuses of either species but recent estimates put their Alaskan populations at about 358,000-417,000 (Piatt et al. 2007, USFWS 2013a) and 26,000-44,000 (USFWS 2010, 2013a) birds, for MAMU and KIMU respectively. Alaska supports 80% and 70%, respectively, of the likely global populations of these species. MAMU range from the Aleutian islands to central California but the bulk of their population breeds in south-east and south-central Alaska (Nelson 1997, Piatt et al. 2007). Through most of their range Marbled Murrelets nest in large old-growth trees but in Alaska about 5% of the population nests on the ground (Piatt et al. 2007). KIMU have a more restricted range, nesting in south-central Alaska, some of the Aleutian Islands, parts of north-west Alaska and, in smaller numbers, in the Russian Far East (Day et al. 1999). This species nests exclusively on the ground, usually on or close to sparsely vegetated glacial moraines but also on other rocky open hill slopes. Both species are primarily piscivorous, foraging by diving in nearshore waters; in the case of KIMU usually in turbid glacially affected waters

(Day et al. 2003, Arimitsu et al. 2010). Both species fly from their marine foraging areas to inland nest sites, usually in near-dark twilight hours.

Both murrelets have been censused and monitored in Alaska using at-sea vessel surveys (e.g., Gould and Forsell 1989, Agler et al. 1998, Piatt et al. 2007). Although well-tested standard protocols are applied in these at-sea surveys, four major problems remain in their effectiveness in tracking population trends. First, murrelets are highly mobile and regularly move 10s of km between foraging sites in summer (Speckman et al. 2000, Whitworth et al. 2000, Kuletz 2005), probably in response to the movements and transient availability of their primary prey (small schooling fish, and zooplankton). The result is highly variable short- and long-term numbers along both fixed and randomized vessel transect routes (Agler et al. 1998, Miller et al. 2006, Kissling et al. 2007c,d). Second, differentiation of the two murrelet species during at-sea surveys is difficult; the birds tend to avoid approaching boats by diving or taking flight, making positive identification to species difficult (Kuletz 2005). Third, boat surveys are expensive and logistically demanding (a crew of three is usually used and access to suitable accommodation and staging sites for boat surveys is a restriction in Alaskan waters). Consequently only a small proportion of the Alaskan coast has been censused for either species and relatively small areas are routinely covered by boat surveys to track population trends (e.g., Piatt et al. 2007, USFWS 2010, Kissling et al. 2011). Fourth, the effectiveness of at-sea surveys is dependent on sea and weather conditions. The small murrelets become difficult to see when seas become choppy or under low light conditions (Evans Mack et al. 2003). Even under optimal conditions, at-sea surveys yield highly variable data and power analyses usually suggest that monitoring of populations at sea requires a 10-15 year investment to detect a 50% change in populations with adequate (>80%) power (Miller et al. 2006, Kissling et al. 2007c,d).

These species face numerous anthropogenic threats including habitat loss, oil spills, interactions with commercial fisheries, human disturbance, and climate change.

Determining the effects of these threats on the status and trends of BRMU populations is difficult because they nest in cryptic or difficult areas to access, and they are long-lived species with low fecundity, deferred maturity, and the propensity for not breeding every year. Because of these life history traits, BRMU populations are highly susceptible to small changes in adult mortality rates. Accurate and timely updates of their population status, distribution, and trends are needed in order to responsibly manage these species.

The following sections address specifics about KIMU and MAMU ecology, as related to monitoring abundance, trends, and productivity.

7.1 KITTLITZ'S MURRELET

The range of the KIMU encompasses a vast region from the Russian Far East across to the Aleutian Islands and southeastern Alaska, and north to northwestern Alaska (Artukhin et al. 2011, USFWS 2013a). Its breeding range extends throughout much of coastal Alaska, where an estimated 70% of the global population is thought to nest, with the balance breeding in portions of eastern Russia (USFWS 2010). The southern extent of their breeding range is thought to be LeConte Bay however several sightings have occurred from British Columbia to southern California during the breeding season (these could be failed breeders; Carter et al. 2011). Kissling et al. (2011) found that roughly 79% of the regional population in southeast Alaska was found between Icy and Yakutat Bays. MAMU outnumbered KIMU in all the areas Kissling et al. (2011) surveyed except for Icy Bay where KIMU outnumbered MAMU. In northern Alaska, KIMU has been observed from Cape Prince of Whales to Point Barrow with two records from the Beaufort Sea (Day et al. 2011). In the Aleutians, the Near Islands support a small, isolated population of KIMU but very few MAMU. The largest population of KIMU outside the Gulf of Alaska was found at Unalaska Island, which also supports the greatest concentration of glacial ice in the Aleutian Islands (Madison et al. 2011). Significant populations were found at Atka, Attu, and Adak islands (Romano et al.

2005a, 2005b). Most of those islands have not been thoroughly surveyed, and significant pockets of KIMU may yet be discovered (Madison et al. 2011). It also is possible that populations either are shifting in the face of environmental change or that some populations are declining at the same time that others are increasing (Day 2011). In the Russian portion of the Bering Sea, Artukhin et al. (2011) reported the highest densities of KIMU were observed in the coastal waters of the eastern and southeastern portions of the Koryak Highlands and the southern Chukotka Peninsula. In the Sea of Okhotsk, KIMU are reported to occupy the coastline from Amakhton Bay to Tavatum Bay (Artukhin et al. 2011). As the breeding season nears in March and April, KIMU move inshore near to known breeding areas (USFWS 2013a).

Intra-specific analyses of genetic data (allozymes, cytochrome b, mtDNA, and nuclear DNA) indicate two strongly differentiated genetic groups: one in the western Aleutian Islands and the other in the Gulf of Alaska (Friesen et al. 1996, Birt et al. 2011). These differences should be accounted for in selecting areas to survey for KIMU.

KIMU spend the entire year in marine waters within and adjacent to Alaska and Russia. During the breeding season (April-August) they are generally found within 6km of shore; in winter they move farther offshore (at least to 170km) and northward (USFWS 2013b, Piatt et al. unpublished data). Patterns of movement during the breeding season begin with birds showing up off breeding areas in March and April, numbers peaking in late June and early July, and then birds rapidly leaving breeding areas post-breeding in late July to mid-August (Klosiewski and Laing 1994, Kendall and Agler 1998, Kuletz et al. 2003, Robards et al. 2003, Kissling et al. 2007b, Kuletz et al. 2008). Arimitsu et al. (2011) also found that KIMU densities within the Kenai Fjords National Park generally increased between June and July but birds rapidly dispersed by August. In Prince William Sound, KIMU were more common in early and mid-summer than in late summer (Day et al.

2003). These movements have implications for the timing of future breeding season systematic surveys.

At the end of the breeding season (late July through August), some KIMU move westward and then northward as far as the Beaufort Sea, although their winter distribution and movements are poorly known (USFWS 2013b). KIMU have been observed in open water leads in the sea ice off Kodiak Island, the Alaska Peninsula, throughout the Bering Sea, as well as in offshore waters of the northern Gulf of Alaska (USFWS 2013b; Kuletz, unpublished data). Radios deployed on a few individuals indicated that some birds moved north to the Bering Sea after breeding in Southeast Alaska (Kissling et al. 2015). In northern Alaska, KIMU were found over the shelf of the Chukchi Sea during mid-April to mid- or late- October with the highest density in September–October (Day et al. 2011, Madison et al. 2012). Birds may remain in the area until their pre-basic molt is complete.

KIMU have a strong association with glaciated and formerly-glaciated habitats including tidewater glaciers, glaciated fjords, floating ice, and outflows of glacial streams (e.g., Kuletz 1996, Day et al. 2000, Piatt et al. 1999, Arimitsu et al. 2011, Piatt et al. 2011). Day et al. (2003) reported that KIMU preferred glacial-affected and glacial-stream-stream affected habitats, areas with 0.5–45% ice, sea-surface water temperatures of 3–6°C, and highly turbid waters (< 1m of visibility and avoided feeding in waters with ≥ 2 m of visibility). KIMU also preferred water depths 41–60m, areas 51–100m from shore, and ≤100 m from fresh water. KIMU avoided water depths of 0–20 m, areas >150 m from shore, >250 m from fresh water, and fine-alluvium shoreline substrates (Day et al. 2003). In Prince William Sound, KIMU preferred College and Harriman Fjords which have the greatest effects of glaciers over Unakwik Inlet and Blackstone Bay (Day et al. 2000). KIMU also occur in some areas without existing tidewater glaciers, including the Aleutian Islands (Piatt et al. 2007, Kenney and Kaler 2013). It is also important to note that the Asiatic breeding range is not related to glaciers, as no glaciers exist in this area (Artukhin et al.

2011). It will be important to compare ecology and demography of KIMU in areas with and without glacial influence to investigate whether there are fitness advantages to this species in different habitats or parts of its range (USFWS 2013b).

KIMU are piscivorous but also eat zooplankton throughout the year, more so than MAMU (Hobsen et al. 1994, Day et al. 1999). During pre-breeding their focus in on lower-trophic prey, such as macrozooplankton, but during breeding they feed on a combination of zooplankton and schooling fishes, such as Pacific capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*) among others (e.g., Kuletz et al. 2008, Hatch et al. 2011, Kaler et al. 2010, Allyn 2012, Lawonn 2012). KIMU likely switch among prey types between seasons or years depending on availability, as do MAMU (Ostrand et al. 2004, Becker et al. 2007). KIMU forage throughout the day and forage as single birds or in small groups, but seldom in mixed-species feeding flocks (Day et al. 1999, Day and Nigro 2000, Madison et al. 2011).

To date, 234 KIMU nests have been found in Alaska (n=230) and Russia (n=4; USFWS 2013b). Based on these nests, KIMU nesting habitat is generally characterized by sparsely vegetated or unvegetated talus slopes, scree-fields, and cliff and rock ledges in coastal uplands and mountains, near glaciers or in historically-glaciated areas up to 75 km inland and 2,000m elevation (Day et al. 1983, Day 1995, Konyukhov et al. 1998, Piatt et al. 1999, Day et al. 1999, Kaler et al. 2009, Lawonn 2012, Kissling, unpublished data). Nests have been found primarily by radio telemetry and by systematically searching areas along transects in suitable habitat, but they have also been found accidentally during other research or by hikers. Considerable time has been spent systematically searching areas for nests and radio telemetry is expensive, both which have implications for attempting to monitor KIMU productivity.

7.2 MARBLED MURRELET

MAMU are distributed along the Pacific coast of North America, with birds breeding from central California through Oregon, Washington, British Columbia, southern Alaska, westward through the Aleutian Island chain, and as far north as Bristol Bay (Nelson, 1997, Gaston and Jones 1998, Burger, 2002). The northern extreme of the MAMU breeding range extends to Bristol Bay and Cook Inlet. The wintering range encompasses the breeding range but also extends into as far south as Baja California, Mexico (Nelson 1997, McShane et al. 2004). Non-breeding birds have also been recorded in the northern Bering Sea and the southern Chuckchi Sea during winter (Day et al. 2011, Kuletz, unpublished data). MAMU appear to be most abundant in Prince William Sound, off Kodiak Island, and from Southeast Alaska (Glacier Bay) to southern British Columbia (McShane et al. 2004, Piatt et al. 2007).

Significant differentiation in MAMU (based on introns, microsatellite loci, mtDNA,), were found between peripheral areas in the Aleutian Islands and central California compared with the central portion of their range (Congdon et al. 2000, Friesen et al. 2005). Despite small sample sizes and number of loci, this differentiation should be considered when monitoring populations in the Aleutian Island versus the rest of Alaska.

Patterns of movement for MAMU in Alaska are largely unknown, but most movements occur after the end of the breeding season and again before the next breeding season (Piatt et al. 2007, Nelson et al. 2010). At-sea densities are highly variable within the breeding season, depending on the juxtaposition of breeding habitat and foraging habitat, including shallow water, tidal rips and prey availability. Barbaree et al. (2015) found that nesting MAMU remain close to nesting sites if foraging conditions are adequate, but will move 200km or more roundtrip to forage if conditions change in proximity to nesting sites. MAMU begin courtship as early as January while still in basic plumage (Nelson 1997). If they move out of breeding areas in winter, they begin to congregate in higher numbers near nesting sites in March and April. Populations peak in May and June (Piatt et al. 2007). Some post-breeding MAMU move away from nesting sites beginning in August, but the scale at which they move is dependent on many factors such as prey availability and location of breeding site (Nelson et al. 2010). Some failed breeders also move away from breeding sites at various times throughout the breeding season (Barbaree 2011).

Some MAMU remain relatively near breeding sites throughout the year, while others disperse widely after the breeding season to better foraging sites, offshore, or to more protected waters (Nelson et al. 2010, Kissling et al. 2015; Piatt, unpublished data). In Prince William Sound and Glacier Bay, numbers of MAMU declined by as much as 80% between the breeding and winter seasons (e.g., Klosiewski and Laing 1994, DeGange 1996). Overwintering areas in Alaska include the Bering Sea, Kodiak Archipelago, Cook Inlet, Prince William Sound, Southeast Alaska, and out to 300 km in the Gulf of Alaska (Piatt et al. 2007; Kuletz, unpublished data).

Within most of it geographic range during the breeding season, MAMU occur primarily within 5 km of shore, but in Alaska, significant numbers also occur farther offshore, especially in the Gulf of Alaska (Piatt and Naslund 1995, McShane et al. 2004, Piatt et al. 2007). MAMU are associated primarily with protected bays, fjords, and inland passes where mixing of freshwater runoff and saltwater is an important oceanographic feature (Burger 1995, Piatt and Naslund 1995, Nelson 1997, McShane et al. 2004, Barbaree et al. 2015). In Prince William Sound, Day et al. (2003) found that MAMU preferred glacial-unaffected habitats, areas with 0% ice cover, water clarity 2–4 m, sea-surface temperatures (SST) 17–24%, water depths ≤40 m, areas 51–150 m from shore, and >1000 m from freshwater. MAMU avoided glacial-affected and marine-sill-affected habitats, water depth >40 m, and areas >150 m from shore (Day et al. 2003).

Data on MAMU foraging habits are sparse in some areas of Alaska, but available evidence indicates spatial, temporal and age-related differences in diet (Piatt et al.

2007). MAMU feed primarily on small schooling fish, such as Pacific sand lance, Pacific herring (*Clupea harengus*), and Pacific capelin, throughout the year, but add invertebrates, such as euphausiids and mysids, to their diet in winter and spring (e.g., Krasnow and Sanger 1982, Carter 1984, Burkett 1995, Kuletz 2005). Chicks are fed a lower diversity of prey and larger, higher quality prey than adults (Kuletz 2005, Newman et al. 2006). Adult MAMU diet in Alaska appears much more diverse compared to areas further south (Piatt et al. 2007). Unlike KIMU, MAMU are often found associating with large mixed-species foraging flocks in Alaska and may be the initiator of those flocks (Ostrand 1999, Haynes et al. 2011).

To date, at least 92 MAMU nests have been found in Alaska at up to 1,100m in elevation and 52km inland (DeGange 1996, Piatt et al. 2007, Willson et al. 2010, Barbaree et al. 2014). Most of the nests have been located in trees (n=56), while the rest were located on the ground in forested habitat or on cliffs (n=36). Tree nests occurred in mixed-conifer forests in three tree species, western hemlock (*Tsuga heterophylla*), mountain hemlock (*T. mertensiana*), and Sitka spruce (*Picea sitchensis*). Ground nests were located on mossy ledges near cliffs or on tree roots (e.g., Ford and Brown 1995, Willson et al. 2010). Cliff nests were on small ledges or in crevices on steep, vertical cliffs with sparse epiphyte and vegetation cover (e.g., Johnston and Carter 1985, Nelson et al. 2010). In northern areas without trees (Aleutian Islands), MAMU nest on rocky terrain or scree slopes in the open. In areas with trees, from Kodiak Island east and south to Southeast Alaska, MAMU nest both on the ground (includes cliffs) and in trees. Willson et al. (2010) suggested that the abundance of coastal streams in forested areas with high gradients and associated openings, cliffs, and rocky outcrops in Southeast Alaska offer MAMU numerous potential nest sites both on the ground and in nearby trees. Abundant cliff habitat on mainland Southeast Alaska adds to the variety of habitats available for nesting (Barbaree et al. 2014).

MAMU nests have been found opportunistically and by radio telemetry. Running transects along slopes with suitable habitat works for locating KIMU nests, but is not really feasible with MAMU except in the Aleutians. For MAMU, monitoring productivity will require extensive expenditures in radio telemetry. Repeated monitoring of MAMU productivity might not be feasible without new technologies (e.g., SAT tags).

7.3 MAMU VS. KIMU IDENTIFICATION

Both MAMU and KIMU can be distinguished from other alcids by their small size, conical bodies, and relatively long, pointed wings in flight. However, identification of these two species in the field can be difficult depending on lighting, distance, and behavior. The following is a brief summary of similarities and differences summarized from *http://alaska.usgs.gov/science/biology/seabirds_foragefish/products/protocols/field_id_guide_to_KIMU.pdf).*

KIMU are slightly heavier than MAMU (ca. 240 g vs. 225 g) and have a shorter bill (ca. 12 mm vs. 16 mm). Both KIMU and MAMU have mottled plumage above and below, darkish crowns and backs, and dark wings above and below. The color of the plumage of KIMU and MAMU can be an excellent way to distinguish between the two species. At sea, KIMU can appear gray, silver, or a warm tan color, and their back is mottled gray with flecking of tan or gold. In contrast, the MAMU is mottled brown on the back, with flecks of rufous-brown color. At sea, the MAMU will never appear gray or silver and if the observer sees rufous-brown flecking on the back, it is definitive for MAMU. If the observer sees a light gray-, silver-, or tan-toned bird and is positive there is no rufous-brown flecking on the back, then it is a KIMU. However, under poor lighting conditions, and/or when birds are flying quickly away, either species may appear dark-gray or brown. If the observer is not positive about the plumage or identification then the bird should be recorded only as a *Brachyramphus* murrelet (i.e., species unknown).

The most definitive characteristic for identifying KIMU is the outer white tail feathers. MAMU have an all-brown tail, while the outer tail feathers of the KIMU are pure white, and this character is most conspicuous when the bird is taking off from the water. KIMU's often 'explode' while taking off from the water with little or no pattering of feet along the surface like other alcids (similar to MAMU). At the moment of take-off, and for a few seconds afterwards, the outer white tail feathers are usually (but not always) evident as the bird fans its tail for take-off. Within seconds, however, they straighten their tail feathers and the white outer feathers are no longer visible. Thus, during surveys, observers should be vigilant about watching murrelets on the water as the boat approaches, using binoculars to view the bird(s) just as it takes off from the water. Viewing the outer tail feathers is the best chance to identify the bird to species.

The call of the MAMU is very load and distinct, and can often be heard above surrounding noise. MAMU's most commonly make a loud, sharp two-note whistle, with the second note descending in tone, "kee-earr". In contrast, the KIMU call is a very quiet 'groan' call, pronounced like 'urrrhha' and sounding in quality somewhat like a Pacific Loon or Oldsquaw. Both species of murrelets have variations in their calls, but those described here are commonly heard at sea and are distinctive. See Nelson (1997), Dechesne (1998), and Van Pelt et al. (1999) for more details on their vocalizations.

Training is extremely important for ensuring positive identification of KIMU and MAMU during at-sea surveys. Crews should spend time before surveys learning to distinguish between the two species by comparison in the field. Viewing photos from different angles and in different light can also be valuable.

8. MONITORING STRATEGY

A future population monitoring strategy might consist of a three-tiered approach:

1) Comprehensive, Alaska-wide, at-sea surveys to determine *Brachyramphus* murrelet population size at infrequent intervals (*e.g.,* every 15 years)
2) Intensive at-sea surveys of specific emphasis areas at frequent intervals (*e.g.,* every 1-3 years)
3) Periodic evaluation of reproductive success, factors influencing trends, and monitoring methods, including development of new methods as needed.

These protocols would focus on distribution, population trends, and reproductive success, important for not only monitoring population changes but attempting to assess the reasons for population change.

At-sea monitoring is one of the explicitly stated goals of the USFWS Seabird Conservation Plan (USFWS 2009) and, for BRMU, at-sea surveys provide the only method for monitoring changes in populations. Marine surveys are also useful in assessing the relative roles of breeding and non-breeding birds in local marine ecosystems, and in assessing risks to oil spills and fisheries. We recommend that a comprehensive program for monitoring murrelets at sea in Alaska be developed through coordination between federal agencies, seabird scientists, and other public and private stakeholders, including the Pacific Seabird Group.

However, new data collection and analysis of existing data are needed to establish the sufficiency of and statistical goals for a monitoring strategy. Other parameters that can be invaluable to monitoring efforts include survival rates, recruitment rates, breeding chronology, adult and juvenile survival, diet composition, and chick growth rates. These parameters are critical for exploring the links between ocean conditions and changes in seabird populations. Collection of these data, however, is highly labor-intensive and not necessarily logistically feasible for BRMU. We recommend that comprehensive protocols be developed for these parameters as more data become available and research methods issues are resolved.

The monitoring program should consider six life history parameters that are used to track and model seabird population trends:

1) Population Inventory (distribution and abundance of total breeding pairs)
2) Population Index (annual number of breeding pairs at all or selected colonies or sample plots)
3) Productivity Index (reproductive success)
4) Breeding Chronology
5) Diet Composition
6) Adult Survival

Population inventories and indexes are important in order to monitor changes over time. The other parameters listed are recommended to provide information about the overall status of BRMU in Alaska, within the broader ecological context of the North Pacific. Diet composition and adult survival are important for helping to determine underlying causes of population change. Knowledge of seabird demographic processes (*i.e.,* adult survival, reproductive success, recruitment, age at first breeding) is crucial for assessing impacts of anthropogenic change on seabird populations and in designing and evaluating restoration projects (Nur and Sydeman 1999). Logistics and feasibility of data collection, will vary with area and species.

Population Inventories: The goal of population inventories are to detect large-scale changes over time in the distribution and abundance of breeding murrelets. All areas within the breeding range of the BRMU would be surveyed every 15 years. Population inventories will assist managers in determining the total size of breeding populations and identify geographic shifts in distribution and abundance. Colony inventory monitoring can corroborate trends documented with intensive monitoring (*i.e.*, population and productivity indexes), especially when intensive monitoring is limited and may not be widely representative. However, inventories also serve to identify any different trends and conservation issues at breeding areas that are not intensively monitored.

Population Index: The goal of population monitoring should be to detect a change in murrelet populations through strategic monitoring at key sites on a frequent basis (every 1-3 years). Population inventories should detect large-scale changes in abundance and distribution of seabird colonies at a region-wide scale. Population and productivity indexes target changes in breeding populations, reproductive success, and, where possible, survival and diet. Data collection for these two indexes should occur every 1-3 years and should focus on a carefully selected subset of breeding locations. Partners are critical to the expansion of existing monitoring programs and the ultimate success in achieving the monitoring goals and objectives outlined in this plan.

It was decided that new data collection and analysis of existing population data were needed before statistical goals could be set for a monitoring program (*i.e.,* how large a change to detect, over what period of time, with what level of significance and power). Hatch (2003) recommended power to detect a negative trend of 6.7% per year (50% decline in 10 years) with $\alpha = 0.05$ and $\beta = 0.9$.

Productivity Index: The goal of productivity indexes are to detect a change in reproductive success among years through frequent (every 1-3 years) strategic monitoring at key sites. Productivity, or reproductive success, of murrelets is sensitive to annual variation in food availability, nest predation, and disturbances. This level of intensive monitoring would provide the best data for assessing trends and testing hypotheses about the effects of changes in ocean conditions on productivity of seabird populations. Frequent visits are labor-intensive, however, and may not be logistically feasible at most KIMU nesting sites and nearly impossible at MAMU nesting sites because of the inaccessibility of nests. Further discussion is needed to determine the feasibility of implementing effective productivity monitoring where useful productivity data can be collected.

Breeding Chronology: Changes in breeding chronology may signal changes in the marine environment related to climate change. Tracking this parameter can be difficult without frequent visits to nesting areas or marking birds with transmitters. However, changes in dates of arrival to breeding areas could be used as a surrogate to onset of breeding, if funds are not available for more intensive surveys.

Diet: Diet composition data provide an important link between the breeding populations and productivity of murrelets and conditions in the marine environment. Relative prey consumption, in association with data on murrelet productivity, can be used to understand the functional relationships between murrelet populations and ocean conditions. Diet data can be collected at sites that are monitored for productivity.

Adult Survival: Adult survival is the most important and sensitive parameter in BRMU population trends. BRMU generally have high survival rates (>89%; Beissinger 1995, Kissling et al. 2015); any anthropogenic factors that affect adult survival will have significant impact on population trajectory. Initiating mark-recapture studies, such as Kissling et al. (2015), will be valuable for monitoring adult survival rates. Given the expense, however, determining the factors that affect adult survival (e.g., bycatch, predation) and attempting to minimize the effects on BRMU could help overall BRMU populations. Other factors that likely affect adult survival in the marine environment, including prey availability, overwinter conditions, and ocean health, are difficult to control.

The strength of designing a regional program with standardized protocols lies in the ability to compile and compare indexes among sites throughout Alaska. In addition to maintaining their own databases, managers and researchers are expected to contribute their monitoring data to the Pacific Seabird Monitoring Database, currently maintained by the USGS–BRD, Alaska Science Center, Anchorage, AK.

The Pacific Seabird Monitoring Database is a comprehensive repository for North Pacific seabird monitoring results. The database stores data on 86 species that breed in the Pacific Ocean (north of 20 degrees N latitude) and incorporates a variety of population parameters, including abundance, productivity, diet composition, and survival. The database has two major components: (1) relational data management and retrieval and (2) spatial analysis and mapping. Data input and retrieval capabilities have recently been made available online (http://seabirds.usgs.gov/).

9. POPULATION MONITORING

This section summarizes historic surveys for BRMU populations and trends throughout Alaska and Russia, and the associated recommendations for monitoring based on those surveys. Following those summaries are our recommendations for methods that should be considered for inclusion in a future, detailed monitoring plan.

9.1 HISTORIC AT-SEA POPULATION ESTIMATES AND TRENDS

Because murrelet nests are non-aggregated, dispersed throughout coastal forest and tundra habitat, and are cryptic, individuals cannot be reliably counted inland. Therefore, at-sea surveys, from a boat, are the most cost-efficient and consistent method for estimating BRMU abundance and trends in Alaska (Madsen et al. 1999, Miller et al. 2006, Piatt et al. 2007, Day 2011). Following is a summary of population estimates and trends based on historic surveys.

9.1.1 WHEN SURVEYS HAVE BEEN CONDUCTED

Breeding surveys for both MAMU and KIMU have typically been conducted from late June through July during peak breeding activity and when weather and sea conditions are most conducive for accurate surveys. If the size of the breeding population is of greatest interest, a period early in incubation should be sampled, before subadults arrive on the breeding grounds. If the overall population size is of greatest interest, a period in early to middle chick-rearing (when numbers at sea are highest) is most appropriate in many locations (Day 2011). The total number of murrelets on the water varies throughout summer (DeGange 1996, Speckman et al. 2000, Kuletz 2005). Numbers on the water increase after incubation (May–June) and by as much as 20 to 40 percent during late July and early August (Kuletz and Kendall 1998, Speckman et al. 2000, Lindell 2005). Monitoring in June should give an idea of the approximate number of birds that might be attempting to breed, whereas monitoring in July will help track the maximal size of the population and, in some locations, provides a chance to search for fledglings (Day 2011). Interanuual variability in local attendance of murrelets at sea may result in part from phytoplankton blooms that determine trophic dynamics at lower levels (Arimitsu et al. 2011). Speckman et al. (2000) demonstrated that interannual variability in MAMU abundance, apparent nesting phenology and chick production were related to differences in marine production and ocean climate among years. Monitoring when the variability is lowest will result in more precise population estimates and will improve precision for trend monitoring and, hence, statistical power for detection of trends (Day 2011).

9.1.2 WHERE SURVEYS HAVE BEEN CONDUCTED

At-sea population surveys of BRMU have been conducted in various areas throughout Alaska and Russia for the past 40 years (Table 1, Figure 2). Studies included in Table 1 are those that attempted to distinguish between MAMU and KIMU; those that did not attempt to distinguish between the species are not included. Birds that could not be identified to species due to field conditions or behavior were listed as BRMU. Core MAMU breeding populations are found in Prince William Sound, the Kodiak Archipelago, Glacier Bay and Southeast Alaska (Table 1). Core KIMU breeding populations are found in southern Alaska including the Alaska Peninsula (south side), Prince William Sound, Lower Cook Inlet, Kachemak Bay, Kenai Fjords, Icy Bay, Yakutat Bay and the Malaspina Forelands, and Glacier Bay (Table 1). Smaller breeding populations of both species are present in the Aleutian Islands (Piatt et al. 2007, Kenney and Kaler 2013). Icy Bay supports 3% of the global population of KIMU (USFWS 2013a) and is one of the densest populations of this species during the breeding season (Kissling et al. 2011). The Near Islands support a small population of KIMU but very few observations of MAMU (Piatt et al. 2007). KIMU have been found at only a few islands in the Aleutian chain, notably those with long complex shorelines, high mountains and remnant glaciers (Madison et al. 2011). The largest population of KIMU outside the Gulf of Alaska was found at Unalaska Island, which also supports the greatest concentration of glacial ice in the Aleutian Islands (Madison et al. 2011). Although most Aleutian Islands were not thoroughly surveyed, significant populations were found at Atka, Attu, and Adak islands (Madison et al. 2011). Smaller numbers have been reported from Unimak, Umnak, Amlia, Kanaga, Tanaga, Kiska islands, and Agattu Island, where dozens of nest sites have been located in recent years (Madison et al. 2011, Kenney and Kaler 2013). KIMU are also present in northern Alaska (Kissling and Lewis 2015), but no breeding MAMU populations are present north of Bristol Bay (Table 1). Where the two species co-occur, MAMU abundance is typically much higher than KIMU. An extreme example of differences in distribution is included in Kuletz (1996) who found that KIMU accounted for as little as 1% of all murrelets at Naked Island in Prince William Sound. Northern Alaska appears to provide a substantial amount of potential nesting habitat for KIMU, especially on the Seward and Lisburne Peninsulas (Day et al. 2011, Felis et al. 2015, Kissling and Lewis 2015). Felis et al. (2015) estimated that more than 11% of the total land area on those peninsulas serves as potential nesting habitat for this species.

The Asian coast likely supports a larger proportion of the global population of KIMU than previously acknowledged, and an expansion of surveys, research and monitoring of this species in Asia will be important for its conservation (Artukhin et al. 2011). The northern boundary of winter distribution lies along the Sireniki polynya near the southern coast of Chukotka Peninsula (Artukhin et al. 2011). Migrating and wintering birds have also been recorded near northeastern Sakhalin and the islands of northern Japan. In the Bering Sea, highest densities were observed in the coastal waters of the eastern and southern parts of the Koryak Highlands and southern Chukotka Peninsula. In the Sea of Okhotsk, the species occupies roughly 500 km of coastline from Amakhton Bay to Tavatum Bay (Artukhin et al. 2011).

9.1.3 POPULATION TRENDS

The total population of MAMU is estimated to be between 358,200-417,500 individuals, based on 271,000 individuals in Alaska (Piatt et al. 2007), 72,600-125,600 in British Columbia (Bertram et al. 2007), and 14,631-20,952 individuals in Washington, Oregon and California (Falxa et al. 2008). The best evidence indicates that the minimum global population of the Kittlitz's murrelet currently is between 26,000 and 42,000 individuals (USFWS 2013a). It is important to note that a considerable portion of the global KIMU population may breed and winter along the Asian coast.

Although estimating BRMU populations has been fraught with problems of differing survey methodology, most results indicate that there has been a rapid and widespread decline in populations throughout Alaska. It appears that MAMU have declined by 45–79% in Alaska with evidence for major declines in abundance strongest in Southeast Alaska and Prince William Sound (Piatt et al. 2007). Rates of decline (-12.7 vs. -11.8 %) estimated from Icy Strait and Glacier Bay in Southeast Alaska are supported by observed trends from a region wide survey (-11.5 %). Declines in Prince William Sound were less extreme, but still large at -6.7% per year. Numbers along the Malaspina Forelands, in Kachemak Bay, and at Adak Island were all negative, and slightly positive at Kenai Fjords, but small sample sizes and highly variable data make it difficult to define trends in these areas (Piatt et al 2007).

The range-wide status of KIMU also has been difficult to assess (Kissling et al. 2011). Across all local populations with sufficient data, it appears that populations have declined by 84% between 1989 and 2000, but have since begun to stabilize or decline at a comparatively much slower rate (USFWS 2013a). The greatest downward trends were reported for Prince William Sound, Glacier Bay, Lower Cook Inlet, and Kachemak Bay (Kuletz et al. 2011a, Kuletz et al. 2011b, Piatt et al. 2011). Moreover, Kissling et al. (2015) estimates are consistent with the observed decline of 10% per annum between 2002 and 2012 in the Icy Bay population. Artukhin et al. (2011) suggests that a considerable portion of the global KIMU population may breed and winter along the Asian coast which would have important implications for the conservation and protection of KIMU, in light of recent declines documented in parts of the species' Alaskan range. Clearly, additional surveys need to be conducted at several locations so that a rigorous baseline can be established for monitoring population trends.

9.2 HISTORIC SURVEY METHODS AND RECOMMENDATIONS

No standardized survey protocols have been developed for surveying BRMU in Alaska. Standardized MAMU surveys are conducted in Washington, Oregon and California (Raphael et al. 2007). Reliable census methods for murrelets are needed in Alaska to refine population estimates, establish long-term monitoring programs and undertake habitat association studies. The goal of this section is to review what has been done in terms of BRMU surveys in Alaska and provide recommendations for use in development of a detailed standardized survey protocol for both species. Recommendations are for both KIMU and MAMU unless otherwise noted.

Line transect methodology appears to generate more accurate density and population estimates and lower coefficients of variation compared to strip transects

(Kissling et al. 2007a,b,c, Kirchhoff 2008, Arimitsu et al. 2010, Day 2011). Strip transects underestimate marine population size when observers are unable to detect every bird within the strips (Arimitsu et al. 2010). Line transects however, incorporate detection probability based on perpendicular distance of detected birds to the line transect, essentially creating a correction factor for undetected birds (Bentivoglio et al. 2002, Arimitsu et al. 2010). An orthogonal or zigzag pattern out from the shoreline appears to be the best transect design because of changing densities with increasing distance from shore (Kirchhoff 2008, Kirchhoff et al. 2010, Day 2011).

Evidence also indicates that a stratified sampling design in which strata accurately reflect differences in the anticipated density of BRMU are optimal (e.g., Kuletz et al. 2003; Hoekman et al. 2011a,b). For example, one approach is to use a stratified systematic sample with intense sampling in glaciated parts of fjords and less-intense sampling in outer parts of fjords (Romano et al. 2006, Arimitsu et al. 2010). Another approach is based on distance from shore or sea depth in which survey areas are stratified between pelagic waters (>200 m from shore) and shoreline waters (<200 m from shore) (Allyn 2002). The degree of stratification and the reasons for stratification has varied dramatically among studies (Day 2011). The number of strata within a restricted area (e.g., Glacier Bay) has ranged from 1 (several studies) to 11 (Drew et al. 2008), whereas studies that have covered a larger geographic area have had even more strata (Day 2011). Thus, study design must consider the high mobility of BRMU when stratifying samples within bays.

Replicate sampling, sampling the same area multiple times over a short period, has been identified as an important survey design for BRMU (Romano et al. 2004, Kissling et al. 2007b, Kirchhoff et al. 2010). Replicates improve the ability to detect trends and help gain a better estimate of the variation around estimates (Day 2011). Several studies (e.g., Kissling et al. 2007b, Kirchhoff et al. 2010) have indicated dramatic among-survey variability and recommend the collection of replicate samples. Replicates should be conducted over a short period, preferably just a few days (e.g., Day and Nigro 1999, Romano et al. 2004).

Breeding surveys for both MAMU and KIMU are typically conducted from late June through July when breeding populations are highest and weather and sea conditions are most conducive for accurate surveys. Depending on safety conditions, some surveys are only conducted during specific tidal phases (i.e., slack tide vs. flood and ebb tide). Various boat/vessel platforms are used for surveys (Table 2) with the deciding factors being safety (i.e., type of vessel best suited for local conditions) and availability of the vessel(s). What is most important is consistency among years. In the past, there has been substantial variation among studies in sampling platforms, viewing height of observers above water, and the number of observers (Day 2011). Criteria for terminating a survey has also been variable, ranging from using wave height or Beaufort sea scale >2 to poor visibility and/or heavy precipitation, glare, or fog (Day 2011). One study varied criteria seasonally, ranging from seas >0.5 m in summer to >1.8 m in winter (Agler et al. 1995), and two varied criteria spatially, with the cutoffs >0.5 m in the nearshore zone (where smaller boats generally are used) and >1 m in the offshore zone (Romano et al. 2005a, 2005b). Hence, a well-planned study design is very important in minimizing variation in estimates.

The detectability of BRMU during at-sea surveys can be impacted from a variety of factors. Ship speed has varied considerably among studies with vessel speed ranging between 10 and 20 km/h, with a few at ~10 km/h (e.g., Bailey 1976, Bailey and Rice 1989, Day and Nigro 1999, Kissling et al. 2007c, Kirchhoff 2008) and some >20 km/h (e.g., Romano et al. 2005a, 2005b, Arimitsu et al. 2010). Ship speed can affect data quality because if ship speed is too great, birds can either be disturbed and fly away or be underwater as the ship passes (Day 2011). Recording flying birds during surveys must be standardized. One method is to use the snapshot method (Gould and Forsell 1989) to count flying birds. This snapshot method should be adjusted based upon the length of time it takes for the vessel to move forward by a particular distance (the size of your sampling zone) ahead of the present position. This ensures the observer conducts a count on a "new" section of sampling zone ahead of the vessel in each snapshot. BRMU detectability from boats declines dramatically beyond 100 m (Kuletz 1996) and differentiation between the two species is difficult at greater distances (e.g., Arimitsu et al. 2010). Surveys failing to account for unidentified murrelets and for incomplete detections near the transect center line will create substantial and variable bias and error in density estimates and decrease the ability for a monitoring program to assess population status and trend (Hoekman et al. 2011b). However, Kirchhoff (2011) concludes that positive identification rates of 75–90% should be an attainable goal while providing a suitable basis for allocating the unidentified fraction to species-level.

The primary data-analysis methodology for KIMU in Alaska has been to calculate standardized mean densities (birds/km²) by sampling method (nearshore, offshore, etc.) and geographic stratum (Day 2011). Population size was estimated by multiplying estimated densities (and their associated measures of variation) by the area of the method-geographic stratum with a ratio estimator (which is designed to improve stratified sampling by incorporating covariates in the estimation), then summed across strata to generate a total population estimate for the area of interest (Day 2011). Some studies (e.g., Kissling et al. 2007a, 2007b, 2007c, Arimitsu et al. 2011) used the software DISTANCE to generate detection functions that can be used to generate corrected density and population estimates. Studies that examined population trends generally used linear regression on densities and/or population size (e.g., Kuletz et al. 2007).

9.2.1 BRMU SURVEY RECOMMENDATIONS FROM THE LITERATURE

The following recommendations regarding monitoring BRMU in Alaska have been made by multiple authors (Gould and Forsell 1989, Kuletz et al. 2003, Romano et al. 2006, Kissling et al. 2007a, 2007b, 2007c, 2007d, 2015, Piatt et al. 2007, Drew et al. 2008, Kirchhoff 2008, Arimitsu et al. 2010, Kirchhoff et al. 2010, Day 2011, Hoekman et al. 2011a, 2011b). General recommendations that could be applied to surveys throughout Alaska and Russia were summarized first, followed by area specific recommendations of where best to survey.

TYPE OF SURVEY

- Line transect methodology employing software such as DISTANCE to generate detection functions to more accurately estimate density and population estimates
- Standardize how distance is calculated during surveys

WHEN TO SURVEY

- The best time to survey BRMU populations for status and trends analysis depend on the question of interest. If the size of the total population is of greatest interest, a period in early to middle chick-rearing when numbers are highest (approximately mid-July in the northern Gulf of Alaska—but September and October in the Chukchi Sea) is best. The period of lowest variability in numbers usually occurs around mid–late summer (around mid-July) in the northern Gulf of Alaska in most locations but not all (e.g., Kenai Fjords, where the lowest variability is in early June).
- Conduct breeding surveys from late June through July when breeding populations are highest and weather and sea conditions are most conducive for accurate surveys

HOW TO SURVEY

- Develop a plan that includes coordinated survey efforts and continue monitoring populations in key areas to ensure continued population stability and to detect any change in population trajectory as soon as possible
- Conduct surveys to estimate population size in areas not surveyed yet or adequately

- Layout a spatially-intensive series of sampling lines orthogonal to shorelines to account for nearshore-offshore density gradient
- Consider sampling alternating set of lines as replicates
- Transects should be stratified using bathymetry, water clarity, shoreline substrate, or other environmental variables of biological significance
- Use a minimum of two highly skilled observers (who are capable of differentiating the species)
- Consider BRMU-specific surveys rather than multi-species surveys
- Use consistent ship speed within survey and between survey years, slow enough so birds will not be disturbed and fly away or be underwater as ship passes
- Use the same survey platform year after year so detection probabilities can be incorporated for each area
- Establish a set criteria for stopping surveys based on sea conditions and visibility
- Minimize the number of unidentified birds in samples – unidentified birds complicate analyses and reduce confidence in population estimates and consequently trend analyses
- Incorporate flying birds into sampling methods and population estimates using the snapshot method
- Incorporate the use of population projection models to estimate survival
- Use population size rather than density, as the metric of interest
- Use a stratified sampling design in which strata accurately reflect differences in the density of BRMU
- Fill data gaps that serve as challenges to estimating population trend accurately and precisely such as within-season and across-season movements and nest area fidelity
- Determine fledging dispersal and behavior in order to evaluate reliability of monitoring trends in productivity using at sea surveys

SPECIFIC TO KIMU

- Monitoring guidelines based on actual survey data should be developed before monitoring areas with smaller populations and lower densities
- Initiate coordinated research efforts to compare ecology and demography of KIMU in areas with and without glacial influence to investigate whether there are fitness advantages to this species in different habitats or parts of its range.
- Conduct survey's every 1-2 years in areas with populations > 1,000 birds or with peak densities > 5 birds/km^2 (i.e., Icy Bay, Glacier Bay)
- Conduct surveys every 5 years in areas with populations < 1,000 birds or with peak densities < 5 birds/km^2 (i.e., Malaspina Forelands, Yakutat Bay, Outer Coast and associated bays, Wilderness Bays)
- Revisit areas known to previously support KIMU (e.g., LeConte Bay) every 5 years

WHERE TO SURVEY

Refer to Figure 2 for the following locations of historic and recommended surveys.

ALASKA

SE Alaska

- Icy Strait (only a small area has been surveyed near Glacier Bay)
- Glacier Bay
- Malaspina Forelands
- Yakutat Bay
- Icy Bay
- Outer coast and associated bays (not mapped in Figure 2)

Northern Gulf of Alaska

- Prince William Sound
- Gulf of Alaska
- Lower Cook Inlet

- Kenai Fjords
- Kachemak Bay
- Kodiak archipelago
- Alaska Peninsula

Aleutian Islands

- Near Islands (Attu)
- Andreanof Islands (Adak, Atka, Kagalaska)
- Fox Islands (Unalaska)
- Agattu (KIMU only)

Russia (KIMU only)

- Dezhnev Bay to Kamchatsky Bay
- Northern Sea of Okhotsk
- de Long Strait to Kamchatsky Bay
- Southeastern coast of the Chukotka Peninsula
- Northeastern coast of the Gulf of Anadyr
- Eastern and southern coasts of Koryak Highlands (Bolshoy Tigil Bay; Severnaya Mochevna Bay and adjacent areas of Kamchatka Peninsula (The Koryak Highlands region could be one of the most important areas for this species)
- Northwestern coast of Shelikhov Bay

9.3 RECOMMENDED METHODS FOR FUTURE BRMU POPULATION AND TREND SURVEYS

Current population size and trend information should be refined through additional at-sea surveys, refined survey sampling design, and data analysis techniques. Information on BRMU survivorship estimates and juvenile: adult ratios at-sea also should be collected over a number of years (e.g., 5—10 years) to further validate the current population model. Several years are required to account for possible natural variability that may lead to variation in breeding success.

9.3.1 VESSELS

Population surveys for BRMU are most effectively conducted from boats. To ensure the safety of observers, the type of survey vessel should be selected based on where surveys will be conducted and on sea conditions. Within an area or ecoregion, the same survey platform should be used year after year so detection probabilities can be incorporated for each area. The viewing height of the observer above the water should be recorded (the higher the viewing platform, the greater the view ahead of and either side of the vessel).

9.3.2 OBSERVERS

Ideally, there should be at least two highly skilled observers (to reduce the number of unknown BRMU recorded) along with the boat driver. Observers should record all observations using a GPS-integrated voice recording system that stamps each observation with a location and time (e.g., Fischer and Larned 2004).

9.3.3 SHIP SPEED

Ship speed during surveys has varied considerably (10 km/hr - > 20 km/hr) among studies, (e.g., Day and Nigro 1999, Romano et al. 2005a, 2005b, Kissling et al. 2007c, Kirchhoff 2008, Arimitsu et al. 2010). Ship speed has implications for data quality in terms of the distance at which birds become disturbed and fly away (greater distance with greater ship's speed), rather than sitting on the water, thus decreasing the identification rate. High speeds also increase the chances of missing birds that happen to be diving as the ship nears (Day 2011). Therefore, we recommend ship speed be consistent among surveys and should average ~10 km/hr.

9.3.4 SURVEY LINES

The layout of survey lines also has varied dramatically among studies (e.g., Day and Nigro 1999, Kissling et al. 2007c, Drew and Piatt 2008, Kuletz et al. 2008). We recommend survey lines be laid out orthogonal or zigzagging out from shorelines because of changing densities of BRMU.

9.3.5 SURVEY METHODOLOGY

Line transect survey methodology (Buckland et al. 2001) using the program DISTANCE (Thomas et al. 2002) to generate detection functions should be employed.

9.3.6 SURVEY PERIOD

Based on past survey information, surveys should be conducted consistently at the same time of year. To determine overall population and trends, the best time to survey will be early to mid-July in most areas (September-October in Chukchi Sea). Kissling et al. (2007d) recommend monitoring surveys In Icy Bay occur during the first two weeks of July given the population peak during these periods.

9.3.7 DATA COLLECTION

Flying birds should be counted as a “snapshot” of birds in the air ahead of the ship (see Gould and Forsell 1989). A new snapshot should be taken every time the ship advances the distance the observer is looking ahead of the ship (determined prior to start of project). Data to be recorded should include: species, group size (birds within 2 m of one another at first detection or birds more than 2 m apart but exhibiting associative behavior; Raphael et al. 2007), and behavior (e.g., on water, flying, foraging). At set intervals (e.g., every 30 minutes), observers should record weather, sea and ice conditions, swell height, wind speed and direction, water temperature, and water clarity.

9.3.8 SPECIES

Surveys should be conducted for BRMU only. Counting other birds while surveying for BRMU can affect BRMU detectability.

9.3.9 CRITERIA FOR STOPPING SURVEYS

Specific criteria for stopping surveys should be specified ahead of time, based on sea state and visibility. If Beaufort >2 and visibility is <100 m due to heavy precipitation, or fog, surveys should be terminated.

9.3.10 STRATIFICATION

We recommend using a stratified sampling design in which strata accurately reflect differences in the anticipated density of BRMU (e.g., Kuletz et al. 2003; Hoekman et al. 2011a, 2011b). For KIMU, strata should be designed with intense sampling in glaciated areas of fjords and less intense sampling in outer areas of the fjords (Romano et al. 2006, Arimitsu et al. 2010). Incorporate the nearshore–offshore gradient in densities into the sampling design and analytical methodology using GIS to develop post-sampling strata based on a particular study area in a particular year. This approach should achieve more accurate and more precise population estimates. Lay out a spatially-intensive series of sampling lines orthogonal to shorelines, to account for this nearshore–offshore density gradient (Kissling et al. 2007c, Drew et al. 2008, Kirchhoff 2008). Strata should be defined based on geographic location, bathymetry, and distance from shore. Pelagic transects can be used to account for variability across space that could not occur with shoreline transects (Kissling et al. 2007d).

9.3.11 REPLICATE SURVEY LINES

Sample alternating sets of lines as replicate estimates. Kissling et al. (2007c) recommend survey lines be 2 km long and spaced ~2 km apart to minimize disturbance to birds; an alternating set of lines spaced 1 km between these 2-km lines could form a second set of lines to be sampled. Because of among-survey variability (e.g., Kissling et al. 2007b, Kirchhoff et al. 2010), replicate samples should be conducted and within a few days to reduce variability. Because BRMU numbers vary seasonally and inter-annually, this information should be taken into account when designing each study plan.

9.3.12 MODELING/ANALYSES

Simulation analyses to determine sampling effort for locations that have spatially-adequate data should be conducted prior to sampling (see Drew et al. 2008). Use population size rather than density as the metric of interest. Among-survey spatial variation is the major component of variation in estimating the variation around population estimates compared to the more minor component of detection probabilities (see Day 2011). Therefore, an intensive study design is very important in minimizing variation in estimates. Using a program such as DISTANCE (Thomas et al. 2002) to model the probability of detection and effective area sampled is advantageous because the software uses a key function to approximate the probability of detection at distance *r*, *(πr2),* and improves the fit with a series expansion term (Thomas et al. 2002). Another advantage of using DISTANCE is that it employs Akaike's Information Criterion (AIC) to select the most parsimonious model from a set of potential models for g(πr2; Burnham and Anderson 2002, Thomas et al. 2002). A high degree of clumping will ultimately be a limiting factor in generating precise estimates of BRMU abundance. Simulations and corresponding power analyses conducted by Kissling et al. (2007d) for KIMU in Icy Bay demonstrated that to detect an annual decline of 10% with a power of 0.9, they would need to monitor for 10-15 years. They strongly suggest surveying annually in Icy Bay given the importance of this area for KIMU and lack of information about inter-annual variation. To do this, it would require conducting two bay-wide surveys (~65 km each) with two survey crews to reduce temporal variation (Kissling et al. 2007d).

9.3.13 WHERE TO CONDUCT SURVEYS

The following areas should be emphasized in future survey efforts for tracking BRMU populations and trends in Alaska (Figure 2). These areas will track a majority of the BRMU populations in Alaska (see Table 1). Surveying at the Fox Islands in the Aleutians will allow for monitoring potentially distinct populations of KIMU and MAMU. Additional areas in the Aleutian Islands could be surveyed when logistically possible with other research ventures (e.g., *Tiglax* availability). Surveys in gap areas listed below could be surveyed on a longer timeframe (e.g., every 10 years) as time and money allow.

SE Alaska

- Stephens Passage/Port Snettisham area
- Glacier Bay
- Icy Strait
- Malaspina Forelands

Northern Gulf of Alaska

- Prince William Sound
- Kenai Fjords
- Kachemak Bay
- Lower Cook Inlet
- Kodiak archipelago

Aleutian Islands

- Fox Islands (Unalaska)

9.3.14 GAPS IN LOCATION OF HISTORIC SURVEYS

Gaps in historic surveys in Alaska and Russia occur in the following areas (see Figure 2 for gaps in Alaska). In addition to areas listed below, potential nesting habitat may also occur in small areas along the Bering Sea from the Alaska Peninsula to the Seward Peninsula, including along Norton Sound.

ALASKA

SE Alaska

- South of Glacier Bay many areas not surveyed or surveyed only on Agler et al. (1998)

Aleutian Islands

- Unimak Island
- Umnak Island
- Amlia Island

- Kanaga Island
- Tanaga Island
- Kiska Island

Beaufort and Chukchi Sea (KIMU only)

- Seward Peninsula
- Lisburne Peninsula

RUSSIA

Surveys for KIMU in Russia are needed throughout the Bering and Chukchi Seas. While gaps in surveys in Russia occur throughout Russian waters, the following areas are of particular interest based on historic information:

- Penzhina Bay
- Diomede Island
- Wrangel Island
- Commander Islands

10. PRODUCTIVITY

10.1 INLAND NESTING SITES

MAMU and KIMU exhibit varying degrees of niche overlap in Alaska (Day and Nigro 2000, Day et al. 2003). A latitudinal cline is evident, with Alaska MAMU having a shorter and later breeding season than do populations to the south. The breeding season (early May to mid-September) of MAMU in Alaska is estimated to be, on average, 64 days shorter in Alaska than in California (Hamer and Nelson 1995). There appears to be considerable interannual variation in nesting phenology (Doerr and Walsh 1994, Speckman et al. 2000, Kuletz and Kendall 1998, Kuletz 2005, McFarlane et al. 2005) suggesting local environmental influences on breeding dates (Kuletz 2005). MAMU are solitary nesters that generally nest in mossy limbs of old growth conifers but also nest on the ground or on mossy cliff ledges (Nelson 1997, McShane et al. 2004, Willson et al. 2010, Barbaree et al. 2014). MAMU have high nest area fidelity and depend on cryptic nest sites to avoid predation (McShane et al. 2004). MAMU lay and incubate a single egg from mid-May to early June (McShane et al. 2004). Adults exchange incubation duties every 24 hours at dawn. Chicks are present from mid-June to mid-September and fledglings are present from mid-July to early October. Both parents feed chicks; chicks typically receive one to eight feedings per day with 66% of meals being delivered early morning before sunrise and the rest at dusk, with periodic feedings during the day (Nelson 1997). Chicks may fledge 27 to 40 days after hatching. Fledged juveniles do not appear to receive any parental care and generally are observed as solitary individuals, patchily distributed on marine waters (but see Kuletz and Piatt 1999).

MAMU fly inland at all time of the year, except during the fall flightless molt (O'Donnell et al. 1995, G. van Vliet, personal communication). Nesting murrelets are generally silent near their nesting sites (e.g., Nelson and Peck 1995), but social calling and activity by nesting and non-nesting birds occurs over nest sites throughout the breeding season. Peak inland activity and vocalizations occur during July, when both breeders and non-breeders are thought to be present (Nelson 1997).

KIMU are solitary nesters, and nest sites are generally located in coastal mountains of Alaska and the eastern coast of Russia (Burkett et al. 2009). KIMU are spatially associated with glaciers across much of their range (van Vliet 1993, Kuletz et al. 2003) although they are found in non-glacial habitats in the Aleutian Islands (Piatt et al. 2007, Kenney and Kaler 2013) and Asia (Artukhin et al. 2011). KIMU nests tend to be found on very sparsely vegetated, steep slopes, of high-elevation (>400 m) and often north-facing scree slopes (Day et al. 1999, Burkett et al. 2009, Lawonn 2012). Lawonn (2012) concluded that the high dispersion of active nests and sparse vegetation in areas near nest sites indicates that nest site selection by KIMU on Kodiak Island reflects a strategy to avoid encounters with nest predators. KIMU appear to exhibit nest site and nest area fidelity (Kaler et al. 2010, Lawonn 2012). Kenney and Kaler (2013) suggest that locating non-active KIMU nests will expedite the process of finding active nests (breeding habitat) and using vegetative cues to locate these nests will help to identify nesting habitat to determine reproductive success and nest-site selection.

In south-coastal Alaska, KIMU move into known breeding areas March–April and densities peak in late June and early July (USFWS 2013a). KIMU will lay a single egg; incubation lasts approximately 30 days and both parents participate in the incubation and rearing (Burkett et al. 2009, Lawonn 2012). Adults exchanged incubation duties at the nest every 24 or 48 h, almost exclusively during early morning twilight (Lawonn 2012). Eggs hatch mid-June through July and chicks are fed fish for 21 to 40 days (Burkett et al. 2009, Day et al. 1999, Kaler et al. 2010) after hatching and fed a single fish at a rate of 1–12 times per day (Burkett et al. 2009) with an average of 3.9 to 4.8 fish per day, depending on the year (Lawonn 2012). On Kodiak Island, Pacific sand lance (*Ammodytes hexapterus*), a high-lipid forage fish, accounted for about 92% of all identifiable chick meal deliveries. Parental visits to the nest during chick-rearing occurred primarily after sunrise in the early to mid-morning hours, and during evening twilight (Lawonn 2012). Kaler et al. (2009) found reproductive potential was low because of a one-egg clutch size, a long nesting cycle, slow rates of growth and fledging at a relatively low mass.

Burkett et al. (2009) found adult KIMU flew inland throughout the breeding season (May-Aug) and vocalized while flying. Peak KIMU activity, including flight and call behavior, occurred in July. KIMU continued to fly inland and interact through their flight and calling behavior after all known nests in the vicinity failed. Once fledged, juveniles spend most of their time in the marine environment.

Predation risk and food availability are thought to be two of the most important ecological factors affecting chick development in alcids (Sealy 1973, Ydenberg

1989). The nesting areas of BRMU in general are at high-risk relative to the ocean environment (Lawonn 2012) in contrast to other alcids, which are thought to have relatively “safe” nest sites (Ydenberg 1989). The presence of terrestrial predators that can readily access BRMU nest sites and the crypsis characteristic of the genus suggest the importance of predation as a selective force in the evolution of the life history of BRMU species (Lawonn 2012). Cryptic KIMU nests dispersed at high elevations and MAMU nests high in trees with cover are likely an adaptation to minimize predation risk (Kaler et al. 2009, Nelson and Hamer 1995). Evidence supporting this hypothesis includes observations of high adult mortality caused by avian predators near nesting habitats (e.g., Kissling et al. 2007d) and high rates of nest depredation in both KIMU and MAMU (Nelson and Hamer 1995, Kaler et al. 2009, Lawonn 2012, Kissling and Lewis 2015). However, the potential cost of nesting in remote habitats could be reduced rates of provisioning that result in slow development of eggs and young, and long periods of exposure (Kaler et al. 2009).

Nesting success of BRMU is very low (<62%; Kaler et al. 2009, Lawonn 2012, Barbaree et al. 2014, Kissling et al. 2015), and for MAMU reproduction is almost an order of magnitude lower in contemporary murrelet populations than in historic populations (Beissinger and Peery 2007). Overall, most BRMU nest failures (>30%; >65% for MAMU) were attributed to depredation of the egg or chick by avian and mammalian predators (e.g., Nelson and Hamer 1995, Hèbert and Golightly 2006, Kaler et al. 2009, Lawonn 2012, Kissling et al. 2015). Kissling et al. (2015) suggested that low fecundity for KIMU in Icy Bay was due largely to low breeding propensity, not low nesting success. Despite some differences between BRMU in nest survival and cause of failure, sustained low recruitment is the key driving factor in BRMU population declines (e.g., USFWS 2012). Monitoring productivity at nests will be critical to for exploring the links between inland conditions (e.g., predators), ocean conditions, and changes in BRMU populations.

10.2 RECOMMENDATIONS FOR MONITORING NESTING PRODUCTIVITY

Additional broad-scale studies of demographic viability, including estimating vital rates and factors affecting them, are needed in order to quantify marine and terrestrial habitat requirements and evaluate source-sink dynamics (Kissling and Lewis 2015). Additional effort is needed, not only in monitoring current nest sites and locating new nesting areas but also in characterizing nesting habitat (e.g., elevation, slope, aspect, rock type, percent vegetation, etc.; Burkett et al. 2009, Madison et al. 2011, Lawonn 2012, Kenney and Kaler 2013). Moreover, inland research methods can measure hatching, fledgling, and reproductive success, collect samples (e.g., blood, feathers, or egg-shell fragments) for stable isotope, sex identification (Peery et al. 2004), and genetic studies, and monitor incubation, delivery of prey to chicks, and prey identification (Burkett et al. 2009). Stable isotope analyses can be used to infer variation in the diet and trophic level of murrelets. For example, breast feathers are regrown during both the pre-breeding and post-breeding molts, while secondary feathers are only replaced during the pre-basic molt (Carter and Stein 1995). Thus, brown-tipped breast feathers represent the pre-breeding diet (March to April), and both secondaries and all-white breast feathers represent the post-breeding diet (August to September; Becker et al. 2007).

Monitoring and describing BRMU inland habitat use can be conducted in a variety of ways, including radar, audio-visual surveys, autonomous acoustic recordings, telemetry, and LiDAR (Light Detection And Ranging). Radar can sample large areas and detect silently flying birds, audio-visual surveys help identify species and indicate stand occupancy, and autonomous acoustic recorders allow season-long monitoring and show seasonal and spatial trends in activity (Cragg 2013, Cragg et al. 2014). LiDAR (Light Detection And Ranging) provides a means of quantifying 3-dimensional canopy structure with variables that are ecologically relevant to MAMU nesting habitat, and which have not been as accurately quantified by other mensuration methods (Hagar et al. 2014). Because of their low cost and flexible programming, automated acoustic recorders offer an affordable way to pre-sample areas, prior to more intensive or expensive (radar) surveys (Buxton and Jones 2012, Cragg et al. 2014). Automated acoustic recorders, which can operate unattended in remote locations for weeks (Buxton and Jones 2012), offer an affordable alternative for season-long monitoring with minimal field logistics (Cragg et al. 2014). One downside of using radar alone is that it is affected by wind (radar is unreliable in winds exceeding 18 km h^{-1}; Cragg et al. 2014). Therefore Cragg et al. (2014) recommend that population monitoring and habitat studies of BRMU in Alaska should include combinations of radar, acoustic recordings, as well as audio-visual surveys. Without visual confirmation, MAMU and KIMU cannot be distinguished using combinations of radar and acoustic recordings, therefore, at-sea surveys still would be required to determine localized species proportions (Cragg et al. 2014).

Because identifying and managing nesting habitat for MAMU is difficult, Waterhouse et al. (2009) recommends low-level aerial surveying from a helicopter as a means of assessing forested landscapes for key microhabitat features such as availability of potential platforms and developed moss pads for nests, foliage cover above the nest, and accessibility that are not distinguishable on air photos, satellite images, or forest cover maps. Using an information-theoretic approach, they identified that the Resource Selection Function scores of nest patches improved as elevation decreased, slope grade increased, and the proportion of emergent and canopy trees with mossy pads increased. These findings support the potential utility of the low-level aerial survey method for identifying or confirming MAMU nesting habitat for land-management purposes (Waterhouse et al. 2009).

Several useful techniques have been used to monitor BRMU at nest sites (e.g., cameras or intensive stakeouts, Willson et al. 2010, Kissling et al. 2015) and during the breeding and post-breeding season (e.g., telemetry; Barbaree et al. 2014, Kissling et al. 2015). Kissling and Lewis (2015) used cameras to monitor KIMU nest fate with cameras set to take a photograph every minute. They did caution, however, that camera settings be of short duration (e.g., less than one minute) because cameras may fail to record depredation events, thereby erroneously concluding that the nest was abandoned. Because of BRMU, and KIMU in particular, solitary nesting habits and apparent preference for nesting in inaccessible, mountainous areas, or remote islands in the Gulf of Alaska and Aleutian Islands (Day et al. 1999, Kaler et al. 2010), re-sighting banded individuals at nesting sites (e.g., Jones et al. 2007, Morrison et al. 2011) is not feasible. Consequently, little is known about the nesting ecology of this species, including basic information on their nesting habitat preferences and breeding distribution (Kenney and Kaler 2013). Kenney and Kaler (2013) found that nest scrapes where a KIMU chick survived for at least 10–15 days contained dense mosses (*Tetraplodon mnioides*; a coprophilous moss usually found growing on fecal materials and animal remains), grasses (*Poaceae*), and a fecal ring around the perimeter of the nest scrape from chick defecation. The nutrient-rich guano enables vegetative growth in the nutrient-poor soils and the mosses and grasses growing at these old nest sites contrast with the otherwise sparsely vegetated mountain slopes and provide an excellent visual cue (Kenney and Kaler 2013). The use of vegetative cues to locate non-active nests provided an effective tool to help explain the breeding range of KIMU and identify nesting habitat. Vegetation cues could be used at other islands with alpine nesting habitat in the Aleutian Archipelago (e.g. Attu, Kiska, Atka, Unalaska and Unimak Islands) where KIMU have been observed foraging in nearshore waters (Kenney and Kaler 2013). Furthermore, the use of the vegetative search cue at non-active nest sites may be applicable in locating breeding habitat of KIMU elsewhere throughout its range (e.g. mainland Alaska and Russia; Kenney and Kaler 2013). The identification of non-active nests could provide evidence of habitat use, contribute to our current knowledge of nest site selection, and help to advance future long-term monitoring studies (Kenney and Kaler 2013).

Little is also known about KIMU nesting habits in northern Alaska even though this region constitutes a large portion of this species' range and potential nesting habitat (Felis et al. 2015). In order to estimate KIMU nest density and success, and identify factors influencing nest fate in northern Alaska, Kissling and Lewis (2015) developed a sampling design and tested field methods for locating and monitoring active murrelet nests in such a way to allow comparison of metrics across multiple study areas within the species' range. Kissling and Lewis (2015) suggest establishing line transects within a 200 m2 block size (size used to avoid inaccuracies in ecotype assignment and to space line transects within the block closer together) and have a set of criteria for eliminating a block from the sample and/or a modified design that allowed for blocks to be partially sampled. If the terrain is too dangerous to search on foot (e.g., contains glacial crevasses), they recommend radio-telemetry or radar be used. Kissling and Lewis (2015) believe that correlating KIMU incubation shift length with ocean conditions and productivity, especially if done in combination with individual murrelet movements during the breeding season would be insightful in understanding factors contributing to nest abandonment and identifying sink habitats and conditions.

The best method to characterize breeding success accurately has been the use of radio telemetry (Kissling et al. 2015). By capturing birds on the water, it ensures nests are sampled without pre-selection. Such data are vital for demographic analyses. Barbaree et al. (2014) and Kissling et al. (2015) captured MAMU and KIMU, respectively using the night lighting technique (Whitworth et al. 1997) and attaching VHF radios. With intensive aerial flights they monitored activity patterns and located nests sites. Using VHF telemetry with a multi-state mark–recapture framework, Kissling et al. (2015) presented the first-ever estimates of breeding season and annual survival of KIMU in Icy Bay. They found mean apparent annual survival across all years was 0.80 and a nonbreeding season survival probability of 0.90. Survival was lower than expected based on life-history theory and allometry, and fatality risk was greater in the breeding season compared to other parts of the year. The limitations of this study were that they were unable to track individuals with radio-telemetry beyond one breeding season because of battery life limitations of transmitters, and they had a low mean recapture probability of banded birds. Determining hatch year to after hatch year ratios of birds on the water during at-sea surveys will continue to be important as indices of productivity, however, because they are relatively easy and inexpensive. In some situations, it may be possible to calibrate the information from at-sea surveys against other, more direct measures of nesting success, but a substantial commitment of resources will be required (Day 2011).

10.2.1 COVARIATES FOR MONITORING BRMU REPRODUCTION

- Food Availability (e.g., prey abundance near nest sites, prey quality)
- Predation (avian and mammalian predators)
- Contaminates
- Climate Change
- Inclement weather

10.2.2 COVARIATES FOR BRMU HABITAT MONITORING

MAMU – TREE NESTERS

- Stand age (Old-growth trees; typically > 250 yrs)
- Average tree diameter
- Average tree height
- Distance to marine areas
- Fragmentation level
- Percent canopy closure
- Epiphyte mats on branches
- Availability of potential platform limbs
- Elevation

MAMU – GROUND NESTERS

- Elevation
- Slope (degree)
- Aspect
- Distance to coast
- Location in relation to forest

KIMU

- Elevation
- Slope (degree)
- Aspect
- Distance to coast
- Percent vegetation
- Rock size and type
- Distance from glacier

10.2.3 PRIORITIES FOR INLAND MONITORING AND RESEARCH

1. Capture MAMU and KIMU at sea and attach VHF or satellite transmitters to monitor activity patterns and locate nest sites.
2. Continue to monitor current nest sites and locate new nesting areas while simultaneously characterizing nesting habitat (e.g., elevation, slope, aspect, rock type, percent vegetation, distance to coast, etc.).
3. Establish line transects within a block to estimate KIMU nest density and success and allow comparison of metrics across multiple study areas.
4. Use automatic acoustic recorders to pre-sample areas.
5. Use a combination of radar, automatic acoustic recorders, and audio-visual surveys to maximize population monitoring and habitat studies.
6. Use cameras to monitor nests to identify prey, and monitor prey delivery to chicks and to better define avian predation and nest depredation.
7. Measure hatching, fledgling, and reproductive success, collect samples (e.g., blood, feathers, or egg-shell fragments) for stable isotope (infer variation in

diet and trophic level), sex identification, and genetic studies, and monitor incubation, delivery of prey to chicks, and prey identification.

10.3 AT-SEA JUVENILE SURVEYS

Late summer counts of MAMU juveniles at sea are used as an index of reproductive success, but little is known about juvenile dispersal or habitat use (Kuletz and Piatt 1999). Counts of recently fledged MAMU juveniles at sea are usually reported as a ratio of juveniles to adults counted concurrently on the water during the latter part of the breeding cycle (Andersen and Beissinger 1995, Ralph and Long 1995, Kuletz and Kendall 1998, Lougheed 1999, Lougheed et al. 2002). There are issues with using HY:AHY ratios as an indication of MAMU (and likely KIMU) productivity including post-breeding migration of adults and the number of years required to detect significant (>50%) changes in productivity (>5 surveys per year for >10 years for 80% power; Kuletz and Kendall 1998). Despite these issues, if studies are designed to account for potential variation (e.g., seasonal changes in abundance, juvenile habitat use), they can be a useful tool for tracking population productivity.

Juvenile murrelets may at times congregate in “nursery areas” near shore or in extensive kelp beds (Sealy 1975, Beissinger 1995, Strachan et al. 1995, Strong et al. 1995, Kuletz and Piatt 1999). The only described example of nursery areas in Alaska is from Kachemak Bay (Kuletz and Piatt 1999). Within the “nursery” itself, juveniles outnumbered after-hatch-year birds in a ratio of 1.3 to 1. This shallow water, semi-protected area provided protection from prevailing southwesterly winds, occurred in an area of locally productive waters, and provided large *Nereocystis* kelp beds, not common elsewhere in the bay (Kuletz and Piatt 1999). In addition, the kelp made it difficult to see the juveniles, and so may have provided protection from avian predators such as gulls and Bald Eagles (*Haliaeetus leucocephalus*), which were common in this area. *Nereocystis* kelp beds may be the primary defining characteristic of the nursery and if juveniles gather in specific habitats such as this after fledging, productivity surveys could be improved by identifying their location and time of use (Kuletz and Piatt 1999). Clearly, additional information is needed to locate and define not only MAMU juvenile habitat areas but to define what juvenile KIMU habitats would include.

11. THREATS

Threats to BRMU include food limitation (Piatt et al. 2007, Day 2011), loss of nesting habitat, low productivity (Day and Nigro 2004, Piatt et al. 2007, Kaler et al. 2009, Lawonn et al. 2012), and poor fledging success (Kaler et al. 2009), avian predation and nest depredation (Nelson and Hamer 1995, Piatt et al. 2007, Kaler et al. 2009, Lawonn 2012, Kissling and Lewis 2015), by-catch in commercial gillnet fisheries (van Vliet and McAllister 1994, Kuletz et al. 2003, Agness et al. 2008), petroleum contamination (Carter and Kuletz 1995, Kuletz 1996, Piatt and Naslund 1995, Nelson 1997, Gaston and Jones 1998, Burger 2002), climate change (Piatt and Anderson 1996, Agler et al. 1999, Anderson and Piatt 1999), and deglaciation (KIMU; Kuletz et al. 2003), and disturbance by vessel traffic (Kuletz 1994, Piatt and Naslund 1995, Kuletz et al. 2003, Piatt et al. 2007, Agness et al. 2008, 2013). Moreover, marine regime shifts and glacial retreat may be changing forage fish availability. Details of threats are listed below.

10.1 FOOD LIMITATION

Changes in oceanic conditions in the Gulf of Alaska since the 1970s and the commercial fishing industry may have affected forage fish availability (Piatt et al. 2007). BRMU often experience difficult foraging conditions, especially during the summer, making them vulnerable to factors that increase the variability of prey in space and time (Day 2011). Reduced diversity and abundance of high energy forage fishes may reduce the ability of BRMU to feed young during nesting season and further lower survivorship and recruitment. Studies suggest not all foraging habitats for BRMU during the breeding season should be viewed as equal as particular marine hotspots have been identified and should be monitored as priority areas for conservation during the breeding season (Barbaree et al. 2015).

10.2 LOSS OF NESTING HABITAT

Loss of old-growth forests from timber harvest, fragmentation and edge effects, increased predation, human disturbance, wildfire, and insects all contribute to loss of MAMU nesting habitat (Burger 2002, Burger and Waterhouse 2009, Piatt et al. 2007). Multiple radar studies have shown that when breeding habitat is reduced by logging, the birds do not simply relocate to remaining forest patches in higher densities, but suffer a population decline (Burger 2001). KIMU are solitary nesters, and nest sites are generally located on inaccessible mountain slopes, volcanoes or remote islands in the Gulf of Alaska and Aleutian Archipelago (Day et al. 1999, Kaler et al. 2010). Consequently, little is known about the nesting ecology of this species (Kenney and Kaler 2013). Although an increasing number of KIMU nests have been located in recent years (Kaler et al. 2009, Lawonn 2012. Kenney and Kaler 2013, Kissling and Lewis 2015), clearly greater effort should be made to increase our knowledge of KIMU nesting habitat and potential threats to this habitat.

10.3 LOW REPRODUCTIVE SUCCESS

Because BRMU are solitary nesters with secretive breeding habits and remote, often inaccessible nest sites, attempting to measure reproductive success can be challenging. There is a tendency for the frequency of MAMU nest failure to increase from incubation to chick-rearing (Piatt et al. 2007). In Prince William Sound, MAMU productivity (as gauged by density of recently fledged juveniles at sea) has been studied in relation to the abundance of prey such as herring and sand lance (Kuletz et al. 1995, Kuletz and Kendall 1998, Kuletz 2005). Kuletz (2005) found the highest MAMU productivity occurred when local fish abundance was highest and suggested the association may be non-linear, with a threshold level of local fish abundance required before a consistent and measureable response in murrelet productivity would occur. There is scattered but increasing evidence that low reproductive output may be limiting KIMU population growth (Day and Nigro 2004, Kaler et al. 2009, Lawonn et al. 2012). KIMU breeding in the western Aleutians have been found to have low reproductive success, with losses during the incubation period primarily due to avian predators (e.g., Glaucous-winged gulls*, Larus glaucescens*) locating unattended eggs, and chick mortality during the nestling period largely due to inclement weather (Kaler et al. 2008, Kaler et al. 2009).

10.4 PREDATION/DEPREDATION

The most frequently reported cause of MAMU nest failure was depredation of the egg or chick by a known or presumed avian predator (Piatt et al. 2007). Nelson and Hamer (1995) proposed that MAMU become more vulnerable to predators as a result of habitat fragmentation and the creation of forest “edge” habitat through clear-cutting. They suggest this as an explanation for lower nesting success in sites located closer to forest edges. MAMU has been found to suffer increased corvid predation and disturbance at forest edges adjacent to recently cleared areas (Burger 2002, Malt and Lank 2007, 2009). Sharp-shined Hawks (*Accipiter striatus*) have killed adult MAMU near the nest site in Prince William Sound (Marks and Naslund 1994) and Steller’s Jays (*Cyanocitta stelleri*) were likely predators at several nests on Naked Island, Prince William Sound (Naslund et al. 1995). The remains of MAMU also have been collected in the nests of Northern Goshawks (*Accipiter gentilis*; Burger 2002) and Peregrine Falcons (*Falco peregrinus*; Nelson and Hamer 1995) in Alaska. Predation of KIMU nests (Lawonn 2012, Kissling and Lewis 2015) may play a significant role in understanding source–sink dynamics of KIMU. On Agattu Island, Glaucous-winged Gulls (sustained by refuse from fish processing facilities in the Aleutian Islands; Gibson and Byrd 2007) and Common Ravens (*Corvus corax*) are potential predators of KIMU eggs and chicks, whereas Peregrine Falcons and Snowy Owls (*Nyctea scandiaca*) may prey upon adult KIMU (Kaler et al. 2009). All nests monitored during a study in Northwestern Alaska failed at the egg stage (Kissling and Lewis 2015). One nest failed definitively due to fox predation, and Kissling and Lewis (2015) found circumstantial evidence that predators may have contributed to the failure of the other two nests.

10.5 FISHERIES BYCATCH

BRMU mortality in gill-net fisheries has been documented in Prince William Sound, Yakutat Bay, near Kodiak Island, Alaska (Wynne et al. 1992, Carter et al. 1995, Manly et al. 2007) as well as the nearshore gillnet fishery in Russia (Artukhin et al. 2011) and Japanese salmon drift nests (Artukhin et al. 2010). Near shore BRMU by-catch comprised between 11% and 70% of seabird mortality from gillnets (Wynne et al. 1992, Carter et al. 1995, Manly et al. 2007). KIMU have been caught in commercial gillnet fisheries in Prince William Sound at a disproportionately higher number than MAMU relative to their respective population sizes at the time (Wynne et al. 1992, Agler et al. 1998, Day et al. 1999). Though very uncommon, KIMU represented 5% during 1990 and 30% during 1991 of murrelet by-catch in Prince William Sound gillnets (Wynne et al. 1991, 1992).

10.6 MARINE POLLUTION

Mortality of BRMU due to oil pollution is one of the major threats to murrelet populations. Large oil-spills and chronic oil pollution can cause considerable mortality (Carter and Kuletz 1995, Kuletz 1996, Piatt and Naslund 1995, Nelson 1997, Gaston and Jones 1998, Burger 2002), and although it has been occurring for several decades, it has been poorly documented (Carter and Kuletz 1995). The 1989 *Exxon Valdez* oil spill released nearly 11 million gallons of crude oil into Prince William Sound, caused the largest single mortality of murrelets (about 8,400 birds) in the world and contributed to the decline in BRMU populations in Prince William Sound (Kuletz 1996). In the Aleutians, over 2,700 ship voyages occur each year adjacent to KIMU habitat and are made by vessels that have no State oil spill contingency plans and no State certificate of financial responsibility (NRPGCII 2005). This vessel traffic includes as many as 1,600 voyages by container ships with a typical fuel capacity of 1.8 million gallons of persistent oil, and as many as 30-40 voyages by tank ships that may carry as much as 800 million gallons of oil as cargo and fuel (NRPGCII 2005). From 1995 through August 2005, at least 1,923 small fuel spills from vessels resulted in the release of more than 271,700 gallons of petroleum hydrocarbons in Alaska waters (Alaska Department of Environmental Conservation, Anchorage, unpublished data, 2005). Ninety percent of those spills occurred in marine habitat within the range of KIMU (U.S. Fish and Wildlife Service, unpublished data). In northeastern Asia, a potential danger for KIMU is pending oil and gas development on the shelf of northeastern Sakhalin, where KIMU migration apparently takes place, as well as plans to drill for gas on the western Kamchatka shelf (Gazprom 2010), which borders the KIMU breeding range (Artukhin et al. 2011). Efforts must be expanded to better document mortalities during large and small spills, develop better baseline data to assess impacts, and reduce oil pollution (Carter and Kuletz 1995).

The effects of marine debris and contaminants of BRMU populations are largely unknown. Collecting data on the effects of this marine pollution on BRMU populations should be considered and easily added to studies involving at-sea surveys and captures of BRMU.

10.7 CLIMATE CHANGE/GLACIAL RECESSION

There have been strong links made between KIMU's apparently steep decline in the late 20th century and areas of glacial recession (possibly as a result of climate change; Kuletz et al. 2003, van Pelt 2005, Piatt et al. 2011). Other factors that could conceivably act across a sufficiently large geographical scale include climate-driven changes in marine food webs (Piatt and Anderson 1996, Agler et al. 1999, Anderson and Piatt 1999), decreases in the quality of foraging habitats or efficiency of prey capture due to glacial recession (Kuletz et al. 2003), loss of nesting habitat due to glacial recession and accompanying primary plant succession (USFWS 2011), and habitat changes in the overwintering range (Mueter and Litzow 2008). Because KIMU exhibit a strong association to glacially-influenced marine habitats (Kendall and Agler 1998, Kuletz et al. 2003a, Robards et al. 2003, Van Pelt and Piatt 2003, 2005; Agness 2006), their preference for areas near stable or advancing tidewater glaciers may be related to the diversity and abundance of high energy forage fishes, such as Pacific capelin (*Mallotus villosus*) and Pacific sand lance (Piatt et al. 1994, Day et al. 2000, Agness 2006, Kissling 2007b). The distribution and availability of these high energy forage fishes may change as glaciers recede and the physical parameters of marine habitats are modified.

10.8 DISTURBANCE

The increase in vessel traffic in remote Alaskan waters and its impact on BRMU has become a concern (Kuletz 1994, Piatt and Naslund 1995, Kuletz et al. 2003, Piatt et al. 2007, Agness et al. 2008, 2013). Tidewater, glacial habitats have become a popular destination for tour and recreational vessels (Day et al. 1999, Murphy et al. 2004) and vessel activity is increasing in the glaciated fjords of Glacier Bay, Prince William Sound, Kenai Fjords, Yakutat Bay, and lower Cook Inlet/Kachemak Bay, Alaska (Murphy et al. 2004, Jansen et al. 2006, Hoover-Miller et al. 2011). Furthermore, recreational boating in northern Prince William Sound is projected to increase dramatically over the next 15 years as a result of better access to harbors (Murphy et al. 2004). This increased traffic increases the level of disturbance in BRMU foraging habitats. In Glacier Bay, vessel passage caused a 30-fold increase (from 0%-30%) in flight behavior of KIMU (Agness et al. 2008). Breeding and non-breeding birds were both susceptible to fitness consequences (e.g. reduced reproductive success and survival) resulting from the energy cost (Agness et al. 2013). In Prince William Sound, KIMU were at least temporarily displaced by boat traffic and when boats were present, fewer birds made foraging dives and more birds flew off the water compared to undisturbed focal groups (Kuletz et al. 2003). Moreover, large and fast-moving vessels caused the greatest disturbance to KIMU (Agness et al. 2013) and also had a significant effect on the reactions of MAMU (Bellefleur et al. 2005). Overall, disturbance can impact foraging, increase flushing and diving behaviors, increase energetic demands, and increase exposure to predators. Reducing ship speed or giving BRMU a buffer zone (Hentze 2006) may help reduce the effects of vessel disturbance.

Little is known about the impacts of light pollution from ships and coastal installations on BRMU populations. MAMU are known to leave protected waters at night for open bays and straits, potentially to avoid predation from coastal predators (e.g., owls, eagles; Haynes et al. 2010). These movements may put them in close proximity to night fishing fleets, potentially impacting energetics and survival. Research is needed to explore the potential impacts of light pollution on BRMU populations.

11. RESEARCH

Included herein is a list of research (not in order of priority) needed to help develop a detailed monitoring manual for BRMU in Alaska. This list is based on input from numerous BRMU scientists and managers, including personal communications and publications (e.g., Kissling 2009).

- Conduct analyses of existing population data to determine sample sizes, sampling units and possible sources of error to develop an effective monitoring manual.
- Describe foraging distribution, habitat, demography, and behavior in relation to prey abundance. This may affect location of emphasis area surveys or conclusions about population trends.
- Develop comparative studies of breeding and foraging ecology across BRMU range in Alaska to determine if emphasis survey areas cover the range of ecological conditions.
- Capture and mark BRMU in a variety of areas to look at nesting chronology, nest success, and propensity for renesting to determine the best timing of surveys with respect to region and habitat type.
- Develop reproductive performance models for BRMU throughout key areas in Alaska to determine local and regional effects on population trends.
- Track diet composition and changes using stable isotopes to determine effects of ocean change on BRMU populations.

- Develop a nest monitoring protocol to assess productivity among areas and quantify reasons for nesting success and failure.
- Monitor nesting habitat characteristics, and nest predators presence and abundance, to determine key areas to monitor for population changes.
- Identify spatial and temporal overlap of gillnet fisheries and BRMU to infer "hotspots" for potential bycatch issues. Monitoring in these areas will be important for tracking causes of population change.
- Identify spatial and temporal overlap of high vessel-traffic areas and BRMU distribution to infer "hotspots" for vessel disturbance and potential oiling. Monitoring in these areas will be important for tracking causes of population change.
- Develop technology (e.g., satellite telemetry) to better access nesting success and describe habitat use both inland and at-sea.
- Determine gaps in BRMU distribution to decrease the numbers of areas required to survey during at-sea population inventories.

12. NEXT STEPS

This monitoring plan provides a framework for future development of a detailed monitoring manual. Following review of this framework, we recommend that USFWS and NPS convene a team of experts in seabird monitoring, statistics, and local seabird populations to synthesize data, conduct modeling exercises, and propose a comprehensive monitoring manual for BRMU in Alaska. Detailed data analyses and review will be needed to determine sample units and sizes within each of the ecoregions. In addition, it was decided in the development of this monitoring plan's goals that new data collection and analysis of existing population data were needed before statistical goals could be set for a monitoring program (*i.e.,* how large a change to detect, over what period of time, with what level of significance and power).

REFERENCES

ABC (American Bird Conservancy). 2007. http://www.abcbirds.org/abcprograms/science/watchlist/

Agler, B.A., S.J. Kendall, P.E. Seiser, and D.B. Irons. 1995. Estimates of arine bird and sea otter abundance in lower Cook Inlet, Alaska, during summer 1993 and winter 1994. Minerals Management Service, Anchorage, AK. Report OCS Study MMS 94-0063. 124pp.

Agler, B.A., S.J. Kendall, and D.B. Irons. 1998. Abundance and distribution of Marbled and Kittlitz's Murrelets in southcentral and southeast Alaska. Condor 100:254-265.

Agler, B.A., S.J. Kendall, D.B. Irons, and S.P. Klosiewski. 1999. Declines in marine bird populations in Prince William Sound, Alaska coincident with a climatic regime shift: Waterbirds 22:98-103.

Agness, A.M. 2006. Effects and impacts of vessel activity on the Kittlitz's Murrelet in Glacier Bay, Alaska. M.Sc. thesis, University of Washington, Seattle.

Agness, A.M., J.F. Piatt, J.C. Ha, and G.R. VanBlaricom. 2008. Effects of vessel activity on the near-shore ecology of Kittlitz's Murrelets (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. Auk 125:346–353.

Agness, A.M., K.M. Marshall, J.F. Piatt, J.C. Ha, and G.R. VanBlaricom. 2013. Energy cost of vessel disturbance to Kittlitz's Murrelets *Brachyramphus brevirostris*. Marine Ornithology 41:13–21.

Allyn, A.J. 2012. Population size, habitat use and diet of Kittlitz's Murrelets in Prince William Sound, Alaska. M.Sc. thesis. University of Massachusetts, Amherst. 159pp.

Andersen, H.L. and S.R. Beissinger. 1995. Preliminary observations on juvenile:adult ratios of Marbled Murrelets in Auke Bay, Southeast Alaska. Northwestern Naturalist 76:79-81.

Anderson, P.J. and J.F. Piatt. 1999. Trophic reorganization in the Gulf of Alaska following ocean climate regime shift: Marine Ecology Progress Series 189:117-123.

Andreev, A.V. and T.I. Van Pelt. 2007. The distribution and number of seabirds in coastal waters of the Shelikhov Bay (the Sea of Okhotsk). Bulletin of the North-East Scientific Center, Russian Academy of Sciences Far East Branch 2:4-17. [In Russian]

Arimitsu, M.L., J.F. Piatt, M.D. Romano, E.N. Madison, and J.S. Conaway. 2010. Kittlitz's and Marbled Murrelets in Kenai Fjords National Park, south-central Alaska: at-sea distribution, abundance, and foraging habitat, 2006–08. Unpublished report. U.S. Geological Survey Open-File Report 2010-1181. 80pp.

Arimitsu, M., J.F. Piatt, M.D. Romano, and T.I. Van Pelt. 2011. Status and distribution of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Kenai Fjords, Alaska. Marine Ornithology 39:13–22.

Artukhin, Y.B., V.N. Burkanov, and V.S. Nikulin. 2010. Accidental by-catch of marine birds and mammals in the salmon gillnet fishery in the northwestern Pacific Ocean. Moscow: Skorost' Tsveta. [In Russian]

Artukhin, Y.B., P.S. Vyatkin, A.V. Andreev, N.B. Konyukhov, and T.I. van Pelt. 2011. Status of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Russia. Marine Ornithology 39:23–33.

Bailey, E.P. 1976. Distribution and abundance of marine birds and mammals along the south side of the Kenai Peninsula, Alaska. Murrelet 58:58–72.

Bailey, E. and B. Rice. 1989. Assessment of injury to seabird and marine mammal populations along the southeast coast of the Kenai Peninsula, Alaska, from the *Exxon Valde*z oil spill during summer of 1989. Unpublished report prepared by U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Homer, AK, and Kenai Fjords National Park, Seward, AK. 38pp. + appendices.

Barbaree, B.A. 2011. Nesting season ecology of Marbled Murrelets at a remote mainland fjord in southeast Alaska. M.S. thesis, Corvallis, OR: Oregon State University.

Barbaree, B.A., S.K. Nelson, B.D. Dugger, D.D. Roby, H.R. Carter, D.L. Whitworth, and S.H. Newman. 2014. Nesting ecology of Marbled Murrelets at a remote mainland fjord in Southeast Alaska. Condor 116:173-184.

Barbaree, B.A., S.K. Nelson, and B.D. Dugger. 2015. Marine space use by Marbled Murrelets *Brachyramphus marmoratus* at a mainland fjord system in southeast Alaska. Marine Ornithology 43:1–10.

Becker, B.H., M.Z. Peery, and S.R. Beissinger. 2007. Ocean climate and prey availability affect the trophic level and reproductive success of the Marbled Murrelet, an endangered seabird. Marine Ecology Progress Series 329:267–279.

Beissinger, S.R. 1995. Population trends of the Marbled Murrelet projected from demographic analyses. Pages 385-394 *In* Ralph C.J., G.L. Hunt Jr., M.G. Raphael, and J.F. Piatt, editors. Ecology and conservation of the Marbled Murrelet. USDA Forest Service, General Technical Report PSW-GTR-152.

Beissinger, S.R. and M.Z. Peery. 2007. Reconstructing the historic demography of an endangered seabird. Ecology 88:296-305.

Bellefleur, D., D. Edwards, B. Hansen, and A.E. Burger, A.E. 2005. Marine distribution and abundance of Marbled Murrelets in Pacific Rim National Park Reserve of Canada, 1995-2004: Ucluelet, British Columbia, Parks Canada, Pacific Rim National Park Reserve.

Bentivoglio, N., J. Baldwin, D. Evans Mack, T. Max, S. Miller, S.K. Nelson, C.J. Ralph, M. Raphael, C. Strong, C. Thompson, K. Ostrom, and R. Wilk. 2002. Northwest Forest Plan Marbled Murrelet effectiveness monitoring: Portland, Oregon, U.S. Fish and Wildlife Service, 2000 Annual Report, 72pp.

Bertram, D.F., A.E. Burger, D. Lindsay, A. Cober, and A. Harfenist. 2007. Marbled Murrelet population estimation and trend monitoring in BC. Pacific Seabird Group 34th Annual Meeting, Asilomar, CA.

BirdLife International 2012. *Brachyramphus marmoratus*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>.

Birt, T.P., D. MacKinnin, J.F. Piatt, and V.L. Friesen. 2011. Genetic differentiation of the Kittlitz's Murrelet Brachyramphus brevirostris in the Aleutian Islands and Gulf of Alaska. Marine Ornithology 39: 45–51

Bloxton, T.D. and M.G. Raphael. 2008. Breeding ecology of the Marbled Murrelet in Washington State: Five year project summary (2004-2008). Unpublished report, USDA Forest Service, Pacific Northwest Research Station, Olympia, Washington. 41pp.

Bradley, R.W. and F. Cooke. 2001. Cliff and deciduous tree nests of Marbled Murrelets in southwestern British Columbia. Northwestern Naturalist 82:52-57.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Oxford, England, Oxford University Press.

Burger, A.E. 1995. Marine distribution, abundance, and habitats of Marbled Murrelets in British Columbia. Pages 295-312 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds., Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Burger, A.E. 2001. Using radar to estimate populations and assess habitat associations of Marbled Murrelets. Journal of Wildlife Management 65:696-715.

Burger, A.E. 2002. Conservation assessment of Marbled Murrelets in British Columbia. Part A: Review of the biology, populations, habitat associations, and conservation: Delta, British Columbia, CWS, Pacific and Yukon Region, Technical Report 387, 194pp.

Burger, A.E. and F.L. Waterhouse. 2009. Relationships between habitat area, habitat quality, and populations of nesting Marbled Murrelets. BC Journal of Ecosystems and Management 10:101–112. www.forrex.org/publications/jem/ISS50/vol10_no1_art10.pdf

Burkett, E.M. 1995. Marbled Murrelet food habits and prey ecology. Pages 223-246 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds., Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Burkett, E.M., J.F. Piatt, M.J. Lawonn, and W.H. Pyle. 2009. Breeding ecology and behavior of Kittlitz's Murrelet in Kodiak National Wildlife Refuge, Alaska, 2008. Anchorage, USGS Alaska Science Center, 2008 Annual Report to U.S. Fish and Wildlife Service, 96pp.

Burnham, K.P. and D.R. Anderson.2002. Model selection and multimodel inference: A practical information-theoretic approach (2nd ed.), Springer-Verlag, ISBN 0-387-95364-7.

Buxton, R.T. and I.L. Jones. 2012. Measuring nocturnal seabird activity and status using acoustic recording devices: applications for island restoration. Journal of Field Ornithology 83:47-60.

Carter, H.R. 1984. At-sea biology of the Marbled Murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. M.Sc. Thesis: Winnipeg, University of Manitoba.

Carter, H.R. and J.L. Stein. 1995. Molts and plumages in the annual cycle of the Marbled Murrelet. Pages 99-112 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Carter, H.R. and K.J. Kuletz. 1995. Mortality of Marbled Murrelets due to oil pollution in North America. Pages 261-269 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Carter H.R., M.L.C. McAllister, and M.E.P. Isleib. 1995. Mortality of Marbled Murrelets in gill nets in North America. Pages 271-284 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Carter, H.R., S.K. Nelson, and N. Oka. 2011. Historical and recent occurrences of Kittlitz’s Murrelets in southeastern Russia and Japan. Journal of Yamashina Institute of Ornithology 43:1–21.

Carter, H.R. and S.G. Sealy. 2005. Who solved the mystery of the Marbled Murrelet? Northwestern Naturalist 86:2-11.

Congdon, B.C., J.F. Piatt, K. Martin, and V.L. Friesen. 2000. Mechanisms of population differentiation in Marbled Murrelets: Historical versus contemporary processes. Evolution 54:974-986.

Cragg, J.L. 2013. *Brachyramphus murrelets* at high latitude: behavioural patterns and new methods for population monitoring. M.Sc. thesis, Department of Biology. Victoria, BC, University of Victoria.

Cragg. J.L., A.E. Burger, and J.F. Piatt. 2014. Techniques for monitoring *Brachyramphus* murrelets in Alaska: a comparison of radar, autonomous acoustic recording and audio-visual surveys. Unpublished Report, Victoria, BC: University of Victoria.

Day, R.H. 1995. New information on Kittlitz's Murrelet nests. Condor 97:271-273.

Day, R.H. 2011. Evaluating population trends of Kittlitz’s Murrelet in Alaska. Report prepared for the Alaska Department of Fish and Game, Juneau, AK, USA by ABR, Inc. Environmental Research & Services, Fairbanks, AK, USA. 68pp.

Day, R.H., A.E. Gall, A.K. Prichard, G.J. Divoky, and N.A. Rojek. 2011. The status and distribution of Kittlitz’s Murrelet *Brachyramphus brevirostris* in northern Alaska. Marine Ornithology 39:53–63.

Day, R.H., K.J. Kuletz, and D.A. Nigro. 1999. Kittlitz’s Murrelet (*Brachyramphus brevirostris*). *In* Poole, A., and Gill, F., eds. The Birds of North America, No. 435. Philadelphia and Washington, DC: Academy of Natural Sciences and American Ornithologists’ Union, 28pp.

Day, R.H. and D.A. Nigro. 1999. Status and ecology of Kittlitz's Murrelet in Prince William Sound, 1996–1998. Unpublished *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 98142), prepared by ABR, Inc., Fairbanks, AK. 207pp.

Day, R.H. and D.A. Nigro. 2000. Feeding ecology of Kittlitz’s and Marbled Murrelets in Prince William Sound, Alaska. Waterbirds 23:1–4.

Day, R.H. and D.A. Nigro. 2004. Is the Kittlitz’s Murrelet exhibiting reproductive problems in Prince William Sound, Alaska? Waterbirds 27:89–95.

Day, R.H., D.A. Nigro, and A.K. Prichard. 2000. At-sea habitat use by the Kittlitz’s Murrelet (*Brachyramphus brevirostris*) in nearshore waters of Prince William Sound, Alaska. Marine Ornithology 28:105–114.

Day, R.H., K.L. Oakley, and D.R. Barnard. 1983. Nest sites and eggs of Kittlitz's and Marbled Murrelets. Condor 85:265-273.

Day, R.H., A.K. Prichard, and D.A. Nigro. 2003. Ecological specialization and overlap of *Brachyramphus* murrelets in Prince William Sound, Alaska. The Auk 120:680–699.

Dechesne, S.B.C. 1998. Vocalizations of the Marbled Murrelet (*Brachyramphus marmoratus*): Vocal repertoire and individuality. M.S. Thesis, University of Victoria, Victoria, British Columbia. 134pp.

DeGange, A.R. 1996. Conservation assessment for the Marbled Murrelet in southeast Alaska: Portland, Oregon, U.S. Forest Service, Pacific Northwest Research Station, General Technical Report 388. 72pp.

Doerr, J.G. and P.J. Walsh. 1994. Seasonal activity patterns of Marbled Murrelets at an inland site on Mitkof Island, southeastern Alaska: Alaska, U.S. Forest Service, Petersburg Ranger District, Report on File. 8 p.

Drew, G.S. and J.F. Piatt. 2005. North Pacific Pelagic Seabird Database (NPPSD): compiling datasets and creating an archive, accessible database, and pelagic seabird atlas [unpublished report]. Anchorage, AK: US Geological Survey.

Drew, G. S. and J. F. Piatt. 2008. Using geographic information systems to compare non-uniform marine bird surveys: Detecting the decline of Kittlitz's Murrelet (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. The Auk 125:178-182.

Drew, G.S., S.G. Speckman, J.F. Piatt, J.M. Burgos, and J.L. Bodkin. 2008. Survey design considerations for monitoring marine predator populations in Glacier Bay, Alaska: results and post-hoc analyses of surveys conducted in 1999–

2003. Unpublished report. U.S. Geological Survey Administrative Report. 135pp.

Evans Mack, D., W.P. Ritchie, S.K. Nelson, E. Kuo-Harrison, P. Harrison, and T.E. Hamer. 2003. Methods for surveying Marbled Murrelets in forests: a revised protocol for land management and research. Pacific Seabird Group Technical Publication Number 2. Available from http://www.pacificseabirdgroup.org. 81pp.

Falxa, G., J. Baldwin, M. Lance, S.L. Miller, S.F. Pearson, M.G. Raphael, and C. Strong. 2008. Marbled Murrelet population size and trend in the Northwest Forest Plan area. Abstracts, 35th Annual Meeting of the Pacific Seabird Group, Blaine, Washington, 27 Feb - 2 Mar 2008, p. 64. Little River, CA, USA, Pacific Seabird Group.

Felis, J.J., M.L. Kissling, R.S.A. Kaler, M.J. Lawonn, and L. Kenney. 2015. Identifying Kittlitz's murrelet nest habitat for North America. M.Sc. thesis. Available at U.S. Geological Survey, Santa Cruz, California 95060, USA.

Fischer, J.B. and W.W. Larned. 2004. Summer distribution of marine birds in the Western Beaufort Sea. Arctic 57:143-159.

Ford, C. and M. Brown. 1995. Unusual Marbled Murrelet nest. Wilson Bulletin 107:178-179.

Friesen V.L., Baker A.J., Piatt J.F. 1996. Phylogenetic relationships within the Alcidae (Charadriiformes: Aves) inferred from total molecular evidence. Molecular Biology of Evolution 13:359-367.

Friesen, V.L., T.P. Birt, J.F. Piatt, R.T. Golightly, S.H. Newman, P.N. Hèbert, B.C. Congdon, and G. Gissing. 2005. Population genetic structure and conservation of the Marbled Murrelet (*Brachyramphus marmoratus*). Conservation Genetics 6:607-614.

Gaston, A.J. and I.L. Jones. 1998. The auks. Oxford University Press, New York. 349pp.

GAZPROM 2010. Eastern Gas Program. [Available online at: http://www.gazprom.com/production/projects/east-program; accessed on

29 April 2011]

Gibson, D.D. and G.V. Byrd. 2007. Birds of the Aleutian Islands, Alaska. Lancaster, PA: Nuttall Ornithological Club & American Ornithologist's Union.

Gould, P.J. and D.J. Forsell. 1989. Techniques for shipboard surveys of marine birds: Washington, D.C., U.S. Fish and Wildlife Service Technical Report 25, 22pp.

Hagar, J.C., B.N.I. Eskelson, P.K. Haggerty, S.K. Nelson, and D.G. Vesely. 2014. Modeling Marbled Murrelet (*Brachyramphus marmoratus*) habitat using LiDAR-Derived canopy data. Wildlife Society Bulletin 38(2):237–249; 2014; DOI: 10.1002/wsb.407.

Hamer, T.E. and S.K. Nelson. 1995. Characteristics of Marbled Murrelet nest trees and nesting stands. Pages 69-82 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Hatch, S.A. 2003. Statistical power for detecting trends with applications to seabird monitoring. Biological Conservation 111:317-329.

Hatch, S.A., V.A. Gill, and D.M. Mulcahy. 2011. Migration and wintering sites of Pelagic Cormorants determined by satellite telemetry. Journal of Field Ornithology 82:269-278.

Haynes, T.B., S.K. Nelson, and S.H. Newman. 2010. Diel shifts in the marine distribution of Marbled Murrelets near Port Snettisham, Southeast Alaska. Waterbirds 33:471-478.

Haynes, T.B., S.K. Nelson, and V.M. Padula. 2011. Dynamics of multi-species feeding associations in marine waters near Juneau, Alaska. Marine Ornithology 39:227-234.

Hèbert, P.N. and R.T. Golightly. 2006. Movements, nests, and response to anthropogenic disturbance of Marbled Murrelets (*Brachyramphus marmoratus*) in Redwood National and State Parks, California. Unpublished Report, Sacramento, California: California Department of Fish and Game, Habitat

Conservation Planning Branch Species Conservation and Recovery Program Report: 2006-02.

Hentze, N.T. 2006. Effects of boat disturbance on seabirds off southwestern Vancouver Island, British Columbia: MSc Thesis: British Columbia, University of Victoria.

Hobson, K.A., J.F. Piatt, J.F. and J. Potocchelli. 1994. Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology 63:786–798.

Hoekman, S.T., B.J. Moynahan, M.S. Lindberg, L.S. Sharman, and W.F. Johnson. 2011a. Line transect sampling for murrelets: accounting for incomplete detection and identification. Marine Ornithology 39:35–44.

Hoekman, S.T., B.J. Moynahan, and M.S. Lindberg. 2011b. Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve: 2010 Annual Report. National Park Service, Fort Collins, CO. Natural Resource Technical Report No. NPS/SEAN/NRTR—2011/441. 19 p.

Hoover-Miller, A., S. Atkinson, S. Conlon, J. Prewitt and P. Armato. 2011. Persistent decline in abundance of harbor seals *Phoca vitulina richardsi* over three decades in Aialik Bay, an Alaskan tidewater glacial fjord. Marine Ecology Progress Series 424:259–271.

Jansen, J.K., J.L. Bengtson, S.P. Dahle and J.M. Ver Hoef. 2006. Disturbance of harbor seals by cruise ships in Disenchantment Bay, Alaska: An investigation at three spatial and temporal scales. AFSC Processed Report 2006–02, National Marine Mammal Laboratory, Alaska Fisheries Science Center, National Marine Fisheries Service, 7600 Sand Point Way NE, Seattle, WA 98115. 75pp.

Johnston, S. and H.R. Carter. 1985. Cavity-nesting Marbled Murrelets. Wilson Bulletin 97:1-3.

Jones, I.L., F.M. Hunter, G.L. Robertson, J.C. Williams, and G.V. Byrd. 2007. Covariation among demographic and climate parameters in Whiskered Auklets *Aethia pygmaea*. Journal of Avian Biology 38:450–461.

Kaler, R.S.A., L.A. Kenney, and J.F. Piatt. 2008. Breeding biology of Kittlitz's Murrelet at Agattu Island, Alaska, in 2008: progress report. U.S. Fish and Wildl. Serv. Rep. AMNWR 08/17.

Kaler, R.S.A., L.A. Kenney, and B.K. Sandercock. 2009. Breeding ecology of Kittlitz's Murrelets at Agattu Island, Aleutian Islands, Alaska. Waterbirds 32:363–373.

Kaler, R.S.A., L.A. Kenney, J.F. Piatt, J.C. Williams, and G.V. Byrd. 2010. Breeding ecology of Kittlitz's Murrelet at Agattu Island, Alaska, in 2009: progress report. Adak, Alaska: US Fish and Wildlife Service Report AMNWR 2010/01.

Kendall, S.J. and B.A. Agler. 1998. Distribution and abundance of Kittlitz's Murrelets in southcentral and southeastern Alaska: Colonial Waterbirds 21(1):53-60.

Kenney, L. and R.S.A. Kaler. 2013. Identifying nesting habitat of Kittlitz's murrelets *Brachyramphus brevirostris*: old nests lead to a new breeding record. Marine Ornithology 41:73–74.

Kirchhoff, M. 2008. Methodological considerations for at-sea monitoring of *Brachyramphus* murrelets in Glacier Bay, Alaska. Unpublished report prepared by Alaska Department of Fish and Game, Douglas, AK. 73pp.

Kirchhoff, M., M. Smith, and S. Wright. 2010. Abundance, population trend, and distribution of Marbled Murrelets and Kittlitz's Murrelets in Glacier Bay National Park. Unpublished report to National Park Service, and Alaska Department of Fish and Game, by Audubon Alaska, Anchorage, AK, and Alaska Department of Fish and Game, Juneau, AK. Unpaginated.

Kirchhoff, M.D. 2011. A review of selected surveys of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Alaska: lessons learned. Marine Ornithology 39:77–83.

Kissling, M.L. 2009. Kittlitz's Murrelet information needs workshop: meeting summary. Unpublished Report, Juneau, Alaska: U.S. Fish and Wildlife Service. http://www.pacificseabirdgroup.org/committees/KIMU_InformationNeedsWorkshop.pdf

Kissling, M., K. Kuletz, and S. Brockmann. 2007a. Distribution and abundance of Kittlitz's Murrelets along the outer coast of Glacier Bay National Park and Preserve. Pages 124–128 *In* J. F. Piatt and S. M. Gende, eds. Proceedings of the Fourth Glacier Bay Science Symposium. U.S. Geological Survey, Reston, VA. Scientific Investigations Report 2007–5047.

Kissling, M.L., K.J. Kuletz, S.P. Brockmann, and N.R. Hatch. 2007b. Distribution and abundance of *Brachyramphus* murrelets and other marine species from Icy Bay to LeConte Bay, Southeast Alaska, 2002–2004. Unpublished report prepared by U.S. Fish and Wildlife Service Juneau Field Office, Juneau, AK. 72 p. + appendices.

Kissling, M.L., M. Reid, P. Lukacs, S.M. Gende, and S.B. Lewis. 2007c. Understanding abundance patterns of a declining seabird: implications for monitoring. Ecological Applications 17:2164–2174.

Kissling, M.L., R. Mason, P.M. Lukacs, S.M. Gende, and S.B. Lewis. 2007d. Recommendations for monitoring Kittlitz's Murrelets in Icy Bay. Unpublished Report, Landscape and Wildlife Ecology p. 59-61.

Kissling, M.L, P.M. Lukacs, S.B. Lewis, S.M. Gende, K.J. Kuletz, N.R. Hatch, S.K. Schoen, and S. Oehlers. 2011. Distribution and abundance of the Kittlitz's Murrelet in selected areas of southeastern Alaska. Marine Ornithology 39:3–11.

Kissling, M.L., P.M. Lukacs, S.M. Gende, and S.B. Lewis. 2015. Multi-state mark-recapture model to estimate survival of a dispersed-nesting seabird, the Kittlitz's Murrelet. Journal of Wildlife Management 79:20–30.

Kissling, M.L., and S.B. Lewis. 2015. Nesting activity of the Kittlitz's Murrelet in the Kakagrak Hills, Cape Krusenstern National Monument, Northwestern Alaska, summer 2014. Unpublished report prepared by U.S. Fish and Wildlife Service Juneau Field Office, Juneau, AK. 25pp.

Klosiewski, S.P. and K.K. Laing. 1994. Marine bird populations of Prince William Sound, Alaska, before and after the Exxon Valdez oil spill. NRDA Bird Study

Number 2. Unpublished Report, U.S. Fish and Wildlife Service, Anchorage, Alaska. 85pp.

Krasnow, L.D. and G.A. Sanger. 1982. Feeding ecology of marine birds in the nearshore waters of Kodiak Island. Anchorage, Alaska, U.S. Fish and Wildlife Service, National Fishery Research Center, Migratory Bird Section, Final Report to OCSEAP, Research Unit 45, p. 505-630.

Konyukhov N.B., L.S. Bogoslovskaya, B.M. Zvonov, and T.I. Van Pelt. 1998. Seabirds of the Chukotka Peninsula, Russia. Arctic 51:315–329.

Kuletz, K.J. 1994. Marbled Murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the Exxon Valdez oil spill: Anchorage, Alaska, *Exxon Valdez* Oil Spill Trustee Council, State / Federal Natural Resource Damage Assessment Final Report, Bird Study 6, 62pp.

Kuletz, K.J. 1996. Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay, Alaska, before and after the *Exxon Valdez* oil spill. Pages 770-784 *In* Rice, S.D., R.B., Spies, D.A. Wolfe, and B.A. Wright, eds. Proceedings of the *Exxon Valdez* oil spill symposium. American Fisheries Society Symposium 18.

Kuletz, K.J. 2005. Foraging behavior and productivity of a non-colonial seabird, the Marbled Murrelet (*Brachyramphus marmoratus*), relative to prey and habitat: Dissertation, British Columbia, University of Victoria.

Kuletz, K.J. and S.J. Kendall. 1998. A productivity index for marbled murrelets in Alaska based on surveys at sea. Journal of Wildlife Management 62:446–460.

Kuletz, K.J. and J.F. Piatt.1999. Juvenile marbled murrelet nurseries and the productivity index. Wilson Bulletin 111(2):257-261.

Kuletz, K.J., E.A. Labunski, and K.M. Brenneman. 2003. Distribution and abundance of Kittlitz's Murrelets in Prince William Sound, Alaska, in summer 2001: Anchorage, Alaska, U.S. Fish and Wildlife Service.

Kuletz, K., B. Manly, C. Nations, and D. Irons. 2007. Appendix J: Population trends of Kittlitz's and Marbled Murrelets in Prince William Sound. Pages 233-248 *In*

J. F. Piatt, K. J. Kuletz, A. E. Burger, S. A. Hatch, V. L. Friesen, T. P. Birt, M. L. Arimitsu, G. S. Drew, A. M. A. Harding, and K. S. Bixler. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. U.S. Geological Survey, Reston, VA. Open-file Report 2006–1387.

Kuletz, K.J., E.A. Labunski, and S.G. Speckman. 2008. Abundance, distribution and decadal trends of Kittlitz's and Marbled Murrelets and other marine species in Kachemak Bay, Alaska. Anchorage, Alaska: U.S. Fish and Wildlife Service, Final Report to Alaska Department of Fish and Game, Project No. 14. 119pp.

Kuletz, K.J., C.S. Nations, B. Manly, A. Allyn, D.B. Irons, and A. McKnight. 2011a. Distribution, abundance and population trends of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Prince William Sound, Alaska. Marine Ornithology 39:97–109.

Kuletz, K.J., S.G. Speckman, J.F. Piatt, and E.A. Labunski. 2011b. Distribution, population status and trends of Kittlitz's Murrelet *Brachyramphus brevirostris* in Lower Cook Inlet and Kachemak Bay, Alaska. Marine Ornithology 39:85–95.

Kushlan, J., M. Steinkamp, K. Parsons, J. Capp, M.A. Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Wheeler, and K. Wohl. 2002. Waterbird conservation for the Americas: The North American Waterbird Conservation Plan. Washington, DC. 78pp.

Lawonn, M.J. 2012. Breeding ecology and nest site selection of Kittlitz's Murrelets on Kodiak Island, Alaska. M.Sc. thesis, Oregon State University, Corvallis. 153pp.

Lawonn, M.J., R.M. Corcoran, J.F. Piatt, and W.H. Pyle. 2012. Breeding ecology and behavior of Kittlitz's murrelet in Kodiak National Wildlife Refuge, Alaska: 2011 progress report. Unpublished report, United States Fish and Wildlife Service, Kodiak National Wildlife Refuge. 34pp.

LCC (Landscape Conservation Cooperatives). 2014. http://www.northpacificlcc.org/, http://nplcc.databasin.org/ and http://www.fws.gov/alaska/lcc/index.htm.

Lindell, J. 2005. Results of at-sea *Brachyramphus* murrelet surveys in Icy Strait and other selected areas of Southeast Alaska, 1993-1999. Unpublished report. U.S. Fish and Wildlife Service, Juneau, Alaska. 83pp.

Lougheed, C. 1999. Breeding chronology, breeding success, distribution and movements of Marbled Murrelets (*Brachyramphus marmoratus*) in Desolation Sound, British Columbia. M.Sc. thesis, Simon Fraser University, Burnaby, BC, Canada.

Lougheed, C., L.W. Lougheed, F. Cooke, and S. Boyd. 2002. Local survival of adult and juvenile Marbled Murrelets and their importance for estimating reproductive success. Condor 104:309–318.

Madison, E.N., J.F. Piatt, M.L. Arimitsu, M.L. Romano, T.I. Van Pelt, S.K. Nelson, J.C. Williams, and A.R. DeGange. 2011. Status and distribution of the Kittlitz's Murrelet *Brachyramphus brevirostris* along the Alaska Peninsula and Kodiak and Aleutian islands, Alaska. Marine Ornithology 39:111–122.

Madison, E.N., J.F. Piatt, M.L. Kissling, D.C. Douglas, M.L. Arimitsu, E. Lance, K.J. Kuletz, and G. Drew. 2012. Post-breeding movements of the Kittlitz's Murrelet into the Arctic. Pages 59–60 *In* Abstracts of the Annual Meeting of the Pacific Seabird Group. Turtle Bay, Hawaii: Pacific Seabird Group, 7–10 February 2012.

Madsen, S., D. Evans, T. Hamer, P. Henson, S. Miller, S.K. Nelson, D. Roby, and M. Stapanian. 1999. Marbled Murrelet effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-439. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 51pp.

Malt, J.M. and D.B. Lank. 2007. Temporal dynamics of edge effects on nest predation risk for the Marbled Murrelet. Biological Conservation 140:160–173

Malt, J.M. and D.B. Lank. 2009. Marbled Murrelet nest predation risk in managed forest landscapes: dynamic fragmentation effects at multiple scales. Ecological Applications 19:1274–1287.

Manly B.F., J.M. Sternfeld, and K.J. Kuletz. 2007. Incidental take and interactions of marine mammals and birds in the Kodiak Island salmon set gillnet fishery, 2002 and 2005. Final report by Western EcoSystems Technology, Inc., Cheyenne, Wyoming, for National Marine Fisheries Service, Juneau, Alaska.

Marks, D.K. and N.L. Naslund. 1994. Sharp-Shinned Hawk preys on a Marbled Murrelet nesting in old-growth forest: Wilson Bulletin 106(3):565-567.

McFarlane Tranquilla, L.A., N.R. Parker, R.W. Bradley, D.B. Lank, E.A. Krebs, L.W. Lougheed, and C. Lougheed. 2005. Breeding chronology of Marbled Murrelets varies between coastal and inshore sites in southern British Columbia. Journal of Field Ornithology 76:357-367.

McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, S.K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the Marbled Murrelet in Washington, Oregon, and California. Unpublished report. EDAW, Inc. Seattle, Washington. Prepared for the U.S. Fish and Wildlife Service, Region 1. Portland, Oregon. 370pp.

Miller, S.L, C.J. Ralph, M.G. Raphael, C. Strong, C.W. Thompson, J. Baldwin, M.H. Huff, and G.A. Falxa. 2006. At-sea monitoring of Marbled Murrelet population status and trend in the Northwest Forest Plan area. Chapter 3. Pages 31-60 *In* M.H. Huff et al., tech. coords. Northwest Forest Plan - The first 10 years (1994-2003): status and trends of populations and nesting habitat for the Marbled Murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: US. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Morrison, K.W., J.M. Hipfner, G.S. Blackburn, and D.J. Green. 2011. Effects of extreme climate events on adult survival of three Pacific auks. Auk 128:707–715.

Mueter, F.J. and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the Bering Sea continental shelf. Ecological Applications 18:309–320.

Murphy K.A., L.H. Suring, and A. Iliff. 2004. Western Prince William Sound human use and wildlife disturbance model, Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 99339). U.S.D.A. Forest Service, Chugach National Forest, Anchorage, Alaska.

Naslund, N.L., K.J. Kuletz, M.B. Cody, and D.K. Marks. 1995. Tree and habitat characteristics and reproductive success at Marbled Murrelet tree nests in Alaska: Northwestern Naturalist 76:12-25.

Nelson, S.K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). I*n* Poole A. and F. Gill, eds. The birds of North America, No. 276. Philadelphia and Washington, DC: Academy of Natural Sciences and American Ornithologists' Union.

Nelson, S.K., B.A. Barbaree, B.D. Dugger, and S.H. Newman. 2010. Marbled Murrelet breeding ecology at Port Snettisham, Southeast Alaska, in 2005-2008. Unpublished Report, Corvallis, OR: Oregon State University, and New York, NY: Wildlife Trust. (prepared for Alaska Department of Fish and Game)

Nelson, S.K., and T.E. Hamer. 1995. Nest success and the effects of predation on Marbled Murrelets. Pages 89-97 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Nelson, S.K. and R.W. Peck. 1995. Behavior of the Marbled Murrelet at nine nest sites in Oregon. Northwestern Naturalist 76:43-53.

Newman, S.H., S.K. Nelson, D.L. Whitworth, and H.R. Carter. 2006. Marbled Murrelet (*Brachyramphus marmoratus*) activity patterns and health in Port Snettisham, Southeast Alaska, 2005. Unpublished report, New York: Wildlife Trust. 70pp.

.

NRPGCII (Nuka Research and Planning Group and Cape International, Inc). 2005. Vessel traffic in the Aleutians Subarea. Report to Alaska Department of Environmental Conservation. 56pp.

Nur, N., and W.J. Sydeman. 1999. Survival, breeding probability and reproductive success in relation to population dynamics of Brandt's Cormorants *Phalacrocorax penicillatus*. Bird Study 46:92-102.

O'Donnell, B.P., N.L. Naslund and C.J. Ralph. 1995. Patterns of seasonal variation of activity of Marbled Murrelets in forested stands. Pages 117–128 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Ostrand, W.D. 1999. Marbled Murrelets as initiators of feeding flocks in Prince William Sound, Alaska. Waterbirds 22:314-318.

Ostrand, W.D., S. Howlin, and T. Gotthardt. 2004. Fish school selection by Marbled Murrelets in Prince William Sound, Alaska: responses to changes in availability. Marine Ornithology 32: 9-15.

Peery M.Z., Beissinger S.R., Newman S.H., Burkett E., Williams T.D. 2004. Applying the declining population paradigm: diagnosing causes of poor reproduction in the Marbled Murrelet. Conservation Biology 18:1088–1098.

Piatt, J.F. and P. Anderson. 1996. Response of Common Murres to the *Exxon Valdez* oil spill and long-term changes in the Gulf of Alaska marine ecosystem. Pages 720-737 *In* Rice, S.D., Spies, R.B., Wolfe, D.A., and Wright, B.A., eds. *Exxon Valdez* Oil Spill Symposium, Anchorage, Alaska, 1993, American Fisheries Society Symposium 18.

Piatt, J.F. and N.L. Naslund. 1995. Abundance, distribution, and population status of Marbled Murrelets in Alaska. Pages 285-294 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Piatt, J.F., M. Arimitsu, G. Drew, E.N. Madison, J. Bodkin, and M.D. Romano. 2011. Status and trend of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Glacier Bay, Alaska. Marine Ornithology 39:65–75.

Piatt, J.F., K.J. Kuletz, A.E. Burger, S.A. Hatch, V.L. Friesen, T.P. Birt, M.L. Arimitsu, G.S. Drew, A.M.A. Harding, and K.S. Bixler. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. U.S. Geological Survey Open-File Report 2006-1387. 258pp.

Piatt J.F., N.L. Naslund, and T.I. van Pelt. 1994. Nest-site selection and fidelity in Kittlitz's Murrelet. Beringian Seabird Bulletin 2: 54–56.

Piatt J.F., N.L. Naslund, and T.I. van Pelt. 1999. Discovery of a new Kittlitz's Murrelet nest: clues to habitat selection and nest-site fidelity. Northwest Naturalist 80:8–13.

Piatt, J. F. and A. M. Springer. 2007. Marine ecoregions of Alaska. Pages 522–526 *In* Spies, R.B., ed. Long-term Ecological Change in the Northern Gulf of Alaska. Elsevier, Amsterdam.

Pitocchelli, J., J. Piatt, and M. Cronin. 1995. Morphological and genetic divergence among Alaskan populations of *Brachyramphus* murrelets. Wilson Bull. 107:235–250.

Ralph, C.J. and L.L. Long. 1995. Productivity of Marbled murrelets in California from observations of young at sea. Pages 371-377 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the marbled murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Raphael, M.G., J. Baldwin, G.A. Falxa, M.H. Huff, M. Lance, S.L. Miller, S.F. Pearson, C.J. Ralph, C. Strong, and C. Thompson. 2007. Regional population monitoring of the Marbled Murrelet: field and analytical methods. General Technical Report PNW-GTR-716. Portland, OR: US Forest Service.

Robards, M., G.S. Drew, J.F. Piatt, J.M. Anson, A. Abookire,, J.L. Bodkin, P. Hooge, and S.G. Speckman. 2003. Ecology of selected marine communities in Glacier

Bay: Zooplankton, forage fish, seabirds and marine mammals: Anchorage, USGS Alaska Science Center, Final Report to USNPS, GBNPP, 156pp.

Romano, M.D., M.L. Arimitsu, J.F. Piatt, A.M. Agnes, and G.S. Drew. 2004. At-sea density and distribution of Kittlitz's Murrelets (*Brachyramphus brevirostris*) and Marbled Murrelets (*Brachyramphus marmoratus*) in Glacier Bay, Alaska, summer 2003. Unpublished report prepared for Glacier Bay National Park and Preserve, Gustavus, AK, by U.S. Geological Survey Alaska Science Center, Anchorage, AK. 68pp.

Romano, M.D., J.F. Piatt, and A.R. DeGange. 2005a. At-sea density and abundance of Kittlitz's and Marbled Murrelets around Unalaska Island, Alaska, June 2005. Unpublished report prepared by U.S. Geological Survey Alaska Science Center, Anchorage, AK. 31pp.

Romano, M.D., J.F. Piatt, J. Williams, and A. DeGange. 2005b. At-sea density of Kittlitz's and marbled murrelets around Atka Island, Alaska, June 2004. Unpublished report prepared by U.S. Geological Survey Alaska Science Center, Anchorage, AK. 26pp.

Romano, M.D., J.F. Piatt, and C. Dubuisson. 2006. Kittlitz's and Marbled Murrelets in Kenai Fjords National Park, Alaska: at-sea distribution and abundance, and initial observations of radio-marked Kittlitz's Murrelets. Unpublished report prepared for Kenai Fjords National Park, Seward, AK, by U.S. Geological Survey Alaska Science Center, Anchorage, AK. 47pp.

Sealy, S.G. 1973. Adaptive significance of post-hatching development patterns and growth rates in the Alcidae. Ornis Scandinavica 4: 113-121.

Sealy, S.G. 1975. Feeding ecology of the Ancient and Marbled Murrelets near Langara Island, British Columbia: Canadian Journal of Zoology 53:418-433.

Speckman, S.G., A.M. Springer, J.F. Piatt, and D.L. Thomas. 2000. Temporal variability in abundance of Marbled Murrelets at sea in Southeast Alaska. Waterbirds 23:364–377.

Strachan, G., M.L.C. McAllister, and C.J. Ralph. 1995. Marbled Murrelet at-sea foraging behavior. Pages 247-254 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the Marbled Murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Strong, C.S., B.S. Keitt, W.R. McIver, C.J. Palmer, and I. Gaffney. 1995. Distribution and population estimates of Marbled Murrelets at sea in Oregon during the summers of 1992 and 1993. Pages 339-352 *In* Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G., and Piatt, J.F., eds. Ecology and conservation of the marbled murrelet: Albany, California, U.S. Forest Service, Pacific Southwest Research Station, General Technical Report 152.

Thomas, L., J.L. Laake, S Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, and J.H. Pollard. 2002. Distance 4.1. Release 1. Research unit for wildlife population assessment: University of St. Andrews, United Kingdom, http://www. ruwpa.st-and.ac.uk/distance.

U.S. Fish and Wildlife Service [USFWS]. 1992. Endangered and threatened wildlife and plants; determination of threatened status for the Washington, Oregon and California population of the Marbled Murrelet. USDI Fish and Wildlife Service Fed. Reg. 57: 45328-45337.

U.S. Fish and Wildlife Service. 1997. Recovery plan for the Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon and California. Oregon Field Office, Portland, OR. 203 pp.

U.S. Fish and Wildlife Service. 2009. Alaska Seabird Conservation Plan. U.S. Fish and Wildlife Service, Migratory Bird Management, Anchorage, AK. 136 pp.

U.S. Fish and Wildlife Service. 2010. Status assessment and listing priority assignment form for Kittlitz’s Murrelet. Anchorage, Alaska: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2011. Species assessment and listing priority assignment form: Kittlitz’s Murrelet. Anchorage, Alaska: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2012. Report on Marbled Murrelet recovery implementation team meeting and stakeholder workshop. Lacey, Washington: U.S. Fish and Wildlife Service.

U.S. Fish and Wildlife Service. 2013a.12-month finding on a petition to list Kittlitz's Murrelet as an endangered or threatened species. Federal Register 78:61764.

U.S. Fish and Wildlife Service. 2013b. Threatened and Endangered Species Kittlitz's Murrelet (*Brachyramphus brevirostris*) http://www.fws.gov/alaska/fisheries/endangered/pdf/kittlitzs_murrelet_factsheet.pdf

Van Pelt, T.I. 2005. The mystery of seabird decline. WWF Arctic Bulletin: 15.

Van Pelt, T.I. and J.F. Piatt. 2003. Population status of Kittlitz's and Marbled Murrelets and surveys for other marine bird and mammal species in the Kenai Fjords area, Alaska: Anchorage, USGS Alaska Science Center, Science Support Program Annual Report to USFWS.

Van Pelt, T.I. and J.F. Piatt. 2005. Population status of Kittlitz's Murrelet along the southern coast of the Alaska Peninsula: Anchorage, USGS Alaska Science Center, Final Report to the USFWS, Science Support Program, 65pp.

Van Pelt, T.I., J.F. Piatt, and G.B. van Vliet. 1999. Vocalizations of the Kittlitz's Murrelet. Condor 101:395-398.

van Vliet, G.B. 1993. Status concerns for the "global" population of Kittlitz's murrelet: Is the "glacier murrelet" receding? Pacific Seabird Group Bulletin 20:15–16.

van Vliet, G.B. and M. McAllister. 1994. Kittlitz's murrelet: The species most impacted by direct mortality from the Exxon Valdez oil spill? Pacific Seabirds 21:4–6.

Vyatkin, P.S. 1999. Distribution and numbers of the Kittlitz's Murrelet (*Brachyramphus brevirostris*) on the eastern coast of Kamchatka. Pages 119-120 *In* Poyarkov, N.D., ed. The biology and conservation of the birds of Kamchatka. Vol. 1. Moscow: Dialog-MGU. [In Russian]

Waterhouse, F.L., A.E. Burger, D.B. Lank, P.K. Ott, E.A. Krebs, and N. Parker. 2009. Using the low-level aerial survey method to identify Marbled Murrelet nesting habitat. BC Journal of Ecosystems and Management 10:80–96. www.forrex.org/publications/jem/ISS50/vol10_no1_art8.pdf

Whitworth, D.L., S.K. Nelson, S.H. Newman, G.B. Van Vliet, and W.P. Smith. 2000. Foraging distances of radio-marked Marbled Murrelets from inland areas in southeast Alaska. Condor 102:452-456.

Whitworth, D.L., J.Y. Takekawa, H.R. Carter, and W.R. McIver. 1997. A night-lighting technique for at-sea capture of Xantus' Murrelets. Colonial Waterbirds 20:525–531.

Willson, M.F., K.M. Hocker, and R.H. Armstrong. 2010. Ground-nesting Marbled Murrelets in Juneau, Alaska. Western Birds 41:44–48.

Wynne K., D. Hicks, and N. Munro. 1991. 1990 salmon gillnet fisheries observer programs in Prince William Sound and south Unimak, Alaska. Report by Saltwater, Inc., Anchorage, Alaska. Available from National Marine Fisheries Service, Juneau, Alaska.

Wynne K., D. Hicks, and N. Munro. 1992. 1991 marine mammal observer program for the salmon driftnet fishery of Prince William Sound, Alaska. Final report. Saltwater, Inc., Anchorage, Alaska. Available from National Marine Fisheries Service, Juneau, Alaska.

Ydenberg, R.C. 1989. Growth-mortality trade-offs and the evolution of juvenile life histories in the Alcidae. Ecology 70:1494–1506.

FIGURES

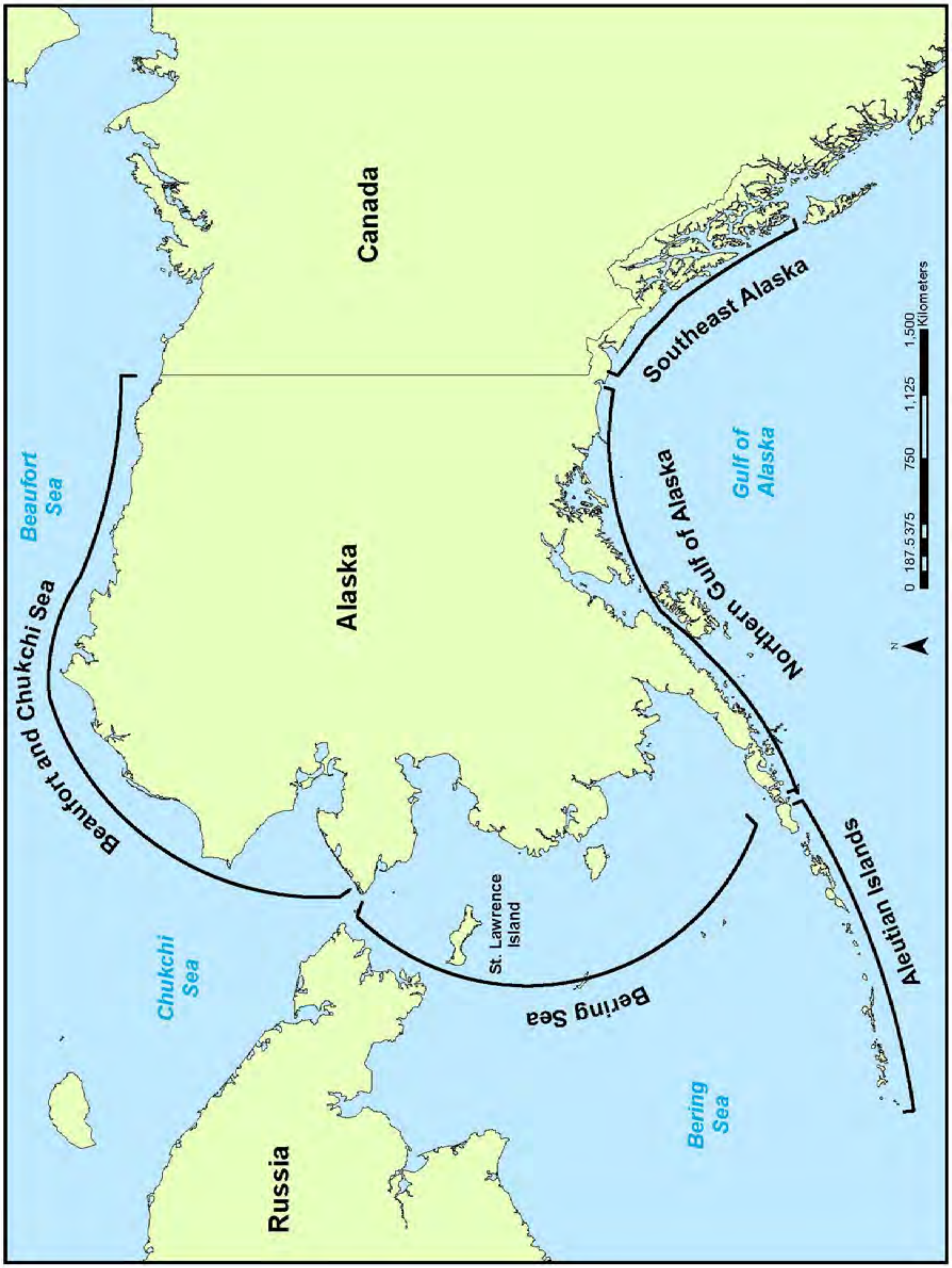


Figure 1. Map of Ecoregions in Alaska (modified from USFWS 2009).

Figure 2. Historic BRUM surveys, gaps in historic surveys, and recommended emphasis areas for future surveys.

Table 1. Historic *Brachyramphus* murrlet at-sea population abundance and density (birds/km²) by survey in Alaska and Russia. Row ID is provided for cross-referencing to survey details in Table 2.

Row ID	Ecoregion	Area and Sub Area	Survey Year	KIMU Abundance (SE)	KIMU abundance (95% CI)	KIMU Density (SE)	KIMU Density (95% CI)	MAMU Abundance (SE)	MAMU abundance (95% CI)	MAMU density (SE)	MAMU Density (95% CI)	BRMU abundance (SE)	BRMU abundanc e (95% CI)	BRMU density (SE)	BRMU Density (95% CI)	Reference(s)
1	SE Alaska	LeConte Bay	2002	0		0		0		0		*		*		Kissling et al. 2007b; Kissling et al. 2011
2	SE Alaska	Thomas Bay	2002	0		0		4967 (3105)		84.6 (52.9)		*		*		Kissling et al. 2007b; Kissling et al. 2011
3	SE Alaska	Wilderness Bays	2002	555 (233)		2.34 (0.98)		9916 (2402)		41.8 (10.1)		*		*		Kissling et al. 2007b; Kissling et al. 2011
4	SE Alaska	Cross Sound	2003	28 (30)		0.05 (0.05)		16027 (5841)		26.5 (9.7)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
5	SE Alaska	Outer Coast	2004	144 (59)		0.18 (0.07)		9896 (1601)		12.2 (2.0)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
6	SE Alaska	Outer Coast Bays	2003	0		0		408 (133)		12.6 (4.1)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
7	SE Alaska	Icy Point	2003	101 (33)		2.25 (0.74)		534 (137)		11.9 (3.1)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
8	SE Alaska	Mouth of Lituya Bay	2004	129 (60)		4.00 (1.86)		1206 (306)		37.3 (9.5)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
9	SE Alaska	Lituya Bay	2003	31 (22)		1.35 (0.96)		92 (41)		4.1 (1.8)		*		*		Kissling et al. 2007a, b; Kissling et al. 2011
10	SE Alaska	Yakutat Bay	2000	966 (183)		0.85 (0.16)		12025 (2282)		10.6 (2.0)		*		*		Kissling et al. 2011
11	SE Alaska	Yakutat Bay	2009	4414 (965)		3.90 (0.85)		12902 (1912)		11.4 (1.7)		*		*		Kissling et al. 2011
12	SE Alaska	Manby Point	2002	988 (437)		5.78 (2.56)		4767 (1631)		27.9 (9.5)		*		*		Kissling et al. 2007b; Kissling et al. 2011
13	SE Alaska	Malaspina Forelands	1992	641 (13)		39.23 (0.81)		386 (13)		23.7 (0.8)		*		*		Kissling et al. 2011
14	SE Alaska	Malaspina Forelands	2002	10 (3)		0.59 (0.19)		378 (3)		23.2 (0.2)		*		*		Kissling et al. 2007b; Kissling et al. 2011
15	SE Alaska	Malaspina Forelands	2008	39 (22)		2.38 (1.34)		343 (133)		21.0 (8.2)		*		*		Kissling et al. 2011
16	SE Alaska	Malaspina Forelands	2009	165 (104)		10.13 (2.13)		373 (218)		22.8 (13.4)		*		*		Kissling et al. 2011
17	SE Alaska	Icy Bay	2002	2660 (99)		27.63 (1.03)		123 (32)		1.28 (0.38)		*		*		Kissling et al. 2007b; Kissling et al. 2011
18	SE Alaska	Icy Bay	2005	1317 (294)		10.31 (2.31)		0		0		*		*		Kissling et al. 2011
19	SE Alaska	Icy Bay	2007	1000 (159)		8.47 (1.35)		0		0		*		*		Kissling et al. 2011
20	SE Alaska	Icy Bay	2008	1949 (286)		16.52 (2.43)		137 (44)		1.16 (0.38)		*		*		Kissling et al. 2011
21	SE Alaska	Icy Bay	2009	705 (216)		5.23 (1.60)		114 (47)		0.85 (0.35)		*		*		Kissling et al. 2011
22	SE Alaska	Lost Coast	2008	646 (259)		1.47 (0.59)		4266 (955)		9.7 (2.2)		*		*		Kissling et al. 2011
23	SE Alaska	Glacier Bay NP - Coastal strata	1991		2937 (1912-4127)		9.08									Piatt et al. 2011
24	SE Alaska	Glacier Bay NP - Coastal strata	1999		389 (222-582)		1.2									Piatt et al. 2011
25	SE Alaska	Glacier Bay NP - Coastal strata	2000		787 (444-1216)		2.43									Piatt et al. 2011
26	SE Alaska	Glacier Bay NP - Coastal strata	2001		651 (392-977)		2.01									Piatt et al. 2011
27	SE Alaska	Glacier Bay NP - Coastal strata	2002		517 (253-820)		1.6									Piatt et al. 2011
28	SE Alaska	Glacier Bay NP - Coastal strata	2003		191 (75-337)		0.59									Piatt et al. 2011

29	SE Alaska	Glacier Bay NP - Coastal strata	2008		454 (134-846)		1.4									Piatt et al. 2011
30	SE Alaska	Glacier Bay NP - Offshore strata	1991		30675 (5002-76404)		32.81									Piatt et al. 2011
31	SE Alaska	Glacier Bay NP - Offshore strata	1999		5147 (2665-8086)		5.5									Piatt et al. 2011
32	SE Alaska	Glacier Bay NP - Offshore strata	2000		5502 (3790-7855)		5.88									Piatt et al. 2011
33	SE Alaska	Glacier Bay NP - Offshore strata	2001		4084 (2709-6140)		4.37									Piatt et al. 2011
34	SE Alaska	Glacier Bay NP - Offshore strata	2002		1808 (738-3941)		1.93									Piatt et al. 2011
35	SE Alaska	Glacier Bay NP - Offshore strata	2003		4204 (2647-5896)		4.5									Piatt et al. 2011
36	SE Alaska	Glacier Bay NP - Offshore strata	2008		3130 (858-5436)		3.35									Piatt et al. 2011
37	SE Alaska	Glacier Bay NP	2008		4923 (1426-8654)		3.93 (1.14-691)		10291 (5487-18024)		8.22 (4.38-14.40)		17041 (8427-23211)		13.61 (7.00-22.55)	Piatt et al. 2011
38	SE Alaska	Glacier Bay NP	2008		58 (0-220)		0.05 (0-0.18)		1904 (565-4482)		1.52 (0.45-3.58)		2410 (694-5690)		1.92 (0.55-4.54)	Piatt et al. 2011
39	SE Alaska	Glacier Bay NP	1991						33616 (7882-79472)							Piatt et al. 1991; Kirchoff et al. 2014
40	SE Alaska	Glacier Bay NP	1993						4397 (1978-7801)							Kirchoff et al. 2014
41	SE Alaska	Glacier Bay NP	1999						5536 (3060-8460)							Drew et al. 2008; Kirchoff et al. 2014
42	SE Alaska	Glacier Bay NP	2000						6289 (4511-8659)							Drew et al. 2008; Kirchoff et al. 2014
43	SE Alaska	Glacier Bay NP	2001						4735 (3282-6803)							Drew et al. 2008; Kirchoff et al. 2014
44	SE Alaska	Glacier Bay NP	2002						2325 (1203-4037)							Drew et al. 2008; Kirchoff et al. 2014
45	SE Alaska	Glacier Bay NP	2003						4394 (2826-6089)							Drew et al. 2008; Kirchoff et al. 2014
46	SE Alaska	Glacier Bay NP							3583 (1271-5884)							Piatt et al. 2011; Kirchoff et al. 2014
47	SE Alaska	Glacier Bay NP							4738 (2906-7133)							Kirchoff et al. 2010; Kirchoff et al. 2014
48	SE Alaska	Glacier Bay NP	2010						6421 (3711-9837)							Kirchoff et al. 2014
49	SE Alaska	Glacier Bay NP	2009	13124 (4062)		12.0 (3.7)		28978 (4077)		26.5 (3.7)						Hoekman et al. 2011a, 2014
50	SE Alaska	Glacier Bay NP	2010	13308 (1357)		11.4 (1.2)		61717 (5372)		52.7 (4.6)						Hoekman et al. 2013, 2014
51	SE Alaska	Glacier Bay NP	2011	7477 (1119)		6.4 (1.0)		73766 (7055)		63.1 (6.0)						Hoekman et al. 2013a, 2014
52	SE Alaska	Glacier Bay NP	2012	16469 (2581)		14.1 (2.2)		52560 (5216)		44.9 (4.5)						Hoekman et al. 2013b, 2014
53	SE Alaska	Glacier Bay NP	2013	7210 (2046)		6.2 (1.7)		84428 (15394)		72.2 (13.2)						Hoekman et al. 2014
54	N. Gulf of Alaska	Prince William Sound	1972	63229 (40879)§				236633 (26391)§				4570 (4018)§				Agler et al 1999; Kuletz et al. 2011a
55	N. Gulf of Alaska	Prince William Sound	1989	6436 (1583)				59284 (5939)				41634 (4129)				Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
56	N. Gulf of Alaska	Prince William Sound	1990	5321 (4250)				39486 (5018)				36624 (3975)				Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
57	N. Gulf of Alaska	Prince William Sound	1991	1184 (563)				42477 (4599)				62816 (7042)				Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a

58	N. Gulf of Alaska	Prince William Sound	1993	2710 (675)§				14177 (2261)§					142546 (21045)§			Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
59	N. Gulf of Alaska	Prince William Sound	1996	1280 (685)				63455 (8062)					17429 (3010)			Kuletz et al. 2003, 2011a
60	N. Gulf of Alaska	Prince William Sound	1998	279 (96)§				49921 (4746)§					3038 (1072)§			Kuletz et al. 2003, 2011a
61	N. Gulf of Alaska	Prince William Sound	2000	1033 (673)				52278 (7271)					1046 (509)			Kuletz et al. 2003, 2011a
62	N. Gulf of Alaska	Prince William Sound	2004	780 (260)				35593 (3930)				836 (186)				Kuletz et al. 2011a
63	N. Gulf of Alaska	Prince William Sound	2005	2689 (1548)				33797 (3679)					6576 (958)			Kuletz et al. 2011a
64	N. Gulf of Alaska	Prince William Sound	2007	2346 (934)	2346 (514-4178)			28958 (4088)	28958 (20945-36971)			2253(521)		2253 (1231-3275)		Kuletz et al. 2011a
65	N. Gulf of Alaska	Prince William Sound	2001		1400 (977-1889)											Kuletz et al. 2011a
66	N. Gulf of Alaska	Prince William Sound	2009		2080 (1409-2990)											Kuletz et al. 2011a
67	N. Gulf of Alaska	Kenai Fjords	2006		925 (393-2179)				6418 (4730-8709)					7586 (5344-10768)		Arimitsu et al. 2010, 2011
68	N. Gulf of Alaska	Kenai Fjords	2007		423 (252-709)				3619 (2371-5524)					4424 (3099-6315)		Arimitsu et al. 2010, 2011
69	N. Gulf of Alaska	Kenai Fjords	2008		801 (359-1785)				10033 (7569-13299)					12547 (10383-15162)		Arimitsu et al. 2010, 2011
70	N. Gulf of Alaska	Kachemak Bay	2005		2015 (±2474)		2.47 (NR)		12092 (±4506)		14.82 (NR)			1842 (±856)	2.26 (NR)	Kuletz et al. 2008
71	N. Gulf of Alaska	Kachemak Bay	2006		3294 (±3171)		4.04 (NR)		11437 (±6895)		14.02 (NR)			829 (±468)	1.02 (NR)	Kuletz et al. 2008
72	N. Gulf of Alaska	Kachemak Bay	2007		1141 (±1759)		1.40 (NR)		9912 (±8201)		12.15 (NR)			993 (±757)	1.22 (NR)	Kuletz et al. 2008
73	N. Gulf of Alaska	Lower Cook Inlet	1993										58227 (±16058)			Agler et al. 1998
74	N. Gulf of Alaska	Lower Cook Inlet	1994										11627 (±7410)			Agler et al. 1998
75	N. Gulf of Alaska	Alaska Peninsula	2003		2382 (1272-4480)			7959 (6049-10423)								Madison et al. 2011
76	Aleutian Islands	Unalaska Island	2005		1642 (1090-2473)			6487 (4946-8508)								Madison et al. 2011
77	Aleutian Islands	Atka Island	2004		1067 (494-2305)			648 (338-1242)								Madison et al. 2011
78	Aleutian Islands	Adak Island	2006		197 (101-386)			920 (614-1378)								Madison et al. 2011
79	Aleutian Islands	Attu Island	2003		590 (347-1004)			35 (0-136)								Madison et al. 2011
80	Aleutian Islands	Attu Island	2009		788 (458-1355)			120 (50-286)								Madison et al. 2011
81	Beaufort & Chukchi Sea	Southern Chukchi	1970-2009		128 (0-309)											Day et al.2011
82	Beaufort & Chukchi Sea	Kotzebue Sound	1970-1999		0											Day et al.2011
83	Beaufort & Chukchi Sea	Northern Chukchi	1970-2009		323 (0-782)											Day et al.2011
84	Beaufort & Chukchi Sea	Arctic Ocean	2000-2009		0											Day et al.2011

85	Beaufort & Chukchi Sea	Beaufort Sea	1970-2009		0											Day et al.2011
86	Beaufort & Chukchi Sea	Southern Chukchi	1970-2009		1052 (0-3075)											Day et al.2011
87	Beaufort & Chukchi Sea	Kotzebue Sound	1970-1999		83 (0-260)											Day et al.2011
88	Beaufort & Chukchi Sea	Northern Chukchi	1970-2009		7382 (1464-16629)											Day et al.2011
89	Beaufort & Chukchi Sea	Arctic Ocean	2000-2009		0											Day et al.2011
90	Beaufort & Chukchi Sea	Beaufort Sea	1970-2009		0											Day et al.2011
91	Russia	Bering Sea	2004				**1.63 birds/km2									Artukhin et al. 2011
92***	Russia	Bering Sea	2005													Artukhin et al. 2011
93	Russia	E. coast Kamchatka	1973				**0–3.8 birds/km2									Vyatkin 1999 Artukhin et al. 2011
94	Russia	E. coast Kamchatka	1975				**0–3.8 birds/km2									Vyatkin 1999 Artukhin et al. 2011
95	Russia	E. coast Kamchatka	1990				**0–3.8 birds/km2									Vyatkin 1999 Artukhin et al. 2011
96	Russia	E. coast Kamchatka	1994				**0–3.8 birds/km2									Vyatkin 1999 Artukhin et al. 2011
97	Russia	E. coast Kamchatka	1995				**0–3.8 birds/km2									Vyatkin 1999 Artukhin et al. 2011
98***	Russia	Eastern Koryak Highlands	1970s-1980s													Artukhin et al. 2011
99***	Russia	Cape Bering - Cape Serdtse-Kamen	1985													Konyukhov *et al.* 1998 Artukhin et al. 2011
100***	Russia	Cape Bering - Cape Serdtse-Kamen	1985													Konyukhov *et al.* 1998 Artukhin et al. 2011
101***	Russia	Cape Bering - Cape Serdtse-Kamen	1987													Konyukhov *et al.* 1998 Artukhin et al. 2011
102***	Russia	Cape Bering - Cape Serdtse-Kamen	1991													Konyukhov *et al.* 1998 Artukhin et al. 2011
103***	Russia	Sea of Okhotsk	2005													Andreev & Van Pelt (2007) Artukhin et al. 2011
104***	Russia	Taygonos Peninsula	2008													Artukhin et al. 2011
105***	Russia	Okhotsk coast	1993-2007													Artukhin et al. 2011

* Unidentified murrelets incorporated into abundance, density estimates and standard errors (SE) of both species; Kissling et al. 2011
** No CI reported
*** No abundance or density estimates reported
§ Years of unusually high (1972 & 1993) and unusually low (1998) population estimates which Kuletz et al. 2011a modeled estimates with and without these years

Table 2. Details of historic at-sea *Brachyramphus* murrlet surveys. Row ID is provided for cross-referencing to abundance and density summaries in Table 1.

Row ID	Ecoregion	Area and Sub Area	Survey Year	Survey date	Survey platform	Transect type	Transect layout	Strata	Other Methods	Reference(s)
1	SE Alaska	LeConte Bay	2002	8-Jul-2002	6 m boat	strip	perpendicular to shore	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
2	SE Alaska	Thomas Bay	2002	7-Jul-2002	6 m boat	strip	perpendicular to shore	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
3	SE Alaska	Wilderness Bays	2002	9-10 July 2002	6 m boat	strip	perpendicular to shore	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
4	SE Alaska	Cross Sound	2003	3-4 July 2003	6 m boat	line	perpendicular to shore	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
5	SE Alaska	Outer Coast	2004	7-13 July 2004	22 m vessel	line	zigzag	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
6	SE Alaska	Outer Coast Bays	2003	5-Jul-2003	6 m boat	line	perpendicular to shore	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
7	SE Alaska	Icy Point	2003	10-Jul-2003	6 m boat	line	perpendicular to shore	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
8	SE Alaska	Mouth of Lituya Bay	2004	14-Jul-2004	6 m boat	line	perpendicular to shore	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
9	SE Alaska	Lituya Bay	2003	6-Jul-2003	6 m boat	line	perpendicular to shore	7, 12, unspecified		Kissling et al. 2007a, b; Kissling et al. 2011
10	SE Alaska	Yakutat Bay	2000	16-19 June 2000	7 m boat	strip	perpendicular to shore	unspecified		Kissling et al. 2011
11	SE Alaska	Yakutat Bay	2009	17-22 June 2009	6 m boat	line	perpendicular to shore	unspecified		Kissling et al. 2011
12	SE Alaska	Manby Point	2002	14-Jul-2002	22 m vessel	strip	zigzag	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
13	SE Alaska	Malaspina Forelands	1992	26-Jul-1992	4 m boat	strip	parallel to shore	unspecified		Kissling et al. 2011
14	SE Alaska	Malaspina Forelands	2002	13-Jul-2002	22 m vessel	strip	parallel to shore	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
15	SE Alaska	Malaspina Forelands	2008	20-Jul-2008	22 m vessel	line	parallel to shore	unspecified		Kissling et al. 2011
16	SE Alaska	Malaspina Forelands	2009	16-Jul-2009	22 m vessel	line	parallel to shore	12, unspecified		Kissling et al. 2011
17	SE Alaska	Icy Bay	2002	11-Jul-2002	6 m boat	strip	perpendicular to shore	12, unspecified		Kissling et al. 2007b; Kissling et al. 2011
18	SE Alaska	Icy Bay	2005	9-Jul-2005	6 m boat	line	perpendicular to shore	unspecified		Kissling et al. 2011
19	SE Alaska	Icy Bay	2007	23-Jul-2007	6 m boat	line	perpendicular to shore	unspecified		Kissling et al. 2011
20	SE Alaska	Icy Bay	2008	14-Jul-2008	6 m boat	line	perpendicular to shore	unspecified		Kissling et al. 2011
21	SE Alaska	Icy Bay	2009	17-Jul-2009	6 m boat	line	perpendicular to shore	unspecified		Kissling et al. 2011
22	SE Alaska	Lost Coast	2008	21-Jul-2008	22 m vessel	line	zigzag	unspecified		Kissling et al. 2011
23	SE Alaska	Glacier Bay NP -Coastal strata	1991	18-Jun-1991	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
24	SE Alaska	Glacier Bay NP -Coastal strata	1999	18-Jun-1999	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
25	SE Alaska	Glacier Bay NP -Coastal strata	2000	19-Jun-2000	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
26	SE Alaska	Glacier Bay NP -Coastal strata	2001	18-Jun-2001	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
27	SE Alaska	Glacier Bay NP -Coastal strata	2002	10-Jun-2002	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
28	SE Alaska	Glacier Bay NP -Coastal strata	2003	12-Jun-2003	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
29	SE Alaska	Glacier Bay NP -Coastal strata	2008	24-Jun-2008	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
30	SE Alaska	Glacier Bay NP - Offshore strata	1991	18-Jun-1991	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
31	SE Alaska	Glacier Bay NP - Offshore strata	1999	18-Jun-1999	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011

32	SE Alaska	Glacier Bay NP - Offshore strata	2000	19-Jun-2000	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
33	SE Alaska	Glacier Bay NP - Offshore strata	2001	18-Jun-2001	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
34	SE Alaska	Glacier Bay NP - Offshore strata	2002	10-Jun-2002	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
35	SE Alaska	Glacier Bay NP - Offshore strata	2003	12-Jun-2003	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
36	SE Alaska	Glacier Bay NP - Offshore strata	2008	24-Jun-2008	boat multiple	line	perpendicular & parallel	unspecified		Piatt et al. 2011
37	SE Alaska	Glacier Bay NP	2008	23-26 June 2008	9 m boat	line	perpendicular & parallel	unspecified	On water	Piatt et al. 2011
38	SE Alaska	Glacier Bay NP	2008	23-26 June 2008	9 m boat	strip	perpendicular & parallel	unspecified	flying	Piatt et al. 2011
39	SE Alaska	Glacier Bay NP	1991	15 June - 15 July 1991	boat multiple			unspecified	non-standard survey	Piatt et al. 1991; Kirchoff et al. 2014
40	SE Alaska	Glacier Bay NP	1993	23-24 June 1993	17 m vessel	strip		unspecified		Kirchoff et al. 2014
41	SE Alaska	Glacier Bay NP	1999	10-26 June 1999	9 m boat	strip		11, unspecified		Drew et al. 2008; Kirchoff et al. 2014
42	SE Alaska	Glacier Bay NP	2000	17-23 June 2000	9 m boat	strip		11, unspecified		Drew et al. 2008; Kirchoff et al. 2014
43	SE Alaska	Glacier Bay NP	2001	16-21 June 2001	12 m boat	strip		11, unspecified		Drew et al. 2008; Kirchoff et al. 2014
44	SE Alaska	Glacier Bay NP	2002	7-13 June 2002	8 m boat	strip		11, unspecified		Drew et al. 2008; Kirchoff et al. 2014
45	SE Alaska	Glacier Bay NP	2003	9-14 June 2003	9-12 m boat	strip		11, unspecified		Drew et al. 2008; Kirchoff et al. 2014
46	SE Alaska	Glacier Bay NP		23-26 June 2008				unspecified, unspecified		Piatt et al. 2011; Kirchoff et al. 2014
47	SE Alaska	Glacier Bay NP		3-10 July 2009	17 m vessel	strip?		unspecified, unspecified		Kirchoff et al. 2010; Kirchoff et al. 2014
48	SE Alaska	Glacier Bay NP	2010	3-8 July 2010	17 m vessel	strip		unspecified		Kirchoff et al. 2014
49	SE Alaska	Glacier Bay NP	2009	Jul-2009	8.5 m vessel	Line	perpendicular & zigzag	2, unspecified		Hoekman et al. 2011a, 2014
50	SE Alaska	Glacier Bay NP	2010	Jul-2010	8.5 m vessel	Line	perpendicular & zigzag	unspecified		Hoekman et al. 2013, 2014
51	SE Alaska	Glacier Bay NP	2011	Jul-2011	8.5 m vessel	Line	perpendicular & zigzag	unspecified		Hoekman et al. 2013a, 2014
52	SE Alaska	Glacier Bay NP	2012	8-16 July 2012	8.5 m vessel	Line	perpendicular & zigzag	unspecified		Hoekman et al. 2013b, 2014
53	SE Alaska	Glacier Bay NP	2013	6-13 July 2013	8.5 m vessel	Line	perpendicular & zigzag	unspecified		Hoekman et al. 2014
54	N. Gulf of Alaska	Prince William Sound	1972	Jul-1972	8 m boat	strip	parallel to shore	2 , 2		Agler et al 1999; Kuletz et al. 2011a
55	N. Gulf of Alaska	Prince William Sound	1989	Jul-1989	8 m boat	strip	parallel to shore	3, 2, 3, 2		Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
56	N. Gulf of Alaska	Prince William Sound	1990	Jul-1990	8 m boat	strip	parallel to shore	3, 2, 3, 2		Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
57	N. Gulf of Alaska	Prince William Sound	1991	Jul-1991	8 m boat	strip	parallel to shore	3, 2, 3, 2		Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
58	N. Gulf of Alaska	Prince William Sound	1993	Jul-1993	8 m boat	strip	parallel to shore	3, 2, 3, 2		Agler et al. 1998, 1999; Kuletz et al. 2003, 2011a
59	N. Gulf of Alaska	Prince William Sound	1996	Jul-1996	8 m boat	strip	parallel to shore	3, 2		Kuletz et al. 2003, 2011a
60	N. Gulf of Alaska	Prince William Sound	1998	Jul-1998	8 m boat	strip	parallel to shore	3, 2		Kuletz et al. 2003, 2011a
61	N. Gulf of Alaska	Prince William Sound	2000	Jul-2000	8 m boat	strip	parallel to shore	3, 2		Kuletz et al. 2003, 2011a
62	N. Gulf of Alaska	Prince William Sound	2004	Jul-2004	8 m boat	strip	parallel to shore	2		Kuletz et al. 2011a
63	N. Gulf of Alaska	Prince William Sound	2005	Jul-2005	8 m boat	strip	parallel to shore	2		Kuletz et al. 2011a
64	N. Gulf of Alaska	Prince William Sound	2007	Jul-2007	8 m boat	strip	parallel to shore	2		Kuletz et al. 2011a

65	N. Gulf of Alaska	Prince William Sound	2001	Jul-2001		strip		2	intensive survey	Kuletz et al. 2011a
66	N. Gulf of Alaska	Prince William Sound	2009	Jul-2009		strip		2	intensive survey	Kuletz et al. 2011a
67	N. Gulf of Alaska	Kenai Fjords	2006	27 June-15 July 2006	4.8 m vessel	line	perpendicular to shore	4, 4		Arimitsu et al. 2010, 2011
68	N. Gulf of Alaska	Kenai Fjords	2007	27 June-15 July 2007	4.8 m vessel	line	perpendicular to shore	4, 4		Arimitsu et al. 2010, 2011
69	N. Gulf of Alaska	Kenai Fjords	2008	27 June-15 July 2008	4.8 m vessel	line	perpendicular to shore	4, 4		Arimitsu et al. 2010, 2011
70	N. Gulf of Alaska	Kachemak Bay	2005	18-26 July 2005	8 m boat	strip	parallel & zigzag	4		Kuletz et al. 2008
71	N. Gulf of Alaska	Kachemak Bay	2006	18-26 July 2006	8 m boat	strip	parallel & zigzag	4		Kuletz et al. 2008
72	N. Gulf of Alaska	Kachemak Bay	2007	18-26 July 2007	8 m boat	strip	parallel & zigzag	4		Kuletz et al. 2008
73	N. Gulf of Alaska	Lower Cook Inlet	1993	7-23 June 1993	7.6 m boat	line		3	combined species	Agler et al. 1998
74	N. Gulf of Alaska	Lower Cook Inlet	1994	8 Feb-10 March 1994	23 m vessel	line		3	combined species	Agler et al. 1998
75	N. Gulf of Alaska	Alaska Peninsula	2003	18 June-13 July 2003	13 m vessel	line		5		Madison et al. 2011
76	Aleutian Islands	Unalaska Island	2005	15-19 June 2005	4.5 m skiff; 37 m vessel	line	parallel	4		Madison et al. 2011
77	Aleutian Islands	Atka Island	2004	11-13 June 2004	4.5 m skiff; 37 m vessel	line	parallel & perpendicular	4		Madison et al. 2011
78	Aleutian Islands	Adak Island	2006	11-13 June 2006	4.5 m skiff; 37 m vessel	line	parallel	2		Madison et al. 2011
79	Aleutian Islands	Attu Island	2003	17-19 July 2003	4.5 m skiff; 37 m vessel	line	parallel	2		Madison et al. 2011
80	Aleutian Islands	Attu Island	2009	25 July-1 Aug 2009	4.5 m skiff; 37 m vessel	line	parallel	2		Madison et al. 2011
81	Beaufort and Chukchi Sea	Southern Chukchi	1970-2009	April-Aug 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
82	Beaufort and Chukchi Sea	Kotzebue Sound	1970-1999	April-Aug 1970-1999	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
83	Beaufort and Chukchi Sea	Northern Chukchi	1970-2009	April-Aug 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
84	Beaufort and Chukchi Sea	Arctic Ocean	2000-2009	April-Aug 2000-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
85	Beaufort and Chukchi Sea	Beaufort Sea	1970-2009	April-Aug 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
86	Beaufort and Chukchi Sea	Southern Chukchi	1970-2009	Sept-Oct 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
87	Beaufort and Chukchi Sea	Kotzebue Sound	1970-1999	Sept-Oct 1970-1999	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
88	Beaufort and Chukchi Sea	Northern Chukchi	1970-2009	Sept-Oct 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
89	Beaufort and Chukchi Sea	Arctic Ocean	2000-2009	Sept-Oct 2000-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
90	Beaufort and Chukchi Sea	Beaufort Sea	1970-2009	Sept-Oct 1970-2009	various	various	various	2	used data from multiple sources; boot strapped 95% CI	Day et al.2011
91	Russia	Bering Sea	2004	17 July - 11 August	50 m vessel	strip	zigzag	unspecified		Artukhin et al. 2011
92	Russia	Bering Sea	2005	19 July - 8 August	50 m vessel	strip	3–20 km from shore	unspecified		Artukhin et al. 2011
93	Russia	E. coast Kamchatka	1973	26 June–4 July	5 m inflatable motorboat	strip	parallel to shore	unspecified		Vyatkin 1999 Artukhin et al. 2011

94	Russia	E. coast Kamchatka	1975	1–5 August	5 m inflatable motorboat	strip	parallel to shore	unspecified		Vyatkin 1999 Artukhin et al. 2011
95	Russia	E. coast Kamchatka	1990	9–22 June	5 m inflatable motorboat	strip	parallel to shore	unspecified		Vyatkin 1999 Artukhin et al. 2011
96	Russia	E. coast Kamchatka	1994	29 June–1 August	5 m inflatable motorboat	strip	parallel to shore	unspecified		Vyatkin 1999 Artukhin et al. 2011
97	Russia	E. coast Kamchatka	1995	1–2 August	5 m inflatable motorboat	strip	parallel to shore	unspecified		Vyatkin 1999 Artukhin et al. 2011
98	Russia	Eastern Koryak Highlands	1970s-1980s					unspecified		Artukhin et al. 2011
99	Russia	Cape Bering - Cape Serdtse-Kamen	1985	2–14 Aug	Skin-covered boat	strip		unspecified		Konyukhov *et al*. 1998 Artukhin et al. 2011
100	Russia	Cape Bering - Cape Serdtse-Kamen	1985	14 Aug–3 Sept	Skin-covered boat	strip		unspecified		Konyukhov *et al*. 1998 Artukhin et al. 2011
101	Russia	Cape Bering - Cape Serdtse-Kamen	1987	6–10 Aug	Skin-covered boat	strip		unspecified		Konyukhov *et al*. 1998 Artukhin et al. 2011
102	Russia	Cape Bering - Cape Serdtse-Kamen	1991	9–13 August	Skin-covered boat	strip		unspecified		Konyukhov *et al*. 1998 Artukhin et al. 2011
103	Russia	Sea of Okhotsk	2005	21 June–13 July	12 m motor vessel	strip	various	unspecified		Andreev & Van Pelt (2007) Artukhin et al. 2011
104	Russia	Taygonos Peninsula	2008	23 July–1 August	12 m motor vessel	strip	various	unspecified		Artukhin et al. 2011
105	Russia	Okhotsk coast	1993-2007					unspecified		Artukhin et al. 2011

Appendix A. Contributors to the Plan

Scott Gende	NPS – Glacier Bay Field Station, Juneau
David Irons	USFWS – Migratory Bird Management, Region 7
Robb Kaler	USFWS – Migratory Bird Management, Region 7
Michelle Kissling	USFWS – Juneau Field Office
Kathy Kuletz	USFWS – Migratory Bird Management, Region 7
James Lawonn	OSU – Graduate Student, Fisheries and Wildlife
Kim Nelson	OSU - Oregon Cooperative Fish and Wildlife Research Unit
John Piatt	USGS – Alaska Science Center