STATUS AND DISTRIBUTION OF THE KITTLITZ'S MURRELET *BRACHYRAMPHUS BREVIROSTRIS* ALONG THE ALASKA PENINSULA AND KODIAK AND ALEUTIAN ISLANDS, ALASKA

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SUMMARY

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The Kittlitz's Murrelet *Brachyramphus brevirostris* is adapted for life in glacial-marine ecosystems, being concentrated in the belt of glaciated fjords in the northern Gulf of Alaska from Glacier Bay to Cook Inlet. Most of the remaining birds are scattered along coasts of the Alaska Peninsula and Aleutian Islands, where they reside in protected bays and inlets, often in proximity to remnant glaciers or recently deglaciated landscapes. We summarize existing information on Kittlitz's Murrelet in this mainly unglaciated region, extending from Kodiak Island in the east to the Near Islands in the west. From recent surveys, we estimated that ~2400 Kittlitz's Murrelets were found in several large embayments along the Alaska Peninsula, where adjacent ice fields feed silt-laden water into the bays. On Kodiak Island, where only remnants of ice remain today, observations of Kittlitz's Murrelets at sea were uncommon. The species has been observed historically around the entire Kodiak Archipelago, however, and dozens of nest sites were found in recent years. We found Kittlitz's Murrelets at only a few islands in the Aleutian chain, notably those with long complex shorelines, high mountains and remnant glaciers. The largest population (~1600 birds) of Kittlitz's Murrelet outside the Gulf of Alaska was found at Unalaska Island, which also supports the greatest concentration of glacial ice in the Aleutian Islands. Significant populations were found at Atka (~1100 birds), Attu (~800) and Adak (~200) islands. 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. Most of those islands have not been thoroughly surveyed, and significant pockets of Kittlitz's Murrelets may yet be discovered. Our estimate of ~6000 Kittlitz's Murrelets along the Alaska Peninsula and Aleutian Islands is also likely to be conservative because of the survey protocols we employed (i.e. early seasonal timing of surveys, strip transects).

Key words: Kittlitz's Murrelet, *Brachyramphus brevirostris*, Marbled Murrelet, *Brachyramphus marmoratus*, distribution, abundance, marine surveys, Kodiak Island, Aleutian Islands, Alaska Peninsula

INTRODUCTION

The Kittlitz's Murrelet is a small, diving seabird that nests inland and forages in coastal marine waters during the breeding season. Most of what we know about the status and biology of Kittlitz's Murrelet comes from studies in heavily glaciated habitats in the Gulf of Alaska, where the species is comparatively abundant in summer (Agler *et al*. 1999, Day *et al*. 2000, Kuletz *et al*. 2003). In contrast, relatively little is known about this species' status in sparsely glaciated or ice-free areas of the western Gulf of Alaska and Aleutian Archipelago (hereafter Aleutians). Although they have been limited, historical sightings, specimen collections and opportunistic nest discoveries (Day *et al*. 1999) provide evidence that Kittlitz's Murrelets are scattered along the Alaska Peninsula and throughout the Aleutian Archipelago (Fig. 1).

Bent (1916) reported that the first specimen of Kittlitz's Murrelet known to exist in any American museum was collected in Unalaska Harbor in 1877. In the early 1900s, the birds were described as locally common (e.g. at Unalaska and Atka islands) but otherwise difficult to find in the Aleutians (Bent 1916). Kittlitz's Murrelets were eventually observed or collected at several other large Aleutian Islands, including Attu, Adak and Unimak (Fig. 1; Gabrielson & Lincoln 1959, Murie 1959, Gibson & Byrd 2007). Kittlitz's Murrelet has been described as common on Adak Island during summer and a rare winter visitor as well (Byrd *et al*. 1974). The first nest discovery in the Aleutians was on Atka Island (Day & Oakley 1983). More recently, discovery of dozens of nest sites on Agattu Island has yielded new information on nesting habitat in the Aleutians and provided the first measure of reproductive success in the region (Kaler *et al*. 2009).

Similar to knowledge of Kittlitz's Murrelet in the Aleutians, information about this seabird along the Alaska Peninsula has emerged slowly during the past century. Birds were found in scattered bays and lagoons along the south side of the Alaska Peninsula from Cape Douglas to False Pass, including Kinak, Katmai, Puale, Amber, Kuiukta and Pavlov bays (Murie 1959, Bailey & Faust 1981, Day *et al*. 1999) and also near the large lagoons at Port Heiden and Port Moller on the north side in late summer (Bartonek & Gibson 1972, Gill *et al*. 1981). At-sea surveys conducted annually around Kodiak Island since the early 1980s indicate the presence of small numbers of Kittlitz's Murrelets year-round (Stenhouse *et al*. 2008). A single nest was discovered in 2006 (Stenhouse *et al*. 2008), and subsequently dozens of nest sites have been located and studied intensively on western Kodiak Island (Lawonn 2009), providing unique insight into the breeding biology of birds in the Gulf of Alaska. Historically, the Alaska Peninsula has been fertile ground for chance discovery of nests, including three in Katmai National Park (Murie 1959, Day 1995) and two on Pavlov Volcano (the first nest ever described, Thayer 1914) and Frosty Peak (Bailey 1973).

Apparent declines in the Kittlitz's Murrelet within core areas of its range, and concerns about threats from oil pollution, gillnet bycatch and changes in food-webs, prompted its designation in May 2004 as a candidate species for listing under the US *Endangered Species Act* (US Fish and Wildlife Service 2010). At that time, little was known about the status of Kittlitz's Murrelet outside the Gulf of Alaska, in part because of the logistical difficulty of working in remote and exposed marine areas of the Aleutians and in part because the region was considered peripheral to the species' primary range.

The Marbled Murrelet *B. marmoratus* is closely related to Kittlitz's Murrelet, feeds nearshore on small schooling fish, and so faces many of the same threats as Kittlitz's Murrelet in Alaska (Piatt *et al*. 2007). Marbled Murrelets breed from central California to the western Aleutians, occupy a broader range of coastal habitat, but nonetheless overlap extensively in distribution with Kittlitz's Murrelet in both core and peripheral parts of their range (Nelson 1997, Day *et al*. 1999). Indeed, Marbled Murrelets are quite common along the Alaska Peninsula and in the Aleutians where, in contrast to their tree-nesting habit elsewhere, they nest on the ground like Kittlitz's Murrelets (Day & Oakley 1983, Gibson & Byrd 2007). Data compiled in a recent status assessment of Marbled Murrelets in Alaska (Piatt *et al*. 2007) suggest the species has declined in core areas of abundance in the Gulf of Alaska and British Columbia.

We conducted surveys from 2003 to 2009 for *Brachyramphus* murrelets at sites in western Alaska believed to be of particular importance to the Kittlitz's Murrelet. Specifically, our focus included portions of the Alaska Peninsula and Kodiak, Unalaska, Atka, Adak and Attu islands (Piatt *et al*. 2005, 2007, Romano *et al*. 2005a,b, Van Pelt & Piatt 2005). In this paper, we document the status and distribution of *Brachyramphus* murrelets, particularly the Kittlitz's Murrelet, in this under-studied area by summarizing results of those surveys. Although survey protocols were the same in all sites, sampling design varied somewhat among areas owing to limitations on where vessels could travel, safety concerns and time constraints. We reported on Marbled Murrelet populations in this region in a recent status assessment (Piatt *et al*. 2007), but update those estimates here using some refinements to our original analysis.

STUDY AREA

We surveyed for Kittlitz's and Marbled murrelets at sea in three primary areas including (from east to west): Kodiak Island (hereafter Kodiak), the southern coast of the Alaska Peninsula, and the Aleutians (Fig. 1). Meltwater from remnant glaciers drains into the bays and inlets along the rugged coastline of the Alaska Peninsula and Kodiak Island. These areas no longer include tidewater glaciers, but do support small hanging glaciers on slopes of high-elevation mountains and volcanoes. Mountains in northwestern Kodiak are currently glacier-free but are composed of barren, ultramafic rock (Wilson *et al*. 2005), which provides a suitable substrate for nesting Kittlitz's Murrelets (Lawonn 2009).

The Aleutian Archipelago consists of about 150 islands spanning ~2000 km, which are the visible portions of a volcanic, oceanic mountain range linking the Alaska and Kamchatka peninsulas.

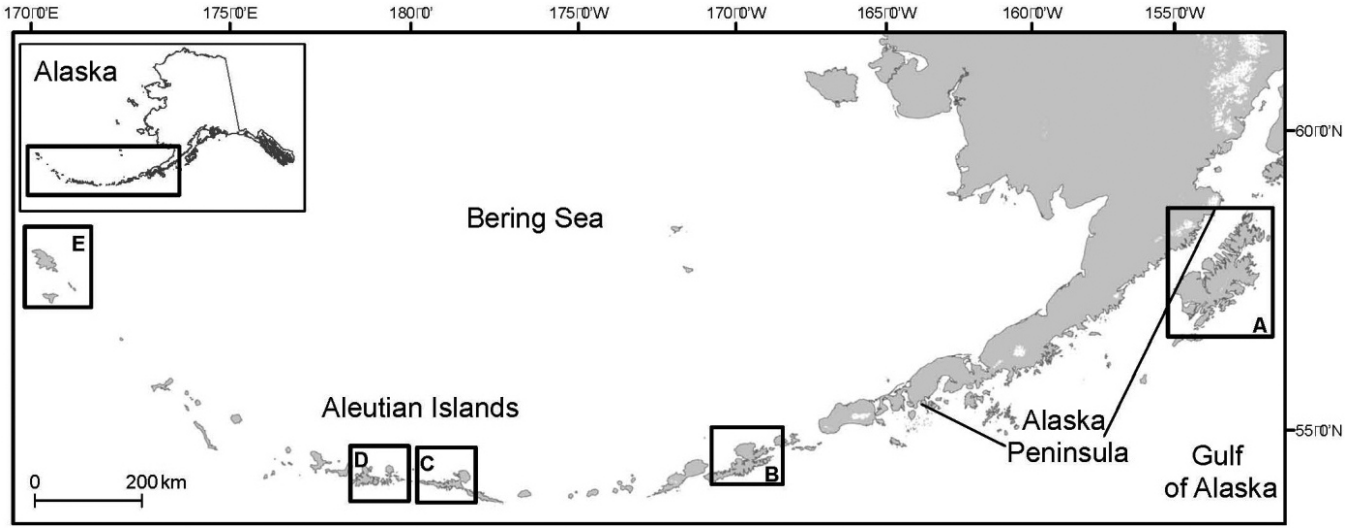

Fig. 1. Study areas at: (a) Kodiak Island, (b) Unalaska Island, (c) Atka Island, (d) Adak Island and (e) Near Islands surveyed for *Brachyramphus* murrelets in 2003–2009. Glacial extent is shown in gray stipple (except for Unalaska).

Several passes through the Aleutian chain permit a general northward flow of Pacific Ocean waters to the Bering Sea, which contributes to local productivity. The Aleutians are characterized by a maritime climate and are known for high winds, cyclonic storms and persistent fog. At least 10 large islands in the eastern and central Aleutians have been reported to contain glaciers currently; these are mainly islands with high (>1200 m) volcanic peaks (Molnia 2008), including Unimak, Unalaska, Umnak, Atka and Tanaga islands. Makushin Volcano on Unalaska Island currently has the greatest concentration of mountainous glaciers in the Aleutian Islands (Molnia 2008). The full extent of glaciation in the Aleutians is unknown, however, owing to the remoteness of the area, nearly perpetual cloud cover on high snow-covered peaks and absence of high-resolution, cloud-free satellite imagery (Molnia 2008). For example, it is not known whether there are any glaciers on the snow-covered peaks of Attu Island, a large, mountainous island at the westernmost end of the Aleutian chain (Fig. 1).

METHODS

Survey design

Our surveys did not benefit from a single design implemented consistently across years and among sites. The layout of survey transects and delineation of sample strata (i.e. nearshore, offshore, protected bays, exposed outer coast) differed depending on *a priori* knowledge of murrelet distribution, local topography and logistical constraints associated with varying survey dates and the use of

TABLE 1
Summary of survey efforts for *Brachyramphus* murrelets by study area along the Alaska Peninsula and Aleutian Islands, Alaska, 2003–2009

Study area and dates	Stratum	Transect length, km	Area sampled, km^2	Stratum area, km^2	% sampled	Total BRMU[a]	% UNMU[a]	% KIMU[a]	% MAMU[a]
Alaska Peninsula, 18 Jun–13 Jul 2003	Outer nearshore 0–0.5 km	369	111	265	41.8	175	16.6	11.4	72.0
	Bay nearshore 0–0.5 km	125	38	235	15.9	52	1.9	17.3	80.8
	Bay offshore >0.5 km	200	60	1705	3.5	199	10.0	34.2	55.8
	Fjord nearshore 0–0.5 km	68	20	114	17.9	336	3.6	4.8	91.7
	Fjord offshore >0.5 km	62	19	272	6.8	148	2.0	6.8	91.2
	Total	824	247	2592	9.5	910	7.1	13.5	79.3
Unalaska Island, 15–19 June 2005	Bays nearshore 0–0.2 km	293	59	85	68.9	1478	6.0	11.7	82.3
	Nearshore 0–0.2 km	148	45	173	25.8	877	15.8	24.9	59.3
	Bays offshore >0.2 km	169	34	85	39.5	196	4.5	8.7	86.7
	Offshore 0.2–5 km	230	69	972	7.1	148	2.4	8.8	68.9
	Total	840	206	1315	15.6	2699	10.1	15.6	74.4
Atka Island, 11–13 June 2004	Offshore 3–10 km	111	33	1422	2.4	1	100.0	0.0	0.0
	Offshore 0.3–3 km	252	76	650	11.6	109	35.8	48.6	15.6
	Offshore bays >0.3 km	34	10	34	30.0	132	18.9	53.8	27.3
	Nearshore 0–0.3 km	272	55	84	64.5	51	33.3	11.8	54.9
	Nearshore bays 0–0.3 km	132	27	42	63.4	136	0.0	32.4	67.6
	Total	801	200	2232	9.0	429	19.1	40.6	40.3
Adak Island, 11–13 Jun 2006	Nearshore 0–0.2 km	477	95	114	83.8	453	1.5	16.3	82.1
	Offshore 0.2–2 km	229	69	413	16.6	96	7.3	17.7	75.0
	Total	706	164	526	31.2	549	2.6	16.6	80.9
Attu Island, 17–19 Jul 2003	Nearshore 0–1 km	389	117	239	32.5	18	38.9	61.1	0.0
	Offshore 1–5 km	391	117	815	14.4	83	47.0	50.6	2.4
	Total	779	234	1054	18.5	101	45.5	52.5	2.0
Attu Island, 25 Jul–1 Aug 2009	Nearshore 0–1 km	252	50	239	21.0	27	29.6	51.9	18.5
	Offshore 1–5 km	419	126	815	15.4	122	17.2	71.3	11.5
	Total	670	176	1054	16.7	149	19.5	67.8	12.8

[a] BRMU = *Brachyramphus* murrelets; UNMU = unidentified murrelets; KIMU = Kittlitz's Murrelets; MAMU = Marbled Murrelets

different survey vessels. For consistency and clarity, we chose to maintain original strata definitions used during the actual surveys at sea, and, therefore, stratum definitions varied among study areas (see Table 1).

Kodiak Island

As part of a pilot study at Kodiak, we conducted surveys 20–28 July 2009 in Viekoda, Uganik, Uyak and Spiridon bays (Fig. 2), where Kittlitz's Murrelet was known to occur historically (Stenhouse *et al*. 2008). We established a set of nearshore and cross-bay transects in the four bays by plotting transects spaced 5 km apart (cross-bay) and perpendicular to shore. A subsample of these transects was then randomly selected for inclusion in the survey. We sampled nearshore transects 100 m offshore when we used a 4.5 m skiff, and 150 m offshore when we used a 16 m vessel (*M/V Alaskan Gyre*). However, rocky nearshore habitat made it impossible to sample within 100–150 m of shore in many areas, and we often had to extend nearshore transects out as far as 500 m. Inclement weather prevented surveys in much of the outer bays and exposed coastline, so we sampled the inner bays more extensively than originally planned. Due to extremely low numbers of Kittlitz's Murrelets observed on transects, and the erratic and incomplete sampling effort, we did not calculate density or extrapolate abundance of murrelets for Kodiak. Here we simply report our few observations and distribution of Kittlitz's Murrelet.

Alaska Peninsula

We used a combination of stratified, systematic and random sampling along the southern coastline from Cape Douglas to Isanotski Strait from 18 June to 13 July 2003 (Fig. 3). We randomly selected whole bays and fjords and systematically surveyed transects within the nearshore (<500 m from shore) and offshore (>500 m from shore) zones of each selected bay and fjord. Along the exposed coastline, outside of all bays and fjords, we divided the shoreline into 5 km segments and randomly selected segments to sample the outer nearshore waters. In total, we sampled five strata: (1) outer nearshore, (2) bay nearshore, (3) bay offshore, (4) fjord nearshore and (5) fjord offshore (see Van Pelt & Piatt 2005 for details). We surveyed areas using a 13 m vessel, the *F/V Alexandria*, with a viewing height of 2.5 m. Densities of murrelets (birds/km^2) on transect were extrapolated to total area within the nearshore zone (<500 m from shore) of bays and outer coastline, and within

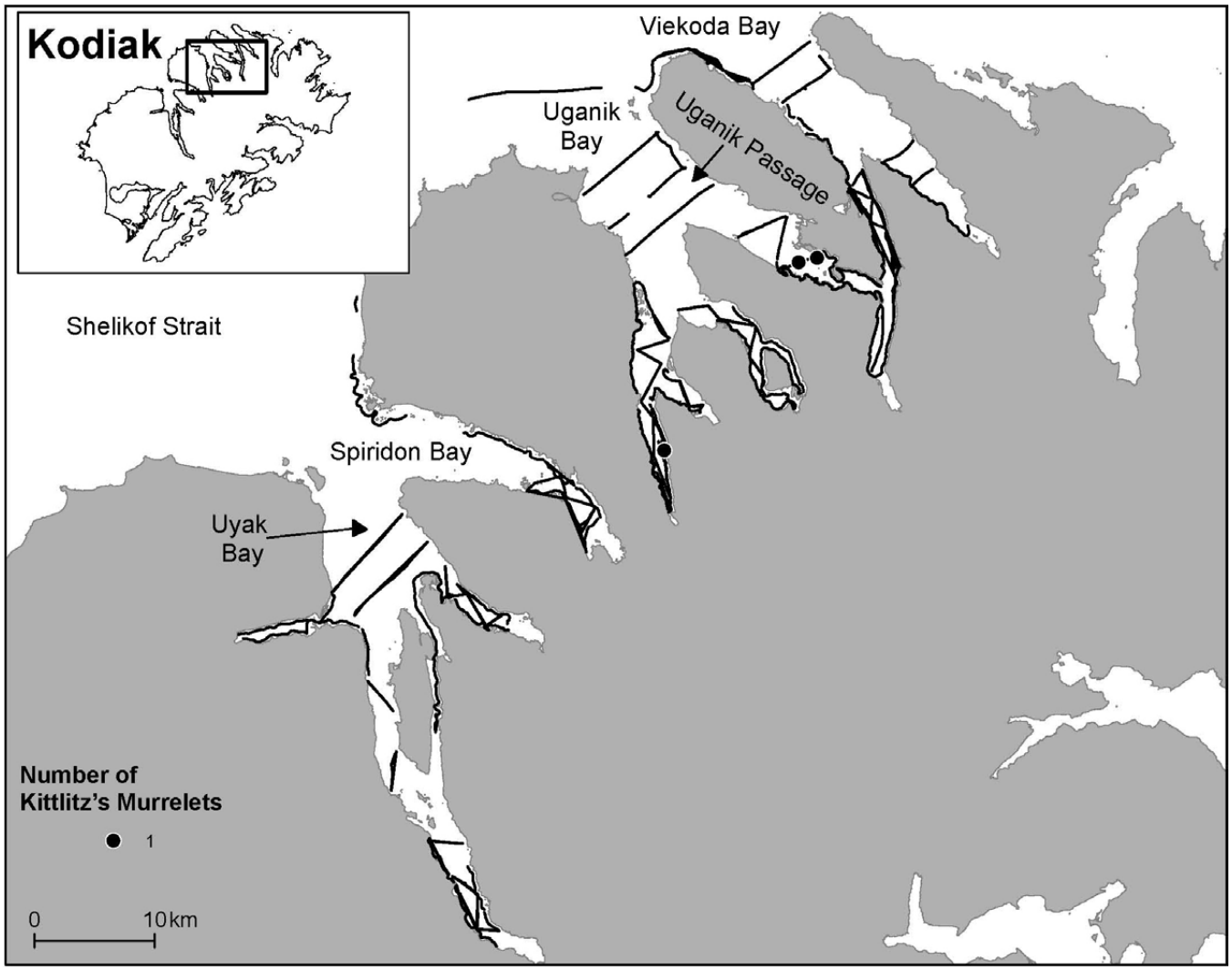

Fig. 2. Survey transects (black lines) and locations of three single Kittlitz's Murrelets sightings during a Kodiak Island survey, 20–28 July 2009.

offshore areas (>500 m from shore) contained within embayments (i.e. inside the area whose outer boundary was defined by a straight line across the mouth of the embayment; see Appendix IV in Van Pelt & Piatt 2005 for details).

Aleutian Archipelago

Unalaska Island.—We were unable to survey the entire perimeter of Unalaska Island with the ship time available to us, so we selected four areas to survey that were likely to harbor most of the Kittlitz's Murrelets residing at Unalaska Island (K. Bell, US Fish and Wildlife Service, pers. comm.): Unalaska Bay, Beaver Inlet, Makushin/Skan Bays, and the southeastern coastline from Eagle Bay to Sedanka Island (Fig. 4). We surveyed the entire coastline or nearshore (<200 m from shore) waters within the selected bays and sampled the offshore waters by randomly selecting and surveying transects spaced 1, 2 and 3 km from shore. We selected these transects by overlaying the entire area with a 10 km grid and randomly choosing one offshore transect within each cell. To simplify this complex design in the analysis, we considered four strata for Unalaska Island: (1) nearshore, (2) offshore, (3) bays nearshore, and (4) bays offshore. The bays nearshore and bays offshore strata included all bays and fjords within the survey area that were at least 200 m wide but not greater than 3000 m wide at the entrance, and at least as long as they were wide at the entrance. The nearshore stratum included all of the survey area within 200 m of the coastline that did not fall within the bays strata. Finally, the offshore stratum included all of the survey area between 200 m and 5 km of the coastline that did not fall within the bays strata (Table 1). In general, we conducted nearshore surveys using a 4.5 m inflatable boat (1.5 m viewing height) and offshore transects using a 37 m vessel, *M/V Tiĝlax̂* (6 m viewing height). Unsurveyed sections of Unalaska Island were not included in the area calculations used to estimate population size.

Atka Island.—At-sea surveys of *Brachyramphus* murrelets were conducted around Atka Island on 11–13 June 2004. Because ship time was limited, we focused on the part of the island with highest potential for observing murrelets (K. Bell, pers. comm.). Nearshore areas (<300 m from shore) were surveyed from 4.5 m inflatable skiffs and offshore areas (>300 m from shore) were surveyed from the 37 m *M/V Tiĝlax̂*. The skiff survey covered approximately 75% of the island's coastline, while the larger vessel opportunistically sampled areas 300 m–10 km offshore (Fig. 5). For safety reasons, the larger vessel usually operated near the skiff (within 1–3 km) and therefore roughly paralleled the coastal survey route. On seven occasions, the ship sampled 9–10 km offshore on paired (out/in) transects (n = 14) oriented perpendicular to the coast. Sampling strata were defined using methods similar to those described above

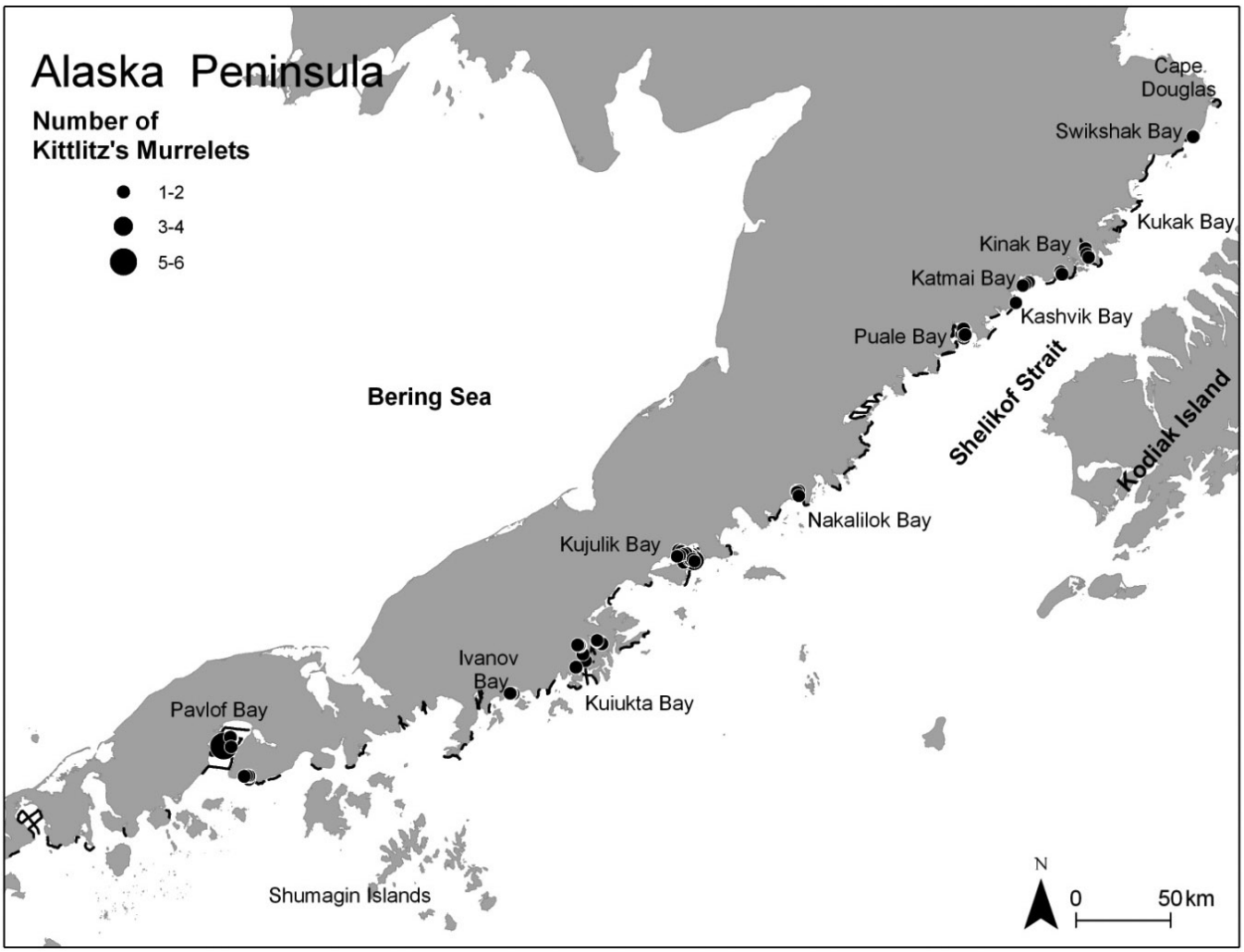

Fig. 3. Survey transects (black lines) and locations of Kittlitz's Murrelets observed along the Alaska Peninsula, 18 June–13 July 2003.

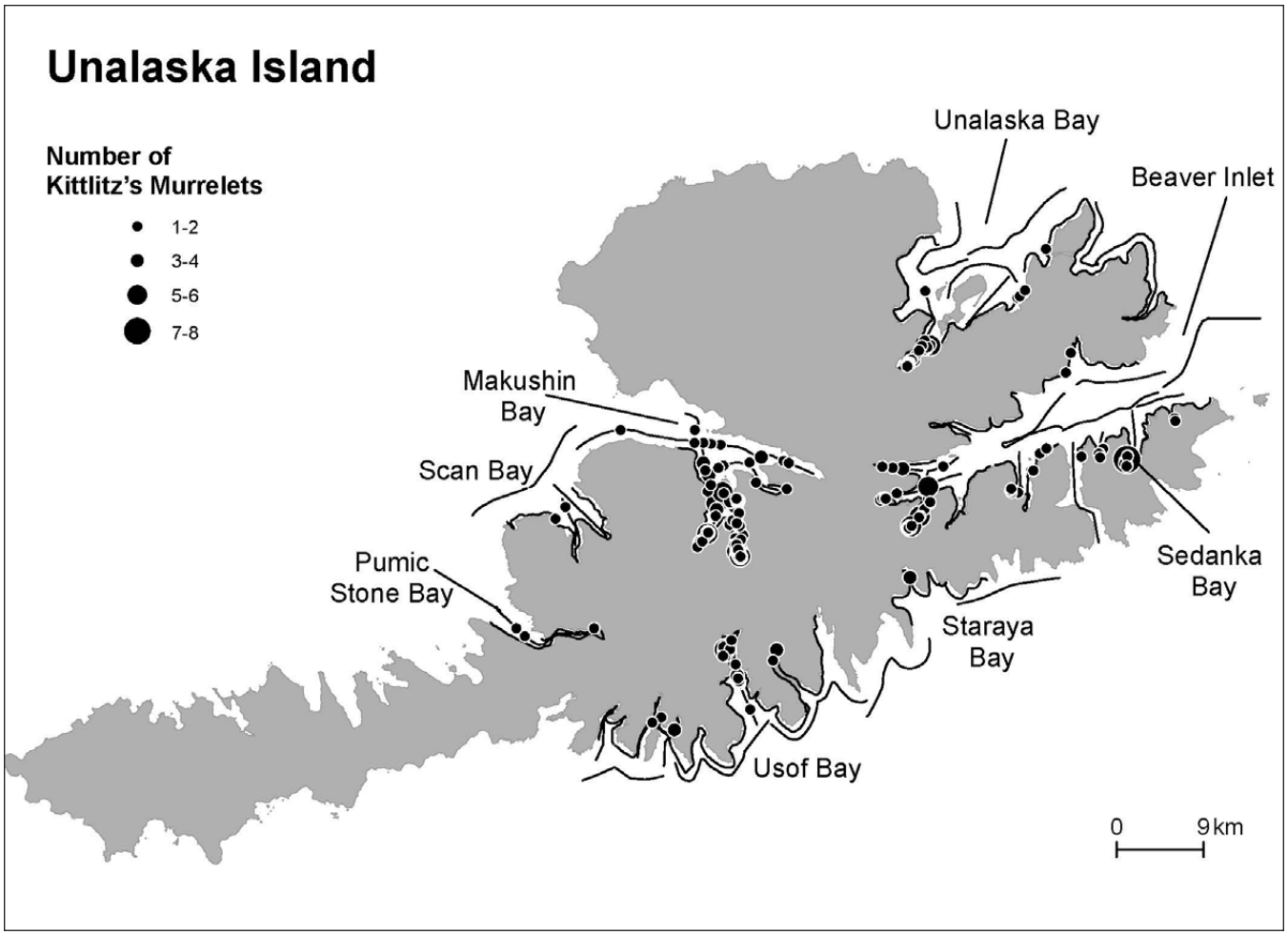

Fig. 4. Survey transects (black lines) and locations of Kittlitz's Murrelets observed during Unalaska Island surveys, 15–19 June 2005.

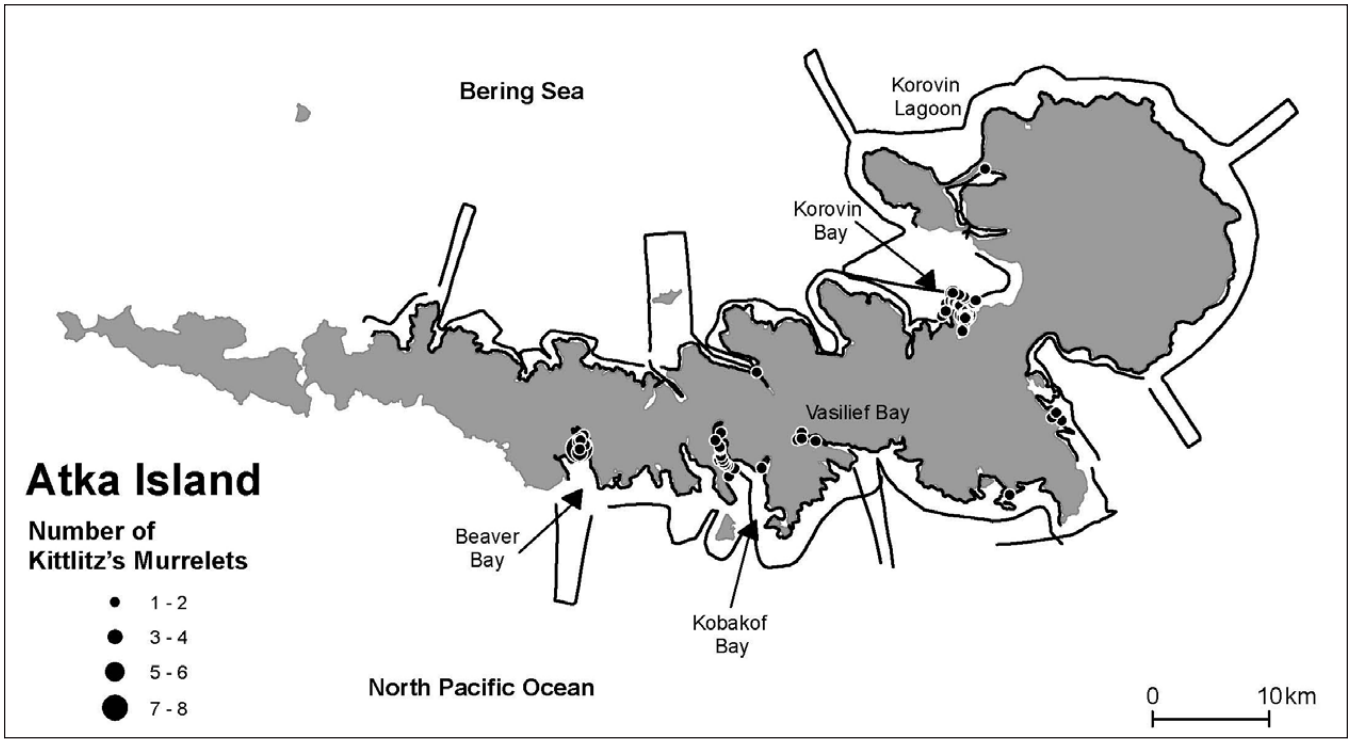

Fig. 5. Survey transects (black lines) and locations of Kittlitz's Murrelets observed during Atka Island surveys, 11–13 June 2004.

for Unalaska Island. A total of five geographic strata were used to estimate density at Atka Island, including: (1) nearshore, (2) offshore 300 m–3 km, (3) offshore 3–10 km, (4) bays nearshore and (5) bays offshore (Table 1).

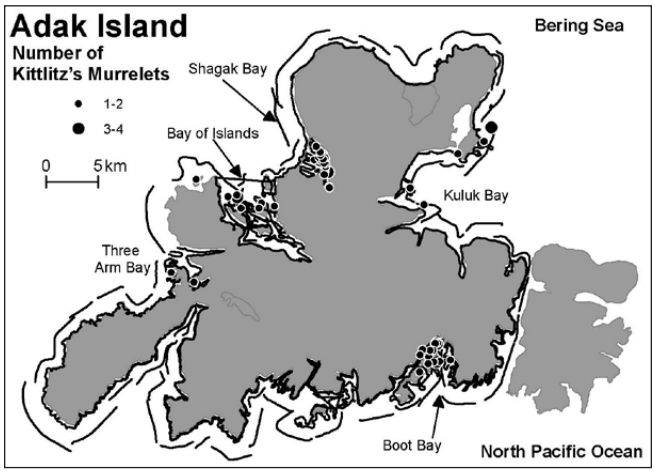

Fig. 6. Survey transects (black lines) and locations of Kittlitz's Murrelets observed during Adak Island surveys, 11–13 June 2006.

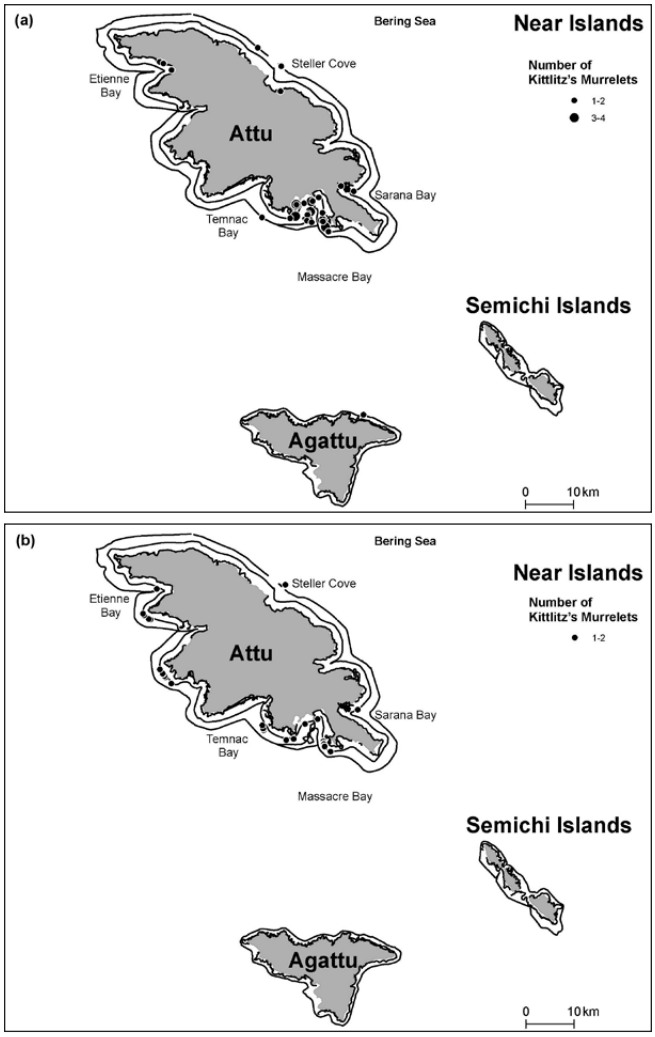

Fig. 7. Survey transects (black lines) and locations of Kittlitz's Murrelets observed during surveys in the Near Islands: (a) 17–19 July 2003 and (b) 25 July–1 Aug 2009.

Adak Island.—We conducted at-sea surveys of Adak Island from 13–17 June 2006 (Fig. 6). Nearshore areas (<200 m from shore) were surveyed from 4.5 m inflatable skiffs and offshore areas (200 –2 km from shore) were surveyed from the 37 m *M/V Tiĝlax̂*. Nearshore surveys covered the entire coastline of the island, and offshore transects at 1 and 2 km from shore were randomly chosen using the same methods employed at Unalaska Island (above). Two geographic strata, nearshore and offshore, were used (Table 1) to estimate densities at sea around Adak Island.

Near Islands.—Kittlitz's and Marbled murrelets were surveyed in the nearshore and offshore waters of the Near Islands, including Attu, Agattu and the Semichi islands on 17–23 July 2003 and again on 25 July–1 August 2009. We used a skiff to survey nearshore areas (<1 km from shore) of each island (Fig. 7). In contrast to other coastal surveys, the skiff used in 2003 was a 7 m rigid-inflatable in which observers stood and were able to census birds 150 m from each side of the vessel. In 2009, a 4.5 m inflatable skiff was used, and transect width was 100 m to either side, as in other surveys described above. The *M/V Tiĝlax̂* surveyed offshore areas (1–5 km from shore) by circumnavigating each island while maintaining a distance of ~1.85 km (1 nautical mile) from shore (Fig. 7); we were able to circumnavigate Attu Island twice, at distances of 1.85 km (1 nautical mile) and 3.70 km (2 nautical miles) from shore (Fig. 7). At the Near Islands, we experienced problems with data logging equipment during the nearshore and offshore surveys in 2003 and nearshore surveys in 2009. We recorded raw counts of species by time and later reconciled our observations with the ship's navigational records.

Density and abundance estimates for murrelets are presented here only for Attu Island, because the majority of murrelets counted on surveys in 2003 (95%) and 2009 (99%) were observed around that island. All nearshore and offshore transects at Attu Island were binned into 10-minute time segments and then separated into two strata for analysis: 0–1 km from shore, and 1–5 km from shore (Table 1). The same area calculations were used for estimating populations in 2003 and 2009.

Survey protocol

In most cases, we initiated surveys in mid-June to coincide with the mid- to late incubation period of Kittlitz's Murrelets in our study areas (Day 1996). This is the phase of the breeding cycle recommended for monitoring Marbled Murrelet population trends, although surveys in July would be better for obtaining peak population counts (Speckman *et al*. 2000). Due to constraints on access to survey vessels, however, we were unable to survey Kodiak and Attu islands until late July, which was presumably during the late chick-rearing or fledging period of murrelets (Day 1996). Attu Island was the only area for which we repeated surveys across years (2003 and 2009), and those surveys occurred on similar dates (17–23 July and 25 July–1 August, respectively; Table 1). Two experienced observers and one recorder identified and enumerated all marine birds and mammals sighted within the survey zone (200 m strip transects from inflatable skiffs or 300 m strip transects from larger vessels) abeam and forward of the vessel (Gould & Forsell 1989, Klosiewski & Laing 1994). We counted all flying birds continuously. We recorded sightings in a data-entry system (dLOG, R.G. Ford Consulting Inc., Portland, Oregon) that logged observations continuously with their geographic coordinates. We monitored weather conditions and recorded the Beaufort sea state

for each transect. If observation conditions were poor for sighting and identifying birds, or if wave height exceeded 0.5 m (small boats) or 1 m (ships), we discontinued the survey until conditions improved.

Data analysis

Within each region, geographic strata were defined relative to distance from shore, or location in bays and fjords (as detailed above). Area calculations were made in ArcGIS (v9.3). Distance from shore for nearshore and offshore areas differed by region because of differences in sampling design, or in some cases, because navigational hazards forced deviations from the intended survey line. To avoid computational errors we estimated population size, density, and log-based confidence intervals by strata in the program DISTANCE (v6.0; Thomas *et al*. 2010). We assumed perfect detection across the strip width for all surveys despite differences in survey platform, observers, weather and other factors. Density estimates were generated by species for each stratum using a uniform key and cosine adjustment after the total number of birds was summed by transect. Global population estimates were calculated as the mean of stratum estimates weighted by stratum area.

Over all surveys, 14% of *Brachyramphus* murrelets observed (n = 4837) were not identified to species; the exact ratio varied by area owing to differing survey conditions and observers (Table 1). We calculated population estimates by prorating unidentified murrelets (Calambodikis & Barlow 2004) on a transect-by-transect basis to obtain total numbers of each species on surveys:

$$M_{A(Total)} = \sum_{i=1}^{n} \left[M_{At} + U_t \left(\frac{M_{At}}{M_{At} + M_{Bt}} \right) \right]$$

where M_t = number of murrelets of species *A* or *B*; *U* is unidentified murrelets observed on transect *t*; and M_{Total} is summed over all n transects. This proration assumes the two murrelet species are equally identifiable—unrealistic perhaps, but necessary in the absence of data on ease of identification (Gerrodette & Forcada 2005). Population estimates included counts on strip transects of all birds on water and all flying birds (Gould & Forsell 1989). The percentage of flying birds in the counts varied among areas: Alaska Peninsula 9%, Unalaska 13%, Adak 3%, Attu (2003) not distinguished, Attu (2009) 50% and Atka 8%.

RESULTS

Kodiak Island

We surveyed 796 linear km (126 km^2) of the northern Kodiak Island coastline (Fig. 2) and recorded 551 murrelets on transects, including <1% Kittlitz's, 76% Marbled, and 24% unidentified *Brachyramphus* murrelets. Despite considerable survey effort, we observed only three Kittlitz's Murrelets, one of which was found near turbid glacier-fed stream outflows in Uganik Bay (Fig. 2).

Alaska Peninsula

We surveyed 824 linear km (247 km^2) of coastline along the Alaska Peninsula, which constituted roughly 10% of the coastal area (Table 1). We observed 910 *Brachyramphus* murrelets, including 14% Kittlitz's, 79% Marbled and 7% unidentified to species. We estimated the population of Kittlitz's Murrelet to be 2382 (95% CI 1272–4480) birds (Table 2). Marbled Murrelets outnumbered Kittlitz's Murrelets more than three-fold in this region (Table 2). The majority of both murrelet species was found within protected bays and fjords. Density of Kittlitz's Murrelet was greatest in the bay offshore stratum (1.13 birds/km^2) and lowest in nearshore areas of the outer coast (0.19 birds/km^2). We observed concentrations of Kittlitz's Murrelets in Kinak, Dakavak, Puale, Nakalilok, Kujulik, Kuiukta, Ivanov and Pavlof bays (Fig. 3).

Aleutian Archipelago

Unalaska Island

We surveyed 840 linear km (206 km^2) of coastline around Unalaska Island, about 16% of the stratum area available to sample. We observed 2702 murrelets on transect, which included 16% Kittlitz's, 74% Marbled and 10% unidentified *Brachyramphus* murrelets. We estimated the population of Kittlitz's Murrelet to be 1642 (95% CI 1090–2473) birds. Marbled Murrelets were about four times more numerous than Kittlitz's Murrelets (Table 2). Kittlitz's Murrelet was distributed throughout the Unalaska Island sampling area, with highest concentrations (49% of all observations) in Makushin Bay and Beaver Inlet (25% of observations; Fig. 4). Kittlitz's Murrelet was most abundant in protected bays and fjords, with only four birds observed on the outer coast.

TABLE 2
Kittlitz's and Marbled murrelet population estimates and coefficients of variation for areas sampled along the Alaska Peninsula and the Aleutian Islands, 2003–2009

Study area	Year	Kittlitz's Murrelet		Marbled Murrelet	
		Population estimate[a]	% coefficient of variation	Population estimate[a]	% coefficient of variation
Alaska Peninsula	2003	2382 (1272–4480)	31.3	7959 (6049–10 423)	14.1
Unalaska Island	2005	1642 (1090–2473)	21.1	6487 (4946–8508)	13.9
Atka Island	2004	1067 (494–2305)	40.9	648 (338–1242)	34.1
Adak Island	2006	197 (101–386)	35.3	920 (614–1378)	20.8
Attu Island	2003	590 (347–1004)	27.6	35 (0–136)	99.3
Attu Island	2009	788 (458–1355)	28.2	120 (50–286)	46.5

[a] Log-based 95% confidence intervals in parentheses.

Atka Island

We surveyed 801 linear km (200 km^2) around Atka Island, about 9% of the available area (Table 1). We counted 429 murrelets; unidentified *Brachyramphus* murrelets accounted for 19% of birds observed during the survey, while Kittlitz's and Marbled murrelets were identified in nearly equal proportions (41% and 40%, respectively). We estimated that the population of Kittlitz's Murrelets was 1067 (95% CI 1090–2473) in the areas sampled (Table 2). Marbled Murrelet density (1.50 birds/km^2) was more than double the Kittlitz's Murrelet density (0.62 birds/km^2) in the nearshore stratum, but Kittlitz's Murrelet was more abundant offshore (Table 1). Overall, Kittlitz's Murrelets were estimated to be 1.6 times more abundant than Marbled Murrelets at Atka Island (Table 2). Kittlitz's Murrelets were clumped in a few large bays around the island (Fig. 5). Beaver, Kobakof and Vasilief bays contained the majority of *Brachyramphus* murrelets on the southern side, whereas murrelets were found mainly in Korovin Bay on the northern side. Within Korovin Bay (Fig. 5), Kittlitz's Murrelets were concentrated in Martin Harbor. No Kittlitz's Murrelets were observed 3–10 km offshore.

Adak Island

We surveyed 706 linear km (164 km^2) around Adak Island (Table 1), about 31% of the area available within defined strata. We observed 549 murrelets, of which 17% were Kittlitz's Murrelet, 81% were Marbled Murrelet and ~3% were unidentified *Brachyramphus* murrelets (Table 1). We estimated a population of 197 (95% CI 101–386) Kittlitz's Murrelets (Table 2). The population of Marbled Murrelet during our surveys was nearly five times that of Kittlitz's Murrelet at Adak (Table 2). Kittlitz's Murrelet was distributed in the inlets, bays and lagoons of Adak Island. The largest concentrations were seen in Shagak Bay and Bay of Islands on the north side of the island and in Boot Bay on the southern coast (Fig. 6). Those three bays provide protection from large swells coming from the Bering Sea and Pacific Ocean.

Near Islands

In 2003 and 2009 we surveyed ~1100 linear km of coastline in the Near Islands, with Attu Island receiving the majority of effort (Table 1). We identified only two Kittlitz's Murrelets on the northern coast of Agattu Island in 2003 (Fig. 7) and none in 2009, although unidentified *Brachyramphus* murrelets were observed in the area. We encountered no Kittlitz's Murrelets around the Semichi Islands in either 2003 or 2009 (Fig. 7). Given the low number of birds observed at Agattu and the Semichis both years, we estimated density and population size of Kittlitz's Murrelet for Attu Island only.

In 2003 we observed 101 *Brachyramphus* murrelets during surveys near Attu Island. Kittlitz's Murrelet accounted for 53%, Marbled Murrelet accounted for <2% and unidentified murrelets accounted for 46% of all *Brachyramphus* murrelets recorded. Experienced observers conducted these surveys, but poor observation conditions resulted in an unusually high frequency of unidentified murrelets. In 2009, 149 *Brachyramphus* murrelets were observed, including 68% Kittlitz's Murrelets, 13% Marbled Murrelets and 19% unidentified to species (Table 1). We estimated the population of Kittlitz's Murrelet at Attu Island was 590 birds (95% CI 347–1004) in 2003 and 788 birds (95% CI 458–1355) in 2009 (Table 2).

At Attu Island, the majority (77%) of Kittlitz's Murrelets were in Massacre Bay (Fig. 7), but we also found smaller numbers in Etienne Bay (6%), Sarana Bay (6%) and Steller Cove (6%). Kittlitz's Murrelets occurred both nearshore and offshore, but they were distributed disproportionately across strata. The majority of Kittlitz's Murrelets observed in Massacre Bay inhabited offshore waters in proximity to several prominent shoals that extend several kilometers from the shoreline.

DISCUSSION

This paper is the first attempt to quantify the abundance and distribution of Kittlitz's Murrelet during the breeding season along the southern coast of the Alaska Peninsula, Kodiak Island and the Aleutians. Our estimates suggest a minimum population of nearly 6100 birds in the region, assuming independence of surveys across years and sites. A partial survey of Kodiak waters suggests a very small at-sea population there. Both Kittlitz's and Marbled murrelets were found along the Alaska Peninsula and the length of the Aleutian chain (Table 2). Marbled Murrelet dominated (>3:1) the marine waters along the Peninsula and near Unalaska and Adak islands (see Piatt *et al*. 2007 for details on Marbled Murrelets in the study area), whereas Kittlitz's Murrelet dominated (>2:1) at Attu and Atka islands. Important murrelet sites shared some marine habitat features, including complex shorelines and protected waters of bays and fjords, often fed by glacial rivers. Kittlitz's Murrelets were rarely found along exposed outer coasts. Population estimates and distribution data presented here establish a baseline for monitoring future population trends as well as a minimum estimate for comparison with Kittlitz's Murrelet populations in the core area of abundance, namely, the more heavily glaciated regions of the Gulf of Alaska (Day *et al*. 1999).

There are several limitations to drawing inferences about murrelet populations based on our surveys. First, although we surveyed much of the prime marine habitat for Kittlitz's Murrelet in the region, some gaps remain. We did not survey several large islands in the Aleutians likely to harbor Kittlitz's Murrelet, and we surveyed only a fraction of the Kodiak Archipelago. Second, strip transects underestimate population size because of the likelihood that not all murrelets within the strip (200–300 m wide) are observed (see Piatt *et al*. 2007 for overview). For example, only about 80% of murrelets within 100 m of a small boat may be detected on surveys (Evans Mack *et al*. 2002), and the probability of detection varies considerably with vessel type (i.e. viewing platform height), number of observers, experience and sea state (Gould & Forsell 1989, Ronconi & Burger 2009). On the other hand, continuous counting of flying birds during a strip census inflates the calculation of abundance (Tasker *et al*. 1984), and this factor varied widely among our surveys. Lastly, timing of surveys can affect counts and therefore population estimates (e.g. Kissling *et al*. 2007, Romano *et al*. 2007, Arimitsu *et al*. 2011). Due to seasonal changes in composition of populations at sea (e.g. incubating breeders, nonbreeders, failed breeders, subadults), the abundance of murrelets on the water is typically lower during incubation (~June) than during chick-rearing (~July), and numbers drop off rapidly post-fledging (early August; Speckman *et al*. 2000, Romano *et al*. 2007, Arimitsu *et al*. 2011). We know nothing about seasonal cycles of murrelets along the Alaska Peninsula or in the Aleutians, but population estimates made in June (Unalaska, Atka, and Adak islands) could be low relative to those made in July (Alaska Peninsula, Attu Island).

We can say little about population trends in the region, because only the Near Islands were surveyed more than once. The estimated Kittlitz's Murrelet population at Attu Island increased from about 600 to 800 birds between surveys in 2003 and 2009 (Table 2), a change that is impossible to interpret with only two years of data. Data collected opportunistically by birdwatchers on visits to Attu Island during spring (mid-May to mid-June) in 23 of 24 years from 1977 to 2000 indicate that Kittlitz's Murrelet was common in Massacre Bay at that time of year (L. Balch, Attours, Inc., unpublished data; see also Gibson & Byrd 2007). The maximum number of Kittlitz's Murrelets recorded by Attours from land-based observation sites averaged 92 birds (SD 77), similar to our ship-based counts in Massacre Bay. Counts exceeding 100 birds (up to 254 birds) were recorded in the 1970s, 1980s and 1990s, with no apparent trend in the data. Together, our surveys and the data from Attours observers hint at population stability near Attu over recent decades—there is no evidence of the rapid and large declines observed in eastern portions of the species' range (e.g. Prince William Sound; Kuletz *et al*. 2011).

The distribution of the Kittlitz's Murrelet has been linked to glacial fjords in southeastern Alaska (Robards *et al*. 2003, Kissling *et al*. 2011) and Prince William Sound (Kuletz *et al*. 2003). Marine habitats affected by tidewater glaciers or glacier-river outflows were preferred by Kittlitz's Murrelets in Prince William Sound (Day *et al*. 2000), Kenai Fjords (Arimitsu 2009) and Glacier Bay (Robards *et al*. 2003). Indeed, it has been hypothesized that apparent population declines of the Kittlitz's Murrelet in the Gulf of Alaska are related to glacial retreat (van Vliet 1993; Kuletz *et al*. 2003). In contrast, the area surveyed in the western Gulf of Alaska and Aleutians is currently devoid of tidewater glaciers, although remnant glacial streams flow into many of the bays and inlets sampled. At Unalaska Island, we found the same affinity of Kittlitz's Murrelet for glacial fjords as documented elsewhere. Unalaska Island has the largest remnant ice fields in the Aleutians and the highest average density of Kittlitz's Murrelet among the areas reported here (Table 2). Elsewhere in the Aleutians, we found no obvious association between glacial river outflows and Kittlitz's Murrelet, though remnant ice is found on many islands with large murrelet populations (Molnia 2008). Similarly, although Kittlitz's Murrelets were scattered along the Alaska Peninsula in rough proximity to glacial ice fields on large volcanoes, no consistent association of birds at sea with glacial river outflows was apparent. Data and imagery on ice in the region are scarce, however (Molnia 2008).

Genetically, Kittlitz's Murrelets from Attu Island and the northern Gulf of Alaska constitute separate evolutionarily significant units (Birt *et al*. 2011). Corresponding phenotypic variation may include adaptations for life in marine habitats less strongly influenced by glacial-marine processes in the Aleutians. If so, the Aleutians may buffer Kittlitz's Murrelet from environmental changes occurring in the Gulf of Alaska, particularly the rapid retreat of glaciers in recent decades (Molnia 2008). As such, it will be useful to study and contrast Kittlitz's Murrelet responses in eastern and western portions of the species' range, and to inquire further into genetic diversity and associations with glacial ice. It will be important to repeat our surveys at key sites in the Aleutians and along the Alaska Peninsula to determine if these peripheral populations track changes observed in core populations in the Gulf of Alaska. This effort will aid the conservation of Kittlitz's Murrelet by defining geographic areas of concern and providing insights into mechanisms that influence distribution, abundance and population trends.

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