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ABUNDANCE AND DISTRIBUTION OF MARBLED AND KITTLITZ'S MURRELETS IN SOUTHCENTRAL AND SOUTHEAST ALASKA[1]

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Abstract. We used small boats to survey Marbled, *Brachyramphus marmoratus,* and Kittlitz's Murrelets, *B. brevirostris* (*Brachyramphus* murrelets) in Lower Cook Inlet, Prince William Sound, and Southeast Alaska. We estimated (± 95% CI) that there were 58,227 ± 16,058 (4.2 birds km^{-2}) murrelets in Lower Cook Inlet in summer and 11,627 ± 7,410 (3.1 birds km^{-2}) murrelets in the eastern half during winter. We estimated a mean of 113,652 ± 25,900 (12.7 birds km^{-2}) murrelets in Prince William Sound in four summers and a mean of 24,979 ± 11,710 (2.8 birds km^{-2}) murrelets in four winters. An estimated 687,061 ± 201,162 (19.4 birds km^{-2}) murrelets were in Southeast Alaska in summer 1994. The summer population of all three areas was estimated to be between 655,482 and 1,062,398 murrelets. Winter abundance for the eastern portion of Lower Cook Inlet and Prince William Sound ranged from 22,646 to 50,164. *Brachyramphus* murrelets were distributed in low densities throughout each of the three study areas, although abundance was not uniform; there were areas of high densities within each study area. The largest densities were found in Southeast Alaska.

Key words: Alaska, Brachyramphus brevirostris, Brachyramphus marmoratus, *distribution, Kittlitz's Murrelet, Marbled Murrelet, population abundance.*

INTRODUCTION

In North America, Marbled Murrelets (*Brachyramphus marmoratus*) range from the Bering Sea south to central California (Ralph et al. 1995). The total North American population of Marbled Murrelets has been estimated as 300,000 birds (Ralph et al. 1995), and approximately 85% of this population breeds in Alaska (Mendenhall 1992, Piatt and Naslund 1995, Ralph et al. 1995). Marbled Murrelets are found along the coast of Alaska, but most of the population is located in southcentral and southeastern Alaska (Piatt and Ford 1993). Abundance declines rapidly south of Alaska, and populations are small and fragmented in British Columbia, Washington, Oregon, and California (Ralph et al. 1995).

Kittlitz's Murrelets (*B. brevirostris*) are restricted to Alaska, northeastern Siberia, and the Sea of Okhotsk, but the majority of individuals occur in Alaska (van Vliet 1993). The distribution of the Kittlitz's Murrelet is less continuous than the Marbled Murrelet. Kittlitz's Murrelet breeding populations generally are associated with tidewater glaciers, remnant high elevation glaciers, and recently de-glaciated regions (Isleib and Kessel 1973). Kittlitz's Murrelets inhabit a range similar to Marbled Murrelets within Alaska but are not found in parts of Southeast Alaska (Mendenhall 1992, Ralph et al. 1995). Present worldwide populations are estimated to be < 20,000 (van Vliet 1993).

Some evidence suggests that *Brachyramphus* murrelet populations in both Alaska and British Columbia have declined substantially over the past 10–20 years (van Vliet 1993, van Vliet and McAllister 1994, Ralph et al. 1995). Recent declines of Marbled Murrelets in the southern portion of their range and fragmentation of their preferred breeding habitat in old-growth forests resulted in the U.S. Fish and Wildlife Service's (USFWS) 1992 listing of this species as threatened in Washington, Oregon, and California (Stein and Miller 1992) and the 1990 listing as nationally threatened in Canada (Ralph et al. 1995). *Brachyramphus* murrelet populations in Alaska are of concern because of their status in Canada and other regions of the United States.

The best source of information about the distribution and abundance of *Brachyramphus* murrelets comes from data obtained at sea (Ralph et al. 1995). Murrelet nests are difficult to find, and detections of calls in nesting areas provide in-

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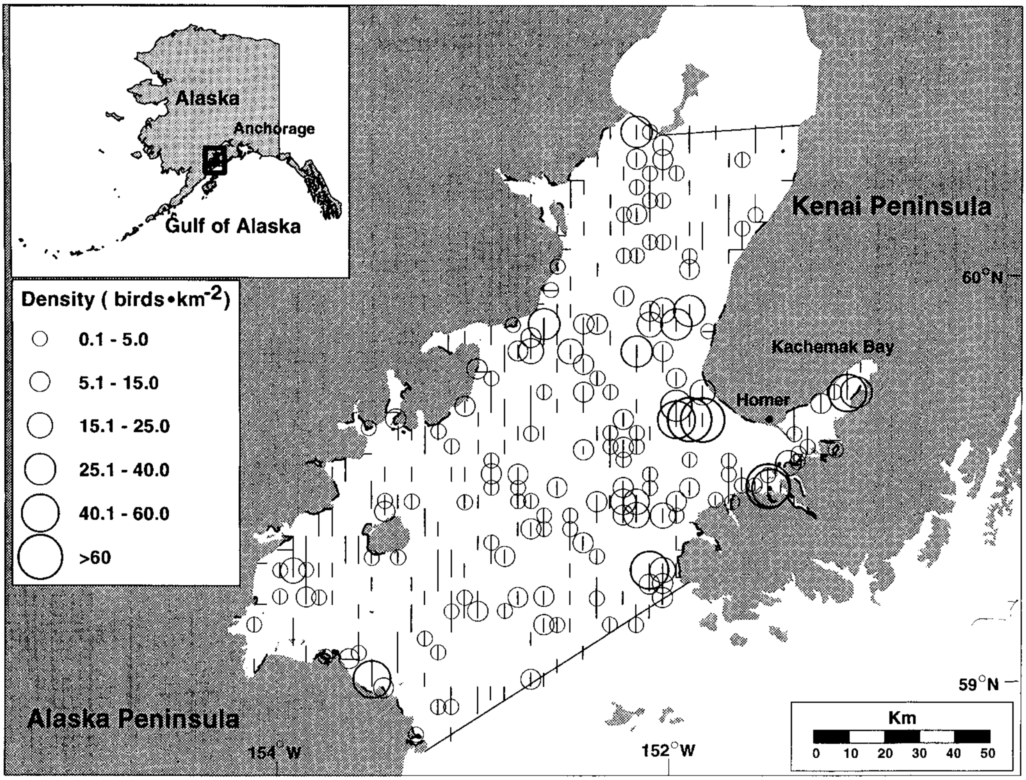

FIGURE 1. Density (birds km^{-2}) of *Brachyramphus* murrelets from a small boat survey of Lower Cook Inlet during summer 1993. Dark lines along the shore represent shoreline transects and vertical or horizontal lines represent offshore transects. The circles show the density of birds and the size of each circle is dependent upon the number of observations for that transect.

dices of activity but cannot be translated into absolute numbers of birds. Previous marine bird surveys in Alaska were conducted in offshore waters (Piatt and Ford 1993). Piatt and Ford (1993) used data from the Outer Continental Shelf Program (OCSEAP) to estimate that the murrelet population of Alaska was 160,000 birds. This estimate was revised to include data from the small boat surveys of Prince William Sound (Agler et al. 1994, 1995c, Klosiewski and Laing 1994) and Lower Cook Inlet (Agler et al. 1995a) presented here, and they estimated the Alaska population as 280,000 birds (Piatt and Naslund 1995).

Recent work has shown that surveys of *Brachyramphus* murrelet populations must be designed to focus on nearshore waters frequented by murrelets (Ralph et al. 1995). The length and remoteness of the Alaska shoreline has restricted systematic surveys of this region. We conducted small boat surveys within three nearshore areas of Alaska (Lower Cook Inlet, Prince William Sound, and Southeast Alaska) to estimate the abundance of marine birds. We present estimates of abundance for *Brachyramphus* murrelets from each of these three areas and a total estimate from all three areas combined. These surveys fill an important gap in our knowledge of *Brachyramphus* murrelet abundance and distribution within southcentral and Southeast Alaska.

METHODS

STUDY AREAS

From west to east, the study areas were: Lower Cook Inlet, Prince William Sound, and Southeast Alaska. Located on the western side of the Kenai Peninsula, Lower Cook Inlet (Fig. 1) was surveyed in June (summer) 1993 and February–March (winter) 1994. In summer, we surveyed 2.2% of the 13,791 km^2 study area (Table 1).

TABLE 1. Area surveyed (km^2), percentage of area surveyed, number of transects surveyed, and percent of blocks randomly sampled, listed by stratum, for three areas in Alaska (Lower Cook Inlet, Prince William Sound, and Southeast Alaska) and used to estimate population abundance of *Brachyramphus* murrelets during summer and winter.

	Area surveyed (km^2)						Number of transects				
	Amount			Percent of total							
Area	Near[a]	Off[b]	Total	Near	Off	Total	Near	% of blocks	Off	% of blocks	Total
Summer											
Lower Cook Inlet	244	13,547	13,791	30.0	1.7	2.2	86	30	325	30	411
Prince William Sound	821	8,161	8,982	28.7	2.2	4.6	212	29	138	24	350
Southeast Alaska	4,690	30,778	35,468	3.2	0.5	0.8	191	3	440	3	631
Winter											
Lower Cook Inlet	68	3,593	3,661	4.7	3.1	4.0	37	50	148	50	185
Prince William Sound	821	8,161	8,982	13.6	1.8	2.9	97	13	106	18	203

[a] Nearshore stratum.
[b] Offshore stratum.

The winter study area was smaller (3,661 km^2), and we surveyed 4% of the total area (Fig. 2, Table 1).

Prince William Sound, located on the eastern side of the Kenai Peninsula, was surveyed in July (summer) 1989, 1990, and 1991, and 1993 (Fig. 3), and March (winter) 1990, 1991, 1993, and 1994 (Fig. 4). The study area of 8,982 km^2 included all waters within the Sound, except for Orca Inlet (Table 1). We surveyed 4.6% and 2.9% of the total area during summer and winter, respectively.

Southeast Alaska was the largest of the three areas surveyed, covering an area of over 35,000 km^2 (Fig. 5, Table 1). The western and southern boundaries were defined as all waters within 5.6 km of shore. We surveyed 0.8% of the total area (Table 1).

DATA COLLECTION

Unless otherwise noted, murrelet refers to both species of *Brachyramphus* murrelets, and we use the common name when referring to a particular species. Survey methods were similar among study areas (Agler et al. 1994, 1995a, 1995b, 1995c, Klosiewski and Laing 1994) to facilitate comparison. We divided each study area into two strata: (1) nearshore (all waters $\leq$ 200 m from land), and (2) offshore (all waters > 200 m from land).

To survey Lower Cook Inlet (summer) and Prince William Sound (summer and winter), we identified and counted birds from three 7.6 m long boats traveling at speeds of 10–15 km hr^{-1}. We surveyed each of these two study areas in $\leq$ 3 weeks to obtain a narrow "snapshot" in time of abundance and distribution. In summer 1993, we surveyed Lower Cook Inlet between 7 and 23 June. We surveyed Prince William Sound over several years during summer (3–30 July) and winter (7–28 March). Within Prince William Sound, we surveyed the same transects each year and calculated a mean of the abundance estimates. In Southeast Alaska, we surveyed during summer 1994 (9 June–27 July). During winter 1994, we surveyed the eastern portion of Lower Cook Inlet (Fig. 3). We divided this study area into three strata: nearshore, bay, and pelagic. We surveyed the nearshore and bay strata between 6 February and 5 March 1994 with the three small boats, and we surveyed the pelagic stratum from 8 February to 10 March 1994 from a 22.3 m vessel. For comparison with Prince William Sound and Southeast Alaska, we combined the bay and pelagic strata into an offshore stratum.

In all surveys, two observers on each boat surveyed a sampling window 100 m on either side, ahead of, and above the vessel. Ralph and Miller (1995) found this to be the effective survey area for detection of Marbled Murrelets at sea. We assumed that all birds on a transect were detected. Observers sampled continuously and used binoculars to aid in species identification. We recorded sightings by species when possible. Because of the difficulty of distinguishing between Marbled and Kittlitz's Murrelets, however, most birds were recorded as *Brachyramphus* murrelets.

Observers changed from year to year but re-

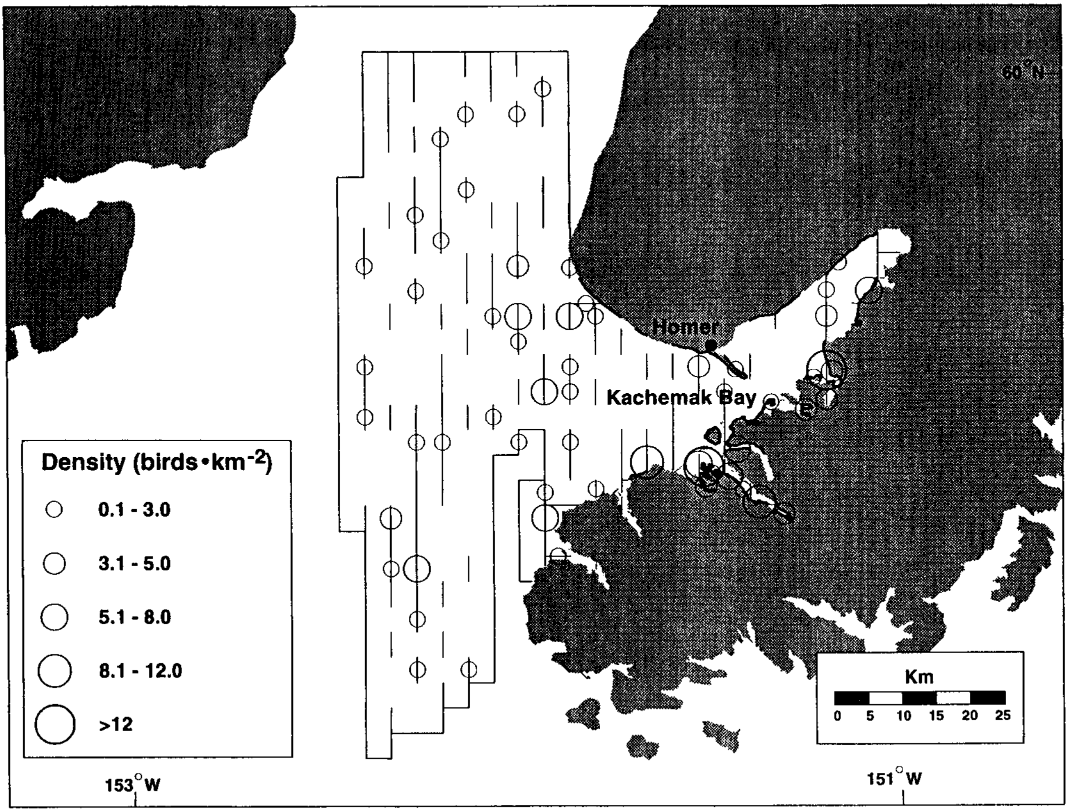

FIGURE 2. Density (birds km^{-2}) of *Brachyramphus* murrelets from a boat survey of the eastern portion of Lower Cook Inlet during winter 1994. Dark lines along the shore represent shoreline transects and vertical or horizontal lines represent offshore transects. The circles show the density of birds and the size of each circle is dependent upon the number of observations for that transect.

mained the same within a single survey. To reduce the bias of inter-observer variability, observers were trained to follow protocols prior to each survey. Observers practiced estimating distances with a duck decoy, and during winter 1994, radar was added to the survey vessels, allowing us to measure our distance from land more accurately. We surveyed during all phases of the tidal cycle. To avoid missing *Brachyramphus* murrelets, most transects were surveyed when wave height was ≤ 0.3 m and were not surveyed when wave height exceeded 0.6 m.

STRATIFICATION

To separate the starting points of the transects, we divided each stratum (nearshore and offshore) into latitude-longitude blocks. We then randomly chose a sample of these blocks from each stratum (Table 1). Sizes of the randomly-chosen blocks differed among areas: (1) Lower Cook Inlet (3.7-km long blocks), (2) Prince William Sound (nearshore stratum by habitat; offshore stratum by 9.3-km long blocks), and (3) Southeast Alaska (1.9-km long blocks). In Lower Cook Inlet and Southeast Alaska, we surveyed one edge of a chosen block. In Prince William Sound, we surveyed two north-south transect lines, each 200 m wide, located one minute of longitude inside the eastern and western boundaries of a chosen block. Sometimes adjacent blocks were chosen randomly, resulting in the appearance of one long transect. We paused between transects to collect environmental data and to increase independence of the sampling units.

DATA ANALYSIS

We used a ratio estimator (Cochran 1977) to estimate population abundances and variances for each strata, then calculated area-wide population

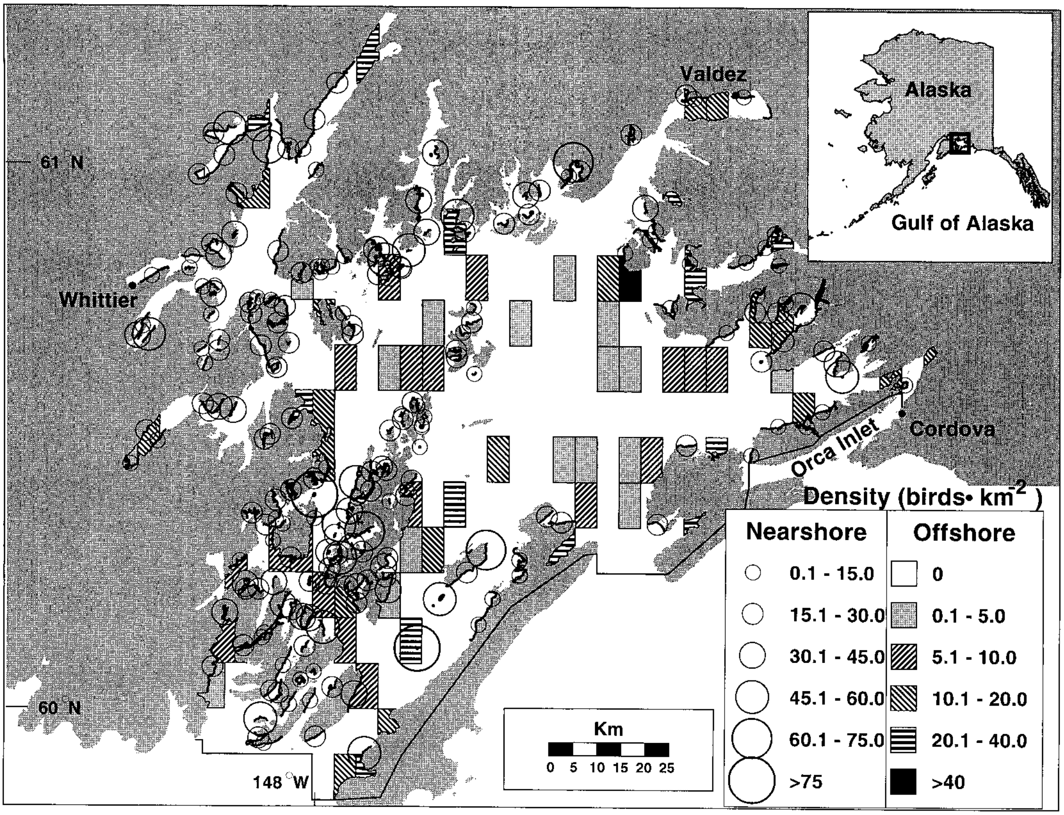

FIGURE 3. Mean density (birds km^{-2}) of *Brachyramphus* murrelets from small boat surveys of Prince William Sound during summer 1989–1991 and 1993. Nearshore transects are shown with dark lines along the shore and offshore transects are shown as blocks. Circles represent densities on nearshore transects, and shading patterns denote densities in offshore blocks.

estimates by adding the estimates for each stratum. We calculated 95% confidence intervals for these estimates from the sum of the variances of each stratum. To calculate a total population estimate for all three study areas combined, we summed the estimates then recalculated the confidence intervals (CI) and coefficients of variation (CV) from the summed variances.

To compare study areas within Alaska, we calculated bird densities for each study area. To calculate this we divided the total population of the study site by the total area. To examine the distribution patterns of murrelets among study areas, we plotted densities with a geographical information system (Strategic Mapping 1992). These densities were determined by dividing the number of birds recorded on a transect by the area of that transect. Transects were distributed throughout the study area, but, due to the random distribution of the transects, some localities (e.g., the middle of Frederick Sound, Fig. 5) were not surveyed. Thus, these maps provide a general indication of murrelet abundance and distribution within a study area.

RESULTS

We estimated (n ± 95% CI) that 58,227 ± 16,058 *Brachyramphus* murrelets occurred in Lower Cook Inlet in summer 1993, a mean of 113,652 ± 25,900 murrelets was in Prince William Sound in summer 1989–1991 and 1993, and 687,061 ± 201,162 murrelets were in Southeast Alaska in summer 1994 (Table 2). Thus, most (~76%) *Brachyramphus* murrelets occurring in our study areas in summer occurred in Southeast Alaska. Lower Cook Inlet represented only 6% of the total population, and Prince William Sound contained 18% of the total estimated population in the study areas. Our sample represented 2% of the estimate for Low-

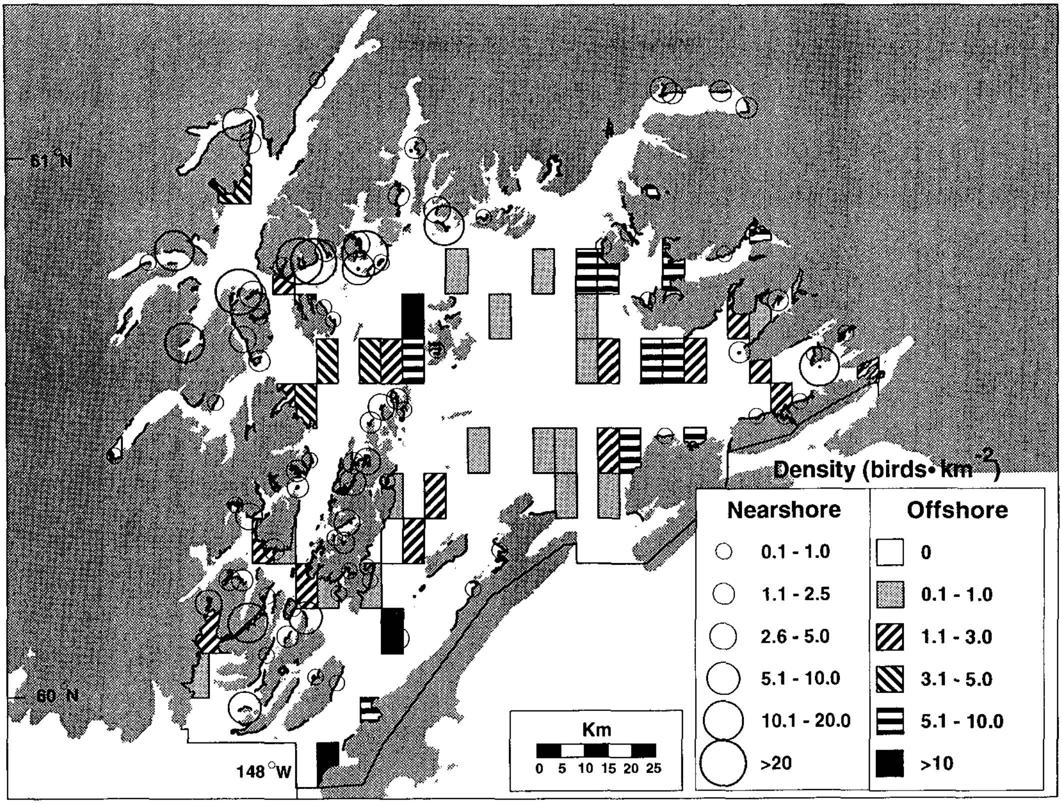

FIGURE 4. Mean density (birds km^{-2}) of *Brachyramphus* murrelets from small boat surveys of Prince William Sound during winter 1990, 1991, 1993, and 1994. Nearshore transects are shown with dark lines along the shore and offshore transects are shown as blocks. Circles represent densities on nearshore transects are circles, and shading patterns denote densities in offshore blocks.

er Cook Inlet, 6% of the estimate for Prince William Sound, and 1% of the estimate for Southeast Alaska (Table 3).

The estimated winter population of *Brachyramphus* murrelets in the eastern portion of Lower Cook Inlet was 11,627 ± 7,410 murrelets. The mean of the estimates from Prince William Sound was 24,979 ± 11,710 murrelets during winter 1990, 1991, 1993, and 1994 (Table 2). Winter estimates for both areas were lower than summer estimates, suggesting that most *Brachyramphus* murrelets leave Lower Cook Inlet and Prince William Sound for the winter.

Total summer density estimates were highest in Southeast Alaska, intermediate in Prince William Sound, and lowest in Lower Cook Inlet (Table 2). Winter density estimates were similar between eastern Lower Cook Inlet and Prince William Sound (Table 2). In both Lower Cook Inlet and Southeast Alaska, the summer densities in the offshore stratum were higher than in the nearshore stratum (Table 2). In Prince William Sound, however, nearshore densities were much greater than offshore densities. During the winter, densities were fairly similar between strata (Table 2).

Most birds were not identified to species. In Lower Cook Inlet, 81% were identified only as *Brachyramphus* murrelets, and in Prince William Sound, 62% were identified in this manner, whereas, in Southeast Alaska, 63% of murrelets were classified as Marbled Murrelets. The percentage of the birds recorded as Kittlitz's Murrelets decreased from west to east: Lower Cook Inlet (6%), Prince William Sound (3%), and Southeast Alaska (1%).

In summer 1993, *Brachyramphus* murrelets were observed throughout Lower Cook Inlet; the

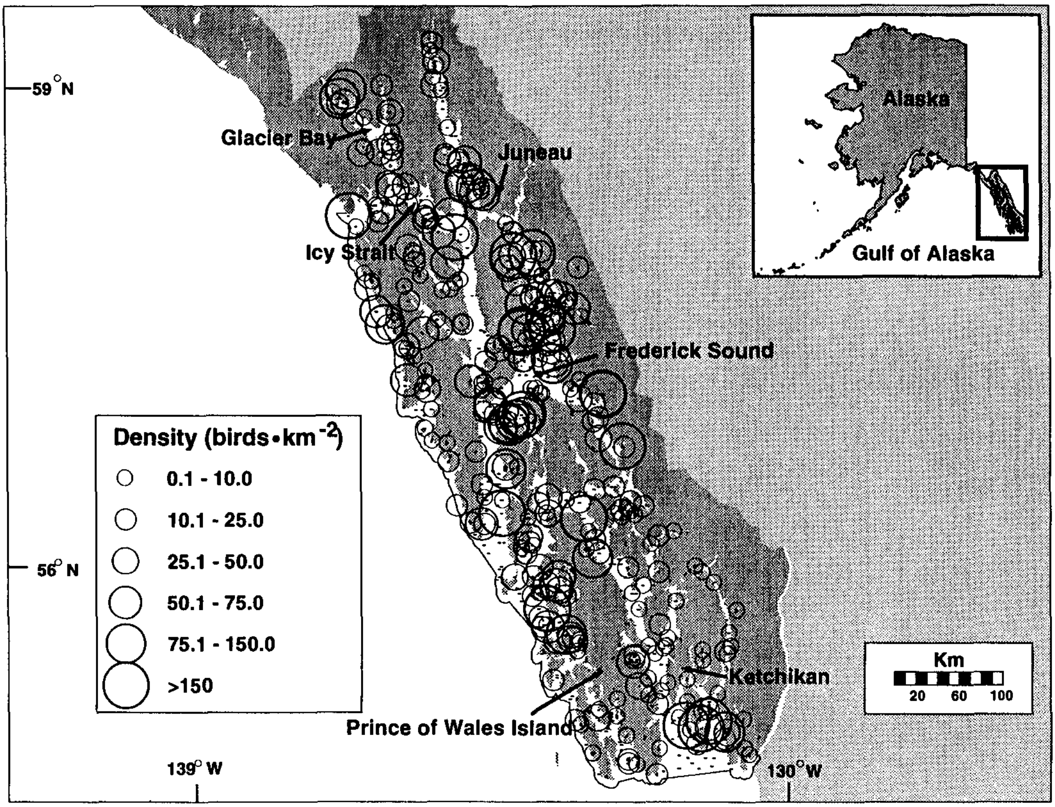

FIGURE 5. Density (birds km^{-2}) of *Brachyramphus* murrelets from a small boat survey of Southeast Alaska during summer 1994. Dark lines along the shore represent shoreline transects and vertical or horizontal lines represent offshore transects. The circles show the density of birds and the size of each circle is dependent upon the number of observations for that transect.

largest numbers were observed on the outer edge and on the south side of Kachemak Bay (Fig. 1). Murrelets also were distributed in lower densities throughout the central and eastern portions of the Inlet. During the winter 1994 surveys of eastern Lower Cook Inlet, densities of murrelets were greatly reduced, but most observations of *Brachyramphus* murrelets occurred in protected waters on the south side of Kachemak Bay (Fig. 2).

In Prince William Sound, *Brachyramphus* murrelets occurred throughout the nearshore portions of the Sound during the summer, with highest densities in the southwestern and northern portions (Fig. 3). Murrelets were found in low densities offshore (Fig. 3). During winter, the highest densities in the nearshore stratum were found in the northwestern portion of the Sound (Fig. 4). The highest offshore densities of *Brachyramphus* murrelets occurred along the northwest corner of Naked Island and in the southwestern portion of the Sound (Fig. 4).

In Southeast Alaska, *Brachyramphus* murrelets were distributed throughout the study area during summer 1994. The largest densities were observed west of Prince of Wales Island, in Frederick Sound, south of Ketchikan, and south of Juneau (Fig. 5).

In summer, the total *Brachyramphus* population for the three study areas combined was 858,940 ± 203,458 birds. Thus, *Brachyramphus* murrelet population size in summer ranged from 655,482 to 1,062,398 birds. The winter estimate calculated only for Prince William Sound and the eastern portion of Lower Cook Inlet was 36,405 ± 13,759 birds. The estimated density of murrelets for the combined study areas was 14.7 birds km^{-2} in summer and 2.9 birds km^{-2} in winter.

TABLE 2. Estimates of population abundance ($n \pm 95\%$ CI) and densities (birds km^{-2}) for *Brachyramphus* murrelets in three areas of Alaska during summer. Winter estimates from Prince William Sound and Lower Cook Inlet only.

Area	Nearshore *n*	Nearshore Density	Offshore *n*	Offshore Density	Total *n*	Total Density
Summer						
Lower Cook Inlet	447 ± 345	1.8	57,780 ± 16,055	4.3	58,227 ± 16,058	4.2
Prince William Sound	18,312 ± 3,090	22.3	95,340 ± 25,715	11.7	113,652 ± 25,900	12.6
Southeast Alaska	84,807 ± 40,695	18.1	602,254 ± 197,003	19.6	687,061 ± 201,162	19.4
Winter						
Lower Cook Inlet	144 ± 65	2.1	10,126 ± 7,388	3.2	11,627 ± 7,410	3.1
Prince William Sound	1,891 ± 1,023	2.3	23,088 ± 11,666	2.8	24,979 ± 11,710	2.8

DISCUSSION

Because nest sites are difficult to find, counting Marbled Murrelets at sea currently is the best method for estimating the size of regional populations (Ralph et al. 1995, Strong et al. 1995). At-sea surveys, such as those conducted here, can cover large regions and be standardized for repeatability. Thus, data from these surveys of the inshore waters of Alaska provide important information regarding the abundance and distribution of *Brachyramphus* murrelets in Alaska. We surveyed much of the primary *Brachyramphus* murrelet habitat within Alaska; thus, our estimate provides an index of the state-wide population.

Previous estimates of the *Brachyramphus* murrelet population in Alaska were lower than those reported here. Mendenhall (1992) reported one statewide estimate of 250,000 birds, based upon partial surveys and qualitative reports. Piatt and Naslund (1995), using a combination of estimates from OCSEAP data and from the small boat surveys of Prince William Sound (Agler et al. 1994, 1995c, Klosiewski and Laing 1994) and Lower Cook Inlet (Agler et al. 1995a), estimated the *Brachyramphus* murrelet population of Alaska, including the Aleutians, as 280,000 birds. The OCSEAP surveys covered 40,000 km of transect and included over 15,000 observations of murrelets. Although the OCSEAP surveys were geographically extensive, they did not necessarily represent all areas because they were unable to survey nearshore waters (Piatt and Naslund 1995) where most murrelets occur (Ralph et al. 1995). Survey effort within Prince William Sound and Southeast Alaska, where most of the Alaska population of *Brachyramphus* murrelets reside, was limited (Piatt and Naslund 1995). The results of our small boat surveys represent the first population estimates for *Brachyramphus* murrelet populations within three important nearshore habitats of Alaska.

Although *Brachyramphus* murrelets are resident year-round in Alaska waters, those from the northern Gulf of Alaska are believed to overwinter in Southeast Alaska and British Columbia (Piatt and Naslund 1995). Burger (1995) and Speich and Wahl (1995) suggested that in winter murrelets move from the outer, exposed coast of Vancouver Island and the Straits of Juan de Fuca into the sheltered and productive waters of northern and eastern Puget Sound. Our winter estimates for both Lower Cook Inlet and Prince William Sound were lower than summer estimates, supporting the hypothesis that murrelets exhibit seasonal movement away from inshore summer breeding localities in these areas (Kuletz 1996).

POSSIBLE SOURCES OF ERROR

There are few seabird population estimates based on at-sea counts. Population estimates based on such counts are subject to several sources of error, and these sources and their magnitudes vary with location and season (Ralph et al. 1995). Several factors, described below, might have caused biases in the population estimates presented in this paper, resulting in under- or overestimation of population size.

(1). Bird flux through transect. We counted birds continuously, which may have overestimated abundance of murrelets by measuring bird flux instead of density (Tasker et al. 1984, Gould and Forsell 1989). To minimize the problem of birds flying through transects, we used a small

TABLE 3. Number of *Brachyramphus* murrelets sighted in three areas of Alaska (Lower Cook Inlet, Prince William Sound, and Southeast Alaska) and used to estimate population abundance during summer.

Area	Species	Stratum		
		Nearshore	Offshore	Total
Lower Cook Inlet	Marbled Murrelet	31	132	163
	Kittlitz's Murrelet	16	57	73
	Brachyramphus murrelet	87	783	870
	Total	134	972	1,106
Prince William Sound	Marbled Murrelet	2,062	635	2,697
	Kittlitz's Murrelet	176	59	235
	Brachyramphus murrelet	3,071	1,249	4,320
	Total	5,309	1,943	7,252
Southeast Alaska	Marbled Murrelet	1,214	1,925	3,139
	Kittlitz's Murrelet	15	24	39
	Brachyramphus murrelet	1,567	969	2,536
	Total	2,796	2,918	5,714

survey area window. Other methods, using "snapshot" counts of flying birds, may reduce this source of error (Gould and Forsell 1989). We recommend that both "snapshot" counts and the present method be used simultaneously in future surveys to develop a correction factor between the two methods and allow comparison among years. Because bird flux was a large source of error, we recalculated the estimates without any *Brachyramphus* murrelets recorded as flying. The combined estimate of *Brachyramphus* murrelet population abundance during summer from the three study areas without flying birds was 659,014 ± 158,462 murrelets. This was 199,926 murrelets less than the point estimate including flying birds.

(2). Lack of detection. We assumed that all murrelets on the transect line were detected, but marine strip transects fail to detect some individuals during rough seas and when the species of interest commonly dives. The number missed increased with distance from the survey vessel (Dixon 1977, Ralph and Miller 1995); consequently, we limited our survey distance to 100 m. Murrelets can be hidden by rough seas and are easily obscured by white caps. We discontinued surveys when waves exceeded 0.6 m in height or when whitecaps became so frequent that we felt we were missing birds.

We also assumed that no birds were missed by diving while we surveyed a transect. Dive times ranging from 6 to 115 sec have been reported for murrelets (Thoresen 1989, Strachan et al. 1995). We calculated that on the offshore transects where we traveled at 15 km hr^{-1}, we would cover 150 m in 30 sec. Thus, we might miss some diving birds, but observers scan up to 200 m ahead of the boat to prevent this. On nearshore transects, we traveled slower, reducing this problem. Ralph and Miller (1995) estimated that the effect of foraging birds being underwater was minimal and probably < 5% of the total population.

(3). Inter-observer variability. Even though observers changed from year to year, we believe the effects of interobserver variation was minimal. Within each season, observers were consistent among study areas. Similar protocols were adhered to among all surveys. Most observers were skilled in bird identification, and all observers participated in training prior to a survey. Interobserver variation in estimation of the 100-m transect width could affect the population estimates. Underestimation of the distance to birds would reduce the transect width and would result in an overestimate of the total population (Ralph et al. 1995). Observers practiced estimating distance with a decoy deployed at 100 m and used the boats' radar units to keep a constant distance from shore.

(4). Seasonal variation. The proportion of the murrelet population that breeds ranges from 30 to 85% (Carter and Sealy 1987, Beissinger 1995), so during incubation, which in Alaska occurs in June (Kuletz 1996), 15 to 42% of all breeding birds would be unavailable for counting. We compared a June 1990 survey of Prince William Sound to one conducted in July 1990 (K. Laing, USFWS, unpubl. data) and found that population estimates of *Brachyramphus* murrelets were higher during July. The Lower Cook Inlet survey was conducted during June, and

Southeast Alaska was surveyed in June and July. The population sizes in these areas may have been underestimated due to incubating birds being unavailable for counting.

(5). Repeated counting of individuals. We may have overestimated population size by repeatedly counting the same individuals. A proportion of birds that fly in response to the boat will fly in the same direction as the vessel, where they could be double-counted later. An earlier study found that of the 10.7% of birds that flew in avoidance, 22% flew in the direction of travel (Strong et al. 1995). If each of these birds was double-counted once, the estimate would be inflated by 2.3%, adding 20,809 birds to the population estimate for all three study areas.

(6). Time of day. Murrelets forage throughout the day and in some cases at night (Carter and Sealy 1990). Murrelets may move from one feeding site to another during the early morning and late afternoon (Carter and Sealy 1990). They also may gather in the early morning offshore from their nesting sites then move to foraging sites (Strachan et al. 1995). Radio-tagged murrelets were found to repeatedly use the same localities for foraging (Kuletz, USFWS, unpubl. data). We surveyed between 07:55 and 21:30, so we may have encountered some movements between transects.

(7). Effect of tides. Because we had a large number of samples at all tidal stages, effects of tides on murrelet numbers probably were minimal (S. Klosiewski, USFWS, pers. comm.). In British Columbia, the relationship between tides and Marbled Murrelet counts was not consistent. Murrelets aggregated in some locations with strong tidal flow but were sparse or absent at other locations where marine birds were feeding (Burger 1995). No correlation with tides was observed during repeated surveys of murrelets near Naked Island in Prince William Sound (Carter and Sealy 1990).

(8). Effects of El Niño and other oceanographic events. An El Niño event in 1993 created low prey availability off the Oregon coast, which may have altered murrelet distribution and abundance estimates (Strong et al. 1995). El Niño effects in 1992 and 1993 caused many murrelets in British Columbia to relocate, but they appeared to return in 1994 (Burger 1995). We surveyed Lower Cook Inlet and Prince William Sound during 1993, so it was possible that the same El Niño event affected murrelet distribution in those study areas. The 1993 Prince William Sound estimate was higher than previous estimates, but the 1996 estimate (Agler et al., unpubl. data) was lower. Thus, it is possible that birds relocated into Prince William Sound during the 1993 El Niño.

We had relatively precise estimates for surveys of this magnitude. The CV's ranged from 0.13 to 0.15 for the summer estimates and 0.25 to 0.33 for the winter estimates. The summer estimates tended to have better precision because we surveyed more transects than during winter. These levels of precision allow for evaluation of long-term population trends over time.

The accuracy of pelagic surveys for estimating population size has never been determined for any species (Ralph et al. 1995) and is subject to the sources of error listed above. To examine the accuracy of our estimates, we compared our population estimates with an independent large boat survey of murrelets conducted in Glacier Bay and Icy Strait in Southeast Alaska (J. Lindell, USFWS, unpubl. data). We calculated that 27,264 ± 13,964 murrelets were present in Glacier Bay and 10,028 ± 6,755 murrelets were in Icy Strait during summer 1994. Lindell (unpubl. data) calculated that 25,825 ± 3,525 murrelets were in Glacier Bay during 1993, and eight surveys in Icy Strait from 1993 to 1995 yielded a mean of 20,575 murrelets. The similarity of these estimates strengthens the probability that our estimates from the small boat surveys were comparable with other surveys.

MANAGEMENT IMPLICATIONS

Little is known about the biology of Marbled and Kittlitz's Murrelets (Ralph et al. 1995). Murrelet populations declined significantly in Prince William Sound between 1972 and 1991 (Klosiewski and Laing 1994). Preferred Marbled Murrelet nesting habitat in Southeast Alaska, where a large proportion of the population resides, has declined over the last 30 years (Perry 1995, Piatt and Naslund 1995).

Our population estimates provided no information on what proportion of the Alaska *Brachyramphus* murrelet population actually nests. A large proportion of some alcid populations do not breed for lack of a nest site or other reasons, constituting a "floater population" (Divoky et al. 1974, Manuwal 1974). The proportion of nonbreeding adults probably varies somewhat by year, as it does for other alcids, and with variables such as oceanographic conditions and weather. An important consideration is that the proportion of nonbreeding adult murrelets may be considerable for the Alaska population if loss of nesting habitat has left many pairs without nest sites. Thus, more work needs to be done on the life history characteristics of this species to determine how environmental and human-caused factors contribute to the number of "floaters" in any year.

When evaluating the conservation status of murrelets, we feel that it is important to be conservative in presenting population estimates. We conducted boat surveys of three areas in south-central and Southeast Alaska where most of the *Brachyramphus* murrelet population breeds. When we exclude flying birds, the largest source of possible error in our calculations, we suggest that 500,000 to 800,000 murrelets inhabit these areas during summer. Although this estimate is greater than previously thought, it is a similar order of magnitude to the most recent estimate (Piatt and Naslund 1995).

These surveys were designed to be easily repeated, and this, combined with the high levels of precision, will permit examination of long-term population trends of *Brachyramphus* murrelets, regardless of the accuracy of the point estimates. Thus, future surveys need to be executed to allow examination of trends of the *Brachyramphus* murrelet population of Alaska.

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