Chapter 28

Abundance, Distribution, and Population Status of Marbled Murrelets in Alaska

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Abstract: Ship-based surveys conducted throughout Alaska during the 1970's and 1980's, and more recent small boat surveys conducted in the northern Gulf of Alaska, suggest that about 280,000 murrelets reside in Alaska during summer. Most Marbled Murrelets are concentrated offshore of large tracts of coastal coniferous forests in southeast Alaska, Prince William Sound, and the Kodiak Archipelago. About 1– 3 percent of murrelets breed wholly outside of forested areas in Alaska, and these presumably all nest on the ground. At sea, murrelets tend to occupy sheltered waters of bays, fiords, and island straits, and often aggregate near large river outflows or tide rips. Small boat surveys of Prince William Sound and Christmas Bird Count trends suggest that Marbled Murrelet populations in Alaska declined by about 50 percent between 1972 and 1992. Population declines may have resulted from cumulative effects of oil pollution, gill netting, logging of old-growth breeding habitat, and natural changes in the marine environment. The *Exxon Valdez* oil spill killed an estimated 8,400 murrelets in 1989, or about 3 percent of the Alaska population. The toll from chronic pollution is unknown. About 3300 murrelets (89 percent adult) die annually in fishing nets in Alaska — a sustained adult mortality rate of 1.5 percent per annum. The extent or effect on murrelets of logging in Alaska are unknown. While only 7 percent of the old-growth has been harvested in the Tongass National Forest, about 40 percent of the highly productive old-growth in the forest has already been logged. A decline in forage fish populations in the Gulf of Alaska during the last 20 years may account for reduced breeding success and population size of several seabird species, including murrelets. Murrelet populations should be sensitive to small increases in adult mortality from the above factors because production by murrelets is low and must therefore be balanced by a low annual adult mortality rate.

The North American subspecies of the Marbled Murrelet (*Brachyramphus marmoratus marmoratus*) breeds primarily in old-growth coniferous rainforests along the west coast from California to Alaska. Populations of this subspecies range as far west as the Aleutian Islands and north into the Bering Sea. The Asian subspecies *B. m. perdix* occurs from the Commander Islands and west throughout the Sea of Okhotsk (Ewins and others 1993). However, this subspecies is sufficiently distinct morphologically and genetically from the North American subspecies to be considered a separate species (the "Long-billed Murrelet"; Friesen and others 1994a; Piatt and others 1994). Thus, Alaska contains the extreme western and northern range of the Marbled Murrelet in North America.

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The bulk of the North American population of Marbled Murrelet resides in Alaska. Population estimates have ranged from hundreds of thousands to millions (Ewins and others 1993), but recent estimates suggest that about 250,000 murrelets reside in Alaska (Mendenhall 1992; Piatt and Ford 1993). In this chapter we review information on the abundance and distribution of Marbled Murrelets in Alaska, and the status of populations. Except for the congeneric Kittlitz's Murrelet (*B. brevirostris*), all other auks breed in colonies and nest on the ground—mostly on predator-free islands. In Alaska, a small proportion of Marbled Murrelets also breed on the ground, usually on rocky or sparsely vegetated inland slopes (Day and others 1983; Marks, pers. comm.; Mendenhall 1992).

Abundance and Distribution

Survey Methods

Whereas most surface-nesting seabirds may be censused conveniently at their colonies, population estimates of burrow-nesting, nocturnal, and forest-nesting seabirds are more difficult to obtain. Murrelet population estimates are based solely on counts of birds at sea (Carter and Ericksen 1992; Klosiewski and Laing 1994; Mendenhall 1992; Nelson and others 1992; Piatt and Ford 1993; Rodway and others 1992, in press; Sealy and Carter 1984; Speich and others 1992). A wide variety of observation platforms and sampling methods have been used to collect data and extrapolate abundance—which makes it difficult to pool or compare data from adjacent geographic areas.

No method for censusing murrelets at sea has ever been ground-truthed for accuracy. Studies of at-sea behavior of murrelets in British Columbia (Carter and Sealy 1990; Rodway and others, in press; Sealy and Carter 1984), southeast Alaska (Speckman and others 1993), and Oregon (Varoujean and Williams, this volume; Strong and others, this volume) reveal that time of day and season, tide state, and weather conditions are all important variables influencing murrelet aggregation behavior, distribution, and detectability. High temporal variability in murrelet abundance at sea undermines the confidence we may have in the accuracy of absolute population estimates—although statistically precise (±15-30 percent) measures of abundance are available in some areas (e.g., Barkley Sound, Carter and Sealy 1990, Sealy and Carter 1984; Prince William Sound, Klosiewski and Laing 1994).

Surveys conducted at smaller spatial or temporal scales than those over which movements of birds occur may underestimate populations (Rodway and others, in press). The detectability of murrelets declines with distance from the observer and rough sea conditions (Kuletz 1994), and these factors may also lead to underestimates of at-sea densities (Ralph and Miller, this volume). Larger scale boat-based surveys may overestimate populations as birds move within the survey area and are recounted (Rodway and others, in press). Continuous counting of flying birds during boat-based surveys may significantly overestimate densities (Gaston and others 1987; Varoujean and Williams, this volume; Strong and others, this volume). Aerial surveys provide a good synoptic picture of distribution, but may underestimate densities at sea (Strong and others, this volume).

Murrelet Distribution

Piatt and Ford (1993) used ship-based census data collected under the Outer Continental Shelf Environmental Assessment Program (OCSEAP) to assess the abundance and distribution of regional murrelet populations (*figs. 1* and *2*, *table 1*). The relative distribution of important murrelet habitat revealed by OCSEAP data is supported by fine-scale surveys conducted in different areas of Alaska (Agler and others 1994, Forsell and Gould 1981, Klosiewski and Laing 1994, Kuletz 1994, Piatt 1993).

Although murrelets range widely in Alaska, they are concentrated during the breeding season in three main areas: the Kodiak Archipelago, Prince William Sound, and the Alexander Archipelago (*figs. 1* and *2*, *table 1*). At a smaller scale, areas of concentration (*fig. 2*) include in the Alexander Archipelago: Stephens Passage, Lynn Canal, Sumner Strait, Chatham Strait, Icy Strait, and Glacier Bay; on the outer coast: Yakutat Bay, Icy Bay; all of western Prince William Sound; along the south Kenai Peninsula; in lower Cook Inlet: Kachemak Bay and Kamishak Bay; in the Kodiak Archipelago: around Afognak Island, in Chiniak Bay and

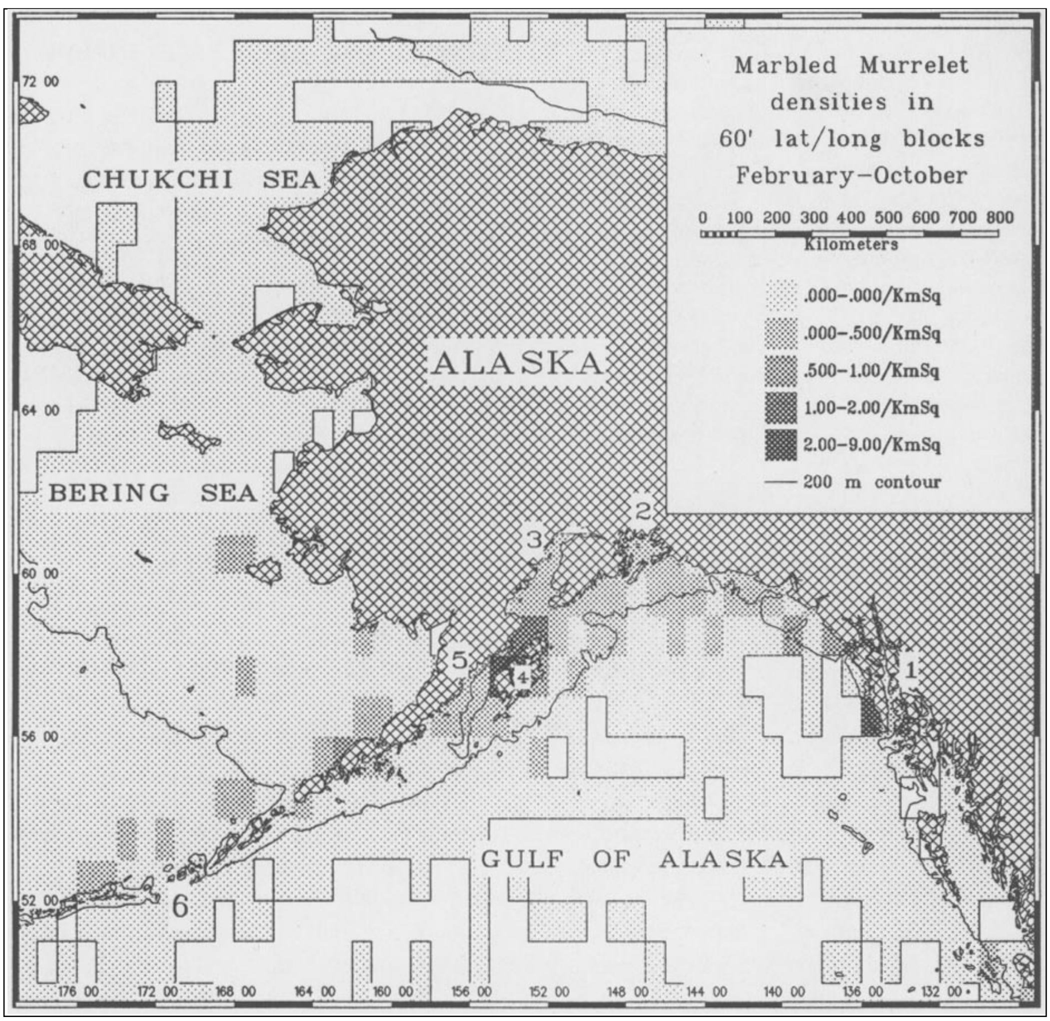

Figure 1—Distribution of Marbled Murrelets and survey coverage in 60' latitude-longitude blocks in Alaska (from Piatt and Ford 1993). Data compiled for the months of February - October. Murrelet densities are scaled geometrically. Similar analyses for breeding and non-breeding seasons were used for estimating population sizes (*table 1*). Numbered areas are: 1-Southeast Alaska (Alexander Archipelago), 2- Prince William Sound, 3- Cook Inlet, 4- Kodiak Archipelago, 5- Alaska Peninsula, 6- Aleutian Islands.

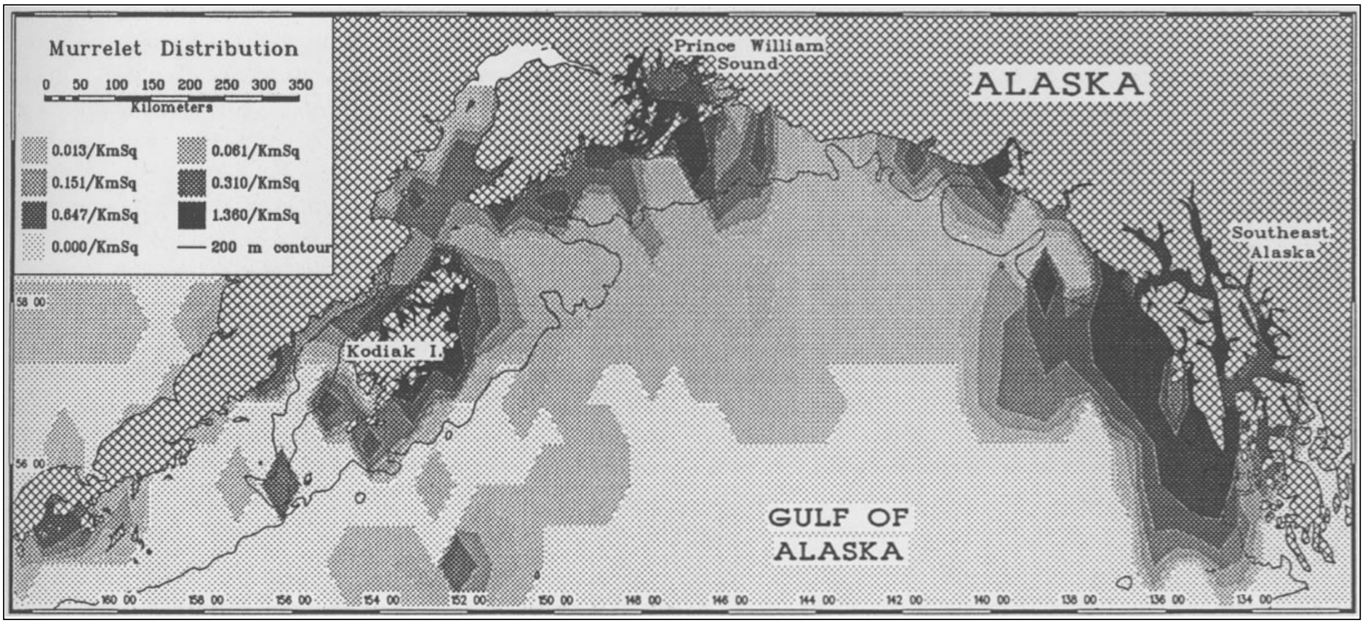

Figure 2—Distribution of Marbled Murrelets in the northern Gulf of Alaska (from Piatt and Ford 1993). Density contour polygons calculated from data grouped in 30' latitude-longitude blocks and scaled arithmetically.

Table 1—Abundance of Marbled Murrelets in different marine areas of Alaska during breeding (May-July) and nonbreeding (February-April and August-October) periods as estimated by extrapolation from OCSEAP data. From Piatt and Ford (1993)

Marine area	Km^2	Estimated number of murrelets			
		Breeding		Non-breeding	
		n	pct.	*n*	pct.
Gulf of Alaska*					
Offshore (50-300 km)	488,000	9,820	6.4	30,000	18.0
Alexander Archipelago	48,200	96,200	62.9	87,100	52.3
Northern Gulf Coast**	83,000	21,200	13.9	12,800	7.7
Kodiak Archipelago	30,300	21,900	14.3	27,800	16.7
Alaska Peninsula	40,500	1,580	1.0	2,420	1.5
Aleutian Islands (<100 km)	95,000	370	0.2	1,840	1.1
Bering Sea					
Alaska Penninsula (<50 km)	27,700	1,300	0.8	3,380	2.0
Bering Shelf	570,000	660	0.4	1,130	0.7
Chukchi, Beaufort Sea	685,000	0	0.0	0	0.0
TOTAL	2,067,700	153,030		166,470	
Survey Effort					
60' blocks sampled		510		533	
Transect distance (km)		18,224		22,400	

* Area within ca. 50 km of coast unless otherwise stated.
** Population size underestimated, see text.

Sitkadilak Strait; along the Alaska Peninsula: Halo Bay, Kukak Bay, Wide Bay, and the Shumagin Islands. In the Aleutians, small numbers are found at Unalaska, Adak, and Attu islands, and other large islands in the chain.

Murrelets are most abundant in sheltered “inside waters”, which includes bays, fiords, and island passes located in coastal areas of the northern Gulf of Alaska (*fig. 2*). The distribution of the majority of murrelets surveyed at sea coincides spatially with the terrestrial distribution in Alaska of coastal old-growth coniferous forests — especially Sitka spruce (*Picea sitchensis*) and hemlock (*Tsuga* spp.) (USDA Forest Service Alaska Region 1991, 1992; Viereck and Little 1972), which are used for nesting by murrelets (Naslund and others 1993, Quinlan and Hughes 1990). Ship-based studies of lower Cook Inlet conducted in 1992 (Piatt 1993) suggest that waters subject to strong tidal mixing provide poor foraging habitat for murrelets compared to stratified coastal waters (*fig. 3*). Marbled Murrelet distribution in summer may be determined largely by the spatial co-occurrence of terrestrial breeding habitat and suitable marine foraging areas.

During the breeding season, low densities of murrelets (possibly nonbreeders) may be found in outside waters (>50 km from shore). Excluding these offshore birds during the breeding season, Piatt and Ford (1993) found that only 3.1 percent of all murrelets were distributed outside the range of coastal coniferous forests in Alaska (i.e., west of and including the Alaska Peninsula). It appears that murrelets disperse to the south and west in winter, as numbers decline in sheltered northern Gulf waters, but increase offshore, along the Alaska Peninsula, and in the Aleutians (*table 1*). Murrelet populations in Prince William Sound diminish by about 75 percent in winter (Klosiewski and Laing 1994).

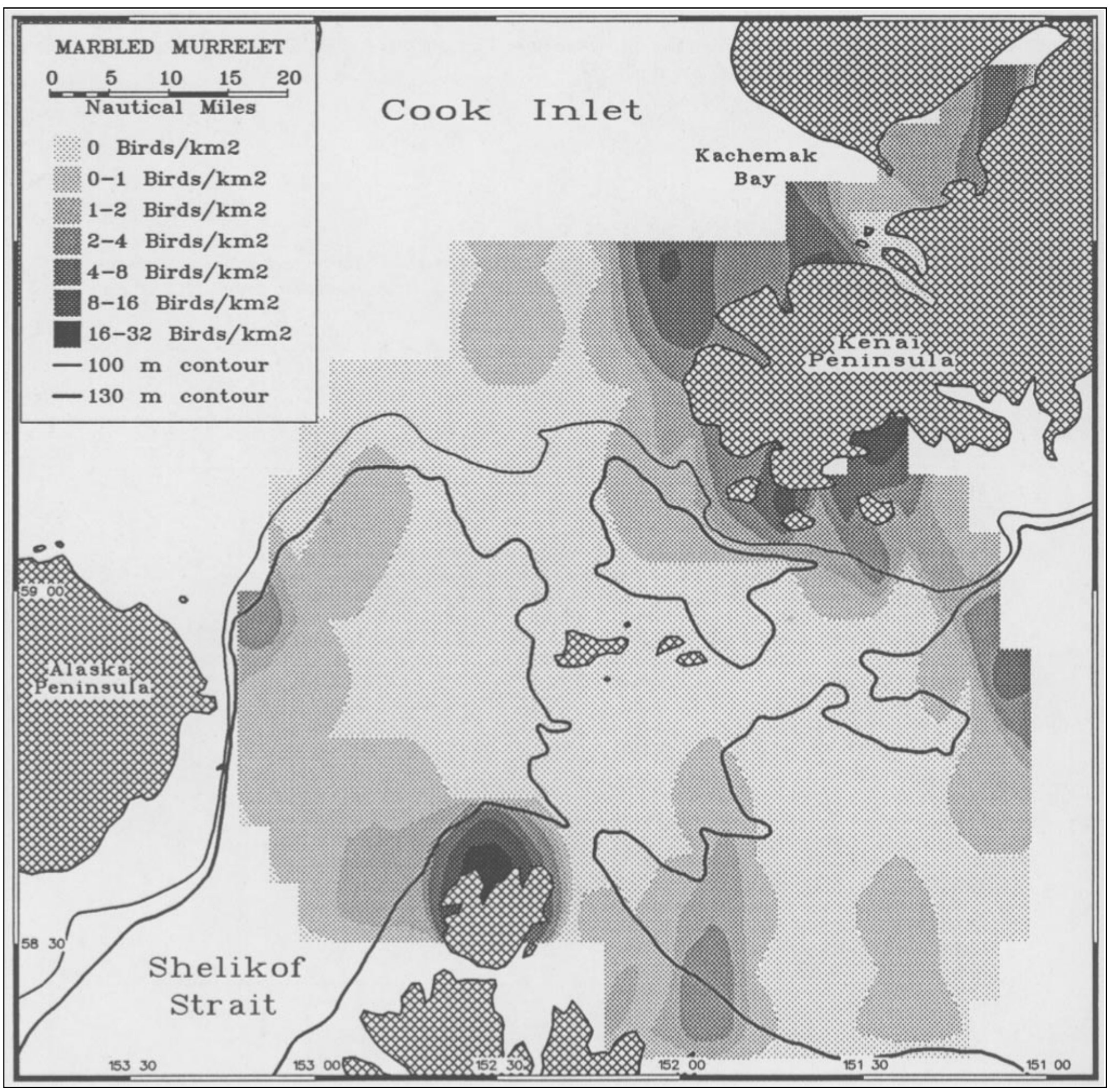

Figure 3—Distribution of Marbled Murrelets in lower Cook Inlet during July, 1992 (from Piatt 1993).

Murrelet Abundance

Piatt and Ford (1993) estimated the abundance of regional murrelet populations (*table 1*) by extrapolating from coarse-scaled OCSEAP data. The population estimate for the Northern Gulf of Alaska (*table 1*) is undoubtedly an underestimate because of poor sampling of Prince William Sound and Cook Inlet. Repetitive small-boat surveys conducted in Prince William Sound after the *Exxon Valdez* oil spill yielded summer (July) population estimates (±20 percent) of 107,000, 81,000, and 106,000 *Brachyramphus* murrelets in 1989, 1990, and 1991, respectively (Klosiewski and Laing 1994). Averaging these estimates, and subtracting the proportion that were Kittlitz's Murrelets (ca. 10 percent), suggests that about 89,000 Marbled Murrelets use Prince William Sound in summer. Ship-based surveys conducted in lower Cook Inlet in summer, 1992, suggest that about 18,000 *Brachyramphus* murrelets may be found in a 50 km radius of the Barren Islands; with high concentrations along the Kenai Peninsula and near Shuyak Island in the Kodiak Archipelago (Piatt 1993; *fig. 3*). Small-boat surveys in 1993 of a larger area in lower Cook Inlet (*fig. 4*) suggest that about 60,000 *Brachyramphus* murrelets use this area during summer (Agler and others 1994).

The OCSEAP estimate for murrelet populations throughout the entire Kodiak Archipelago in winter (*table 1*) is similar to the estimate (15,000-20,000) given by Forsell and Gould (1981) for wintering populations of *Brachyramphus* murrelets in selected bays of Kodiak and Afognak islands. Reflecting an influx of post-breeding birds, winter populations are higher (*table 1*) and birds appear to move into more sheltered bays and fiords. Summer and winter populations concentrate in different areas (*figs. 5* and *6*).

No other published regional estimates are available for comparison with the OCSEAP data. Mike McAllister conducted hundreds of surveys throughout much of the northern Gulf of Alaska between 1983 and 1991. Based on a preliminary examination of his data (McAllister, pers. comm.), he made the following summer population estimates:

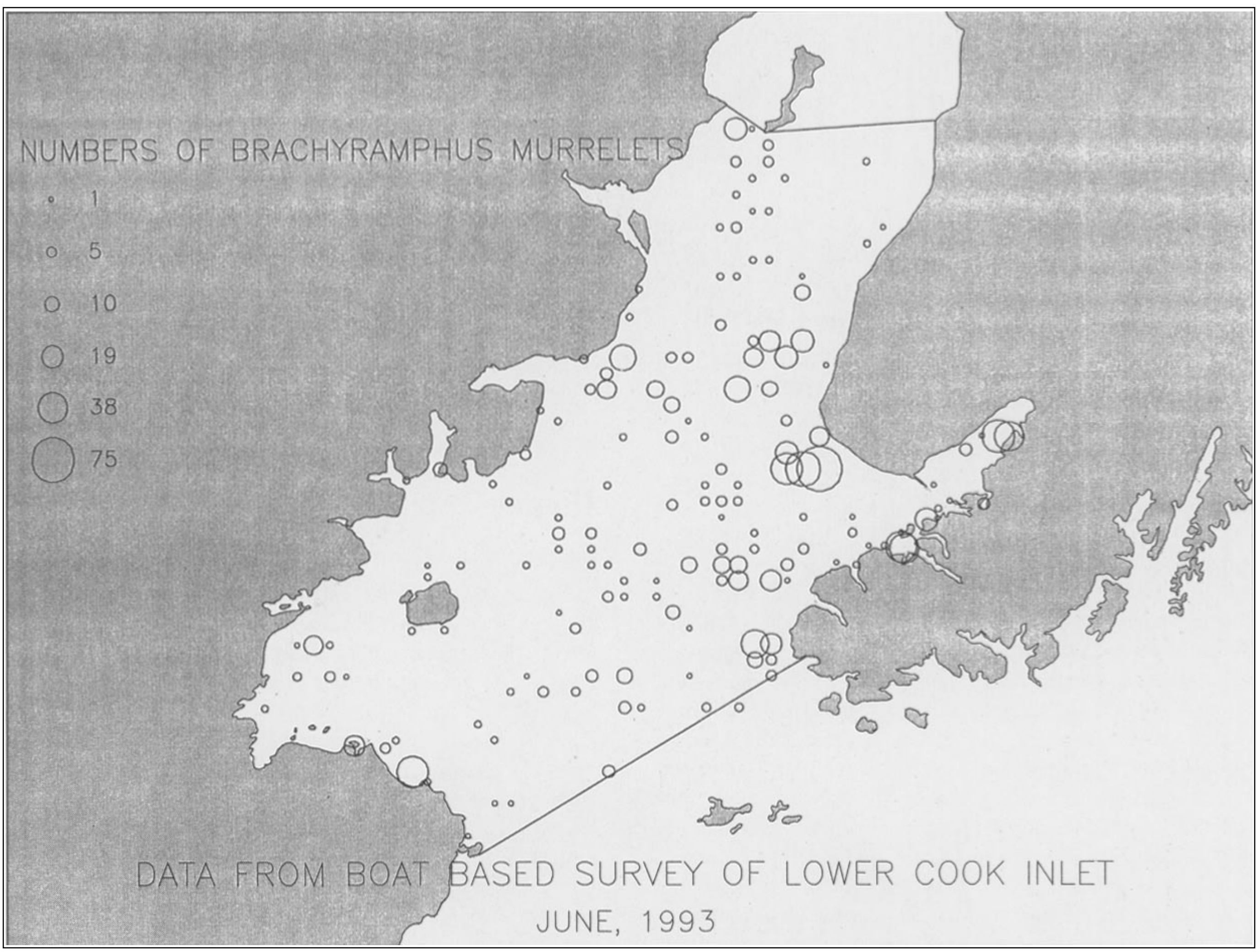

Figure 4—Distribution of Marbled Murrelets in lower Cook Inlet during June, 1993 (from Agler and others 1994).

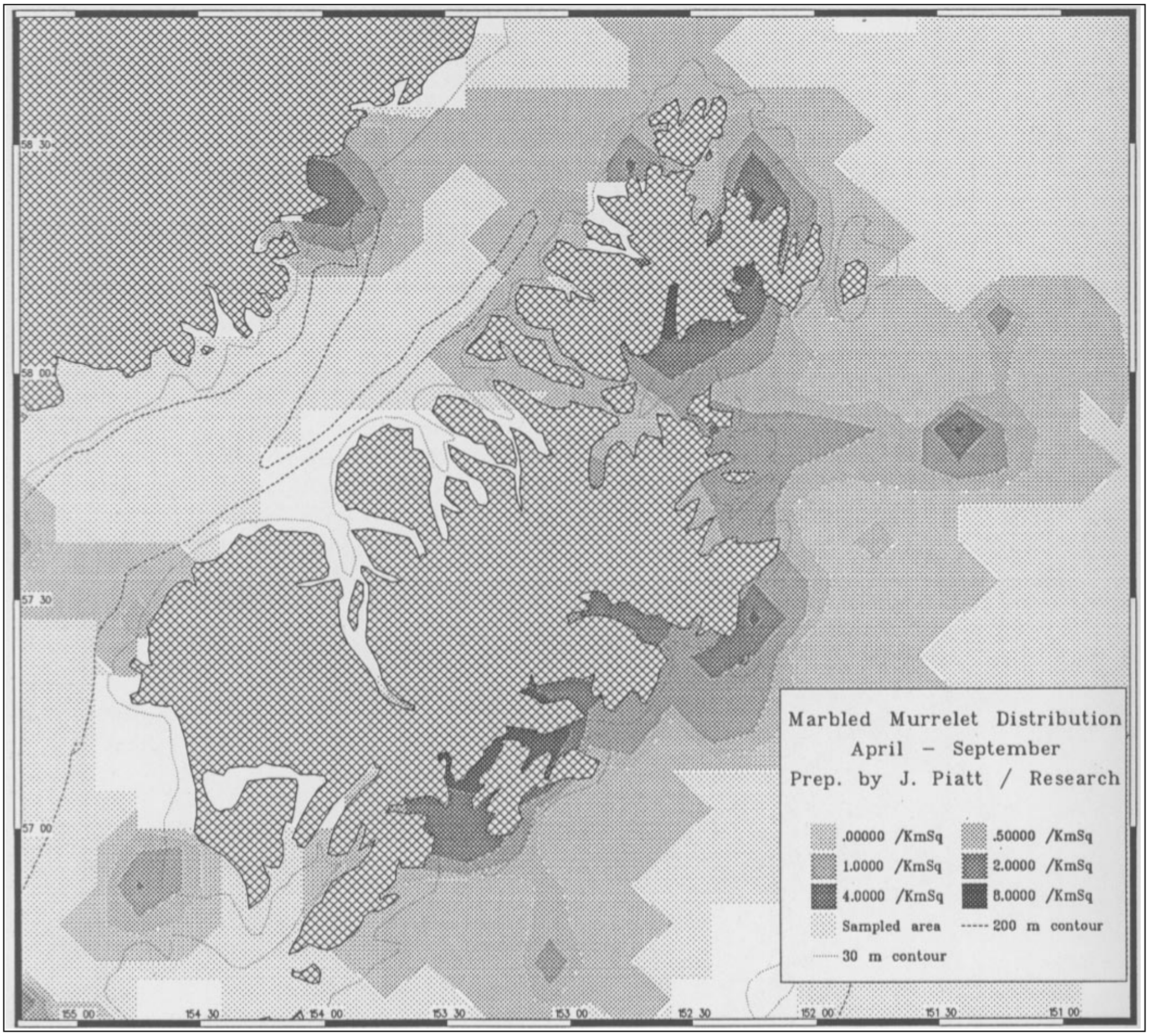

Figure 5—Distribution of Marbled Murrelets around the Kodiak Archipelago in summer (April-September). Density contour polygons calculated from data grouped in 5' latitude-longitude blocks and scaled geometrically.

Southeast Alaska: 45,000–70,000; Northern Gulf Coast (including Prince William Sound): 32,000–60,500; Kodiak Archipelago: 7,000–13,000; Alaska Peninsula: 4,000–10,000.

Combining results of the Alaska-wide OCSEAP surveys, and the more recent fine-scale surveys of Prince William Sound and Cook Inlet, we conclude that Marbled Murrelet populations in Alaska are in the low 10^5 category, possibly around 280,000 individuals. One important implication of the OCSEAP data is that only about 3 percent of the Alaskan Marbled Murrelet population resides in wholly nonforested regions during the breeding season. If we factor in the fine-scale survey results, then the proportion of murrelets residing in non-forested regions is further reduced to only 1.4 percent of the total Alaskan population. Presumably at least this fraction of the population nests on the ground. Some murrelets also nest on the ground in alpine habitat of forested areas and, rarely, on the ground in forests (Ford and Brown 1994; Kuletz, pers. comm.; Mendenhall 1992).

Human Threats to Populations

Logging of Old-Growth Nesting Habitat

Aside from a small fraction that nest on the ground (see above), most Marbled Murrelets in Alaska nest in old-growth forests (Kuletz and others, this volume; Naslund and others 1993), and populations are therefore affected directly by logging of these forests. Unlike factors leading to direct mortality, such as oil spills and gill-nets, it is difficult to quantify the impact of logging on murrelet populations. However, it is obvious that logging of breeding habitat must lead to an immediate reduction in murrelet production. If murrelets do not, or can not, breed elsewhere in subsequent years, then removal of habitat must eventually lead to reduced population size as adults are culled over time from breeding populations, but are not replaced by new recruits. The massive (85–90 percent) reduction in old-growth nesting habitat in California, Oregon, Washington, and British Columbia because

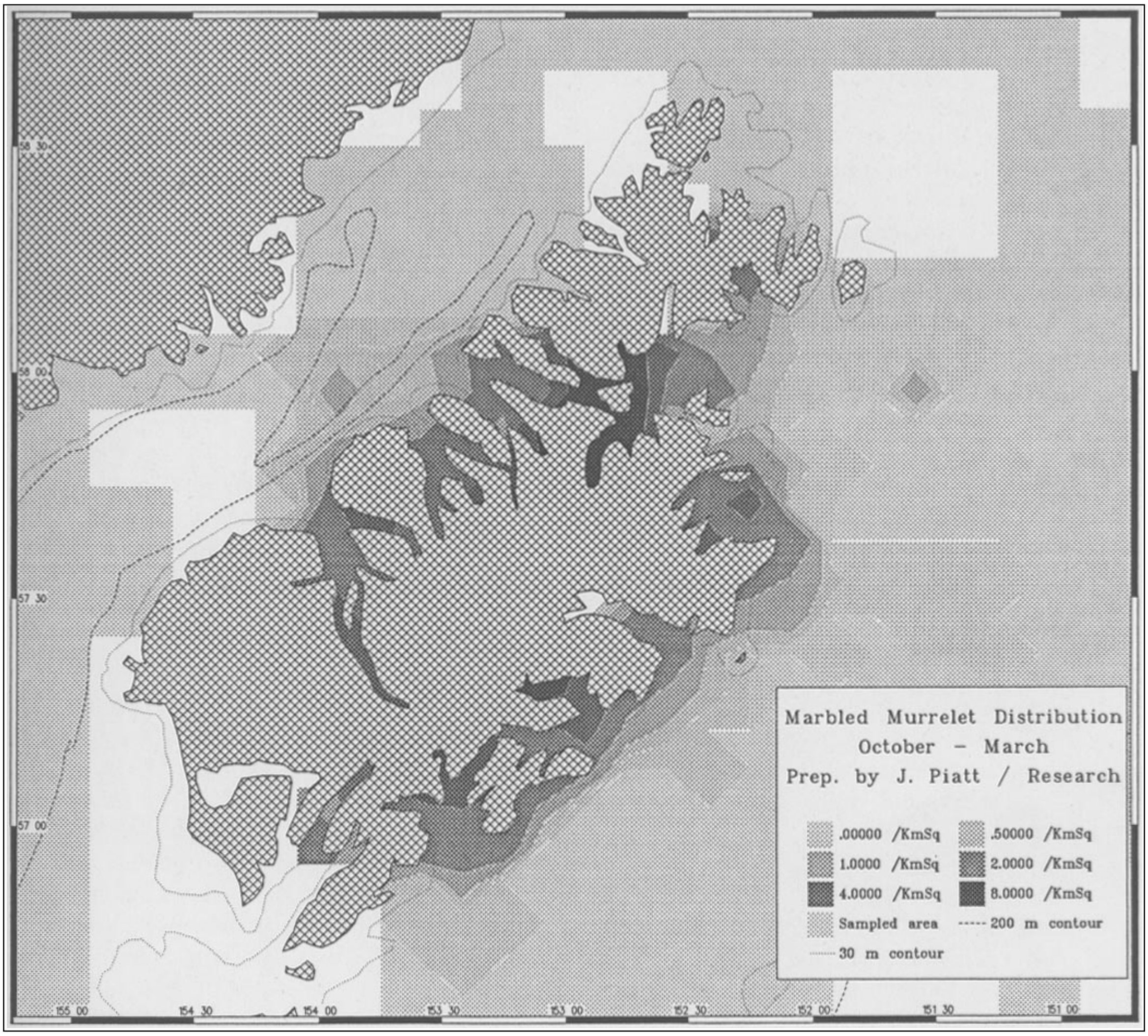

Figure 6—Distribution of Marbled Murrelets around the Kodiak Archipelago in winter (October-March). Density contour polygons calculated from data grouped in 5' latitude-longitude blocks and scaled geometrically.

of logging is credited for the decline and fragmentation of murrelet populations in these regions (Rodway and others 1992; Sealy and Carter 1984; Stein and Miller 1992). Despite the relatively large present-day population of murrelets in Alaska, there is no reason to expect that populations here will fare any better without habitat conservation.

Despite Alaska's image as a pristine wilderness, much old-growth habitat here has already been logged. Exact figures on timber harvest and the proportion of old-growth remaining are largely unpublished or undocumented (Mendenhall 1992). While only 7 percent of the old-growth has been harvested in the Tongass National Forest, a significant portion (about 40 percent) of the highly productive old-growth in the forest has already been eliminated, and remaining habitat continues to be logged (USDA Forest Service Alaska Region 1991; Perry, this volume). Substantial areas of potential nesting habitat have also been logged on state and private lands elsewhere in Alaska, principally in Prince William Sound and the Kodiak Archipelago, and logging pressure continues, as we and others (Mendenhall 1992; Forsell, pers. comm.) have observed. Privately-owned forests, much of which were selected or granted because of their old-growth holdings, are found in all areas of known importance to murrelets. Clear-cutting is planned or underway on all privately-owned forests (Mendenhall 1992).

Gill Nets

The impact of gill-net mortality on Marbled Murrelets in Alaska is poorly known. Anecdotal evidence from the past suggested that 100's to 1000's of murrelets were caught in gill-net fisheries in coastal areas of Alaska during the 1970's (Mendenhall 1992; Carter and Sealy 1984). Quantitative data on seabird bycatch from Prince William Sound in 1990 and 1991 (Wynne and others 1991, 1992) reveal that these earlier estimates were probably of the right order of magnitude. Extrapolating from observed bird bycatch rates and the proportion of total salmon catch observed, it appears that 923 and 714 *Brachyramphus* murrelets (84 percent Marbled) were killed in Prince William Sound gill net fisheries in 1990 and 1991, respectively. A more careful analysis of 1990 data, using mean bycatch rates per week and gill net effort, indicates that 1,468 (95 percent confidence limits 813-2043) seabirds (97 percent murrelets) were killed in nets in 1990 (Wynne and others 1991). Of 18 murrelet specimens examined, 16 (89 percent) were in adult breeding plumage and 2 were juveniles. Most murrelets were caught in late July—just prior to the post-breeding period for murrelets.

In 1989, there were 1,972 salmon drift net permits and 4,947 set net permits issued for the Gulf of Alaska (DeGange, pers. comm.; DeGange and others 1993). Extrapolating from Prince William Sound with 598 drift net permits, and assuming that 1000 murrelets die there in nets annually, then as many as 900, 1100, and 300 murrelets may drown in gill nets in Southeast Alaska, lower Cook Inlet, and along the Alaska Peninsula, respectively. In total, some 3300 (2940 adult) murrelets may drown in fish nets annually throughout their range in Alaska. Assuming a population size of 280,000 individuals, of which 70 percent are adult breeders, then as much as 1.5 percent of adult mortality may derive from drowning in nets. This estimate does not include mortality in set nets, pound nets or seine nets, which anecdotal evidence suggests also kill a number of murrelets each year.

Oil Pollution

Chronic low-volume oil pollution is a significant source of seabird mortality in many parts of the world (Burger and Fry 1993, Piatt and others 1991), but effects on murrelets in Alaska are largely unknown, owing to the remoteness of bird populations in Alaska and the sparse human population. Two oil spills in 1970 may have each killed about 100,000 seabirds, mostly murres (McKnight and Knoder 1979). Limited beach survey data suggests that low-level mortality occurs throughout the year. In 1988 and 1989 alone, 43 oil spills involving 14 million gallons of oil were reported in Alaskan waters (including 11 million from the *Exxon Valdez*). Several of these spills were in the vicinity of major seabird colonies, but damages were not documented. Chronic oil pollution is likely to get worse as fishing fleets expand and more oil, and gas development occurs in offshore environments (Lensink 1984).

Following the *Exxon Valdez* oil spill in Prince William Sound during March 1989, about 30,000 seabirds were recovered and the actual kill toll ranged between 100,000-300,000 birds (Piatt and others 1990). Both Marbled and Kittlitz's murrelets were affected by the spill, as were many other alcids. A total of 612 Marbled Murrelets were retrieved from beaches. Another 413 unidentified murrelets were recovered and, if we prorate these birds by the proportion that were Marbled Murrelets in each area of recovery, then the total number of Marbled Murrelets retrieved was 808. Only a fraction of birds killed at sea made it to shore (ca. 10 percent), and if we apply recovery rates estimated by Ecological Consulting, Inc. (1991) and Piatt and others (1990) for each region affected, then about 8400 Marbled Murrelets were killed by the *Exxon Valdez* oil spill (see also Kuletz 1994). This represents a one-time loss of 3 percent of the total Alaska population, and about 7 percent of the population in the spill zone (Kuletz 1994). Similarly, about 530 Kittlitz's Murrelets were killed, or about 3 percent of their total Alaska population (van Vliet 1993).

Boat Traffic

Owing to their coastal distribution and use of relatively sheltered marine habitats, murrelets are more exposed to vessel activities than most other seabirds in Alaska. Disturbance can disrupt feeding birds and persistent boat traffic may prevent murrelets from using important foraging areas (Speckman, pers. comm.). Even in areas where murrelets may habituate to existing boat traffic, changes in boat activity may influence murrelet foraging activity. Following the *Exxon Valdez* oil spill in Alaska, boat activity increased greatly in Prince William Sound and Kachemak Bay because of rescue and clean-up efforts. There, Kuletz (1994) found that murrelet numbers were negatively correlated with numbers of boats and low-flying aircraft. Evidence also suggested that breeding may have been disrupted (Kuletz 1994). Increasing activity by fishing, commercial, tourist and private boats in areas known to be important for murrelets (e.g., Glacier Bay National Park, Prince William Sound, Kenai Fiords National Park, and Kachemak Bay) may have important long-term implications for murrelet populations in Alaska. The potential impact of vessel disturbance on murrelet foraging and breeding success requires more study.

Other Factors Influencing Population Dynamics

Natural Changes in the Environment

A variety of independent data indicate that a marked "change of state" in the marine ecosystem of the Gulf of Alaska occurred during the last 20 years (Piatt and Anderson, in press). This shift has been manifested by marked changes in sea water temperatures, composition of marine fish communities, reduced overall fish biomass, and dramatic changes in the diet and population ecology of higher vertebrates that depend on those fish populations (Piatt and Anderson, in press). In particular, productivity and populations of Common Murres (*Uria aalge*), Black-legged Kittiwakes (*Rissa tridactyla*), Stellar sea lions (*Eumetopias jubatus*), and harbor seals (*Phoca vitulina*) declined dramatically in various areas of the Gulf of Alaska during the 1980's. Declines in Marbled Murrelet populations in Alaska (see below) also coincided with these changes in the marine ecosystem, and may be related to changes in forage fish availability during this time. Between the late 1970's to the late 1980's, high quality capelin (*Mallotus villosus*) were replaced largely by lower quality pollock (*Theragra chalcogramma*) in the diets of Marbled Murrelets (Piatt and Anderson, in press). Unlike short-term phenomenon such as El Niño events, this long-term shift represents a more pervasive and persistent change in the ecosystem and can potentially have long-term effects on Alaskan murrelet populations. In the short term, evidence suggests that murrelets and other seabirds will have difficulty recovering from impacts of the 1989 *Exxon Valdez* oil spill and other sources of adult mortality until conditions favorable for seabirds are re-established in the Gulf of Alaska (Piatt and Anderson, in press).

Life History

As a group, the Alcidae exhibit life history characteristics typical of other seabirds. Laying only 1–2 eggs per breeding season, they have a low capacity for production but this is balanced by low adult mortality and long life (see review by De Santo and Nelson, this volume). Compared to other fish-feeding members (e.g., murres, puffins, auks) within the family, however, it is clear that murrelets are extreme in their adaptation for very low production (see below), which must be balanced by very high adult survival rates. This is important to consider when evaluating the long-term impacts of anthropogenic and natural mortality factors on populations in Alaska. Whereas murres (*Uria* spp.), with natural adult mortality rates of 8–12 percent per annum and annual chick production rates of 0.5–0.9 chicks per pair, may be able to compensate relatively quickly for acute or chronic mortality losses of adults, increases in mortality of adult murrelets may have more serious demographic consequences. Thus, losses of 1–3 percent of adult murrelets resulting from oil spills and gill nets (see above) are cause for serious concern.

No data are available on adult survivorship in murrelets, but much evidence suggests that production is extremely low and regulated largely by predation. Indeed, predation pressure appears to have been a major ecological factor influencing the evolution of murrelet life history strategies. Excepting its close relative, the Kittlitz's Murrelet, Marbled Murrelets are the only alcid with cryptic plumage and nesting behavior. Breeding Marbled Murrelets fly silently to their woodland nest-sites for incubation exchange or chick-feeding, and like the even smaller *Synthliboramphus* murrelets, fly mostly at dawn, dusk, or in darkness (Gaston 1992; Naslund 1993a; Nelson and Hamer, this volume a). Selection for breeding in old growth forest by Marbled Murrelets may have arisen because of the scarcity of predators relative to second growth or disturbed habitat.

Despite their best efforts to avoid predation, Marbled Murrelets suffer the highest nesting failure known for any alcid, largely due to predation. Only 28 percent of 32 nests with known outcomes have ever fledged young successfully (Nelson and Hamer, this volume b). In southcentral Alaska, all nests (n = 8) failed where breeding success was known (Marks, pers. comm.; Naslund and others, in press). Abandonment and predation were implicated as factors causing nesting failure. Adults also suffer from predation by raptors and possibly corvids (Marks and Naslund 1994, Singer and others 1991). Being only slightly smaller and larger, respectively, than Marbled Murrelets, *Synthliboramphus* murrelets and *Cepphus* guillemots also suffer from high levels of chick and adult predation. However, these species have compensated through the evolution of 2-egg clutches—unique among the Alcidae. Thus, Marbled Murrelets stand out among the Alcidae for having extremely low levels of production, and a limited capacity for dealing with increased predation pressure or unnatural sources of mortality.

Population Trends

There are few quantitative data to assess population trends of murrelets in Alaska. We analyzed 20 years (1972–1991) of Christmas Bird Count (CBC) data in the northern Gulf of Alaska (*fig. 7*). Totals for each year were calculated as the sum of all murrelets seen on CBC's in Sitka, Juneau, Glacier Bay, Cordova, and Kodiak Island. We could not take the average of counts among sites (n = 5) because of missing data (see below). There was considerable inter-annual variation in total numbers, which we smoothed by taking 5-year running averages of the annual data (*fig. 7*). Unsmoothed data were extremely variable, and did not reveal a statistically significant trend. However, the smoothed data suggest a steady decline in abundance of about 50 percent from the early 1970's to the early 1990's. This analysis is biased because some years of CBC data are missing (16 out of a possible 100 counts). As most (11) missing CBC counts were from the first decade (1972-1980) of study, the downward trend is greater than indicated in *figure 7*.

Interpretation of CBC's is confounded by several effects including survey conditions and observer effort (Arbib 1981, Bock and Root 1981). CBC data may be most suitable for monitoring long-term trends in species (such as the Marbled Murrelet) that occur regularly, are widely distributed, and occupy easily-censused, discrete habitats (Bock and Root 1981, Trapp 1984). We chose not to standardize the CBC data by dividing murrelet numbers by some measure of census effort (e.g., party-hours) because this approach may not be appropriate for some species likely to be well censused, regardless of how many people participate in the census (Bock and Root 1981). If we had standardized the data for effort, which increased by more than 50 percent over the period of study (*fig. 7*), the apparent decline in Marbled Murrelets would have been even more pronounced.

Compelling evidence for a major decline in murrelet abundance is also provided by comparing results of surveys that were conducted in Prince William Sound during 1972-1973 with those conducted after (1989-1991) the *Exxon Valdez* oil spill (Klosiewski and Laing 1994). Based on randomly-selected transects censused throughout the entire Sound, and on surveys conducted in both winter and summer, populations of *Brachyramphus* murrelets apparently declined by 67-73 percent between the early 1970's and late 1980's.

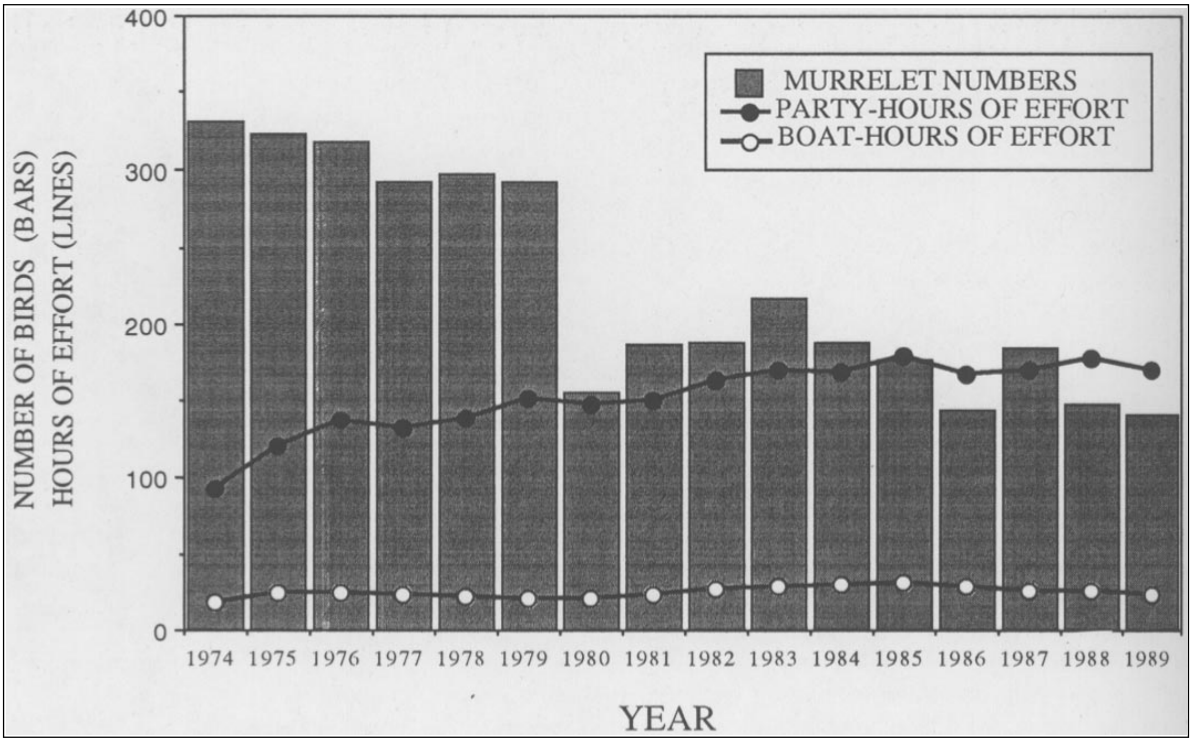

Figure 7—Numbers of Marbled Murrelets observed on Christmas Bird Counts (CBC) at five coastal sites in Alaska (see text). Numbers are 5-year running means of CBC data collected from 1972-1991. Survey effort (lines) also presented as 5-year running means.

Surveys in all years were conducted using similar protocols, population estimates were relatively precise (±37-47 percent in winter, ±16-32 percent in summer), and declines observed on surveys conducted in summer were highly significant ($P < 0.01$; Klosiewski and Laing 1994). Declines observed for murrelets were paralleled by population declines in 15 other marine bird species as well. These declines could not be accounted for by losses from the *Exxon Valdez* oil spill, and suggest that other large-scale factors have influenced marine bird populations in Prince William Sound during the 20-year interval between surveys (Klosiewski and Laing 1994). This is consistent with observations on other marine animals in the Gulf of Alaska (above).

In summary, the bulk of Marbled Murrelet populations in North America reside in Alaska. Most murrelets are concentrated in areas containing large tracts of coastal old-growth forests. Populations in Alaska have apparently declined by more than 50 percent over the last 20 years. This decline has presumably occurred in response to the cumulative effects of habitat loss (logging), gill-net mortality, oil pollution, and natural changes in the marine environment. Life history characteristics of the Marbled Murrelet predispose the species to slow recovery from natural and anthropogenic perturbations, and make it particularly vulnerable to factors which increase adult mortality.

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